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12th International Conference on

Air Quality
Science and Application

Online Conference

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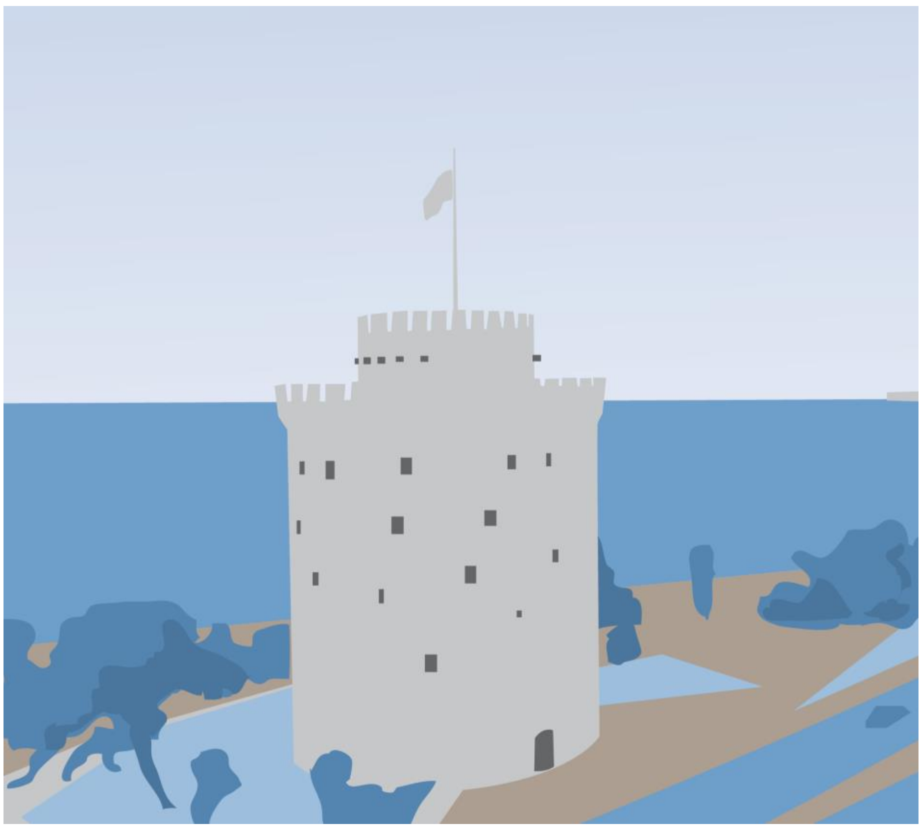

EDITORS

Nicolas Moussiopoulos, Ranjeet S. Sokhi, George Tsegas,
Evangelia Fragkou, Eleftherios Chourdakis, Ioannis Pipilis

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12th International Conference on

Air Quality

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Under the auspices of the

Hellenic Ministry of Environment and Energy

and the

School of Mechanical Engineering – Aristotle University Thessaloniki

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PREFACE

It was with great enthusiasm that we were looking forward to greeting you all in the vibrant port city of Thessaloniki, Greece for the 12th International Conference on Air Quality - Science and Application. The rapid spread of COVID-19 and the responses from Governments across the globe meant that we could no longer proceed with our usual physical conference. With the support of the wider air quality research community, the 12th International Conference became the first major atmospheric research meeting to change to an online format to minimize the risk to the delegates and the public from COVID-19.

The Aristotle University Thessaloniki (AUTh) have been at the forefront of developing the online platform for the 12th International Conference. Having our AUTh colleagues at our side through this period has lessened the enormity of the challenge for which we are truly grateful.

This online meeting is a continuation of the series that began at the University of Hertfordshire, UK in July 1996. Subsequent meetings have been held at the Technical University of Madrid (1999), Loutraki, Greece (2001), Charles University, Prague (2003), Valencia, Spain (2005), Cyprus (2007), Istanbul, Turkey (2009) Athens, Greece (2012), Garmisch-Partenkirchen (2014), Milan (2016) and Barcelona (2018).

While the controls to limit air pollution have increased throughout the world, the problem of poor air quality persists in all cities of the globe. With increasing public awareness, the issue of poor air quality remains at the forefront of societal concern. As urbanisation grows, scientific research is showing that impact from air pollution in cities depends on contributions from local scales and from regional and global scales including interactions with climate change. Improvements in technology need to go hand in hand with management and assessment strategies and effective control policies for reducing the health impact of air pollution.

The presentations at the Conference address the diversity of scales, processes and interactions affecting air pollution and its impact on health and the environment. As usual, the conference is stimulating cross-fertilisation of ideas and cooperation between the different air pollution science and user communities. In particular, there is greater involvement of city, regional and global air pollution, climate change, users and health communities at the meeting. For the first time, the Conference opens with invited key note talks from leading international scientists and policy representatives to discuss major advances in air quality science and highlight emerging challenges.

This international conference brings together scientists, users and policy makers from across the globe to discuss the latest scientific advances in the understanding of air pollution and its impacts on our health and environment. The conference will also discuss new applications and developments in management strategies and assessment tools for policy and decision makers. This proceeding presents a collection of abstracts presented at the Conferences under the following science themes:

Keynote and Plenary Talks

Air Pollution Sources and Emissions

Air Quality Management and Policy Development

Air Quality and Meteorological Predictions and Climate Interactions

Development, Application and Evaluation of Models for Local to Global Scales

Exposure and Health Assessment Related to Air Pollution

Special Session – Air Pollution and Health

Special Session – Sensors, Crowd Sourcing and Air Quality Model Simulations

Special Session – Shipping and Air Quality

Special Session – Air Pollution in Urban Areas

Ranjeet S Sokhi, University of Hertfordshire, UK
Nicolas Moussiopoulos, Aristotle University Thessaloniki, Greece
April 2020

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Keynote and Plenary Talks

RECENT DEVELOPMENTS IN EU CLEAN AIR POLICY

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Summary

Europe's ambient air quality is slowly improving, but fine particulate matter and nitrogen dioxide in particular continue to cause serious impacts on health. Recent estimates point to more than 400.000 premature deaths in the EU each year (EEA, 2019). Air pollution remains the largest environmental health burden in Europe.

The most recent developments in EU Clean Air Policy relate to the so-called fitness check of air quality legislation—a retrospective evaluation exercise—and to the publication of the European Green Deal communication—an ambitious roadmap with actions to boost the efficient use of resources by moving to a clean, circular economy and restore biodiversity and cut pollution.

Fitness check of EU Air Quality legislation

To determine whether and to what extent improvements in ambient air quality are attributable to EU legislation on the matter, an evaluation exercise or '*fitness check*' was recently completed by the European Commission. The fitness check of ambient air quality legislation covered the two EU Ambient Air Quality (AAQ) Directives (Directives 2008/50/EC and 2004/107/EC). These Directives set air quality standards and requirements to ensure that Member States monitor and/or assess air quality in their territory, in a harmonised and comparable manner. The fitness check of the AAQ Directives drew on experience from all Member States, focusing on the period from 2008 to 2018. The findings of the fitness check confirmed that air quality remains a major health and environmental concern, and characterised EU air quality standards as instrumental, and partially effective, to reduce pollution. While recognising that current EU standards are less ambitious than scientific advice (i.e., the World Health Organization's Air Quality Guidelines), the fitness check highlighted the effectiveness of legally binding limit values rather than other types of air standards (EC, 2019a).

The European Green Deal

The European Green Deal is Europe's response to the challenges of tackling climate change and protecting the environment. It is also a *growth strategy* that aims to transform the EU into a fair and prosperous society, with a modern, resource-efficient economy with no net emissions of greenhouse gases by the year 2050. The European Green Deal communication (EC, 2019b) presents the initial roadmap of the key policies and measures needed to achieve the objectives of the European Green Deal.

Fig.1 Main outline of the European Green Deal

Beyond its climate and nature protection ambitions, the European Green Deals places great emphasis in reducing the main forms of pollution (from air, water, soil and consumer products) with the aim to protect human health.

In the domain of air pollution, the European Green Deal communication announces that the European Commission will draw from the lessons learnt in the fitness check of current air quality legislation and propose to strengthen provisions on monitoring, modelling and air quality plans to help local authorities achieve cleaner air. The Commission will notably also propose to revise air quality standards to align them more closely with the World Health Organization's recommendations.

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CRITICAL ASSESSMENT OF DISPERSION MODELLING AFTER SIX DECADES OF DEVELOPMENT

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A brief history and assessment is given of transport and dispersion (T&D) models. Although air pollution was obviously bad prior to WW-I, the primary impetus for development of T&D models during and after WW-I was the widespread use of chemical weapons. Fundamental theoretical advances were made by Richardson, Batchelor, and many other famous fluid dynamicists. The earliest models were analytical (e.g., Gaussian and K-theory) models used for surface boundary layer releases. With the advent of nuclear weapons in WW-II, new emphasis was placed on plume rise and dispersion of large thermal radiological explosions. Thus, the full troposphere and stratosphere had to be modeled. Deposition (wet and dry) was a main concern for many radiological substances. The next major step change was, e.g., the Clean Air Act in the US beginning in the 1970s in the US, and similar legislation in other countries. This effort initially focused on T&D models for industrial sources, such as fossil power plant stacks. The first applied models were analytical plume rise and Gaussian T&D models. Soon computer codes were written to solve these equations and produce outputs at many spatial locations and every hour of the year. Regional pollution interests arose in the 1980s, initially spurred by the acid rain problem. Many countries developed regional 3-D time-dependent Eulerian model systems to account for multiple sources and T&D and deposition over broad areas. Chemical mechanisms were included. This type of model is still in wide use, and, as computer speed and storage have increased, spatial domains have become larger, grid sizes have become smaller, time steps have been reduced, and more physical and chemical mechanisms are included. In the past few years, these regional air pollution models have become routinely linked with outputs of NWP models such as WRF and ECMWF.

At the same time that the use of regional Eulerian models has grown, the puff, particle and plume T&D models for small scales and mesoscales have been improved. Several agencies and countries now have Lagrangian particle or puff models that are linked with an NWP model and are applied at all scales (mainly for no more than a few sources). In addition, great advances have been made in specialized applied T&D models for urban areas, complex terrain, and industrial chemicals with molecular weights significantly different from that of ambient air.

Computational Fluid Dynamics (CFD) models have been developed and used to assess flows and T&D for small domains (on the order of 1 km) since the 1980s. They are generally too slow to be used for routine applications. In the past decade, some NWP models have been modified so that they can treat flow and dispersion in urban street canyons and complex terrain. For example, RAMS and WRF can now be run in nested mode down to an inner domain with grid size of 1 m. As computer speed and storage improve, in the future, these nested models will likely take over most applied T&D analyses.

EFFECTS OF EUROPEAN EMISSION REDUCTIONS ON AIR QUALITY IN THE NETHERLANDS AND THE ASSOCIATED HEALTH EFFECTS

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Summary

Policies implemented in Europe since the 1970s to improve the air quality have resulted in decreases in emissions in many countries and in corresponding reductions in concentrations of sulphur dioxide (SO_2), nitrogen dioxides (NO_2) and particulate matter (PM). We report here how much the air quality and associated health effects in the Netherlands have improved since 1980 and which countries and sectors are responsible for this. We used a Baseline scenario with reported emissions and a World Avoided scenario. In the latter it is assumed that no air quality policies were adopted from 1980 onwards with continued growth in emissions. In this scenario, the annual average $PM_{2.5}$ concentration in the Netherlands increases from 59 $\mu g\ m^{-3}$ in 1980 to 102 $\mu g\ m^{-3}$ in 2015, while in the Baseline scenario concentrations decreased to about 12 $\mu g\ m^{-3}$. The avoided $PM_{2.5}$ concentration in 2015 accounts for more than half (56%) of reductions in emissions in sectors outside the Netherlands. Foreign (38%) and domestic (16%) industry is the main contributing sector, followed by agriculture (23%) and transport (15%). In 2015, the corresponding avoided years of life lost in the Netherlands attributable to avoided air pollution emissions is about 700,000 per year, with an associated increase in average life expectancy of about 6 years.

Introduction

Concerns over the effects of air pollution resulted in policy measures, adopted in Europe since the 1970s, to reduce emissions of SO_2, NO_x, NH_3, particulate matter, and other compounds. In tandem with policy measures to reduce emissions, air quality limit values were agreed in Europe starting in the 1980 for concentrations of SO_2 and suspended particles. These policies have resulted in significant reductions in emissions of air pollutants in European countries in the last few decades and corresponding reductions in concentrations of air pollutants. We quantified the benefits of emissions reductions in Europe since 1980 on the air quality in the Netherlands and related health effects.

Methodology and Results

To quantify the air quality benefits we performed model calculations with high spatial resolution for concentrations of NO_2, PM_{10}, $PM_{2.5}$, and elemental carbon (EC) in the Netherlands from 1980 to 2015 using two scenarios. One scenario, called the Baseline, follows the reported emissions of all relevant air pollutants in all European countries. A second scenario, called World Avoided, is defined as a scenario in which no emission reduction measures were taken and assumes that emissions would have continued to grow from 1980 onwards based on growth in economic activities and demographic changes. The health effects are expressed as DALY (Disability Adjusted Life Years) and reductions in life expectancy. The largest contribution (53% of the DALYs) to the avoided health impacts can be attributed to industry and associated with avoided SO_2 emissions and sulphate aerosols (Figure 1). The second largest contribution (22% of the DALYs) can be attributed to agriculture in the Netherlands and other countries. These benefits, which are associated with reductions in NH_3 emissions and ammonium aerosols. The third largest contribution (17% of the DALYs) can be attributed to road transport and non-road transport, with the contributions from the Netherlands being about twice that from the other countries combined.

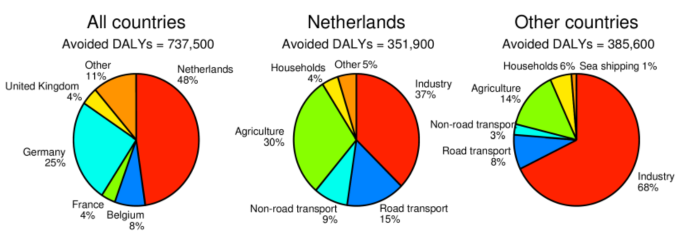

Figure 1. Contributions to the avoided number of DALYs in the Netherlands in 2015, calculated as the difference between the World Avoided scenario and the Baseline scenario.

Conclusions

Large increases in concentrations of many air pollutants have been avoided in the Netherlands through reductions in emissions in the Netherlands itself and in other countries in Europe. The avoided health effects can be attributed to reductions in emissions in the sectors in the Netherlands (48%), Germany (25%) and other countries, with the largest contributions from industry (53%), agriculture (22%), and transport (17%). It is clear that public health in the Netherlands has profited from international cooperation to abate transboundary air pollution. Similarly health in surrounding countries will have profited from the measures taken in the Netherlands as the country was, and still is, a net-exporter of air pollutants.

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SHIP EMISSION ABATEMENT - JUMPING OUT OF THE FRYING PAN, INTO THE FIRE?

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Summary

Efforts to reduce ship related air pollution may lead to unwanted side effects. Stringent sulphur limits for marine fuels offer options for compliance, some of which may create new environmental problems. With the introduction of the global 0.5% sulphur cap in 2020, it is expected that the number of SOx scrubbers may increase up to 4000 units in the next few years. It is crucial that the consequences of scrubber use are investigated in detail to ensure that the sulphur regulation in its current form is still fit for purpose. This paper outlines the first step of the EMERGE project, which involves a development of inventories for air emissions and discharges from ships.

Introduction

The struggle to reduce the environmental impact of ships have led to ambitious regulatory changes concerning air pollutants (NOx, SOx), greenhouse gases and various discharge rules, which may lead to harmful side effects. Some of the current regulatory texts, like the EU sulphur directive, are written in a technologically neutral way which leaves ship operators several compliance options. In case of sulphur reductions, available options include LNG engines, exhaust gas cleaning system (EGCS) installation and switch to low sulphur fuels, but EGCS also known as SOx scrubbers create a new pollutant side stream directly to the sea from ships.

Methods and results

This work is based on the emission studies based on Automatic Identification System (AIS) data and the application of the STEAM3 model. The model has been recently updated and it now includes description of various discharges from ships. Over 99% of the discharge comes from open loop scrubbers which use seawater to clean the exhaust gases, after which the effluent is released back to the sea. Thus far this discharge has concentrated on Northern Europe, but it will become a global issue once the 2020 global sulphur cap becomes effective. Already in the Baltic Sea the 2018 release of scrubber effluents exceeded 80 million tonnes from 100 ships.

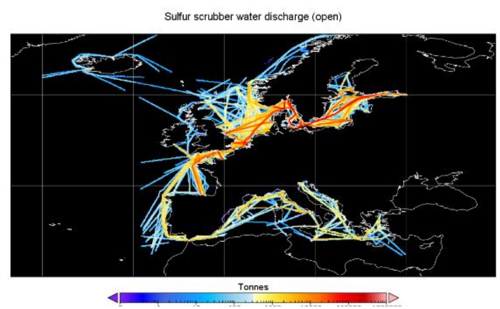

Figure 1. Geographical distribution of effluent discharge from SOx scrubbing with open loop systems. The color scale is logarithmic and indicates the release in tonnes of seawater.

Conclusions

This work is a starting point of a large EU project EMERGE, which deals with both air and water pollution from ships. In the Baltic Sea, shipping has been reported as a significant source of copper and zinc both from scrubber effluents and organometallic hull paints. It is therefore necessary to conduct a thorough assessment in larger scale to identify potential pitfalls of available EGCS systems.

Acknowledgements

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AIR POLLUTION RESEARCH IN SUPPORT OF CIRCULAR TRANSITION

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Summary
The air quality research community can substantially contribute to the successful implementation of circular transition by participating at scenario intercomparisons focussing on holistic assessments containing emission estimates and pollutant dispersion simulations.

Introduction
In contrast to the traditional linear economic approach (make, use, dispose), circular economy allows keeping resources in use for as long as possible, extracting the maximum value from them whilst in use, then recovering and regenerating products and materials at the end of each service life. The rational use of raw materials and energy, as well as the minimization of wastes are invaluable for mitigating climate change. Therefore, EU legislation stipulates the transition towards a circular economy ('circular transition'; EC, 2019). Traditionally, research on circular transition focuses on externalities related to GHG emissions in conjunction with fuel substitution, energy (re)use and waste management. Yet, a holistic climate change and air quality assessment approach could prove very helpful for accurately evaluating the environmental sustainability of the proposed transition modes, for providing an integrated policy framework with existing air pollution abatement efforts and for foreseeing and mitigating local effects. The introduction of recycled (waste-derived) fuel in production processes is a prototypical example of the need for holistic assessment. On the one hand there are significant benefits from waste reuse as fuel vs its disposal (energy and carbon footprint reduction, lower disposal-related pollutant emissions), on the other one has to consider the potential impacts from fuel substitution (i.e., less experience with novel fuels, possibly a lower calorific value and increased levels of individual emissions which would not occur with the traditional fuel). The air quality research community can substantially contribute to the success of such a holistic assessment by comparing the 'do-nothing' and circular transition scenarios in terms of realistic and reliable emission estimates and (where appropriate multiscale) dispersion simulations.

Case study 1: Alternative fuels in cement production
Fossil fuels have been and still are the major energy source in cement production. However, over the last few decades there is a steady global trend of increasing use of alternative fuels, driven by both cost incentives and a series of environmental benefits. The impact of using alternative (e.g. waste-derived) fuel mixes in the plant kiln on air quality in the surroundings of a given plant should be assessed in the frame of a holistic approach by estimating the exhaust air emissions from the rotary kiln for the conventional fuel, as well as for mixtures of conventional with alternative fuels, and subsequently simulating the dispersion of the pollutants emitted. An example for such an assessment is the study conducted to analyse the prospects for the partial replacement of conventional fossil fuel (pet coke) with alternative fuels in the TITAN cement factory in Thessaloniki, Greece (Moussiopoulos et al., 2020).

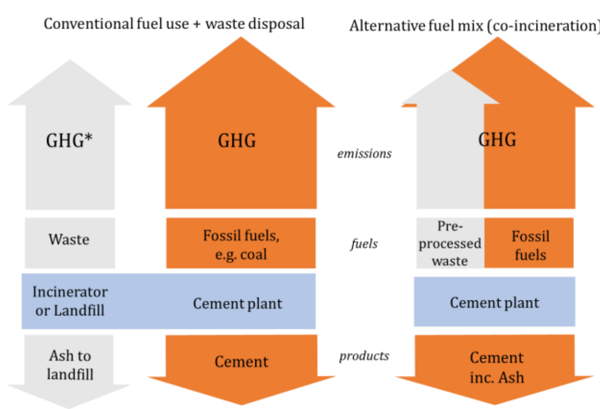

Fig.1 Atmospheric emissions and waste flows in cement production with conventional vs alternative fuel mixes

Case study 2: Environmental aspects of circular practices in agriculture
Smart farming practices imply several potential air quality impacts. Assuming individual scenarios, emissions and waste streams have to be estimated and the pollutant dispersion has to be analysed, and then the results have to be compared to those of the 'do-nothing' scenario. Such comparisons are the subject of the Gaia Sense project (Barmpas et al., 2020).

Conclusions
The air quality research community is capable of providing methodologies, approaches and experience to assist in the implementation of circular transition. Additional work may be needed for novel emissions quantification and for reliable/integrated impact assessment in unprecedented situations.

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AIR QUALITY CHALLENGES FACING GLOBAL CITIES – A MULTISCALE ANALYSIS

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Summary
Air quality in all global cities is still of major concern in terms of health impacts and compliance with regulatory standards and limit values. While there has been much progress with reduction of emissions of key air pollutants, concentrations of PM_{10}, $PM_{2.5}$, O_3, NO_2 still often exceed the national standards and certainly the WHO guidelines which are usually more stringent. This paper examines new results emerging from a number of cities across the globe to contrast the scientific challenges which are not only driven by different emission contributions but also by differences in the prevailing meteorology, orography and air quality management capacity. Results are discussed from a number of initiatives coordinated by World Meteorological Organisation's Global Atmospheric Watch GURME project and other projects such the Air Pollution and Human Health programme focussing on Delhi.

Introduction
Air pollution has been widely recognized as a major global health risk with major implications for the cities of the world (World Bank 2016). The magnitude and distribution of air pollutant concentrations results from a complex set of multiscale interactions between source emissions, chemical transformations and prevailing meteorology. As a consequence, air quality within a city cannot simply be assessed with local scale approaches where for example more than half of the air pollution can result from outside the city (e.g. Singh et al., 2014). These challenges impose a significant constraint on air quality and meteorological models to predict and forecast air pollution on multiple scales (e.g. street to regional). For example, current meteorological and air pollution model predictions can significantly deviate from observations during extreme stable conditions, which often affect many cities during winter periods. This paper examines the outcomes of recent projects to quantify local and regional contributions to urban air pollution concentrations. Based on the analysis of observational and modelling data, it also makes recommendations for local air quality management.

Methodology and results
From a large number of global cities covering most regions of the world, a number of cities (e.g. London, Helsinki, Delhi, Mexico City, Singapore and Shanghai) have been selected taking account of population, geographical representation, emissions distributions and prevalent meteorological conditions. For each city, multiscale models (e.g. WRF-Chem, SILAM) have been applied to estimate local and regional contributions for PM_{10}, $PM_{2.5}$, NO_2 and O_3. For Delhi, as an example (see Figure 1), WRF-Chem model has been coupled with the OSCAR Air Quality Assessment System (Singh et al., 2014). For each city, the air quality model predictions have been evaluated with available measurements from routinely operated networks and campaign periods. The study quantifies local and regional contributions to the key air pollutants. In the case of $PM_{2.5}$, regional contributions can be as large as 70% of total concentrations. The paper discusses the spatial and temporal distributions within and outside the city and, where possible, the study contrasts episodic and more typical periods and comments on the implications for air quality management.

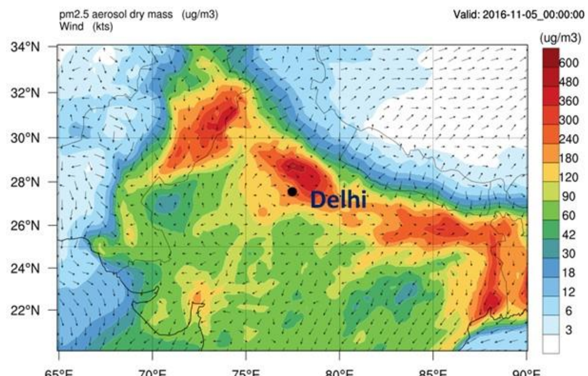

Figure 1. WRF-Chem modelled predictions over northern India. An example showing regional spatial distribution of $PM_{2.5}$ affecting Delhi.

Conclusion
Results from a multiple city investigation are analysed to quantify local and regional contributions to concentrations of particulate matter, NO_2 and O_3. Model predictions of spatial distributions are used to estimate the urban and rural contributions of air pollutants, especially contrasting particulate matter and O_3. Analysis of predicted meteorological fields reveals the stark modification of concentration distributions due to the surrounding topography and boundary layer evolution. The implications of air quality management are considered in light of emission and meteorological conditions affecting global cities.

Acknowledgement
We acknowledge the support of the World Meteorological Organisation (WMO), Global Atmospheric Watch (GAW) Programme and the GAW Urban Research Meteorology and Environment (GURME) project. Analysis of Delhi forms part of the PROMOTE project which belongs to the Indo-UK Joint programme on Atmospheric Pollution and Human Health funded by NERC, UK and MOES, India. The paper does not discuss policy issues and the conclusions drawn in the paper are based on the interpretation of observation and modelling results.

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ADVANCES IN AIR QUALITY MODELING AND FORECASTING

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Summary
Advance approaches in AQF combine an ensemble of state-of-the-art models, high-resolution emission inventories, space observations and surface measurements of most relevant chemical species to provide hindcasts, analyses and forecasts from global to regional air pollution and downscaling for selected countries and urban areas.

Introduction
The importance of and interest to research and investigations of atmospheric composition and its modeling for different applications are substantially increased (see e.g. WWOSC, 2015; CCMM, 2016; GAW IP, 2017). Air quality forecast (AQF) and assessment systems help decision makers to improve air quality and public health, mitigate the occurrence of acute air pollution episodes, particularly in urban areas, and reduce the associated impacts on agriculture, ecosystems and climate.

Results
Based on published reviews (e.g. Carmichael et al. 2008, Hollingsworth 2008, Zhang 2008, Menut and Bessagnet 2010, Grell and Baklanov 2011, Kukkonen et al. 2012, Zhang et al. 2012a,b, Baklanov et al. 2014, 2017, Ryan 2016, Benedetti et al. 2018, Bai et al. 2018, Kumar et al. 2018, Sokhi et al. 2019) and recent analyses, the presentation discusses main gaps, challenges, applications and advances, main trends and research needs in further developments of atmospheric composition and air quality modeling and forecasting, including the following trends in the development of modern atmospheric composition modelling and AQF systems: (i) Seamless prediction of the Earth system approach; (ii) Online coupling of atmospheric dynamics and chemistry models; (iii) Multi-scale prediction approach; (iv) Emission modeling for improved emission data; (v) Bias correction techniques; (vi) Multi-platform observations and data assimilation; (v) Ensemble approach; (vi) Subseasonal to seasonal forecast; (vii) Fit for purpose approach; (viii) Impact based forecast.

Conclusions
Main trends and research priorities in seamless AQF as well as capacity building, training and education aspects of modern AQF systems and applications, following Zhang et al. (2019), are highlighted and discussed.

Acknowledgement
We acknowledge a number of WMO experts and authors of the Best Practices & Training Materials for CW-AQF book.

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INNOVATIVE APPLICATIONS FOR THE AUGMENTED USE OF SATELLITE OBSERVATIONS TO SUPPORT AIR QUALITY MANAGEMENT

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Summary

This study has the principal aim of making satellite measurements of air pollutants and further derived products accessible to end-users such as authorities, air pollution experts and organisations that are involved in regional- and local-scale air quality management, health impact assessment and related epidemiology. Our vision is to facilitate air quality analysis and related decision making exploiting new and upcoming satellite data, combined with air pollution information from other monitoring systems and modelling. An easily accessible, user-friendly visualisation of the satellite data along with available air quality data from measurements and modelling is implemented. Furthermore, methodological approaches which enable refinements of satellite products using dispersion models are conducted.

Introduction

Satellite data play currently a minor role in air quality management. At present, ground based measurements and/or model simulations are used to assess the temporal and spatial evolution of air quality. The Achilles' heel of such modelling is emission data and their spatiotemporal variation. Air pollutant satellite data can be increasingly exploited now also using the data of the recently launched TROPOMI instrument (13th October 2017) for determining the variability of air pollution on annual, seasonal and daily scale.

Methodology

Real-time and archived satellite data are provided (see Fig. 1 left) together with other air quality data (surface measurements, emission data, model results) for end users (e.g. authorities) on a dedicated platform. The large spatial coverage and fast availability of satellite data provides an added value for environmental assessment studies. The customizable data management platform will be used and further developed to enable air pollution authorities and experts an integral view of air pollution patterns over Europe and particularly Austria (Fig. 1 right).

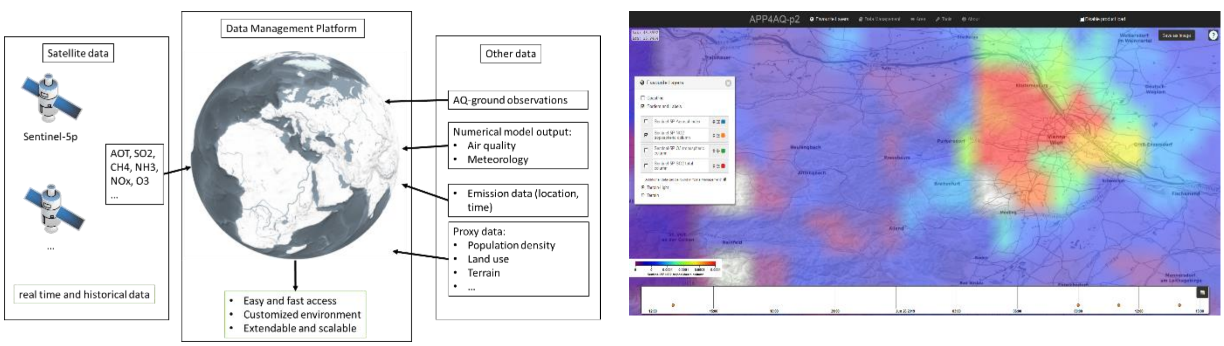

Figure 1: Left: Exemplified flow chart which gives an overview of the data which is integrated into the data management platform. Right: total column of TROPOMI NO_2 over Austria.

Conclusions

A user-friendly accessible platform for representing satellite data was implemented. It does not only enable first and swift air quality analysis, the investigation of its spatiotemporal evolution, but also helps improving understanding of increased air pollution levels e.g. during episodes, Saharan dust, and forest fires. In the next step, we will work on the harmonisation of satellite data with air quality measurements and area-wide modelled air pollutants to further process, quantify and validate satellite data. On this basis, the spatial variability of emission inventories can also be further validated and matched.

Acknowledgement

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A MULTI-SCALE SIMULATION TOOL TO ASSESS THE EFFECTS OF NATURE-BASED SOLUTIONS (NBS) IN URBAN AIR QUALITY

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Summary
Nature-based solutions (NBS) are seen as a valuable way to reduce urban pollution in urban environments but there is little quantitative information on its effectiveness. The aim of this study was to perform computational fluid dynamic (CFD) simulations to determine the effects of NBS in the urban air quality. Using a multi-scale modeling approach, we analyse the effects of the NBS for a specific area of city of Madrid (Spain). The sensitivity studies show how the different urban NBS affect to local air pollution concentrations. The impact of NBS in complex urban environments was simulated using a multi-scale modeling tool, from a mesoscale level to a micro-scale level, during a NO_2 episode period (2016). In certain hot spots we find significant effects of NBS to the local air pollution.

Introduction
Air pollution is one of the major health problems in densely populated cities. NBS can be used to mitigate air pollution, but successful implementation of NBS is largely dependent on having sufficient scientific knowledge of their effects on air pollution. NBS are based on the creation, improvement or restoration of ecosystems, including green soils and infrastructure (green cycle paths, tree planting, green infrastructure such as acoustic barriers, green facades and roofs, mobile and floating gardens, etc.). NBS can work in two different ways: a) Directly, i.e. by reducing air pollutants through physical deposition processes and b) Indirectly, i.e. by changing the ventilation of street canyons and thus air pollution flows. The impact of NBS on air quality is highly dependent on the context in which it is applied; sometimes NBS can improve urban air quality, but other times they can be ineffective or even detrimental. Before these NBS can be applied, it is important to confirm that these solutions are effective to improve air quality. To achieve this, we have implemented a simulation tool to see how NBS can affect pollution in urban areas, either through increases or decreases.

Methodology and Results
An innovative multi-scale model of urban air pollution is presented. The simulation tool combines the WRF/Chem (NCAR, US) chemistry–transport model that includes a comprehensive treatment of atmospheric chemistry and transport on spatial scales down to 1 km (Grell et al., 2005) and the micro-scale CFD PALM-4U (BMBF, DE) model that describes the atmospheric concentrations of pollutants in an urban area with a spatial resolution of meters (Maronga et al., 2015). We reproduced airflow and air pollution diffusion using three-dimensional steady-state isothermal flow field model. PALM-4U solves both structural details of the complex urban surface and turbulent eddies larger than 10 m in size. The CFD simulations were configured to follow the recommendations of COST Action 732 about the use of CFDs. In order to analyse the effect of NBS onto the air pollution, a small domain has been built with a real morphological environment existing in the urban area of Madrid. The initial results indicate that NBS have a positive effect on reducing the overall pollution in an urban area. As for the tested NBS, ones are better at reducing pollution than the others. Results indicate that the proposed numerical model could reproduce the distribution of air pollution concentrations in a real urban environment. Our simulations show that NBS can absorb atmospheric pollutants directly and indirectly through ventilation process.

Conclusions
The coupled WRF/Chem-PALM-4U modelling system is a reliable method to understand the complicated flow and pollutants dispersion within urban areas. The modelling system can be used as a tool to evaluate NBS at street level. The integrated modelling system is suitable for testing and evaluating NBS mitigation strategies on a scale of metres and obtaining information on their effectiveness without having to implement it in reality. The findings provide a useful strategy with the implementation of NBS in urban areas to mitigate atmospheric pollution. The results can be useful guidelines for urban planners to devise the location specific mitigation plans for their cities. NBS are beneficial for air quality, but they are not a solution to the air quality problems at a city scale. This analysis is the first of multiple studies of using NBS to enhance air quality in dense urban areas. In the future, we will run more numerical simulations to further improve the simulation tool and increase our understanding of the effects of NBS on urban air pollution.

Acknowledgement
The UPM authors thankfully acknowledge the computer resources, technical expertise and assistance provided by the Centro de Supercomputación y Visualización de Madrid (CESVIMA).

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A SMART AIR QUALITY NETWORK IN URBAN AREA FOR THREE-DIMENSIONAL, HIGH-SPATIOTEMPORAL AIR QUALITY STUDY

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Summary
The Smart Air Quality Network (SmartAQnet) project is focused on acquisition of individual air pollution exposure and health risks data by integration of existing air quality network with in situ instrument, spatially high-resolved network, unmanned aerial vehicle (UAV) sounding and remote sensing data sets by a new air pollutant monitoring strategy in the urban space. Long-term ground-based remote sensing is performed by three ceilometers for boundary layer height (BLH) detection over the model region Augsburg, Germany as well as a Radio-Acoustic Sounding System (RASS) for temperature and wind profile measurements at the Augsburg University campus and completed by UAV height profiling with low-weight meteorological sensors and particle counter to monitor the three-dimensional variability of the lower atmosphere. Based on these results an observation strategy is under development which allows continuous precise BLH information applicable for evaluation of numerical and statistical simulation of high-spatiotemporal resolved air pollution data as well as provides a basis for nowcasting of air quality.

Introduction
The project SmartAQnet, funded by the German Federal Ministry of Transport and Digital Infrastructure - Bundesministerium für Verkehr und digitale Infrastruktur (BMVI) under grant no. 19F2003B from 2017 until 2020, is aimed at reduction of gaps in currently available spatial and temporal air pollution data coverage. The architecture to build up a test network is realized in the model region Augsburg, Germany, including a consistent and also intelligent communication of measuring devices by a complete Internet of Things Stack using the latest Smart Data technologies. UAV sounding and remote sensing by three ceilometers and a RASS complete by height profiling the monitoring of air pollution and meteorological parameters. An introduction to the project was given by Budde et al. (2017) and Budde et al. (2018). Results about meteorological influences upon spatial variation of air pollution exposure will be presented on this data basis which is more than one year long. Special focus is on the information content of the different measurement principles for detection of particulate matter, concluded information about atmospheric layering as well as mixing and transport conditions for emitted particulate matter. Better understanding of these complex processes support knowledge about the formation of quality of air and especially high air pollution episodes as well as development of hot spot pollution regions.

Methodology and Results
The ceilometers Vaisala CL31 and CL51 are mini-lidar with a vertical resolution of about 10 m and a lowest detectable layer at around 50 m. A gradient method is applied to determine from optical vertical backscatter profiles routinely BLH up to 4,000 m height. The METEK-RASS measures profiles of wind speed, wind direction, variance of the vertical wind component by analysing the Doppler shift of the acoustic signal and of acoustic temperature by electro-magnetic wave sounding of the acoustic disturbance in the atmosphere with a vertical resolution of 20 m from about 60 m up to a height of 540 m. The UAV systems used are self-constructed fixed-wing aerial vehicles and a rotorcraft of type DJI Matrice 600 pro which are equipped with low-weight weather parameter sensors (SHT75, P14rapid and Temod-I²C) and particle counter (Alphasense OPC-N2).
Figure 1 shows that the $PM_{2.5}$ concentration decreases above the temperature inversion indicating that the temperature inversion is the upper boundary of the near-surface well-mixed layer. The comparison of the profile of the acoustic potential temperature between RASS and UAV data shows good agreement within a difference of up to 2°C. The comparison between the BLH calculations is characterized by several similarities in different situations. The differences are caused by the diverse measurement methods but also by the respective weather condition.

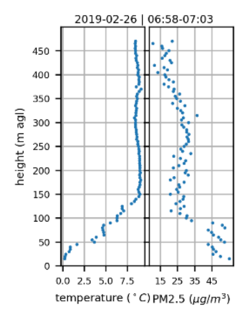

Fig.1 UAV measurements of temperature and PM2.5

Conclusions
Measurements of vertical profiles of air pollution and meteorological parameters by use of UAVs is a new concept in science, which has advantages and disadvantages compared to remote sensing devices. The combination of these measurement methods is required for obtaining temporally and spatially high-resolution data.

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AIR QUALITY MODELING OVER EUROPE FOR THE YEAR 2018 USING POLYPHEMUS/DLR BASED ON TNO EMISSIONS

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Summary
Due to lack of updated emission data for air quality study over Europe for the year 2018 period and high dependency of model results on accuracy of emission data, emission data for this year is estimated from 12 years TNO emission trends. Application of the new estimated emission product decreased the nitrogen dioxide (NO_2) bias between POLYPHEMUS/DLR model and the Copernicus Sentinel-5P satellite (S5P) tropospheric NO_2 column for most of Europe.

Introduction
The satellite and ground observations provide important data to get a better understanding of air pollution to be able to reduce the health risk in real time by alarming the groups of people in danger. One mean to reduce the exposure and reducing the risk is emission reduction. This can be tested by air quality models by predicting the concentration of pollutants and by performing scenario studies to assist policy makers. Although the models are powerful tools and getting more sophisticated and reliable, they are highly sensitive to the accuracy of emission inventory data. The latest available and accessible European emission data set from TNO belongs to the year 2011 and we found implementing this data results in overestimation of nitrogen dioxide (NO_2) in POLYPHEMUS/DLR model compared to the S5P tropospheric NO_2 columns. This can be due to the reduction of NO_2 emission during last years in the most European countries in order to respect emission regulations. In this study, we implement a trend analysis of 12 years TNO emission data in order to estimate the emission for the year 2018 and reduce the model NO_2 bias.

Methodology and Results
For preparing weather condition and atmospheric parameters the Weather Research and Forecasting (WRF2) model Version 3.5 is used for this study and the results are interpolated for the Chemistry transport model (CTM) POLYPHEMUS/DLR. The POLYPHEMUS/DLR model platform contains several modules for chemistry, transport, and aerosols. Initial and boundary conditions are extracted from a 10 year MOZART3 (Model for OZone and Related chemical Tracers) run. In this study, for the emission inventory data, TNO product is used, which is available for Europe in 7 km resolution. The latest available and accessible European emission data set from TNO Company belongs to the year 2011 and using this data introduce a large bias in the model results compared to S5P (Figure 1 up). To increase the reliability of the emission data set, we investigated twelve years trend of available TNO emission data between 2002 and 2011 with the aim to estimate emission maps for the year 2018. The emission estimation was performed for all species and all emission sectors with the exception of point source due to the lack of a clear trend. Application of the new estimated emission data decreased the bias between model and S5P NO2 (Figure 1 down). Moreover, by comparing the model results using TNO 2011 and estimated TNO 2018 emission a third emission product is calculated with respect to the model and S5P bias analysis. In all comparisons, average kernel profiles from S5P products were implemented in the calculation of the model total tropospheric NO_2 column when comparing to satellite observation.

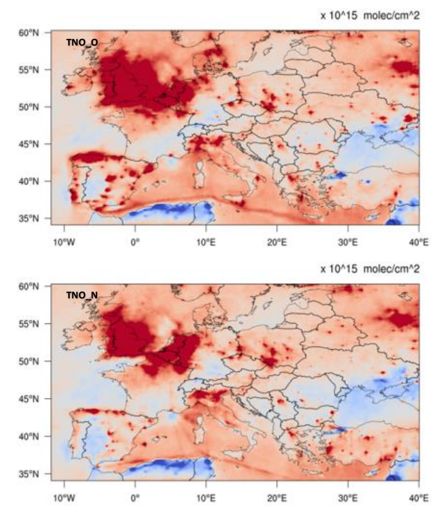

Fig.1 NO_2 tropospheric total column Bias between model and Satellite using TNO 2011 (up) and estimated TNO for the year 2018

Conclusions
An outdated emission data can introduce a large bias in air quality model results. Having an updated and accurate emission data is not straightforward due to the fast changes in pollutant emission sources in the last years because of concerns about climate change and health risks and changes in emission regulations. Application of a trend analysis over TNO emission inventory data timeseries and estimating the emission for the year 2018, results in the NO_2 bias reduction between the model and satellite data. The estimated emission is comparable with a new emission inventory over Germany (GRETA).

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ADVANCED MODELLING APPROACH FOR THE ESTIMATION OF SHIPPING EMISSIONS CONTRIBUTION TO INLAND AIR POLLUTION

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Summary

The Horizon 2020 funded EMERGE project aims to to quantify and evaluate the effects of emission reduction solutions, such as scrubbers, for shipping in Europe for several scenarios, and to develop effective strategies and measures to reduce the environmental impacts of shipping. EMERGE will develop an integrated modelling framework to assess the combined impacts of shipping emissions on the aquatic and atmospheric environments, and the effects on marine ecosystems.

Introduction

Combustion in ship engines produces a range of primary and secondary pollutants (Particulate matter (PM), SO_x, NO_x and O_3) that have important environmental, health, economic and climatic impacts. In view of new and more strict global standards that will be enforced on January 1st 2020 for shipping emissions, accurate emission estimates and realistic simulations on the effect of abatement measures are a prerequisite for efficient management of air pollution problems associated with shipping emissions. Within the EMERGE project, refined atmospheric models that will take into account ocean-atmosphere interactions will be developed and employed in real-world test cases involving actual vessels and main shipping routes in Europe.

Methodology and Results

EMERGE will provide new real-world emission inventories for several years on a European scale for the shipping emissions to both water and the atmosphere. This realistic emissions dataset will be used as input for advanced atmospheric model simulations to quantify shipping emissions contribution to air pollution levels. Atmospheric dispersion modelling will include the deployment of chemical transport models, a range of urban scale dispersion models, and a Meso-scale model combined with a photochemical dispersion model (MEMO/MARS). In addition to air quality, model simulations will be used for the assessment of the interactions of the atmosphere and the seas at different scales, based on treatments for atmospheric deposition to the sea, and for the formation and dispersion of sea spray. In order to estimate shipping emissions reduction due to abatement measures to air pollution levels at the local scale, a two-way coupled mesoscale model MEMO and microscale Computational Fluid Dynamics (CFD) model MIMO modelling system will be employed. In the two-way MEMICO (Tsegas et al., 2015) coupling scheme, a three-dimensional spatial interpolation scheme, a spatial adjustment of values within the surface layer, and the formulation of the lateral boundary conditions to introduce the interpolated values into the microscale model are applied. For simulating pollutant chemistry and dispersion characteristics, the mesoscale dispersion model MARS-aero is applied at the same spatial resolution as MEMICO, which downscales from a spatial resolution of 500m for the entire selected area to 1m for selected coastal locations. Microscale atmospheric modelling will also be conducted with the ANSYS CFX CFD code and the atmospheric Large Eddy Simulation flow model Parallelized Large-Eddy Simulation Model (PALM LES), in order to parameterise the deposition of air pollutants from the ship funnel to water in the vicinity of the ship.

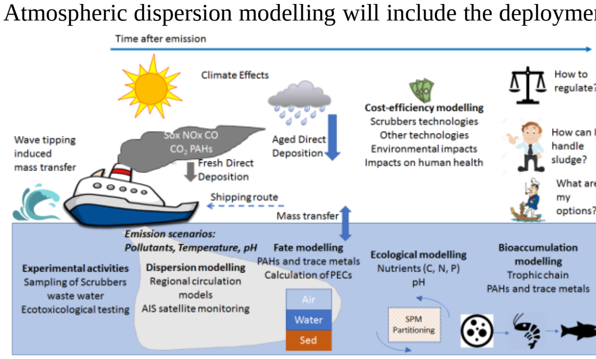

Fig.1 EMERGE schematic concept

Conclusions

Within the EMERGE project, an integrated multi-scale modelling framework will be developed for assessing the impacts of reduction options and techniques of the shipping emissions, such as the use of scrubbers, using unprecedented spatial resolutions (5 km for the whole Europe and 1 km for case studies). The chemical transport models used in EMERGE will provide quantitative predictions on the effects of various measures, scenarios and strategies. The models will also be deployed for the assessment of the ocean-atmosphere interactions at different scales.

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LONG TERM EXPOSURE ESTIMATES OF PARTICLE NUMBER CONCENTRATIONS IN DENMARK

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Summary
Modelling of ambient particle number concentrations has recently been implemented in the Danish air quality modelling system and validated against long-term measurements. Exposure estimates are provided for the whole of Denmark for 40 years (1979 – 2018) with a spatial resolution of 1 km x 1 km taking all emission sectors into account and additionally at street location considering the road traffic contribution.

Introduction
For various elements of Traffic-Related Air Pollution (TRAP) a relationship has been found with adverse health effects. Traditional components of TRAP such as NO_2, CO, O_3, PM_{10}, $PM_{2.5}$ and lately also BC/EC are included in exposure models and their effects are investigated in health studies for a long time. This has been done by application of e.g. the Danish DEHM/UBM/AirGIS exposure modelling systems (http://envs.au.dk/en/knowledge/air/models/).

Ultrafine particles (UFP) have attracted significant attention as another health relevant component of TRAP in various recent studies, especially in studies of short-term effects of air pollution. The Health Effects Institute (HEI) funded the project "Health Effects of Air Pollution Components, Noise and Socioeconomic Status (HERMES)" with one of the aims to establish particle number /UFP as new pollution component in all three Danish air pollution models that are used for exposure assessment: the regional model, Danish Eulerian Hemispheric Model (DEHM); the Urban Background Model (UBM) and the Operational Street Pollution Model (OSPM®).

Methodology and Results
Based on a literature review focusing on ultrafine particle modelling studies conducted in Europe the M7 particle dynamics module (Vignati et al., 2004) was chosen for implementation into DEHM. The M7 module is developed mainly for air pollution modelling purposes and has been used by several groups in Europe and was recently applied in the EU TRANSPHORM project to model particle number concentration in five European cities (Kukkonen et al. 2016). In this project the recently developed European particle number emission database by TNO (Denier van der Gon et al. 2014), is used as modelling input for the European domain in an about 7 km x 7 km spatial resolution. Simultaneously a 1km x 1km spatial resolution UFP database is developed for Denmark.

This paper describes the implementation of M7 into the Danish DEHM/UBM/AirGIS system taking the most relevant dynamic processes into account at the different atmospheric transport time scales (Ketzel et al. 2004). The model results are validated against more than 15 years continuous UFP measurements at various Danish stations as well as European UFP measurements from the EBAS atmospheric composition database (http://ebas.nilu.no/). Fig. 1 provides an example of the validation for a street monitoring station.

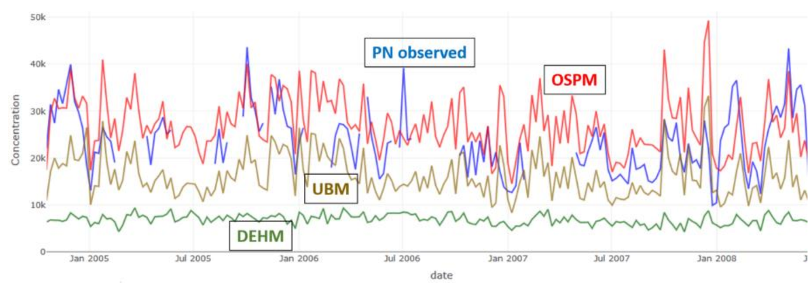

Fig.1 Weekly mean time series of calculated total particle number (10-100nm) concentration with contributions of the 3 models, compared to measurements at the street location, H.C. Andersens Boulevard in Copenhagen. Units #/cm3.

Conclusions
We obtain satisfying results when comparing our model estimates with observations, considering the complexity of the particle number concentrations, both with respect to potential uncertainties in the measurements and the uncertainties in the emission estimates and modelling of the complex dynamical processes.

Acknowledgement
Research described in this article was conducted under contract to the Health Effects Institute (HEI), an organisation jointly funded by the United States Environmental Protection Agency (EPA) (Assistance Award No. R-82811201) and certain motor vehicle and engine manufactures.

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MAPPING PERCENTILE STATISTICS OF ELEMENT CONCENTRATIONS IN MOSS COLLECTED FROM 1990 TO 2015 THROUGHOUT GERMANY

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Summary
This paper presents air quality data in terms of heavy metals and nitrogen concentrations in moss specimens collected across Germany. The calculation of quantiles of the distribution of measured values enables their statistically meaningful scaling as well as their measurement campaigns integrating and specific mapping, the mapping of spatial differences even with strongly decreasing element contents as well as the mapping of the spatial structures of a Multi Metal Index covering all chemical elements.

Background
Monitoring and mapping of atmospheric deposition can be achieved by use of chemical transport models, technical sampling devices and bio-accumulators such as moss. Within the European moss survey programme, since 1990 every five years moss have been sampled at up to about 7312 sites in up to 34 countries, among them Germany. Sampling, chemical determination of heavy metals (since 1990), nitrogen (since 2005), and persistent organic pollutants (POPs since 2010) in moss specimens, quality control and statistical evaluation were conducted according an harmonized methodology. Mapping the percentile statistics of heavy metals and nitrogen concentration in moss sampled in forests across Germany is the focus of this paper.

Methodology
To this end, element- and survey-specific as well as heavy metals and surveys integrating statistical evaluations and GIS-mapping were performed based on data collected in five (1990-2005, 2015) of the six (additionally 2010) European Moss Surveys in which Germany participated. The number of moss sampling sites ranged between 4499 and 7312 in 20 to 34 European countries. In Germany, mosses were sampled at 592 (1990), 1026 (1995), 1028 (2000), 726 (2005) and 400 (2015), respectively, sites. The reduction of monitoring sites since 2005 was conducted using a statistical methodology ensuring the validity of monitoring results.

Results
The results encompass a) maps on element- and survey-specific quantiles (ten percentile classes: 0-10, > 10-20, , …, > 90-90) depicting the spatial structure of the ten percentile classes for each element and monitoring campaign and (shifts of?) the geographical position of relative hot spots of element concentrations (Figure 1 top); b) maps on element-specific and surveys integrating ten percentile classes (Figure 1 bottom) depicting the spatial structure of up to ten percentile classes for each element integrating survey data of all monitoring campaigns, where the number of percentiles depends from the decrease or increase of element concentration across time; c) maps on the spatial structure of a Multi Metal Index integrating several heavy metals by transforming their measurement values into 1 to 10 scores according to the percentile classes.

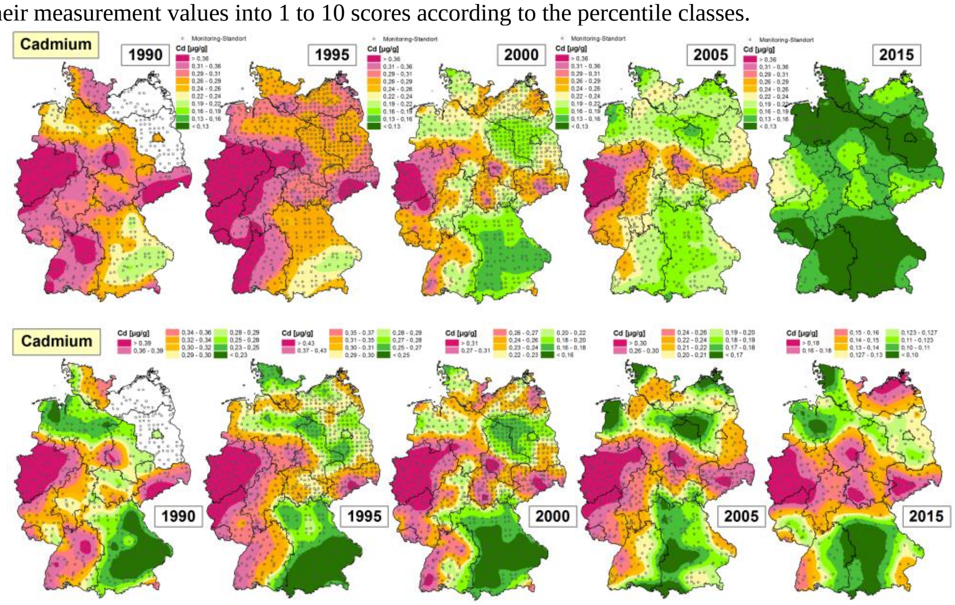

Figure 1: Spatial patterns of percentile classes integrating the surveys 1990-2015 (top) and of the 10 survey-specific percentile classes (bottom) of Cd-concentrations in moss specimens.

Conclusion
Cr, Hg, Sb and Zn show, contrary to Fe and Pb, no constant decrease of element concentrations, but an intermediate increase between 2000 and 2005, which did not continue until 2015. Al, As, Cd, Cu and V stagnated between 2000 and 2005, Hg from 2005 to 2015. Therefore, Cr, Sb and Zn are focused in this paper together with Cd, Hg, Pb and N which are of priority according to the Convention on Long-range Transboundary Air Pollution. Survey-specific statistical analyses corroborate that the spatial patterns of element concentrations in moss are changing across time.

LIFE-LONG EXPOSURE TO PM2.5 AND NO2 AND DERIVED HEALTH EFFECTS FOR POPULATION SUBGROUPS IN EUROPE

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Summary

To estimate the health impacts caused by PM2.5 and NO_2 usually the annual average outdoor concentration of these substances in the background of cities is used. However obviously the correct indicator would be the concentration of these pollutants in the inhaled air. Furthermore, chronic diseases develop over many years, so obviously not the concentration averaged over one (recent) year, but the course of the annual averaged concentration of the whole adult life time should be used. Thus a methodology has been developed, that uses a number of characteristic data of a person like age, home site, socioeconomic status a.s.o. to estimate the lifelong exposure to PM2.5 and NO_2 of this person. Using this exposure and exposure response functions, health impacts, e.g. the life expectancy loss are calculated.

Introduction

When estimating the health impacts caused by air pollution, usually concentration-response relationships are used, that link the urban background concentration of pollutants with health impacts. However, obviously a better indicator is the concentration at the places, where people are and thus inhale the pollutants. As people are most of the time indoors, it is necessary to take into account also indoor sources like smoking frying, using wood stoves, candles a.s.o.. Furthermore, the most important diseases are chronic diseases, that develop within many years of inhalation. Thus the course of the exposure during the lifetime of the analysed person is needed. Thus a methodology to simulate the lifelong exposure to PM2.5 and NO_2 for European population subgroups characterised by age, gender, region, socio-economic status and behavioural habits has been developed and applied to estimate health impacts.

Methodology

Monitoring data form measurement stations (Air Base), modelled concentration data form EMEP/MSC-W and interpolated concentration data from EIONET and emissions form the EDGAR-Hyde data base are used are used to provide maps for the annual outdoor concentration of NO2 and PM2.5 in Europe. A newly developed mass-balance model is used to assess the concentration of pollutants in indoor micro-environments based on the penetration of pollutants from outdoor into the rooms and on information about the source strength of indoor sources. Tim-activity patterns for persons with different features are then derived by analysing the data from the Multinational Time Use Study (MTUS). A life course trajectory model for predicting retrospectively the transition between socio-economic status during the life of the analysed person has been developed. The results of the exposure modelling are subsequently used with exposure response functions (ERFs), aggregation factors and monetary values to assess health impacts and damage costs

Results

Results show that the annual average exposure to PM2.5 and NO_2 at European level kept increasing from the 1950s to a peak between the 1980s and the 1990s and showed a decrease until 2015 due to the implementation of a series of directives. It is also revealed that the exposure to both pollutants was largely affected by geographical location, gender and income level. The average annual exposure over the lifetime of an 80-year-old European to PM2.5 and NO_2 amounted to 23.86 (95% CI: 2.95–81.86) and 13.49 (95% CI: 1.36–43.84) μg/m3. The exposure to both pollutants led to YOLL (years of life lost) of 3.53×10^{-2} (95% CI: 4.79×10^{-3}-5.98×10^{-2}) and 4.76×10^{-3} (95% CI: 0.00-3.03×10^{-2}) per year, i.e. an average loss of life expectancy of 0.42 and 0.06 month respectively per life year exposed.

Acknowledgement

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Air Pollution Sources and Emissions

EXPLORING EQUIVALENT BLACK CARBON (EBC) CONCENTRATIONS IN SWITZERLAND WITH THE AETHALOMETER MODEL

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Summary

Black carbon (BC) is a constituent of particulate matter (PM) which is relevant for negative human health and climate outcomes. When aethalometers (optical absorption instruments) are used to monitor BC and calibrated with collocated elemental carbon (EC) measurements, the result is named equivalent black carbon (EBC). EBC can be apportioned into traffic and woodburning components by a data processing technique called the "aethalometer model" [1]. This model was applied to six EBC monitoring sites across Switzerland between 2008 and 2018. The model outputs were evaluated and the results were used for a formal trend analysis. The traffic EBC component was found to be significantly decreasing across all of Switzerland, with the exception of an isolated, rural-mountain location. The woodburning EBC trends were more variable however, and in some locations where wood smoke loads are known to be high, EBC did not significantly decrease during the monitoring period. The conclusions illuminated by the application aethalometer model have important implications for air quality in Switzerland.

Introduction

Despite the lack of legal limits in Europe and elsewhere, black carbon (BC) or soot is an important atmospheric pollutant to monitor, understand, and control due to negative human health and climate outcomes. Aethalometers measure BC by monitoring optical absorption of sampled aerosol at a number of distinct wavelengths. When aethalometers' observations are transformed into BC mass with collocated elemental carbon (EC) measurements, the result is called equivalent black carbon (EBC). The "aethalometer model" can be used to apportion EBC into traffic (EBC_{TR}) and woodburning (EBC_{WB}) components by exploiting differing spectral dependencies of the aerosol emitted by these different combustion processes [1]. The aethalometer model was applied to six monitoring EBC sites across Switzerland and the results were used to conduct a trend analysis to explore how EBC_{TR} and EBC_{WB} concentrations have changed over time.

Methodology and results

The aethalometer model was applied to six EBC monitoring sites across Switzerland. The site types ranged from urban-traffic to rural-mountain classifications and data between 2008 and 2018 were analysed. The aethalometer model's outputs were evaluated by investigating diurnal cycles, model coefficients, and ambient temperature dependencies. For one EBC site, San Vittore, the model failed, most likely due to a heavy load of very freshly emitted wood smoke during the cooler months, making the two-sources approach inappropriate under such conditions. This site was not used for further analysis. The trend analysis indicated that with the exception of an isolated, rural-mountain monitoring location, EBC_{TR} significantly decreased across the analysis period at a maximum rate of -0.13 μg m^{-3} year^{-1} at Bern-Bollwerk (an urban traffic site). The observed trends of EBC_{TR} were interpreted as a success of the widespread installation of diesel particulate filters (DPFs) across the vehicle fleet. EBC_{WB} trends were however different than those seen in EBC_{TR} (for example Figure 1). At most locations, EBC_{WB} were found to be significantly decreasing between 2008 and 2018, but critically, not at Magadino-Cadenazzo, a monitoring site south of the Alps which is known to experience a high load of woodburning-sourced particulate matter and soot. This suggests that efforts to reduce soot emissions in some of Switzerland rural communities have not been effective. Rigi-Seebodenalp, the isolated rural-mountain monitoring site showed no significant trends in either EBC_{TR} or EBC_{WB}.

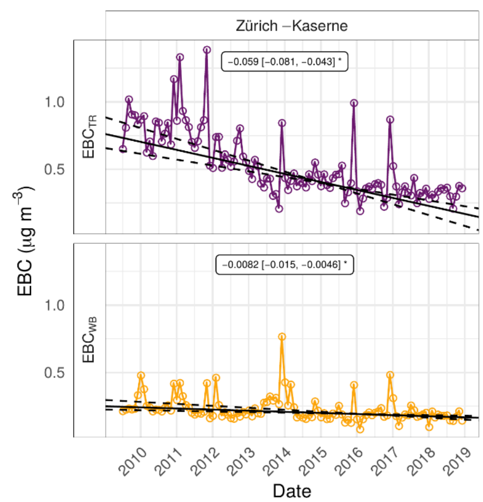

Figure 2. EBC_{TR} and EBC_{WB} trends at Zürich-Kaserne, an urban-background monitoring site. Labels indicate trends and 95 CIs in μg m^{-3} year^{-1}.

Conclusions

The aethalometer model is a useful and pragmatic tool to extract additional information from multi-wavelength aethalometer time series. For Swiss EBC monitoring sites, the technique was useful to expose trends in EBC_{TR} or EBC_{WB} and these trends have important implications for local air quality in Switzerland.

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LEVELS AND SOURCES OF BLACK CARBON LONG-TERM MEASUREMENTS IN ATHENS, GREECE

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Summary
This study investigates the long-term Black Carbon (BC) concentrations, characteristics, source apportionment and associations with meteorology and boundary-layer dynamics over Athens, covering a period of 4 years (May 2015 – April 2019) based on Aethalometer (AE-33) measurements. The BC concentrations and their wood-burning component (BC_{wb}) were evaluated against biomass-burning tracers, OC, EC concentrations to determine the role of residential burning on the Athens air quality, whereas the fossil fuel related activities (quantified as BC_{ff}) are also considered.

Introduction
Black carbon is the result of incomplete combustion of fossil fuels (diesel, oil, coal) and biomass (domestic wood burning, agricultural waste, forest fires) and is a major absorbing aerosol, with significant implications in atmospheric heating and climate change, and impacts on human health as well. Increased levels of particulates, including BC, have been observed in winter-time “smog events” encountered in Athens after 2010 (Fourtziou et al., 2017). Nevertheless, the full characterization of BC in the long term has not yet been addressed for Athens. The current work targets to fill this gap by providing information on the BC-aerosol characteristics and their temporal evolution (seasonal, monthly and diurnal), using long-term, high resolution measurements, to deliver a BC source apportionment analysis (BC_{ff} vs BC_{wb}) for an extended period and to examine the BC inter-annual trends during the 4-year period and its use for the evaluation of winter-time air quality.

Methodology and Results
The average BC concentration was determined at 1.9 ± 2.5 μg m^{-3} (ranging from 0.1 to 32.7 μg m^{-3} in hourly basis), with a well-defined seasonality characterized by increased winter-time levels (see Fig.1). Pronounced morning and evening/night peaks are found in the BC concentrations in winter, while for the rest of the seasons, this diurnal cycle appears to flatten out, with the exception of the morning traffic peak. On an annual basis, the biomass-burning fraction (BB%) of BC accounts for 22 ± 12%, while the fossil-fuel combustion (BC_{ff}) component (traffic and domestic heating emissions) increases during summer (83%) and in the morning hours. BC_{wb} exhibits higher contribution in winter (32%), especially during the night hours (39%), and it is highly correlated with other BB tracers during winter nights (e.g. levoglucosan, non-sea-salt-K^+, m/z 60 fragment), as well as with the fine fraction ($PM_{2.5}$) OC and EC. BC levels are effectively reduced by precipitation, while they significantly build-up for wind speeds <3 m s^{-1} and mixing-layer height (MLH) < 500 m.

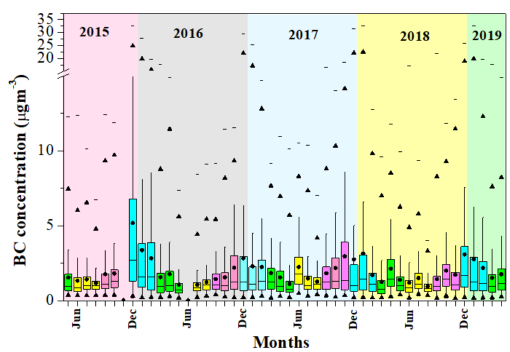

Fig.1 Monthly variation of the BC concentrations during May 2015 – April 2019.

Conclusions
The fossil fuel-related component dominated, with mean fractions ranging from 68% in winter to 83% in summer. However, the BC_{wb} was considerable, accounting for almost half of the total BC during the winter nights. The residential wood-burning emissions are mostly responsible for the large BC increase during winter nights, whereas the low BC levels during daytime in the warm season are mainly attributed to dilution into a deeper MLH. Long-term trend analysis of BC and its components did not reveal any statistically significant tendency, while during the winter months a statistically significant declining trend was found in the BC concentrations.

Acknowledgement
We acknowledge support of this work by the project “THESPIA II - Foundations of synergistic and integrated management methodologies and tools for monitoring and forecasting of environmental issues and pressures” (MIS 5002517)) which is implemented under the Action “Reinforcement of the Research and Innovation Infrastructure”, funded by the Operational Programme "Competitiveness, Entrepreneurship and Innovation" (NSRF 2014-2020) and co-financed by Greece and the European Union (European Regional Development Fund).

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SOURCE APPORTIONMENT OF POLYCYCLIC AROMATIC HYDROCARBONS (PAHS) IN AEROSOLS AND STUDY OF THEIR EFFECT IN HUMAN HEALTH: A COMPARISON BETWEEN THE WARM AND THE COLD SEASON OF THE YEAR

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Summary

The aim of this study is to identify the main sources emitting PAHs in the atmosphere of Thessaloniki and to assess the risk of lung cancer induced by exposure to PAHs. Furthermore, the study examines the variation of emission sources and PAHs induced lung cancer risk throughout the seasons of the year. Measurements were included three different sampling sites in an effort to include areas of Thessaloniki with various atmospheric conditions. The concentrations of PAHs were higher in winter compared to summer. The combination of conditional probability function and Positive Matrix Factorization was used for the apportionment of the main PAHs emission sources and their geographical origin. The study shows the temporal trend and spatial variations in the concentration of PAHs.

Introduction

PAHs are produced during the incomplete combustion of organic material. This fact is an indication for their emission sources which may include forest fires, volcanic activity, combustion of domestic heating fuels, coal and coal tar production, oil refinement, vehicle and means of transportation emissions (Tarantini et al., 2011). In Greece, the financial crisis that has been going on for over a decade now has forced citizens to search for cheaper and less eco-friendly fuels for domestic heating and their vehicles. The aim of this study examines the variation of emission sources and PAHs induced lung cancer risk throughout the seasons of the year 2017 and compare the cancer risk induced by PAHs, measured during the winter of 2013.

Methodology and Results

$PM_{2.5}$ were measured in three different stations in the city (rural, urban background, traffic) during February-March (cold season) and June-August (warm season) of 2017 followed by chemical analysis of 19 PAHs. It was concluded that PAH levels were increased during the cold period of the year. Using the Positive Matrix Factorization model it was found that the main emission sources for the rural station were biomass combustion (28%) and vehicle emissions combined with industrial activity (72%); for the urban background station industrial activity (18%), vehicle emissions (38%) and biomass combustion (44%); and for the traffic station biomass combustion (36%), vehicle emissions (54%) and industrial activity (10%). Using PMF results, the conditional probability function indicates as the most possible sources of PAHs the oil refinery situated in the western part of Thessaloniki, the cement production factory in the district of Efkarpia and main roads of the city (Ring Road, Lagada Street etc.). Based on the toxicity of benzo[a]pyrene, the Toxic Equivalent Quotients (TEQ) for the warm period of the year were calculated as follows: 0.29 ng/m^3 for the rural station, 1.05 ng/m^3 for the urban background station and 0.62 ng/m^3 for the traffic station. For the cold time of the year the values were 1.01 ng/m^3 for the rural station, 2.16 ng/m^3 for the urban background station and 2.56 ng/m^3 for the traffic station. Using the Multiple Path Particle Deposition model, the particle deposition along the human respiratory tract per age group was modelled in order to calculate the PAH-induced lung cancer risk. The maximum value of cancer risk was estimated for children (0-3 months old) in the urban traffic station, during the cold time of the year (1.741×10^{-6}) and the minimum risk was calculated for the female adults' group, in the rural station, during the warm period of the year (0.043×10^{-6}). Cancer risk assessment has also been carried out by Sarigiannis et al. (2015) who studied PAH-induced lung cancer risk in Thessaloniki during the winter of 2012-2013. The measurements were performed the same period as in the present study. The results showed an increase in cancer risk in the traffic station, from 2013 to 2017 indicating an increase of PAHs emissions during that time and a relative stability of cancer risk for the urban background station. Furthermore, the population living in proximity to the traffic station is at higher risk, as the result of the extensive use of diesel vehicles.

Conclusions

Ambient air PAH levels in the urban environment are greatly affected by seasonal effects of emissions patterns. The use of a refined methodology assessing the levels of exposure and the health risk from exposure to PAHs, allows us to significantly differentiate the actual health risk between different urban sites as well as between different age groups. On the urban scale the most significant PAH sources in ambient air are industrial activities and road transport.

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LONG TERM AIR QUALITY INDEX (LTAQI)

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Summary

Air quality index (AQI) is usually based on concentrations of three main species (nitrogen oxides, ozone and PM_{10}). Also, AQI often shows only currently concentration from the measurement stations. Effects on the health and environment depend on all species present in ambient air and their mutual interactions. Not only short-term effect but even more importantly is long- term impacts on human health. Bottom up emission inventory built based on the EMEP methodology includes twenty-three species. Seventeen of them were used to calculate extended long term AQI (ltAQI) for Slovenia.

Introduction

Effects of air pollution on health is an active research topic. To get into account their mutual impact on the health is in important to capture all known species due to their mutual interactions and different health impact. Common AQI were describe in the article *Air quality indices: a review* written by Plaia A. and Ruggieri M. (Plaia A., Ruggieri M., 2011). Since more and more European country assesses their National Emissions Inventory on the bottom-up methodology we get better spatial and temporal distribution of the concentration. That is the first step to develop ItAQI.

Methodology and Results

We built an emission inventory for Slovenia based on the EMEP methodology (EMEP/EEA, 2019). Spatial resolution of results is 100 m × 100 m. Temporal resolution is from one hour in case of traffic, to seasonal in case of agricultural emissions. The four main sectors are small combustion, road traffic, industry, agriculture and other. Precise data about buildings was used to calculate energy needs and emissions of every building. Slovenian road network and data from 500 traffic counters was used to calculate number of vehicles on each road for every hour (CIP model). Data base of industrial sources is based on measurements of pollutant concentrations in flue-gas stacks. Emissions from agriculture are calculated based on number of animals, type of farm and application of fertilizers.

Result is spatially and temporally varying base of emissions.

We used this data to make a first attempt at developing an extended ltAQI that includes seventeen species. Emission inventory was up scaled to 1 km × 1 km. For each grid cell and for each pollutant ratio of yearly emissions and limit value was calculated. Results were recalculated to be in range 0 to 1. Final ltAQI for each 1 km^2 grid cell is a sum of all seventeen values.

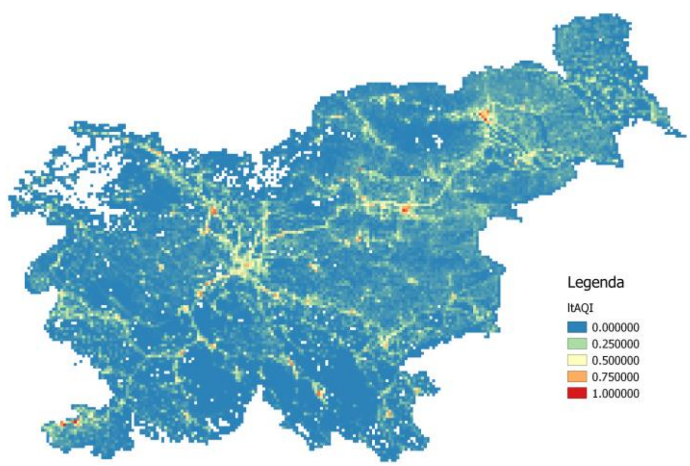

Fig.1 long term air quality index for Slovenia.

Conclusions

Results show that air quality in proximity of highways is average if there are no other sources nearby, otherwise below average. Lowest air quality was determined in areas of industrial facilities in proximity of residential areas. Important pollutants in Slovenia are nitrogen oxides, particulate matter, heavy metals and POPs.

Simplifications used in derivation of ltAQI are that meteorological conditions were not included and all species were treated equal.

Acknowledgement

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THE CONTRIBUTION OF HIGH EMITTERS VEHICLES TO FPS NUMBER CONCENTRATION IN THE HISTORICAL CENTRE OF NAPLES

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Summary
FPs from 20 to 1000 nm have been measured in a deep street canyon in the historic centre of Naples. At the same time traffic flow was registered using a camera. FPs measurements and video of traffic flow were synchronised so that it is possible to connect the increment of FPs concentration to the passage of vehicles. The operation is possible because the street is narrow and single-lane. The analysis of curves vs. time of both FPs and vehicles flow allows the individuation of high emitter PN vehicles. Their number and typology (cars, motorcycles and commercial light duty vehicles) was evaluated together with their contribution to the total FPs number concentration in the street canyon

Introduction
PM is a very hazardous airborne pollutant with major effects on cardiorespiratory system. The highest risk is associated with the inhalation of the fine particles (FPs) fraction with dimensions below 1 μm (Kumar et al. 2010). High levels of PN concentration are generally registered in urban areas (Kumar et al. 2014). Many anthropogenic activities release primary PM in the atmosphere, contributing to the formation of secondary PM. To ascertain the relative importance of each is quite difficult. Traffic flow is one of the principal sectors contributing to PM emissions in urban areas, depending on the age and the emissive characteristics of the vehicular fleet circulating. In a previous monitoring campaign, a large spatial variability of FPs number concentration was observed in the area of Naples with very high concentration levels at deep street canyon receptors (Murena and Prati 2019). To better assess the correlation between FPs number concentration and traffic flow a monitoring campaign was carried out in a deep street canyon.

Methodology
The PN concentration was measured using an isopropyl alcohol-based condensation particle counter (CPC) P-Track 8525. The range of diameters measured by the instrument is from 20 to 1000 nm with a maximum measurable concentration of $5 \cdot 10^5$ pt/cm^3. The range corresponds with that of FPs (Kumar et al. 2010). The monitoring campaign was carried out inside the historical centre of Naples at via S. Teresella degli Spagnoli having width (W=5.3 m) and average height ($H \approx 20$ m). Therefore, it is a deep street canyon with AR≈4. FPs number concentration was measured at heights of 3 m. Traffic flow was measured using a video camera. For the analysis of results, the vehicles are lumped in three classes: cars, motorcycles and light commercial duty vehicles.

Results
High FPs number concentration was observed during the monitoring campaign. The period average value being $5.6 \cdot 10^4$ #/cm^3. However, this is an underestimation of the true value because in several cases the full scale of $5 \cdot 10^5$ #/cm^3 was exceeded. The average traffic flow was of about 150 vehicles/hour (minimum 50 maximum 250 vehicles per hour). FPs number concentration peaks were observed at the passage of each vehicle. In many cases the increase was limited, in some cases evident and in the remaining it was huge. We defined "highly FPs emitter vehicles" those determining a peak of FPs number concentration $\geq 4 \cdot 10^5$ #/cm^3. The percentage of vehicles belonging to this category was estimated at 0.31% of the whole. If we exclude the peaks of FPs number concentration corresponding to the passage in the street canyon of these vehicles, we obtain a reduction of the period average concentration of FPs number concentration of about 10.3%.

Conclusions
The reduction of the concentration of airborne pollutants is mandatory in the most of urban areas all over the world. One of the most hazardous pollutants is particulate matter especially the fraction of fine particles ($20 < D < 1000$ nm). We showed as in the case of Naples, where the contribution of vehicular traffic to the primary PM emissions is relevant and the vehicular fleet is characterised by the presence of "old" vehicles, a significant reduction of FPs number concentration (≈ 10%) in the atmosphere could be attained through the individuation and the driving ban of these vehicles (≈ 0.31% of the whole circulating fleet). The results could be of interest also for other urban areas world-wide with the same characteristics of Naples.

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EFFECT OF DILUTION CONDITIONS ON ENGINE EXHAUST VOLATILE AND NON-VOLATILE PARTICLE EMISSIONS

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Summary
The aim of this study is to determine the effect of dilution conditions of the exhaust sampling system on volatile and non-volatile particle emissions. This would ultimately allow for the development of a reliable methodology for measuring engine particulate emissions. A parametric analysis with respect to dilution temperature was conducted using the CFD software STAR-CCM+. The results revealed a strong dependence of particle number and mass concentrations on dilution conditions.

Introduction
Engine exhaust particulate emissions are known to negatively impact the respiratory as well as the cardiovascular system of human. Consequently, measuring and regulating these emissions is of great importance for maintaining a low air quality index and minimizing public health risk. However, current regulations do not include volatile PN emissions as there is no established method for measuring them. The development of such methods is therefore critical in moving forward towards improving global air quality.

Methodology and Results
A Multicomponent Modal Aerosol Model (MMAM) was developed using the Fortran programming language based on the methodologies presented in (Olin et al., 2015) and (Olin et al. 2016). The model was coupled with the Computational Fluid Dynamics software STAR-CCM+ for the purpose of simulating engine exhaust particle emissions. Specifically, the physical processes modeled were those of nucleation, condensation and coagulation. Furthermore, three different species were considered (hydrocarbons, sulfuric acid, water) to account for the chemical composition of particles. All three species participate in the condensation mechanism. However, for particle formation only water and sulfuric acid were considered (Binary Homogenous Nucleation).
The model was used to simulate particle formation and growth through the sampling system in which the exhaust gas is diluted sequentially with two different diluters (see Fig.1). A parametric analysis was made by varying the dilution temperature of the first diluter while keeping the other at ambient temperature. Initial results showed that decreasing dilution's air temperature resulted in an exponential increase of the number and mass concentrations of volatile particles. Another important observation was that the nucleation process was greatly enhanced at the parts of the sampling system where the setup was exposed to ambient temperature. Regarding soot particles, no changes in their number concentration were observed for different dilution temperatures as would be expected. Dropping the temperature however below a certain point to allow for condensation of the gas species had a prominent effect on the mass concentrations of these particles making it orders of magnitude greater than what it would have been in the absence of condensation.

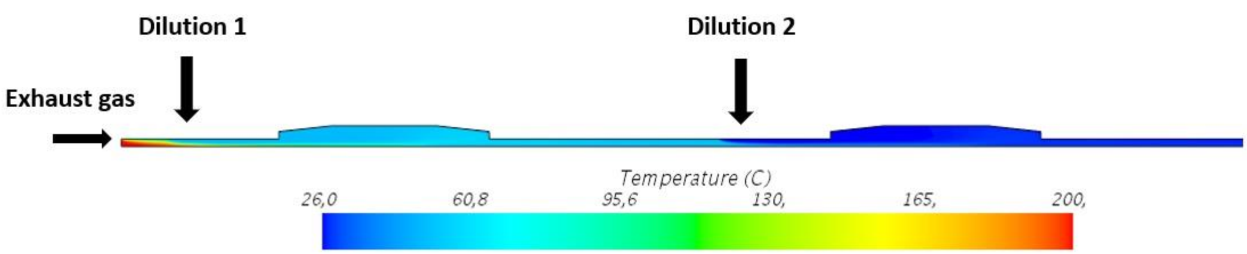

Fig 1 Temperature distribution in the exhaust sampling system.

Conclusion
It is evident from this study that particle number and mass concentrations are highly dependent upon the dilution conditions of the sampling system. Using these results, it is possible to develop a standardized and reliable methodology that would enhance the measurement of particle emissions.

Acknowledgement
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EXPERIMENTAL ASSESSMENT OF THE POWER MANAGEMENT AND POLLUTANT EMISSIONS OF PLUG-IN HYBRID VEHICLES

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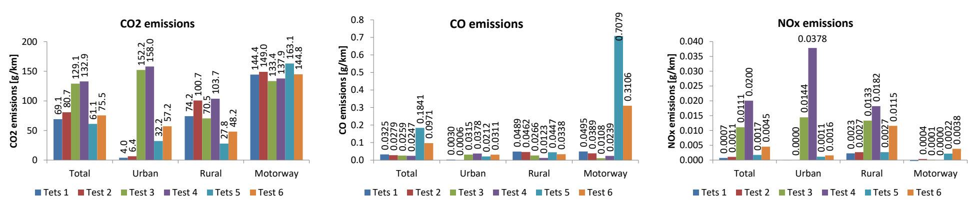
Summary
The main target of this study is to evaluate the emissions performance of two PHEVs in correlation with fuel/energy consumption and power management. Two Plug-in hybrid vehicles (PHEVs) were tested in the laboratory under Type Approval (TA) and real world driving cycles and on the road under real driving conditions. Regulated pollutant emissions and power flow of electric components were measured during the tests. The evaluation and analysis of the results revealed the correlation between power management and tailpipe exhaust emissions performance.

Introduction
Transport sector and especially light duty vehicles are major contributors to CO_2 and pollutant emissions at urban areas in European Union (EEA 2018). Vehicle powertrain electrification is one of the key measures towards the reduction of fuel consumption and CO_2 emissions from passenger cars. Plug-in hybrid vehicles (PHEV) offer a potential for high CO_2 emissions reduction but with the challenge to keep also pollutant emissions at a low level.

Methodology and Results
The study is based on measurements conducted on two PHEVs of the same vehicle segment, but with different powertrain and drivetrain layouts. Laboratory tests were conducted on a one-axle chassis dynamometer whereas the real world experimental campaign took place on pre-defined Real Driving Emissions (RDE) compliant and non-compliant routes. In order to record real time instantaneous emissions both vehicles were instrumented with a Portable Emission Measurement System (PEMS) during on road tests. In addition to the aforementioned equipment, during the experimental campaign a power analyser was used in order to measure the power, current and voltage from the electric motor(s) and the high-voltage battery. With the data recorded with this device it was possible to identify the combined operation between the internal combustion engine and the electrical components.
Fig 3 illustrates CO_2, CO and NOx emissions results from RDE tests on one of the vehicles. CO_2 and NOx emissions, as expected, were very low when the test started with fully charged battery. For these tests (Tests 1 &2), CO emissions results were found to be slightly higher, especially in the rural and motorway part of the trip, than the CO emissions measured at tests started with low initial battery SOC (Tests 3 &4). This behaviour is attributed to the system operation and the selection between full electric (no ICE operation) and hybrid mode that regulates the condition of the after-treatment system (in terms of the temperature of the system) and as a consequence the cold start events. Furthermore, the evaluation of the instantaneous emissions performance along with the power distribution provides a more detailed overview of the connection between power management and emissions performance.



Test #	Start	Initial Battery SOC [%]	
Tets 1	Cold	High / fully charged	82.8
Test 2	Cold	High / fully charged	82.0
Test 3	Hot	Low / depleted battery	15.7
Test 4	Hot	Low / depleted battery	13.7
Tets 5	Cold	High / fully charged	82.4
Test 6	Cold	High / fully charged	82.8

Fig 3 Emissions performance of one of the tested vehicles

Conclusions
The outcome of this study and the analysis of the experimental results provide an insight of the environmental performance of PHEVs under laboratory and real driving conditions, in accordance also to the power management. The results indicate that PHEVs are suitable for urban driving, as they are potentially zero emission vehicles, but only when high-voltage battery is fully charged. Furthermore, its was found that pollutant emissions of plug-in hybrid powertrains are high when a lot of cold start events occur, especially at high engine power demand, i.e. at rural (Test 1 and Test 2) or motorway (Test 5) sections. The increase of market penetration of PHEVs may lead to a significant decrease of CO_2 emissions when electric power potential is fully exploited. However, additional effort may be needed in order to achieve an equally good performance in pollutant emissions.

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MODELLING OF AIR POLLUTION BY PEAT FIRE SMOKE AND FORECAST OF ITS IMPACT ON ROAD VISIBILITY AND DRIVERS HEALTH

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Summary
In the present study there was developed: 1) an emission and dispersion model of smoke components (CO and PM) from burning peat; 2) an approach to estimate its impact on road visibility and people (drivers and passengers) health through acute risks; 3) criteria for ranking road situation by hazard level depending on the values of these indicators. The model was tested through the investigation of an emergency caused by a peat fire that lasted in Irkutsk Region (situated in Siberia) near the Federal Motorway P-255 "Siberia" from 26.10.15 to 15.01.16.

Introduction
Peat land fires are of major concern in the Russian Federation. Peat can burn deep underground for meters, even in damp conditions and in winter under the snow layer. Peat fires are difficult to extinguish, and they can last for months. Winter peat fires are often smoldering fires that create a lot of smoke because of incomplete combustion and result in greater emissions of carbon monoxide and other harmful substances including PM_{10} and $PM_{2.5}$, VOCs etc. If a wildfire develops near a motorway, the smoke reduces the visibility, affects human health and may result in a multi-vehicle crash or in an emergency, as it was many times in the Russian Federation, in the United States and in other countries [1, 2]. Peat fire smoke dispersion models, as well as approaches for the forecast of the impact of air pollution on the roadway visibility and people health, are highly needed in Russia.

Methodology
For the dispersion modelling of CO and PM emissions from peat fire, we have developed an approach [2] based on K-theory (analytical approximation of results of joint numerical integration of the equation of atmospheric diffusion and the system of equations of hydrothermodynamics for the atmospheric boundary layer, Berlyand and Genikhovich). For the forecast of smoke (PM concentration) impact on the road visibility, we have developed a method based on Trabert approach. For the estimation of health risks due to CO and PM, we have used national software "Risks" designed to calculate acute and chronic health risks from air pollution. In addition, we have developed criteria to rank on-road situation by hazard level depending on the values of these indicators.

Results and Conclusions
The model was tested through the investigation of an emergency caused by a peat fire that lasted in Irkutsk Region (situated in Siberia) near the Federal Motorway P-255 "Siberia" from 26.10.15 to 15.01.16.

Fig. 1 Smoldering peat bog near the Federal motorway P-255 "Siberia" in fall-winter 2015-2016

The results of numerical investigations have shown that a smoldering winter peat fire on the territory of 20 hectares at ambient air temperature about -25 ^{0}C and low wind (1,5-2,5 m/s) with CO emission rate 108-177 g/s, $PM_{2.5}$ emission rate 14,5-26,5 g/s, PM_{10} emission rate 15,5-28,5 g/s may lead to high air pollution and haze on the road 1-2 km far from the fire. CO concentration may exceed National 20-minute Limit Value (LV_{20min}) by 1.2-1.5 times, PM_{10} concentration – by 2.5-7.0 times and $PM_{2.5}$ – by 4.5-11.5 times. The on-road visibility may decrease to 40-170 m. The results of simulation have also shown that a real emergency may happen at night time because of a "super smog" – a dense smog formed by the peat fire smoke and the fog. In this case, CO concentration may exceed LV_{20min} by 1.9-2.5 times $PM_{2.5}$ concentration – by 7-20, PM_{10} concentration – by 4-11 times. The on-road visibility may fall to 7-11 m.
The model has been developed in support of management of road safety and risk management in emergencies caused by wildfires.

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SOURCE APPORTIONMENT OF ORGANIC CARBON AT AN URBAN SITE OF THE EASTERN MEDITERRANEAN DURING WINTERTIME

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Summary

This study aims to characterize the main air pollution sources of carbonaceous aerosols (black carbon, organic aerosols) and their atmospheric precursors (Volatile Organic Compounds) during wintertime at an urban background site in Nicosia (Cyprus). On-line mass spectrometry techniques have been deployed in parallel for a continuous (near real-time) monitoring of both VOCs and Organic Aerosols and completed by a 7 wavelength Aethalometer for dense measurements of Black Carbon. The 2-month sampling period covered the coldest months of the year (December and January) with the objective to apportion the major primary/secondary sources of organic carbon pollution and better evaluate their concentrations, temporal variability and geographical origins. Very high concentrations of carbonaceous aerosols and VOCs were recorded systematically every evening, pointing out the major contribution as domestic wood burning. This source is seen to be amplified by stagnant (low wind speed) conditions and shallow boundary layer heights at night and highlights the contribution of emissions from domestic wood burning in Cyprus.

Introduction

The Eastern Mediterranean and Middle East (EMME) region is a hotspot for air pollution which is expected to worsen in the near future due to strong population growth, unregulated atmospheric (anthropogenic) emissions, and increasing influence of desert dust. Although anthropogenic emissions of gaseous and particulate pollutants are suspected to be key factors responsible for poor air quality, our current knowledge on these emissions and their impacts remains highly uncertain in a region which supplies 2/3 of the world's known oil and natural gas consumption.

Methodology and Results

In the framework of the "AQ-SERVE" integrated project, a 2-month (6th December 2018 to 12th February 2019) intensive field campaign was performed at an urban background site in the capital city of Cyprus, Nicosia. Atmospheric measurements of fine aerosols (PM1) and Volatile Organic Compounds (VOCs) were conducted using online and offline state-of-the-art atmospheric instruments. The chemical composition of PM1 was retrieved using a quadrupole aerosol mass spectrometer (Q-ACSM, Aerodyne Res. Inc.) and more than 20 individual VOCs were monitored and quantified by a compact proton transfer reaction mass spectrometer (PTR-MS, Ionicon Analytik). Source apportionment was conducted using Positive Matrix Factorization (PMF) analysis to identify and characterize the various anthropogenic and natural sources of aerosols and precursor gases. Comparison of Organic Aerosol (OA) sources (traffic/biomass burning) was performed against apportioned Black Carbon (traffic/biomass burning) measured with a 7-λ Aethalometer (AE33, Magee Scientific). PMF analysis has highlighted BBOA and HOA as primary sources of organic aerosols. ACSM data were quality controlled through 1) chemical mass closure performed with a Scanning Mobility Particle Sizer (SMPS, TSI Inc.) which was used to derive PM1 mass concentration, and 2) direct comparison with co-located 24h PM2.5 filter sampling of ions (SO4, NO3, NH4), and carbon (OC). Analysis of carbohydrates (levoglucosan/ mannosan/ galactosan) was used to further validate the contribution from the Biomass Burning Organic Aerosol (BBOA) fraction, while the NOx data and $BC_{traffic}$ validate the Hydrocarbon Organic Aerosol (HOA) fraction. Finally, VOCs species (benzene, toluene, xylene, etc.) were used as tracers to identify traffic and biomass burning emissions.

Conclusions

During the campaign, high daily variability in organic aerosols was observed, which is primarily attributed to domestic biomass burning. High organic aerosols concentrations were also recorded during weekends likely due to increased in use of domestic fireplaces. These results were corroborated by online measurements of VOCs and more specifically from wood burning tracers.

Acknowledgements

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THE IMPACT OF BIOMASS BURNING EMISSIONS ON PM CONCENTRATION IN THE GREATER ALPINE REGION

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Summary
This study aims to present the results of two monitoring campaigns performed in the north-western Italian Alps (Aosta Valley) in order to quantify, for the first time in this region, the impact of biomass burning on particle matter (PM) concentrations. Two sites (rural and suburban) were equipped to measure PM10 (beta absorption and gravimetric determination) and black carbon concentrations (aethalometer). Analytical techniques such as High Performance Liquid Chromatography (HPLC), gas-chromatography with FID detector (GC-FID), ion chromatography (IC) and thermal–optical transmittance (TOT) analysis were used to identify polycyclic aromatic hydrocarbons, levoglucosan, inorganic water-soluble ions, elemental and organic carbon components of PM10, respectively.
Correlation with different metrics were tested in order to define the site-specific parameters necessary to evaluate the contribution of biomass burning on the total PM10 concentration.
The application of positive matrix factorization helped identify the emission sources. Noticeable differences in the biomass burning contributions were found between the rural site and the suburban area, this latter being affected by local traffic and urban emissions. The results of this study may be of help in identifying the most impacting pollution sources in the Greater Alpine Region and in developing multi-scale mitigation plans.

Introduction
Biomass burning covers a large share of heat demand in the Greater Alpine Region, reaching 90% for small municipalities. Biomass is a renewable energy source, CO2 neutral emissions helping contrast climate change, but its combustion, besides being energetically inefficient, involves the emission of pollutants such as particulate matter (PM), polycyclic aromatic hydrocarbons (PAHs), black (BC) and brown carbon (BrC) and volatile organic compounds (VOCs). Pollution becomes more intense in the Alps since wood is a widely used fuel in mountainous areas, and the environmental conditions, such as orography and low winter temperatures, favor stagnation at the bottom of the valleys where pollutants are emitted.

Methodology and results
The monitoring system provided the following data:
- equivalent BC mass concentration
- PM10 concentration (beta absorption and gravimetric determination)
- PM10 chemical speciation (elemental and organic carbon, levoglucosan, PAHs, water soluble inorganic ions).

Correlations between these parameters, and notably between BC and levoglucosan have been studied, and the biomass burning contribution on total PM10 (PMbb) has been calculated.
In the rural site, the estimated PMbb varied between 0% and 84%, with higher values for the coldest months, in particular in December (average value 46%), and negligible contribution in the warm season, where also levoglucosan and benzo(a)pyrene measured concentrations are very low.
The suburban site showed a very low biomass burning contribution, reaching its maximum values in winter, as expected.

Conclusions
Since the practice of biomass burning keeps spreading in the Greater Alpine Region, PMbb is expected to play an increasingly important role on atmospheric pollution in this area. Win-win approaches must be defined at the local and regional levels to reduce the drawbacks of this fundamental renewable energy source.

Fig.1 rural site of measure

Acknowledgement
Part of this work was supported by EU-funded BBCLEAN project within the Interreg Alpine Space program. The campaign in the suburban site of Aosta was organized in collaboration with University of Milano-Bicocca.
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RESIDENTIAL HEATING IN ATHENS, GREECE: EMISSIONS AND IMPORTANT PARAMETERS

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Summary
This study aims to quantify the annual residential emissions for the Attica region in Greece based on energy consumption data provided by local authorities and European datasets, emission factors proposed by the EMEP/EAA Emission Inventory Guidebook 2016 and useful information concerning the residential heating profile obtained by a survey that was carried out to the Greek citizens. Analysis helped to identify the sources and fuel types that define emissions in local level. The residential sector contributed to CO, NOx and PM_{10} emissions in Attica. Boilers are the main heating source in all regional units of Attica and the use of thermal oil is mainly associated with NOx emissions.

Introduction
The recent European Environment Agency (EEA, 2019) report on air quality shows that "Poor air quality continues to damage Europeans' health, especially in urban areas". Attica is a region that encompasses the densely populated Greater Athens Area and is known for air pollution problems caused by traffic and residential heating. From 2009 onwards, the economic crisis influenced significantly the anthropogenic activities and consequently the energy consumption of the households (Santamouris et. al. 2013). This study aims to create a comprehensive emissions inventory from the residential sector for Attica based on official data from local authorities and European databases in order to depict emissions profile and reveal the key parameters that define them. A survey was also held in winter of 2018 for the collection of data about residential heating in local scale.

Methodology and Results
Residential emissions were calculated for the year 2015 for the Attica region based on the Tier 2 methodology proposed by the EMEP/EAA Emission Inventory Guidebook 2016. Energy consumption data were provided by Eurostat, Odysee-Mure project (https://www.odyssee-mure.eu/) and the Hellenic Statistical Authority. Attica is divided in 8 regional units (e.g. East Attica, West Attica, North Athens, etc.). The annual energy consumption per fuel type was distributed to each regional unit based on the number of households using each fuel type. Afterwards, the energy consumption per fuel type was attributed to the relevant heating source. In order to collect data on residential heating profile in Greece a survey was held last winter.
As shown in table 1, oil consumption prevails to the total energy consumption since 73.87% of total households in Attica use it for heating, followed by natural gas (11.41%) and electricity (8.10%). Concerning the source, survey results revealed that in Attica the average use of boilers, stoves, fireplaces and air condition for residential heating is 67.63%, 7.92%, 13.35% and 17.96% respectively. Based on the above, emissions were calculated for each regional unit separately. The pollutants that are mainly related to residential heating for this area are CO, NOx and PM_{10} (fig.1). High values are emitted in Central Athens, where the 30% of Attica's population lives. NOx emissions are associated with boilers while fireplaces are the main source of CO emissions. Both fireplaces and boilers contribute almost equally to PM_{10} emissions. However, in East Attica fireplaces are responsible for the 83% and 86% of PM_{10} and CO emissions respectively.

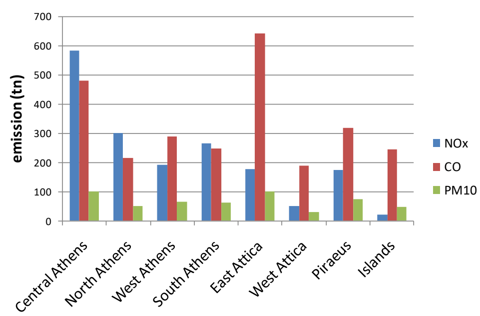

Fig.1 Residential emissions in Attica for the year 2015

Table.1 Energy source used by households for residential heating in Attica (reference year: 2015)

Energy source	% contribution
Oil	73.87
Natural Gas	11.41
Electricity	8.10
Other (e.g. LPG, Kerosene)	2.27
Biomass	0.28
Solar Thermal	0.17
No source	3.90
Total	100.00

Conclusions
Energy consumption in households accounts for about 26% of the total energy used in Greece for the year 2015, according to the energy balance provided by Eurostat. Therefore, it is very important to study in depth households' emissions as well as the parameters that define them. Moreover, scientific studies should be in line with the local socioeconomic changes which as a consequence have an impact on the amount and spread of emissions.

Acknowledgement
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DEVELOPMENT ON GLOBAL WILD FIRE EMISSION REPRESENTATION

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Summary

The present work is focused on the reconsideration of the wild-land fire emission coefficients over the globe in IS4FIRES (the Integrated Monitoring and Modelling System for wildland fires). The top-down approach was used to recalibrate the fire emission depending on the specific land use type and the intensity of the fire. The total column integrated CO concentrations were computed by IS4FIRES-SILAM (System for Integrated modeLling of Atmospheric composition) modelling system and compared with the observed spatially collocated MOPITT fire plumes during the year 2017. The preliminary existing set of the common fire emission coefficients (varying with the land use only) were split to the flaming and smouldering components and were adjusted independently for the 6 continents (Africa, Asia, Australia, Europe, Northern America and Southern America) on the monthly level based on the daily averaged values (Fig.1). This approach allowed to take into account the seasonality on different continents of the emission from the fires of varying intensity. The implementation of newly derived fire emission coefficients in IS4FIRES-SILAM system and comparison it with AERONET observations demonstrated the improvement in Asia and Northern America.

Introduction

The global air quality forecast is still struggling from the huge uncertainties related to the emission produced by the wild-land fires. The estimates on emitted amount of fire generated pollutants in existent databases could be by an order of magnitude different. One of the advanced tools calculating the fire emission is the IS4FIRES (Sofiev et al., 2009; Soares et al., 2015). This system is based on the combination of remote-sensing of the active fires and the vegetation characteristics (land use types). The integration of IS4FIRES into the SILAM model allowed to compute the 3-D transport of fire released compounds.

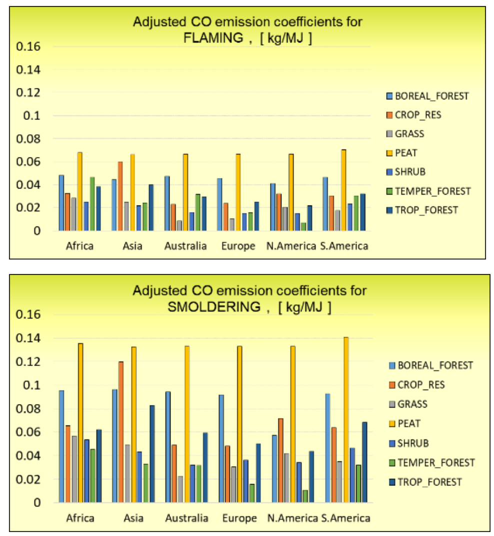

Fig.1 Adjusted emission coefficients for flaming and smouldering fires for IS4FIRES

Methodology and Results

SILAMv.5.6 global run was configured for the year 2017 with the grid resolution of 0.5 x 0.5°. Model setup included only fire emission sources (CO and PM). The output was co-located with MOPITT CO column data. The following calibration was based on the RMSE minimization with Tikhonov regularization of the difference between the measured (MOPITT) and computed total CO column (SILAM).

Since for this iteratoni, CO was considered as non-reactive component, the fire-induced plumes were singled out of the CO distribution pattern and only areas with CO column completely dominated byfresh fire plumes were taken into consideration. The monthly wise continent dependent adjustment for fires of varying intensity was performed with non-zero regularization term and had disregarded the very thin plumes and minor daily correlations between SILAM and MOPITT. Additional cleaning was implemented to eliminate the cross-correlation between flaming/smouldering cases for the pixels occupied by the identical land use types. CO newly computed emission coefficients were used to scale the rest of gaseous compounds based on the dependencies presented in Akagi et al., 2011.

Conclusions

The CO based revision of the wild-land fires emission on the monthly level with specification on the fire intensity and geographical region is shown to be efficient for the top-down calibration of pyrogenic emission from the burning areas. The comparison of full SILAM run (all emission sources and chemical transformations involved and the updated fire emission coefficients included) with the ground measurements demonstrated region dependent improvement. The next step will include full-scale parameter assimilation for CO and then PM to better represent the aerosols emitted from fires.

Acknowledgement

This work was supported by the H2020 project EXHAUSTION and also contributed to CAMS-44 (Development Of the Global Fire Assimilation System) and the CAMS-50 (Regional production) projects.

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PM2.5 SOURCE APPORTIONMENT IN 6 EUROPEAN CITIES: THE ICARUS PROJECT

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Summary

This study presents the results from source apportionment application on PM2.5 data collected in six European cities (Athens, Brno, Ljubljana, Madrid, Stuttgart and Thessaloniki) in the frame of H2020 ICARUS project. In particular, PM2.5 samples collected from three different sites in each city (traffic, urban background and rural) were chemically analyzed for ions, heavy metals, organic/elemental carbon (OC/EC) and Polycyclic Aromatic Hydrocarbons (PAHs). The chemical composition data was introduced in PMF (Positive Matrix Factorization) and Lenschow approach models with the scope of identifying the main groups of sources and estimating their contribution to PM2.5 concentrations.

Introduction

Particulate matter air pollution deriving from traffic, industrial emissions, oil combustion, biomass burning and other anthropogenic activities as well as natural sources comprises one of the major global concerns. PM2.5 is an air pollution metric widely used to assess air quality, with the EU having set targets for reduction in PM2.5 levels and population exposure. Consequently, one of the major challenges for the scientific community is to identify, quantify and characterize, at the appropriate scale, the sources of atmospheric particles in the aspect of proposing effective control strategies to the public authorities. Although studies for source apportionment are rapidly spreading globally, revealing both PM local and regional origin, the comparability of results among the different sampling sites is often hampered, leading to the need for harmonized source apportionment outcomes from multi-city studies.

Methodology and Results

EPA PMFv.5 and Lenschow approach models were run for each sampling site/city (n=60 samples per site, including warm and cold season). Depending on the case, PMF model resulted in a number of five to eight PM2.5 sources for each site/city. Biomass combustion contribution to PM2.5 (11-43%) indicated the prevalence of the source during winter/fireplaces-burning periods, without excluding biomass combustion emissions from agricultural activities. Fuel oil combustion source (contribution 8-27%) presented almost similar factor profiles among the sites but different temporal variation. In the majority of the cases, traffic was represented by two different factors: traffic-exhausts and traffic non-exhausts. Traffic-exhausts contribution ranged between 6% (Thessaloniki rural) and 32% (Ljubljana traffic site). In all cases, the source contribution was higher at the traffic sites of the cities except for Athens, where the maximum value was found for rural site, where frequent transit of heavy vehicles was reported. Traffic non-exhausts source, including anthropogenic dust sources such as elemental materials emitted from vehicles brake pads, tires and mechanical parts, presented different factor profiles among the several sites. Its contribution ranged between 3% (Athens rural site) and 25% (Ljubljana urban background site, though including soil dust too). A secondary aerosol source (9-34%) was identified either as secondary sulfate only, either as secondary sulfates and nitrate (when inorganic aerosol is represented rather than sulfate exclusively). Finally, two natural-origin sources were identified: Soil dust associated with elements from the earth's crust presented different profile among the sites, even in the same city. Sea salt source contribution appeared with the minimum values (1-4%) in Athens, Ljubljana and Thessaloniki cities. Lenschow approach indicated that around 40 % of PM2.5 sources are coming from the regional background and 50 % of the PM2.5 composition is related with traffic. However, the main contribution of this sector was not the exhaust gases but the tyre and brake wear and resuspension of the particles, which means that even zero-emission cars would still, aggravate the air quality inside the cities.

Conclusions

The common and simultaneous sampling and analysis procedure in ICARUS campaigns, offered a prospect of a harmonized source apportionment approach, with the scope of identifying the similarities and differences of PM2.5 source chemical fingerprints across the cities and sampling sites. Traffic, biomass burning and fuel oil combustion are the prevailing sources for PM2.5 measured in ICARUS cities.

Acknowledgement

This work was supported by ICARUS; This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 690105.

NEW NORDIC EMISSION INVENTORY – SPATIAL DISTRIBUTION OF MACHINERY AND RESIDENTIAL COMBUSTION EMISSIONS

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Summary
We have developed a new Nordic air pollution emission inventory with 1 km x 1 km spatial resolution for 1990-2014. The inventory will be used for health and welfare impact assessments from air pollution. In this paper we describe how spatial distribution of the emissions is changed by the implementation of local knowledge by comparing machinery and residential wood combustion sectors to the commonly used TNO MACC-III inventory.

Introduction
Air pollution health impact assessments are based on air quality modelling, which rely on spatially distributed emission data. Higher resolution emissions enable more accurate impact assessment, especially on the local (e.g. municipal) level. In this study we present a new Nordic emission inventory with high spatial resolution. To assess the effect of incorporation of local knowledge on the spatial distribution of $PM_{2.5}$ emissions, the machinery and residential wood combustion (RWC) sectors were compared to the European-wide TNO MACC-III inventory (Kuenen et al., 2014).

Methodology and Results
The emission inventory covers the Nordic countries with a 1 km x 1 km resolution for the period 1990-2014. Iceland is included in the inventory separately, but excluded in this comparison, as RWC is rare and machinery emissions are yet to be accounted for. The spatial distribution of the emissions was compared visually and by calculating the index of agreement (Duveiller et al., 2017) by aggregating the Nordic inventory to the TNO grid (0.125° × 0.0625°). The emissions were normalized within each country for the comparison to focus on differences in spatial distribution.
In general, the Nordic inventory had more machinery emissions weighted to rural areas in each country than MACC-III. Index of agreement was lowest in Denmark (0.48) and Sweden (0.58), and highest in Finland (0.83) and Norway (0.71). In Denmark the emissions in the MACC-III inventory were weighted more to population centres and major roads, in contrast to the Nordic inventory, where emissions were more evenly spread and areas in the West with lower population density stood out. In Sweden there were differences related to how smaller municipalities were weighted and whether remote rural areas contained emissions. In Finland and Norway the differences were smaller, mainly caused by slightly higher emission weighting to rural areas.

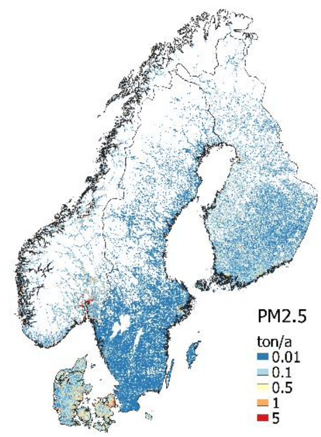

Fig. 1 Spatial distribution of RWC $PM_{2.5}$ emissions in the Nordic inventory.

For RWC, index of agreement ranged between 0.65-0.77 inside the countries, showing less disparity than in machinery, but still indicating differences between the inventories. The Nordic inventory had more emissions distributed to rural areas and less in cities in Finland and Sweden, whereas in Norway MACC-III had more cells with emissions in the rural areas. The Nordic inventory also had more emissions in coastal areas, especially in Denmark.

Conclusions
The comparison showed differences in spatial distribution of emissions between European and more local emission inventory. Furthermore, the differences could not be explained by a single factor, and each country would need to be studied individually. This highlights the need for regional/local knowledge to be applied to spatial distribution of emissions, preferably on subsector level.

Acknowledgement
This work was funded by NordForsk under the Nordic Programme on Health and Welfare Project #75007: Understanding the link between air pollution and distribution of related health impacts and welfare in the Nordic countries (NordicWelfAir). The study was also supported by NABCEA-project funded by the Academy of Finland.

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IMPACT OF TRAFFIC EMISSIONS IN 2040 ON AIR QUALITY IN GERMANY

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Summary

Traffic emissions in Germany were calculated with a sophisticated model chain including models for transport, fleet composition and technology, and emission factors. A complex atmospheric chemistry transport model system was applied for studying the impact of road traffic emissions on air quality including interactions with pollutants from other sources. Traffic contributed around 40% to the average NO_2 concentrations in the most polluted areas in Central Europe in 2010. Following our scenarios for 2040, NO_2 concentrations will be reduced by more than 50% compared to 2010. Traffic will only contribute 20% to the future concentrations, i.e. traffic emissions will exhibit larger reductions than other sectors.

Introduction

Traffic is still the dominant source of NOx and a significant source of CO, VOCs and particulate matter in Europe. Although emissions have decreased substantially in the last 20-30 years, annual limit values for NO_2 are still exceeded in many European cities. In addition, NOx and VOC emissions contribute to ozone formation, secondary aerosol particle formation and to reactive nitrogen inputs into sensitive ecosystems.

In the German project Traffic Development and Environment ("Verkehrsentwicklung und Umwelt", VEU) a model chain was built up that includes traffic models, fleet composition developments, new driving technologies, emission factors and atmospheric chemistry transport models. This model chain was first used to calculate current day traffic emissions in Germany and then to develop consistent future scenarios for 2040. These scenarios were based on possible story lines for economic, societal and technological developments in Germany. The effects on air quality were studied for 2010 and 2040 with the COSMO-CLM/CMAQ model system established at Helmholtz-Zentrum Geesthacht.

Methodology and Results

The traffic emission model chain has been applied to first calculate emissions in Germany in 2010 on three road types (urban, extra-urban, motorway) based on travelled kilometers and emission factors from the Handbook of Emission Factors (HBEFA), version 3.3., differentiated by vehicle type and age. Traffic emissions in other European countries were taken from European emission inventories (EMEP) and then split into travelled kilometers and average emissions factors based on the fleet composition in Germany. This was done for applying the same technology developments until 2040 for vehicles travelling in Central Europe and consequently deriving consistent future scenarios for traffic emissions. Traffic emissions were then fed into the SMOKE for Europe model system (Bieser et al, 2011) and combined with anthropogenic emissions from all other relevant sectors as well as biogenic emissions. Air quality simulations were performed with the COSMO-CLM/CMAQ model for a 6 x 6 km² grid comprising Central Europe for 2010 and subsequently also for three traffic emission scenarios in 2040. Meteorological conditions in January and July 2010 were taken to represent winter and summer conditions, respectively.

In large areas of Central Europe, the concentrations in January are higher than 25 µg/m³ on a monthly average basis. About 40-50 % of the NO_2 is caused by traffic emissions. In July, average concentrations are much lower. Values above 20 µg/m³ are only reached in large cities and in the English Channel, where shipping emissions are a major source. In many regions, road traffic has a slightly lower share of approx. 35 – 45 % in the total concentrations than in January.

Three future scenarios were created for traffic emissions in 2040. The Reference scenario includes the all developments in legislation, technology and fleet composition that can already be foreseen, today. In the Free Play scenario, regulations are less strict and prices for fuel and technologies steer the emission developments. In contrary to that, in the Regulated Shift scenario stricter regulations and incentives for new technologies and for using public transport lead to traffic emission reductions. In all scenarios, other emissions were reduced as well according to the ECLIPSE CLE scenario (Amann et al, 2014). Compared to 2010, monthly average NO_2 concentrations would be below 10 µg/m³ in large parts of Europe. Traffic emissions would contribute about 20% to the average concentrations. The results for the Free Play scenario are close to those in the Reference scenario. In the Regulated Shift scenario, NO_2 concentrations caused by road traffic are further reduced.

Conclusions

It could be shown that in 2010 traffic had a share of approx. 40% to the average NO_2 concentrations in Central Europe. According to scenarios for 2040, NO_2 concentrations will be significantly reduced compared to 2010. The overall importance of traffic emissions would be around 20% which is much lower than in 2010. The results in the Regulated Shift scenario show that NO_2 concentrations caused by road traffic could be further reduced to approx. 15% of the total concentrations.

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DEVELOPMENT NATIONAL EMISSION FACTORS OF TURKISH PUBLIC ENERGY PRODUCTION INDUSTRY AND QUANTIFICATION OF VARIABILITY AND UNCERTAINTY

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Summary

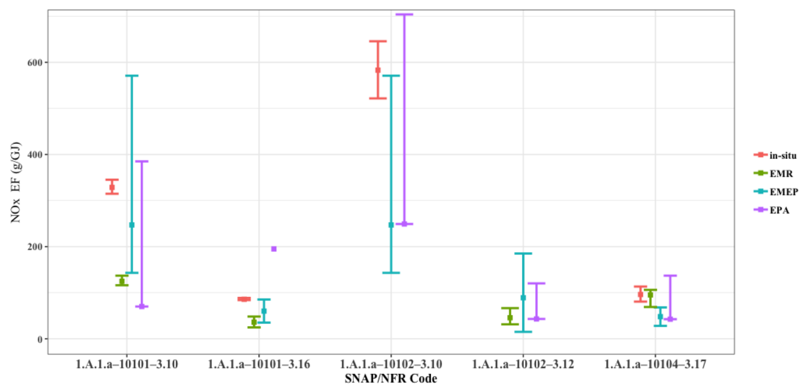
The broad objective of this study is quantifying dust, SO_2, CO, NO, NO_2 and NO_x emission factors (EFs) from in-situ measurements conducted within the scope of this study for Turkish public electricity and heat production industry. Variability and uncertainty analysis techniques including distribution fitting, Monte Carlo simulation and Bootstrap technique were adopted in quantifying uncertainty of EFs.

Introduction

Public electricity and heat production sector is responsible from 59% of SO_2, 29% of CO_2, 24% of NO_x and 10% of N_2O emissions of Turkey (TurkStat, 2013; MoEU, 2013). Currently national emission inventories of Turkey are calculated by obtaining EFs from guidebooks such as European Monitoring and Evaluation Programme (EMEP) air pollutant emission inventory guidebook (EEA, 2013), Intergovernmental Panel on Climate Change (IPCC) emission inventory guidelines (IPCC,2006) and United States Environmental Protection Agency (EPA) AP42 EFs (EPA, 1995). Development of country-specific EF is not a common practice in Turkey, yet. Nevertheless, in a small number of EF development studies, general attitude is assuming the sample of EFs to be normally distributed in uncertainty analysis. Such a practice brings negative EFs into consideration due to the nature of normal distribution.

Methodology and Results

EF calculation part of this study benefits from a national project (TUBITAK, 2012). 120 stack measurements were conducted in 8 plants for only public electricity and heat production plants in Marmara region. Emission measurements from official emission permit reports (EMRs) of 32 energy production plants (339 stack measurements) were used for comparison purposes, but they are not primary source of EFs since the reliability is questioned by the administrative and academic community (they are prepared by the facility-company cooperation). EMEP guidebook's SNAP/NFR coding system was taken into consideration in order to group EFs.



In variability analysis methodology, data is visualized by plotting cumulative distribution functions and histogram, then some statistical parameters are calculated; including but not limited to Skewness, Kurtosis and coefficient of variation. Uncertainty of each EF is calculated independently, which in turn requires a deep effort on fitting correct distribution, applying Monte Carlo method in order to generate random datasets from assigned distribution, and applying Bootstrap simulation for each of the alternative probability models generated by Monte Carlo approach. Finally, a reasonably stable characterization of the percentiles of the distribution is developed. At the end, the results are compared to the original dataset by generating probability bands and results are compared with EMRs, EMEP and EPA EFs.

In Fig. 1, a sample of results are given for NO_x EFs. Average of in-situ EFs (calculated in this study) are generally larger than all other studies and uncertainty ranges are narrower in in-situ EFs. This situation causes prediction of large NO_x emissions in emission inventories with low uncertainty. Generally this situation is same in CO and SO_2 EFs. However, dust EFs are generally lower than other studies.

Conclusions

Development country specific EFs are crucial for emission inventories which are also an important source for air quality models. Country-specific EFs should be generated in order to decrease uncertainty in those emission inventories. This situation will lead to produce better predictions in air quality model estimates and will be a valuable source in policy making.

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Scientific and Technological Research Council of Turkey (TUBITAK). Public Research Support Group (KAMAG) project (project number is 111G037) conducted between 2012 and 2016; Development Of National Air Pollution Emission Management System

Short Presentations

OPTIMIZATION OF FABRIC FILTER SYSTEMS FOR FLUE GAS CLEANING OF SMALL-SCALE BIOMASS FIRING SYSTEMS

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Summary
An efficient dust separation from the flue gas of a 24kW biomass boiler as well as the regeneration process of the stainless steel fabric filters was verified. The separation efficiencies for dust varied in a range of 69.4 to 96.4% with maximum pressure drops below 1200Pa depending on the selected filter mesh size and selected fuels i.e. wood chips and wood pellets. The dust concentrations after the filter chamber were below 10mg/m^3 and considerably below the limit value of 20mg/m^3 as mentioned in the 1st Federal Emission Control Regulation (1.BImSchV). Particle size distribution measurements showed a high amount of submicron particles with an aerodynamic diameter below 0.5µm for which the surface filter showed lower separation efficiency. The filter system offers a high application potential for small-scale firing systems.

Introduction
Biomass, especially wood, is the most important source of renewable energy in the German heating market as it is a CO_2-neutral fuel. Nevertheless, biomass combustion contributes significantly to ambient air pollution (Johansson et al. 2003). Usually electrostatic precipitators (ESP) are used to reduce particle emissions from biomass combustion units but the utilization of surface filters, e.g. stainless steel fabric filter, is also possible. This study aims to optimize surface filter systems for small-scale firing-systems.

Methodology
Experiments were carried out on a 24kW biomass boiler which was fed with wood pellets and wood chips according to the specifications from the manufacturer. The boiler was equipped with a fabric filter system, as shown in Fig.1. The regeneration of fabric filter was done by pulse-jet cleaning by a compressed air pulse. During the starting phase, the cold flue gas was directly sucked through the chimney. After achieving a stable temperature level, the whole flue gas was sucked through the fabric filter. All experiments were carried out under full-load of the biomass boiler. The gaseous and particle emissions were measured before and after the fabric filter. The dust samples (PM) were taken before and after the fabric filter (out-stack-sampling) according to guideline VDI 2066-1 for dust measurements in gas flows. The composition of the flue gas (CO, CO_2, O_2) and temperatures (T) were measured continuously.

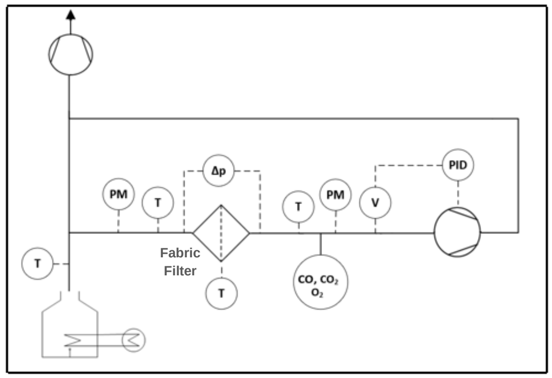

Fig.1 Scheme of the facility

Results and Discussion
Raw gas concentrations for wood chips and wood pellets varied between 40.1 to 63.9mg/m^3 and 10.8 to 26.5mg/m^3 respectively, referred to the reference oxygen content of 13%. The concentrations behind the fabric filter varied depending on mesh size of the applied fabric filter and were always below the limit value of 20mg/m^3. The regeneration process of the fabric filter systems was carried out during pressure drops below 1200Pa which can be a reason for smaller separation efficiencies fluctuating between 69.4 and 96.4% depending on filter cake formation. The number distribution is dominated by submicron particles with aerodynamic diameters < 0.5µm. The amount of this fraction was close to 70%.

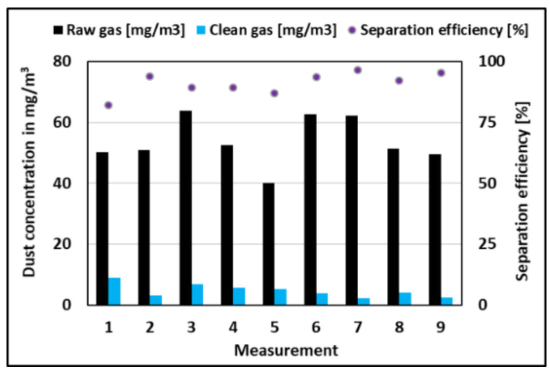

Fig.2 Measurement of dust concentrations before and after the fabric filter when the boiler was fired with wood chips

Conclusion
The fabric filter system is suitable for effective flue gas cleaning on automated wood firing systems with low energy consumption. Low concentrations can be achieved during operation which will meet the requirements of the future.

Acknowledgement
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MILE21: RAISING USER AWARENESS ON ON-ROAD FUEL CONSUMPTION

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Summary
The MILE21 – LIFE project aims to raise user awareness on the divergence between on-road and official fuel consumption and CO_2 emission values in passenger cars. The project is developing an online platform, where the users can compare different vehicles, monitor and also calculate their trip fuel consumption in order to promote a greener driving behavior. In addition, the platform also deploys a pollutant labeling scheme that promotes the most environmentally friendly vehicles.

Introduction
It is common knowledge among the drivers that the fuel consumption values that are communicated to them when they select their vehicles present a divergence with the ones they experience on-road. This divergence is backed by scientific evidence and it has been closely monitored in several studies (Fontaras et al., 2017) and it was estimated to be at 39% in 2018 (Tietge et al., 2019). In order to address this issue, the European Commission has introduced a new procedure for measuring official fuel consumption values (Regulation (EU) 2017/1151) and also enforces the deployment of On-Board Fuel Consumption Meters (OBFCM) in new vehicles after 2020, while at the same time focuses to inform the public on the divergence. The MILE21 – LIFE project focuses on the latter and has created a platform where the users can retrieve realistic on-road fuel consumption values over the market-available passenger cars and also report and calculate fuel consumption of their trip. The consortium comprises of consumer organization that contribute to promoting and engaging the users with the platform and technical institutions and research organizations that contribute to the technical background of the platform.

Methodology and Results
The main aim of the MILE21 platform is to raise user awareness on fuel consumption by providing representative values of on-road vehicle operation. Although the main aim of the platform is fuel consumption and CO_2 emissions, it also includes a vehicle pollutant labelling scheme that is based in collaborating with other projects. The users are able to compare different vehicles from a database and also report their own fuel consumption. In addition to this, the users can calculate the fuel consumption of their individual trips by choosing their vehicle and desired route. In order to achieve higher user engagement with the platform a dedicated UX investigation was performed and laid the groundwork for a user-centric platform design.
The development of the fuel consumption calculation tool made use of on-road and laboratory measurements that were used to calibrate a vehicle simulation model. In the first step, a series of OBD loggers was scheduled to be installed on a large number of vehicles throughout Europe to monitor their fuel consumption. A methodology had to be developed to calculate fuel consumption from the available OBD signals, as OBFCM signals were not available at the time of the study. The methodology made use mainly of the air flow mass, lambda and load values and showed that the divergence in the calculated values was below 10%. It was also found that the calculation was more accurate under hot engine operating conditions, with a divergence of below 3% than in cold where it could be up to 10%, which could be attributed to the lambda sensor sensitivity. In the second step, the measurements were used to calibrate a vehicle simulation model. The model was found to have an average error of below 5%, which could be reduced to below 2% if it is calibrated for a specific vehicle model (Tsiakmakis et al., 2019). The vehicle simulation approach is suitable to provide a representative fuel consumption value, but it was identified that it would cause increased running times if it was deployed on an online platform. For this reason, in the next step, it was chosen to perform a massive simulation plan that it would consider all the possible vehicle configurations under different operation conditions. Subsequently, based on an approach deployed by the JRC green driving tool - but with vehicle specific data - the input and output data are to be correlated to produce a metamodel that would calculate fuel consumption faster. A similar approach was deployed for heavy-duty vehicles with an error below 5% (Zacharof et al., 2017).

Conclusions
The scientific background supports the development of robust tools for providing representative on-road fuel consumption values with an increased accuracy. On the other hand, the engagement of consumer organizations in the project ensures that the platform is user friendly and it promotes the dissemination. These two aspects are expected to contribute to the aimed total 3% reduction of road CO_2 emissions by 2026 compared to 2018 values.

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Air Quality Management and Policy Development

COST-BENEFIT ANALYSIS OF CARBON MITIGATION MEASURES IN EUROPEAN CITIES: THE IMPORTANCE OF CO-BENEFITS

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Summary
This study has been developed within the European Union funded Horizon 2020 project Integrated Climate forcing and Air pollution Reduction in Urban Systems (ICARUS project). In this study we apply cost-benefit analysis (CBA) to evaluate a number of air quality measures which have been proposed by the cities within the ICARUS project. The selected measures relate to three broad areas: energy efficiency, active transportation, and alternative fuel vehicles.

Introduction
This study has been developed within the European Union funded Horizon 2020 project Integrated Climate forcing and Air pollution Reduction in Urban Systems (ICARUS). ICARUS brings together researchers from 18 European Institutions and policy makers from nine cities in Europe with the aim of developing strategies towards the improvement of air quality and environment in urban settings in order to enhance citizens' health and wellbeing.
In this study we apply CBA and cost-effectiveness analysis to evaluate some of the carbon mitigation strategies which have been proposed by the cities within the ICARUS project. The selected measures relate to three broad areas: energy efficiency, active transportation, alternative fuel vehicles.

Methodology and Results
In using CBA, we compare the costs and benefits of a project by expressing them, where possible, in a common metric, i.e. in monetary values. In this study, capital and operational and maintenance costs of the selected measures have therefore been compared to the overall benefits. For each analysed measure benefits include health benefits achieved through the reduction of PM and NO_2 and carbon savings. For energy efficiency measures, among the benefits also operational and maintenance savings and energy savings from the replaced technology are included. For active transportation measures the following impacts are taken into account: fuel savings from decreased car use, health benefits deriving from the increased walking and cycling, travel time, noise and accidents. For measures relating to alternative fuel vehicles, fuel and maintenance costs savings are considered, as well as noise and construction and demolition costs of electric vehicles. In the case of non-tangible impacts, a monetary value has been assigned using parameters and estimates suggested by the literature. Moreover, in this study we present cost-effectiveness analysis to compare the costs of a measure with the achieved outcomes, i.e. the tonnes of carbon (CO2eq) saved, respect to the baseline scenario.

Conclusions
Our analysis shows the importance of the inclusion of health co-benefits in economic analysis of carbon mitigation strategies. Options that may appear costly in terms of the financial cost per tonne of carbon reduced become viable in many cases when co-benefits are considered. Different strategies in different cities may be appropriate. It is therefore important to define a policy at an appropriate scale (the urban level) to address carbon mitigation.

Acknowledgement
This work was carried out within the project within the European Union funded Horizon 2020 project "Integrated Climate forcing and Air pollution Reduction in Urban Systems" (Grant agreement No. 690105).

USE OF CHEMICAL TRANSPORT MODELS FOR DEVELOPMENT OF EMISSION CONTROL STRATEGIES

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Summary
In this work a chemical transport model and the SHERPA tool were used to examine and compare emission reduction potentials for two emission sectors (traffic and non-industrial combustion sector) in Croatia. 15% emission reduction scenarios were used for each emission sector independently and for both combined. Results of all runs were compared to assess the impact on air concentrations at Croatian territory. CTM results provided better spatial distribution of air concentrations compared to SHERPA hence order of magnitude was captured well by both models. Further investigation of linearity and analysis of source apportionment with labelling is envisaged.

Introduction
Implementation of cost-efficient emission control strategies is one of the main goals of air quality protection policies for which testing of different methodologies is useful. To assess the impact of emission changes on surface concentration levels, CTM as well as the screening methodology SHERPA (Screening for High Emission Reduction Potential on Air) developed by JRC can be used. In this study we compare results obtained by LOTOS-EUROS CTM calculations with results of SHERPA tool for different emission scenarios. Our aim is to evaluate advantages and limitations of both methodologies for selected scenarios and to assess their impact on air concentrations at Croatian territory.

Methodology and Results
LOTOS-EUROS model was used for emission reduction scenarios of NO_2, PM_{10} and $PM_{2.5}$ for Croatia (year 2018). ECMWF meteorological data (F1280 grid, resolution of 0.07°x 0.07°) and CAMS-REG-AP version 2.2 emission data aggregated by GNFR sectors provided by TNO were used. Outer domain (0.5°x0.25° resolution) covered 10°W-45°E; 30°N-60°N while nested domain covered the area 13°E-23.5°E; 41.5°N -47°N, with spatial resolution 0.1° x 0.05°. Emission reduction scenario's (15%) were used for traffic sector (F), residential combustion sector (C) and both sectors (C and F) combined. Hence, four model runs were made: the base model run without emission reductions and model runs with three scenarios. The same four scenario approach was used with SHERPA tool and results compared. Both methodologies provide comparable results with respect to annual average concentration values, however, spatial distributions differ considerably. Spatial distribution differences show that both SHERPA and CTM are highly sensitive to the underlying emission gridding assumptions (proxies). Since CTM used the latest update of the emission inventory results for areas of highways and roads, especially for NO_2 compared to SHERPA look much more realistic. SHERPA overestimates the influence of population density in rural areas and does not depict the road traffic influence. As expected, surface concentrations of NO_2 are more affected by reductions of road transport emissions while PM concentrations are more affected by reductions in the sector of other stationary combustion. Combined scenario results show that linearity is conserved in case of emission reduction by 15%.

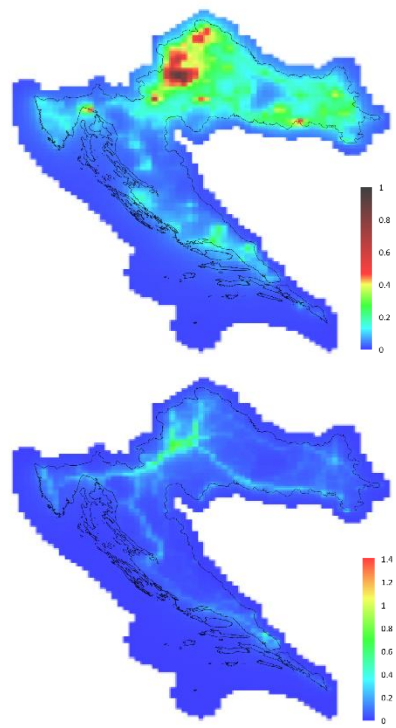

Fig.1 The effects of 15% emission reduction scenario on a) PM_{10} concentration (residental combustion sector) and b) NO_2 concentration (traffic sector).

Conclusions
To complete LOTOS-EUROS scenario runs took more time then SHERPA tool runs. However, CTM provided more precise and detailed results, especially with respect to spatial distributions. SHERPA tool provided semi-adequate general screening results but should be used with caution in case of need for specific and detailed spatial analysis. The 15% emission reduction scenario was used in order to avoid the non-linearity problem that can become noticeable if larger emission reductions apply. Hence the analysis of reduction scenarios with purpose to determine the linearity span as well as the analysis of source apportionment labelling approach will be the next step to encompass this work.

Acknowledgement
This work was done within the scope of the project "AIRQ – Expansion and Modernisation of the National Network for Continuous Air Quality Monitoring" (KK.06.2.1.02.0001) and is supported by the EU from the European Regional Development Fund.

INNOVATIVE ATMOSPHERIC DISPERSION MODELLING IN SUPPORT OF SMART FARMING APPLICATIONS WITHIN THE FRAME OF THE EU LIFE+ GAIA SENSE PROJECT

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Summary
The project LIFE GAIA Sense focuses on the development and application of an innovative "Smart Farming" system that aims at reducing the consumption of natural resources and minimising environmental impact, while increasing crop production. One of the main objectives of the project is to evaluate the environmental impact of the GAIA Sense application in terms of air, soil and water pollution. A combined use of multi-scale dispersion modelling and continuous measurements of several atmospheric pollutants is employed to assess the emission, dispersion and deposition of gases and particulates, taking advantage of collected meteorological data as provided by the on-site GAIA sensors and meteorological stations.

Introduction
GAIA Sense is an innovative "Smart Farming" (SF) solution that aims at reducing the consumption of natural resources, as a way to protect the environment and support Circular Economy models. Within the frame of environmental impact assessment of the GAIA Sense solution, a novel multiscale modelling method for determining air pollution levels is developed. Aiming to address the limitations which arise as a result of the disparities between the different modelling scales, a collection of interpolating metamodels was formed introducing MEMICO, a two-way scheme for coupling the mesoscale model MEMO and the microscale model MIMO.

Methodology and Results
In order to realistically assess air quality impacts of the SF GAIA Sense system at the local scale, a two-way scheme is used for coupling the mesoscale model MEMO and the microscale model MIMO, utilising a collection of interpolating metamodels. In the two-way MEMICO (Tsegas et al., 2015) coupling scheme, a three-dimensional spatial interpolation scheme, a spatial adjustment of values within the surface layer, and the formulation of the lateral boundary conditions to introduce the interpolated values into the microscale model are applied. For simulating pollutant chemistry and dispersion characteristics, the mesoscale dispersion model MARS-aero is applied at the same spatial resolution as MEMICO, which downscales from a spatial resolution of 500m for the entire selected area to 1m for selected agricultural locations. Specifically, an atmospheric dispersion model in conjunction with a mathematical model that simulates soil water movement and solutes fate will be used. Specific subroutines will simulate atmospheric emissions, chemistry and deposition, nitrogen incorporating mineralisation, immobilisation, nitrification, denitrification, ammonium exchange, uptake and mass transport. As the accuracy of modelling estimates strongly depends on the availability of extensive and detailed input data, the influx of meteorological and soil moisture data from IoT devices (GAIAtrons) and meteorological stations will significantly boost the accuracy and precision (i.e. forecasting skill) of the air quality modelling system. In order to produce maps of air pollutant levels at very high spatial resolution over the pilot agricultural domains, detailed input data will be collected from open data sources and formatted to be used in the modelling applications. In addition to the mathematical models, a Life Cycle Assessment model will be applied for the estimation of pollutants fate using international standards and eco- indicators.

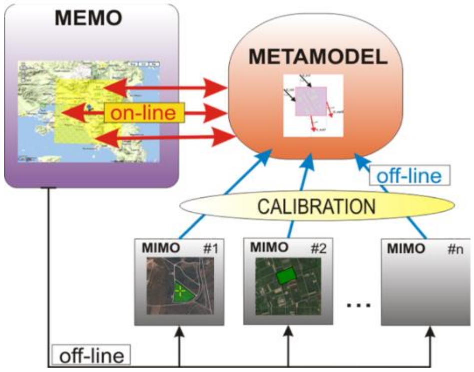

Fig.1 The MEMICO modelling system

Conclusions
The LIFE GAIA Sense project aims at presenting an efficient and robust tool for implementing the EU policies in the areas of water, waste and air management, reducing the contribution of the agricultural sector over the major environmental burdens. The atmospheric modelling is one of several components contributing to the comprehensive evaluation of the environmental impact of GAIA Sense application. Traditional modelling tools are further developed in order to realistically cope with the complex system of characteristic soil-atmosphere interactions in crop areas.

Acknowledgement
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ASSESSMENT OF THE MADRID REGION AIR QUALITY ZONING BASED ON MESOSCALE MODELLING AND K-MEANS CLUSTERING

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Summary

This study applies a novel methodology to assess the air quality zoning in Madrid. We analyse the spatial variability of the principal pollutants (nitrogen dioxide (NO_2), ozone (O_3) and particulate matter (PM_{10} and $PM_{2.5}$)) according to a chemical-transport model (CMAQ) annual simulation. From that information, various statistical analyses are carried out to assess the current zoning and to propose an alternative that maximizes the statistical differences in the concentration fields among zones. Furthermore, total coverage and redundancy of the existing stations within each zone are investigated.

Introduction

Madrid currently considers seven zones of air quality based on administrative, geographic and land use criteria. This zoning was proposed in 2014 and needs to be reviewed according to the Air Quality Directive (2008/50/EU). There is a lack of standardize methodologies and a need to incorporate objective scientific criteria to define the new zoning, ultimately contributing to a better air quality management.

Methodology and Results

A 1 km^2 resolution simulation over the whole Madrid region was run for the year 2015 with the Community Multiscale Air Quality (CMAQ) modelling system, version 5.0.2 (Byun and Schere, 2006). From the model outputs, we produced all the relevant indicators according to Directive 2008/50/EU. For each of the 179 municipalities in the region, central estimates and dispersion parameters (mean, median, quartile 25 (Q1), quartile 75 (Q3), interquartile range (IQR), standard deviation (sd) and coefficient variation (cv)) were computed considering the individual values of the grid cells overlapped. A Principal Components Analysis (PCA) reveals that mean, median, Q1 and Q3 are the most informative parameters for all the pollutants are important, while cv is also significant for PM_{10} and $PM_{2.5}$. Once classification variables are identified, we apply a k-means clustering algorithm (Hartigan et al., 1979) for the classification process. The number of zones is discussed according to Elbow, Silhouette (Kaufman and Rousseeuw, 2009) and Gap statistic (Tibshirani et al., 2001) tests. The results for all the classification tests are visualized through Box and whiskers plots and analysed by means of Kruskal-Wallis test and Dunn test as *post-hoc* assessment to understand whether differences among air quality zones are statistically significant. Lastly, we analyse the intersection and union of the 47 air quality monitoring stations in the region to characterize total coverage and potential redundancy within each area.

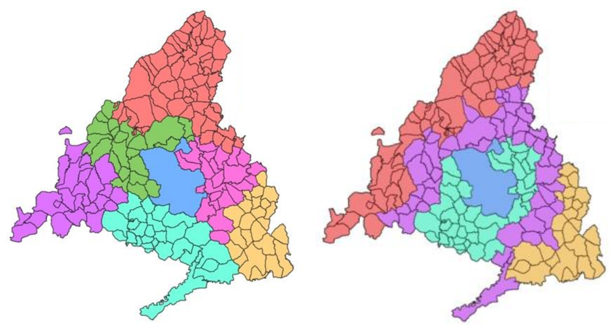

Fig.1 Current (left) and proposed (right) zones for NO_2, PM_{10}, $PM_{2.5}$ in the Madrid Region

Conclusions

A new methodology based on the combination of a chemical-transport model and a cluster analysis was used to revise current air quality zoning in the Madrid region and to propose a new one (Fig. 1) that reflects more accurately homogeneous areas form the air quality point of view. The number of zones and distribution of municipalities varies with the pollutant and AQ parameter analysed. A new zoning with less areas and a concentric distribution shows better statistical significance and coverage.

Acknowledgement

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BC FOOTPRINT – A CONCEPT FOR ENVIRONMENTAL EVALUATION OF BLACK CARBON EMISSIONS

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Summary

Black carbon (BC) particles in the atmosphere have a remarkable impact on the warming of climate and health of human populations. However, established metrics to estimate the impacts of BC, especially on climate, are lacking, and the institutional bodies and legal instruments to mitigate the negative impacts are only in the very early phase of development. This project aims to develop a new concept for the evaluation of various environmental impacts of BC emissions in a uniform framework. The knowledge base will be strengthened in the evaluation of all parts of the impact chain from BC emissions and measurements to atmospheric BC concentrations to climatic and health effects. The ultimate goal is to develop an easy-to-use BC Footprint concept that can be utilized widely by researchers, authorities and businesses. Furthermore, an aim is to facilitate a dialogue between the scientific and private technology sector, political actors and citizens.

Introduction

Black carbon (BC) is at present the second most important contributor to climate warming after CO_2. Dark BC particles in the atmosphere absorb solar radiation thus warming the surrounding air, and, when they are transported and deposited on snow and ice covered areas, they reduce the albedo of the surfaces thus accelerating the melting of glaciers. Due to relatively short lifetime in the atmosphere, from days to weeks, mitigation of BC can affect surface temperatures faster than those of long-lived greenhouse gases. The magnitude of the climate impact strongly depends on the location of BC emission sources; emission taking place in the northern latitudes, near snow covered Arctic areas, have been estimated to have particularly large temperature response (Sand et al., 2016). These temporal and spatial aspects make the climate impact assessment of BC in a footprint-type, generalized tool a challenging task. In addition to climate, BC significantly affects public health in urban areas (Janssen et al., 2014), which needs to be addressed as well in a comprehensive environmental evaluation.

Methodology and expected results

The Black Carbon Footprint project brings together scientists, authorities and businesses from different disciplines to enhance the understanding and knowledge base of BC-related aspects and develop a concept for the evaluation of BC-induced environmental impacts (Timonen et al., 2019). There will be experts involved from all the relevant sectors along the impact chain: BC emission measurement and emission factor evaluation, monitoring and instrumentation of BC in ambient air, atmospheric sciences and modelling, and BC emission control technologies and institutional frameworks for emission mitigation. For the climate impacts of BC, the temporal and spatial dimensions, that are different from global long-lived greenhouse gases, make the assessment scheme a rather multidimensional task. The shorter atmospheric life-time and strong dependency of the location of emission source along the north-south gradient need to be taken into account. The work will base on work by Kupiainen et al. (2019) who have developed climate metrics for Finnish BC and other air pollution emissions at various time horizons.

Conclusions

The Black Carbon Footprint concept will be a practical tool to assess and demonstrate environmental impacts of products and practises from BC point-of-view, facilitate dialogue between scientific community, industrial actors, policy makers and citizens, and enhance capabilities to develop improved and comparable BC measurement methods, emission mitigation technologies, and national and international emission reduction policies.

Acknowledgement

This work was and will be supported by Business Finland, HSY Helsinki Region Environmental Authority Services, Valmet Technologies, Vaisala, Tampere City, Pegasor, Dekati, AX-Consulting, AGCO Power, Airmodus, and SSAB Europe in the project 1462/31/2019 Black Carbon Footprint.

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USE OF ALTERNATIVE FUELS IN A CEMENT FACTORY AS A CONTRIBUTION TO CIRCULAR ECONOMY: AIR QUALITY ASPECTS

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Summary

The present study aims to investigate the effect on atmospheric emissions and air quality of the partial replacement of conventional fossil fuel (pet coke) with alternative fuels in the TITAN cement factory in Thessaloniki. More specifically, the study focuses on the impact of co-incineration of different mixes of alternative fuels' derived from waste materials on the flue emission of gaseous and particulate pollutants and the resulting dispersion patterns in the surrounding areas. A quantification of the relevant emission rates based on real-time measurements and extrapolated emission factors is performed. Dispersion patterns under different fuel mix scenarios and meteorological conditions are simulated by means of a Lagrangian dispersion model.

Introduction

Fossil fuels have been and still are the major energy source in cement production. However, over the last few decades there is a steady global trend of increasing use of alternative fuels, driven both by cost incentives, as well as by a series of environmental benefits. In the frame of the present study, the prospects for the partial replacement of conventional fossil fuel (pet coke) used in the TITAN cement factory in Thessaloniki, Greece, with alternative fuels are investigated. In particular, the study focuses on the impact of the use of alternative waste-derived fuel mixes in the plant kiln on the emissions of air pollutants. Exhaust air emissions from the rotary kiln are estimated for the conventional fuel and for mixtures of conventional with alternative fuels, based on emission factors obtained by literature review, but also using the continuous measurements conducted by TITAN.

Methodology and Results

Emission series are calculated for an entire calendar year taking into account activity and operational parameter data registered for the specific time period. Based on these emission estimates, it is concluded that that legislative limit values for air pollutants are not exceeded when alternative fuels are used. Using the emission estimates and measurements in the flue gas, the dispersion of the atmospheric pollutants around the factory and in nearby inhabited areas is simulated with the use of AUSTAL2000 model. AUSTAL 2000 is a Lagrangian air pollution emission and dispersion model, developed in strict adherence to the German VDI 3945 standard. For the purposes of the present application, AUSTAL2000 was applied for a 10×10 km^2 area with the stack of the plant in the centre for a full calendar year. On-site meteorological measurements and meteorological fields calculated by the mesoscale model MEMO were used as meteorological input data. Figure 1 depicts the spatial pattern of the TITAN plant's contribution to PM_{10} and NO_2 annual average concentrations for the conventional flue scenario. Results from the dispersion simulations suggest that the factory's contribution to the annual average air pollution levels in the surrounding area is very low.

Based on the above, the introduction of alternative fuels in the cement production process of the plant appears to have an overall positive effect on the related atmospheric emissions. Simulation results indicate that contributions to the air pollution over surrounding areas are very low for all of the fuel mix scenarios. Notably, even during extremely unfavourable atmospheric conditions, NO_2 concentrations remain below the threshold values set by European legislation. In conclusion, the increased use of alternative fuels appears to lead to a reduction in the unit's contribution to the levels of gas emissions in the surrounding area, including NO_2.

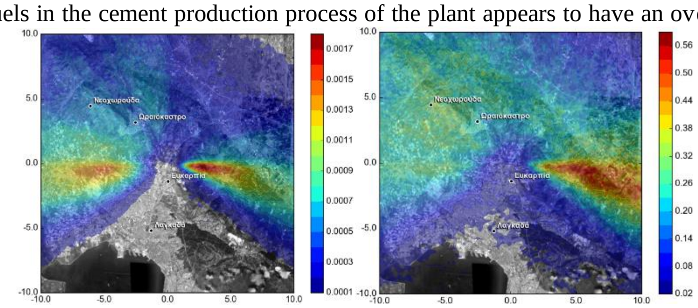

Fig.1 Spatial pattern of the factory's contribution to the annual average concentrations of PM_{10} (left) and NO_2 (right) for the baseline scenario.

Conclusions

The introduction of alternative fuels in the cement production process of the TITAN cement plant appears to have an overall positive effect on the related atmospheric emissions. In any case, even the worst-case contribution of the plant in the air pollution levels of the surrounding area is extremely small. As a result, the participation of alternative fuels in the fuel mix of the plant is considered to be environmentally beneficial.

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Short Presentations

SILAM APPLICATION TO AFRICAN AQ ASSESSMENT AND HANDS-ON TRAINING AT PREFIA WORKSHOP

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Summary

Within the WMO PREFIA model intercomparison project, several CTMs were applied to African continent. The activities laid down the ground for a Training on "Seamless Prediction of Air Pollution in Africa" 9-12 October 2019 in Nairobi, KENYA. One of the training sessions used SILAM as the modelling tool. During 3x3 hours sessions the students were offered to set-up SILAM and make several simulations from very simplistic "toy" cases, to a full-chemistry simulations of air-quality for the home country of participants. The continental SILAM PREFIA simulations were used as the boundaries and initial conditions. The assignment aimed at two goals: (i) each trainee got a prototype setup for SILAM AQ simulations for own country of origin, (ii) the basic features of the setup and input information were assessed.

SILAM model

Silam (System for Integrated modeLlong of Atmospheric coMposition, http://silam.fmi.fi) is an offline chemistry-transport model applicable from global to regional gamma-mesoscale domains. It is capable of simulating full spectrum of processes affecting the air composition, including emissions, transport, dry and wed depositions, chemical transformations and aerosol dynamics. Silam can be driven with a variety of numerical weather prediction (NWP) and climate models. Silam features an efficient scaling, so small cases can be efficiently run on a very modest hardware, which makes it a good model for training purposes.

The outcome of the simulations

A prototype real-life case was made on a base of the year-long SILAM simulations for 2017 for the PREFIA domain with 0.2º resolution (Fig.1). The simulations were driven with 0.5º extract of ERA5 reanalysis and used 1.44º global SILAM output as chemical boundary conditions (BC). For the individual-countries training simulations, a period of Oct 2017 was extracted from global ERA5, and BC datasets for the PREFIA domain. BC were also used as initial conditions. A special extract of CAMS_REG_GLOB_2_1 anthropogenic-emissions inventory for the same domain was prepared. In addition to that GEIA lightning, MEGAN v2 BVOC inventories were used. Emissions of sea salt, wind-blown dust were simulated with SILAM online. The wild-land fires emissions were simulated with IS4FIRES (http://is4fires.fmi.fi) model.

The students modified the given template to simulate their own country and performed 3-days long simulations with same 0.2º resolution with typical domain size of 50-100 cells on each direction.

Four countries were analysed by the trainees Cameroon, Cote d'Ivoire, Egypt and Southern Africa. Already a quick outlook of the obtained results showed numerous intriguing deficiencies, primarily concerning the emission information. In particular, many cities and industrial areas were absent whereas regional emissions had actual resolution much coarser than the declared 0.1º. E.g. for Cameroon the emissions of Doulala and Yaounde, cities with population of 2-3~mln each, except for a few point sources were missing from the inventory. The traffic emissions for Cameroon were distributed over 2º × 2º cells, despite the nominal resolution of the inventory is 20 times finer. A lack of observational information complicated the model evaluation but the comparison with the satellite data on AOD and NO_2 column load generally confirmed the strong dependence of the model skills and completeness of the emission database.

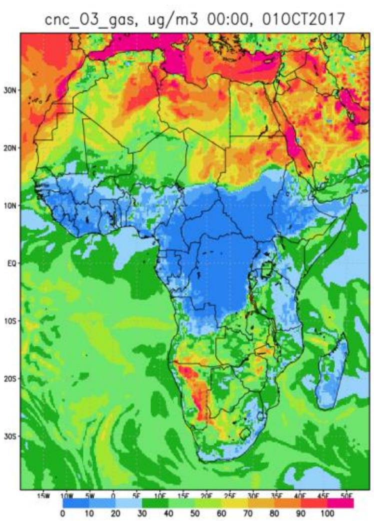

Fig.1 SILAM O3 concentrations at PREFIA domain

Conclusions

As a result of the training the trainees got a practical experience of installing and setting up the SILAM simulations. The deficiencies in the existing emission inventories for Africa were identified and discussed. The main recommendation of the training was concerning the improvement of the emission inventory by, at least, incorporating the major cities and traffic routes into the maps of NOx and VOC emission. Their proper treatment is a pre-requisite to reasonable representation of chemical processes over the continent.

Acknowledgements

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ANALYSING PARTICULATE MATTER EXCEEDANCES IN ATHENS AND THESSALONIKI

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Summary
As coal, oil and gas continue to hold the major share of global primary energy demand growth and following the 3 year plateau for the period 2014-16, a significant rise of emissions is monitored globally, reaching unprecedented levels in 2018 (OECD, 2019; IEA, 2019). In the current paper, the particulate matter (PM) data are analysed as monitored over the period 2015-2018 in the greater areas of Athens and Thessaloniki. Significant correlations of PM exceedances and indication of seasonality are captured and assessed.
Many countries, which are still mainly powered by fossil fuels, have to address the issue of balancing the public health impact and comfort along with the need for economic growth and sustainability. Innovative and intelligent use of energy, smart fine dust alarm, enhancement of novel local and regional financing actions that are capable to trigger the citizens' motivation for the implementation of low-emission solutions in housing and transport, and similarly the industrial sector should be considered.

Introduction
Research on atmospheric particulate matter has increased over the last years mainly due to the adverse effect on both human health and ecosystems. Urban and suburban areas remain highly influenced by local parameters such as climatic conditions, intense traffic and industrial development, transboundary pollution. As reported by EEA (2018a), a percentage of 13 % of the European urban population was exposed to PM_{10} concentrations exceeding the daily limit value and approximately 42 % was exposed to levels above the stricter WHO AQG value for PM_{10} in 2016. Air quality episodes and exceedances were recorded both at background and traffic stations, with a greater percentage in the first ones (EEA, 2018b), indicating that other than traffic sources, such as commercial buildings, industrial operation and household heating, are generating a significant proportion of emissions and should be neglected.

Methodology and Results
Data monitored by the Greek Ministry of Environment and Energy are analysed covering the period 2015-18 in Greater Athens and Thessaloniki Areas. A variety of stations areas and types are selected, such as urban and suburban, traffic, background and industrial in both cities. Indicatively, the daily maximum PM_{10} concentration levels in the Greater Thessaloniki Area varied between 90-201 μg/m^3 monitored in Panorama and Sindos, respectively, while there is a rising number of exceedances over the years (see Fig. 1). Statistical analysis was performed so as to identify the relation between PM_{10} over the year and the type of station and describe any possible relation between 2 major Greek cities. Strong positive correlation was observed between PM_{10} and year. Similar analysis is attempted for Athens.The results suggests that there is a rising trend in PM concentration values in Greece. In order to address the air quality issues and protect public health, one of the most popular means is the promotion of innovation strategies, either it comes as a product, a process, organizational, production, marketing or service.

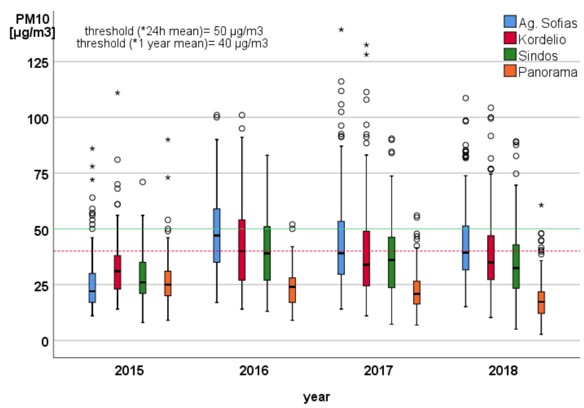

Fig.1 Average PM_{10} concentrations in Thessaloniki stations for the period 2015-2018.

Conclusions
As PM concentration levels have a positive, slightly growing trend in Greece, the need to adopt innovative solutions, energy saving schemes and enhance zero - or nearly zero- emission strategies are imperative in urban planning, in multifold aspects, including traffic, constructions, housing and industrial operation. Hence, there is need to introduce suitable sustainable actions and legislation in order to successfully address all challenges.

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MODELLED VEHICULAR TRAFFIC CONTRIBUTIONS TO AMBIENT $PM_{2.5}$ CONCENTRATIONS IN THE MEGACITY OF LAGOS

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Summary

The aim of this study is to quantify the influence of meteorology and road-traffic emission on ambient concentrations of $PM_{2.5}$ in Lagos. A Gaussian dispersion model (OSCAR) was configured and applied for the purpose of this investigation. The model was evaluated by comparing predicted $PM_{2.5}$ and observed concentrations, using statistical parameters. Based on the evaluated model, traffic increment to $PM_{2.5}$ was quantified and predicted to be between 37% and 44% near three major roads, during the study period, November 2018. The study also compared the impact of emission factors (EFs) from different sources. In the absence of national emissions datasets, COPERT 5 values were employed.

Introduction

Lagos, one of Africa's three megacities, has a population of around 21 million. With an estimated annual growth rate of 3.5 %, the population is expected to reach 40 million by 2050. The level of air pollution in the megacity has increased and is projected to increase in the future. While there are many source categories of air pollution in Lagos, road traffic has been previously reported as the most prominent. However, the contributions of street and road traffic emissions to ambient $PM_{2.5}$ concentration in Lagos have previously not been quantified. In this study, likely to be the first of its kind, a Gaussian dispersion model (OSCAR) has been adapted to simulate and analyse the effect of vehicular emissions on ambient $PM_{2.5}$ concentrations in the city of Lagos.

Methodology and results

Traffic, meteorological and emission data were pre-processed as input for the dispersion model (OSCAR). In a previous study, OSCAR was evaluated with measurements from the London Air Quality Network (Singh et al, 2014). In this study, the domain was set to 27 km × 19 km incorporating 27900 user-defined receptors located 74 road links. Simulations were carried out using emission factors (EFs) from COPERT 5 and West African information sources. The model predictions were compared with urban in-situ measurements and the comparison showed improved model performance with COPERT datasets, compared with the use of the corresponding West African data. Model evaluation showed correlation coefficient (R) and factor of two (F2) values of 0.66 and 0.80, respectively, for the hourly concentrations in 2018 indicating good agreement with measured $PM_{2.5}$ concentrations. Traffic increment in terms of $PM_{2.5}$ was quantified for periods of 2010 and 2018. For November 2018, the increment was predicted to be up to 44% near three major roads shown in Figure 1. Further modelling analysis showed that under fixed meteorological conditions, emission rate and traffic increment would have increased by a factor of 7 between the years 2010 and 2018.

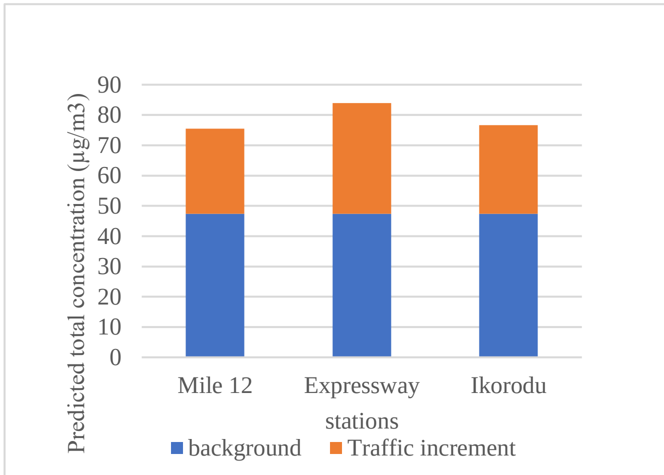

Fig.1 Predicted traffic increment in terms of PM2.5 concentrations near three major roads in the city of Lagos in November 2018. "Background "Includes both the regional background and the contributions from the other urban source categories.

Conclusion

The model evaluation showed good agreement with observed data. Traffic increment along three major roads in Lagos in 2018 was predicted to be significant and could be up to 44% of the total concentration of $PM_{2.5}$. The modelling analysis also showed that from 2010 to 2018 the contributions of traffic to ambient $PM_{2.5}$ concentration increased by a factor of 7.

Acknowledgement

The traffic data used was provided by Lagos Metropolitan Area Transport Authority (LAMATA). The Centre for Atmospheric Research, National Space Research and Development Agency (CARNASDA) provided some of the meteorological data.

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DEVELOPMENT OF AN ADAPTABLE AIR QUALITY MANAGEMENT SYSTEM FOR SUPPORTING URBAN-SCALE ASSESSMENT IN EUROPE

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Summary
The present work aims at the modification of an existing Air Quality Management System (AQMS; Moussiopoulos et al., 2016), developed by the Laboratory of Heat Transfer and Environmental Engineering (LHTEE), in order to provide and adaptable air quality modelling platform for urban-scale applications in Europe. As a first instantiation of the system, development on both the back-end and the front-end, as well as user-interface of the AQMS focuses on incorporating the mesoscale wind field model GRAM (Oettl, D., 2000) and the Lagrangian dispersion model GRAL (Oettl and Uhrner, 2011). The work is collaborative implemented with the Karlsruhe Institute of Technology/Technology for Pervasive Computing KIT/TECO research group.

Introduction
Operational air quality modelling has been increasingly recognized as an indispensable component of any integrated air quality assessment strategy, especially in view of the provisions of the European Air Quality Directive (2008/50/EC). As a result, integrated informational systems known as Air Quality Management Systems (AQMS) have been developed aiming to offer technical users and policy makers a consistent and robust environment for their regular workflows. In this framework, an AQMS is developed targeting scenario assessment applications in Europe. The core of this AQMS consists of a model system which performs nested-grid meteorological and photochemical model simulations in two parallel operational modes, providing users with updated air quality nowcasting and forecasting calculations for the areas of interest. In addition, air quality assessment and decision making is supported by the AQMS through a range of additional features, such as the capability to study emission scenarios and assess their effect on air quality over user defined domains.

Methodology and Results
The modularity of the developed software system is demonstrated through the integration of the GRAM/GRAL model system with application to specific use cases in German cities. The developed modules provide the AQMS with model-adaptable interfaces for the preparation of input emissions data, domain and model configuration, validation and visualization of results. Development on the model interface involved the specification of functional parameters of the AQMS back-end (Fig. 1) and corresponding APIs, as well as the implementation of scheduling and bookeeping glue code specific to the operation of GRAM and GRAL. Additionally, a test application of the new modelling system is targeted as part of the functional verification of the system (including user feedback), and validation of the modelling core through comparison with monitoring data. The system is currently being tested and refined to meet the needs of specific applications in German cities, pursued by the KIT/TECO group in the framework of the SmartAQnet project (URL).

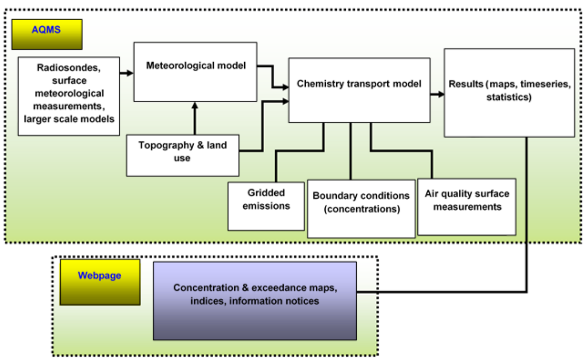

Fig.1 AQMS architecture and interfacing

Conclusions
The new AQMS version constitutes an evolutionary improvement towards a model-agnostic system for the management of meteorological and photochemical simulations, capable of offering a range of useful features for air quality assessment. Individual models can be incorporated with little effort using a minimal interfacing layer. Results of the operational calculations can be reviewed and visualised via a user-friendly web page, while an off-line module provides support for air quality related assessment and decision making, based on custom emission scenarios. The capabilities offered by the AQMS for producing high quality assessments of air quality, by adaptively incorporating a suite of dispersion modelling tools, are expected to be a valuable aid to the authorities towards compliance with the relevant EU standards.

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ASSESSMENT OF AIR QUALITY IMPACTS FROM THE DEPLOYMENT OF AN INTELLIGENT TRANSPORT SYSTEM IN BALKAN CITIES

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Summary

The EU funded Step2Smart project aims to develop an open architecture methodology, building on both existing and new systems, which will be implemented and evaluated in pilot actions in the cities Nicosia, Chania and Kos. Pilot campaigns of Intelligent Transport Systems (ITSs) will be used to link transport to cities with reducing environmental pollutants. The basic tool for this is an operational Air Quality Management System (AQMS) which has been adopted by the Department of Labour Inspection of the Ministry of Labour, Welfare and Social Insurance as the official software platform for air quality management in Cyprus (Moussiopoulos et al., 2016).

Introduction

The goal of improving air quality in order to protect human health and promote public welfare has been consistently set forward in the European Union during the past decades. Towards this goal, numerous regulations and standards, a broad suite of management tools and several monitoring networks to track progress have been established. All of these components depend on robust and up-to-date scientific and technical input, which includes an understanding of relationships between air pollutant levels and their impacts on human health, ecosystems, atmospheric visibility, and damage to materials and monuments. In this direction, an original Interoperable Open Architecture System for urban transport management and environmental impact assessment has been developed in the frame of the Step2Smart project. The system relies on ITS application to associate city transport management with the reduction of air pollution.

Methodology and Results

An operational AQMS has been installed and used operationally in the Department of Labour Inspection (DLI) of the Republic of Cyprus. The core of the AQMS consists of a model system which performs nested-grid meteorological and photochemical model simulations in two parallel operational modes Air quality assessment and decision making is also supported by enabling authorized users to interactively configure custom emission scenarios and computationally assess air quality trends over user-defined domains of interest. The various operational and off-line workflows of the AQMS are presented in Figure 1. One of the Step2Smart objectives is to implement a streamlined link between traffic management and air quality assessment with the aid of a data assimilation module which are developed and incorporated in the AQMS. As regards the AQMS operational application, at the end of each day a wide range of statistical indicators are calculated according to the guidelines set by COST728 (2008), for the station locations and pollutants of interest, and numerous charts are produced for visually assessing the accuracy of the simulations in both nowcasting and forecasting model. The accuracy in predicting air pollution levels at the local/street scale is consistently lower than in the urban. Thus, a statistical approach for determining street increments of concentrations was evaluated in a pilot two-month application, using the AQMS's operational mesoscale calculations of urban background concentrations and meteorological fields in order to provide the functional relationship with the required input parameters. The results of this pilot application were then compared with observational data. The validation process indicated a clear improvement in the AQMS's ability to predict pollution levels at the street scale.

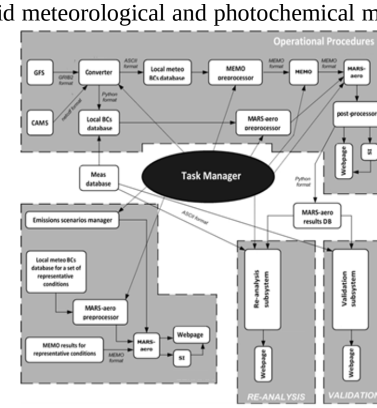

Fig.1 AQMS architecture and interfacing

Conclusions

Within the Step2SMART INTERREG project, the efficiency of pilot measures in terms of emission reduction and air quality improvement will be assessed using the AQMS. In this direction, a two-way link between the AQMS and the traffic loads monitoring software of the Department of Public Works of the Ministry of Transport, Communications and Works of Cyprus is implemented. Measured traffic loads in Nicosia are taken into account by the AQMS in real-time, for calculating accurate pollutant emissions to be fed into AQMS. The final results of this work will be used as guidelines for the future development of Sustainable Urban Mobility Plans (SUMPs) for similar mid-sized island cities.

Acknowledgement

The "Step2Smart" Project is co-funded by the European Union and national funds of the participating countries

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INDUSTRIAL AIR POLLUTANTS IN SNOW COVER IN ESTONIA THROUGHOUT PAST 35 YEARS

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Summary
This study is an overview of deposition of pollutants emitted from oil-shale-based thermal power plants and industries in wintertime snow cover of North-Eastern Estonia. Snow samples collected in 13 winters out during past 35 years (1985-2019) have been analysed for main cations and anions, focusing Ca^{2+} and $SO4^{2-}$ as the most abundant pollutants. The snow-based deposition fluxes have been diminished by 1.5-2 decimal orders along with decrease of emissions due to both restructuration of economy and emission reduction measures, but remain still remarkable compared to remote areas.

Introduction
Snow is a natural collector of air pollutants deposited from the ambient air. In Northern Europe, where permanent snow cover lasts for weeks or months, it is possible to measure average deposition fluxes, taking once the samples through accumulated snow package, which is a relatively cheap method. The snow-based measurements are useful for mapping the deposition fluxes, evaluating the long-term trends in air pollution and validating the air pollution transport models. In this study the measurements in Ida-Viru district in North-Eastern corner of Estonia (2972 km^2) are presented. Measurements in 1985 were performed by Voll et al. (1989) and 1987 Paalme et al. (1988) and during 1994-2019 led by the author.

Methodology and Results
The samples were taken from accumulated snow cover in end of winters in 1985, 1987, 1994, 1996, 1999-2001, 2008-2010, 2018 and 2019, in total 259 samples from Ida-Viru district, at distances from immediate neighbourhood up to 50 km from major power plants and oil shale (*kukersite*) processing factories. The duration of snow accumulation season through different winters was 13-92 days. Samples were analysed for main anions ($SO4^{2-}$, Cl^{2-}, NO^{3-}, F^{2-}) and cations (Ca^{2+}, Mg^{2+}, Na^{+}, Ca^{+}), paying most attention to Ca^{2+}, which is a major constituent of emitted fly ash (about 21%) and $SO4^{2-}$, to which contribute both gaseous SO_2 emissions and sulphates in ashes. The emission data since 1995 are taken from Estonian Statistics (https://www.stat.ee/) and web-based environmental reports of major enterprises Eesti Energia and Viru Keemia Grupp. Earlier data are composed from (Liblik & Kundel, 1995) and (Liblik & Punning, 1999).

The deposition fluxes of main cations and anions have decreased since 1985 by factor of 30-100, along with emission of fly ash, which has decreased nearly 100-fold, first due to economic collapse on 1990-s and later on due to installation of more effective filters and renovation of furnaces (Fig. 1). According to measurements in recent years, the deposition fluxes near power plants and oil shale processing facilities still remain a few times higher than in remote areas. It was found that sample-wise linear correlation coefficient between Ca^{2+} and $SO4^{2-}$ fluxes throughout all studied winters is 0.79.

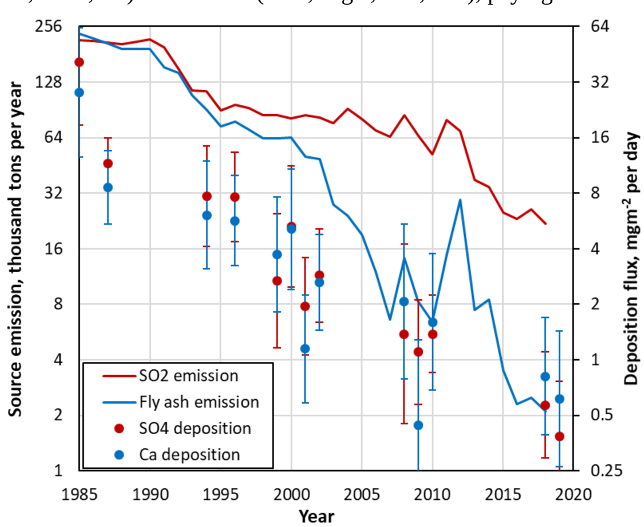

Fig.1 Snow-based deposition fluxes (logarithmic average and standard deviation) compared with emissions from Ida-Viru district.

Conclusions
The experience through 35 years proves that snow sampling is an adequate and handy tool for quantification of deposition of atmospheric emissions, which are detectable through main anions and cations.

Acknowledgement
This overview was supported by Estonian Ministry of Education and Science, Institutional research grant IUT20-11. Author is thankful to numerous colleagues for assistance in fieldwork during 1994-2009.

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Air Quality and Meteorological Predictions / Climate Interactions

AIR QUALITY FORECAST SYSTEM FOR ISRAEL: EXPERIENCE OVER THE PAST DECADE

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Summary
In 2003, ARIA Technologies provided to the Israeli Ministry of Environment a complete air quality modelling platform including the installation and configuration of an operational forecast system for air pollution. Since then this system is under maintenance, its performances are evaluated every year and improvements are regularly brought to the system. This document aims at sharing feedbacks about maintaining an operational system over 17 years, explaining the step by step improvement methodology and exposing the results of the different configuration tests.

Introduction
ARIA Technologies has been providing services to the Ministry of Environment since 2003. It includes the provision of a complete list of software (from gaussian to lagrangian models) allowing the client to configure and run scenarios. Among the software installed, an automatic forecast system runs every day on the cloud. The air quality forecasting system includes currently the WRF meteorological model and the photochemical model CHIMERE which run on a few km grid over Israel.

Methodology and Results
When installed in 2003, the system configuration included the CHIMERE model at a 3km resolution over Israel, fed by the meteorological model ALADIN at 9km resolution. The system included a detailed emission inventory over Israel. At the boundaries, global inventories were used (GEIA and RETRO inventories at this time).
It has been shown from model/measure comparison exercises that the model tended to underestimate the ozone production inland and more specifically during the summer period. The main emissions of primary pollutants are located on the coastline as it's the most urbanized area in Israel. In summer the sea breeze brings these pollutants inland producing high concentrations of ozone.
In a first step, the attention was focused on the improvement of ozone forecast. For this, several options have been tested :

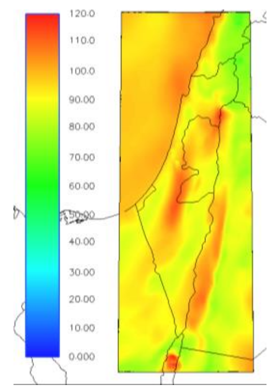

Fig 4 Illustration of ozone concentration fields

- Testing the role of meteorological drivers: in 2010, the ALADIN model has been replaced by the WRF model and more precisely the resolution of the model has been increased from 9 to 6 and then 3km, thanks to more powerful hardware with more CPUs, which played a non-negligible role in the restitution of the sea breeze. Currently tests with the COSMO model, operated by the Israeli Meteorological Service, are ongoing.
- Testing the Israeli inventory upgrades: Several updates of the inventory have been done since the first validation tests conducted in 2010. Results have shown a nice improvement due to the update of the inventory and more specifically due to the focus on VOC emissions which have been increased. The role of surrounding countries emissions is also a key issue as Jordan and Egypt are hot spots of emissions. An ongoing and related project (EMME-CARE) aims at improving the inventory in the Middle East region.
- Improving the primary pollutants simulation in the main agglomerations: Tests have shown that the FARM model applied at a 1km resolution over Tel Aviv agglomeration was able to represent correctly the NO_2 episodes in winter which was not the case with CHIMERE at 3 km. A prognostic code (SWIFT) using a refined landuse has also been used to improve the meteorological input.
- Test of different chemical mechanism: the latest version of CHIMERE (v2017) includes the SAPRC chemical mechanism which proposes a more complete description of VOCs compared to the current mechanism MELCHIOR2.

Conclusions
The israeli forecast system is a successful example of operational forecast system that has been able to evaluate according to the possibilities offered by growing hardware resources and model evolutions.

Acknowledgement
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AIR QUALITY FORECASTING BASED ON METEOROLOGY

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Summary
In this study we present some selected results of a parameterized method of air quality forecasting that is based on the assumption that changes in air pollution levels from one day to another are mainly affected by the local meteorology. From this study it was emerged that there is a significant correlation between PM_{10} levels and weather factors based on data acquired from 2011 onwards. Surface temperature and wind speed were identified as key weather factors for air quality forecasting.

Introduction
The present forecasting methodology is based upon the physical principle that the dispersion of particulate matter depends, to the largest extent, upon the current meteorology (e.g. Latini et al. 2002, Zeng et al. 2017). It is well recognized that pollution variations are not generally caused by sudden variations in the emission of pollutants, but result mainly from the meteorological conditions, which differentiate the ability of the atmosphere to disperse the pollutants. Having this as a guide, we developed a semi-empirical algorithm that is based on a statistical analysis of the air quality for a specific area for a historical time interval of one year.

Methodology and Results
The developed algorithm enables the estimation of 1-day PM_{10} forecasts, based only on the forecast daily average values of temperature and wind speed for the following day. Knowing the temperature and wind speed of the following day, the PM_{10} levels can be estimated with an acceptable credibility. In case that air pollution levels of the previous day are available from official or low-cost properly calibrated ground-based sensors or from satellite missions (e.g. CAMS), they can be integrated in the algorithm to increase the accuracy of the estimated forecast. The methodology was validated by comparing the produced forecast concentration of PM_{10} with a set of field data from official air quality monitoring stations for several cities. It was deduced that the proposed algorithm estimates PM_{10} concentration with an error of less than 30% for most of these cities.

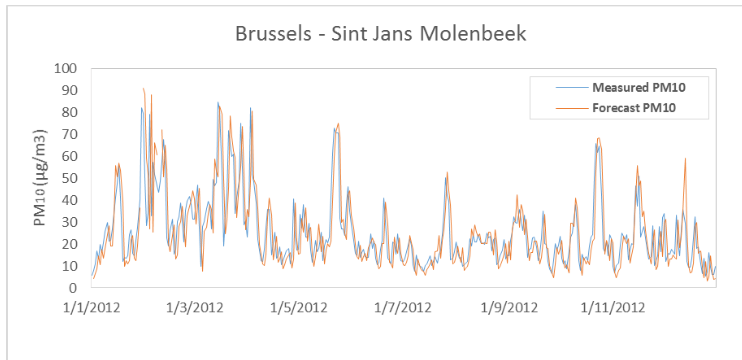

Fig.1 Correlation of PM10 estimates with official data in Brussels

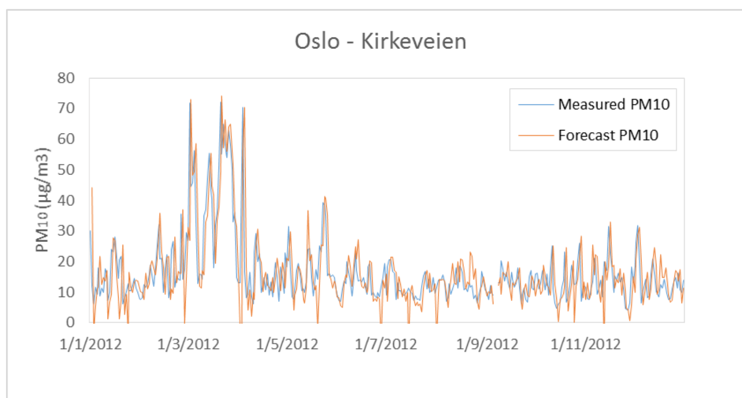

Fig.2 Correlation of PM10 estimates with official data in Oslo

Conclusions
The current study shows that meteorological conditions influence pollutants' dispersion, and thus PM_{10} levels can be estimated only from the forecast meteorology. The proposed algorithm requires very limited resources, while it should be customized for every city of interest and a simple formula is produced as a result. This formula needs an update every two to three years depending on the city.

Acknowledgement
Further validation tests of the proposed algorithm will be executed with low-cost sensor data that will be produced in Greece within the project Sympnia (T1EDK-05515), funded by the Greek General Secretariat for Research and Technology.

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EFFECTS OF GLOBAL METEOROLOGICAL DATASETS IN MODELING METEOROLOGY AND AIR QUALITY IN THE ANDEAN REGION OF SOUTHERN ECUADOR

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Summary
We used GFS, FNL, NCEPR2 and ERA-Interim datasets, for modeling meteorological and air quality variables in Cuenca, a city located in the Andean region of Southern Ecuador. Unexpectedly, the modeling performance decreased when using the reanalysis datasets. It suggests that for modeling purposes in this region, nowadays it is advisable the use of analysis datasets as GFS or FNL rather than reanalysis products.

Introduction
Numerical air quality models work with resolutions of few km for mesoscale studies. These models use outputs from global meteorological datasets to define the initial and boundary conditions of nested domains. One of these datasets is the Global Forecast System (GFS), which is produced by the National Center for Environmental Prediction (NCEP), taking current observations to forecast the weather. The FNL (Final) Operational Global Analysis data is another NCEP's product, which ingests about 10% more observations than GFS analysis. The NCEP Reanalysis 2 (NCEPR2) describes past weather data, based on the assimilation of additional observations not ingested for the GFS and FNL products. ERA-Interim is another global atmospheric reanalysis, produced by the European Centre for Medium-Range Weather Forecasts (ECMWF). As reanalysis datasets incorporate more observations than analysis products, it is expected they improve the modeling performance.

Method and Results
We used the GFS, FNL, NCEPR2, and ERA-Interim datasets to generate the initial and boundary conditions in the city of Cuenca (Andean region of Southern Ecuador, 2400 masl, Fig. 1), for simulating meteorological variables and air quality during September 2014, with the on-line Weather Research & Forecasting with Chemistry (WRF-Chem V3.2) model. The air quality network, modeling approach, and performance metrics are described in Parra (2018). Modeling captured 61.5 and 63.2% of the records (meteorology, short-term and long-term air quality) when working with the GFS and FNL respectively (Fig. 2). However, the performances did not improve and even decreased to 57.6 and 58.2% when working with NCEPR2 and ERA-Interim. For short-term air quality records, the performances were 54.6, 53.7, 50.9, and 51.9%; for the GFS, FNL, NCEPR2, and ERA-Interim respectively.

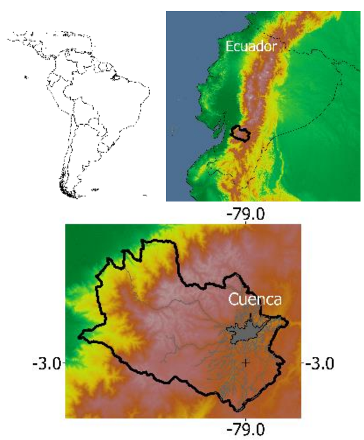

Fig.1 Location of Cuenca (Andean region of Southern Ecuador

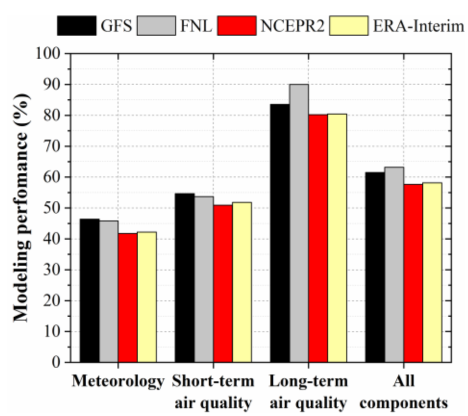

Fig.2 Summary of modeling performances

Conclusions
The decrease in performance when using the reanalysis datasets was unexpected. It suggests that, for this kind of studies in the Southern region of Ecuador, it is advisable the use of GFS or FNL rather than reanalysis products. One reason for this decrease could be the lack or the scarcity of records from this region, used nowadays for preparing the reanalysis products. Our results also indicate the need for a review of the processes for generating reanalysis datasets, to improve the modeling performance over the Andean Equatorial region.

Acknowledgment
This research is part of the project "Emisiones atmosféricas y Calidad del Aire en el Ecuador 2019–2020". Simulations were done at the High-Performance Computing system at the Universidad San Francisco de Quito.

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INFLUENCE OF BOUNDARY CONDITIONS AND CLOUD CHEMISTRY ON SULFATE CONCENTRATIONS IN A NESTED MODEL SETUP

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Summary
Nested European and Swiss national COSMO-ART simulations were performed to obtain adequate boundary conditions for gas-phase chemical, aerosol and meteorological conditions for a city-resolving simulation of Zürich using GRAMM/GRAL. Since sulfate is an important component of the aerosol produced mainly at large distances from the city, the importance of long-range transport versus regional production and cloud-phase chemistry was analysed and simulation results were compared to station measurements. Good agreement was only obtained when including proper boundary conditions for the outer, European domain and when considering cloud chemistry. Only a small fraction of the background sulfate over the city was from regional emissions within Switzerland.

Introduction
Reducing air pollution, which is the world's largest single environmental health risk, demands better-informed air quality policies. Consequently, multi-scale air quality models are being developed with the goal to resolve cities. One of the major challenges in such model systems is to properly represent all large- and regional-scale processes that may critically determine the background concentration levels over a given city. This is particularly true for longer-lived species such as aerosols, for which background levels often dominate the concentration levels even within the city (Putaud et al., 2004). In this study, the impact of processes across a wide range of scales on aerosol background concentrations over Switzerland and the city of Zurich is examined. In particular, the sulfate aerosol concentration in Switzerland is being investigated in a nested model set-up and attributed to global, European and Swiss sources. Furthermore, an efficient mechanism for sulfur oxidation in the aqueous phase was introduced.

Methodology and Results
The regional climate chemistry model COSMO-ART (Vogel et al. 2009) was used in a 1-way coupled mode. The outer, European, domain, which was driven by chemical boundary conditions from the global MOZART model, had a 6.6 km horizontal resolution and the inner, Swiss, domain one of 2.2 km. The boundary conditions for gas-phase and aerosol concentrations on the European domain were varied across simulations. Additionally, European and Swiss precursor emissions were varied to investigate their influence. Model results from summer and winter periods were compared to measurements from the air quality monitoring network NABEL at four Swiss stations. Modelled concentrations of sulfate in the aerosol phase compared well to measurements when the full European and Swiss emission dataset was used in conjunction with aqueous sulfur oxidation. Sulfate boundary conditions from MOZART also had a significant impact on concentrations over Switzerland and had to be slightly reduced to obtain a better match with observations. The simulations were usually within ±20% of the station data under summer and winter meteorological conditions.

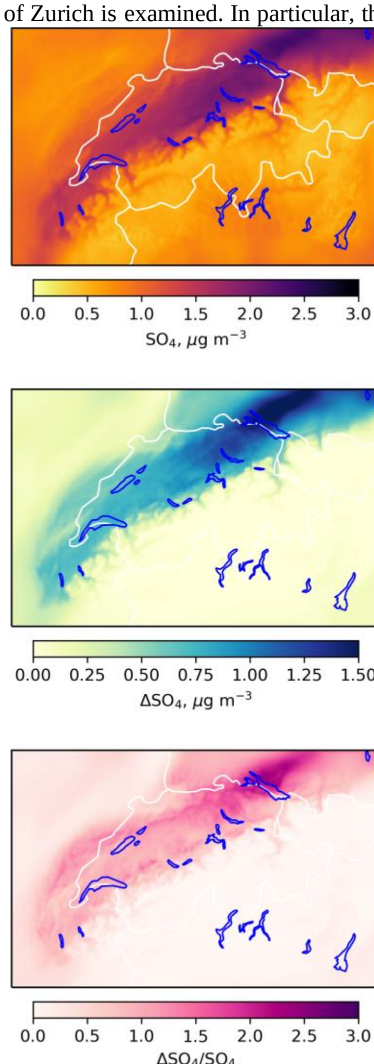

Fig.1 Daily mean field, 04.02.2015 for
a) sulfate concentration in the aerosol phase.
b) absolute increase due to aqueous oxidation
c) relative increase due to aqueous oxidation

Conclusions
The nested COSMO-ART can adequately reproduce local sulfate concentrations when using proper boundary conditions and emission values in its domain. The high day-to-day variability highlights the importance to use such a model set-up to obtain adequate boundary values for future high-resolution simulations over the city of Zürich with the GRAMM/GRAL model system (Berchet et al. 2017).

Acknowledgement
This work was supported by the Swiss Federal Office for the Environment (FOEN).

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TOWARDS TO POLLUTION ASSESSMENT IN MOSCOW USING GC-MS PLUS FTIR COMBINED APPROACH

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Summary

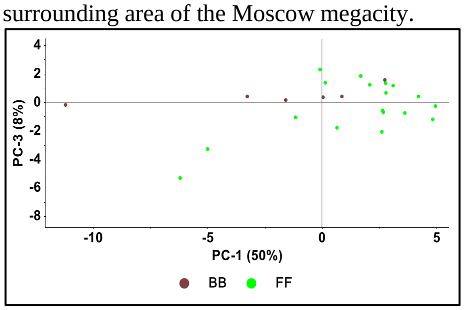
In a megacity, a high population and a wide range of human activities lead to large-scale ecological impacts. Currently, the chemical and physical aerosol characterization allows the evaluation of PM composition in many megacities. So far, Moscow remains one of mega-cities with limit of source apportionment evaluation. For the first time, this study fits the aims of air quality research by presenting the development of a new analytical and statistical approach, which deeply characterize the urban background of the Moscow megacity, providing a pollution assessment too.

Introduction

The complex nature of aerosol, composed of hundreds of organic and inorganic compounds, requires the application of comprehensive chemical analysis to evaluate the characteristics of PM at the different sources. In-situ derivatisation thermal desorption gas chromatography time-of-flight mass spectrometry (IDTD-GC-TOFMS) provides the determination of semi-volatile and low-volatile organic compounds from ambient particulate matter (PM). Subsequently, organic compounds are used as markers for source assessment. Fourier Transform Infrared (FTIR) spectroscopy determines the functional groups of the classes of compounds in the entire aerosol. The application of chemometrics tools on FTIR dataset is promising to evaluate the impact of different emission sources on the aerosol composition in urban environment. This study has done the development of a source identification for Moscow megacity, evaluating numerous season - dependent emissions, combining ambient FTIR, functional markers as well as IDTD-GC-TOFMS results with a statistical analysis approach.

Methodology and Results

Aerosol samples have been collected at Meteorological Observatory (MO) of Moscow State University (MSU) in Moscow, from April to May 2017, during a spring season when complementary impact of agriculture fires around is increased complementary to urban emissions and biogenic activity. Spectral light absorption evaluated by Angstrom Absorption Exponent (AAE) is used to differentiate between the periods influenced by biomass burning (BB) and others affected by urban fossil fuel (FF) combustion. The carbonaceous part of the aerosol has been characterised through the quantification of organic and elemental carbon, alkanes, polycyclic aromatic hydrocarbons (PAHs), oxidized PAHs, hopans, and anhydrosugars by IDTD-GC-TOFMS (Orasche et al., 2011). DRS-FTIR spectroscopy has been used to measure functional groups representative the classes of compounds for entire aerosol. Functional markers determine the impact of transport (diesel, gasoline) (Popovicheva et al., 2017) and regional BB (Popovicheva et al., 2014) . A new-developed approach which combine GC-MS and FTIR data with principal component analyses (PCA), is able to concentrate the data variability indicating the major pollution sources. The score plot shows the daily differentiation on two FF and BB-affected periods related to high and weak spectral dependence (AAE) (Fig.1). Identification of BB-affected periods discriminates the daily aerosol composition change with respect to air mass transportation and number of fires detected in surrounding area of the Moscow megacity.



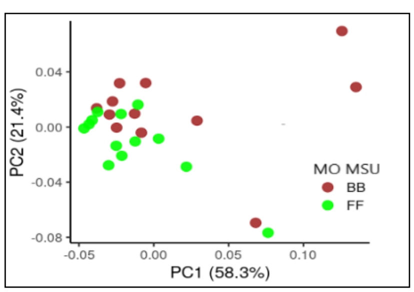


Figure 1. Score plot discriminates impacts of BB and FF at MO MSU by left) GC-MS and right) FTIR.

Conclusions

Combining attentive analytical and statistical approaches, representative compounds and functionalities in entire aerosol organic composition describe the highest quantity of variability. Principal component analyses highlight the main emission sources from organic and functional marker species relating to gasoline/diesel traffic, biomass burning, biogenic activity, and secondary formation in the atmosphere.

Acknowledgement. This work was supported by RSF project No.19-77-30004.

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PARTICLE CONCENTRATIONS ON A MOUNTAIN SLOPE IN RELATION TO THE ATMOSPHERIC BOUNDARY LAYER HEIGHT

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Summary

Experimental results related to the influence of the atmospheric boundary layer (ABL) height on the vertical distribution of the aerosol particles obtained during typical summer days are discussed. Space and time variations in the aerosol particle concentrations were measured by six-channel laser-based aerosol particle counters (LPCs) at three different altitudes: at 577 m a.s.l. at Astronomical Observatory (AO) in the Borisova Gradina Park; and at two sites situated at 900 m and 1350 m a.s.l. on the northern slope of Vitosha Mountain. The used aerosol counters measured both particle number and mass concentrations. The combined effect of daily development of ABL height (ceilometer observations), meteorological parameters, and hourly variations in the concentrations of the different aerosol fractions was discussed. The purpose of the experimental measurements conducted in July 2015 and July 2018 was to study the vertical evolution of aerosol particles in relation to the concentrations during the development of the mixing layer.

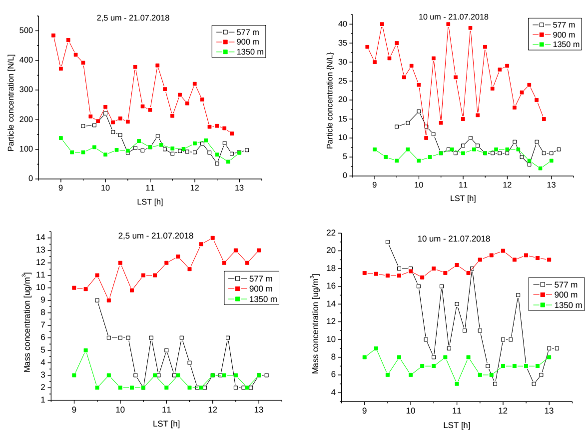
Intruduction

The purpose of the experimental measurements conducted in July 2015 and July 2018 was to study the vertical profile of aerosol particles along the mountain slope in relation to the development of the mixing layer.

Methodology and Results

The Ceilometer-lidar (light source - Nd: YAG laser with center wavelength at 1064 nm; measuring range 30-15 000 m; resolution 15 m; measurement time 60 s; pulse duration about 1 ns; 5–7 kHz pulse repetition rate; impulse energy 8 μJ) observations were taken continuously during the campaigns at AO. The particle number counters used are: 2 six-channel PC200 (*TROTEC, Germany*) with channels for particle size of 0.3, 0.5, 1, 2.5, 5 and 10 μm, located in AO and at 1350 m a.s.l. on Vitosha and one six-channel HHPC-6 (*MetOne, USA*) with particle size channels of 0.3, 0.5, 0.7, 1, 2 and 5 μm, set at 900 m on Vitosha. The sampling rate of was 2.83 l/min. Two two-channel BQ20 (*TROTEC, Germany*) with particle size channels at 2.5 and 10 μm for measuring the number of particles and their mass were placed at the AO and at 1350 m a.s.l. The sampling rate was 0.9 l/min. The accuracy of the devices is in the range of 15-20%. Meteorological data were obtained from an automatic weather station located at AO and from other sources.

According ceilometer observations, on both days ABL height reached maximum of about 1650 m between 12-13 LST, the residual layer (RL) was fully destroyed from the rising ML at about 10 LST and the SBL was of 500-600 m height in the morning hours. The results obtained confirmed that during the ML development and, respectively, the increase of its height, the aerosol particle number concentrations for sizes 0.3 and 0.5μm decrease. Near the sunset when the aerosol particle concentrations increase and MLH decreases two layers are formed – SBL at ground level and RL over it trapping mainly fine mode aerosol particles. Considering the temporal and spatial changes of aerosols at the different sites of observations WRF-GDAS model (ARL - NOAA) was used for determination of the atmospheric boundary layer (ABL) heights for the studied days and for comparison with obtained ceilometer data.



Variations of the particle number concentrations

Conclusions

Particle number concentrations decreased with the growth of ABL, the afternoon concentrations being 4 times lower than in the morning. This behavior is more clearly seen in the fine fraction of aerosols. The highest aerosol concentrations and mass concentrations were measured at altitude of 900 m a.s. due to the presence of elevated temperature inversion. The comparison of simulated observations of atmospheric boundary layer data and Ceilometer-lidar data on 07 July 2015 and 21 July 2018 are in good agreement within 10 - 15%.

Acknowledgement

This work has been carried out in the framework of the National Science Program "Environmental Protection and Reduction of Risks of Adverse Events and Natural Disasters", approved by the Resolution of the Council of Ministers № 577/17.08.2018 and supported by the Ministry of Education and Science (MES) of Bulgaria (Agreement № D01-230/06.12.2018). The study was partly supported by the National Science Fund of Bulgaria project DN04/4. We acknowledge NOAA-ARL for the use of WRF-GDAS model.

COST ACTION CA18235 "PROFILING THE ATMOSPHERIC BOUNDARY LAYER AT EUROPEAN SCALE" (PROBE)

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Summary
COST Action CA18235 (PROBE) is launched to improve the operational availability of ground-based sensor data on atmospheric boundary layer (ABL) and therefore, to overcome the identified observational gap between dense network of surface-based meteorological sensors and upper atmosphere measurements from satellites. The Action contributes to the improvement of air quality by improving the direct sensing of pollutants in the ABL, understanding and operative monitoring of physical properties of ABL to enhance the quality of chemical transport modelling.

Main facts
Start of Action - 29/10/2019.
End of Action - 28/10/2023.
COST countries involved: Albania, Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Poland, Portugal, Romania, Serbia, Slovakia, Slovenia, Spain, Switzerland, Turkey, United Kingdom.
Chair of the Action: Domenico Cimini.
COST Science Officer: Estelle Emeriau.

Challenge
Atmospheric boundary layer (ABL) represents an observational gap between dense network of surface-based meteorological sensors and upper atmosphere measurements from satellites. Compared to these well-standardised measurements, the ABL profiling is not properly coordinated and lacking international standards. Measurements are divided between different institutions, which reduces the effectiveness of use of existing extensive datasets. The aim of this Action is to overcome the observational gap, promoting inter-institutional knowledge exchange, enhancing pan-European research coordination and tailoring the measurement networks for clearly identified applications. Vertical profiles of aerosol and cloud characteristics, wind, turbulence, air temperature and humidity are the variables in focus. Automatic lidar ceilometer, cloud radar, Doppler wind lidar, microwave radiometer and radar wind profiler, among others, are the techniques to quantify those variables, keeping in mind the complex urban boundary layer in first order.

Work groups
From Action MOU (COST, 2019), Fig. 1:
- WG1: Knowledge exchange. Coordinating the exchange of ABL profiling knowledge between different groups of stakeholders.
- WG2: Advanced ABL profiling. Coordinating the development of new and improved ABL products from the synergy of ABL profiling instruments.
- WG3: Tailored measurement networks. Improving the capabilities of ABL profiling networks (harmonized data formats, processing methods, optimal measurement strategies).
- WG4: Operation and data quality. Improved instrument operations, standardized methods for transforming instrument output into physical ABL properties

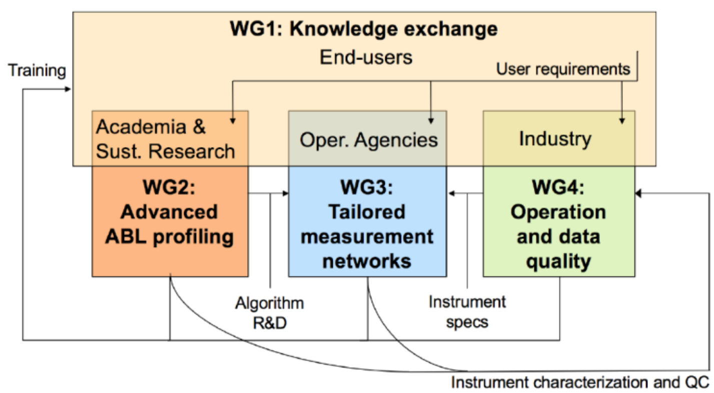

Fig.1 Structure of work groups in PROBE (COST, 2019)

Stakeholders and relevance to ambient air quality
At first meeting of WG1 following stakeholders were identified: urban municipalities, air quality authorities, community of chemical transport modelling, weather services, wind and solar energy producers, insurance companies, aviation, climate modelling etc. The Action contributes to the improvement of air quality two ways: (1) direct sensing of pollutants in the ABL and (2) understanding and operative monitoring of physical properties of ABL to enhance the quality of chemical transport modelling.

Acknowledgement
This is presentation is a dissemination paper of and funded by COST Action CA18235 (PROBE).

Reference
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URBAN HEAT ISLAND CIRCULATION ANALYSIS INTEGRATING MODEL SIMULATION AND MICROMETEOROLOGICAL OBSERVATIONS

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Summary
The availability of a micrometeorological observations network monitoring urban, suburban and rural background locations in Rome allowed to verify WRF model capability to reconstruct meteorological and atmospheric turbulence conditions variability. Model simulations compared satisfactorily with measurements at both rural and sub-urban locations. The use of BEP (Building Effect Parameterization; Martilli et al., 2002) urban canopy model was able to remove the wind speed overestimation at the urban location, and to improve u_* and TKE estimation, while minor effects were observed on computed temperature and humidity. Model results allowed to identify the area affected by Rome heat island and buildings drag effect. Scenario simulations have been used to separate the urban heat island effect from the natural temperature and humidity variability in Mediterranean areas affected by frequent sea breeze circulations.

Introduction
The importance to quantify the urban heat island and wind speed reduction caused by anthropogenic heat release, heat storage and increased drag, characterising the urban texture, is growing due to the increasing frequency of heat waves and the difficulties faced by air pollution mitigation policies to achieve a healthier urban air quality. Mediterranean conurbations are exposed to the increasing occurrence of uncomfortable hot temperature conditions, whose health effects are often worsened by concomitant high ozone concentrations, while stagnation conditions causing high PM and NO_2 concentrations, are not sufficiently mitigated by milder winter temperature. The investigation performed by Ciardini et al. (2019) has been compared and complemented with WRF model simulations to improve the territory characterization and enable scenario analyses.

Methodology and Results
The land cover description required by WRF urban parameterizations has been built processing CORINE land cover 2012 and digital buildings data available for Rome and the other major Italian cities. The impact of BEP urban parameterization has been analysed comparing their results with reference WRF simulations and local observations during summer and winter periods representative of frequent circulation conditions of major interest for air quality applications. BEP proved to largely improve results for wind speed (Fig.1), u* and TKE (Fig.2) at urban location without degradation of results at the other monitored locations. WRF simulations with BEP have been then extended to the three full years 2013-2015 confirming satisfactory results (statistical indicators for year 2015: temperature BIAS=0.65C, RMSE=2.2C, Corr.=0.96; relative humidity BIAS=-3.3%; RMSE=12.3%; Corr.=0.78; wind speed BIAS=0.03m/s, RMSE= 0.8m/s; Corr.=0.62). The results obtained fostered the use of model simulations to analyse the urban heat island features to extend the findings of Ciardini al. (2019) to the whole region potentially involved. Scenario simulations have been used to separate urban canopy forcing effects from the meteorological variability induced by topography and sea breeze circulation.

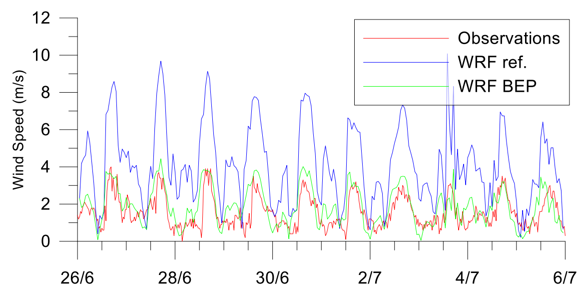

Fig.1 Wind speed comparison at Rome urban station (summer).

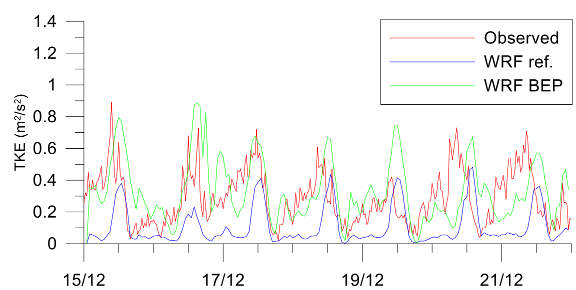

Fig.2 TKE comparison at Rome urban station (winter).

Conclusions
WRF reconstructed satisfactorily temperature and humidity at urban/suburban locations with standard urban canopy treatment while the large wind speed overestimation has been removed by BEP parameterization improving friction velocity and turbulent kinetic energy estimation. Model simulations allowed to extend the heat island investigations based on experimental observations analysis to the whole region, identifying the area impacted by the urban canopy forcing effects.

Acknowledgement
This work was supported by INAIL Bando Ricerche in Collaborazione (BRiC) ID 04/2016.

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INTERCOMPARISION OF PLANETERY BOUNDARY LAYER SCHEMES: IMPLICATIONS FOR THE MODELLING OF LONG-RANGE PATHOGEN DISPERSION

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Summary
A hybrid dynamical modelling framework (EAD-LS) has been used to investigate the role of planetary boundary layer (PBL) parameterizations in long-range pathogen dispersion over Europe. Simulations for 31 years (1985-2015) with 10 ensemble members were conducted for this purpose. The results indicate that the UW parameterization scheme significantly reduces the biases in temperature, precipitation and wind fields compared to the well-established Holtslag PBL scheme. This improvement in the UW scheme is mainly due better representation of eddy heat diffusivity and water vapour tendency. Furthermore this hybrid dynamical modelling framework has been applied to a real case (Nicolaisen et al. 2017) to study the role of PBL and its implications in airborne plant pathogen outbreak over Northwestern Europe. Overall, the results suggest that the selection of the PBL scheme and the chosen vertical structure in modelling framework plays an important role in simulations of long-range pathogen dispersion.

Introduction
It's well known that the PBL acts as a sort of interactive buffer zone between the underlying surface and the free atmosphere, and therefore an understanding of PBL and its role in the release and transport of airborne pathogens are of concern. Meteorological aspects of observed and model simulated PBL do not receive much attention in scientific literature, even though four of the most often analyzed variables in release and transport of pathogens (humidity, temperature, precipitation and wind intensity at the surface), are controlled by the PBL processes. Considering this, an attempt has been made to examine the role and choice of PBL schemes to explain long-range pathogen dispersion over Europe.

Methodology and Results
In this study the initial and lateral boundary conditions from the European Centre for Medium-Range Weather Forecasts (ECMWF) ERA-Interim have been used to drive the Regional Climate Model (RCM). The model domain covers the whole of the Europe (Fig.1) region with a horizontal resolution of 20 km and 36 vertical levels. Simulations were conducted for 31 years (1985-2015) (with 10 ensemble members). The model-simulated results are validated with the ERA-5 reanalysis data. The results indicate that the UW PBL scheme significantly reduces the biases in temperature, precipitation and wind fields compared to the Holtslag scheme as vertical profiles of eddy heat diffusivity and water vapour tendency. Furthermore Fig. 2 shows the implications of the PBL in airborne plant pathogen outbreaks over three locations in Northwestern Europe (NE). It is clear from the diagram that the south easterly wind from south-east of Europe and the RH at 850hPa have played an important role by providing favourable conditions for release and migration of plant pathogens over three locations in NE.

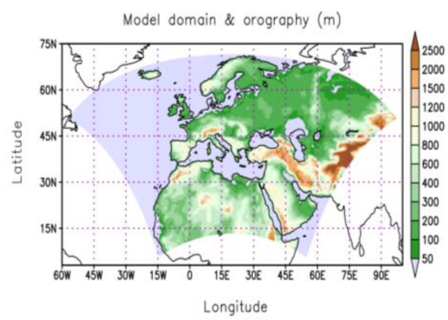

Fig.1 Model domain and topography (m)

Conclusions
This study shows how better representation of PBL schemes can improve simulations of long-range pathogen dispersion over Europe. Results of this study have major implications for the crop protection and food security of the region.

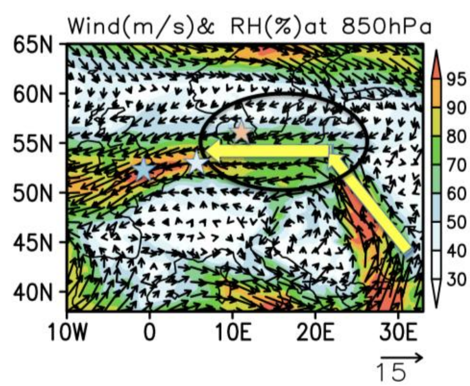

Figure. 2 Wind (m/s) and RH (%) at 850hPa

Acknowledgement
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AEROSOL-CLOUD INTERACTION IN 1985 AND TODAY

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Summary

Aerosol concentrations over Germany in 1985 and 2013 were simulated using an aerosol-chemistry transport model. The aerosol fields from the two simulations were used in a high-resolution meteorological model for a sensitivity study on cloud properties. The modelled aerosol and cloud variables were compared to a variety of available observations, including satellites, remote sensing and in-situ observations. Finally, the radiative forcing of the aerosol could be estimated from the different sensitivity simulations.

Introduction

Due to reduction of emissions the ambient aerosol mass and number in Europe was strongly decreased since the 1980s. Hence, today's number of particles in the CCN size range is smaller. The $HD(CP)^2$ (High Definition Clouds and Precipitation for Climate Prediction) project amongst others aimed at analysing the effect of the emission reduction on cloud properties.

Methodology and results

As a pre-requisite, the aerosol mass, number, and composition over Germany were simulated for 1985 and 2013 using the regional chemistry-transport-model COSMO-MUSCAT (Wolke et al., 2012). In order to estimate the emissions of the year 1985 scaling factors were introduced, which were derived from the mean concentration reduction of PM, SO_2, and soot.

The model results were compared to observations from the two $HD(CP)^2$ campaigns that took place in 2013 (HOPE, HOPE-Melpitz) as well as the AVHRR (Zhao et al., 2017) aerosol optical thickness product, which is available from 1981 onwards. Despite the fact, that emissions of the 1980s are very uncertain, the modelled AOD is in good agreement with observations. The modelled mean CCN number concentration in 1985 is a factor of 2-4 higher than in 2013.

Within $HD(CP)^2$, the ICON weather forecast model (Zängl et al., 2015) was applied in a configuration allowing for large-eddy simulations. In these simulations, the time-varying CCN fields for the year 1985 and 2013 calculated with COSMO-MUSCAT were used as input for ICON-LEM. In the present-day simulation, the cloud droplet number is in agreement with observations, whereas the perturbed (1985) simulation is not with droplet numbers twice as high as in 2013. Also for other cloud variables systematic changes between the two scenarios were observed. The effective radiative forcing due to aerosol-cloud interactions could be determined for the region and simulation period to -2.6 W m^{-2}.

Acknowledgement

This work is funded by the German Federal Ministry of Education and Research (BMBF) within the framework programme "Research for Sustain5 able Development (FONA)", www.fona.de, through the research programme "$HD(CP)^2$ - High Definition Clouds and Precipitation for Climate Prediction", under the numbers FKZ 01LK1209C, 01LK1212C, 01LK1501E, 01LK1502I, 01LK1503A, 01LK1503E, 01LK1503F, 01LK1503G, 01LK1503H, 01LK1504A and 01LK1507A. The authors gratefully acknowledge the computing time granted at Forschungszentrum Jülich.

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Short Presentations

ISOMASS AND PROBABILITY MAPS OF ASH FALLOUT DUE TO VULCANIAN ERUPTIONS AT THE TUNGURAHUA VOLCANO

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Summary
We analyzed the historical forecasted ash fallout quantities of four years, due to Vulcanian eruptions at the Tungurahua volcano (Ecuador). The proximal region at the west side of the volcano (about 100 km to the left of the crater) shown the highest probability (>0.7) to be affected by ash fallout (0.01-1.2 kg/m2).

Introduction
Since April of 2015, we are daily forecasting the ash dispersion and ash fallout due to Vulcanian eruptions at the Tungurahua (Fig. 1), one of the most active volcanoes in Ecuador. For this purpose, we are using the meteorological Weather Research & Forecasting (WRF) and the FALL3D models. The last uses the outputs from WRF to simulate the dispersion of volcanic ash. Previously and based on field data and numerical studies, the corresponding eruption source parameters (ESP) were proposed (Parra et al., 2016). These ESP correspond to the eruption of 14-Jul-2013, which is considered representative for actual Vulcanian eruptions at the Tungurahua volcano. Parra (2018) describes in more detail the approach and the components of the forecasting system. The study of the historical forecasting data allows the production of useful information, as the distribution of mass per unit area (isomass) and probability maps of ash fallout.

Method and Results
We analyzed the forecasted results of the ash fallout quantities of four years (April of 2015 to March of 2019) to obtain the average isomass (average value for each cell of the modeling domain, 199x199 cells, 4km of spatial resolution) and probability (in each cell, number of days with ash fallout larger than 0.0001 kg/m2, divided by the total number of forecasted days) maps, considering periods of three months: February-March-April (FMA), May-June-July (MJJ), August-September-October (ASO), and November-December-January (NDJ)(Fig. 2).

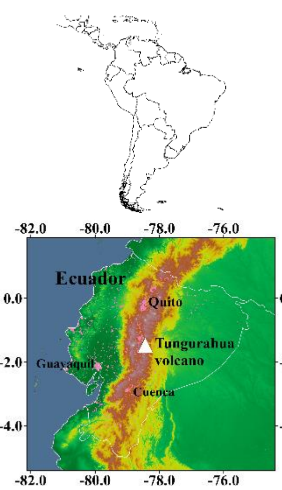

Fig.1 Location of the Tungurahua volcano

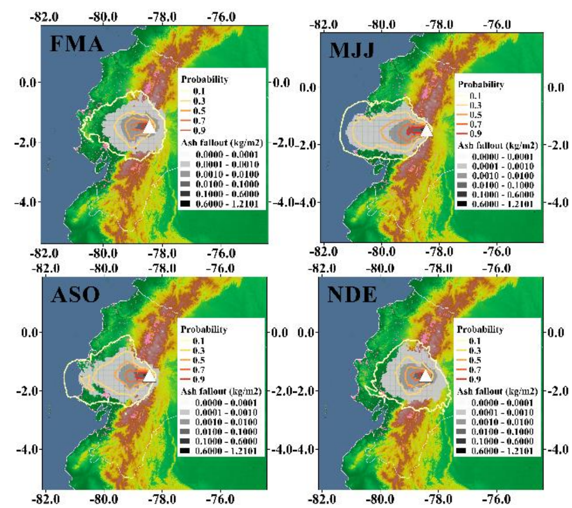

Fig.2 Isomass (shaded, kg/m2) and probability (contours) maps of ash fallout due to Vulcanian eruptions at Tungurahua volcano

Conclusions
The proximal region at the west of the volcano (about 100 km to the left) shown the highest probability (>0.7) to be affected by ash fallout (0.01-1.2 kg/m2). The distant region at the west (100 km up the coast border) presented low-medium probabilities (0.1-0.7) and ash fallout quantities (0.0001-0.01 kg/m2). Most of the Northern, Southern, and Eastern regions of the country shown very low probability (<0.1) to be affected by negligible amounts (<0.0001 kg/m2) of ash fallout.

Acknowledgement
This research is part of the project "Emisiones atmosféricas y Calidad del Aire en el Ecuador 2019–2020". Simulations were done at the High-Performance Computing system at the Universidad San Francisco de Quito.

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VALIDATION AND EXPLOITATION OF AN AIR QUALITY FORECAST SYSTEM OVER THE KINGDOM OF MOROCCO

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Summary

In the context of the PCMA (Pôle de Compétences des Milieux Atmosphériques) project, a forecasting air quality platform has been deployed over the Kingdom of Morocco with a zoom in the urban area including Rabat and Casablanca, the most populated region. After the phases of configuration and validation, the chain is now operational and allow forecasting critical air pollution events . Meanwhile, an air quality station was implemented at ENSMR including PM, NO/NO2, O3 measurements.

Introduction

Atmospheric pollution remains a global issue that has significant impacts on population's health and economic developments. Morocco, which hold COP22, commits in a proactive policy toward climate change and pollution. In the context of the PCMA project, a collaboration between Institut Mines Télécom Lille-Douai and Ecole Nationale Supérieur des Mines de Rabat, a modeling and forecasting air quality system has been implemented over Morocco and at finer scale over the cities of Casablanca and Rabat.

Methodology and Results

The computational chain allows to assess the air quality in a predictive mode based on the implementation of two models : the Weather and Research Forecasting (WRF, http://www.wrf-model.org) and CHIMERE (http://euler.lmd.polytechnique.fr/chimere/).

- WRF is a mesoscale meteorological model that provides the forecasting of meteorological parameters over three embedded domains from North Africa (45 km resolution) to the cities of Rabat and Casablanca (5 km resolution). WRF uses GFS forecast as input
- CHIMERE is a multi-scale chemistry transport model that resolves chemical reactions and is designed to produce daily forecast of primary and secondary pollutants forced by the WRF model. HTAP2 emission inventory (0.1 degree resolution) is used.

A validation of the WRF/CHIMERE chain models has been performed and preliminary results show quite good performance of the models to reproduce the concentration patterns of O3 and PM10 pollutants. The model correctly reproduces the desert dust raising and transport from Sahara.

Figure 5 : Operational air quality forecast system

The modeling chain is operational and provides national air quality forecast with a zoom at finer scale over the local area including the cities of Rabat, Casablanca and El Jadida. The platform allows to understand the contributions of different sources (anthropogenic versus biogenic such as desert dust, national versus transboundary transport) for each primary and secondary pollutants , as well as the meteorological situations that lead to critical episodes.

Conclusions

In conclusions, the air quality modeling system deployed over the Kingdom of Morocco provides forecast of pollution at D+1 and D+2 horizons. The platform can be used to test and ameliorate the emission reduction policies. The capability to evaluate and quantify effects of reduction and mitigation emission scenarios is highly efficient to improve emission control policy and thus air pollution levels. Next step should be to improve the emission inventory for the finest resolution (at least). The platform should also be used to deal with scenarios to help policy makers.

Acknowledgement

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IMPACT OF WOOD COMBUSTION ON AMBIENT AIR QUALITY IN A RESIDENTIAL AREA – COMPARISON OF DIFFERENT PARTICLE METRICS

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Summary

The aim of this work is to evaluate the suitability of black carbon (BC), lung-deposited surface area (LDSA and particle number (PN) concentration for the long-term monitoring of residential wood combustion (RWC) aerosols in detached housing areas. During a 4-month campaign (Jan-Apr 2019) in a detached housing area in Helsinki, the concentrations of BC, LDSA and PN were measured and compared with fine particle mass ($PM_{2.5}$), RWC emission tracers (e.g. levoglucosan), particle size distributions, and gaseous components (NO_x, CO_2). Furthermore, the diurnal concentration patterns from the small housing area site were compared to those from traffic and background sites. The correlations between daily BC concentrations and levoglucosan were very high (R^2=0.89) in the small housing area, indicating that BC is a good parameter for the monitoring of RWC particles in small housing areas. In contrast, PN is a very weak parameter for RWC emission monitoring, since the correlation between levoglucosan and PN was very low (R^2=0.44). LDSA is also a suitable parameter for RWC monitoring, but particles from traffic exhausts are smaller in size than those from RWC, which emphasise traffic emissions in LDSA results.

Introduction

$PM_{2.5}$ concentration is currently one of the key parameters in regulated urban air quality monitoring networks. However, $PM_{2.5}$ do not provide information on the sources and properties of particles. For instance, particles from combustion processes might be especially detrimental to health due to their very small size and toxic chemical components. There are at least three unregulated particulate parameters that have high potential to complement long-term monitoring of combustion particles: BC, LDSA and PN. The aim of the present work is 1) to evaluate the suitability of these three different parameters for air quality monitoring of wood combustion emissions in small housing areas, and 2) to demonstrate the size distributions and compositions of particles from different sources to obtain a better understanding of the BC, LDSA and PN results.

Methodology and Results

We conducted a 4-month (Jan-Apr 2019) measurement campaign in a detached housing area (Pirkkola) in Helsinki, Finland. The following parameters were measured with online instruments: BC (Aethalometer AE33, Magee Scientific), LDSA (10-400 nm size range; AQ Urban, Pegasor), PN (>5 nm; CPC A20, Airmodus), $PM_{2.5}$ (Grimm 180), chemical compositions and size distributions of PM_1 particles (SP-AMS, Aerodyne Research Inc.), as well as gaseous components (NO_x and CO_2). Daily PM_{10} samples were collected for levoglucosan (Levo) and benzo(a)pyrene (BaP) analyses, since they both are good tracers for RWC emissions in Finland. Furthermore, data from other measurement stations (traffic, urban background and rural background) were utilized for comparisons.

Table 1. Correlations (R^2>0.7 bold) of daily concentrations in a detached housing area in Jan-Apr 2019.

	Levo	BaP	$PM_{2.5}$	BC	LDSA	PN	NO_x
BaP	**0.85**	1.00					
$PM_{2.5}$	0.58	0.33	1.00				
BC	**0.89**	**0.80**	0.66	1.00			
LDSA	**0.73**	0.53	**0.79**	**0.84**	1.00		
PN	0.44	0.46	0.28	0.58	**0.73**	1.00	
NO_x	0.62	0.53	0.54	**0.80**	**0.81**	**0.76**	1.00
CO_2	0.36	0.27	0.52	0.49	0.68	0.65	0.65

The correlations of daily BC concentrations with Levo (R^2=0.89; Table 1) and BaP (R^2=0.80) were very high, indicating that BC is a good complementary parameter for the monitoring of RWC particles in small housing areas. In contrast, PN is a very weak parameter for RWC monitoring, since the correlation between Levo and PN was very low (R^2=0.44). The correlation results of LDSA seem to indicate three main sources for LDSA concentrations: wood combustion (R^2=0.73 for Levo), traffic exhaust (R^2=0.81 for NO_x), as well as regionally and long-range transported particles (R^2=0.79 for $PM_{2.5}$). The diurnal variations of particulate and gaseous components were compared in the different measurement sites (BC and LDSA demonstrated in Fig. 1). In the evenings (18:00-24:00), the emissions from wood combustion caused high concentrations of BC, $PM_{2.5}$ and LDSA in the small housing area. However, the highest PN, LDSA and BC concentrations were measured in the traffic site during rush hours. Based on the chemical size distribution measurements, fresh particle mass from traffic exhausts is mainly in the 50-300 nm size range (vacuum diameter, SP-AMS), while the fresh emissions from RWC also contain larger particles (~50-1000 nm). The size distribution results indicate that LDSA measurements in the 10-400 nm size range (AQ Urban, Pegasor) might underestimate the total LDSA area of $PM_{2.5}$ particles from RWC.

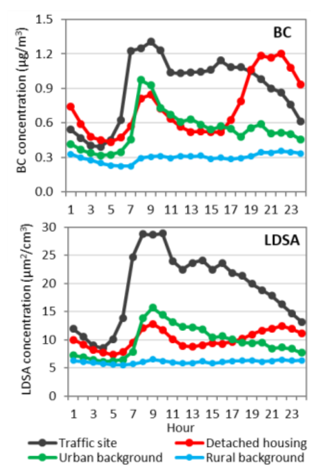

Fig. 1 Hourly variations of BC and LDSA concentrations at different sites in Jan-Apr 2019.

Conclusions

Our results indicate that BC and LDSA are both useful parameters to complement $PM_{2.5}$ and BaP monitoring in small housing areas with RWC emissions.

Acknowledgement

This work was supported by the European Regional Development Fund in the Urban Innovative Action HOPE project (UIA03-240), and by Business Finland, HSY, Valmet Technologies, Vaisala, Tampere City, Pegasor, Dekati, AX-Consulting, AGCO Power, Airmodus, and SSAB Europe in the project Black Carbon Footprint.

ATMOSPHERIC BOUNDARY LAYER HEIGHT AND OPTICAL CHARACTERISTICS OF THE AEROSOLS OVER SOFIA DURING WARM SEASONS OF 2018 AND 2019

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Summary

Results from a complex investigation of the aerosol structure and atmospheric boundary-layer (ABL) height in Sofia are presented. The ABL height is determined from high temporal and spatial resolution ceilometer data. Several days from spring - autumn experiments in 2018 and 2019 were used to illustrate the relation between the profiles of meteorological parameters, aerosol structure and the ABL height. The purpose of the work is to compare the ABL height from observations and modelling. Ceilometer and Laser Particle Counter (LPC) data are analysed to determine the daytime structure and formation of aerosol layer over Sofia. HYSPLIT back trajectory model was applied and WRF-GDAS was used to obtain a modelled ABL height. The difference between modeled and observed ABL height was found to be less than 20-25%. The BSC-DREAM dust model was used as additional source of information for selected days.

Intruduction

The height of convective ABL determines the volume in which different gaseous and aerosol pollutants are mixed due to turbulent processes within a time scale of one hour. The combination of ceilometer and particle counter measurements provides comprehensive information on both the aerosols concentrations in the entire atmosphere as well as about the vertical structure of aerosol optical properties. This investigation presents results from complex experiments on ABL formation in Sofia and atmospheric aerosol optical and microphysical characteristics by means of remote sensing devices as well as in situ measurements.

Methodology and Results

The ***ceilometer-lidar*** *(Jenoptik CHM 15k)* with specifications: light source - a microchip Nd:YAG laser with wavelength of 1064 nm; measuring range 30-15000 m; vertical resolution 15 m; measuring time 60 s; pulse duration of 1 ns; pulse repetition rate 5-7 kHz; energy per pulse 8 μJ and ***Laser particle counter*** - a portable LPC BQ20 *(TROTEC, Germany)* with particle size channels at 2.5 μm and 10 μm for particle number and mass concentration measurements were used. The observed ABL height varied from 200 m to 3000 m for the presented experimental days (*seilometer data on Fig. 2*). During the campaigns, the particle concentrations (PM) at wavelength λ =2.5 μm ranged from 1 to 20 $\mu g/m^3$, and at λ = 10 μm - from 5 to $50 \mu g/m^3$.

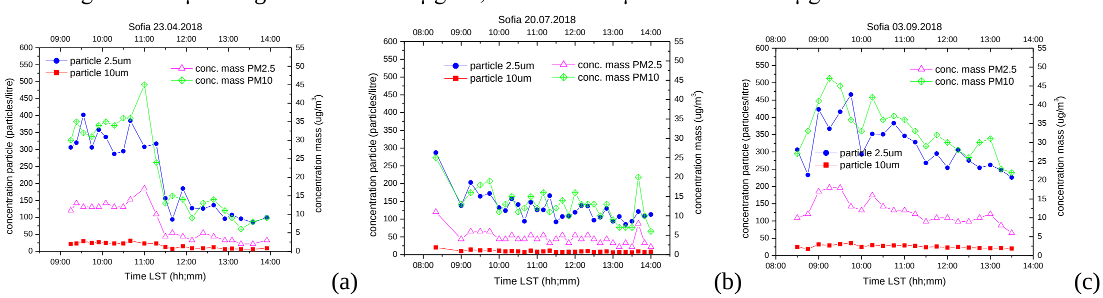

Fig. 1. The laser particle counter (LPC) data obtained on 23.04.2018 (a), 20.07.2018(b) and 03.09.2018 (c).

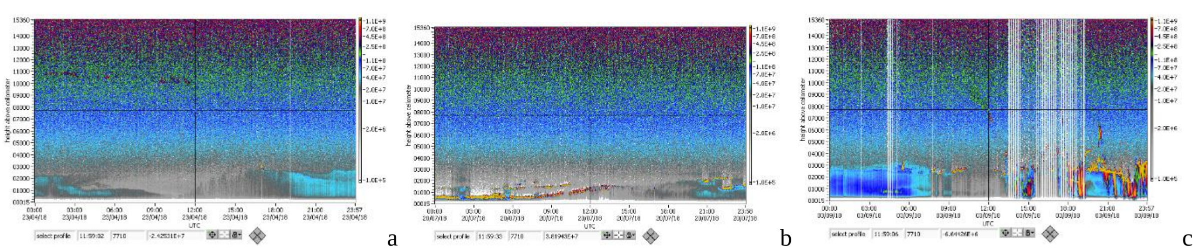

Fig. 2. Ceilometer data obtained on 23.04.2018 (a), 20.07.2018(b) and 03.09.2018 (c).

Conclusions

The presented study examine the relation between the ABL development and the daily behavior of particle number concentrations in different size-ranges in case of clear sky days and with Saharan dust intrusion over Sofia, Bulgaria. With the growth of ABL height, the concentration of aerosol particles decreased and when the ABL height was maximal, the concentration was minimal.

Acknowledgement

This work has been carried out in the framework of the National Science Program "Environmental Protection and Reduction of Risks of Adverse Events and Natural Disasters", approved by the Resolution of the Council of Ministers № 577/17.08.2018 and supported by the (MES) of Bulgaria *(Agreement № D01-230/06.12.2018)*. The authors acknowledge the NOAA ARL for the HYSPLIT model simulations, WRF-GDAS Model and READY website used in this publication. The authors express their gratitude to the BSC for the BSC Dust model and aerosol dust data used in this publication.

Development, Application and Evaluation of Air Quality Related Models for Local to Global Scales

HIGH-RESOLUTION ASSESSMENT OF URBAN AIR QUALITY WITH A 3D TURBULENCE-RESOLVING MODEL (PALM)

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Summary. Urban air quality is one of the most prominent environmental concerns for a modern city dweller. Accurate monitoring of air quality is difficult due to intrinsic urban landscape heterogeneity and superposition of multiple polluting sources. Existing approaches often do not provide the necessary spatial details and peak concentrations of pollutants, especially at larger distances from measuring stations. A more advanced approach is needed. This study presents a very high-resolution air quality assessment with the large-eddy simulation model PALM. This fully three-dimensional primitive-equation hydro-dynamical model resolves both structural details of the complex urban surface and turbulent eddies larger than 10 m in size. We ran a set of 9 meteorological scenarios in order to assess the dispersion of pollutants in Bergen, a middle-sized Norwegian city embedded in a coastal valley. This set of scenarios represents typically observed conditions with high air pollution from nitrogen dioxide (NO_2) and particulate matter ($PM_{2.5}$). The modelling methodology helped to identify pathways and patterns of air pollution caused by the three main local air pollution sources in the city. These are road vehicle traffic, domestic house heating with wood-burning fireplaces and ships docked in the harbour area next to the city centre. The study produced vulnerability maps, highlighting the most impacted districts for each scenario.

Introduction. Local air quality is frequently assessed with simplified statistical models, such as a family of Gaussian models, e.g. CALINE, or with more sophisticated models, which include parametrized turbulent diffusion, such as e.g. AIRMOD. Statistical models are however poor in predicting a horizontal pollution transport in turbulent atmospheric boundary layers (ABLs) as they do not account for turbulent eddies, meandering flows and flow-surface structure interactions. Recent advances in computational fluid dynamics and growing performance of parallel computers open an opportunity to further extent the model-based urban air quality assessment. Turbulence-resolving, or at least turbulence-permitting, large-eddy simulation models have been already used in several cities to investigate turbulent flows and atmospheric pollution. The western coast of Norway is known for its picturesque mountain landscapes with see inlets (fjords) penetrating deep into coastal valleys. Similar, if not as dramatic, settings with coastal valleys opening into sea inlets and bays are frequently accommodating harbour cities in other parts of the globe as well.

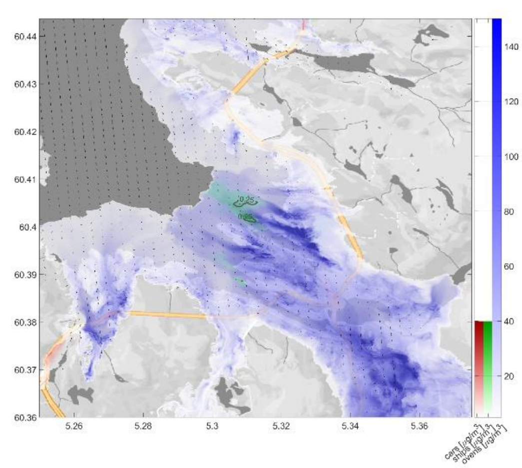

Figure. The simulated $PM_{2.5}$ emissions from the road traffic (red shading), ships in the harbour (green shading) and wood-burning fireplaces (blue shading). Due to the dominating impact of the emissions from wood-burning fireplaces, the red and green colours are only visible at their emission hot spots in the harbour and at the major roads in the south-eastern part of the domain. The concentrations were sampled at 5 m above the surface. The wind vectors characterize the flow 55 m above the surface. The sampled data were averaged over the last 15 min of the 6 h dispersion run.

Results. This study makes the next step on the bridge between idealized feasibility studies and applied air quality assessments. It utilizes the Large-Eddy Simulation (LES) Model PALM (Maronga et al., 2015) to investigate the dispersion of pollutants in a weakly turbulent ABL under archetypical, but frequently observed, weather conditions, which lead to dangerous deterioration of the air quality, in our case in Bergen. Bergen is embedded in a relatively deep and narrow coastal valley. The minimum distance between the mountains is approximately 1 km when measured across the valley floor; it is approximately 4 km when measured between the mountain peaks. The polluted air during cold winter days tends to accumulate and stagnate in the valley, whereas local circulations redistribute the pollutions across the central city districts. Thus, the local circulations are likely to determine air quality and health risks for the districts' populations. The effect of the local circulations could be accounted for in the PALM simulations (Wolf-Grosse et al., 2017), but not in statistical models relying on coarse-resolution (~ 1 km) mesoscale models. Dispersion of nitrogen dioxide (NO_2) and particulate matter ($PM_{2.5}$) is modelled over the densely populated central Bergen under weak winds and typical scenarios of severe air pollution. Results from this study have already been adopted by the Bergen Harbour Authority to assist their routine assessment of the impact of ship exhaust from the harbour. There are three major sources of the $PM_{2.5}$ emission in Bergen, namely: the ships; the road traffic; and the wood-burning fireplaces. Figure shows that the last source (fireplaces) absolutely dominates, even after its rescaling to provide more reasonable concentrations. The emissions per ship are approximately 34 times of that from a single wood-burning fireplace after applying the scaling factor of 0.1. However, the fireplaces are located at lower heights and cluster in the most populated area. The ships emit the $PM_{2.5}$ in the harbour area where the pollution is effectively transported offshore and diluted. The $PM_{2.5}$ concentrations from the road traffic are overall low.

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THE INFLUENCE OF RESIDENTIAL WOOD COMBUSTION ON THE CONCENTRATIONS OF PM2.5 IN FOUR NORDIC CITIES

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Summary

This study aims to analyse and inter-compare the methodologies of evaluating the emissions, the concentrations and the dispersion on regional and urban scales of $PM_{2.5}$ originated from residential wood combustion (RWC) in four Nordic cities: the metropolitan areas of Copenhagen, Oslo and Helsinki, and Umeå The numerical predictions were also evaluated against measured urban scale data regarding $PM_{2.5}$ concentrations. The accuracy of the predicted concentrations was evaluated based on urban concentration measurements. This work presents for the first time a systematic assessment of the influences of RWC on air quality in several Nordic cities. Results indicated that Copenhagen and Oslo documented the highest predicted emissions of $PM_{2.5}$ originated from residential wood combustion. Stricter and more efficient emission regulations should be set in the Nordic countries with respect to RWC, especially in urban areas, for the protection of human health.

Introduction

Wood combustion or other kinds of biomass for residential heating is a significant source of atmospheric pollution. Wood combustion emissions are commonly known less accurately than those from most other source categories. Biomass combustion has been found to contribute significantly to particulate matter emissions in numerous countries worldwide.

Methodology and Results

The assessment of $PM_{2.5}$ emissions originated from residential wood combustion (RWC) was based on: 1) surveys regarding the amounts and use of wood stoves, boilers and other relevant appliances, 2) national or literature-based emission factors, 3) the assessments of the spatial distribution of the emissions, and 4) various national or local register data. The model evaluation against experimental data showed that overall, the fractional bias values and the agreement of the daily modelled and measured time series of the $PM_{2.5}$ concentrations were good or fairly good. Results showed that the highest emissions from RWC were mostly located outside the city centres for Helsinki and Copenhagen. Moreover, both the measured and predicted concentration values were the highest for Copenhagen compared with the other three cities. The annual average fractions of RWC contributions to the concentrations of $PM_{2.5}$ ranged spatially from 0 to 15 %, from 0 to 20 %, from 8 to 30 % and from 0 to 60 % in Helsinki, Copenhagen, Umeå and Oslo, respectively (Figure 1). The contributions of RWC in Oslo were clearly the highest compared with the other three target cities.

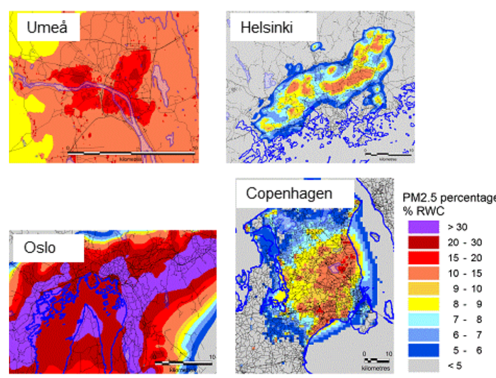

Fig 1. The source contributions of residential wood combustion to the concentrations of $PM_{2.5}$

Conclusions

Whereas attempts have been made to regulate RWC in the Nordic countries and elsewhere, there are grounds for increased policy and technical measures, to avoid and alleviate harmful impacts of RWC, including especially those on human health. The range of measures could include regulatory ones, information campaigns and economic steering, and their combinations.

Acknowledgement

This study has been part of the project "Understanding the link between Air pollution and Distribution of related Health Impacts and Welfare in the Nordic countries", project #75007 (NordicWelfAir), funded by Nordforsk. This study was also part of the Swedish Clean Air and Climate research programme (SCAC) by the Swedish Environmental Protection Agency.

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A PRESENTATION OF THE EPISODE URBAN SCALE AIR QUALITY MODEL AND ITS APPLICATION TO NORDIC WINTER CONDITIONS

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Summary
To meet the needs of air quality monitoring and assessment, we have developed the urban scale air quality model EPISODE. EPISODE using a combination of a Eulerian grid model and sub-grid dispersion processes, it is capable of representing both pollution at the urban background scale and at fine scales below 100 meters. We demonstrate the model's capabilities by simulating NO_2 concentrations for one year in six Norwegian cities and then evaluate its performance using in-situ observations. The model is able to adequately represent NO_2 pollution on an annual basis, and capture significant individual pollution episodes. The model shows improved performance during autumn and winter seasons compared to summer, with the two former being the seasons with higher concentrations of NO_2 in Nordic countries.

Introduction
Air pollution represents a major hazard to human health. An estimated 3 million people die each year worldwide due to ambient air pollution (World Health Organization, 2016), which includes combined effects from O_3, NO_2, SO_2, and particulate matter (PM). 90% of the world's population breathes air that does not comply with WHO guidelines (World Health Organization, 2016), and this exposure to poor air quality is disproportionately weighted to populations living in urban areas.

The European Commission Directive 2008/50/EC (EU, 2008) indicates that air quality modelling should be applied to allow the wider spatial interpretation of in-situ measurement data. The health impacts of urban air pollution and the requirements from legislation combine to create a need to develop urban air quality models. Such a model needs to provide air quality exposure mapping and to support policy-making through an assessment of emission abatement measures, and the processes that define air quality. We have therefore developed the urban scale air quality model, EPISODE, which we present here.

Model Description and Methods
EPISODE is a Eulerian urban dispersion model that can be used for the calculation of a variety of airborne pollutant concentrations. We focus here on the implementation and application of the model for NO_2 pollution. EPISODE consists of a Eulerian 3D grid model with embedded sub-grid dispersion models (e.g., a Gaussian plume model) for dispersion of pollution from line (i.e., roads) and point sources (e.g., chimney stacks). It considers the atmospheric processes advection, diffusion, and a representation of NO_2 photochemistry using the photostationary steady state approximation for NO_2. EPISODE calculates hourly air concentrations representative of the grids and at receptor points. The latter allow EPISODE to estimate concentrations representative of the levels experienced by the population (i.e., their exposure). This methodological framework makes it suitable for simulating NO_2 concentrations at fine scale resolution (< 100 m) in Nordic environments. The model can be run in an offline nested mode using output concentrations from a global or regional chemical transport model and forced by meteorology from a numerical weather prediction model; it also can be driven by air quality and meteorological observations.

We present a case study for six Norwegian cities whereby we simulate NO_2 pollution for the entire year of 2015. The model is evaluated against in-situ observations for the entire year and for specific episodes of enhanced pollution during winter. We evaluate the model performance using the FAIRMODE DELTA Tool that utilizes traditional statistical metrics, e.g., RMSE, Pearson correlation, R, and bias along with some specialised tests for air quality model evaluation.

Results and Conclusions
We find that EPISODE attains the DELTA Tool (Thunis et al., 2012)model quality objective in all of the stations we evaluate against in the six cities. Further, the other statistical evaluations show adequate model performance, but that the model scores show greatly improved correlations during winter and autumn compared to the summer. We attribute this to the use of the photostationary steady state scheme for NO_2, which should perform best in the absence of local ozone photochemical production during the darker seasons. During 2015, instances of non-compliance with the NO_2 annual limit set in the 2008/50/EC directive (AQD) occurred in Norwegian cities. NO_2 pollution episodes with the highest NO_2 concentrations, which lead to the occurrence of exceedances of the AQD hourly limit for NO_2 occur primarily in the winter and autumn in Norwegian cities, so this strongly supports the use of EPISODE in the application of these winter-time events. Overall, we conclude that the model is suitable for assessment of annual mean NO_2 concentrations and also for the study of hourly NO_2 concentrations in the Nordic winter and autumn environment. Further, we conclude that it is suitable for a range of policy applications that include: pollution episode analysis, evaluation of seasonal statistics, policy and planning support, and air quality management.

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COMBINED USE OF CHEMICAL-TRANSPORT/RANDOM-FOREST MODELS AND DYNAMIC POPULATION DATA TO ASSESS AIR POLLUTION POPULATION EXPOSURE

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Summary

This study deals with the estimation of NO_2, O_3, $PM_{2.5}$ and PM_{10} population exposure in six metropolitan areas of Italy using a combined approach based on a chemical-transport model (CTM) and a machine learning random-forest (RF) algorithm. The concentration fields computed by the CTM, at 1 km horizontal resolution, alongside additional high resolution spatial and temporal predictors are used as inputs in the RF to increase the spatial resolution of concentration fields (200 m) and to capture air pollutant gradients across the urban areas. These fields are then coupled with high-resolution dynamic population data, derived by mobile phone traffic, to estimate population-weighted exposure and to identify differences among them.

Introduction

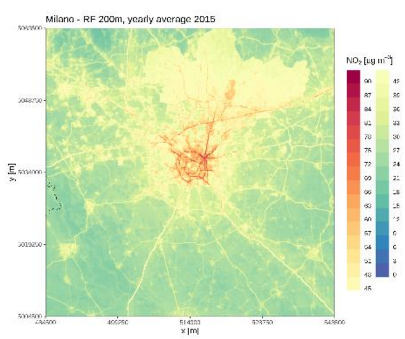
Air pollution is recognised to cause health effects particularly among the population living in urban areas. Depending on the method used to estimate exposure, prediction errors and misclassification of exposures for non-ubiquitary pollutants, such as NO_2, may occur. Machine-learning methods are viable solutions to improve accuracy in exposure estimation. A multi-city exposure assessment study has been carried out, within BEEP project, to support detailed epidemiological studies.

Materials and methods

A multi-city exposure assessment study has been carried out in Turin, Milan, Bologna, Rome, Bari and Palermo. They span from North to South to catch different urban characteristics and environmental/climate conditions across the country. NO_2, PM_{10}, $PM_{2.5}$ and O_3 concentration fields have been estimated over the six urban areas, at 1 km resolution, by means of a modelling system based on the CTM FARM fed by local emission inventories and meteorological data provided by WRF meteorological model run with urban boundary layer parametrization. CTM results were used as input to a machine learning RF model in addition to high-resolution spatial predictors related to the urban structures (such as population, land cover, impervious surfaces, vegetation index, elevation and traffic volumes derived by Open Transport Map service) to predict daily air pollutants concentrations at 200m resolution during years 2013-2015. To estimate population exposure, dynamic population information, based on mobile phone traffic data available for the period March-April 2015, were matched in time and space with CTM/RF model results. Data have been provided on hourly basis over irregular grids covering the cities with higher spatial resolution in downtown zones and coarser resolution in the outskirts. Citywide population exposures were calculated by weighting pollutants concentrations for the population involved (PWE) at model's cell levels. To evaluate the amount of population exposed to specific pollution concentration values, cumulative population-weighted exposures were calculated.

Results

Model results were validated against observations by applying a 10-fold cross validation approach, i.e. randomly splitting the total set of monitors into ten groups, then applying, in turn, the model on nine groups and predicting it to the tenth group. Mean cross-validation R^2 of 0.59, 0.72, 0.76 and 0.75 for NO_2, PM_{10}, $PM_{2.5}$ and O_3 respectively were achieved. The RF model improved the spatial details of concentrations with respect to CTM model. The figure shows yearly average NO_2 for the city of Milan as an example. Highway and provincial roads are clearly visible, as well as downtown roads. As far as dynamic population is considered, PWE median values exhibit a clear South-North geographic gradient with highest exposure to cities located in the Po Valley area (Turin, Milan), followed by Rome. Conversely, O_3 PWE exhibits an opposite geographic gradient with higher exposure for cities with Mediterranean climates (Bari, Palermo and Rome) and lower in cities with continental ones (Turin and Milan). The hourly cumulative population exposures allowed assessing the amount of population exposed to different air pollution levels. For most of the time, a large part of population is estimated to be exposed to concentrations lower than 50 and 40 $\mu g/m^3$ for NO_2 and PM_{10} respectively regardless of the city. Some pollution episodes are identified, particularly for PM_{10} and for the cities of Turin, Milan and Rome. During them, the whole population is affected by PM_{10} concentrations higher than 80 $\mu g/m^3$.



Conclusions

Machine learning methods are demonstrated to provide high accuracy in estimating air pollution at urban level. Dynamic population data are very useful in assessing the amount of population involved. The air pollutants predictions made available will provide novel evidence on the short-term and long-term health effects in the main metropolitan areas of Italy.

Acknowledgement

This work was supported by INAIL Bando Ricerche in Collaborazione (BRiC) ID 04/2016. Population data were provided by TIM company (TIM Big Data Challenge 2015).

DETERMINATION OF OPTIMUM POSITIONING OF ATMOSPHERIC POLLUTANT MEASURING INSTRUMENTS USING COMPUTATIONAL FLUID DYNAMICS

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Summary

This study shows how Computational Fluid Dynamics (CFD) can help in the determination of the most favourable placing of pollutant measuring devices. The problem of best positioning of a traffic pollution monitoring station in a local urban region is examined as an example. It is argued that except of the maximization of the measured variables, more parameters should be taken into account, like the local flow field and the ratio of concentration standard deviation to concentration mean value, which should preferably be low. A guidance for choosing the best position is proposed.

Introduction

The suburb of Agia Varvara is located at the western part of Athens, in which no pollution monitoring station exists. One of the proposed places for such a station is the area of the intersection of "Eleftheriou Venizelou" and "Megalou Alexandrou" avenues, at Agia Varvara. The main pollution contribution at the region is from the traffic. The identification of the best position for the station is not a trivial task though. In this work ten carefully chosen alternative positions (sensors) are examined (Fig.1). Reynolds-Averaged Navier-Stokes (RANS) CFD simulations are performed for various wind directions and a guidance for choosing the most informative position is presented.

Methodology and Results

An area of 1 km x 1 km x 100 m is examined. The grid resolution at the central part is 2 x 2 x 1 m. The geometry is imported into the ADREA-HF code with the aid of orthophoto maps and topographic charts. The road traffic is provided from a recent study performed for the municipality. Area sources are considered, using emission indexes from the National Atmospheric Emissions Inventory of UK (of year 2014, since the Greek vehicle fleet is five years older). Only the carbon monoxide is examined, as an example. The concentration *variances* are also calculated (Andronopoulos et al., 2002). The most frequent wind directions are modelled, namely S, NNW (about 30% possibility of occurrence each) and N (about 15% possibility). For each direction, the average concentration for each sensor (average over all wind speeds; wind speed distribution is taken from the wind rose), is presented at Fig.2(a). A simple method to choose the best position is to calculate for each sensor the global average C_{gl} for all wind directions and speeds. This yields 0.33, 0.33, 0.31, 0,27 (mgr/m^3) for the positions 1, 4, 10, 6 respectively and less for the others. This way though, we don't know if the chosen position presents high/ representative values for *all* frequent wind directions. Also the chosen position might be in a highly unsteady flow area, thus risking intermittent measurements. This is critical in case of pollution events or accidents, which we also want to cover. The proposed methodology rejects positions that don't have the desirable characteristics, by using two tests: Test 1: Accepted are sensors whose C_{av} value is one of the five higher values among all ten sensors for the particular direction. Test 2: Ratio of concentration standard deviation to mean value (σ/μ, which is an indicator of signal instability) is below 0.5 (Fig.2(b)). In this case only *position 4* meets all the criteria (Fig.3), which additionally has high global C_{gl}. Flow-field observation reveals that even better sensor positioning could be proposed. It also gives signs of unsteadiness at some parts of the flow field; Large Eddy Simulation (LES) is needed in order to further investigate that.

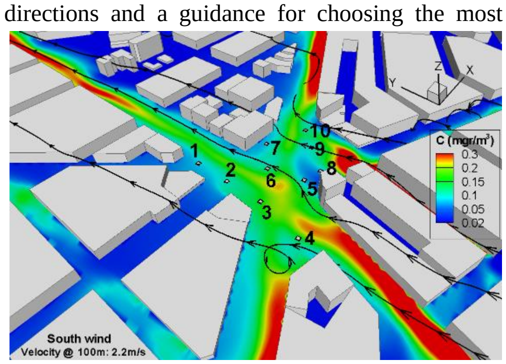

Fig.1 Concentration contours at 2.5 m for South wind

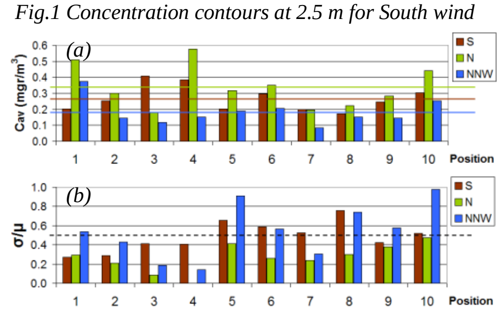

Fig.2 (a) Concentrations for each position (average values of all wind speeds for each wind direction) (b) Ratio of concentration standard deviation to mean value (σ/μ) for each position/ wind direction

Position:	1	2	3	4	5	6	7	8	9	10
test 1 -S		√	√	√		√				√
test 1 -N	√			√	√	√				√
test 1 -NNW	√			√	√	√				√
test 2 -S	√	√	√	√					√	
test 2 -N	√	√	√	√	√	√	√	√	√	√
test 2 -NNW		√	√	√			√			
ALL tests	FAIL	FAIL	FAIL	PASS	FAIL	FAIL	FAIL	FAIL	FAIL	FAIL

Fig.3 Pass/ fail matrix for the examined positions and wind directions (tests described in text)

Conclusions

A methodology for CFD-aided positioning of pollution measuring instruments, which introduces the examination of the parameter σ/μ, is presented and tested. It can be adapted in any other case by loosing/ tightening the criteria or adding more tests. A necessary complement of the methodology, is the flow field investigation in order to interpret/ assure the results.

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FAST PRE-COMPUTED LARGE-EDDY SIMULATION BASED DISPERSION MODELLING METHOD FOR HAZARDOUS MATERIAL RELEASES IN URBAN ENVIRONMENTS – PART 1: THE CONCEPT

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Summary
The concept of a completely new kind of fast contaminant-dispersion modelling method for urban areas based on pre-computed high-resolution building-resolving large-eddy simulations is presented. The new concept works also in the inverse mode allowing back-tracking of possibly unknown source location based on contaminant observations.

Introduction
Dispersion of airbourne hazardous materials (contaminants) in urban environment is typically much more complicated than that in open environment, and it depends strongly on the particular features of the urban structure. Traditional dispersion models, such as Gaussian dispersion models are not able to capture these effects and may therefore predict totally wrong dispersion results, see e.g. (Patnaik et al, 2010). On the other hand, high-resolution Computational Fluid Dynamics (CFD) models can take the effects of urban environment into account and are thus able to predict realistic dispersion results in urban environment. However, use of high-resolution CFD is very laborious and time consuming and therefore usually not feasible for practical purposes, especially not for emergency situations. A natural question is: could pre-computed CFD results be used for fast and easy modelling of the dispersion of a particular release in prevailing meteorological conditions in a selected area of interest? Here, the principal problem is that the location of the release source is unknown at the time of the pre-computations. Patnaik et al. (2010) introduced the so called dispersion-nomograph approach to circumvent this problem. In their technique, dispersion is not modelled in the CFD pre-computations. Instead, the modelled turbulent wind fields are diagnosed in a specific way to form the dispersion nomographs which essentially carry the information of the outer bounds of the areas where the contaminant released from any location can travel. They use pre-computed Large-Eddy Simulations (LES) to model the wind fields in a sufficient number of meteorological conditions. Here, we propose a new approach which is based on Lagrangian-stochastic (LS) particle transport from distributed source grid within the LES pre-computations, and specific on-line data collection and analysis (DCA) algorithm. We claim that our approach is physically even more realistic than the dispersion nomograph approach.

The concept and the methodology
The core of our concept is that the laborious and time consuming LES-LS are carried out well in advance of the use and the necessary data is stored in a specific data set. When the user invokes the user software, it first gets the prevailing meteorological conditions and then reads the necessary data form the pre-computed data set. Using these information, the user-software reconstructs the results and displays them on the map. The result can be a concentration map of a plume spreading from a known source location – either an estimate of the absolute concentration if the source strength is known or can be estimated, or a relative concentration if the source strength is totally unknown. On the other hand, if even the source location is unknown but some contaminant is observed in the air, the model can be used in the inverse, i.e. back-tracking mode. In this case, the result is a source area for a given observation point. If observations are available from several points, their source-area information can be combined to outline the area where the yet unknown source is located. The basic idea is that Lagrangian particles are released within the LES from a large number of source points forming a two-dimensional grid that covers all locations considered as possible release locations. In our current implementation, the source grid spacing is 8 m and the horizontal domain coverage varies from 9.5 to 37.7 km^2. The source grid acts also as the sensor grid for defining the plumes resulting from all possible source points and source areas for all possible observation points. Particles observed at each sensor point during the LES-LS run are sorted according to their source location and recorder cumulatively. This task is undertaken by the DCA algorithm within the LES-LS model. Both the LES-LS model itself and the DCA algorithm are efficiently parallellized. The LES-LS is run typically for several hours with frozen boundary conditions such that sufficiently large number of particles travel through statistically stationary turbulent wind field and accumulate a saturated set of information. The plume and source-area information accumulated during the LES-LS run is stored in a one-dimensional form (the independent variable is x, the coordinate roughly in the nominal mean-wind direction). Later, when the data is used, two dimensional maps are reconstructed from this one-dimensional information which includes: the left edge, the right edge, the mean concentration (or source-area function) across the plume, y-location of the peak value, the minimum arrival time of the contaminant measured from the start of the release and the maximum removal time measured from the end of the release. The LES-LS runs are made for a sufficient number of wind directions and possibly other conditions if considered necessary. However, the wind speed is not varied. Instead, a nominal reference wind speed is used in the LES-LS runs and the results are rescaled in the reconstruction phase for the prevailing wind speed in the emergency situation to be analysed.

Conclusions and outlook
The method is currently being implemented for central Helsinki. More information on our LES-LS pre-computations and our first results, experiences and conclusions are given in the Part 2 by M. Aarnio and the Part 3 by H. Hannuniemi.

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FAST PRE-COMPUTED LARGE EDDY SIMULATION BASED DISPERSION MODELLING METHOD FOR HAZARDOUS MATERIAL RELEASES IN URBAN ENVIRONMENTS– PART 2: LARGE-EDDY SIMULATION PRE-COMPUTATIONS

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Summary

Our study presents a new fast modelling method that can be used to accurately describe dispersion of hazardous airborne material in urban environments. The specific aim of the method is to simulate a large ($O(10^5)$) set of evenly distributed airbourne hazardous material plumes, and source-area functions for backtracking unknown source locations, in an urban area as a set of time-consuming pre-computations. The input and methods of modelling the various phenomena in an urban environment are discussed. The model we have used is a computational fluid dynamics model called the Parallelized Large-Eddy Simulation (LES) Model (PALM) (Maronga et. Al, 2015).

Introduction

Using the Reynolds averaged approach with parameterised descriptions for turbulence produces only time-averaged solutions not representative in complex urban environments. Therefore, we have chosen to use LES to keep both computational load and the aqcuired accuracy at acceptable levels. The LES of hazardous material dispersion from arbitrary source in an urban area is based on various data describing meteorological conditions and the urban structure. The Lagrangian Stochastic (LS) parcel model and a specific on-line data collection and analysis (DCA) algorithm form the core of the method. The methods enabling the reduction of the computation load and time while obtaining results that are representative of dispersion in the relevant meteorological situations in this urban area are grid nesting and choice of a limited number description of a variety of meteorological situations used to produce a pre-computed database.

Method

The **LS model** describes the movement of massless computational parcels as a combibation of a LES resolved wind field and an additional small stochastic velocity field that depends on the parameterized sub-grid turbulence. The two-dimensional LS source grids describe the locations of the LS parcel release points inside the LES grid. The **DCA algorithm** is the method where information about the origin and location of each LS parcel from each source is combined and distilled into a dataset describing the outer spatial limits and some other information of each plume and source-area function. The assumption is that the plume outline will converge at some point in simulated time as sufficient number of parcels from each source have travelled through the computation domain with the turbulent wind flow. The DCA algorithm has been presented in more detail in Part 1: the Concept by A. Hellsten. The **computational domain** consists of three nested structured cubic grids with increasing resolution at 8 m, 4 m and 2 m towards the most important areas. The largest domain (root domain) size is 12.3 x 8.2 km^2 with height of 320 m, comprising the urban boundary-layer. This outermost domain grid requires several **boundary conditions** set by the user. These define a free slip condition for the top surface of the grid, a cyclic condition between the two grid side boundaries, zero velocity components (no-slip) at ground and building surfaces, and for the inlet a recycling condition where the values of the turbulent fluctuations of the variables at the inlet are taken from a *yz*-plane parallel to the inlet at a distance of 2 km. The use of a large outermost domain inside which smaller nested domains are embedded makes the setting of boundary conditions for the nested domains easier, as the nested domains' (nest2 and nest3) boundary values are obtained from the embedding larger grid solution. LES enables the solution of the most important details of turbulent flow at these resolutions in street, street canyon and courtyard environments, and including the effects of trees. The nesting is two-way, meaning that the values of the variables at a boundary of two nested grids are passed both ways. The use of **three nested grids** enables the focusing of the simulation load onto the principal target area. The LS source grids used in our simulations were 8 m equidistant grids covering the nest2 and nest3 LES grids. The **LES-LS runs** are made for a sufficient number of wind directions and possibly other conditions if considered necessary. The computational domains are rotated for each wind-direction case such that the mean wind direction is roughly in the *x*-direction. However, the wind speed is not varied in the LES-LS runs; a nominal reference wind speed is used and the results are rescaled in the reconstruction phase for the prevailing wind speed in the situation to be analysed. Similarly, a nominal reference source strength for all the sources is selected purely from computational and statistical points of view, and the results are rescaled by the actual source strength in the reconstruction phase if the source strength is known or can be estimated. Each LES-LS run simulates a statistically stationary situation and the simulations are run for several hours in order to ensure statistically converged results.

Conclusions

We have presented a fast modelling method utilising pre-computed LES-LS simulations with specific data collection and analysis algorithm coupled to Lagrangian parcel model can be applied to the simulation of hazardous airbourne material accidents in complex urban environments when certain techniques diminishing the computational load are utilised. Some simulation results for plumes, source-area functions and source backtracking for the Helsinki downtown area are presented in Part 3: Case Study by H. Hannuniemi.

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USING THE K-MEANS CLUSTERING METHOD TO IDENTIFY FLOW PATTERNS IN A STREET CANYON

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Summary

This study presents a numerical methodology that quantifies the flow patterns inside street canyons, to make easier their systematic modelling in street scale Air Quality Models (AQMs). A set of 19 street canyons was studied using Large Eddy Simulations. This set covered four reference velocities from 1.5 up to 7 m/s) and six aspect ratios (*H*/*W*, hereafter *AR*) from 1 up to 0.20. The results were studied using Unsupervised Learning clustering techniques. The k-means clustering method produced the more consistent results, dividing the flow inside the canyon in four Regions with similar shape. The areas covered by each Region were measured and correlated with the *AR* of the canyon, using a standard least-squares regression analysis. This produced four equations that calculate the area covered by each Region as a function of the *AR*.

Introduction

Street scale Air Quality Models (AQMs) employ several parameterisations for the modelling of flow inside street canyons. For example, the Operational Street Pollution Model (Berkowicz et al., 1997) assumes that a part of the canyon is covered by the recirculation zone, which circulates the pollutants inside the canyon and restricts their removal to the upper atmosphere. It is obvious, that the recirculating phenomena need to be properly modelled, to increase the accuracy and capabilities of AQMs. Searching for a similar division, we employed several clustering techniques, that generally divide a set of observations into groups (clusters) with similar characteristics.

Methodology and Results

The employed Large Eddy Simulations produced the wind flow fields for the 19 studied cases. The average and dimensionless horizontal (U/U_{ref}) and vertical (W/U_{ref}) velocities were taken from the cells in the area between the two buildings. These pairs were fed into the k-means algorithm (MacQueen, 1967), which divided them into four qualitative groups (see Fig. 1a). These pairs of velocities were replotted into their physical domain (i.e. the area between the two buildings), holding their cluster characterization from before. The produced plots presented four consistent Regions that covered similar places of all the studied canyons, so numbers from 1 to 4 were given to them, as shown in Fig. 1b. The areas covered by the four Regions (named as REG1, REG2, etc.) were calculated for each studied case and the results were studied with the least-squares regression method. More than 50 combinations were examined, including additions, multiplications and ratios of REG1, REG2, REG3, REG4 and the *AR*. A set of four equations was produced, including the three combinations with the best measured coefficient of determination (R^2) and a fourth one that equated the addition of all four Regions to the unity for closure. The plots of these combinations (REG3 and ln(*AR*), REG3/REG2 and *AR* and REG1+REG2 and *AR* are presented in Fig. 2.

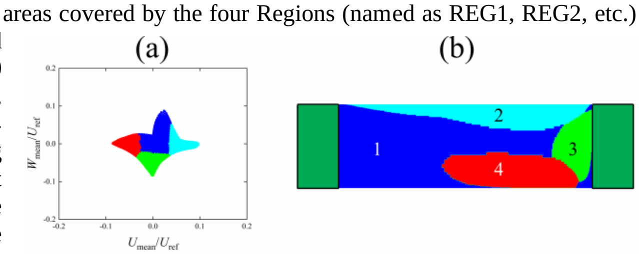

Fig.1 Application of the methodology for a street with AR = 1/3 (a) scatter plot; (b) contour plot.

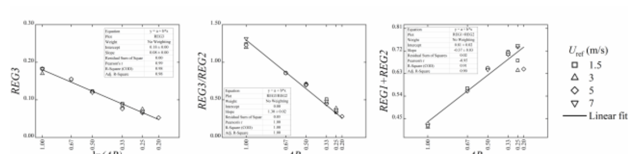

Fig.2 The three correlations that connect the areas of the four Regions with AR

Conclusions

The blending of Computational Fluid Dynamics and Unsupervised Learning created a set of four equations that connect the areas of the created Regions with the *AR* of the canyon. The presented methodology can be expanded to cover more parameters such us oblique wind direction, different number of clusters, as well as employ more methods for data analysis.

Acknowledgement

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MODEL VALIDATION ACTIVITIES IN THE FRAME OF THE COPERNICUS ATMOSPHERE MONITORING SERVICE

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Summary
This work concerns the wide-ranging tropospheric evaluation and model inter-comparison activities taking place in the frame of the Copernicus Atmosphere Monitoring Service (http://atmosphere.copernicus.eu, CAMS). The focus is on above the surface validation of regional scale models over large time periods.

Introduction
Towards the goal of continuous atmospheric monitoring, CAMS has been established as a component of the European Earth Observation program Copernicus and was developed in the past 10 years by a series of MACC research projects. CAMS is currently providing operational forecasts, analyses and reanalyses of atmospheric composition (reactive gases, greenhouse gases and aerosols) on the global and European scale. For the global component of CAMS, the numerical weather prediction Integrated Forecasting System (IFS) of the European Centre for Medium-Range Weather Forecasts (ECMWF) has been extended to provide daily forecasts, analyses, and reanalyses of atmospheric composition, by introducing an atmospheric chemistry module into the IFS (named CIFS or CAMS-global) and by combining with satellite observations of atmospheric composition (Flemming et al., 2015). Validation activities concerning CIFS have been outlined in Eskes et al. (2015). For the regional (i.e. European) component of CAMS, an operational system is run on a daily basis providing air quality forecasts and near-real-time analyses for the European domain, based on an ensemble of nine regional chemical transport models (Marecal et al., 2015), an operational activity that is coordinated by Meteo-France.

Methodology and Results
Within CAMS, a unique opportunity is presented for comprehensive tropospheric evaluation and model inter-comparisons over long time periods since the participating models have been running in operational mode for a number of years. Towards this direction, the CAMS-84 sub-project deals with the validation of the services provided. It provides 3-monthly updates of validation reports for the global and regional services, where the validation is based on a large number of observations and measurement techniques, including surface in-situ, surface remote sensing, observations by airplanes, balloon soundings, observations from ships and satellite observations (Eskes et al., 2018).

Conclusions
Important insight into the performance of individual regional chemical transport models is gained through the activities of the CAMS-84 sub-project of the Copernicus Atmosphere Monitoring Service, where model output is evaluated above the surface and checked for consistency against the global component of the operational CAMS system. This activity is also in a unique position to perform a long term assessment of the benefits of a model ensemble approach to provide optimal modelling estimates for atmospheric composition at the regional scale.

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Short Presentations

MODELLING OF AIR POLLUTION BY PEAT FIRE SMOKE AND FORECAST OF ITS IMPACT ON ROAD VISIBILITY AND DRIVERS HEALTH

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Summary
In the present study there was developed: 1) an emission and dispersion model of smoke components (CO and PM) from burning peat; 2) an approach to estimate its impact on road visibility and people (drivers and passengers) health through acute risks; 3) criteria for ranking road situation by hazard level depending on the values of these indicators. The model was tested through the investigation of an emergency caused by a peat fire that lasted in Irkutsk Region (situated in Siberia) near the Federal Motorway P-255 "Siberia" from 26.10.15 to 15.01.16.

Introduction
Peat land fires are of major concern in the Russian Federation. Peat can burn deep underground for meters, even in damp conditions and in winter under the snow layer. Peat fires are difficult to extinguish, and they can last for months. Winter peat fires are often smoldering fires that create a lot of smoke because of incomplete combustion and result in greater emissions of carbon monoxide and other harmful substances including PM_{10} and $PM_{2.5}$, VOCs etc. If a wildfire develops near a motorway, the smoke reduces the visibility, affects human health and may result in a multi-vehicle crash or in an emergency, as it was many times in the Russian Federation, in the United States and in other countries [1, 2]. Peat fire smoke dispersion models, as well as approaches for the forecast of the impact of air pollution on the roadway visibility and people health, are highly needed in Russia.

Methodology
For the dispersion modelling of CO and PM emissions from peat fire, we have developed an approach [2] based on K-theory (analytical approximation of results of joint numerical integration of the equation of atmospheric diffusion and the system of equations of hydrothermodynamics for the atmospheric boundary layer, Berlyand and Genikhovich). For the forecast of smoke (PM concentration) impact on the road visibility, we have developed a method based on Trabert approach. For the estimation of health risks due to CO and PM, we have used national software "Risks" designed to calculate acute and chronic health risks from air pollution. In addition, we have developed criteria to rank on-road situation by hazard level depending on the values of these indicators.

Results and Conclusions
The model was tested through the investigation of an emergency caused by a peat fire that lasted in Irkutsk Region (situated in Siberia) near the Federal Motorway P-255 "Siberia" from 26.10.15 to 15.01.16.

Fig. 1 - Smoldering peat bog near the Federal motorway P-255 "Siberia" in fall-winter 2015-2016

The results of numerical investigations have shown that a smoldering winter peat fire on the territory of 20 hectares at ambient air temperature about -25 ^{0}C and low wind (1,5-2,5 m/s) with CO emission rate 108-177 g/s, $PM_{2.5}$ emission rate 14,5-26,5 g/s, PM_{10} emission rate 15,5-28,5 g/s may lead to high air pollution and haze on the road 1-2 km far from the fire. CO concentration may exceed National 20-minute Limit Value (LV_{20min}) by 1.2-1.5 times, PM_{10} concentration – by 2.5-7.0 times and $PM_{2.5}$ – by 4.5-11.5 times. The on-road visibility may decrease to 40-170 m. The results of simulation have also shown that a real emergency may happen at night time because of a "super smog" – a dense smog formed by the peat fire smoke and the fog. In this case, CO concentration may exceed LV_{20min} by 1.9-2.5 times $PM_{2.5}$ concentration – by 7-20, PM_{10} concentration – by 4-11 times. The on-road visibility may fall to 7-11 m.
The model has been developed in support of management of road safety and risk management in emergencies caused by wildfires.

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FAST PRE-COMPUTED LARGE-EDDY SIMULATION BASED DISPERSION MODELLING METHOD FOR HAZARDOUS MATERIAL RELEASES IN URBAN ENVIRONMENTS – PART 3: CASE STUDY

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Summary
We present a case study of implementing our new pre-computed Large-Eddy Simulation (LES) based dispersion modelling method for airborne hazardous material accidents. The domain of the case study is at city center and the spatial dimension of the innermost modelling area shown in figures is 3 x 3 km^2 with grid size of 2 m. The case study demonstrates that the method produces realistic plumes in an urban environment. A modelling tool based on this method can be used at airborne hazardous material accidents to help estimate for example the extent of contamination area.

Introduction
The method is based on pre-computed LES coupled with a Lagrangian-Stochastic (LS) particle model, and specific data collection and analysis (DCA) algorithm. The modelling concept has been described by A. Hellsten in Part 1, and the LES precomputations have been described by M.A. Aarnio in Part 2. The use of pre-computed LES-LS enables realistic modelling of the effects of complex urban structures on plume dispersion and source-area function. Input data for the LES-LS calculations include accurate surface elevation and building height information, street network, and tree height and location information. For this case study the input data is gathered and pre-processed from open data sources. The reconstruction of the plumes, and source area assessment, is fast and it can be done directly in the actual accident situation because the time-consuming LES-LS calculations are done beforehand. Some preliminary results are discussed in this presentation. The results suggest that our new concept is promising.

Results
For this first case study, the database consists of simulated results for 18 different wind directions under near neutral stratification. Stable and unstable stratification will be modelled in the next phase of the model development. When the data is used in an accident situation, the user software inputs the prevailing mean wind speed and direction, reads the necessary data from the database, interpolates these results to the prevailing mean wind direction and rescales the results according to the actual wind speed. Resulting plume or source area are displayed on a map. The user software and graphical user interface (GUI) are still under development. It should be noted that the asymptotic shape of the plume is independent of the (non-zero) wind speed in near neutral stratification but it varies remarkably depending on source location and the wind direction. This diversity is owing to the different urban structures (building and street configuration, terrain shape, trees) the plumes encounter during their course. This can be seen in Fig 1 displaying two examples of plumes originating from sources at different locations. The method is not limited to any particular source location as the source can be located in any point in the urban canopy within the modelling domain. For instance, in the lower plot the plume width increases with unexpected rate immediately downstream from the source e.g. due to street channeling. Both plumes show significant differences from the typical plume shape predicted by traditional models such as Gaussian dispersion models. The concentration of the contaminant in the plume can be estimated if the amount of the release is known.

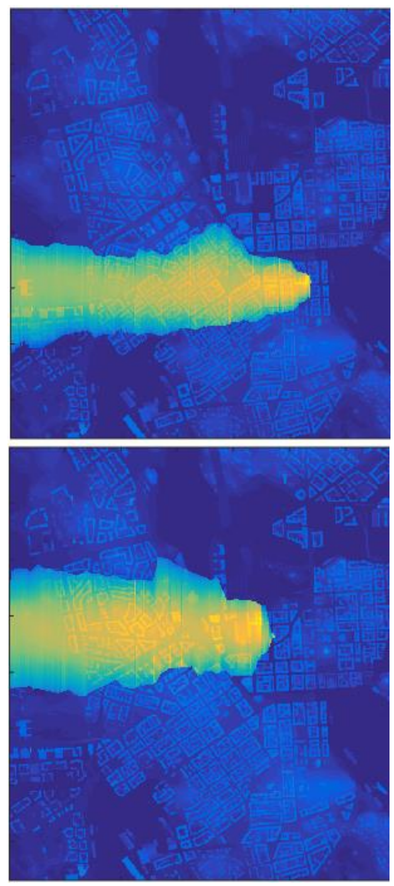

Fig.1 Reconstructed plumes with different source locations. The wind is blowing from east.

The method can be used also in the inverse mode for back-tracking sources in unknown locations if there are at least one observation available. This is based on source-area function information computed and stored in the database simultaneously with the plume information. The inverse mode operation and source area assessment will be explained and discussed in the presentation.

Conclusions
The case study demonstrates that the pre-computed LES-LS based dispersion modelling method produces realistic plumes in an urban environment. The shape of the plumes is notably different with different source locations owing to the different urban structure. A modelling tool based on this method can be used at airborne hazardous material accidents to help estimate the extent of contamination area, or when observations are available to assess the source area, or to assess when the concentration is dropped to non-harmful level. The results are displayed on a map, which is fast and easy way of getting information, and this helps the responsible authorities to make timely decisions at accident situations.

MODELLING OF THE AIR FLOW AND ODOUR POLLUTION IN THE ORE MOUNTAINS, GERMANY

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Summary

The regional chemistry transport model COSMO-MUSCAT (Wolke et al., 2012) was applied for simulations of the air flow in the complex terrain of the Ore Mountains, Germany, to investigate the potential role of industrial facilities as source for malodorous substances. The simulations were conducted with a horizontal resolution of 200 m x 200 m. The investigations were conducted using both source-receptor relations from dispersion calculations as well as back-trajectories. It was found that for most malodour events pollutants accumulate over a long time in the North Bohemian Basin during stable stratification conditions before they are eventually transported across the Ore Mountain ridge.

Introduction

During the last years, the local authorities of the Ore Mountains region, Saxony, Germany have received an increasing number of complaints about malodour events in their localities. These events are mainly observed for specific weather situations with southerly wind. The malodour events were always recognized during stable conditions with southerly flow. Therefore, it was expected that the origin of the malodour is presumably in the North Bohemian Basin. However, the malodour is not recognized in areas close to potential industrial emitters.

Methodology and results

The air flow in the Ore Mountains for three selected periods were analysed in order to locate or narrow down potential sources and source regions. The investigations were performed with the chemistry transport model system COSMO-MUSCAT. Horizontal grid resolutions of 200 m were used for an appropriate description of the complex mountainous topography and the exact location of the emissions. In addition to dispersion calculations, a detailed analysis of backward trajectories was performed. For the chosen periods, a high number of complaints and objective reports by volunteers were available, indicating a strong malodour event.

Similar to earlier studies, the present work found accumulation of potential odour pollutants under stable stratification and weak winds in the North Bohemian Basin. The flow patterns occurring during the overflow of the Ore Mountains ridge depend very strongly on the fine structure of the orography. In earlier simulations with horizontal grid resolutions of more than 1 km, these could not be resolved accurately. In the now performed high-resolution model calculations also fine flow patterns could be visualized and analyzed. This made it possible to investigate individual transport routes through the valleys and circulations within the valleys. Moreover, the increased vertical resolution enabled to map the vertical transport and emission from stacks more realistically. Interesting differences were seen in the transport pathways from near-ground sources (lowest 100 m) and higher emitters (200-400 m, e.g. stacks), where the emission height of the latter were often close to or even above the inversion layer and the emitted tracers subject to higher wind speed.

Overall, no clear allocation to a source or region could be made that could explain all the malodor complaints considered. With certainty, only the sources in the west of the investigated area (west and south of Chomutov, Czech Republic) can be excluded as causes of the malodorous substances. For each of the periods studied, source regions can be narrowed down and others excluded, however, these differ between the different periods. In particular, none of the sources studied can explain all the reports made by the volunteers.

Acknowledgement

This work was funded by and conducted on behalf the Landesamt für Umwelt, Landwirtschaft und Geologie (Environmental Agency of Saxony).

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Exposure and Health Assessment Related to Air Pollution

SIMPLIFIED APPROACHES IN QUANTIFYING EXPOSURE STATISTICAL BEHAVIOUR DUE TO AIRBORNE HAZARDOUS RELEASES OF SHORT TIME DURATION

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Summary

The present study main aim is to introduce simplified approaches in estimating exposure due to airborne hazardous releases in urban environments. The question is to what extend a single suitable continuous release simulation can be utilised in estimating major exposure parameters statistical behaviour replacing in many cases a prohibitive large number of CFD simulations required otherwise. The present effort is to seek for further experimental evidence on the validity of the hypothesis introduced by Bartzis et al (2019) that key exposure parameters are directly related to the corresponding continuous release concentrations. The present results strengthen further the abovementioned hypothesis

Introduction

The exposure due to airborne hazardous releases of short time duration is stochastic in nature and strongly dependent on the release time. Its assessment often requires a relatively large number of dispersion simulations especially if one needs to consider a variety of release times and in the same time reveal the statistical behaviour of the associated exposure parameters due to atmospheric turbulence. The problem becomes more challenging if the dispersion environment is geometrically complex e.g. an urban environment. Reliable prediction of the exposure statistics with direct simulations is more likely to require a prohibitive number of CFD RANS or LES simulations. In such cases, there is a pressing need for simplified approaches without any discount on the obtained results reliability.

Methodology and Results

The basic idea introduced by Bartzis et al (2019) is to what degree key exposure parameters for short time releases are related to a corresponding continuous release concentration. It is noticed that the continuous release dispersion is a well-studied problem with several existing models able to produce reliable results. In other words, if the idea is valid the associated modelling simulations are expected to be more reliable compared to direct puff release simulations. The idea's validity is based on theoretical considerations and limited experimental evidence. Here, in the frame of seeking for further experimental evidence, all available data of the Michelstadt Wind Tunnel Experiments for puff and continuous releases have been considered (http://www.elizas.eu/index.html). The experiments consist of continuous and puff releases in three (3) different locations within the urban canopy (Berbekar et al, 2015). An illustrative result applying the proposed methodology is given in Fig 1.

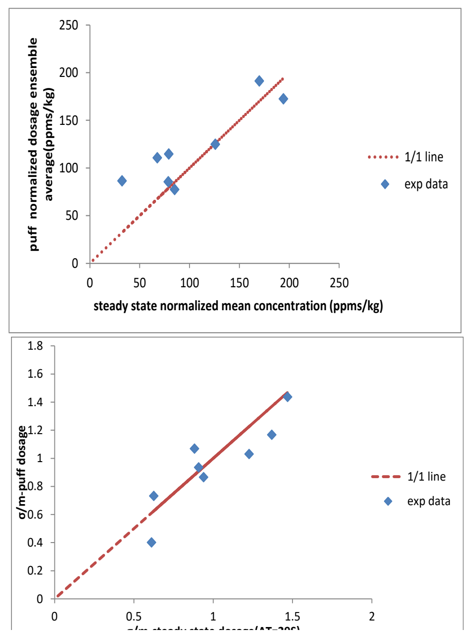

Fig 1. Puff releases vs continuous release: The dosages mean and sigma.

Conclusions

The present analysis gives further support to the hypothesis that key exposure parameters for short time releases can be estimated by using the corresponding continuous release concentration. The results are more reliable in the areas where CFD RANS approximation is valid enough.

Acknowledgement

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TOWARDS A BETTER ASSESSMENT OF INDIVIDUAL EXPOSURE: A SIMPLE STATISTICAL APPROACH TO DESCRIBE THE HETEROGENEITY OF URBAN AIR QUALITY

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Summary
A major challenge in quantifying the health effect of air pollution is to develop the resources needed to reliably estimate the spatial and temporal variations of pollutant concentrations in urban microenvironments. But these data are not easily accessible. Between, on the one hand, thin-scale models requiring a huge mass of hard-to-access forcing data and consuming phenomenal computing times, and on the other hand, regional-scale models that do not consider sub-kilometric phenomena, we propose here a statistical downscaling method allowing to simply assess the concentrations of pollutants in road-traffic micro-environments, from Chemistry-Transport Model outputs.

Introduction
Since the 2000s, there has been a major awareness in urban areas around the health risks of air pollution. It has been driven by the evolution of knowledge about the fine fraction of atmospheric particles, the development of epidemiological and toxicological studies on the health impacts of urban pollution (WHO 2016), as well as the significant increase in the incidence of chronic respiratory diseases in the urban population (Cesaroni et al., 2013). The literature today recognizes the heterogeneous nature of urban air quality, particularly near the traffic lanes, and several studies have highlighted the phenomenon of "contrasts of exposure", which induces environmental inequalities (Deguen et al., 2015). Such advances strongly question city dwellers about their own exposure, and require consideration of air quality at a very small scale in exposure assessment studies.

Methodology and Results
We have developed a statistical method to represent the proximity to road traffic in the city, based on a chemistry-transport model outputs (here the CHIMERE model outputs), taking into account the density of the traffic flow and the possibility of confinement related to local buildings. Our approach is based on a learning method, in which the model outputs are compared to the measurements and are then corrected, for different states of proximity to the road traffic. Using about thirty comparison points, over a whole year of measurements (at the hourly time step), we have been able to produce a statistically robust correction of the value modeled by CHIMERE. This correction is based on a multiple regression approach and uses two correction coefficients. In a final step, we compared the correction coefficients, the proximity to road traffic and the intensity of the traffic, in order to be able to guess the values of the coefficients for any traffic environment.

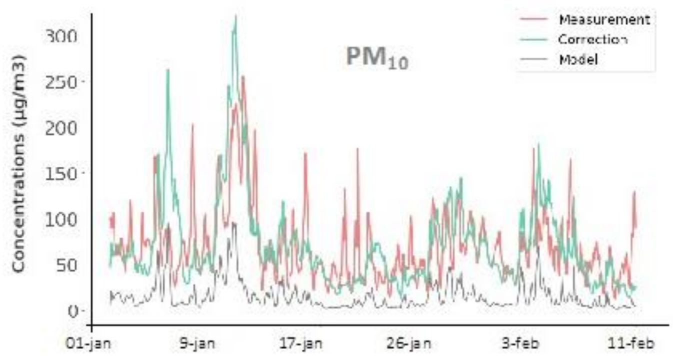

Fig.1 Comparison of the CHIMERE kilometric ouputs (grey line), CHIMERE corrected outputs (green line) and AIRPARIF monitoring network measurements (red line) for PM_{10} for a Paris traffic site in 2009.

Conclusions
As a result, we have been able to improve the CTM outputs, and to produce a refined mapping of air quality throughout the Paris region. This is a necessary first step for a better assessment of the exposure of individuals to atmospheric pollutants in urban areas.

Acknowledgement
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IN-CAR EXPOSURE TO THE MAJOR TRAFFIC RELATED AIR POLLUTANTS AND CO2 CONCENTRATION UNDER DIFFERENT SETTINGS

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Summary
In-car exposure to traffic-related air pollutants (TRAPs), such as nitrogen dioxide (NO_2) and fine particulate matter ($PM_{2.5}$), where passengers spend most of their times in traffic congestions, could cause a wide range of adverse health effects. This study investigates the impacts of TRAPs and carbon dioxide (CO_2) concentrations to minimise in-car exposure in three different primary ventilation settings during morning, afternoon, and evening peak hours.

Introduction
Short-term exposure to TRAPS has been associated with asthma attack and morbidity (Shah et al., 2015). Among other modes of transportations (bus and underground), in-car exposure was reported to be the least in terms of $PM_{2.5}$ exposure (Rivas et al., 2017). The maximum gaseous and $PM_{2.5}$ concentrations were observed while passing through traffic intersections (Kumar and Goel, 2016). The suggested ways to minimise exposure to TRAPs could cause exposure to high CO_2 concentrations, which are explored here.

Methodology and Results
We conducted a mobile monitoring campaign to measure NO_2/$PM_{2.5}$/CO_2 with 5/6/1 sec time resolution for 5 days in Guildford, UK. The study investigated three primary ventilation settings, windows open (WO) – without controlled ventilation setting, windows closed with air conditioning (AC) on ambient air mode (WCAA), and windows closed with AC on recirculation (WCRC) during the morning, afternoon and evening peak hours. The selected route covers diverse places, including parks, residential, commercial areas and train/bus stations. Figure 1 shows $PM_{2.5}$ and NO_2 box plots of different settings in different peak hours. High $PM_{2.5}$ and NO_2 concentrations were observed in case of WO and WCAA that prove the suitability of WCRC setting in less in-car exposure. In case of $PM_{2.5}$, morning peak hour was relatively higher than that of afternoon and evening peak hours (Kumar et al., 2018). However, driving on WCRC setting led to increasing CO_2 concentration, which could cause drowsiness, headaches, sleepiness and stagnant, stale, loss of attention, increased heart rate, slight nausea, and accident.

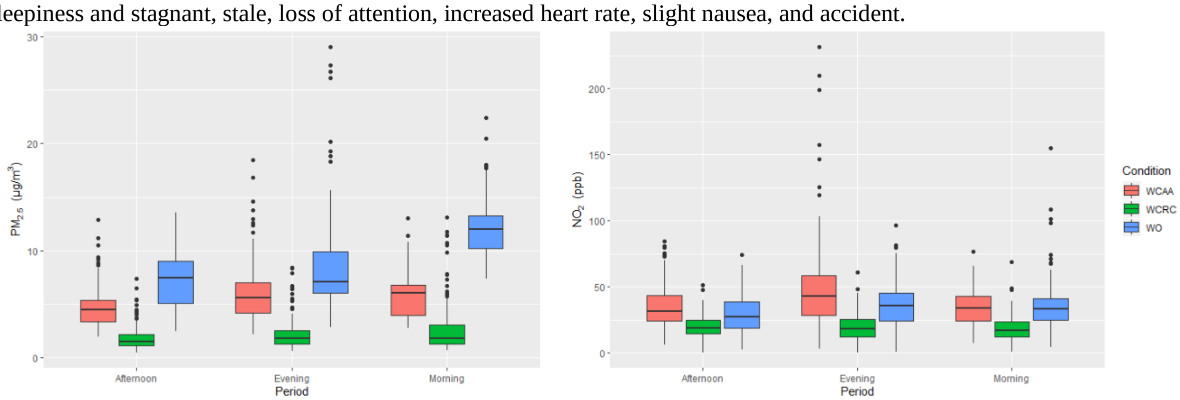

Fig. 1. $PM_{2.5}$/NO_2 concentrations in different settings and peak hours.

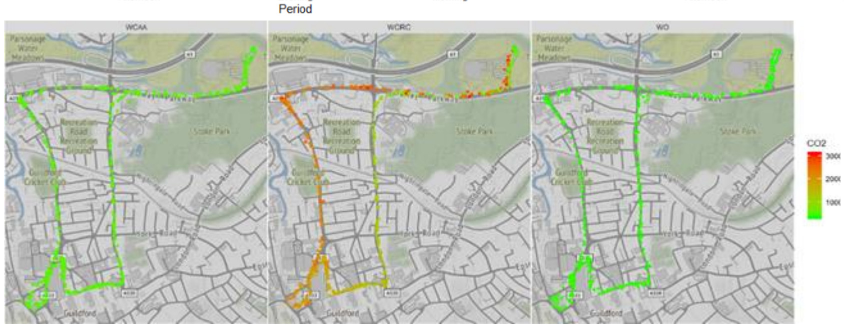

Fig. 2. Total CO_2 concentration for WCAA (left), WCRC (middle), and WO (right) on a map of Guildford. Red color represent CO_2 concentration up to 3000 ppb.

Conclusions
Following WCRC setting is not always a way to minimise exposure to TRAPs, because it increases exposure to high CO_2 concentration, which should be avoided during long-distance driving.

Acknowledgement
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A NOVEL APPROACH FOR DYNAMIC POPULATION ACTIVITY IN URBAN-SCALE EXPOSURE ESTIMATES

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Summary
Static population distribution in population exposure estimates does not account for people moving in space and time, thus introduces inconsistencies in exposure estimates. We developed a generic approach to account for dynamic population activity, applicable to any European urban area, limiting the necessity of individually measured data or large-scale surveys. Thereby, we aim to reduce uncertainties of exposure estimates in health-effect studies.

Introduction
Population exposure estimates are used in epidemiological studies to evaluate health risks associated with impacts of air pollution on human health. Traditional approaches in exposure modelling assume that air pollutants' concentrations at the residential address of the study population are representative of overall exposure. This approach is acknowledged to introducing bias in the quantification of human health effects, as individual and population-level mobility is non-existent. To sufficiently model population numbers for exposure estimates, the dynamic population activity (DPA) must be known. Information on DPA is mostly derived from national or municipal surveys and is scarce. Recent population-activity-based exposure studies focus on utilising mobile devices to assess mobility but published studies are few, owing to issues related to data protection, privacy and data access. To address these aspects, we developed a generic approach to model DPA utilizing publicly available datasets, thus ensuring applicability to any European urban area. The overall goal is to improve exposure estimates for health-effect studies and policy support, especially in areas lacking information on population activity.

Methodology and Results
We developed a generic approach to model DPA integrating the Copernicus Urban Atlas 2012 land use and land cover product with literature based and microenvironment-specific diurnal activity data (commuting included), while also considering indoor and outdoor environments (Ramacher et al. 2019). This approach produces maps with distribution of citizens in various microenvironments (MEs) and hours of the day. These maps can consequently be used to calculate population-level outdoor exposure when paired with consistent spatio-temporal air pollution concentration fields. In this study, we applied the generic DPA approach to the cities of Hamburg (DE) and Athens (GR). Hourly, urban-scale pollutant concentrations were produced by the Chemistry Transport Model (CTM) EPISODE-CityChem (Karl et al. 2019) driven by detailed local emission inventories, 4D meteorological fields and regional pollutant boundary conditions for 2015. Both the concentrations for NO_x, O_3 and $PM_{2.5}$ as well as the DPA maps for Hamburg and Athens were simulated on a 100 m horizontal resolution grid, and were then combined to calculate population exposure (Fig. 1). We additionally used gridded population densities (based on residential addresses) to calculate population exposure, i.e. following a static population approach. We compared the exposures from the two approaches to capture the effect of a population moving in space and time. It is found that accounting for diurnal dynamic activity in different MEs leads to an increase in total population exposure of up to 10% in both cities. This is attributed to people moving to more polluted areas and to commuting activity, inside or outside of the city. Besides the increase in total population exposure, the intra-urban patterns of high and low exposures are changing drastically between the two approaches. Moreover, we assessed the impact of outdoor pollutant concentrations infiltrating MEs characterized as indoor environments. We investigated decreases in calculated total population exposure to outdoor concentrations of up to 30% (e.g. for NO_x) in indoor environments, when taking into account ME specific outdoor to indoor infiltration ratios.

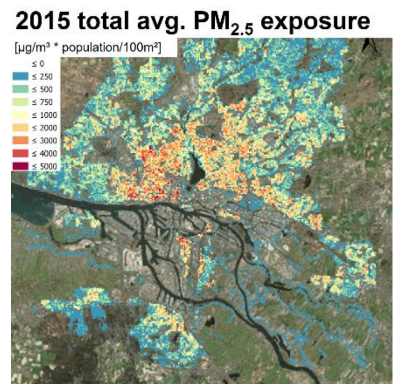

Fig.1: Total avg. $PM_{2.5}$ exposure in Hamburg 2015 based on DPA.

Conclusions
The presented approach to account for dynamic instead of static population activity in urban population exposure calculations, is beneficial for cities in European regions where relevant population data are missing. It is found that by taking into account movement of population through different urban environments as well as commuting per se, the overall exposure estimates are elevated when compared to a static approach. Furthermore, we have shown that by considering infiltration of outdoor concentrations to indoor environments there are substantial decreases in population exposure estimates. This approach and the implications on exposure estimates is believed to be of interest to air pollution health studies.

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SENSOR BASED MONITORING OF PERSONAL EXPOSITION AND INDOOR AIR QUALITY IN MADRID (SPAIN)

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Summary

An emerging concern for citizens is related to the amount of anthropogenic pollutants such as NO_2, O_3, COVs, PMs which are present in the air and how their contribution can shape the indoor and outdoor Air Quality. However, the lack of reliable data about the real exposition of citizens to air pollutants, including indoor air, make difficult to develop Environmental Policies that could improve the population wellbeing. To investigate the levels of personal exposition to these pollutants, a multi scale monitoring study was performed in the frame of the ICARUS project, an H2020 Grant focused on developing tools to reduce the levels of atmospheric pollutants in 6 European cities including Madrid. One of the main goals of the project is to adapt the use of "smart" technologies as personal devices and Air quality (AQ) sensors to provide reliable data of the individual exposition pattern to air pollutants.

Introduction

The AQ in our cities depend on a complex interplay between several factors, among others the meteorological conditions, wind direction and pollutant emissions. Besides, recent studies agreed that the poor air quality in our cities are behind of the increasing rates of respiratory and circulatory diseases in many countries (Landrigan MD, et al., 2018). Therefore, monitoring individual and population exposition to air pollutants with sensor based technologies provide a valuable information that can be used to prevent some of the harmful effects of these pollutants. All the data shown belong to Madrid volunteers that participated in the campaigns held in 2019.

Methodology and Results

The present study included 100 volunteers selected by age, gender and neighborhood in the city of Madrid (Spain). All the individuals were invited to participate in two different studies and to fill in the epidemiological survey. The first study was focused on the monitoring of the indoor AQ in their household and the second one was designed to monitor the daily exposition to Particulate matter. Both studies were held in two different seasons, winter and summer during 7 days. The data for the indoor AQ campaign were obtained from UHOO® devices an AQ sensor that measure air parameters such as Temperature, Humidity, CO_2, CO, NO_2, PM2,5, COVs and O_3. In addition, passive devices were used to sampling radon at each home. In the other hand, the volunteers were carrying a portable device (IOTECH®) for monitoring the daily exposition to particulate matter, PM1, PM2,5 and PM10.

More than 90% of the indoor AQ sensors (UHOO® devices) employed in the study provided reliable data for all the analyzed pollutants. For different reasons, less than 10 % of the devices do not show enough data. The overall analysis of the Madrid household indoor AQ data showed that more than 90 % of the household keep on suitable air quality levels according to the Spanish Indoor Air Standard, UNE 171330-2:2014. However at least 42 % of the households showed high levels of COVs in comparison with the recommended standard value. Less than 10% showed a worrying level of exposition to CO_2. Concerned to radon, the measurements showed that only 15% of households exceeded the radon levels recommended by the WHO. The analysis of the portable devices (IOTECH®) showed trustworthy data for exposition levels to particulate matter (PM2,5 and PM10) when compare with the data provided by Madrid AQ network. In fact, 65% of the volunteers showed no harmful levels of exposition to any PM when compare with EC limit values (Directive 2008/50/CE). We also have found that 21% of the volunteers exceeded the recommended exposition level to PM2,5 and almost a 10% cope with higher exposition levels to PM10.

Conclusions

The sensor based technologies are a promising tool to monitor and assess the population exposition to air pollutants. Besides, the analysis of the exposition levels opens up the possibility to design new epidemiological studies to address the health outcomes and to explore the relationship between exposition to air pollutants and disease in the population.

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THE IMPACT FUGUTIVE PARTICULATE MATTER IN A CITY OF ARID DESERT CLIMATE

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Summary
This study aims to develop an effective and accurate emissions inventory for fugitive Particulate Matter (fPM), representative of arid environments. Field measurements, source apportionment, dispersion modelling and regression analysis were used to derive emission factors (EFs) and models for the quantification of windblown dust and non-exhaust traffic PM in areas with arid desert climates.

Introduction
The developing arid region (i.e. North Africa, Middle East and Central Asia; ~ 19% of the world's total area) generates massive amounts of fugitive Particulate Matter (fPM) in the form of natural dust, contributing more than 50% of urban PM (Alolayan et al., 2013). On the other hand, the region is suffering an increasing PM load attributed to road traffic and construction, as a result of the rapid urbanization and industrialization taking place in region. Although there is a number of emission models available in literature for the quantification of aeolian and road dust, these models were developed and evaluated for the typical fleets, environments, and climate conditions of Europe and North America, and hence deemed to be uncertain for arid desert climates.

Methodology and Results
EFs and models for wind-blown and vehicle-induced fPM were developed using a combination of field measurements, source apportionment using Positive Matrix Factorization (PMF) model, dispersion modelling, and regression analysis. Two field campaigns were conducted to collect measurements of fPM from a construction site and a road-adjacent site in the Middle Eastern city of Doha. The emission flux of windblown dust was calculated using the Fugitive Dust Model (FDM) and fitted to a power law function that expresses the wind velocity dependence. The fitted functions were considered acceptable (adjusted R^2 0.13-0.69), and the power factors are in the same range of those reported in literature for similar sources. The emission fluxes for non-exhaust traffic PM were modelled using CALPUFF model, and fitted using linear and non-linear regression analysis. The linear regression yielded a fitted EF for non-exhaust traffic PM10 ranging from 220 to 330 mg VKT^{-1} (adjusted R^2 ~0.61-0.64). Our derived models were used to simulate fPM from soil and road network over Qatar for the year 2015. The results showed that annual concentrations over Doha (Fig. 1) exceeded the WHO's recommended limits. Our models showed better performance compared to literature, and the model estimates were within a FAC2 of measurements. Finally, the health impacts were calculated following the WHO's environmental burden of disease method.

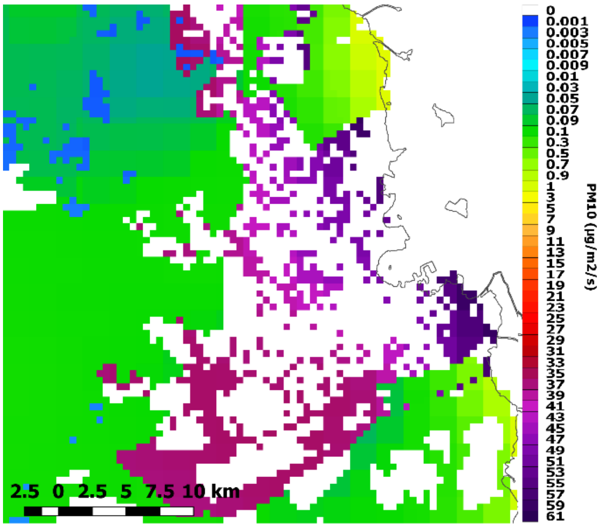

Fig. 1 annual PM10 emissions (µg m^{-2} s^{-1}) from barren lands over Doha

Conclusions
We present one of the first EFs and models to estimate fPM, a major pollution source in arid regions. The outcome of this study is expected to contribute to the improvement of PM emission inventories by focusing on an overlooked but significant pollution sources. Although the results may be plausible, we recommend further investigations to improve emissions modelling of fPM to build a diverse database for the arid desert climates.

Acknowledgement
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SPATIO-TEMPORAL VARIABILITY OF DESERT DUST STORMS IN EASTERN MEDITERRANEAN (CRETE, CYPRUS, ISRAEL) BETWEEN 2006-2017 USING A UNIFORM METHODOLOGY

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Summary

The study aims to evaluate the dust storms characteristics at a regional scale in the Eastern Mediterranean. An algorithm based on daily ground measurements (PM_{10}, particulate matter $\leq$ 10 µm), satellite products (dust aerosol optical depth) and meteorological parameters, was used to identify dust intrusions for three Eastern Mediterranean locations (Crete-Greece, Cyprus, and Israel) between 2006-2017.We observed a high variability in the frequency and intensity of dust storms, characterized by a steady trend with sporadic peaks. The years with the highest dust frequency were not necessarily the years with the most intense episodes. Specifically, the highest dust frequency was observed in 2010 at all three locations, but the highest annual median dust-PM_{10} level was observed in 2012 in Crete and Israel, and in 2010 in Cyprus.

Introduction

The characteristics of dust storms (mainly frequency and intensity) have been shown to change over time, in response to climate change and land use; and their health implications are expected to become more severe (e.g., Goudie 2014). However, there is little information regarding the long-term trends of dust storms at a regional scale as dust identification and analysis methodologies differ across studies. We applied the same methodology to identify dust events and conduct a time trends (2006-2017) analysis of dust storms frequency and intensity for three locations in the Eastern Mediterranean that are highly impacted from dust storms: i) Crete-Greece, which is impacted by long range transport commonly from Africa; ii) Cyprus, impacted by long range transport from both Africa and Middle East; and iii) Israel, impacted by abating deserts of the Arabian Peninsula and long range transport from Africa.

Methodology and Results

We applied the Classification and Regression Tree (CART) algorithm on both ground (PM_{10} concentrations, weather variables) and satellite (Dust-Aerosol Optical Depth, from Copernicus Atmosphere Monitoring Service global reanalysis dataset produced by the ECMWF) measurements to identify dust events where dust was travelling in the lower atmosphere levels but also in the upper levels. We examined the linear (Theil-Sen estimator and Mann-Kendall test of significance) and non-linear trend (Generalized Additive Model with a penalized regression spline function on time) of dust storms characteristics. The CART analysis identified Dust-AOD and PM_{10} as the most significant variables in describing dust storms for all three sites. We observed a non-monotonic trend with inter-annual variability and spatial differences 2006-2017 (see Fig. 1). The year with the highest frequency was not necessarily the year we observed the peaks for other dust characteristics (PM_{10} 24h- average, Dust-AOD, hourly and daily PM_{10} maxima, seasonality). However, the year with the highest dust storms frequency and intensity was the year with the lowest precipitation.

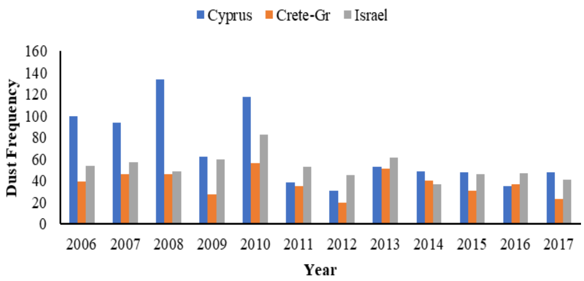

Fig.1 Annual Dust Frequency

Conclusions

We observed a steady trend of dust storms intensity and frequency with sporadic peaks, probably due to the inter-annual variability of local, regional and global climatic conditions. The choice of the study period under examination can affect the outcome, and therefore, future studies are needed to study the changes of dust storms over several decades and in relation to climate change including synoptic-scale conditions.

Acknowledgement

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FINE AEROSOL CHEMICAL COMPOSITION AND SOURCES IN EUROPE USING HIGH TIME RESOLUTION INSTRUMENTATION

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Summary

Atmospheric aerosols exert a negative impact on human health and affect the climate and the environment. These effects are dependent on the size and chemical composition of fine aerosol particles, emitted by different emission sources and generated and influenced by various atmospheric processes. The main challenge of COST Action CA16109 Chemical On-Line cOmpoSition and Source Apportionment of fine aerosoL, COLOSSAL, is to assess the spatial and temporal variability of fine atmospheric aerosols, their chemical composition, and sources in a consistent and repeatable manner.

Introduction

Understanding the human health effects caused by exposure to aerosols, and their impact on the climate and the environment requires an improved appreciation of their variation and origin. The European network COLOSSAL, COST Action CA16109 (https://www.costcolossal.eu/), aims to achieve this by assessing the spatial and temporal variability of fine atmospheric aerosols across Europe, their chemical composition, and sources (Fig. 1). The limited knowledge of organic aerosol (OA) types and sources, as well as the origin of black (BC) and brown (BrC) carbon, makes mitigation a challenge. The COLOSSAL aim is to perform this with high time resolution, gaining further insight into the sources and processes governing the production and evolution of aerosols in the atmosphere.

Methodology and Results

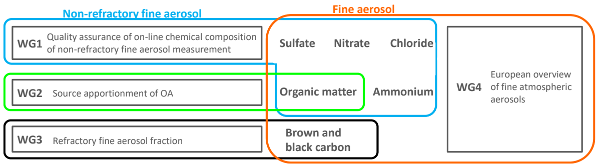

Fig.1 COST Action CA16109 structure.

As of October 2019, 79 institutions from 34 countries have joined their efforts within this Action. The instrumental advances in the last two decades, specifically the development of field-deployable aerosol mass spectrometers such as the Aerosol Chemical Speciation Monitor, fostered new research approaches regarding OA characterization. Non-refractory ammonium, nitrate, sulfate, chloride, and high time resolution organic mass spectra can be quantified (Ng et al., 2011; Fröhlich et al., 2013). The multivariate statistical analysis of such mass spectra ensemble allows the identification of OA components, either linked to primary sources or atmospheric processing (Zhang et al., 2011).
The refractory BC and BrC can be determined using filter photometers - Aethalometers, measuring the light absorption at different wavelengths. The validated measurement methods and coordinated analysis of multi-wavelength light absorption data, allowing the assessment of BrC, is still a very young application field, as is the application of source apportionment models to these data allowing to distinguish BC and BrC origin (road traffic vs biomass burning) (Zotter et al., 2017).

Conclusions and outlook

The processing and interpretation of European data is enhanced within the COLOSSAL network. Activities carried out within the network towards the joint interpretation of refractory and non-refractory aerosol fractions are a step forward. More than 20 one-year datasets for organic aerosol sources and types are being jointly interpreted. Outcomes will be relevant for air quality modellers, epidemiologists and policy makers.

Acknowledgement

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VARIATION OF PM_{10} CONCENTRATION IN THE RESIDENTIAL AREA NEAR THE MAIN TRAFFIC ARTERIES

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Summary
Air pollution is considered responsible for increased morbidity and mortality due to respiratory problems created mainly by long term exposure. Mathematical models are essential tools for most air pollution studies. The air quality models are the means whereby pollutant emissions can be correlated to atmospheric pollutant concentrations. The uncertainties in the assessment of air quality are linked to both the quality of measured values of pollutant concentrations using the different types of devices and the input data for the model. This study aims to analyse the levels of pollution in the urban area in the spring and summer season, where monitoring stations are installed to measure the Particulate Matters (PMs) and meteorological parameters. The Libelium PMs monitoring station includes sensors based on laser technology, and the timestamp for measuring was set-up at 15 min. The improved estimation of air quality consists in combining the measurements results with the results obtained by modelling the emissions from car traffic with the atmospheric dispersion model. The model used in this use case was AERMOD View 9.5. The distribution in space and time of the PM_{10} concentrations were studied. The results of this paper indicate a high correlation between the measured and modelled PM_{10} concentration.

Introduction
Air pollution has a significant influence on health worldwide, globally, 6.5 million premature deaths in 2015 were associated with air pollution (EEA, 2017). The impact of air pollution levels on health are dependent on pollutant concentrations and exposure levels. PMs pollution sources are represented by natural phenomena (i.e. volcanic eruptions, pollen dispersion and carry-over of particles from soil surface by wind velocity) and anthropogenic activities (i.e. production processes, construction sites, and industrial landfills).

Methodology and Results
For the assessment of air quality in the selected area IoT devices was deployed. The data flow architecture (see Fig.1) include an acquisition platform (Libelium) composed of modular acquisition nodes (Waspmotes) and the Meshlium device, which acts as IoT-Gateway. The data acquisition modules connect via 4G / WiFi to the Internet or another (private) network to which Meshlium is connected and sends data to it. Once parsed in the Meshlium, the IoT gateway stored the data in a MySQL database that ensures local persistence of data. Data visualization is then realized with an open platform for analytics and monitoring (Grafana). The model surface was 4 km^2 and the receptor network considered have 121 points, including the one where the monitoring station were deployed. The daily and period time concentration maps for PM_{10} are presented in Fig. 2.

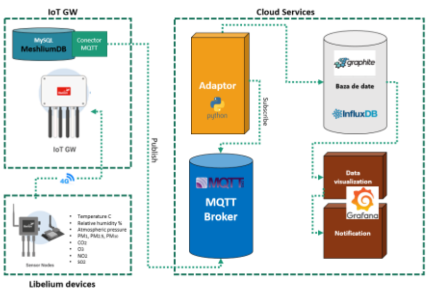

Fig.1 Data flow architecture

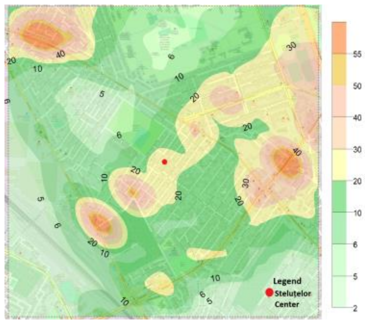

Fig.2 PM_{10} daily concentration

Conclusions
The comparison of modelled and monitored PM concentrations indicates that for general human exposure assessment in the selected area could be used only air dispersion modelling (based on equal mean values). Also, the analysis shows that monitored of PM concentration represent the most adequate value (based on differences registered in variances) for human health impact assessment for sensitive persons (children at risk).

Acknowledgement
This work has been supported in part by Tel-MonAer project subsidiary contract no.1223/22.01.2018, from the NETIO project ID: P 40270, MySmis Code: 105976.

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SPATIAL DISTRIBUTION OF ULTRAFINE PARTICLE NUMBERS RELATED TO ROAD TYPES AND LAND USE CLASSES IN BERLIN-ADLERSHOF

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Summary
This study analyses spatial variability of ultra-fine particles (UFP) at Adlershof in the Southeast of Berlin. Total particle number concentration (PNC) were measured on a 27 km long route both in winter and in summer. PNC was associated with road types and land use classes. After accounting for background concentration, we find reliable correlations of concentration levels and PNC with traffic volume and land use.

Introduction
Spatial and temporal variability of UFP are of high significance regarding exposure and health impacts. The impact of particulate matter on human morbidity and mortality has been well documented (e.g. Atkinson et al. 2015), especially the impact of traffic-induced particles (Khreis et al. 2016). Due to their small size, UFP can be especially harmful because of high lung deposition efficiency and the ability to enter the blood stream directly (Hertel et al. 2010). Since UFP is highly spatially and temporally variable but there are very few continuous measurement stations, modelling spatial patterns provides information on small-scale concentration differences. This study focusses on single localities between the micro- and meso-scale showing the use of Land Use Regression (LUR) to improve statistical spatial modelling, and compares differences between winter and summer.

Methodology and Results
In Berlin-Adlershof, stationary long-term measurements stared 2016 to quantify the effect of weather patterns on PNC of UFP. Mobile measurements were carried out in the surrounding area in 2018 to identify particle sources as well as differences in peaks and background concentrations along the route.
During a winter and a summer campaign respectively, air quality was recorded along a 27 km bike route. The route goes along different road types and includes several land use classes. Measurements took place mostly outside of the rush-hours on 12 days in winter and 16 days in summer, leading to 16 and 27 measurement cycles including different weather conditions and daytimes. Total PNC, air temperature, humidity and wind speed were recorded.
Stationary as well as mobile measurements show that the variability of PNC depends largely upon time due to fluctuations in particle sources – during the day as well as the week – and changing background concentrations. PNC still differs for various spatial contexts and depending on weather conditions even after the data has been processed with respect to high temporal variability. We show that spatial patterns can only be analysed and explained once the influence of temporal variability (background concentration) has been deducted. For the modelling of spatial patterns, either the given background concentration must be included or only the local additional load must be considered. Due to the low data density regarding UFP measurement data, this modelling is largely constrained.
The results indicate substantial links between total PNC and road types as well as land use, in peak and background concentrations as well as in the spread of observed concentrations. Surroundings in between built-up areas show on average 25 – 50 % higher concentrations from local sources than green areas during the summer campaign. Roads with a higher traffic volume show not only higher average and maximal concentrations but also higher statistical spread. Expectedly, during days with higher wind speed, the concentrations are lower, especially during situations with wind from Southwest.

Conclusions
This study shows the relevance of including background concentrations in the modelling of spatial patterns of PNC. Land use regression provides a statistical method to explain spatial patterns of UFP and improves models especially when including the influence of roads.

Acknowledgement
This study is part of the Project ‘B-3DO’ within the program ‘Urban Climate under Change [UC²]’ funded by the German Federal Ministry of Education and Research (BMBF) within sub-project URBMOBI-GIS, grant No. 01LP1602B. We thank all the project partners within (UC²) for their support.
This study was financially supported by the Caroline von Humboldt program of the Humboldt-Universität zu Berlin.

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Short Presentations

INFLUENCES OF METEOROLOGICAL PARAMETERS ON FINE PARTICLE AND BLACK CARBON EXPOSURE LEVELS INSIDE BUSES IN SÃO PAULO

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Summary
This work aims to investigate the impact of meteorological parameters on commuter exposure to fine particulate matter ($PM_{2.5}$) and black carbon (BC) inside buses in the city of São Paulo, Brazil. We carried out a field campaign measuring the commuter exposure to $PM_{2.5}$ and BC concentrations inside bus cabins in São Paulo and correlated it with the meteorological data (from Agua Funda Meteorological Station/IAG-USP - AFMS) and $PM_{2.5}$ concentrations outside bus cabins (from several downtown CETESB Air Quality Stations - AQS). The results showed that the average exposure was 19±8 μg/m^3 to $PM_{2.5}$ and 10±5 μg/m^3 to BC. Negative significant correlations were found between wind speed and $PM_{2.5}$ exposure levels. Positive significant correlations were found between temperature/relative humidity and $PM_{2.5}$ exposure levels. Also, positive correlations were found among AQS and $PM_{2.5}$ exposure levels. No significant correlation was found with BC.

Introduction
$PM_{2.5}$ and BC have extensively been associated to adverse health effects, particularly with cardiovascular and respiratory diseases and even cancer (Jansen et al., 2005; Kim et al., 2015). The proximity of commuters to on-road vehicles makes them directly exposed and vulnerable to traffic related air pollutants, especially $PM_{2.5}$ and BC. Thereby, in this work we: (i) assess the commuters' exposure to $PM_{2.5}$ and BC inside the transport microenvironments, especially inside buses, where several studies indicated the highest air pollutants concentration values among transport modes, and (ii) investigate the role of meteorological parameters in exposure levels in the city of São Paulo.

Methodology and Results
Commuters' exposure to $PM_{2.5}$ inside bus cabins was measured in the urban area of São Paulo during seven days in the summer (16 – 23 February) of 2017. In total, more than 39 hours of measurements in four different bus lines were sampled. A portable aerosol monitor (DustTrak TSI 8530) was carried inside a custom backpack, with a $PM_{2.5}$ inlet fixed in the breathing zone. The average exposure concentration measured inside bus cabins was 19±8 μg/m^3 and 10±5 μg/m^3, to $PM_{2.5}$ and BC, respectively. Outside bus cabins, the average $PM_{2.5}$ concentration was 14±8 μg/m^3. In AFMS, temperature and relative humidity are hourly measured, and wind speed is an hourly averaged value. $PM_{2.5}$ of AQS is also hourly averaged. We calculated Pearson correlations among all parameters with the exposure concentrations measured inside bus cabins made during the following hour, and the results are shown in Table 1. $PM_{2.5}$ exposure levels showed negative correlation with wind speed ($r = -0.49$; $p < .05$) and temperature ($r = -0.41$; $p < .05$). Relative humidity was found to be positive correlated with exposure levels in buses ($r = 0.36$; $p < .05$). We found positive significant correlations between $PM_{2.5}$ from AQS and bus commuters' exposure to $PM_{2.5}$. No correlation was found for BC exposure levels.

Table 1 - Pearson's correlation coefficient (r) between meteorological parameters of AFMS or $PM_{2.5}$ concentrations in AQS and $PM_{2.5}$/BC exposure levels inside buses. Correlations in bold are significant ($p < 0.05$).

	Parameter (unit)	**Correlation (r)**	
		$PM_{2.5}$ (n=39)	BC (n=41)
AFMS	Temperature (°C)	**-0.41**	-0.23
	Relative Humidity (%)	**0.36**	0.10
	Wind Speed (km/h)	**-0.49**	-0.31
AQS	Pq. Dom Pedro (μg/m³)	**0.58**	0.06
	Ibirapuera (μg/m³)	**0.56**	-0.02
	IPEN (μg/m³)	**0.46**	-0.07

Conclusions
The negative correlations demonstrate that higher wind speeds and temperatures have a role on reducing $PM_{2.5}$ levels by enhancing mechanical and thermal turbulence. In addition, the positive correlation between exposure levels and $PM_{2.5}$ in AQS points the strong connection between ambient pollution and commuter exposure. $PM_{2.5}$ concentration inside bus cabins were on average 1.4 times higher than the concentration outside. The absence of significant correlations between meteorological parameters and BC exposure levels can suggest that the turbulence generated by higher temperatures and wind speeds, or the deposition of particles due to high relative humidity are incapable of reducing solely the concentration levels, and that BC is associated to more local sources when compared to $PM_{2.5}$. This study can elucidate the determinants on bus commuter's exposure to fine particles. Further investigation is necessary.

Acknowledgement
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DIFFERENTIAL GENE EXPRESSION OF WISTAR RATS IN IMMUNOLOGICAL CELL-SIGNALING PATHWAYS AFTER EXPOSURE TO PM2.5 AND PM1 AMBIENT PARTICLES

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Summary
The current study aimed at exploring the differential gene expression in Wistar rats, after exposure to $PM_{2.5}$ and PM_1 ambient air particles for an eight-week period. In parallel, filtered PM2.5 and PM1 was collected in separate samplers. Gene expression analysis after microarrays analysis showed significantly altered gene expression of several immunological markers. This study showed that natural exposure to PM2.5 and PM1 induced airway and lung inflammation and moreover it triggered a T-helper type 2 inflammatory (Th2) response upregulating the gene expression of interleukin-4 (IL-4), IL-5, IL-13 and IL-25. Interleukins 5 and 13 can lead to eosinophilia and goblet cell hyperplasia and both play an important role at the immune response in mucosal sites such as the airway epithelium. In addition, gene expression analysis revealed pathway activation of the aryl hydrocarbon receptor (AhR), which is a ligand-dependent transcription factor that is involved in the detection of intracellular changes and sensing oxygen and redox potential.

Introduction
Particulate matter (PM) is one of the most important environmental issues in Europe. The toxicity induced by PM2.5 and PM1 is a combination of effect of particles, adsorbed toxic compounds, biological components such as endotoxin, pollen, fungal spores, viruses, and bacteria, polycyclic aromatic hydrocarbons (PAHs), volatile organic compounds (VOCs) and heavy metals (Wang et al., 2018). Up till now there is no study that analyzed the differential gene expression after natural exposure to PM2.5 and PM1. In order to understand the biological mechanisms triggered by PM2.5 and PM1 exposure that lead to airway inflammation, in this study, we aimed at evaluating the following hypotheses: (1) How natural exposure to PM2.5 and PM1 in Wistar rats can alter the gene expression after whole genome analysis in comparison to the control group; (2) What is the type of immune response triggered after exposure to PM2.5 and PM1; (3) How gene expression is altered in rats after exposure to PM2.5 and PM1 from a traffic-related area would correlate with the concentrations of other measured components such as PAHs and heavy metals.

Methodology and Results
An eight-week exposure campaign was carried out between August and October of 2019 in a location in the urban area of Thessaloniki. The urban background site is located in the Kalamaria district of Eastern Thessaloniki. Briefly, nine 10-week old Wistar rats were randomly separated in three groups (PM2.5, PM1, control) in modified plexiglass cages that were connected to Tecora samplers with an operational flow rate of 2.3 m^3h^{-1} of filtered air. In parallel, while the experiment was running another two samplers were used to collect PM2.5 and PM1 samples on PTFE filters (pall Corporation, 47 mm diameter) for 24 h. After animal euthanasia blood and tissues were collected for microarray gene expression analysis using a SureScan array from Agilent. Analytical techniques such as X-Ray Fluorescence Spectroscopy and GC/MS/MS were used to determine and quantify the composition of PAHs and metals. Results showed a significant two-fold up-regulation in expression of genes related to interleukins connected to a Th2 inflammatory response such as IL-4, IL-5, IL-13 and IL-25. In addition, genes related to the AhR-pathway and to oxidative stress where up-regulated. Moreover, PM-component analysis showed high concentrations of Pb (Lead) and V (Vanadium).

Conclusions
Besides the increased amount of research, we are still lacking knowledge on the biological mechanisms triggered by exposure to PM2.5 and PM1 ambient air particles. In the current study, a whole-body natural exposure of Wistar rats to PM2.5 and PM1 was performed for eight weeks. Gene expression analysis showed an up-regulation of a Th2 inflammatory response. Still further research needs to be performed to elucidate further the biological mechanisms triggered after exposure to PM2.5 and PM1.

Acknowledgement
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ATHLETES' EXPOSURE TO AIR POLLUTION DURING IAAF WORLD RELAYS: A PILOT STUDY

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Summary
A comprehensive air quality assessment was carried out during the IAAF World Relays Yokohama 2019, in order to propose and test a methodology aiming to understand the association between air quality, athletic performance and exacerbation of respiratory diseases. It was included on-line and off-line instrumentation for air pollutants and meteorological parameters. Personal exposure to polycyclic aromatic hydrocarbons was quantified through silicone wristbands, a novel and simple approach to assess potentially toxic organic compounds. Finally, air quality perception and exacerbation of symptoms of already-diagnosed diseases were assessed by athletes through questionnaires during training sessions.

Introduction
Some adverse effects of exposure to air contaminants during exercise include exacerbation of asthma, decreases of the lung function, as well as exercise-induced bronchoconstriction. These effects are more relevant for athletes during their trainings and competitions, since they could affect to their athletic performance. In this context, evaluating and mitigating the exposure of air contaminants during the exercise should be manage in sports venue. The study performs a comprehensive air quality evaluation during the IAAF World Relays Yokohama 2019, in the warm-up track and in the main stadium.

Methodology and Results
The study was carried out using on-line and off-line instrumentation for particulate and gaseous contaminants and for meteorological parameters, which were compared with local reference data. Questionnaires during the training sessions were filled in to assess air quality perception as well as exacerbation diseases symptoms already diagnosed (respiratory and cardiovascular). NO_2 concentrations inside the stadium (25.2-33.7 μgm^{-3}) were comparable with the Yokohama urban background, demonstrating the impact of urban sources (e.g., traffic) on athletes' exposure during the competition and the training. The study shows how the assessment of the hourly air pollutant trends are useful to provide guidance for reducing athletes' exposure, identifying the day periods with the lowest air pollutant concentrations. Finally, the polycyclic aromatic hydrocarbons (PAHs) exposure was analysed using silicone wristbands.

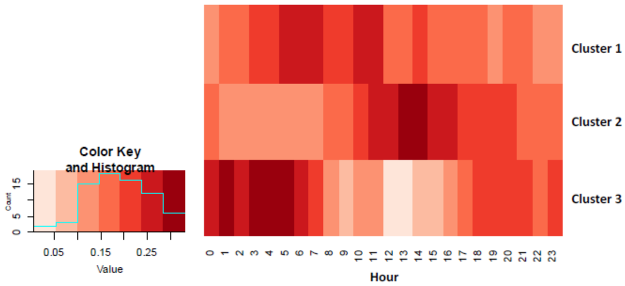

Figure 1. Heatmap of the k-Means clustering applied to the hourly variation of all the available air quality parameters.

Conclusions
The assessment of hourly air pollutant could be a valuable tool to schedule training and competitions. Moreover, this would have special added value for athletes with respiratory conditions. Regarding the wristbands, they are a simple approach to assess personal exposure to potentially PAHs, however they show a high variability across volunteers due to body lotions and perfumes onto the skin. Further research would be necessary regarding the specific air contaminants that may intensify respiratory conditions typical of the athlete community. Finally, the availability of high time-resolved exposure data in stadiums brings up the possibility to study the doses of specific pollutants for individual athletes, in order to understand the impact of air pollutants on athletic performance.

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Special Session – Air Pollution and Health

AN INTERDISCIPLINARY VIEW ON AIR POLLUTION AND IS IMPACT ON HEALTH AND WELFARE IN THE NORDIC COUNTRIES

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Summary
By combining detailed air pollution maps with unique health registers and socio-demographic data for the Nordic region, the NordicWelfAir project is exploring the potential for improving our understanding of the negative impacts of air pollution – for both the human health and the society in general. This requires an interdisciplinary approach. We will present an overview and highlights from this on-going project.

Introduction
The overall aims of NordicWelfAir are: 1) to further understand the link between air pollution levels, the chemical composition of the pollution and the associated health effects, and 2) to investigate, assess and compare the effects of air pollution on the distribution of associated health impacts, socio-economic and welfare impacts in the Nordic countries. The interdisciplinary research collaboration is on-going (2015-2021) and involves 16 research partners from the five Nordic countries.

Methodology and Results
1) A detailed common Nordic emission inventory down to 1 km x 1 km resolution is constructed. 2) Integrated modelling, where a state-of-the-art advanced air pollution model systems from global to national scale are used for calculation of high resolution air pollution levels (1979-2018). 3) Identification and analysis of health effects of air pollution are investigated. 4) An assessment of the overall negative health outcomes of air pollution in terms of e.g. premature deaths in the Nordic countries for selected population groups, using alternative approaches (including Lehtomäki et al. 2018) and ultimately upgrading the integrated model system EVA. 5) Distribution of welfare impacts and the challenges air pollution and associated effects pose for the Nordic welfare systems.

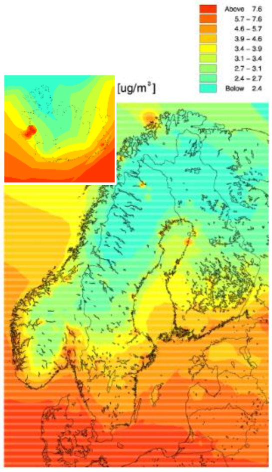

Fig.1 Example of the modelled (DEHM/UBM) $PM_{2.5}$ conc. (1 km x 1 km) across the Nordic region (note: different scale for Iceland).

Conclusions
Based on a 40-year long model simulation with the DEHM/UBM, SILAM and MATCH model systems (Fig 1), new health and welfare studies are in progress. This includes a Danish cohort study, where we find higher risks of all-cause and cardiovascular disease mortality with higher long-term exposure to air pollution (Hvidtfeldt et al. 2019). The link with socio-economic data indicates that the burdens of air pollution are not shared equally across population groups in Norway (Moss, 2019). Lack of policy integration and insufficient sharing of governing capacity are among the key barriers identified for addressing air pollution and uneven distribution of health and welfare costs, while this varies across the Nordic countries and across levels of governance.

Acknowledgement
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HEALTH EFFECTS OF CLIMATE CHANGE IN EUROPE: THE EXHAUSTION PROJECT

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Summary
The project "Exposure to heat and air pollution in Europe – cardiopulmonary impacts and benefits of mitigation and adaptation" (EXHAUSTION) aims to quantify the changes in cardiopulmonary mortality and morbidity due to extreme heat and air pollution (including from wildfires) under selected climate and socio-economic pathway scenarios while including a diverse set of adaptation mechanisms and strategies. The project will estimate the associated costs of health effects and identify effective strategies for minimizing adverse impacts.

Introduction
Global warming increases the likelihood of heat waves and wildfires. Both are deadly. While extreme heat increases death and disease rates from cardiopulmonary disease (CPD), wildfires cause severe air pollution, with adverse impacts for cardiopulmonary health as well. CPD is highly prevalent in Europe and increases with an ageing population. Extreme heat and air pollutants could multiply their effects by acting on the same pathophysiological pathways. In Europe, extreme heat is identified as a key climate change risk in the near and long term (EEA, 2017). We review existing research gaps and present the content and innovative aspects of EXHAUSTION and excerpts from the project's review studies on exposure-response, climate-air quality links, and adaptation strategies.

Methodology and Results
Based on the most updated and advanced climate modelling efforts, the EXHAUSTION project will develop population exposure projections for extreme temperatures and air pollution for Europe. It will draw on health registries, including a time-series database in a multi-country observational study and rich cohort data bases from several countries, to investigate the exposure-response relationship between heat, air pollution and CPD, including potential interactive effects. The epidemiological analyses will help identify vulnerability indicators in populations across Europe and will inform the development of advanced adaptation strategies to identify how, e.g., age, sex and socio-economic status affect the prediction of probabilities for CPD arising from extreme heat and wildfires. The economic costs of the attributable CPD cases and related benefits of adaptation options will be estimated and integrated in a macroeconomic model to project the consequences of the CPD burden for the European economies (Fig. 1).

Conclusions
The interdisciplinary work of EXHAUSTION's 14 partners from across Europe makes a considerable effort in bridging an important science-policy gap. The quantification of costs and benefits of climate action (mitigation and adaptation) will enable specific stakeholders (e.g., policy advisors, policy makers, and health professionals) to make evidence-based decisions, selecting the best possible actions to alleviate climate change-induced ill health.

Acknowledgement
The project lasts for four years (2019-2023) and is supported by EU's Horizon 2020 programme (European Commission contribution 6.7 million Euros, grant agreement 820655).

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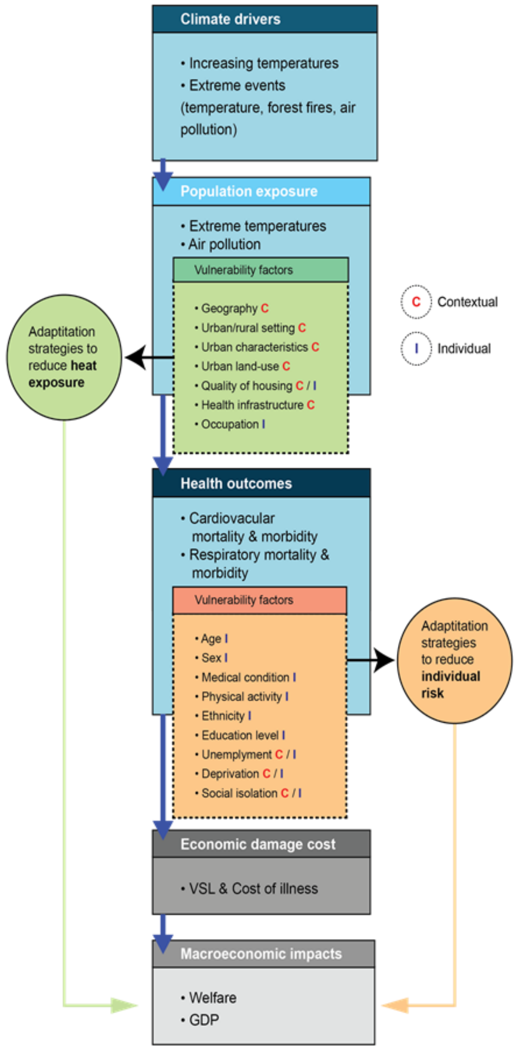

Fig. 1. The causal pathway to health and economic impacts of climate change addressed in EXHAUSTION. VSL: Value of Statistical Life

MODELLING OF THE PUBLIC HEALTH COSTS OF FINE PARTICULATE MATTER AND RESULTS FOR FINLAND IN 2015

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Summary

We have developed an integrated tool of assessment that can be used for evaluating the public health costs caused by the concentrations of fine particulate matter ($PM_{2.5}$) in ambient air. The model can be used in assessing the impacts of various alternative air quality abatement measures, policies and strategies. The model has been applied for the evaluation of the costs of the domestic emissions that influence the concentrations of $PM_{2.5}$ in Finland in 2015. It was found that economically the most effective measures would be the reduction of the emissions in urban areas of (i) road transport, (ii) non-road vehicles and machinery, and (iii) residential wood combustion. The reduction of the precursor emissions of $PM_{2.5}$ was clearly less effective, compared with reducing directly the emissions of $PM_{2.5}$. We have also designed a user-friendly web-based tool of assessment that is available open access.

Introduction

The overarching aim of this study was to develop an integrated tool of assessment for evaluating the public health costs caused by the ambient air concentrations of fine particulate matter ($PM_{2.5}$). The model includes the impacts on human health; however, it does not address the impacts on climate change or the state of the environment.

Methodology and Results

First, the national Finnish emissions were evaluated using the Finnish Regional Emission Scenarios model (FRES) on a resolution of 250 x 250 m^2 for the whole of Finland. Second, the atmospheric dispersion was analyzed by using the chemical transport model SILAM and the FRES model. Third, the health impacts were assessed by combining the spatially resolved concentration and population datasets, and by analyzing the impacts for various health outcomes. Fourth, the economic impacts for the health outcomes were evaluated. The model can be used to evaluate the costs of the health damages for various emission source categories.

Source category and the emission height	Region, in which the reduction of emission takes place		
Emissions at low height	**Urban area**	**Non-urban area**	
Road transport, primary $PM_{2.5}$	140 (80–320)	13 (7.6–31)	
Non-road and machinery, primary $PM_{2.5}$	170 (100–390)	5.0 (2.8–11)	
Residential houses, wood and sauna stoves, primary $PM_{2.5}$	70 (40–160)	8.7 (4.8–19)	
	Whole of Finland		
Recreational houses, wood stoves and sauna stoves, primary $PM_{2.5}$	5.5 (3.1–13)		
Residential houses, wood boilers, primary $PM_{2.5}$	12 (6.6–27)		
Road transport, NO_x emissions forming secondary $PM_{2.5}$	0.82 (0.46–1.8)		
Agriculture, NH_3 emissions forming secondary $PM_{2.5}$	1.2 (0.70–2.8)		
Emissions at substantial height	**Helsinki capital area**	**Municipalities with > 50 000 inhabitants**	**Other areas**
Industry and power plants, primary $PM_{2.5}$	20 (11–44)	6.9 (3.9–16)	5.4 (3.1–12)
	Whole of Finland		
Industry and power plants SO_2 emissions forming secondary $PM_{2.5}$	1.3 (0.73–3.1)		
Industry and power plants, NO_x emissions forming secondary $PM_{2.5}$	0.43 (0.24–1.0)		

Table 1. Economic benefits obtained by the assumed reductions of emissions, in thousand euros per ton of emissions. The results are presented for the various source categories, in various domains. The first presented value has been computed based on the average value of life year, and the two values in parenthesis based on the median value of life year and the

Conclusions

The economic benefits were clearly largest for the emission reductions for the source categories that have low emission heights, such as vehicular traffic, non-road and machinery, and residential wood combustion. For all source categories, the emission reductions were substantially more effective, even by an order of magnitude, in the urban areas, compared with those in rural areas. The reduction of the precursor emissions of $PM_{2.5}$ was clearly less effective, compared with reducing directly the emissions of $PM_{2.5}$. The models and the numerical results can be used to inter-compare the cost-efficiency of different potential emission mitigation measures and strategies.

Acknowledgement

We acknowledge the Government of Finland and Nordforsk, the project 'Understanding the link between Air pollution and Distribution of related Health Impacts and Welfare in the Nordic countries (NordicWelfAir)'.

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REVIEW ON THE METHODOLOGY SUPPORTING THE HEALTH IMPACT ASSESSMENT BY THE EUROPEAN ENVIRONMENT AGENCY

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Summary

This paper describes the methodology applied to assess health impacts across Europe in 2016, published in the latest European Environmental Agency's (EEA) *Air Quality in Europe* report (EEA, 2019). The methodology applied is based on the work by de Leeuw and Horálek (2016), with a few adjustments. To illustrate the health impact related to the air pollution, the number of premature deaths (PD) and years of life lost (YLL) were estimated for fine particulate matter ($PM_{2.5}$), ozone (O_3) and nitrogen dioxide (NO_2). Moreover, a sensitivity analysis was undertaken to comprehend how much the presumed baseline concentration levels (C_0), the concentration below which no health effects are expected, affect the estimations. In addition, a benefit analysis, assuming attainment of the WHO guidelines across Europe in terms of health outcomes, shows a reduction of around 30 % of the 2016 PD and YLL levels.

Introduction

The exposure to ambient air pollution leads to adverse effects on human health and ecosystems. Epidemiological studies have shown that especially the exposure to pollutants such as $PM_{2.5}$, O_3, and NO_2 is associated with cardiovascular and respiratory diseases leading to increased sickness, hospital admissions and premature death (Beelen et al., 2014). Thus, assessing health impact attributed to air pollutants is critical to manage air pollution risks.

Methodology & Results

The assessment presented here is based on the methodology by de Leeuw and Horálek (2016) with some adjustments to reflect the year in question. To calculate PD and YLL, population and demographic data per country, age, and sex was combined with gridded concentrations (EEA, 2019). The estimation of the relative risk followed the recommendations in the HRAPIE project (WHO, 2013). For $PM_{2.5}$, all-cause (natural) mortality is considered in ages above 30, for all concentrations, assuming an increase in the risk of mortality of 6.2 % for a 10 µg/m3 increase of $PM_{2.5}$. For NO_2, all-cause (natural) mortality is considered in ages above 30, for concentrations above 20 µg/m3, assuming an increase in the risk of mortality of 5.5 % for a 10 µg/m3 increase of NO_2. For O_3, all-cause (natural) mortality is considered for all ages assuming an increase in the risk of mortality of 0.29 % per 10 µg/m3 increase of O_3 values over 35 ppb. PD and YLL are estimated per grid cell, then summed-up to obtain results per country. The largest health impacts (YLL) are estimated for the countries with the largest populations. However, in relative terms, when considering YLL per 100 000 inhabitants, the largest relative impacts are observed in central and eastern European countries, and the lowest are found the northern and north-western parts of Europe. Sensitivity and benefit analysis studies were carried out and benchmarked against the current 2016 calculation. The sensitivity analysis assumed different C_0 for $PM_{2.5}$ ($C_0 = 2.5$ µg.m^{-3}) and NO_2 ($C_0 = 10$ µg.m^{-3}), while for O_3 SOMO10 was calculated instead of SOMO35. The analysis indicates that such changes can have considerable impacts on the results. The largest impact is for O_3 and NO_2, with an increase over 70 % on PD and YYL, and the lowest for $PM_{2.5}$, with a decrease of ~21%. The benefit analysis was calculated by assuming that all grid-cells across Europe with annual mean concentrations in 2016 above the WHO guidelines of $PM_{2.5}$ and NO_2 will be in attainment. For $PM_{2.5}$, the results show a considerable reduction (of 30%) in the estimated PD and YLL on average when the WHO guideline (10 µg/m3) is attained across Europe. The reduction for NO_2 is less significant, with a estimated 2.4 % reduction when WHO guideline (40 µg/m3) is attained across Europe.

Conclusions

Health impacts due to exposure to air pollution across Europe remain high, especially over central and eastern European countries. The use of different C_0 can have an important impact on the estimation of PD and YLL, with the lowest impact on $PM_{2.5,}$ and the highest on O_3 and NO_2 estimations. Furthermore, the attainment of the WHO guideline shows for $PM_{2.5}$ would lead to a 30% reduction, on average, in PD and YLL in Europe.

Acknowledgement

This work was founded by the EEA and co-founded by the Norwegian Ministry of Climate and Environment. The authors would like to gratefully thank Frank de Leeuw (National Institute for Public Health and the Environment) for his assistance.

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PAHS IN FINE PARTICULATE MATTER OF SIX EUROPEAN CITIES: SEASONAL AND SPATIAL VARIATIONS AND IMPLICATIONS FOR HUMAN HEALTH

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Summary

This study aims to evaluate the spatial and seasonal variations of polycyclic aromatic hydrocarbons (PAHs) from six European cities. In order to reach this goal, fine particles ($PM_{2.5}$) were collected on a daily basis in winter and summer at a traffic, an urban background and a rural site in each of the cities involved. Higher PAH levels were found in winter compared to summer. In winter, PAH concentrations were the highest at Brno compared to the other cities involved. The cancer risks from inhalation of PAHs were evaluated for each city.

Introduction

PAHs are mainly emitted in urban areas by anthropogenic sources (i.e. traffic, domestic heating, biomass burning). In air, they are partly carried by particulate matter. A number of these compounds are carcinogens. The aim of this study is to provide novel atmospheric data on PAHs at various types of site and different seasons across European cities. Six cities involved in the project ICARUS were chosen. The seasonal and spatial variations as well as the implications for human health were investigated.

Methodology and Results

In this study, 24-h air samples of fine particles (i.e. $PM_{2.5}$) were collected using an active air sampler and quartz fibre filters for 30 days in each winter and summer at a traffic, an urban background and a rural site at/near Athens, Brno, Ljubljana, Madrid, Stuttgart and Thessaloniki. The filters were extracted and analyzed by means of gas chromatography coupled to mass spectrometry.

PAH levels were significantly higher in winter compared to summer in all cities investigated. These seasonal variations can be attributed to increased sources such as domestic heating or higher cold-start emissions from traffic, but also lower atmospheric boundary layer and higher gas-to-particle conversion and, probably, longer atmospheric lifetimes in winter. Nitro- and oxy-PAHs, which were also analysed in the samples from Brno and Ljubljana, showed similar seasonal variations.

Concerning the spatial distributions, the winter PAH concentrations found at Brno in central Europe were the highest. In terms of variability within the city, large differences were found among the cities. For example, in Brno, the highest PAH levels were found at the traffic site while the lowest were found at the rural site for both seasons, highlighting that traffic is the most important PAH source within the city. On the other hand, in Athens, the highest PAH levels in winter were found at the rural site, which could be due to the increase in the usage of wood combustion for domestic heating in rural areas since the economic crisis. In Ljubljana, no significant differences in the PAH concentrations were found between the traffic and the urban background sites which suggest that traffic is not controlling the PAH levels within the city. In winter, it was found that traffic controlled the nitro-PAH levels in Brno and Ljubljana but not those of oxy-PAHs.

For each of the sites involved, human health risks resulting from outdoor workday inhalation exposure will be evaluated with respect to the risk of developing cancer using a probabilistic approach. In addition, these derived cancer risks will be compared with those obtained when taking into account the PAH particle size distribution, the bioavailable fraction of the PAHs, including the ones estimated for nitro- and oxy-PAHs, if available.

Conclusions

This study has shown that PAH levels in $PM_{2.5}$ in urban areas are subject to large seasonal and spatial variations, considerably contributing to cancer incidence risk from inhalation exposure.

Acknowledgement

This project was supported by the European Union's H2020 Framework Programme (ICARUS project) under grant agreement No – 690105 and by the RECETOX (LM2015051) and ACTRIS (LM2015037) research infrastructures funded by the Ministry of Education, Youth and Sports of the Czech Republic and the European Structural and Investment Funds (CZ.02.1.01/0.0/0.0/16_013/0001761 and CZ.02.1.01/0.0/0.0/16_013/0001315).

HEALTH RELATED COST-BENEFIT ANALYSIS OF EMISSION REDUCTION MEASURES UNDER THE NEC DIRECTIVE FOR 2030

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Summary
In the scope of the new National Emission Ceilings (NEC) Directive, this work focuses on the health related cost-benefit analysis of emission reduction scenarios designed for Portugal. The general methodology is based on the application of a modelling approach starting by an environmental-economic model to generate an optimal spatial distributed emissions scenario to attain NEC targets at least cost, then using an air quality model to estimate the air quality impacts and finally considering concentration-response functions to estimate health impacts and monetary benefits (external costs) that are compared with internal costs of the optimal scenario measures to perform a cost-benefit analysis. This presentation will highlight the methodological approach and the main outcomes to support the development of the National Air Pollution Control Programme and the implementation the NEC Directive in Portugal.

Introduction
The National Emission Ceilings (NEC) Directive published in December 2016 sets stricter limit values for the pollutants NOx, SO2, NH3, NMVOC and PM2.5 to be attained by 2030.
This work aims to present the main outcomes of the recently concluded research project FUTURAR that aimed to identify a set of measures to fulfil the NEC Directive at least cost and to estimate the impacts, costs and benefits on air quality and health.

Methodology and Results
The EESIP-Air environmental-economics model was applied to an optimal (least-cost) scenario in terms of emission totals, as to obtain the corresponding spatial distribution of emissions resulting from the regional and sectorial application of measures with the highest potential emission reduction at the least cost. Figure 1 depicts the country totals and the share by activity sector obtained for the optimal scenario for the pollutants addressed by the NEC directive, and the corresponding values for the EMEP gridded emissions inventory for 2015, as the baseline for the present study.

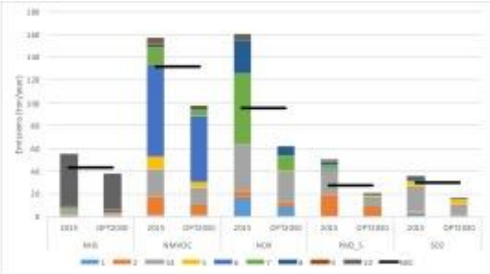

Fig.1 Total annual emissions (kton) and emission share by SNAP sector for the 2015 emission inventory and the optimal scenario (NEC represented by a black line).

Air quality impacts were evaluated by the application of WRF-CAMx air quality modelling system over Portugal at 5x5 km^2 for the optimal scenario and for a baseline scenario. Concentration deltas by grid cell and pollutant, together with population data and appropriate morbidity and mortality health indicators were used to estimate health impacts of long-term exposures. Two approaches for Concentration-Response Functions (CRF) were considered and compared in terms of results obtained – the linear ones recommended by HRAPIE project and the non-linear functions from WHO (2018). As an example Figure 2 displays the health benefit spatial distribution for NO2 related mortality. The cost-benefit analysis was then computed considering the implementation cost of the proposed measures and the external costs related to health benefits of the optimal scenario.

Conclusions
The optimal scenario evidences the need to implement measures for industry and agriculture beyond the current legislation commitments leading to an improvement of air quality and health in Portugal, especially in the two main urban areas of Porto and Lisbon, where the biggest and most costly effort on reductions is foreseen, and thus allowing fulfilling the NEC and also the air quality limit values in 2030. The comparison of CRF approaches highlights the large uncertainty in estimating health impacts of air pollution.
The outcomes of FUTURAR contribute to the NEC directive implementation in Portugal through the support to the development of the National Air Pollution Control Program for Portugal.

Acknowledgement
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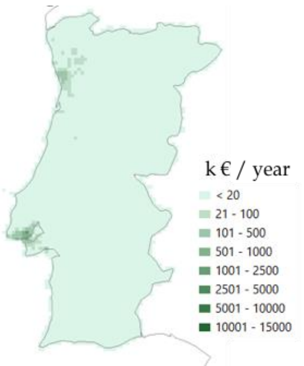

Fig.2 Benefit regarding the total mortality indicator due to exposure to NO_2

AIR POLLUTION, HEAT AND HEALTH DURING SUMMER 2018 AND 2019 IN GERMANY

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Summary
Since the beginning of this century unusual extreme summer heat events occurred in Germany more frequently, added and combined with an increased ozone background concentration level. The study examines extraordinary environmental exposure situations with extreme heat and high ozone concentration, resulting in acute health impacts (shown by morbidity and mortality data), predominantly for the elderly people countrywide during the extreme summer events of 2018 and 2019.

Introduction
High temperatures and ozone concentrations have periodically affected large areas in Europe (mostly in the south), particularly in urban settings. In Germany, about 75% of the population living in urban areas and at risk of multiple exposures. There is evidence that episodes of heat and poor air quality pose significant consequences for public health, as single impact and in combination. Summer heat is an additional driver for and connected with increasing photochemical concentration, such as tropospheric ozone, and the main challenge of health-related impacts on public health in view of climate change. Burning of fossil fuels increases both health-related air pollution concentrations, as well as air emissions relevant to the climate.

Methods and Results
The environmental burden of both measurements of ozone (data source: Federal Environmental Agencies) and air temperature during the summer seasons of 2018 and 2019 (data source: German Met Service) have been investigated at four big urban agglomerations (Hamburg, Berlin, Frankfurt/Main and Munich), considering the specific inner-city exposure situation of urban heat islands. Various threshold values are explored to identify events combined with a high burden of ozone and heat. For the first time, public health data on heat-related morbidity of non-communicable diseases of a pilot study in Frankfurt/Main has been taken into consideration.

During the extreme summer heat events of 2018 and 2019 record temperatures were measured by duration (up maximum of 18 consecutive days above 30 °C in 2018) and maximum (42.3 °C in 2019). The number of days with a daily maximum temperature above 30 °C is similar at the different sites whereas during night minimum temperatures (daily minimum temperature above 20 °C) appear much more frequent at the built-up city centre compared to the suburbs (factor > 3). The study showed spatial differences for these episodes between the four cities, with a gradient from North to South. After many years of reduced ozone burden during these summer heat events ozone peaks have reached concentration above 180 µg/m³ (1-h mean value). Results reveal that heat events are accompanied by increased ozone concentration, especially during the most intense and longest heat events, resulting in a considerable number of excess mortality cases. Besides, morbidity data of severe acute services, such as hospital admission, emergency department visits and emergency service calls were used for heat-related morbidity surveillance in Frankfurt/Main. The assessment of the long lasting extreme heat episode of summer 2018 showed a significant increase of heat related mortality and morbidity, such as unclear fever and exsiccosis, particularly for the elderly population.

Conclusions
Heat events have been shown to be temporally co-occurring with high ozone concentrations, with the highest probability for most intense and longest extreme heat episodes. Due elderly people are predominantly threatened with health-related problems during summer extremes, health systems need to be better prepared and gradually adapt to the effects of extreme heat in combination with high ozone events driven by climate change. Furthermore, a registry of vulnerable people at risks, for example form heart and pulmonary/airway diseases, could be of essential support for general practitioners and hospital emergency units at the local level.

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AIR POLLUTION HEALTH IMPACT ASSESSMENT OF FIVE WIN-WIN POLICIY SOLUTIONS AT THE URBAN SCALE IN THE CITY OF MILAN

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Summary

This study aims at presenting the results of air quality improvements on the environment and human health brought by the potential implementation of five selected policy options as *win-win solutions* at the urban scale in the city of Milan (Italy). To this end, for each of the selected policy, the following effects have been evaluated: (a) change in emissions of major air pollutants; (b) change in emissions of greenhouse gases (GHGs); (c) changes in ambient concentration of air pollutants; (d) changes in the exposure to air pollutants; (e) changes in the associated impacts on human health. The impacts of the five selected policy options were carried out under the assumption of RCP4.5 scenario for climate change.

Introduction

Many cities worldwide are affected by air pollution, while being themselves major contributors to the emissions of air pollutants and GHG. Effective policies and measures to reduce emissions have to consider the interest of citizens for clean air and rely on the feasibility of interventions designed to achieve these goals. Numerous epidemiological studies have found an association between air pollution and a wide range of adverse health effects in the general population; the effects have ranged from subtle subclinical effects to premature death. Air Pollution Health Impact Assessment (AP-HIA) aims to estimate the risks of past, current or future exposure to air pollution and of changes in exposure that may result from planned policies or policy options.

Methodology and Results

Spatially distributed (1×1 km) business-as-usual (BAU) emission inventories for the major air pollutants were developed for years 2015, 2020 and 2030 for the city of Milan. The emissions values (E) were disaggregated by sector groups/subgroups/activities and by type of fuel based on the expected changes in activities (A) and emission factors (EF) for each sector (E = A × EF). The derived emission inventories fed the WRF-Chem model to estimate air pollution concentration levels. According with Milan city stakeholders, five key policies/measures with different time horizons (2020-2030) aiming at reducing air pollutants and GHGs emissions in different sectors were selected: TRANSPORTS (1) Low Emission Zone (*Area B*) and (2) Conversion of all public buses to electric ones; BUILDINGS (3) Improvement of energy efficiency in existing and new residential flats; ENERGY SUPPLY (4) Photovoltaic, solar power and district heating; LAND USE (5) Planting of 25,000 new trees per year. The new emission inventories for each policy have been provided to the WRF-Chem model to estimate changes in the air concentration levels with respect to the BAU scenarios. *Area B*, *Electric Bus* and *Building* scenarios resulted in lower NO_2 levels, in particular *Area B* showed a significant reduction also for $PM_{2.5}$ concentrations. Health impact assessment was based on the population attributable risk fraction concept (Ostro, 2004) making use of the HRAPIE concentration-response (C-R) functions (WHO, 2013). Results showed: (a) the implementation of a Low Emission Zone (*Area B*) banning the entrance of the most polluted vehicles shows by far the highest health benefit (between 5 and 18 less mortality cases on yearly basis); (b) *Electric Bus* and *Building* scenarios show higher health benefits among the other measures (between 2 and 5 less mortality cases on yearly basis); (c) all policies simulated show the highest health impacts in the periods 2031-2035 and 2036-2040 and the lowest ones in the period 2021-2025 most likely due to partial implementation of the analysed policies as well as the prevalent meteorological conditions, which may favour pollutant dispersion across less populated areas.

Conclusions

An AP-HIA can aid to answer specific policy questions, in many countries it is required as part of the decision-making process for new programmes, projects, regulations, and policies aimed at improving AQ or that may affect AQ as a side-effect. The findings, as an integrated policy assessment, provides a synthesis in terms of decision-making support for the considered policy areas. Based on these results, further cost-benefit analysis could be performed taking into account additional economic, political and social factors, creating an useful tool for policy makers and for an improved compliance to the measures by citizens.

Acknowledgement

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HOW ATMOSPHERIC SIMULATION CHAMBERS CAN HELP TO INVESTIGATE THE IMPACT OF AIR QUALITY ON HEALTH

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Summary

Using CESAM, an atmospheric simulation chamber (cesam.cnrs.fr), we have developed a totally innovative platform for exposing mice to realistic atmospheric conditions. Here we present the first toxicological analyses of the organs of these mice after 48 hours to several days of exposure, carried out as part of feasibility experiments aimed at testing this experimental concept.

Introduction

The World Health Organization (WHO) estimated that there were 3.7 million premature deaths due to air pollution in 2014, and confirmed that air pollution is the greatest environmental risk to health. Pollution would thus be responsible for a loss of more than 3% of productivity (premature death, incapacity for work due to diseases, etc.). The studies conducted so far show that the effects of air pollution on health depend not only on the quality of the surrounding air, but also on the subjects exposed and their individual vulnerability (asthma, obesity, period of life, etc.). Despite the evidence on the adverse health effects of exposure to air micro-pollutants, there are still uncertainties about the nature of these effects, and progress need to be made on their quantification. This limitation of knowledge is mainly attributed to the complexity of the polluted atmospheres, and to the great difficulty to model the impact of realistic situations of exposure.

Methodology and Results

The innovative approach we set up to support such studies is to realistically simulate, at the laboratory, the atmospheric mixture in all its complexity, thus keeping the ability to control, reproduce and carefully characterize the experimental conditions. We used the CESAM chamber (4.2 m^3 stainless steel atmospheric simulation, evacuable down to a few 10^{-7} atm, temperature controlled between +15°C and +60°C) in order to study the myriad of products arising from the atmospheric oxidation of primary organic compounds. The experimental protocol consists in the continuous injection of relevant mixtures of primary pollutants (mainly nitrogen oxides, organic compounds from a representative mix of anthropogenic emissions, sulphur dioxide, soot, inorganic salts and potentially mineral dust particles if needed - e.g. to simulate Beijing's atmosphere) at low concentrations (ppb levels) in air in the CESAM simulation chamber operated as a slow flow reactor. The residence time of simulated air parcels in the experimental volume is fixed to 4 hours, in order to represent air masses of regional scale. During this time the synthetic mixture is exposed to an artificial solar irradiation, allowing secondary pollutants such as ozone, nitric acid, formaldehyde, peroxyacetyl nitrate (PANs) as well as complex polyfunctional organics including SOA (Secondary Organic Aerosol) to be produced and to reach their chemical steady state. Mice are exposed to constant flows of such a mixture during time scales of week to address their effects on health.

In order to scale the pollutant concentrations in the initial mix, we were able to run a predictive model to estimate the concentrations of all gaseous and particulate species in CESAM, after a residence time of 4 hours in the chamber. The model takes into account the injection of 9 precursors (gaseous chemicals) in the simulation chamber: nitrous acid, toluene, acetylene, ethane, benzene, meta-xylene, ortho-xylene, para-xylene, ethyl-benzene and n-pentane. After 20 hours of flowing and mixing in the chamber (this duration can be reduced to some hours by increasing the concentrations and flows of precursors) the targeted concentrations of pollutants are obtained. Then the lights simulating the sunlight irradiation are switched on, and taking into account in the order of 1500 reactions involving around 3000 chemicals the model predicts what will be the photo-stationary concentrations in the chamber for each of those photoproducts.

The CESAM laboratory is equipped with a comprehensive set of analytical instruments and benefit from the instrumental environment dedicated to atmospheric chemistry provided by LISA (http://www.cesam.cnrs.fr), especially gaseous pollutants analysers (O_3, NO, NO_2, SO_2, CO, CO_2, COV…) and aerosols properties (mass and size distributions, hygroscopicity…). This allows us to accurately and precisely measure the time evolution of the pollutants concentrations within the different exposure compartments. Once the requested steady-state CESAM experimental conditions are reached, a desired volumetric flowrate is transferred to the compartment where the living organisms are exposed, thanks to a pressure of 11 millibars inside CESAM. In each experiment, the compartments undergo a constant air flow from the simulation chamber. Furthermore, we make sure that the path between the chamber and the exposure devices is minimized, in order to preserve the numerous reactive chemicals present in the simulated atmosphere.

Conclusions

Here we present the first toxicological analyses related to organs/tissue of these mice after exposure of 48h to several day, carried out with a representative atmosphere of Beijing or a representative atmosphere of Paris.

Acknowledgement

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SCHOOLCHILDREN RESPIRATORY HEALTH AND ALLERGIES RELATED TO AIR QUALITY IN INDUSTRIAL AREA OF ESTONIA

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Summary

This study aims to quantify industrial pollutants from oil shale industry and examine the associations between respiratory symptoms, and allergies among schoolchildren living in industrial area of Estonia and industrial pollutants (phenol, benzene, formaldehyde, hydrogen sulphide, benzo(a)pyrene, particulate matter, and fine particles). During the study we e have found some associations with some pollutants, but not in all cases. The possible explanations could be first poor exposure data due to low quality emission data. Second this could be partly explained by improvement in air quality that could be in some extent reflected in improvement in children's health. Although the prevalence of respiratory outcomes remain still higher compared to other regions of Estonia from our previous studies.

Introduction

In Estonia, most polluted industrial area is Ida-Viru County in North-Eastern region of Estonia. To this area is concentrated power generation from oil shale, oil shale extraction and shale oil production. Compared to other counties of Estonia children in Ida-Viru county have higher prevalence of respiratory symptoms and asthma diagnosis. There is still high concern that industry-related air pollution affects children health. The current study aimed to look in more detail those associations, especially in regards industry specific pollutants as phenol, benzene, formaldehyde, hydrogen sulphide, benzo(a)pyrene, particulate matter and fine particles.

Methodology and Results

Altogether 1,041 schoolchildren from 20 schools in Ida-Viru County participated in this cross-sectional study. Schools were selected by location to represent different air pollution levels inside the Ida-Viru County. We conducted first questionnaire study on respiratory health and allergy symptoms. Subsequently the clinical examinations to measure fractional exhaled nitric oxide (FeNO), spirometry and allergies (from blood samples) were followed. The annual average concentrations of industry-specific air pollutants as phenol, benzene, formaldehyde, hydrogen sulphide, benzo(a)pyrene and particulate matter (PM_{10}) and fine particles ($PM_{2,5}$) were modelled in Ida-Viru County using and Eulerian air quality dispersion model. The model was based on reported emission from national data-bases and the results were validated for levels from two monitoring stations. All participants' home and school addresses were geocoded and linked to air pollution exposure. The emissions originated from oil shale industry were also modelled separately to differentiate the effects. We used adjusted logistic regression models to assess how the pollutants exposure has affected respiratory health and allergies among children.

Nevertheless, during the first analysis we have found some effects for some pollutants, but to the smaller extent compared to our earlier analysis four years earlier (Idavain et al., 2019). One of the explanations could be that to some extent children's health has improvement compared to previous studies in this area and weaker associations appear. However, some of the respiratory outcomes' prevalence remain high compared to other regions of Estonia.

Conclusions

We can see in some extent children's health improvement compared to previous studies in this area, but several respiratory outcomes remain high compared to other regions of Estonia and exposure to pollutants increase the odds for reporting respiratory outcomes. Although we have to admit the rather low quality emission data that might explain the insignificant associations in several cases.

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Acknowledgement

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Short Presentations

DOES THE BENEFIT OF REDUCING CO2 EMISSIONS JUSTIFY THE USE OF WOOD STOVES DESPITE THE HIGH ENVIRONMENTAL HEALTH IMPACTS CAUSED?

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Summary
This study aims at estimating the social costs of different heating techniques to find out, whether the benefits of climate protection by using wood and pellet firings outweigh the disadvantages, namely the health impacts caused by emitting much more air pollutants then e.g. oil and gas firings. Results how, that in cities health impacts heavily outweigh the climate benefits, thus small wood stoves should not be used. In rural areas, wood stoves could be beneficial, especially if they are equipped with an efficient dust filter.

Introduction
When a tree is growing, it uses CO_2 from the atmosphere to produce wood, thus burning wood is (nearly) climate neutral. However, wood burning in small stoves creates a lot of air pollution, especially particulate matter and nitrogen oxides. Thus the question arises, whether, when aiming at optimizing the wellbeing of the population, the benefit of being climate friendly more than compensates the disadvantage of causing severe health impacts; or in short, whether it increases or decreases the overall wellbeing of the population, if a wood stove is operated in a certain place.

Methodology and Results
To answer the question raised above, we calculate the social costs of wood stoves and of alternative heating devices such as oil and gas heating systems. Social costs are an expression of all relevant costs and negative impacts imposed. In the case of firings these are the costs of the heating including investment and fuel costs, the negative impacts of climate change caused by greenhouse gas emissions and the health impacts caused by air pollution.

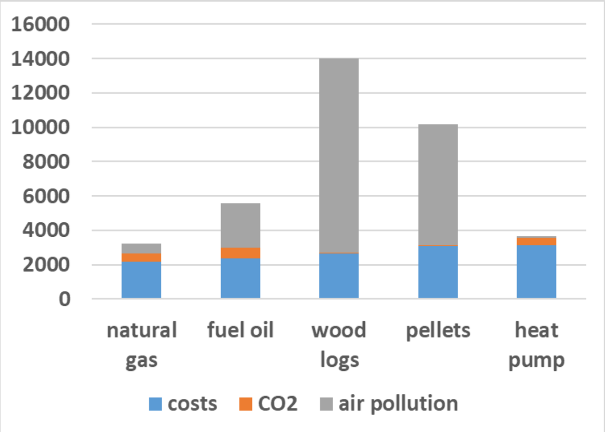

Fig.1 Social Costs of heating devices located in Stuttgart

Social Costs are calculated for wood stoves, pellet stoves, gas and oil heatings and electric heat pumps. Two sites are chosen, as an urban site the centre of Stuttgart, as a rural site the village of Bechtoldsweiler (in the South West of Germany). To estimate the health impacts, a detailed simulation of the hourly operation of the stoves including start up and closedown processes has been made for a typical year to calculate the emissions of air pollutants and greenhouse gases. Next, atmospheric modelling is carried out to estimate the change in the annual average concentration of air pollutants in the area around the site and furthermore in the region. Using the concentration change and concentration-response functions the health impacts are calculated. To convert the health impacts into external costs, they are multiplied with specific cost factors derived from contingent valuation (willingness to pay studies).
To assess the damage costs of greenhouse gas emissions an avoidance cost approach is used, i.e. marginal avoidance costs to reach an agreed climate protection objective, i.e. to limit the temperature increase of earth's surface to less than 2°, is used. Thus a monetary value (carbon cost) of 77€/t CO2 (44€/t CO2 – 135 €/t CO2) is applied. The resulting social costs for Stuttgart are shown in Fig. 1. The social costs for wood logs and pellets are significantly higher than for the alternatives. Even when introducing particulate filters, the social costs stay higher, as than still the NOx emissions cause considerable health effects. In rural areas, the differences in social costs between the heating types are not very different; among others, the NO2 concentration is so low, that no health impact due to NO2 occurs. However, wood and pellet stoves equipped with dust filters (e.g. electrostatic filters) have lower social costs than those without.

Conclusions
In cities the use of small (< 100kW) wood or pellet stoves is not beneficial for society and thus should not be allowed. This is different in rural areas, however there it would be beneficial to tighten the emission limits in such a way, that (electrostatic) dust filters have to be used.

Acknowledgement
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DEVELOPING A PERSONALIZED AIR QUALITY INDEX FOR THE BETTER UNDERSTANDING OF AIR POLLUTION IMPACTS ON HEALTH AND WELLBEING

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Summary
In this study we present the rationale and development of a new air quality index that takes into account the specific sensitivities and interests of each concerned individual. The design of the index was performed based on the existing global and European health and air quality standards and on epidemiological studies. Currently, the index is validated by individuals through a mobile application, and will be further improved from the feedback that will be collected.

Introduction
Air quality indices are a tool used by scientists and environmental protection departments around the world to communicate the air quality information to the wider public. So far, many indices have been adopted to qualify the air quality levels and inform the public about the associated health effects (e.g. Schmitt 2019), with most prevalent in Europe the European AQI (Air Quality Index). However, these indices do not consider the specific characteristics of each citizen which means that people may set at risk their health and wellbeing. Safe air quality levels for an average person, for example, do not always mean that air quality is also safe for people with asthma, elderly or pregnant women. These people need specific information and alerts customized to their needs, thus the necessity of developing a highly personalized air quality index arises.

Methodology and Results
In the proposed study, the existing air quality indices have been assessed along with the air pollution standards set by the World Health Organization, the US Environmental Protection Agency, and the European Environment Agency, for the development of a new personalized index using known exposure-response relationships for different population groups. According to literature review and epidemiological studies of wide scale (e.g. Stilianakis 2015), the susceptibility of each population group to each atmospheric pollutant was analyzed. Children, people suffering from cardiovascular and respiratory diseases, pregnant women, and the elderly are the most susceptible individuals to particulate matter. Specifically, for children and people with cardiovascular diseases, an increase in PM by 10 μg/m^3 is associated with an increase of approximately 0.8% of hospital admissions compared with the general public. The respective percentage for people with respiratory sensitivities, the elderly, and pregnant women is estimated at around 0.6%. Regarding people working or exercising outdoors, as they inhale more air, the potential health problems are increased by 0.4% compared to people who do not perform any physical activity outdoors. Individuals who belong to any combination of the above groups may suffer from a respective increase in health sensitivity from particulate matter pollution.

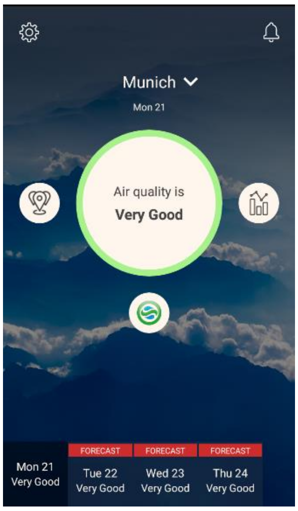

Fig.1 The proposed index used in a mobile application

Respectively to particulate matter, the most susceptible groups to sulfur dioxide are people suffering from cardiovascular or respiratory diseases and children, followed by the elderly, and pregnant women. Carbon monoxide pollution mainly affects children and people with cardiovascular diseases, while the potential health problems are increased by 0.5% to people with respiratory diseases, the elderly, and pregnant women compared to an average person. The elderly and people with respiratory sensitivities, followed by children and pregnant women are more susceptible to ozone pollution. The index is divided into four colored classes which have different boundaries for each group of interest and each concerned pollutant. The index is ranging from very good to bad and is accompanied by the respective health and activity recommendations.

Conclusions
The present study concludes that a personalized air quality index would help individuals better protect their health and avoid adverse impacts of air pollution. The proposed index is currently used in a mobile application aiming to inform people on the current and forecast air pollution levels, called Envi4All (Fig. 1) for demonstration purposes. Through these activities, air quality data from low cost sensors that will be distributed in Thessaloniki, Greece will enable the further validation of the index, while the wider use of the mobile application is expected to provide insights on the acceptance of the index by the users.

Acknowledgement
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ADAPTATION STRATEGIES TO REDUCE HUMAN HEALTH IMPACT ASSOCIATED WITH ENVIRONMENTAL RISK FACTORS EXPOSURE: A NEW MARKET FOR CLIMATE SERVICES

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Summary

Considering the rising demand for adaptation solutions in a climate change context, two potential environmental modelling applications are described in this manuscript, based on past EU Projects experiences. Most of the sector has no detailed information regarding the baseline impact of air pollution or weather extreme events (i.e. heatwaves), neither the projection losses in the future climate. H2020-Insurance showcased a Risk/Impact assessment based on high resolution air quality and meteorological databases integrated with morbidity/mortality data and provided present/future climate impact on health. For contexts whereas the risk awareness is built and strong, forecast systems are key resources to alert the population and give recommendation to reduce exposure. Therefore, we included the overview of AIRE Salud system in Chile.

Introduction

Climate change impact reduction can be achieved by exposure reduction and improved health care management. Adaptation strategies based on sustainable urban-infrastructure planning and warning systems (Banwell, 2018). On this study, we present two test cases, applied for EU Projects (H2020 Insurance - Germany and CAMS/AIRE SALUD – Chile), to illustrate the potential of air quality and meteorological modelling for climate change adaptation. During the winter, there is a pressure increase in the Chilean health system due the increase in respiratory infections morbidity, associated with environmental conditions. AIRE SALUD is a data-based Respiratory Infection Epidemiological Forecast System for the Santiago Metropolitan Region, designed to support authorities and health care management during a winter campaign. The H2020 Insurance Project aimed to help the health insurance sector to understand the relation between the air quality, climate extremes and health conditions in a given population, quantifying potential losses associated with the current and future climate risk. The Health DEMO focused on COPD patients and explored potential adaptation measures to improve prevention.

Methodology and Results

CAMS Project – AIRE SALUD (www.airesalud.cl): The AIRE SALUD system is based on a geospatial analysis of medical consultations in public emergencies recorded between 2011 and 2018 by the Department of Health Statistics and Information (DEIS) of the Ministry of Health of Chile. This integrates demographic data, socioeconomic vulnerability factors, participatory web data flows and atmospheric variables, and allowed the development of geostatistical/machine learning algorithms to predict the increase in respiratory infections in the Santiago Metropolitan Region with a week of anticipation, with a confidence level of over 87%. The Respiratory Infection Admissions Forecast results are illustrated on Fig. 1.

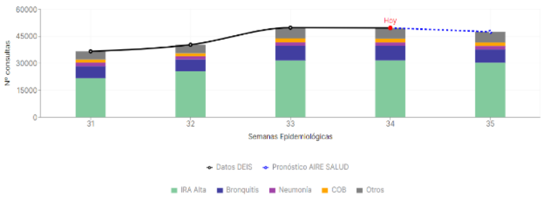

Fig.1 - AIRESalud Resp. Infections Forecast example (b).

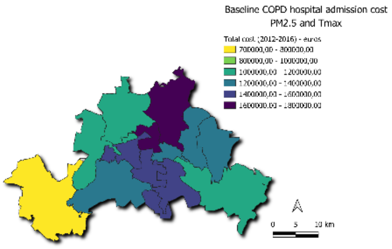

Fig.2 – H2020 losses estimation example.

H2020 Insurance – Health DEMO (https://h2020insurance.oasishub.co/): Based on morbidly data and high-resolution environmental data, we calculated district specific climate relative risk for COPD hospital admissions in Berlin and Potsdam, considering the period between 2012-2016. The attributable morbidity and the associated cost were calculated for the present condition. Climate change projections on air quality and heat exposure were computed and the potential future losses estimated. In parallel, a clinical trial demonstrated how specific counteracting measures (establish ideal room temperatures, telemedicine to monitor the domestic environment, etc.) can help to reduce the hospital stay and shorten recovery time.

Conclusions

The applications described present a potential as decision making tool for adaptation plan in urban areas, improving population resilience and/or giving support on healthcare infrastructure planning strategy.

Acknowledgement

OASIS Hub Team for the support for the H2020 Project.

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Special Session – Sensors, Crowd Sourcing and Air Quality Model Simulations

INTERPETING MEASUREMENTS FROM AIR QUALITY SENSOR NETWORKS: DATA ASSIMILATION AND PHYSICAL MODELLING

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Summary

The Interreg Balkan-Med AIRTHINGS project exploits rapid developments in sensor technology and numerical air quality modelling, in order to provide reliable regulatory air quality assessment services. A combination of data fusion and data assimilation methods is employed to incorporate emission data, real-time sensor measurements and sensor error management in the two-way coupled meso-micro MEMICO dispersion modelling system. Model results are further analysed off-line to detect diurnal, seasonal or spatial pollution patterns. In line with the provisions of the Interreg Balkan-Med program, the combined data are freely available through an Open Data Platform.

Introduction

The AIRTHINGS project focuses on the combination of low-cost innovative air pollution sensors with advanced air quality modelling tools, for the purpose of supporting regulatory assessment services. Air quality measuring sensors are used in selected cities of five Balkan countries, to provide real time air quality data. A continuous quality testing and data assimilation process integrates emission data and real-time sensor measurements in an operational atmospheric modelling system based on the MEMO/MARS-aero and MIMO numerical models. This information is used to identify and quantify source contributions in the areas of interest, particularly during periods of exceedances above EU limit values.

Methodology and Results

An Operational Air Quality System (AQMS) is deployed in AIRTHINGS target cities, based on the coupled mesoscale MEMO and MARS-aero chemical dispersion models. In order to provide additional information on finer spatial scales contributions (concentration increments), the coupling scheme MEMICO (Tsegas et al., 2015) has been applied for coupling the mesoscale model MEMO and the microscale model MIMO. In the two-way coupling scheme, a three-dimensional spatial interpolation scheme, a spatial adjustment of values within the surface layer, and the formulation of the lateral boundary conditions to introduce the interpolated values into the microscale model are utilised. The third component of the modelling system is an advanced operational Data Assimilation (DA) system (denoted AQMS+DA), which incorporates the data and control streams from the sensor networks. In this way, additional information is incorporated on the forecast results from sensors denoted as "traffic stations", on spatial scales not normally resolved by the MEMO/MARS-aero system. Additionally, the accuracy of the mesoscale calculation themselves is improved by assimilated data from sensors located away from streets, chimneys of heating systems, denoted as “background stations”. The combined operation of the AQMS+DA system can be described as a sequence of eight steps: **1.** Transfer of concentration data, **2.** Timebase checking, **3.** Sanity checking, **4.** Sensor classification and data normalisation, **5.** Calculation of numerical tendencies, **6.** Spatial “smearing” of tendencies, **7.** Incorporation of tendencies in the dynamical terms and step integration, **8.** Extraction of normalisation terms/data. Steps 1-8 are repeated on a 5- or 10-minute frequency, or whenever a new packet of sensor data becomes available. During this period, additional iterations of steps 4-8 could be performed internally, in order to improve the accuracy of the last available data.

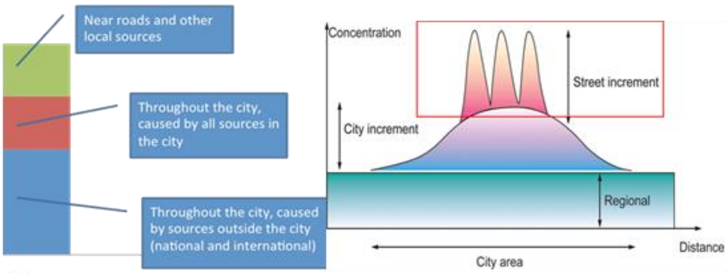

Fig.1 Estimation of concentration increments in different spatial scales

Conclusions

The coupled mesoscale modelling system MEMO/MARS-aero and the mesoscale-microscale MEMICO two-way coupling methodology implement the physical modelling core of an Air Quality Management System deployed in the Balkan region. An advanced data assimilation platform aims to alleviate issues typically related to the accuracy and consistency of data provided by networks of inexpensive sensors. The dynamical core of the modelling tools provides the means to evaluate, integrate and complement the sensor data on pollutant levels in predictions of high temporal and spatial resolution.

Acknowledgement

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CITY-SCALE GEOSPATIAL DISTRIBUTION OF CO_2 BASED ON A DENSE SENSOR NETWORK

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Summary
Knowledge about high-resolution geospatial distribution of air quality parameters is crucial for a wealth of applications, including emissions estimation and health-related studies. Such information can be obtained by combining (low-cost) sensors and numerical models. The Carbosense project is a demonstration of this approach. It consists of a dense CO_2 sensor network of more than 250 nodes covering all of Switzerland, including over 50 nodes in the city of Zurich. A fully operational data processing chain provides reliable, quality-controlled measurements, which are combined with both statistical and atmospheric transport models. Carbosense is designed to provide specific emission estimates, but also to increase our general understanding of running and exploiting dense sensor networks.

Introduction
The interest in dense CO_2 measurement networks is growing, especially in urban areas. The interest closely relates to the need for tools to monitor the success of policies implemented by cities and communities for the reduction of greenhouse gas emissions. The operation of low-cost sensor networks for CO_2 and for other air pollutants such NO_2, CO or particulate matter (PM) faces similar challenges and many methods and findings are transferable. Key elements for such networks are the design of the sensor nodes featuring low energy consumption and wireless data transfer, sensor integration and calibration, and the development of strategies to provide accurate and reliable measurements on the long-term.
In addition to anthropogenic CO_2 emissions, biosphere activity (uptake by photosynthesis and respiration) and transport are important factors contributing to the atmospheric CO_2 concentration. An optimal exploitation of measurements from dense CO_2 sensor networks can be achieved by combination with statistical or atmospheric transport models as such joint systems have the potential to identify CO_2 sinks and sources and to quantify CO_2 fluxes. Furthermore, model output may be used to adjust sensor measurements and to enhance their accuracy.

Methodology and Results
Within the Carbosense project a dense CO_2 sensor network that covers the whole of Switzerland was set-up (Fig. 1). It consists of 250 nodes and has a focus on the city of Zurich where more than 50 sensors are deployed. The network consists of three types of measurement units: (i) seven high-precision laser spectrometers (Picarro G1301/G2302/G2401), (ii) 15 temperature stabilized, mains powered NDIR low-cost instruments with reference gas supply (SenseAir HPP) and (iii) 250 nodes of battery-powered NDIR low-cost sensors (SenseAir LP8). The Carbosense network is operational since July 2017.

An extensive data record (> 2 years) is available for LP8 and HPP sensor measurements, and some general conclusions can be drawn: (i) The HPP and LP8 sensors reach an accuracy of about 3 ppm and 10 ppm, respectively. Data yield for the LP8 sensors is about 70 %. Data processing, filtering and flagging is crucial, and several options for further improvements have been identified, (ii) The sensor measurements are generally in good agreement with results obtained using an atmospheric transport model (COSMO-GHG). However, the model regularly underestimates CO_2 concentrations during time periods with shallow boundary layer. This discrepancy will be exploited to analyse and improve the corresponding transport model parameters, (iii) For certain metrological conditions, the agreement between modelling and measurements is excellent, which creates opportunities for using the atmospheric transport model for the drift correction of the LP8 sensors, (iv) The sensor data together with geographic information is highly valuable in combination with statistical models. CO_2 sensor measurements in the city of Zurich clearly show the impact of traffic, concurring with co-located NO and NO_2 measurements. First versions of statistical models are set up for the city of Zurich that rely on emission inventories, vegetation data, and elevation. The improvement of these models is ongoing and shall ultimately lead to accurate CO_2 maps with high spatio-temporal resolution.

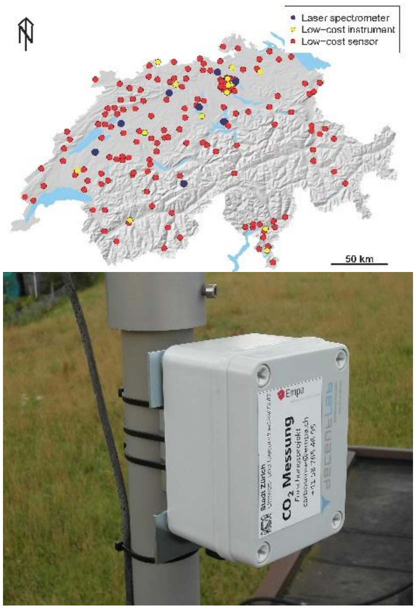

Fig. 1 Carbosense sensor network (top) and Decentlab LoRaWAN DL-LP8 low-cost sensor node (bottom).

Acknowledgement
We acknowledge Swisscom, the Federal Office for Meteorology and Climatology MeteoSwiss, the Swiss National Air Pollution Monitoring Network (NABEL) and the Environment and Health Protection Department (UGZ) of the city of Zurich for the generous support of the Carbosense network. Financial support from the Swiss State Secretariat for Education, Research and Innovation (Eurostars Project E!11401 CO2.GLOBAL) and from the Swiss Data Science Center (SDSC) through the project CarboSense4D is gratefully acknowledged.

ASSESMENT OF HETEROGENITY OF AIR POLLUTION WITHIN AN URBAN CANOPY

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Summary
This study aims is to analyze one-year measurements of the air quality from citizen science networks and compared to the measurements of measuring sites from local authorities using regression analyses on diurnal and seasonal cycles. Additionally, dispersion processes of tracer within an idealized urban area are executed with the microscale model MITRAS. The measurements of the citizen science network can provide a good overview about the tendencies of the air quality. The model results show that the citizen science network is too coarse to be representative for the city quarter.

Introduction
Air pollution is an important topic within urban areas. Limit values as given in the European Guidelines are introduced to reduce negative effects on humans and vegetation. Exceedances of the limit values are to be assessed using measurements (EU, 2008). In case of found exceedances of the limit values, the local authorities need to act to reduce pollution levels. Highest values are found for several pollutants (NOx, NO2, particles) within densely build-up urban areas with traffic emissions being the major source and dispersion being very much impacted by the urban structures. The quality assured measuring network used by the authorities is often too coarse to determine the heterogeneity in the concentration field. Therefore, EU (2008) specifies that the measurements should be made at so named hot spots. Low cost sample devices as employed in several citizen science projects might help to overcome the data sparsity. Voluntaries measure the air quality at many sites, contribute to the measurement networks and provide the data on the web. However, the questions arising are: a) Are these data of sufficient high quality to provide results comparable to those of the quality assured networks? b) is the network density sufficient to determine concentration patterns within the urban canopy layer?

Methodology and Results
Analyses of a citizen science network, which measures particulate matter (PM10, PM2.5) were compared to measurements provided by the authority's, using two hot-spot areas in the city of Hamburg as an example. One-year data from the citizen science project were selected; from the 50 sites 25 sensors have a sufficient amount of data to calculate annual averages or to compare the number of daily exceedances. To determine how well the measurements agree with each other, a regression analyses was performed dependent on seasonal and diurnal cycles. Additionally, model simulations with the microscale obstacle resolving model MITRAS (Salim et al. 2018) were performed for two characteristic building structures and different meteorological situations. The model results were used to determine local hot spots as well as areas where measurements might represent the concentration of particles for the urban quarter. The low cost sensor measurements show a general agreement to the city's measurements, however, the values per sensor differ. Moreover, the measurements of the low-cost-sensor depends on relative humidity, resulting in over- or underestimations in certain cases. The model results clearly show that only a few sites allow for measurements to be representative for a city quarter.

Conclusion
The measurements of the citizen science project can provide a good overview about the tendencies of the air quality, but are currently not in the state to provide measurements calling for legal action.

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HIGH-RESOLUTION MAPPING OF URBAN AIR QUALITY BASED ON LOW-COST SENSORS AND NEURAL NETWORK MODEL: APPLICATION TO GRENOBLE CITY, FRANCE

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Summary
This study aims to evaluate the performance of data assimilation, easily generalizable to any city, of air quality observations from low-cost sensors combined with deep neural network (DNN) for mapping urban air quality in high-resolution. In this study, 5 fixed sites have been equipped with micro-sensors, between April and August 2019 in Grenoble. Hourly outputs of NO_2 and PM_{10} concentrations coming from the data fusion process have been compared with measurements from reference monitoring stations. A statistical evaluation was performed using criteria developed in the framework of FAIRMODE (Forum for Air quality Modelling). Good results were found, opening perspectives for a generalized use of the solution, with a denser micro-sensor network and real-time input data.

Fig.1 Location of low-cost stations (blue) and traffic reference station (red) on NO_2 concentration map

Introduction
With respect to a traditional observation network based on costly reference analyzers, low-cost microsensors can be easily deployed throughout the city and therefore considerably increase the number of observation points. Even though a single micro-sensor is obviously less accurate than a reference analyzer. In the other side, air quality maps derived from street-level air quality models require a lot of input data, not always available, and can be time consuming. The combination of low-cost networks and simple air quality model can overcome these issues.

Methodology and Results
Low-cost, connected air quality stations developed by eLichens measure PM_{10}, $PM_{2.5}$, PM_1, NO_2, O_3 concentrations. Their performance was investigated by comparison with reference observations during several long field campaigns in France (Grenoble, Lille) and San Francisco (one month to one year). Results have shown good agreement for hourly PM_{10} and O_3 concentrations (R^2: 0.67 to 0.85) and relatively weaker for NO_2 concentrations (R^2: 0.43 to 0.50). A small stations network (5 fixed stations) has been deployed in Grenoble depending on the type of traffic and streets configuration (Fig. 1). Real-time concentrations were assimilated into simulated concentrations map by DNN during spring and summer 2019 to obtain air quality map at 10-m and hourly-scale in near real-time and forecast. The model uses real-time input data concerning background concentrations (Copernicus), weather forecasts (Darksky API), fixed environmental environments (Open Street Map) and traffic data (HERE Maps). To assess the model performance, concentrations were also simulated by the street OSPM model (Kokosimos et al. 2010) but in sub-optimal conditions (incomplete initial conditions, streets other than street-canyon). Concentrations resulting from the data fusion between sensors and model were compared with measurements of 2 traffic reference stations by using the statistical criteria defined by FAIRMODE (Janssen et al. 2017) and Chang and Hanna (2004). A good overall performance on the metrics was found with better results with the neural network, especially on NO_2 concentrations (Fig. 2).

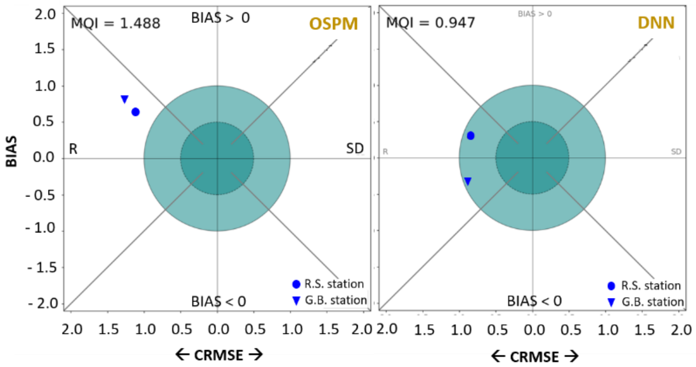

Fig.2 Target diagram to NO_2 model-observed evaluation, with OSPM model (left) and Neural network (right).

Conclusions
A data assimilation process based on low-cost sensors networks and neural network model has been developed for mapping urban air quality in high-resolution. A performance analysis based on few sensors was conducted and showed good results. An incoming deployment of a denser low-cost micro-sensors network in Grenoble is planned and should confirm these first promising results.

Acknowledgement
This work was supported by Région Auvergne Rhône-Alpes. The authors thank B. Singer and I. Walker (Berkeley Laboratory, CA) for their collaboration in a sensor 'characterization and M.Ketzel (Aarhus University) for his help on OSPM model

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ASSESSING THE SPATIO-TEMPORAL DISTRIBUTION OF URBAN AIR POLLUTANTS – AN INTEGRATED SYSTEM BASED ON CROWDSENSING WITH MOBILE SENSORS AND MULTI-SCALE MODELLING

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Summary

This study aims to investigate the details of the spatial and temporal distribution of air pollutants in urban areas. Distributed air-quality measurements with mobile sensors for particulate matter (PM) and black carbon (BC) have been carried out across the City of Leipzig by scientists and citizen volunteers during the period 2019/2020. This has been accompanied by real-time air-quality modelling from regional to pedestrian-level scale, using an up-to-date chemistry transport model framework. As expected, observations and model results show high concentrations along busy roads and lower concentrations in parks and backyards with a distinct dependence on commuting during the course of a day or week. Further work will focus on integrating the rich set of mobile measurements, model data and population statistics to obtain more reliable information on the exposure of individuals

Introduction

The urban atmosphere is strongly influenced by a range of short-lived pollutants. Many of them are known to cause adverse health effects (ultrafine particulate matter, soot, nitrogen oxides, ozone). These air pollutants show a high spatio-temporal variability, which is currently not well represented by standard air quality monitoring meant to measure at main sources as well as by common air-quality forecast. In recent years, TROPOS has developed and explored the potential of spatially differentiated measurements with mobile BC and PM mass sensors (e.g. Alas et al., 2019). Additionally, a sophisticated but efficient model system has been developed, which allows for simulations from regional to street-level scale. Within a knowledge-transfer project, the combination of mobile crowdsensing and high-resolved air-quality forecast recently have been used to assess the spatial distribution of BC and PM2.5 in the medium-sized city of Leipzig in eastern Germany.

Methodology and Results

A set of mobile measurement packages for PM and BC, which are designed lightweight, easy to use and conform with scientific standards, have been developed and used to carry out distributed air-quality measurements by scientists and citizen volunteers across the City of Leipzig in 2019/2020. The data is collected on a web-based platform and is used to improve a real-time model for predicting small-scale pollution. The quasi-operational forecast is based on simulations with the multi-scale chemistry-transport model COSMO-MUSCAT (Wolke et al., 2012), which is equipped with a building effect parameterization, for grid spacings between 28 km over Europe to about 500 m over the city area. Computational Fluid Dynamics (CFD) modelling is then used to bridge the gap to street-level conditions.

Fig.1 Wintertime distribution of BC in the City of Leipzig as measured with mobile sensor. After Alas et al., 2019.

The observations and model results show similar patterns with high concentrations along busy roads especially at crossings, while lower concentrations occur in parks or areas with little traffic. This is in dependence of the day of the week with a typical daily cycle through rush-hour traffic. Due to the strong concentration gradients, the exposure to individual citizens however remains difficult to deduce.

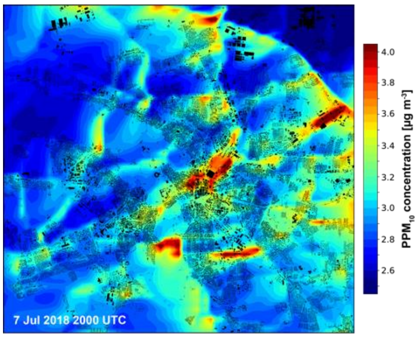

Fig.2 Primary PM concentration from 500–m simulations with the COSMO-MUSCAT model.

Conclusions

The integration of detailed air-quality measurements and high-resolution model simulations promises to enhance our knowledge about the links between pollutant emissions, air quality, and urban climate. The long-term objective of the study is that more reliable exposure information will be obtained by means of measurement and model data and statistical data on the daily patterns of movement and residence of the population.

Acknowledgement

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CHALLENGES IN THE ASSIMILATION OF MOBILE MICRO SENSORS DATA FOR URBAN AIR QUALITY – ANALYSIS OF A PARIS CASE STUDY

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Summary
The use of fixed or mobile micro sensors for air quality monitoring is increasingly popular due to the advantages they offer in cost and setup requirements. Several studies have tested the use of fixed micro sensors observations to improve the estimation of pollutants concentration in combination with atmospheric dispersion models, however, less has been explored in the case of mobile measurements. We focused our work on a measuring campaign over the city of Paris composed of a fleet of vehicles equipped with micro sensors and the simulation results from the Parallel Micro SWIFT SPRAY (PMSS) model for the same period. An extensive analysis of the dataset was performed as well as the application of two methods of data assimilation: the bias correction and the Best Linear Unbiased Estimator (BLUE).

Introduction
The development of new technologies in sensors for air quality monitoring results in a new market offering a large variety of costs and complexity in the instruments. These sensors retrieve information at a variety of temporal and spatial resolutions that are useful for the mapping of air quality and places them as an attractive alternative to expand air quality monitoring networks thanks to their low cost and easy set-up. Furthermore, these observations can be combined with atmospheric dispersion models by different data assimilation methods to improve the air quality assessment. The efficiency of these methods depends on many factors, including the knowledge of the uncertainty in both the observations and the model. Considering this, we present a case study consisting of the assimilation of a set of mobile observations of concentrations recovered during a 5-month campaign in the city of Paris and the simulation results from the PMSS model at high resolution.

Methodology and Results
The observations were obtained from a measuring campaign consisting of micro sensors installed in the frontal air inlet of 20 vehicles used for taxi service and school pick-up service deployed within the inner city of Paris. The sensors were composed a particle detector, providing measurements at frequency of 1 Hz, and a second module dedicated to the gas pollutants with a latency time of 0.0167 Hz. In parallel, the meteorological and concentration fields were recovered from the PMSS model (Moussafir et al., 2004) at a grid resolution of 3 m, covering a spatial domain of 12 x 10 km, and at an hourly mean timestep.
An exploratory analysis of the mobile measurements was performed which included its comparison to observations from the fixed regulatory traffic stations and to the model output. In general, the results showed a positive bias for the NO_2 and a negative bias in the case of PM10 when compared to fixed stations. With regards to the model, the error was spatially inhomogeneous (Figure 1) and showcased areas of larger discrepancy, such as axes within the street network or recirculation areas, that could not be identified with traditional fixed sensors.

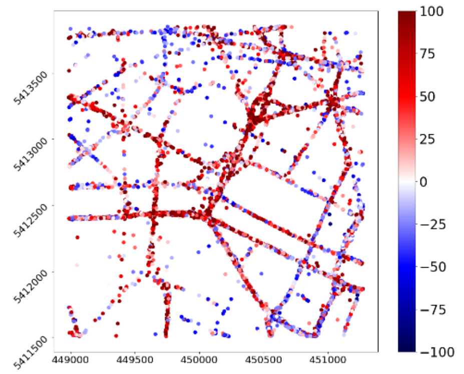

Figure 1. Error in % over the "hypercentre" sub-domain for observations between Sept – Oct – Nov. Red color represents a positive error between Model – Obs and blue color represents a negative error

For the assimilation stage, only locations with more than 20 μ-sensors measurements over the entire period were considered which resulted in 7600 grid point measurements. The assimilation algorithms were applied via the YODA toolkit, developed by the Atmosphere, Impact & Risk research group of the Laboratoire de Mécanique des Fluides et d'Acoustique (LMFA-AIR). To test the robustness of each method, a cross-validation approach was applied using the micro sensors observations as well as the observations from the reference fixed stations.

Conclusions
This study highlighted the information that can be obtained from data provided by a network of mobile sensors with a high sampling frequency. It puts in evidence the obstacles in the interpretation of these data and the need of a deeper insight in the measurement's representativeness, particularly on the effect of the moving sampling in mobile sensors. Current work on this matter is being developed with the help of Computational Fluid Dynamics models which resolves the turbulence field at high resolution and can be used as a source of information of a 3-D concentration field. This study also showed that the main constrain is the assimilation of this type of data is the inhomogeneous distribution of observations within the domain. This raises questions about the confidence levels that should be attributed to this type of measurements and how they could be improved.

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AIR POLLUTION EXPOSURE MANAGEMENT AT THE CITY LEVEL – THE ICARUS APPROACH

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Summary
A city scale ABM was developed and applied for the metropolitan area of Thessaloniki, Greece that feeds into population-based exposure assessment without imposing prior bias, basing its estimations onto emerging properties of the behaviour of the computerised autonomous decision makers (agents) that compose the city-system. Population statistics, road and buildings networks data were transformed into human, road and building agents, respectively. Survey outputs with time-use patterns were associated with human agent rules, aiming to model representative to real-world behaviours. Moreover, time-geography of exposure data, derived from a local sensors campaign, was used to inform and enhance the model. Personal exposure was evaluated by assigning PM concentrations to human agents based on coordinates, type of location and intensity of encountered activities. Study results indicated that PM2.5 inhalation adjusted exposure between housemates can differ by 56.5% whereas exposure between two neighbours can vary by as much as 87%, due to the prevalence of different behaviours. Overall, this study provides details of a new method for evaluating the impacts of different public health policies prior to implementation, reducing, thus, the time and cost required to identify efficient measures.

Introduction
One of the key points which are needed to identify environmental protection strategies is a new paradigm for an enhanced assessment at the individual level, so as to pro-vide policy-makers and city authorities the means to support the implementation of new policies, leading to low pollution levels and maximal wellbeing in urban areas.

Methodology and Results
One of the key points which are needed to identify environmental protection strategies is a new paradigm for an enhanced assessment at the individual level, so as to provide policy-makers and city authorities the means to support the implementation of new policies, leading to low pollution levels and maximal wellbeing in urban areas. Instead of using unrealistic general equilibrium models to simulate societal responses to environmental policies, the proposed methodology makes use of ABM to capture the interactions of several population subgroups, industries and service providers in response to policy options. ABM is a simulation technique that allows us to explore and understand phenomena, where independent entities interact together, forming an emergent whole. While the direct representation of individuals' actions is organizationally difficult, ABM simplifies this process by managing information at the level of the autonomous decision-makers, called "agents" (Sarigiannis et al., 2018). The city-scale ABM developed herein included population statistics, road and buildings networks data were transformed into human, road and building agents, respectively. Time-use survey outputs (MTUS, HETUS) were associated with human agent behavioural rules, aiming to model representative to real-world routines. The campaign-captured personal exposure profiles further enhanced the established ABM. Being parametrized with real monitoring data, the developed model successfully captures behavioural and exposure variations in different types of individuals. ABM results indicated that virtual people that reside in the same location or even in the same dwelling might not necessarily be exposed to similar levels of pollutants. Several cases of entirely different exposure profiles, mainly justified by differences in time-activity patterns, have been observed. Results show that PM2.5 inhalation adjusted exposure between housemates can differ by 32.2% whereas exposure between two neighbours can vary by as much as 77%, due to the prevalence of different behaviours. The developed ABM also provides a deeper understanding on which behavioural trends might be linked with exposure to high levels of pollution. Based on ABM-retrieved results, PM2.5 inhalation adjusted exposure levels of a human agent cycling in the newly developed seaside promenade, at the central-east region of the city, can be up to 37% lower than the exposure levels of a same-age human agent cycling at a crowded street (Tsimiski avenue) of the city's historical centre.

Conclusions
The proposed method can be used for evaluating the probable impacts of different public health policies prior to implementation reducing, therefore, the time and expense required to identify efficient measures. These simulations can further support the design of targeted (planned for smaller area or population groups-specific) interventions, contributing to a better urban management.

Acknowledgement
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EVALUATION OF A CITY-SCALE FORECAST SYSTEM FOR AIR QUALITY IN HAMBURG

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Summary

Air quality (AQ) in Hamburg, Germany, has improved continuously in the last two decades. However, exceedances of the AQ regulatory limits for certain air pollutants occur occasionally. Vehicular road traffic is a major contributor to emissions of nitrogen oxides and fine particulates. A prototype system for city scale AQ forecast is developed based on the Eulerian urban dispersion model EPISODE coupled with the newly developed CityChem extension. We present the prototype model system and quantify the accuracy of predicted hourly concentrations for short-term forecast.

Introduction

Emissions of air pollutants from vehicular traffic, in particular diesel engines, contribute substantially to the current burden in Hamburg, despite stringent European Union regulations on vehicle emissions and increased efficiency of the engines. The way forward in the SMURBS (Smart Urban Solutions for air quality, disasters and city growth) project is to empower and integrate smart city methods with cutting-edge Earth Observation (EO) expertise and city-scale chemistry transport modelling (CTM) to produce new data, information, tools and services, tailored to the needs of the citizens, authorities and policy makers, enabling informed decision making. A prototype for the forecast of urban air quality at high spatial resolution is developed aiming for timely dissemination of AQ information to the citizens.

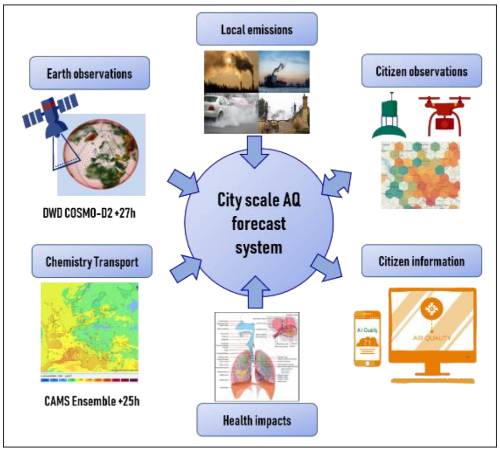

Fig.1 Prototype system for city-scale air quality forecast, enabling informed decision making.

Methodology and Results

The prototype system for city scale AQ forecast integrates the CAMS (Copernicus Atmosphere Monitoring Service) regional air quality ensemble forecast (http://www.regional.atmosphere.copernicus.eu) for Europe; the meteorological forecast of the German weather service (DWD); and a high-resolution emission inventory coupled with the city scale AQ model EPISODE-CityChem (Karl et al., 2019) in a computationally efficient, rapid automatic processing chain (Fig. 1). DWD operates the numerical weather forecast model COSMO-D2 for the very-short range up to +27 h at a horizontal resolution of 2.2 km. Meteorological data from the COSMO-D2 forecast is extracted to generate a diagnostic wind flow field and other meteorological fields for the urban area. Street-scale dispersion modelling and an advanced treatment of the photochemical air pollution are integral part of the city-scale AQ modelling. The primary target of this study is to perform a statistical evaluation of the results of the short-term AQ forecasting system for the Hamburg urban area. Forecasts regarding the upcoming daily average pollutant concentrations will be systematically collected over a one-year period and compared to observation data obtained from monitoring stations of the administrative network, mobile sensors and citizens. The latter, under the Citizen Science (CS) project luftdaten.info, install self-built fine particulate matter sensors outside their homes, thus generating an online, real-time map. Data quality is a known issue in CS. Systematic discrepancies between the citizen observations, the monitoring data, and the forecast will help to detect deficiencies of the citizen-gathered data. In the model system, time profiles for city-scale emissions and emission output rates for line sources can be refined to optimize the alignment between the forecasted concentrations and the monitoring data.

Conclusions

The new system enables AQ forecast of air pollutant concentrations and AQ Index (AQI) on surface spatial maps of 100 m resolution. This prototype system is currently applied in Athens, to demonstrate its replication in any city in Europe. In Hamburg, the forecast system will be offered to the city administration, as a web-based service to inform citizens about upcoming adverse AQ situations, complementing the existing city's service that provides AQI based on current-day in situ measurements. Beyond SMURBS, enhancement of air pollution mitigation will be pursued, by supplementing an intelligent transport system (ITS) with high resolution AQ forecasts.

Acknowledgement

This work is partly supported by the ERA-PLANET trans-national project SMURBS (www.smurbs.eu), Grant Agreement n. 689443, funded under the EU Horizon 2020 Framework Programme.

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HIGHLY SENSITIVE, LOW COST AND PRINTABLE SENSORS FOR AIR QUALITY CONTROL

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Summary

This study focus on highly sensitive low cost sensors synthesized by a simple solution-based method and tested as a self-powered gas sensing element, at room temperature (25 °C). The fundamental development of the design of novel self-powered gas sensing elements, operating at room temperature, based on n- and p-type metal oxides and perovskites paves the way to a new class of low cost, highly promising gas sensing devices. Materials sensing elements characterized by X-ray Diffraction (XRD), Scanning Electron Microscopy (SEM) and Transmission Electron Microscopy (TEM). Self-powered sensing elements have been successfully fabricated by deposition of metal oxides or perovskites on interdigitated electrodes (IDEs) consisting of two connection tracks with 500 digits and a gap of 5 μm in order to investigate their response to gases such as O_3, H_2, CH_4, NO_2 at room temperature.

Introduction

Low-cost sensors for air quality control are attracting more and more attention. The intense research interest for developing new sensors featuring high sensitivity, high selectivity, fast response and long-term stability leads to test, nanostructured materials as sensing elements. The structuring of the matter at the nanoscale offers a high surface-to-volume ratio, which favours the adsorption of gases on the sensing material due to higher interaction between the analyte and the sensing part. The use of metal oxides and perovskites as sensing elements for monitoring air quality has emerged as a low cost alternative due to fast response/recovery rates and low detection limits. Considering the above, we focus on solution based method which is facile, fast, eco-friendly and inexpensive. Sensing elements were deposited on interdigitated electrodes for gas sensing measurements.

Methodology and Results

The as-prepared devices were used for the gas sensing measurements, inside a purpose-built gas test chamber (Fig. 1). Electrical characterization of the devices as a function of gas concentration was performed by monitoring the electrical current level at a constant bias voltage of 10 V, using a Keithley 6517A electrometer. All the sensing measurements were carried out at room temperature. The sensitivity of the sensor is defined as $S\ (\%) = [(I_{gas} - I_{air})/I_{air}] \times 100\%$, where Iair denotes the current value before gas injection, while Igas denotes the maximum current value in the presence of ozone. The response time of the sensor is defined as the time required for a change in the current to reach 90% of the initial value when exposed to a set gas concentration. Similarly, the time required for the current of the sensor to reach 90% of the initial value after the gas has been turned off is defined as the recovery time.

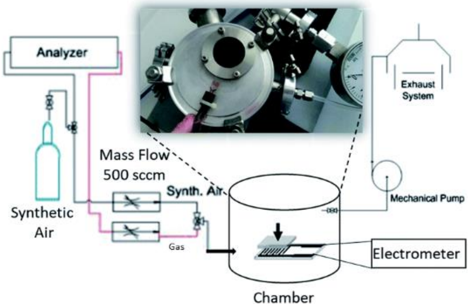

Fig.1 Conductivity-based system with a gas test

For example, $CsPbBr_3$ structure, can operate at room temperature, be self-powered and exhibit high sensitivity and remarkable repeatability. More importantly, they demonstrate higher sensitivity (54% in 187 ppb) and faster response and recovery times compared to hybrid lead mixed halide perovskite ($CH_3NH_3PbI_{3-x}Cl_x$) layers, which is the only lead halide perovskite material tested for ozone sensing, to date.

On the other hand, Cu_2O nanocubes as sensing elements was suitable for detecting ultra-low concentrations of O_3 down to 10 ppb at room temperature with very high sensitivity (28%) and a very low response/recovery time.

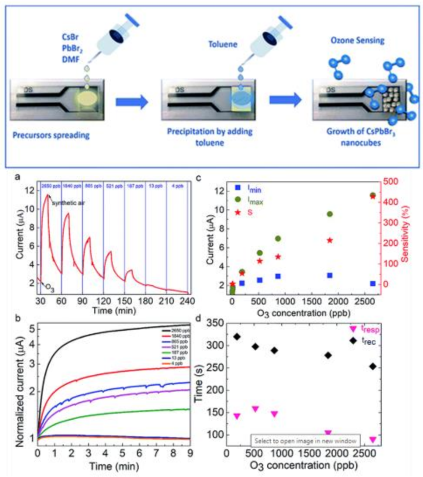

Fig.2 Schematic representation of the sensor fabrication, Electrical response of sensing materials upon applying various ozone concentrations from 2650 down to 4 ppb as a function of the ozone exposure time (a and b). Sensitivity (S) and response (tres) and recovery time (trec) as a function of gas concentration of sensor (c and d).

Conclusions

Solution based method is facile, fast, eco-friendly and inexpensive to prepare sensing elements which were deposited on interdigitated electrodes for gas sensing measurements. Metal Oxides and perovskites could be promising self-powered sensing materials with high sensitivity for oxidative and reducing gases at room temperature, suitable for air quality control.

Acknowledgement

Current work was supported by COST Action TD1105 “EuNetAir” and Stavros Niarchos Foundation within the framework of the project ARCHERS.

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CONTAMINATION ISSUES OF AUTOMOTIVE EXHAUST SENSORS: EFFECT OF AMMONIA AND ASH ON THE RESISTIVE SOOT SENSOR

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Summary
The aim of this study is to evaluate the effect of contamination on the resistive exhaust sensor. Steady-state measurements were performed on a diesel engine dynamometer. The results indicate that NH_3 and ash in high amounts can create deviations from the normal behaviour of the sensor. Contamination prevention mode and the geometry of the sensor tip can significantly reduce the contamination levels. To further improve this behaviour, additional protection measures are currently investigated.

Introduction
On-board monitoring (OBM) of greenhouse gases and pollutant emissions is considered an important topic-area towards lower real-driving vehicular emissions. As an example, on-board fuel consumption monitoring (OBFCM) has been already regulated for EU LDVs (Regulation (EU) 2018/1832). Exhaust sensors (i.e. NO_x, PM sensors) are considered key-parts of an OBM system to secure lifetime emissions covering maintenance, tampering and real-world emissions performance. Sensors will remotely track emission-related data along with the necessary infrastructure to remotely record, report and process the data. Current availability in terms of sensors comprises standalone sensors (i.e. Bosch, Delphi, EmiSense, Continental), prototype miniaturized sensors (i.e. Pegasor, LII-based) and also sensor packages/systems (or SEMS, Smart Emission Measurement System) which combine particulate and gaseous measurements with additional OBD data and remotely monitoring (i.e. NGK/NTK NCEM, ECM mini-PEMS, 3DATX, TNO SEMS). Resistive soot sensors are already incorporated in the OBD system of diesel vehicles to control and diagnose any failure in the DPF. Nevertheless, additionally to soot particles, the diesel exhaust consists of other particles and gaseous emissions including NH_3 and ash. Considering this, we evaluated the effect of NH_3 and ash on the performance, cross-sensitivity and the durability of a resistive soot sensor.

Methodology and Results
The resistive soot sensor correlates the soot mass concentration in the exhaust with the electrical resistance between two sensing electrodes, which decreases as soot accumulates on the sensor surface (see Fig.1). The actual metric of the sensor of DPF condition is the response time, which is the time needed for the sensor to go from the clean to the fully loaded state. The direct effect during sensor exposure and the remaining effect after the end of the exposure were evaluated for NH_3 and ash for 2 sensor generations using an engine dynamometer coupled with a light-duty Euro6-compliant diesel engine. NH_3 emissions are related to the NO_x aftertreatment devices, and ash is mainly derived from engine lubricant and metallic parts either from the engine or the exhaust parts. NH_3, as the main product of urea decomposition, can reach up to 700 ppm in the investigated application. The direct effect of such a high concentration is a reduction in response time by 15% attributed mainly to the different construction of dendrites. Despite the temporary effect of excessive NH_3 slip in an SCR system, the remaining effect after 300h of operation over NH_3 excess was insignificant. Ash accumulation significantly increased the response time of the resistive sensors (up to 250% for the 1st sensor generation at the end of the useful life of the vehicle). The evaluation of the effect of ash showed that the latest sensor generation (improved sensor tip design and usage of a repelling voltage) could retain the increase in response time at approximately 43%.

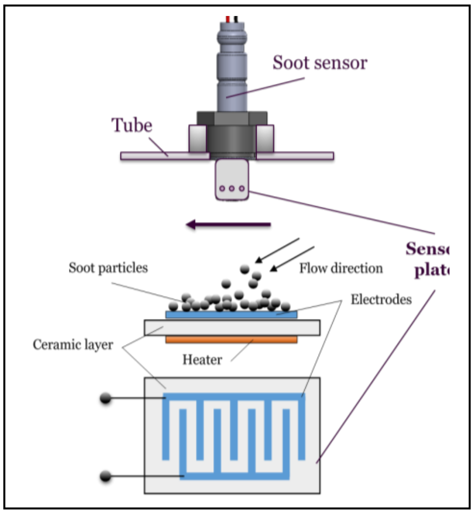

Fig.1 Operating principle of resistive soot sensor

Conclusions
For the successful adaptation of sensors in automotive exhaust applications for OBM purposes, their durability and cross-sensitivities must be thoroughly examined. The optimized sensor tip design and sensor protection modes can reduce the effects in the example of the resistive soot sensor. Therefore, advanced solutions must be used for the new (cheap) sensors that are currently developed for regulated and non-regulated emissions to tackle with contamination issues.

Acknowledgement
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ASSESSING THE PERFORMANCE OF LOW-COST AIR QUALITY GAS SENSORS UNDER CONTROLLED VARIATION OF RELATIVE HUMIDITY AND AIR TEMPERATURE

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Summary
This study intends to determine the influence of relative humidity and air temperature on low-cost air quality gas sensors, as well as the cross sensitivity with other gases, in order to establish a correction algorithm with the purpose of improving the quality of the data obtained from these sensors for air quality monitoring. A comparison between results acquired from professional reference instruments and 4-electrode gas sensors using known concentrations for four pollutants (CO, O_3, NO and NO_2) was carried out to characterize the behaviour of the sensors under different levels of relative humidity and air temperature. The results attained from the experiments showed that after a suitable post processing of the measured data, the quality of the data can be improved. Hence, this technology can be a solution in future air quality monitoring.

Introduction
Air quality monitoring is nowadays of great concern around the world due to its relation with human health and environmental welfare (Kampa and Castanas, 2008). The interest in using low-cost sensors to measure air quality has increased during the last years, because they offer a higher spatial pollutant distribution and time resolution compared to the current devices located in monitoring stations. They also have the advantage of less energy consumption and low space requirements (Yi et al, 2015). However, it has been proved by several studies that these low-cost devices are affected by meteorological parameters such as relative humidity and air temperature, and in addition to that, cross sensitivity with different gases, reducing their reliability (Wei et al, 2018). Taking that into account, and considering the advantages offered by this technology, it was decided to measure and quantify the effect of those parameters and enhance the quality of the data obtained using these low-cost sensors.

Methodology and Results
A sensor platform consisting of four low-cost Alphasese sensors (CO–B4, OX–B431, NO–B4 and NO2–B43F), each one with its respective support circuits were used for collecting the data to be corrected (see Fig.1). CO Monitor (Model APMA–360 from HORIBA), O_3 Monitor (Model 202 from 2B-Technologies) NO, NO_2 and NO_x Monitor (Model 200A from MLU) were used as reference devices. The reference devices were calibrated by means of a Gas Phase Titration (GPT) system (Serinus CAL3000 from Ecotech). Relative humidity and temperature were monitored through a digital humidity and temperature module (HYT 221 from Innovative Sensor Technology). The concentration ranges analysed for the CO, O_3, NO and NO_2 sensors were from 0-750 ppb, 0-150 ppb, 0-300 ppb and 0-150 ppb respectively. The relative humidity variation covered a wide range from 10 % up to 85 % with a step increase of 15 % with a humidification system containing Nafion membranes. Air temperature variation was controlled using a heating band covering a range from 5 °C to 45 °C with a step increase of 10 °C. The data obtained was corrected according to the reference devices and related to the meteorological parameter variation. A linear regression model was successfully applied using the correction factors calculated from the laboratory results; a significant improvement in the data quality was realized. This indicates that after a suitable post-processing of the measured data, these sensors can be used as a potential source of valuable and helpful air quality data with high spatial resolution.

Fig.1 Sensor platform with electronics

Conclusions
The low-cost gas sensors have shown a great potential to be used as a source of useful air quality data after suitable post-processing of the measured data. The relative humidity and air temperature has a significant impact on the results of these air quality sensors and hence should be considered in the correcting algorithm for the post-processing of the measured data. Still the data collected will not be as precise as the one acquired using a professional high-cost instrument.

Acknowledgement
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LOW COST SENSOR BEHAVIOUR ASSESMENT: DEALING WITH LONG-TERM DRIFTS

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Summary

A low-cost sensor, Kunak-Air 10, assessment is performed in the study. Its behaviour is evaluated and compared, in four different situations, with a fixed and a mobile reference station, as well as with another Kunak-Air 10, during a period of one year. It is concluded how this type of sensors have good performance, with an accuracy a precision near to references stations.

Introduction

Regarding the World Meteorological Organization (WMO), the main challenges to deal with using low-cost sensors (LCSs) are (1) the high temperature and relative humidity values, (2) the cross-sensitivity within some atmospheric compounds and (3) the long-term stability and drifts. The objective of the paper is to evaluate the behaviour of a specific LCS, Kunak-Air 10 (K-Air 10) (https://www.kunak.es/) under different field conditions, in Mexico City from Jan 2019 to Dec 2020. This study is part of a project which covers other studies in five continents. The IAAF (International Association of Athletics Federations) and UN Environment (UNEP) are addressing together the poor air quality issue, which has led to seven million deaths globally, according to a World Health Organization study. Before Mexico City, Kunak Technologies S.L has been integrating air quality monitors in several stadiums around the world, in Monaco, Addis Ababa, Sydney and Yokohama.

Methodology and Results

Kunak-Air 10 version 2 provided with CO, NO2, NO, O3, NOx, PM10, PM2.5, PM1, as well as temperature, pressure, humidity and wind sensors. Two K-Air 10 V2 were set in Mexico City, K-Air 10 V2 #1 and K-Air 10 V2 #2. Both were factory calibrated prior to the study and then, they were placed in two different locations: K-Air 10 V2 #1 in the Mexican Olympic Committee (COMex) and K-Air 10 V2 #2, on top the Cien Metros Reference Station. In this context, the study was set in four difference phases, in which K-Air 10 V2 #2 behaviour was assessed. Phase I: K-Air 10 V2 #2 sensor was set and compared with the Cien Metros Fixed reference station and its baseline and span was slightly adjusted. Phase II: K-Air 10 V2 #2 was moved to another location co-located to mobile UMO reference station during CDMX Marathon without any further re-calibration, in order to be compared with the reference station. Phase III, K-Air 10 V2 #2 location was changed to COMex with K-Air 10 V2 #1. In this phase, K-Air 10 V2 #2 was used to adjust K-Air 10 V2 #1 drifts, which has not moved from its original position since January 2019. Finally, in Phase IV the unit is returned to Cien Metros, after 2 months, to check any drift and the stability of data. The data of K-Air 10 V2 #2 was averaged every hour to match data from the reference stations and the 100% of the data was used for the analysis. For instance, it is obtained correlation values of $R^2 = 0.95$ and 0.97 for CO concentration for K-Air 10 V2 #2with the Cien Metros fixed reference station, and with the mobile UMO reference station.

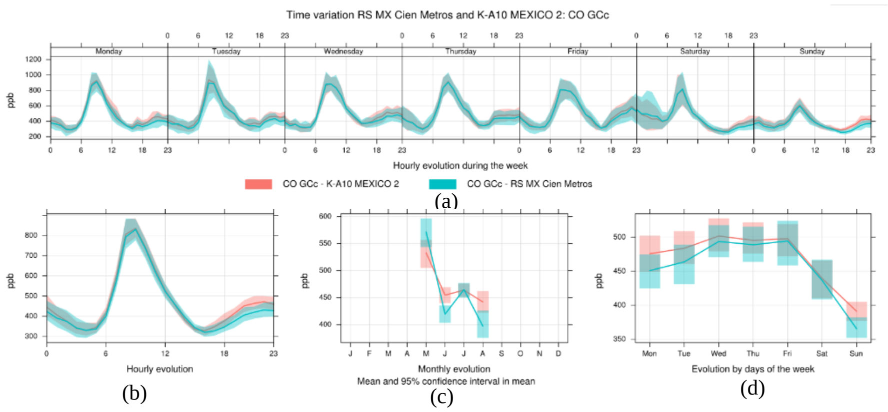

Figure 1. Phase I of K-Air 10 V2 #2 and the Cien Metros Reference Station: CO hourly evolution during (a) the week and (b) the day. Mean and 95% confidence interval in mean for (c) monthly and (d) weekly evolution.

Conclusions

After analysing the data, it is possible to conclude how LCSs can have a very good performances being very useful to extend air quality reference networks. Specifically, Kunak-Air 10 is able to measure with the accuracy and precision very close to reference station. Moreover, the long-term stability and drifts issue is solved by controlling the sensor remotely. Additionally, a procedure to guarantee the quality check and quality assurance is studied by moving the sensor and verifying its behaviour, checking how the precision and accuracy are maintained in time. Finally, Phase IV allows to estimate the drift, and thus, it is possible to give some recommendations about the calibration durability, as well as using the reference stations as a QC&QA element for a specific sensor and for the measurement's campaigns.

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ENVIRONMENTAL TRACE GAS SENSING USING QUANTUM CASCADE LASERS

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Summary
Mid-IR spectroscopy using quantum cascade lasers (QCLs) allows sensitive, selective, and fast detection of air pollutants and greenhouse gases. Recent developments, including dual-wavelength QCLs, create tantalizing options for compact, multi-species analysis in air quality monitoring and other environmental applications.

Introduction
Infrared (IR) spectroscopy is a powerful tool for gas sensing. Especially attractive is the mid-IR spectral region, where the molecules of interest have their fundamental absorption bands with cross sections that are up to five orders of magnitude larger than in the near-IR. With the development of quantum cascade lasers (QCLs), and more recently interband cascade lasers (ICLs), mid-IR light sources have become available that allow the development of highly sensitive and selective gas sensors. Various analytical techniques have taken advantage of these light sources, which have become a game changer for environmental trace-gas sensing.

Methodology and Results
We present illustrative examples from our laboratory based on quantum cascade laser direct absorption spectroscopy for trace-gas analysis in air-quality and other environmental applications. Recent developments allowed significantly improving the performance and reducing the size and cost of such mid-IR spectrometers. Key drivers of this progress are the strongly enhanced performance of lasers and detectors at temperatures that are readily achieved with Peltier cooled devices. Decisive instrumental developments include a robust and lightweight circular segmented multipass cell [1], the concept of intermittent continuous wave driving (icw) [2], and FPGA based electronics for fast data acquisition and treatment [3]. This paper will highlight the corresponding advances and show representative examples, including (i) mobile measurements, e.g. on a tram's roof in the city of Zürich or on a UAV, both featuring robustness, light weight and fast response [4], (ii) air-quality measurements with up to 9 components (CO, NO, NO_2, O_3, SO_2, NH_3 CO_2, N_2O CH_4) in a single instrument using multicolour QCLs [5], and (iii) high-precision and selective NO_2 measurements at rural and remote locations with detection limits in the very low ppt (picomol/mol) concentration range [6].

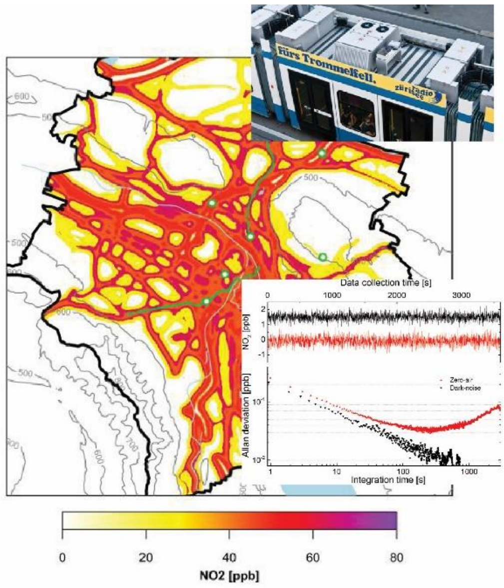

Fig. 1: one hour NO_2 concentration map based on measurements at AQM sites and the mobile QCLAS instrument mounted on a tram. Bottom: Allan deviation plot showing precision and stability with 0.03 ppb minimum after 200 s integration.

Acknowledgement
This work was supported by SNF (Swiss National Science Foundation); MEMO2, a European Training Network (MSCA-ETN); FLAIR (FLying ultrA-broadband single-shot Infra-Red sensor), under Horizon 2020; Zürich Exhalomics; Innosuisse; Euramet/EMPIR MetNO2.

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INNOVATIVE USE OF SENSOR DATA TO IMPROVE SPATIOTEMPORAL EMISSION INVENTORIES

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Summary
This study has the principal aim to establish traffic and residential heating emission inventories to be used for local scale urban air quality modelling. Emission data for PM, NO_x, VOC and SO_2 are processed and allocated at finest possible resolutions. In order to improve the spatiotemporal representation, induction loop sensor data from various locations are used to describe the commuter traffic into and out of the city for different districts. An ongoing core activity is validation based on the entire functional chain: meteorological conditions – emissions – dispersion by using various air quality measurements from the Smart Air Quality Network (SmartAQnet) in Augsburg/Germany (see Fig. 1 left).

Introduction
Detailed, highly resolved bottom-up emission inventories are often the crux in local scale air quality modelling. At present, frequently coarse emission data e.g. from MACC inventory (~7 x 7 km² resolution) are disaggregated using road geometries at finest resolutions and traffic count data. The temporal emission behaviour (activity) is represented by modulating annual mean emissions with fixed hourly, weekday and monthly activity cycles for each source type. In this work, several induction loop sensors are used to improve the spatio-temporal representation of traffic emissions. For the temporal release of different residential heating emissions an approach based on ambient temperature is used.

Methodology
Traffic emissions were computed on annual mean basis using the emission model NEMO and allocated accurately in space (order of metres). In order to represent the characteristics of commuter traffic in Augsburg's city (see Fig. 1 left), a central activity zone (CAZ) was defined and split into four quadrants plus an inner-city quadrant. For each quadrant, a couple of selected adjacent induction loops were used to derive the hourly resolved traffic activity at arterial roads for each direction (see Fig. 1 right). Residential heating emission data were processed based on chimney sweeper surveys and heat demand computations for gas, oil and solid fuels respectively. So-called SigLinDe profiles, based on district heating heat demand assessed as a function of ambient temperature, are used to improve the temporal representation of residential heating emission activity. For the validation work the GRAL modelling system is used at high spatial resolution (3 m) accounting for building influenced flow and dispersion. Results are compared with the SmartAQnet air quality stations and sensor network (scout sites) see Fig. 1. Measurements at the Bourges-Platz were used as time dependent urban background concentrations.

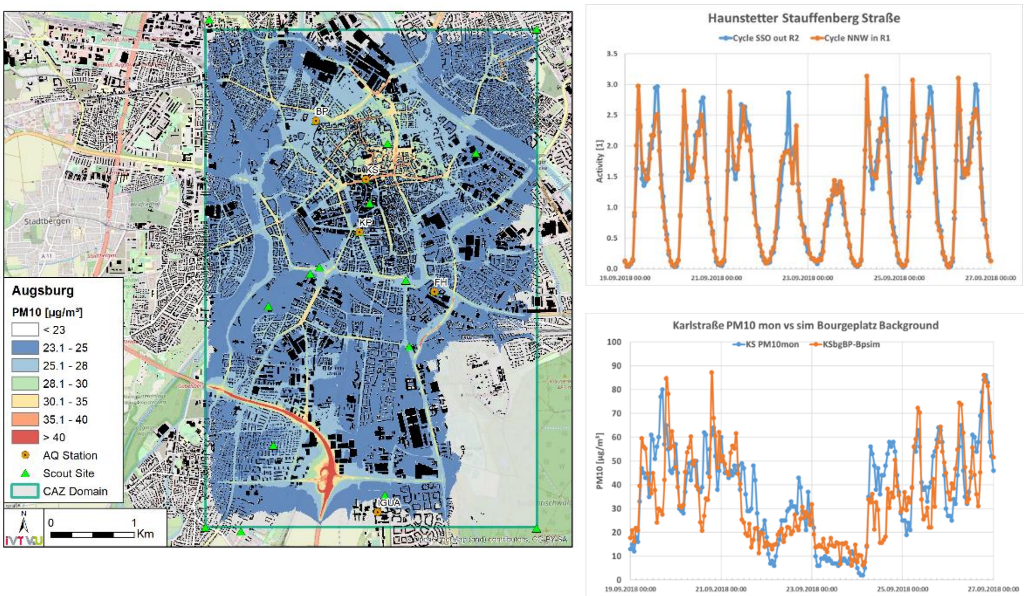

Figure 1: Left: Simulated PM10 19.09-266.09.18 mean value, CAZ Augsburg. Right top: induction loops derived traffic activity = # monit. veh/# veh traffic model annual mean at a major feeder road both directions. Right bottom: simulated vs. monitored PM10 at hotspot monitoring station Augsburg Karlstraße, 19.09-266.09.18.

Conclusions
New and detailed traffic and residential heating emission inventories have been established for the city of Augsburg. Special emphasis was laid on an improved spatiotemporal representation of traffic emissions using various induction loop sensors. Sophisticated flow and dispersion simulations and thorough comparisons with SmartAQnet air quality sensor data is still in progress. So far, highly promising results were obtained for PM10.

AIR QUALITY SIMULATIONS IN AN URBAN AREA WITHIN A SMART AIR QUALITY NETWORK BY THE LARGE EDDY SIMULATION MODEL PALM-4U

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Summary

The large eddy simulation model with online-coupled chemistry PALM-4U was applied within the Smart Air Quality Network (SmartAQnet) project to investigate the complex processes of high air pollution episodes and the development of hot spot pollution regions within the German city of Augsburg (pop. ~ 30.000). First results of the high-resolution model runs are presented and discussed with regard to emission data, boundary layer conditions and dispersion within street canyons.

Introduction

The intent of the SmartAQnet project is to fill gaps in currently available spatial and temporal air-pollution data coverage within an urban environment (Budde et al., 2017). Focussing on the acquisition of individual air pollution exposure and health risks data, a new air pollutant-monitoring strategy in the urban space integrates an existing air quality network into a spatially high-resolved network of in situ instruments ("scouts"), UAV sounding and remote sensing data sets. For a better understanding of the complex processes about the formation of air quality and especially high air-pollution episodes as well as development of hot spot pollution regions, one project task was to apply the urban climate model PALM-4U. The LES based model includes an online-coupled chemistry module and is designed to simulate chemical transformation, advection and deposition of air pollutants in larger urban canopies. Driven by high-resolution preferably precise emission and atmospheric forcing at the boundaries, PALM-4U simulations investigate the dominant role of the large eddies in atmospheric dynamics and the mixing and chemical transformation processes within street canyons of cities for the central area of the city of Augsburg (Germany).

Methodology and Results

PALM-4U is based on the Parallelized Large-Eddy Simulation Model (PALM; Maronga et al, 2015) and was extended by an online-coupled gas phase chemistry module (Maronga et al, 2019). In this study, first results of PALM-4U simulations for a two days intensive measuring period of SmartAQnet in September 2018 are presented. Different areas with 4 m horizontal and vertical resolution sized up to up to 3 km x 4 km around the city center (see Fig 1) will be investigated. High-resolution static model inputs include orography, building heights as well as vegetation, soil and pavement type. PALM-4U offers the option for offline nesting into regional models simulations. Meteorological variables and pollutant concentrations for dynamic boundary conditions are taken from a separate WRF-Chem model run covering central Europe at 7 x 7 km, driven by NCEP GDAS/FNL 0.25 x 0.25 degree global tropospheric analyses grids at its boundaries, and by emissions inputs adapted from the TNO-MACC inventory. In contrast, the PALM-4U runs used high-resolution emission data provided for the SmartAQnet central activity zone. They include precise bottom-up established traffic emissions using road network, traffic volumes, speed limits and induction loop derived traffic activities, as well as pre-processed residential heating emission data based on chimney sweeper surveys and heat demand computations for gas, oil and solid fuels respectively. Due to the very high computational demands of an LES-based mode PALM-4U, compromises with respect to the degree of detail of the gas-phase chemistry mechanisms and of the size of the model domain have to be made. Despite of such compromises simulations may perform much better than even fully coupled regional scale models as fully resolved eddy processes and main chemistry mechanisms are still included as online-coupled processes. The PALM-4U model performance of different emission inventories with different complexity and the impact of lateral boundary conditions from the regional scale model are tested and discussed.

Fig.1 Simulation areas of PALM-4U runs around Augsburg city, shown on traffic density lines, land use, building heights and

Conclusions and outlook

PALM-4U is able to simulate resolved turbulence and chemical transformations in the urban environment on street on street canyon level. Simulations were performed for the central area of the city of Augsburg. Offline nesting into WRF-Chem and use of real-time emissions allows the simulation of realistic situation. Detailed analysis of these complex and costly air pollution data will be performed to provide an efficient way for air quality nowcasting by using statistical appraoches/models.

Acknowledgement

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Short Presentations

ATMOSPHERIC MODEL DATA (ATMODAT) - CREATION OF A MODEL DATA STANDARD FOR OBSTACLE RESOLVING MODELS

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Summary
To assess processes and phenomenom in complex urban areas, obstacle resolving micro-scale models of the atmosphere are increasingly used. But the comparison of results of different obstacle resolving models (ORM) is hindered y the various data formats used for different models and approaches. For global model data a data standard exist within the WCRD Coupled Model Intercomparison Project (CMIP) and therefore model data can be compared more easily. Microscale ORM results are more difficult to compare, because ot the lack of a tailored data standard for these types of model results. As a part of project AtMoDat (Atmospheric Model Data) the creation of a standard for obstacle resolving models, which should be based on existing model standards is in progress. In this study a first attempt to create a standard will be based on the needs of the user community. A web based inventory is developed, where model user can provide information during this confernce on their requirements for this tailored model data standard.

Introduction

Obstacle resolving micro-scale modelling of the atmosphere is important to assess processes in complex urban areas. But the comparison of results of different obstacle resolving models (ORM) is time consuming due to the different model types and approaches used. This includes different filtering methods (RANS, LES), with different numerical grids (Arakawa-A,-B,-C), numerical solution techniques (finite elements, finite volume, finite differences) and with different temporal and spatial resolutions. This hinders reusability of model results by the model user group as well as by others. While for global model data within the WCRD Coupled Model Intercomparison Project (CMIP) a standard exists and data can therefore be compared more easily, microscale ORM results are more difficult to compare. Applying CMIP standards to microscale model results may not fit the need of the microscale model results. The project AtMoDat, funded by the Federal Ministry of Education and Research (BMBF) start an attempt to create a standard for ORM results based on the existing Climate and Forecast (CF) conventions for CMIP. To aim for a better usability and reusability of ORM results, for data storage in archive systems and for a better citation of the used data a standard format is helpful and necessary.

Methodology and Results

Based on the results of a model inventory, a web based survey was developed and circulated to the modeller community to get an overview about the needs of the user community. The participants of this survey shall answer questions about the model data and the model which he used, data processing tools and what standards are already known and used on the model output. Based on the results of the survey, the next step is to extend the collection of model characteristics and eventually a generic scheme shall be provided.

Conclusion

The development of this model data standard will consider the user input. We want to implement suggestions of the user for the handling of model data to the development of the data standard. In order to be wiedly applied the development of a data standard needs to involve the requirements of the community. Please contribute to our survey: uhh.de/orm-survey

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CITY-WIDE AIR QUALITY MEASUREMENT SYSTEM BASED ON IOT NETWORK

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Summary

The aim of this study is to present the development –and field evaluation– of an IT platform for the monitoring and recording of atmospheric conditions in urban environments, mainly through a wireless network of sensor-based air quality monitoring systems that can supplement existing infrastructures.

Introduction

Atmospheric pollution in cities is an important and complex problem. The main sources of gaseous and particulate pollutants are vehicles, industry, central heating and other human activities. The need for stricter environmental quality controls has been widely recognized as an increasing number of diseases, especially respiratory problems are linked to atmospheric pollution (Di et al., 2017). Considering this, we develop integrated and advanced sensors and applications (web and mobile) intended to cover ongoing problems or gaps of existing, regulatory monitoring facilities (Kumar et al., 2015).

This study is part of and implemented in the framework of the ongoing EMISSION (Environmental monitoring integrated system using an IoT network) funded project.

Methodology and Results

The described air pollution monitoring system is based on Internet of Things (IoT) technology. The design follows low-cost and low-power consumption principles. The system comprises of a set of sensors, a processing unit and a communication subsystem. Specifically, the measured quantities and the corresponding sensing devices are temperature, humidity and pressure (T, RH, P: Bosch BME2080), $PM_{2.5}$ and PM_{10} particles (PM: Plantower PMS5003), ozone (O_3: Alphasense OX-B431) and nitrogen dioxide (NO_2: Alphasense NO2-B43F). The processing unit (STM32 NUCLEO-F091RC) was selected due to its high processor performance and its available interfaces, since preprocessing is required during the operation of the station. A GPS unit (UBLOX NEO-6) is used to provide location and time information, a small custom designed UPS unit supports and protects the system from power failures and an SD card is used to store measurements when the station is offline while additionally storing the latest running version of the firmware enabling Over The Air (OTA) firmware upgrade capabilities. Communication is achieved through the cloud with two optional modules depending on the network availability at the installation location. Thus, where a public WiFi network is available the station sends data through a WiFi interface (ESP8266). Otherwise a GPRS modem (SIM808) is used. Measurements, for all parameters, are conducted every 10 seconds. The processing unit stores locally the measurements and calculates average values every 5 minutes. These values are enveloped in a JSON string using GPS data for timestamp and sent over the cloud to the main server. All the above processes including the inherent uncertainty of the sensors call for well-designed and executed QA/QC processes in order to assure the reliability of the information provided to the public and stakeholders. For this, since June 2019, two measuring nodes are systematically tested under different environmental conditions at the Thissio superstation of the National Observatory of Athens, collocated with reference instruments measuring the same parameters, for comparison and calibration purposes.

Conclusions

Sensor-based, low-cost systems appear as a promising platform for monitoring air quality, providing real-time information on the temporal variability of regulatory pollutants. However, rigorous inter-comparison with reference instrumentation remains a prerequisite, in order to adjust the sensor signals to realistic atmospheric pollutants concentrations. It turs out from preliminary results that the calibration results for low-cost sensors can be site and season (including chemical composition changes) specific, indicating the necessity for an integrated design for the evaluation procedure during the operational phase of such networks.

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DEPLOYMENT OF COST-EFFECTIVE SENSORS FOR AIR QUALITY MONITORING BY CITIZENS IN THE REGION OF THESSALONIKI

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Summary

This study presents the development and first results of the installation of a cost-effective air quality wireless sensor network in an urban setting, that provides useful complementary data on local air quality in the greater are of Thessaloniki. 70 new air quality calibrated low-cost sensor devices embedded in 43 boards were delivered to citizens in order to provide near real time measurements of PM_{10}, $PM_{2.5}$, NO_x, O_3 and CO for a six-month measurement campaign. Data collected by these sensors were used for detailed spatial and temporal mapping of air pollution and assessment of population exposure. Although they provide spatially dense air quality data their performance has been evaluated via statistical metrics. This study explores the added value of such an investment in the city recognizing that an increasing accessibility of pollution data through crowdsourcing and citizen science is helping to advance the air quality monitoring market.

Introduction

Poor air quality remains a major environmental concern in many urban agglomerations worldwide. However, quantitative measurements of pollutant concentrations are usually only provided at a few locations. The recent emergence of low-cost sensors technologies, measuring various air pollutants, enables the collection of air pollution data of high spatiotemporal resolution in real-time (e.g. Heimann et al, 2015). In this study we deployed low-cost air quality monitoring sensors and distributed them to citizens of Thessaloniki. The aim of this study is to provide near real time air pollution measurements that will allow the better representation of the air pollution levels in the greater area of Thessaloniki. This study is part and implemented in the framework of an ongoing funded project, "Sympnia-Air quality monitoring and forecasting using satellite and low-cost sensors deriving data" where a detailed local air quality map is under development.

Methodology and Results

70 air quality low-cost sensor devices embedded in 43 boards were developed measuring the concentration of 6 atmospheric pollutants (PM_{10}, $PM_{2.5}$, NO_2, NO, O_3 and CO). Each board consists of 1, 2 or 3 air quality sensors, covering all the combinations for monitoring the appropriate pollutants in various area with different sources, and a control board which integrates all the elements of the hardware such as GPS, data storage, communication ports and signal conditioning. Data from low-cost sensors are collected from a node that consists of a microcontroller for the data processing and a wireless unit that receives the processed data and transfers it to an existing air quality platform. The sensors operate on electricity and transmits data in real time and on hourly base. An Application Programming Interface (API) was developed on the air quality platform for receiving datasets from the sensors, storing them in a database and serving them to a web and mobile application, that will support the existing Envi4All product (Kosmidis et al., 2016). The sensors were tested in the lab and in the field in terms of their sensitivity before delivered to citizen science volunteers. The sensors' spatial distribution was selected in such a way that, inter alia, a homogeneous distribution to be achieved and areas with high expected levels of air pollution to be covered. The overall performance and the first promising results suggest that if supported by the proper post processing, measurements from ground-based official stations and data modelling tools, such sensors have the potential for new strategies in air quality control.

Conclusions

A new dense, sustainable and cost-effective air quality sensor network combined with standard monitoring reference instruments can be promising in the way to:

- Better represent the microclimate of the grater area of Thessaloniki and improve our knowledge of emissions and their source identification
- Motivate citizens to continue these measurements, to increase public awareness and to lower harmful exposure
- Provide complementary information about the levels of air pollution to scientists and public authorities for policy making purposes

Acknowledgement

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PERFORMANCE EVALUATION OF LOW-COST SENSORS INSIDE AN 'ENVILUTION^{TM}' CHAMBER

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Summary
An environmental-pollution chamber (referred to as 'Envilution^{TM} chamber') was designed to create controlled conditions for low-cost sensor (LCS) testing. Various temperature (5 to 40°C) and relative humidity (RH from 10 to 90%) levels with different gaseous and particulate matter (PM) concentrations can be created inside the custom-made 125L chamber for the performance evaluation of LCSs. The LCSs showed excellent correlation ($R^2 > 0.98$) for the tested parameters with the reference instruments.

Introduction
Calibration and performance assessment of LCSs have been carried out only via co-location experiments with reference instruments, which is costly and covers only a limited range of environmental conditions and pollution concentrations (Kumar et al., 2015). Hence, the ability to use a chamber controlling single environmental variables at a time is perceived to offer a faster rate of validation before moving into the more complex field environment. The unique features of the Envilution^{TM} chamber, including affordable cost, small size and lightweight, low maintenance/operational costs and ease of operation, has the potential to make it an on-demand package for LCSs' testing. This paper describes performance assessment of the chamber, while preliminary assessment of two LCSs (named as Badboy and Dougal) in terms of environmental parameters (temperature and RH) and $PM_{2.5}$ concentrations is included for demonstration.

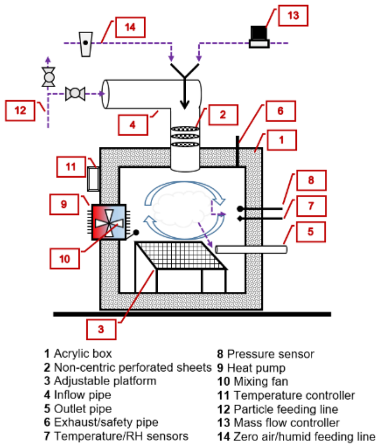

Fig.1 Schematic diagram of the chamber

Methodology and Results
Figure 1 shows a schematic diagram of the chamber with the major components. The pollutants are premixed using both a set of non-centric perforated baffles and a built-in fan inside. The outlet pipe, which transfers sample air towards reference instruments, is located at the centre of the chamber at the same height, where the LCSs were placed on an adjustable platform for testing. A Vaisala temperature/RH sensor and Grimm Portable Mini Laser Aerosol Spectrometer were employed as reference instruments. For testing demonstration, the assessment was conducted based on temperature/RH (HDC1000, Texas Instruments) and $PM_{2.5}$ (HPMA115S0, Honeywell) sensors. During demonstration tests, the performance of LCSs vs. reference instruments was examined during temperature (35 to 5°C), RH (80 – 20%) and $PM_{2.5}$ (200 – 65 μg/m^3) changes. The correlations are shown in Figure 2.

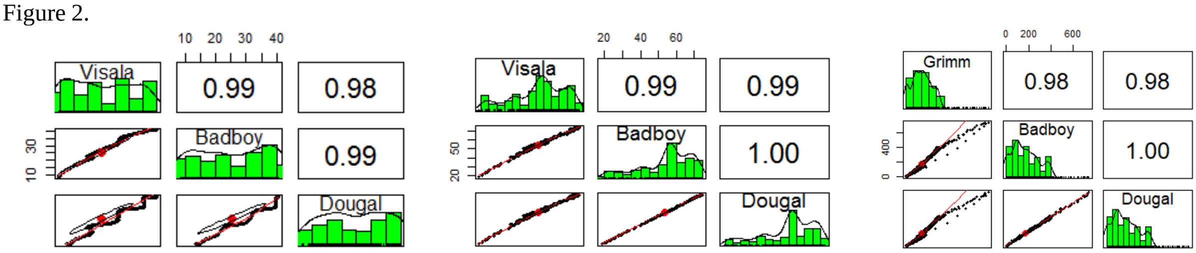

Fig.2 Correlation for temperature (left), RH (centre), and $PM_{2.5}$ (right) with reference instruments.

The RSD% values of the temperature test were < 6.7%, which are comparable with the costly chambers (Papapostolou et al., 2017). In terms of RH at 20%, the RSD% value was only 0.3%, while fluctuation between 20-23% at similar conditions has been reported (Papapostolou et al., 2017). The correlation between sensors and Grimm ($R^2 > 0.98$) showed a high relationship, which is comparable with the previous studies (Wang et al., 2015).

Conclusions
Generating and maintaining different environmental conditions and pollution concentrations by using an affordable Envilution^{TM} chamber is a highly useful facility to evaluate the performance of LCS. A set of experimental studies was designed and conducted to demonstrate its performance in maintaining stable conditions including meteorological parameters and $PM_{2.5}$ pollutant. The results demonstrated the performance of the chamber compared to the available studies in the literature.

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Special Session – Shipping and Air Quality

ENVIRONMENTAL IMPACTS OF SHIPPING: FROM GLOBAL TO LOCAL SCALES

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Summary

Combustion in ship engines produces a range of primary and secondary pollutants that have important environmental, health, economic and climatic impacts. New global standards will be enforced for shipping emissions on January 2020, as a consequence of the expected significant health and environmental effects. This presentation will first examine selected recent results on the environmental effects of shipping by the present authors, especially regarding the effects of potential emission control areas and other emission reduction options. Second, the presentation will evaluate research needs in this area. Third, we will examine a new EU project EMERGE, “Evaluation, control and Mitigation of the EnviRonmental impacts of shippinG Emissions” (2020 – 2024).

Introduction

In complying with the limit values within SECAs (Sulphur Emission Control Areas), ships are currently mandated to use fuel oil with Fuel Sulphur Content within the limits. Alternatively, vessels may be equipped with abatement systems (SOx scrubbers) that decrease SO_2 in the exhaust to within the limits. The extensive seawater scrubbing process will produce large volumes of acidic seawater, which is expected to cause harmful side effects. However, the nature and quantity of such side effects are currently poorly known.

Methodology and Results

Sofiev et al. (2018) evaluated the public health and climate impacts of low-sulphur fuels in global shipping. They found that cleaner low-sulphur marine fuels in 2020 will reduce ship-related premature mortality and morbidity globally by 34 and 54%, respectively. Air pollution originated from shipping is still expected to account for substantial health impacts, ~ 250 000 deaths and ~ 6.4 million childhood asthma cases annually. EERA and FMI (2019) have evaluated the impacts of an introduction of potential Mediterranean Emission Control Area. The associated benefits of implementing SECA standards were evaluated to include 1100 avoided premature deaths annually, reductions in acidifying deposition, and reductions in aerosol optical depth related to haze effects. Karl et al. (2019) evaluated policy options regarding emission regulations for ship traffic and the planned introduction of a nitrogen emission control area (NECA) in the Baltic Sea and the North Sea in 2021. The average contribution of ships to $PM_{2.5}$ levels in coastal land areas was in the range of 3.1 % – 5.7 %.

The major research needs in this area include: (i) Comprehensive evaluation of all the environmental impacts of shipping, including marine environments, ecology, atmosphere, health impacts, climatic impacts and cost-benefit analyses, (ii) Integrated modelling of the dispersion and impacts both in the seas and in the atmosphere, and (iii) modelling of the cost-effectiveness of abatement methods for shipping. The EMERGE consortium will develop an integrated modelling framework to assess the combined impacts of shipping emissions on the aquatic, atmospheric and ecosystem environments. The assessment will include the benefits and costs of control and mitigation options affecting water quality, air pollution exposure, health impact, climate forcing and bioaccumulation of pollutants.

Conclusions

The introduction of additional SECA and NECA regions both globally and in Europe would be clearly beneficial from a public health viewpoint. The harmful effects of the pollution from shipping to both water and air, especially regarding the seawater scrubbing process, will need to be studied comprehensively and quantified. A new EU project EMERGE will provide recommendations and guidance for stakeholders and decision-makers on cost-beneficial options for sustainable shipping.

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HEALTH IMPACTS OF NO_2 SHIP-RELATED AIR POLLUTION IN THE IBERIAN PENINSULA

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Summary

This work aimed to estimate the mortality in terms of deaths and years lost life (YLLs) associated with NO_2 ship-related air pollution and their costs in the Iberian Peninsula for 2015. To estimate the excess of mortality, shipping emissions were obtained using STEAM model and their contributions for NO_2 levels were modelled using EMEP/MSC-W chemistry transport model. Log-linear functions for all-cause (natural) mortality in ages above 30 years were used to estimate mortality. Costs associated with mortality were estimated as the product of the excess burden of disease and its unit health cost value. Results showed an increase in mortality due to NO_2 ship-related air pollution.

Introduction

According to the International Maritime Organization (IMO) international shipping represents around 13% of total anthropogenic emissions of NO_x (Smith et al., 2014). Over the last two decades, emissions of NO_x from land-based sources (traffic, heating, industrial production, power generation, etc.) have decreased substantially in Europe (about 50%) due to new and more effective air pollution and climate policies. An opposite behaviour has been verified in shipping emissions which have been neglected for a long time (Aulinger et al., 2016). Since studies on the impact of shipping emissions on human health are still scarce and the Iberian Peninsula has a very important strategic position in international maritime transport, this work aimed to estimate the mortality associated with NO_2 ship-related air pollution and their costs for 2015.

Methodology and Results

To determine the effects of long-term NO_2 ship-related air pollution, shipping emissions were obtained from an AIS based emission inventory using STEAM model and their contributions for NO_2 levels in the Iberian Peninsula were modelled using EMEP/MSC-W chemistry transport model (simulations with and without shipping emissions). Log-linear functions based on WHO-HRAPIE assuming the relative risk (RR) of 1.055 per 10 $\mu g\ m^{-3}$ (95% CI 1.031–1.08) for the annual average NO_2 concentrations above 20 $\mu g\ m^{-3}$ and for all-cause (natural) mortality in ages above 30 years were used to estimate the attributable fractions (AFs). Then, excess mortality was calculated multiplying AFs by the all-cause (natural) mortality baseline incidence and by the population at LAU2 level. Life expectancy reduction i.e., the increment of YLLs was calculated using WHO life-tables methodology assuming that the number of YLLs was equal to life expectancy at age of death (Prüss-Üstün et al., 2003). Costs associated with mortality and YLLs were estimated as the product of the excess burden of disease and its unit health cost value (VSL for premature deaths and VOLY for YLLs). NO_2 ship-related emissions caused 1536 (95% CI 907–2132) deaths, which corresponded to 10940 (95% CI 6454–15194) YLLs. Estimated premature deaths and YLLs represented an increase of about 35% compared to the scenario without shipping emissions contribution. Moreover, NO_2 ship-related emissions were estimated to cause annual damages of around 416 (245-577) million € yr^{-1} when mortality was valued in terms of YLLs and 3 623 (2 140-5 026) million € yr^{-1} when mortality was valued as deaths.

Conclusions

Results show that NO_2 ship-related air pollution increased the number of premature deaths and YLLs on the Iberian Peninsula for 2015. As from 2015 no NO_x regulations has been released the problem might be even higher now because of the shipping traffic increase. Thus studies on mitigation measures should be performed to quantify emission reductions and consequent reduction on the burden of disease.

Acknowledgments

This work was financially supported by: project UID/EQU/00511/2019 - Laboratory for Process Engineering, Environment, Biotechnology and Energy – LEPABE funded by national funds through FCT/MCTES (PIDDAC) and project EMISSHIP (PTDC/CTA-AMB/32201/2017), funded by FEDER funds through COMPETE2020 – Programa Operacional Competitividade e Internacionalização (POCI) and by national funds (PIDDAC) through FCT/MCTES.

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IMPACT OF SHIPPING EMISSIONS ON AIR QUALITY IN PORTUGAL: IN PRESENT AND FUTURE CLIMATE CHANGE SCENARIOS

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Summary

In this study, we quantify and evaluate the current and future impact of shipping emissions on air quality in the Iberian Peninsula. To do this, a high-resolution emissions inventory was compiled, which includes emissions from every activity sector, and numerical air quality simulations were performed with the WRF-CHIMERE modelling system (already extensively validated for the study region). To obtain current and future contributions of maritime transport to total pollutant concentrations, simulations were divided into two scenarios for the present (2015) and one for the future (2050). For the present scenario, simulations were made with and without shipping emissions, creating our base year for comparison. The results for 2015 indicate significant mean differences for all studied pollutants. These contributions of shipping emissions to total pollutant concentrations are noticeable up to 50 km inland in areas with higher traffic. For 2050, the simulations were performed considering both climate change and shipping emissions projections (using 2015 as a base year). Here, the most noticeable differences are in major urban areas and inland locations. For example, due to the increased temperature, O3 concentrations are slightly higher in some regions, while PM2.5 concentrations also increase because of the decreased precipitation. In terms of air quality, a slight decrease of pollutant concentrations is expected in shipping routes, because of maritime emissions decreasing as well.

Introduction

The European Commission and maritime industry have a long-term objective of "zero-waste, zero-emission" for maritime transport. This is being put into practice with a joint effort from the European Union and the International Maritime Organization (IMO). The objective is to reduce greenhouse gas emissions, mainly for international shipping, and manage the amendment of the IMO to reduce sulphur oxides and nitrogen oxides emissions from ships. This study is focused on the impacts of shipping emissions on regional air quality in the Iberian Peninsula (IP), which has a large amount of ship traffic along the western and southern coast. The present scenario (year 2015) is tested with and without shipping emissions, and the future scenario includes an RCP8.5 climate change scenario (year 2050), and emission projections for shipping.

Methodology and Results

The study was performed by applying a numerical modelling system comprised of the WRF weather forecast model and the CHIMERE chemistry-transport model. This modelling system has already been widely used and validated for these types of studies (Monteiro et al., 2018). The simulations were performed for the European Southwest region, with a horizontal resolution of 25 x 25 km. WRF runs were made for 2015 (present scenario) and 2050 (RCP 8.5 future scenario). An emissions inventory was built using the updated 0.1º x 0.1º emissions inventory, from the EMEP Centre on Emission Inventories and Projections (CEIP), combined with data from the STEAM shipping emissions model.

Regarding the present conditions, the modelling results show critical areas affected by shipping emissions, with a large focus on shipping routes and port areas. The largest differences in terms of spatial distribution were found to be those of O3, due to its formation from NOx precursors and significant transport and dispersion. For the future scenarios two aspect are most evident (see Fig 1). First, since shipping emissions are going to decrease in the future, there were significant differences between the simulations along shipping routes. Second, the contribution of climate change to variations in regional air quality over inland locations is much higher than what is caused due to a decrease in shipping emissions.

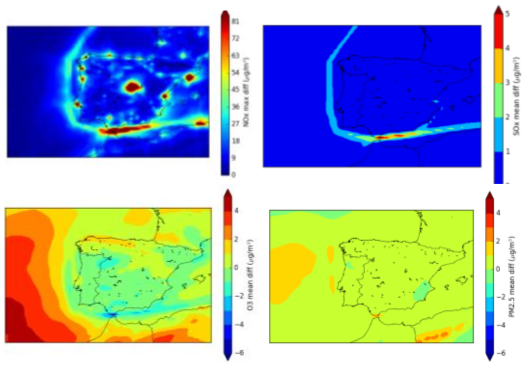

Fig.1 Annual mean differences between 2015 (ref) and 2050 (future climate RCP8.5 and shipping emissions projection), for NOx, SOx, PM2.5 and O3,

Conclusions

The modelling results indicate that the integration of the climatic conditions (as well as the aforementioned emissions projections) suggest a small increase (5%) of the future impacts, for specific pollutants like PM, associated to the expected reduction in precipitation. These outcomes are particularly relevant to support the maritime transport and port sectors, since it will provide them with insight in developing the most adequate mitigation measures to reduce environmental impacts.

Acknowledgement

Thanks are due to FCT/MEC and the co-funding by FEDER, within the PT2020 Partnership Agreement and Compete 2020, for AIRSHIP project (PTDC/AAG-MAA/2569/2014-POCI-01-0145-FEDER-016752) and CESAM (UID/AMB/50017-POCI-01-0145-FEDER-007638).

MEASUREMENT OF SHIP EMISSIONS USING MOBILE PLATFORMS

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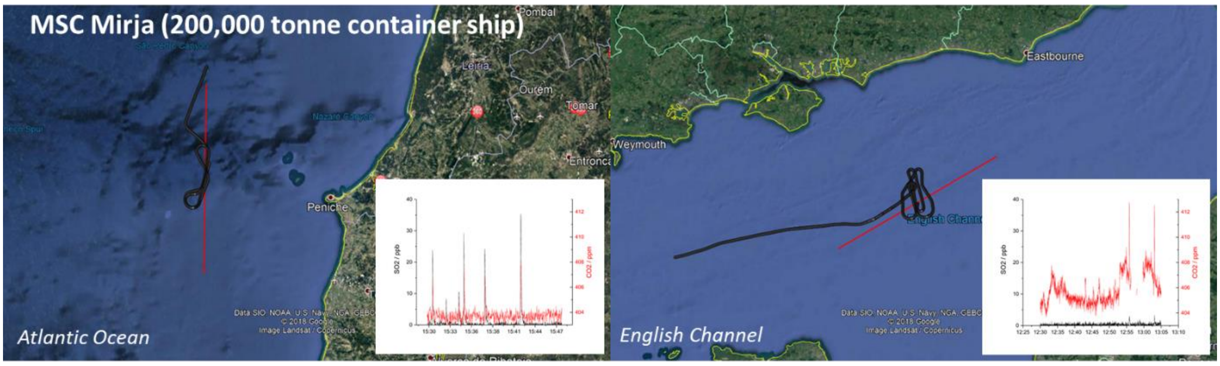
Summary
This study demonstrates the use of a large aircraft and instrumented van to measure emissions from ships. The Facility for Airborne Atmospheric Measurements (FAAM) research aircraft (a converted BAe-146) was used to measure emissions from a variety of ships in the Atlantic Ocean off the coast of Portugal and in the Sulphur Emission Control Area (SECA) in the English Channel. Measurements of a variety of species were made, including NO_x, CO_2, SO_2, O_3, a variety of VOCs and speciated PM. Data were examined from a variety of different ships in order to assess the emission ratios of the various air pollutants to CO_2, including a large container ship that was sampled both in and out of the SECA. In addition, a mobile van was used to measure the emissions of the Port of Immingham, UK. Measurements of SO_2, CO_2, NO_x, VOCs and O_3 were made in order to assess the effect of the port on air pollution in the surrounding towns and villages.

Introduction
Shipping is one of the least regulated sources of emissions of atmospheric pollutants. Ships generally burn low-quality, high-sulphur fuel and the high temperature combustion in ship engines produce emissions high in nitrogen oxides ($NO + NO_2 = NO_x$) but low in other photo-pollutants such as carbon monoxide (CO) and volatile organic compounds (VOCs). It has been estimated that shipping accounts for between 12 and 17% of all NO_x sources globally (Charlton-Perez et al., 2009). Currently, the Sulphur Emission Control Area (SECA), which covers the English Channel and North Sea, dictates that ships must emit no more than 0.1% of sulphur by fuel mass, while outside of this area ships are allowed to emit 3.5% sulphur. However in 2020 the limit in international waters is reducing to 0.5%. Whilst this will have an obvious effect on the amount of sulphur emitted, it is currently unclear what the effect will be on other gas and aerosol emissions. This is largely due to uncertainties in the means of achieving compliance (either by using low sulphur fuel or by using scrubbers). It was shown by measurements near shipping lanes that there was a 3 fold decrease of SO_2 from 2014 to 2015 in response to new regulations on sulphur emissions in the SECA (Yang et al., 2016). The Atmospheric Composition and Radiative forcing changes due to UN International Ship Emissions regulations (ACRUISE) project aims to make measurements of gaseous of chemical species (O_3, CO, NO_x, CO_2, CH_4, SO_2 and a range of VOCs) and speciated PM, in a series of ship plumes in the North Atlantic shipping lanes off the Iberian peninsula and in the English Channel. Flights in summer 2019 and summer 2020 will allow investigation of the effect of the new sulphur emission regulation on the plume content.

Results
Initial results from flights in summer 2019 are presented here. Emission ratios of SO_2, NO_x and VOCs to CO_2 from a variety of ships (>50) have been examined in both international waters and in the SECA in the English Channel. The varying amounts of SO_2 were correlated against factors such as ship type, size and origin, along with any information available about fuel type or exhaust scrubbing technology. One large container ship was sampled both in international waters and, 2 days later in the English Channel, and was found to be emitting significantly less SO_2 (up to a factor of 20) in the SECA (see figure). Some of the plumes were sampled at various distances and heights from source in order to examine the process chemistry of the plumes. These measurements will be repeated in summer 2020 in order to assess the effect of the change in international shipping regulations on the content and chemistry of the plumes. Measurements are also presented of emissions from the Port of Immingham in the UK. Immingham is the largest port in the United Kingdom by tonnage with ~60 million tonnes of cargo passing through each year. Measurements were made over 5 days using an instrumented mobile van in order to examine the effect of the docks and ship movements in the Humber Estuary on air pollution in the surrounding towns and villages.



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THE IMPACT OF SHIPPING ON AIR QUALITY AND HUMAN HEALTH IN THE GOTHENBURG AREA UNDER SEVERAL FUTURE SCENARIOS

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Summary
This study presents impact of current and future shipping on air pollution and human health in the city of Gothenburg. In the framework of the BONUS SHEBA project, the impact of current and scenario emissions from ships on air quality has been investigated on a range of scales with several chemistry-transport models (CTM): from a European domain to city-scale simulations of several harbour cities. Here, we present the contribution of regional and local shipping to concentrations of NO_2, $PM_{2.5}$ and ozone and the associated human exposure and health impacts for 2012 and 2040 under several emission scenarios in the Gothenburg urban area. The future shipping scenarios have been constructed considering development of the trade, the fleet regarding number and size of ships, improvement of the energy efficiency of vessels as well as implementation of environmental legislation.

Introduction
International shipping carries approximately 90% of the world trade and with increasing global population and market the sector is growing steadily. Comparing to other transport sectors shipping is energy efficient, however, there is a large potential for energy effectivization within the sector. Furthermore the environmental regulations regarding emissions to air are weak comparing to other sources. Ships are important source of sulphur dioxide, oxides of nitrogen and particulate matter. Emissions from international shipping deteriorate significantly air quality at coastal areas and in harbour cities emissions in and around ports further impact the air quality (Eyring et al., 2010). Emissions from international shipping are regulated by IMO, however, while emissions of sulphur has been significantly reduced in SECAs after 2015 and will decrease globaly in 2020, significant decrease of emissions of NOx will only take place in NECAs and full impact of legislation will give full effect first after two decades. In this study impact of the currently agreed legislation together with an estimate of development in shipping and in energy effectivization, on air pollution and the associated health impacts, is investigated.

Methodology and Results
To investigate the shipping-related urban air pollution, simulations with The Air Pollution Model (TAPM, Hurley et al. 2005) under different future emission scenarios for the Gothenburg urban area were done. All simulations used meteorological fields for the year 2012 with regional and local emission data for the years 2012 and 2040. For shipping emissions, fine-resolution data for Gothenburg region were calculated with the STEAM model (Jalkanen et al, 2009) for year 2012. For the future scenarios the relative change in emissions between 2012 and 2040 was calculated with help of ship-type specific scenario factors. The boundary conditions in the local model runs were taken from corresponding regional-scale simulations to integrate background concentrations.
Four different future scenarios were investigated, taking into account all of the already decided emission regulations: 1. The business as usual (BAU) scenario considered high energy effectivization, beyond requirements of the Energy Efficiency Design Index (EEDI) regulation of IMO. 2. EEDI scenario, following exactly the requirements of the EEDI regulation, 3. and 4. Wide-scale use of land-powered electricity in the port of Gothenburg applied in BAU and EEDI scenarios. The model results were used to calculate exposures to PM2.5, NO2 and ozone as SOMO35. The health impacts were calculated using the ALPHA-RiskPoll (ARP) model (Holland et al., 2013). The results have shown that shipping-related $PM_{2.5}$ in 2012 caused shortened lifetime with 0.015 years of life lost per person, almost 80% being caused by regional shipping outside Gothenburg. Impact from shipping was 12% of the total calculated impact from PM2.5. In the BAU scenario the impact from shipping was 0.009 years of life lost per person, about 11% of the total calculated impact from PM2.5. Shore electricity reduced impact of PM2.5 from local shipping by c.a. 40%, but only by few percent if also regional shipping is considered.

Conclusions
The study shows significant impacts of shipping on health of citizens of the city. The impacts are expected to decrease significantly in the future as a result of environmental legislation and energy effectivization in shipping.

Acknowledgement
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IMPACT OF SHIP EMISSIONS ON THE URBAN POLLUTION: AN EXPERIMENTAL STUDY

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Summary

We present an experimental study on the dispersion of pollutants released by cruise ships in the port Naples that is one of the most important cruise ports in Mediterranean area. Pollutant emissions released from three cruise ships have been simulated varying the ratio between the emission velocity at the ship stacks and the wind velocity for two wind directions (SE and S). The nearby urban area modelled covers an area of about 1.2 km^2 and the model scale is 1:500 (see Fig. 1a). The objective of this study is to investigate the impact of cruise ships emissions in the port of Naples on the urban canopy.

Introduction

Cruise shipping is a maritime activity marked by continuous growth. In 2018 passenger traffic increased of 15.2% respect to 2017 (AdSP, 2019). In order to assess the impact of ship emissions on nearby urban area, generally monitoring campaigns are carried out on selected pollutants and data analysis techniques are applied to evaluate the contribution of ship emissions (Prati et al., 2015). In alternative, several authors investigated the pollution due to the cruise ships by means of numerical modelling (Murena et al., 2018). Conversely, at our knowledge very few wind tunnel experiments exist.

Fig. 6a Model scale of Naples port in wind tunnel

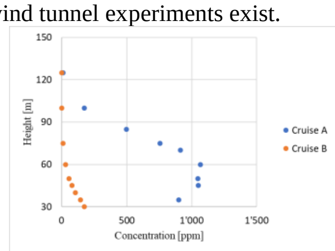

Figure 1c Vertical profile of tracer concentration of two cruises, u_s/u_h =1

Fig. 1b Distribution of tracer[ppm] at ground level

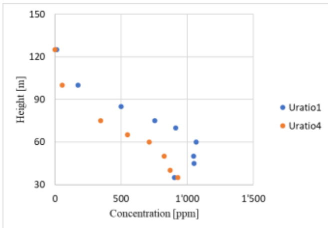

Fig. 1d Vertical profile of tracer concentration varying velocity ratio (u_s/u_h)

Methodology and Results

The experiments were performed in the atmospheric wind tunnel of the LMFA at the Ecole Centrale de Lyon (Fig. 1a). Hot-wire constant temperature anemometer and fast flame ionization detector were used as techniques to investigate respectively flow fields and concentration levels. Ethane was used as tracer, since it has a density similar to air. Fig. 1b shows the ground-level concentration field induced by a single cruise ship in some streets. We also investigated the contribution to the urban pollution due to more cruise ships. Fig 1c shows the vertical profiles (located at star point in Fig. 1b) of the concentration induced by the two cruise ships at hotelling. The shape of the profiles is well approximated by a Gaussian model with ground reflection. The influence of the velocity ratio defined as the ratio of the velocity of the ship emissions, u_s, and the wind velocity at the stack height, u_h is shown in Fig. 1d for u_s/u_h=1 and u_s/u_h=4 corresponding to conditions of high and weak wind, respectively. As can be seen the influence of this parameter on the pollutant dispersion is not negligible and it is necessary to take this into account in order to model this phenomenon accurately.

Conclusions

The results of the wind tunnel experiments give useful information on the effect of urban canopy on the dispersion of air pollutants released in the port of Naples. Furthermore, the concentration and velocity fields form a useful tool to validate and test numerical modelling, as CFD simulations or dispersion models.

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INVESTIGATING THE IMPACT OF LARGE SHIPS ON THE EMISSION DOWNWASH PROCESS WITH AN OBSTACLE RESOLVING MODEL

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Summary
This work presents first results of ship emission downwash modelling with the use of the microscale model MITRAS. Depending on the vessel size and the wind field, more than 30 % of the exhaust can be dispersed below the stack height, which has to be considered in chemistry transport model studies of ship emissions on urban scale.

Introduction
Downwash processes of airborne pollutants in the urban environment have been recognized as an important step on the way of accurate atmospheric transport modelling (e.g. Canepa, 2004). For point sources like power plants, the pollutant downwash is a crucial factor in designing the stack height (Snyder and Lawson, 1976). However, in a time of ever-increasing cruise ship tourism, these building-sized vessels are getting more attention regarding pollutant concentration in urban areas. Having comparatively low stacks, the pollutant downwash process due to the ship itself is expected to have a strong impact on pollutant concentration in the proximity of the ship, i.e. in harbours, where many ships are berthing and manoeuvring. This work aims on improving current dispersion models by investigating the effect of the vessel size on different wind-fields and the pollutant downwash process.

Methodology and Results
We used the microscale model MITRAS to approach the problem. This non-hydrostatic, three-dimensional grid model is able to solve simultaneously the governing equations for flow and temperature field, as well as concentrations (Schlünzen et al., 2003). Therefore, the obstacle-caused turbulence is considered in the wind field. With its very high spatial resolution (in this study down to 2 m · 2 m · 2 m), MITRAS can be used to describe initial plume rise and turbulence effects very precisely.
For this study, the model input parameters are an ambient ground temperature of 15 °C, ambient temperature gradient of -6.5 K/km, wind speed of 5 m/s, exhaust temperature of 200 °C, vertical exhaust speed of 10 m/s and a stack diameter of 2 m. The vessel dimensions are 246 m length, 30 m width and 50 m stack height.
To parametrize and use the microscale results in city-scale models, we calculate the vertical concentration profile in a distance of 100 m in the leeward side of the ship (e.g. Fig. 1 for a west wind/frontal direction). In this distance, the plume motion is no longer affected by the high initial temperature and the movement is buoyancy driven, which is a requirement for the upscaling into larger-scale models. The resulting layers are averages with a spatial resolution of 100 m · 100 m horizontally and 10 m vertically. Results in Figure 2 show relative concentration differences for four wind directions against no-obstacle conditions. All results display a strong downwash process. For crosswind conditions (here North and South) up to 34 % of the emission is dispersed below the stack height.

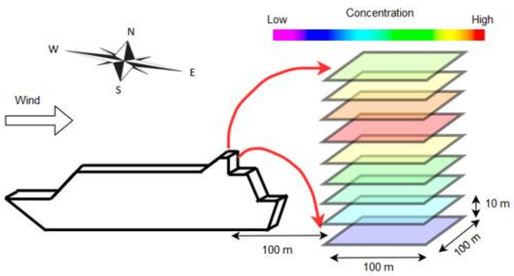

Fig. 1 Schematic view of the modelling approach

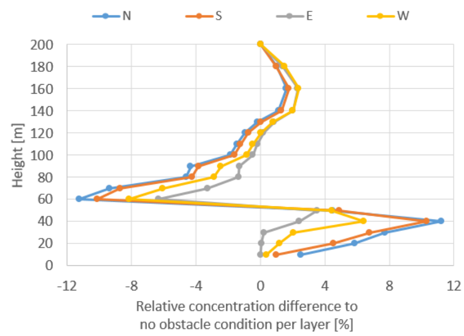

Fig.2 MITRAS results of obstacle-caused dispersion under different wind directions

Conclusions
Parametrizing obstacle-induced downwash processes for large ships by the use of a microscale model can improve the initial concentration profile for ship emissions in larger-scale models by more than 30 % depending on the wind-direction.

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AIR QUALITY MODELING IN CENTRAL ITALY COASTAL AREA: CIVITAVECCHIA PORT SITE CASE STUDY.

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Summary
The study of air quality in coastal areas strictly depends on meteorological conditions and it is essential to analyze the orography of the site and the dynamics that contribute to the accumulation and transport of pollutants to undertaking accurate mitigation and prevention strategies.
In order to analyze the wind dynamics in the PBL, measurements were performed in April 2016 at the port site of Civitavecchia and in the natural protected area of *"Le Saline",* Tarquinia (central Italy). During the campaign an accurate wind characterization (3D) was provided through the use of SODAR, sonic anemometers and three meteorological stations. Measurements carried out at coastal sites made it possible to identify three prevailing meteorological regimes: sea breeze regime, a regime dominated by a low-level jet and a third regime in which synoptic forcings dominate.
The analysis is supported by the use of the WRF mesoscale meteorological model and the CHIMERE chemistry-transport model. Using the WRF-CHIMERE model chain with 1 km horizontal resolution to simulate the meteorological and chemical state of the atmosphere in the areas of interest, four different parameterizations were tested to represent the turbulent mixing of the PBL and the exchanges surface-atmosphere.

Introduction
Using high resolution models (~ 1 km) is fundamental in the analysis of air quality. For this reason it is necessary that the basic meteorological fields such as wind, temperature and precipitation and parameters such as TKE and friction velocity are correctly simulated. The validation of the modeling performance is carried out through a set of observed data, including wind profile measurements, essential to reproduce the dynamics of transport and accumulation of pollutants. For this purpose it was interesting to compare the results of the different parameterizations and their effect on the determination of pollutant concentrations.

Methodology and Results
In April 2016 an intensive campaign of measurements was carried out at the Port of Civitavecchia to study wind behavior at coastal sites. The wind measurements were collected by two SODARs, a sonic anemometer, and three weather stations, two of which were placed on a meteorological tower. The parameters analyzed were wind speed and direction, sensible heat flux, TKE and friction velocity. Data of PM10, SO2, O3 from monitoring stations located in the Port site and in the natural protected area support wind data observed. The model simulations were carried out with the WRF meteorological model coupled with the CHIMERE chemical and transport model at 1 km horizontal resolution. Within the simulations carried out with the WRF model, various tests were performed with different PBL schemes (YSU, BouLac, ACM2, MYNN) to better characterize the wind dynamics. The first results show how that the wind speed profile in the planetary boundary layer is generally overestimated by the WRF model, especially during nighttime and model's skills improves when synoptic-scale forcing is dominant and degrades when local-scale factors dominate. Furthermore, the local PBL closure parameterization is not able to reproduce the dynamic during the development of low-level jet, while the non-local parameterization displays much better skills. There is an apparent tendency of the model in simulating an excessive vertical transport which results in an underestimation of pollutant concentrations.

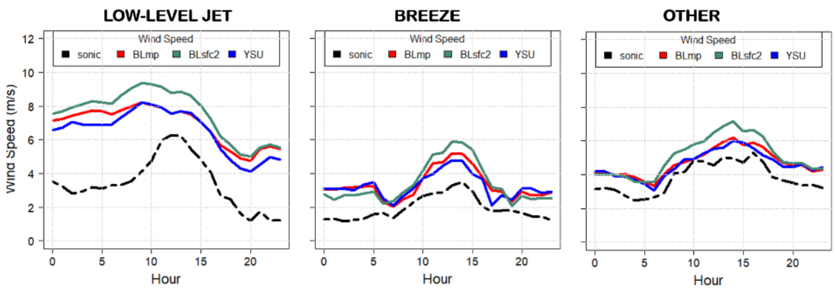

Figure 7 Wind speed time series of three regimes compared with three different PBL schemes.

Acknowledgements
Computational resources were provided by CINECA in the frame of Iscra-C ALTARIS7 project. Observations have been carried out in the framework of the CNR Air-Sea-Lab Project. We thank the Civitavecchia port Authority for hosting the 2016 monitoring campaign.

ASSESSMENT OF THE CONTRIBUTION OF SHIPPING EMISSIONS ON THE AIR QUALITY OF PIRAEUS

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Summary
The present work aims to to quantify the contribution of shipping emissions on the air quality of Piraeus harbour and surrounding areas and to evaluate the effects of emission reduction solutions, including full implementation of low sulphur fuel in the Mediterranean and implementation of a cold ironing system for ships at birth, for reducing the environmental impacts of shipping. For this purpose, the MEMO/MARS-aero chemical dispersion modelling system was applied, based on updated emissions input data from a comprehensive marine emissions inventory.

Introduction
The dominant influence of shipping emissions on air quality of port cities has been demonstrated in a number of case studies. At the same time, a number of technical and legislative control measures in the shipping sector are currently in focus, including the Tier III NOx standards in selected regions since 2016, the upcoming fuel sulphur cap by 2020, and the open discussion to control black carbon (BC) in particular in the Arctic region. In the present work, chemical dispersion calculations are used for assessing the impact of present and future marine traffic on air quality of Piraeus, Greece and the neighbouring areas of the Athens megacity, taking into account the effect of proposed mitigation measures.

Methodology and Results
A comprehensive marine emissions inventory is compiled using a bottom-up methodology on the basis of AIS traffic data, as well as activity and source parameter data obtained from other national databases, covering both merchant and passenger traffic in the area. Emissions from marine traffic were calculated for two distinct areas, corresponding to the main port area of Piraeus and the designated anchorage area in the Saronic gulf. Exhaust emissions from passenger and cargo marine traffic are calculated for each individual vessel inside these areas during the reference year 2015, following the guidelines of the EMEP/EEA 2016 guidebook (EEA, 2016). For the calculation of the main engine exhaust emission factors, engine capacity and technology, as well as fuel type are used, while proxy activity data are used for estimating the emissions of auxiliary engines, which are typically used throughout the anchoring period. A set of calculations of the atmospheric dispersion of pollutants are performed using the MEMO/MARS-aero chemical dispersion model for the Attica region for the reference year 2015, revealing the dominating contribution of the port area on the pollutant levels over the southern part of the city of Piraeus and parts of the city of Athens (Figure 1). In order to assess the effect of current and future mitigation measures, two additional emission scenarios are examined: a 2021 scenario with the full implementation of low sulphur fuel in the Mediterranean and an additional scenario including the implementation of a cold ironing system for the ships at birth. For both scenarios, a significant reduction of average NO_2 and PM_{10} concentrations is observed over the most heavily burdened areas. More specifically, calculations under the cold ironing scenario indicate a potential reduction by 50% of the shipping contributions to the observed concentrations.

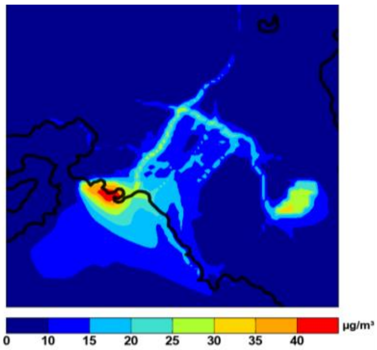

Fig.1 Annual average NO_2 concentrations over the Attica region,

Table 1 Comparison between model predictions and measurements.

Piraeus	Observed (μg/m³)	Baseline (μg/m³)	CI (μg/m³)
PM_{10}	37	31	15
$PM_{2.5}$	25	26	11

Conclusions
Chemical dispersion model simulations using comprehensive emissions data were performed to assess the contribution of shipping emissions on the air quality of Piraeus and the surrounding areas. Two emission reduction scenarios were examined, namely the implementation of low sulphur fuel and of a cold ironing system for ships at birth. Both measures result in significant air quality improvement of affected areas. These results point to the need to prioritize emissions mitigation and other control measures related to the port activities of Piraeus.

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ASSESSMENT OF IMPACT ON AIR QUALITY FROM OCEAN GOING VESSELS COMING TO KOLKATA PORT, INDIA

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Summary

This study aims to understand the environmental impact of marine emissions in port regions in India. Kolkata port is the representative port as it one of the largest major ports and serves a vast hinterland. The riverine port impacts a densely populated area near the docks. NOx emissions constitute around 50% of total emissions from OGVs visiting Kolkata Port followed by SO_x (35%). The total emissions o have an average annual growth of around 6%. Container ships contribute highest percentage of overall emissions (43% to 45%), followed by passengers, oil tankers and general cargo (approximately 15% to 17%). Bulk carriers supply approximately 4% to 5% in all emissions ranges.

Introduction

Rapid economic growth has escalated India's share in international trade increasing pressure on ports. The caveat is that increased shipping activity is accompanied by increased emissions of harmful air pollutants. Kolkata Port must be cognizant of environmental impact of emissions from OGVs in order to develop effective emission reduction strategies. The paper is to gives a perspective of five years' marine emissions inventory (2011 to 2016) and based on these five years data estimate monthly emissions for the next 3 years emissions using different forecasting techniques.

Methodology and Results

A comprehensive emissions inventory based on marine diesel engines (main propulsion engines and auxiliary engines) and detailed vessel activities were computed following the methodology prescribed by (USEPA, 2009).:

$$E_i = EF_i \times P \times LF \times t, \quad (1)$$

Ei : emission of pollutant i in transit segment (tonnes),EFi : emission factor for pollutant i (g/kW-hr),P : rated power of propulsion engine by vessel and engine type (kW),LF : load factor (fraction of rated power) by mode, t : average time for each mode by vessel and engine type per ship call

To forecast emissions for future year different components of marine emissions model such as transit time, hoteling time, count of ships of each ship type category have been estimated using different time series analysis depending on the statistical fit of the data and minimization of Root Mean Square Error (RMSE) of predicted values.

Table 1: Emissions for base year and forecasted years

Year	Container	General Cargo	Bulk Carrier	Oil tanker	Others including Passengers Ships
2011-12	39%	23%	5%	18%	15%
2012-13	40%	18%	3%	19%	20%
2013-14	42%	16%	6%	15%	21%
2014-15	46%	11%	10%	14%	19%
2015-16	49%	10%	10%	16%	15%
2016-17	53%	7%	11%	14%	15%
2017-18	55%	6%	9%	14%	16%
2018-19	58%	4%	9%	14%	15%

The total emissions of NO_x for five years (2011to 2016) are as follows 1490, 1553 , 1835, 1754 and 1867 tons respectively. For forecasted years it is found that containers show the largest increase in forecasted emissions (39-49%) followed by bulk carriers. General cargo contribution is decreasing and emissions from oil tanker remain unchanged. The overall marine emissions from OGVs show an increase between 87 to 163 tons/year from base year 2015 for forecasted years (2016-2019). Non-linear regression analysis shows that variations in marine emissions can explain about 20 % of variability in air pollutant concentrations at the observational site which can be considered as impact.

Reference

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Short Presentations

ADVANCED MODELLING APPROACH FOR THE ASSESSMENT OF THE SHORT- AND LONG-TERM IMPACTS OF SHIPPING EMISSION REDUCTION SCENARIOS ON MARINE AIR QUALITY

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Summary

The Horizon 2020 funded EMERGE project aims to to quantify and evaluate the effects of emission reduction solutions, such as scrubbers, for shipping in Europe for several scenarios, and to develop effective strategies and measures to reduce the environmental impacts of shipping. EMERGE will develop an integrated modelling framework to assess the combined impacts of shipping emissions on the aquatic and atmospheric environments, and the effects on marine ecosystems.

Introduction

Combustion in ship engines produces a range of primary and secondary pollutants (Particulate matter (PM), SO_x, NO_x and O_3) that have important environmental, health, economic and climatic impacts. In view of new and more strict global standards that will be enforced on January 1st 2020 for shipping emissions, accurate emission estimates and realistic simulations on the effect of abatement measures are a prerequisite for efficient management of air pollution problems associated with shipping emissions. Within the EMERGE project, refined atmospheric models that will take into account ocean-atmosphere interactions will be developed and employed in real-world test cases involving actual vessels and main shipping routes in Europe.

Methodology and Results

EMERGE will provide new real-world emission inventories for several years on a European scale for the shipping emissions to both water and the atmosphere. This realistic emissions dataset will be used as input for advanced atmospheric model simulations to quantify shipping emissions contribution to air pollution levels. Atmospheric dispersion modelling will include the deployment of chemical transport models, a range of urban scale dispersion models, and a Meso-scale model combined with a photochemical dispersion model (MEMO/MARS). In addition to air quality, model simulations will be used for the assessment of the interactions of the atmosphere and the seas at different scales, based on treatments for atmospheric deposition to the sea, and for the formation and dispersion of sea spray. In order to estimate shipping emissions reduction due to abatement measures to air pollution levels at the local scale, a two-way coupled mesoscale model MEMO and microscale Computational Fluid Dynamics (CFD) model MIMO modelling system will be employed. In the two-way MEMICO (Tsegas et al., 2015) coupling scheme, a three-dimensional spatial interpolation scheme, a spatial adjustment of values within the surface layer, and the formulation of the lateral boundary conditions to introduce the interpolated values into the microscale model are applied. For simulating pollutant chemistry and dispersion characteristics, the mesoscale dispersion model MARS-aero is applied at the same spatial resolution as MEMICO, which downscales from a spatial resolution of 500m for the entire selected area to 1m for selected coastal locations. Microscale atmospheric modelling will also be conducted with the ANSYS CFX CFD code and the atmospheric Large Eddy Simulation flow model Parallelized Large-Eddy Simulation Model (PALM LES), in order to parameterise the deposition of air pollutants from the ship funnel to water in the vicinity of the ship.

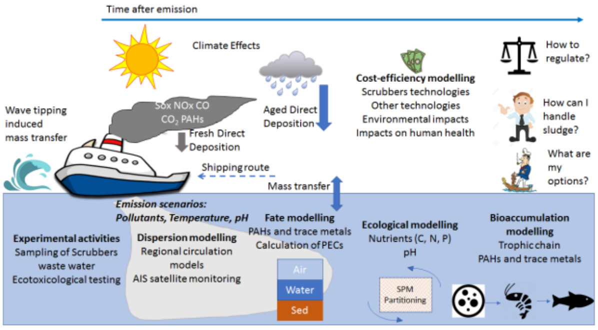

Fig.1 EMERGE schematic concept

Conclusions

Within the EMERGE project, an integrated multi-scale modelling framework will be developed for assessing the impacts of reduction options and techniques of the shipping emissions, such as the use of scrubbers, using unprecedented spatial resolutions (5 km for the whole Europe and 1 km for case studies). The chemical transport models used in EMERGE will provide quantitative predictions on the effects of various measures, scenarios and strategies. The models will also be deployed for the assessment of the ocean-atmosphere interactions at different scales.

Acknowledgement

The EMERGE project has received funding from the European Union's Horizon 2020 research and innovation programme.

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FUTURE DEVELOPMENTS IN SHIP EMISSIONS AND THE RELATED HEALTH IMPATCS ACROSS THE NORDIC REGION

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Summary
It is well known that the exhaust emissions related to shipping activities contribute to negative impacts on the environment and on the human health. In the current study, we make a detailed assessment of the health effects related to current day shipping activities in the Nordic and the Arctic region and investigate how changes in shipping activities might affect air pollution and health effects in the future.

Introduction
Shipping activities are projected to increase in the future due to an increased demand for transport and trade. The changes in the climate can also lead to the opening of new ship routes in the Arctic due to sea ice depletion, and hence increased ship traffic in the Arctic area.

Methodology and Results
The first step has been to setup global scenarios of shipping emissions. They are based on available information on technology developments and international emission abatement solutions discussed by e.g. the International Maritime Organisation (IMO) and emission models developed at the Finnish Meteorological Institute (Johansson et al. 2017) and Aarhus University (Winther et al. 2017). The scenarios includes e.g. a SECA scenario where, the existing SECA zones (i.e. America and North Sea/Baltic Sea) are expanded to cover the entire inventory area, a Heavy Fuel Oil (HFO) ban scenario and a high traffic growth scenario. The resulting air pollution has been simulated by the two chemistry-transport models MATCH and DEHM setup for the Nordic and the Arctic region. Finally, the modelled air quality maps serve as input to the health assessment system EVA (Economic Valuation of Air pollution, Brandt et al. 2013), which has been used to assess and evaluate the impact of ship emissions on the human health.

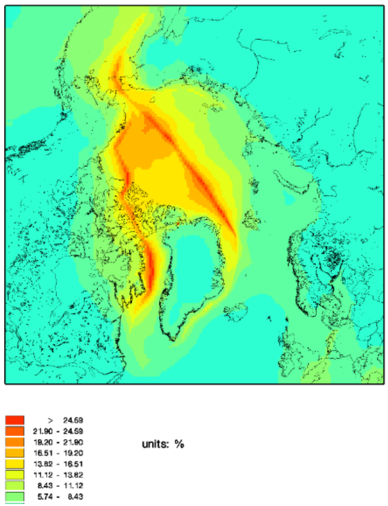

Fig.1: %-change in the 2050 $PM_{2.5}$ concentration in the high traffic scenario relative to the base case.

Conclusions
A number of shipping emission scenarios have been setup towards year 2050. The increase in ship activities work against improved technology and regulation. All in all this leads to a decrease in the SO_2, NO_x emissions in the Nordic area, but an increase in the BC and CO_2 emissions. The health assessment points towards a small improvement in the air quality in e.g. the HFO ban scenario, but more importantly to an increase of up to ca. 300 additional premature deaths in case of the high traffic growth scenario.

Acknowledgement
The EPITOME project funded by NMR and NordForsk under the Nordic Programme on Health and Welfare Project #75007: Understanding the link between air pollution and distribution of related health impacts and welfare in the Nordic countries (NordicWelfAir).

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MEASUREMENTS OF PARTICLE EMISSIONS FROM COMMERCIAL SHIPPING ACTIVITY IN SURROUNDING SEAWATER

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Summary

This study aims to produce information on abundance and the physicochemical characteristics of microparticles emitted in the marine environment by heavy shipping activities. Target particles include organic paint flakes, inorganic micro- and nano-particles used in paints, combustion by-products that deposit on the seawater, as well as from ships waste streams. We have sampled along major shipping lanes off of Piraeus port, in the Aegean sea and characterized the composition, shape, and concentration of particles in seawater, aiming to identify those characteristics that allow identification of the particles origin, i.e. if they are emitted from ships, from which activity on the ship, at what amounts, and how far they may disperse in the water column. This information will be unique in its kind and will offer the raw data will serve as the basis for future scientific reports aiming to influence legislation in maritime activities and control their global environmental impact.

Introduction

Although significant research has been done on the pollution of exhausts in air quality, less is known on the mechanism of particle deposition on the water column and the overall environmental effects of shipping activities in the marine environment, such as contaminants distribution and water acidification (Turner et al 2017). Recent IMO regulations have enforced a reduction of sulphur emissions from shipping from 3.5% to 0.5%, aiming to reduce the atmospheric pollution of ships. However, this initiative is likely to increase the anthropogenic stress on the seawater, e.g. through the use of open loop scrubbers. Ship paints often contain inorganic particles and recently Copper-based nanoparticles have been applied to induce antifouling properties. These particles are gradually released from the ship's hull as nanoparticles or as micron-sized particles or flakes that comprise of the paint substrate and amounts of nanoparticles. In seawater these particles may dissolve, aggregate, settle on the sediments, or remain suspended in the water.

It is therefore, important to understand the release and fate of micro- and nanoparticles emitted from shipping. Our work lays the ground to establish a baseline for particulate pollution from ships, prior to the potentially wide-spread installation of open-loop scrubbers, which will aid future environmental studies. The Piraeus port in Greece, is undergoing major upgrades since the partial acquisition of the port by COSCO shipping, and has emerged as the fourth busiest port in Europe in terms of TEU in 2019 (was sixth in 2018). Obtaining quantitative information of particle composition and concentration at this point in time will serve as a reference for future studies, as the port continues to grow.

Methodology and Results

In this work samples were collected across the major shipping lane outside the Piraues port, in Greece. Water samples were collected at 5 m depth at various locations across a vertical path to the shipping lane for incoming and departing ships, using a Niskin water sampler. The water was immediately filtered through polycarbonate membranes with 10 μm pore size. The membranes were rinsed with MQ water to remove dissolved salts and were allowed to dry under vacuum in a desiccator, for at least 7 days, prior to analysis. An automated light microscopy procedure was applied to identify particles larger than 100 μm. An automated scanning electron microscopy technique equipped with energy dispersive spectroscopy was applied to identify and characterize inorganic particles larger than 10 μm. This procedure aims to identify and differentiate between engine wear metal particles, metal rich soot, metal rich antifouling paint particles and metal loaded mineral particles

Acknowledgements

This project has received funding from the Hellenic Foundation for Research and Innovation (HFRI) and the General Secretariat for Research and Technology (GSRT), under grant agreement No [1317] and the European Commission (ASSEMBLE Plus, Integrating Activities for Advanced Communities, grant agreement no. 730984).

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Special Session Air Pollution in Urban Areas – Science Challenges and Policy Implications

CLEAN AIR ENGINEERING FOR CITIES (CARE-CITIES): CAR EXPOSURE ACROSS NINE GLOBAL CITIES

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Keywords: Fine articulate matter; Transport mode; Commuters exposure; Developing countries; Exposure mitigation
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Introduction

Traffic-related air pollution in cities contributes significantly to commuters' daily particulate matter (PM) exposures. It depends on a number of factors such as time of commuting, traffic volume, congestion and vehicle types (Kumar et al., 2018). To date, most previous studies show results for air pollution exposures based on the mode of commuting in a single city (Rivas et al., 2017) and internationally comparable studies are largely missing, which is the aim of this study.

Methodology

We compared the exposure to PM ($PM_{2.5}$ and PM_{10}) during typical commutes by car across nine large cities in Latin America, Middle-East, South-East Asia and Africa, namely: Dhaka (Bangladesh), Medellin (Colombia), São Paulo (Brazil), Blantyre (Malawi), Dar-es-Salam (Tanzania), Sulaymaniyah (Iraq), Guangzhou (China), Cairo (Egypt), and Chennai (India) during morning peak hours (MP), off-peak hours (OP) and evening peak hours (EP) for three different scenarios (window closed, Fan on; window closed, recirculation; windows open). We have used the same portable instrument (Dylos- DC1700-PM) for all cities and quality control/assurance protocols along with the similar length of routes, measurements time in all cities to make the data comparable as much as possible.

Aim and Results

The overall goal of this work is to understand the underlying driving factors for exposure to fine particulate matter in different cities, test the feasibility of low-cost portable pollution monitoring instruments and develop preliminary exposure profiles of car users, and discussing exposure mitigation strategies via basic field trials run by collaborating partners. The highest PM ($PM_{2.5}$ and PM_{10}) concentrations were found when the window is opened while the lowest levels of PM were observed when the window closed, recirculation is on (Figure 1). The relationships $PM_{2.5}$ and PM_{10} between all cities are also examined. The impact of time and distance for each run is also discussed.

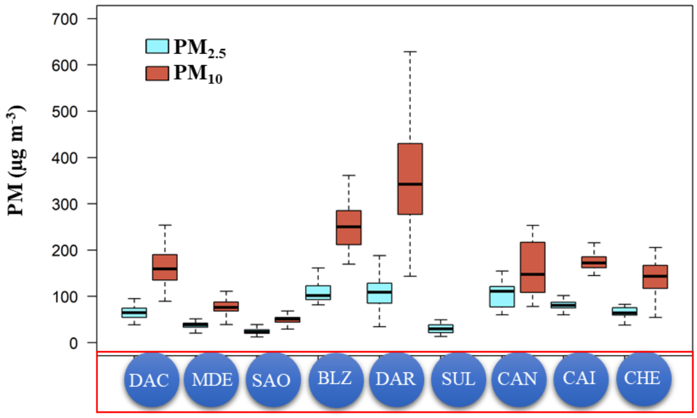

Figure 1. Boxplot for $PM_{2.5}$ and PM_{10} for open window setting during morning peak rush hours for all cities, namely Dhaka (DAC), Medellín (MDE), São Paulo (SAO), Blantyre (BLZ), Dar es Salaam (DAR), Sulaymaniyah (SUL), Guangzhou (CAN), Cairo (CAI), and Chennai (CHE).

Conclusions

Open window trips experienced the highest average $PM_{2.5}$ and PM_{10} levels, while recirculation mode trips experienced the lowest levels. $PM_{2.5}$ and PM_{10} concentrations in cars are significantly higher during morning-peak than off-peak and evening-peak. High levels of PM have been observed in Dar-es-Salam, followed by Dhaka, and Guangzhou.

Acknowledgements

This work is supported by the University of Surrey's Research England funding under the Global Challenge Research Fund (GCRF) programme for the Clean Air Engineering for Cities (CArE-Cities) project. We thank our project partners and collaborations namely, Abdus Salam, Khalid Omer, Maria de Fatima Andrade, Yris Olaya, Ahmed El-Gendy, Shi-Jie Cao, Mukesh Khare, Shiva Nagendra, Vera Ngowi, Adamson S. Muula, Araya Asfaw, Philip Osano, Rana Alaa Abbass, Thiago Nogueira, Veronika Brand, Jenny Martinez, Kosar Hama Aziz, Khalid Omer, Shariful Islam, Farah Jeba, Ming-Rui Meng for planning and carrying out the data collection in their respective cities.

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APPLICATION OF DYNAMIC CHANGE-POINT ANALYSIS TO AIR QUALITY DATA IN INDIA

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Summary

A change-point methodology has been applied to a large air quality dataset for Delhi, India. This analysis was done to try to identify local or short-term events, from longer-term or regional patterns (e.g. agricultural stubble burning in neighbouring states). These could then be potentially linked to meteorological events, specific sources or the effects of policy interventions.

Introduction

It has been estimated that the Indian capital, Delhi, experiences between 10k and 30k deaths brought forward per annum due to ambient particulate matter (Apte *et al.*, 2015). The CADTIME (Clean Air for Delhi Through Interventions, Mitigations and Engagement, See: https://research.ncl.ac.uk/cadtime/) project aims to understand what is required to deliver significant reductions in levels of air pollution in Delhi through affordable, effective and acceptable amelioration or adaptation strategies. An early element to the project was the development of an understanding of general patterns and key drivers of air pollution in Delhi, alongside analysis of previous interventions and their effectiveness.

Methodology and Results

Available hourly time series data for $PM_{2.5}$, PM_{10}, NO_2, NO_x, SO_2 and O_3, alongside meteorological data, were obtained for 43 monitoring sites across the Indian Central National Capital Region (CNCR). After cleaning and filtering of these data, a dynamic, change-point methodology, based on the CROPS (Change-points for a Range Of PenaltieS) approach using the PELT (Pruned Exact Linear Time) algorithm (Killick and Eckley, 2014) was applied to each series. The precise number of change-points identified in each series was allowed to vary, but was based on a fixed threshold criteria for the derivative of penalty from the CROPS method. Data from the individual series, for each pollutant, were the collated and concentrations normalised by the overall mean (see Fig. 1 right) to enable examination of: i) patterns of missing data; ii) suspect readings from instruments; iii) existence of common time-points in spatially proximal sites, or across sites generically. The latter was done to try to identify local or short-term events, from longer-term or regional patterns (e.g. agricultural stubble burning in neighbouring states). These, in turn could then be potentially linked to either meteorological events, or the applications of policies for interventions (such as the Graded Response Action Plan – GRAP). In Fig 1, the pattern of lower $PM_{2.5}$ concentrations during the monsoon season (late June – Sept), and higher concentrations from the onset of winter (Nov-Jan) are evident. The cross CNCR high pollution event of 2017 is also of note. Other pollutants (e.g. NO_x/NO_2) show higher variations associated with local sources such as road traffic.

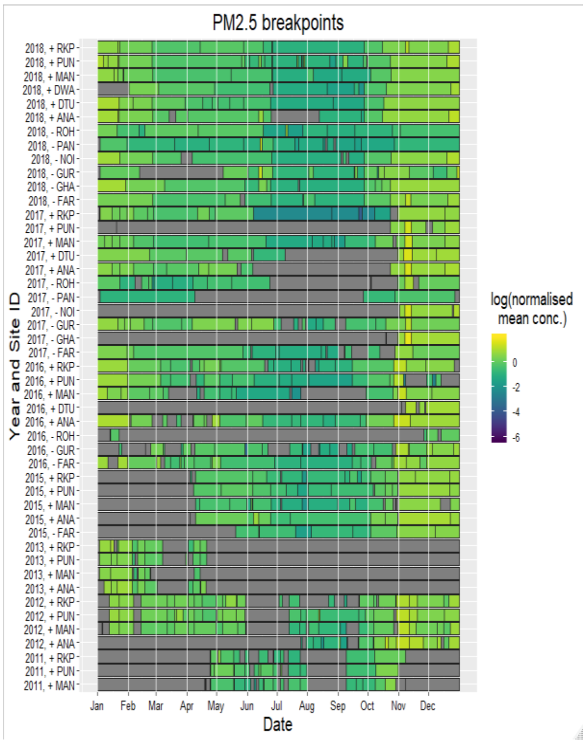

Fig 1. Change-point analysis of select CNCR $PM_{2.5}$ data

Conclusions

The application of the change-point methodology, and subsequent visualisation have aided the identification of patterns and trends in the CPCB time series data for the CNCR. Work is ongoing in the further application of the CROPS/PELT methodology on de-seasonalised data to tease out the effects, if any, of interventions.

Acknowledgements

This work was supported by the UK Natural Environment Research Council (NERC ref: NE/P016588/1). This work uses data downloaded from the public-facing portal for automatic air-quality monitoring of the Central Pollution Control Board (CPCB) of India. These data are collated from a number of institutional and state actors across India, and is used under the terms and conditions of the CPCB. For more information see http://cpcb.nic.in/.

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ANALYSIS OF AIR QUALITY IN THE MEGACITY OF DELHI WITH OBSERVATIONS AND A MULTISCALE COUPLED MODELLING SYSTEM

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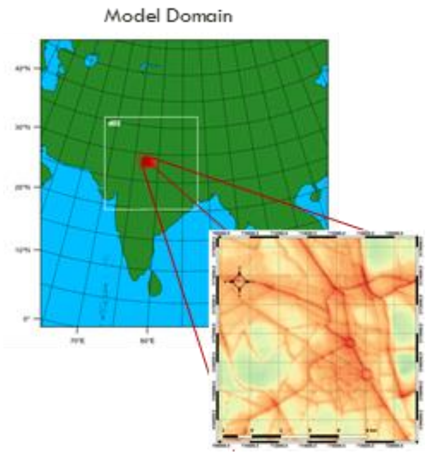
Summary

A coupled modelling system has been developed to analyse concentrations of NOx, O_3 and $PM_{2.5}$ at street, urban and regional scales affecting Delhi. The multiscale modelling system consists of the WRF-Chem model linked with a line source dispersion model, OSCAR. The coupled system uses SAFAR emissions inventory for the Delhi urban area and regional emissions from EDGAR. Simulations have been carried out for the winter campaign period of 2017/18. The performance of the modelling system has been evaluated against SAFAR measurements and measurement from an aerosol optical particle counting sensor. The paper reports on the analysis of variations of the air pollutants under highly stable meteorological conditions.

Introduction

Exposure to the particulate matter (PM) pollution is one of the leading risk factors worldwide having both short-term and long-term health effects. This is a major concern in urban areas where people are exposed to high levels of air pollution especially in megacities such as Delhi. Concentrations of air pollutants are governed by emissions from various sources such as industries, vehicular traffic and biomass burning along with the prevailing meteorological conditions. Regional models can be run at fine resolutions (~1-2km) for air quality and impact analysis, however, further requirements are required to capture gradients observed at finer resolution (~10-100m) which are especially important for exposure and health impact studies. Traffic increments can lead to high spatial gradients of NO_2 and $PM_{2.5}$ away from roadsides within a few 100 meters. The aim of this study is to develop and apply a coupled modelling system to analyse air quality concentrations across Delhi for the winter period of 2017/18.



Methodology and results

Figure 1 shows the modelling domain of the megacity Delhi with an area of 1483 km^2 and located at 28°34'N and 77°12'E north of India. Delhi has a population of 16.8 million as per the census of India (2011). The modelling system couples the Weather Research and Forecasting Chemistry (WRF-Chem) model with the OSCAR Air Quality Assessment System (*Singh et al., 2014*). The WRF-Chem model, has been run at 1.67 km horizontal resolution. The OSCAR model is based on a Gaussian finite line source approach and includes dry deposition. The dispersion parameters are modelled as function of the Obukhov length, friction velocity and mixing height. The coupled modelling system uses SAFAR emissions inventory for Delhi embedded within EDGAR regional emissions. Simulations have been carried out for the winter campaign period of 2017/18. Model predictions have been evaluated with a combination of measurements at six SAFAR (System of Air Quality and Weather Forecasting And Research) sites and data from OPC based UH aerosol monitors. The daily variation in the modelled concentrations of NOx and $PM_{2.5}$ at street levels are captured well by the coupled model. The modelling system also captures the spatial heterogeneity across the city due mainly to road traffic emissions from the road network across Delhi. The traffic increment of the air pollutants over the road network is examined and related to traffic density across the city. The causes of particularly high values of NOx and $PM_{2.5}$ are examined along with the contrast between urban and rural concentrations of O_3.

Conclusion

A multiscale coupled modelling system has been developed for Delhi to predict street, urban and regional scale air quality across Delhi. $PM_{2.5}$ and NO_2 concentrations across the Delhi have been analysed to quantify the spatial heterogeneity in terms of traffic and road network density. As far as we are aware, this is the first study of its kind modelling air quality over Delhi at high resolutions spanning regional to street scales. The implications of spatial distribution of air quality for exposure and health impacts are discussed to aid city and national decision makers when formulating pollution control strategies.

Acknowledgement

This work forms part of the PROMOTE project which is part of the Indo-UK Joint programme on Atmospheric Pollution and Human Health in an Indian Megacity and is funded by NERC, UK and MOES, India. The paper does not discuss policy issues and the conclusions drawn in the paper are based on the interpretation of observation and modelling results.

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URBAN METEOROLOGY AND AIR QUALITY AS A FUNCTION OF DIFFERENT URBAN FEATURES

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Summary
With the growing concerns of global climate change and the rise of global populations, particularly in urban centres, the concept of urban modelling is becoming increasingly important. Highly urbanized centres become the most vulnerable to climate change as they experience the Urban Heat Island (UHI) effect and poor air quality, which have important impacts on the local environment, and human health and comfort. One of the most innovative ways to assess the options of sustainable development is through city specific urban modelling scenarios. ECCC is developing urban modelling capabilities using an interdisciplinary system that combines atmospheric models with an urban high-resolution surface model (Town Energy Balance, TEB).

Introduction
Due to large developmental structures, higher pollution rates, reduced vegetative surfaces, and higher populations, the effects of climate change, such as global warming and the frequency and intensity of extreme events including air pollution, are significantly amplified in these regions. Currently, ECCC is developing urban modelling capability, down to 0.10-km horizontal grid spacing resolution.

Methodology and Results
ECCC's models, Global Environmental Multiscale (GEM) and GEM-Modelling Air quality and CHemistry (GEM-MACH) were coupled for this particular research project with the Town Energy Balance (TEB) model. For urban modelling needs, these systems are cascade from 10-km horizontal grid spacing to 2.5-km, 1-km, 0.25-km and 0.10km. The systems at 2.5-km or higher resolution provide information in urban "blocks" necessary for further in depth urban modelling and is further coupled with TEB to produce even more accurate predictions. TEB can determine factors external from the typical atmospheric variables by accounting for albedo, vegetative areas, pollution, building topography, surface materials, and many more. So far, ECCC performed urban modelling tests with GEM for all major Canadian cities at 0.25-km and some at 0.10-km and we are currently working on the same approach with GEM-MACH systems. Thus far, results revealed that some management strategies in cities, such as modifications of building's radiative and materials properties, greening strategies, water management and anthropogenic heat fluxes, could decrease the impact of extreme atmospheric conditions.

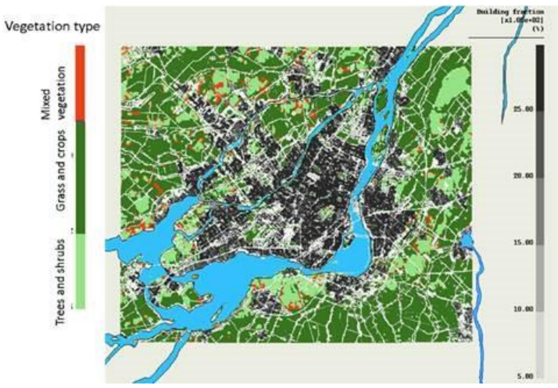

Fig.1 The land cover inputs for Montreal at 0.25-km

Conclusions
Urban scale modelling capabilities provide a better, value-added, weather and air quality forecast. Beyond this objective, urban modelling gives numerous other possibilities for additional scenario modelling as a function of different urban features (road types, green roofs, urban canyon topology, amount of vegetation, soil moisture property, anthropogenic heat sources, number of cars, air conditioning, etc.). This research and modelling method is the perfect starting point to gain better knowledge and understanding of ways to move forward with sustainable urban development and raise awareness to the impacts on human health and well-being.

STUDYING THE RELATIONSHIPS BETWEEN BIOTIC AND ABIOTIC ATMOSPHERIC POLLUTANTS IN THE MADRID REGION

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Summary

In this work we investigate the relationships among the typical abiotic pollutants (PM, NO_x, O_3) and some major biotic agents (bacteria, fungi and pollen) using descriptive and inferential statistics and sophisticated machine learning algorithms. The latter are also tested to predict the biotic pollutants as function of easily available atmospheric measurements from air quality and meteorological stations, or derived variables.

Introduction

Poor air quality is associated to mortality and morbidity through a breadth of respiratory causes, including cardiovascular diseases and lung cancer. According to the World Health Organization ("WHO," 2019), 4.2 million premature deaths worldwide can be attributed to ambient air pollution annually. Typically, pollutants like PM, NO_x, or O_3 have been studied and are measured by networks of Air Quality stations in large cities like Madrid. They are regulated through the Air Quality Directive (*Directive 2008/50/EC*). In addition, the presence of airborne biological particles is gaining interest within the air quality field since they also pose a risk for human health. In addition, pathogenic bacteria are transmitted via aerosols and may interact with other biotic and abiotic components in the atmosphere. In this study, we explore the relationship between the relative abundance of Proteobacteria, Actinobacteria and Ascomycota phyla, as well as Olea pollen, with atmospheric variables and abiotic pollutants.

Methods

Airborne bacteria and fungi were collected using Hirst-spore traps in 12 monitoring locations across the region in 10 weekly campaigns throughout the 2015-2017 period. Bacterial and fungal characterization was performed by high-throughput DNA sequencing of the air sample material as described in (Nunez et al., 2019). Pollen have been measured by the PALINOCAM Network since the year 1993 counting with an exhaustive database, while abiotic pollution data (PM, NO_X, O_3, etc.) were retrieved from the local air quality monitoring network. In this work, classical supervised machine learning algorithms like Generalised Additive Models (GAMs) and more innovative and state-of-the-art Ligth Gradient Boosting Models (LigthGBM) and Artificial Neural Networks (ANNs) are employed to assess the impact of meteorological variables and the more traditional abiotic pollutants in biotic airborne agents. The data pre-processing and calculus was performed using R in Rstudio. The LightGBM was coded in Python with Spyder IDE, whereas the ANNs were implemented in Python 3.7 using Tensorflow's 2.0 API Keras.

Results

The supervised machine learning algorithms that have been obtained predict accurately Olea pollen ($r^2 = 0.75 \pm 0.07$) and reasonably well the biotic phyla studied ($r^2 = 0.45 \pm 0.10$) taking into account the scarcity of available data in the latter case. Descriptive statistics and clustering analysis were also applied to investigate the biotic/abiotic relationships and to obtain an integral vision of the urban air pollution.

Conclusions

This work constitute the first attempt to relate the abiotic to the biotic pollutants to obtain a wider vision of the global urban air pollution in Madrid. The developed models present correlation coefficients up to 0.75 and can be used as a complement to the laboratory processes involved in the experimental determination of bacteria and fungi and to predict the pollen season-based on meteorological factors. This can help predicting when the pollen season starts to prevent the sensible population, and to approximate the bacteria and fungi relative abundances when no measurements are available.

Acknowledgements

This study was carried out within the AIRTEC-CM (urban air quality and climate change integral assessment) scientific programme funded by the Directorate General for Universities and Research of the Greater Madrid Region (S2018/EMT-4329). The Madrid Region and Madrid City Council are acknowledged for air quality data, and the AEMET for the meteorological data.

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CONTRIBUTIONS TO SUMMER GROUND-LEVEL O_3 IN MADRID REGION

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Summary
Tropospheric ozone (O_3) is a secondary pollutant formed in the atmosphere through a set of complex non-linear reactions among their precursors, mainly NMVOC and NO_x (NO+ NO_2). This makes O_3 pollution hard to track and the definition of potential abatement measures rather difficult. In this study, we quantify the contribution of each sector to summer ground-level O_3 in the Madrid region by means of the CMAQ Integrated Source Apportionment Method (CMAQ ISAM). It was found that external influences, represented by boundary conditions, dominate O_3 levels. Among the local sources, road traffic and biogenic emissions are the most relevant contributors.

Introduction
Photochemical pollution is one of the main environmental issues due to its negative impacts on health, ecosystems and climate. 12% of the European population is exposed to high O_3 levels and most urban areas show increasing trends in recent years (EEA, 2018). Southern Europe is very sensitive to O_3 pollution because high radiation and temperature favour photochemical activity. Since these factors are not controllable, air quality improvement strategies must be based on emission reductions. Linking emissions and resulting air quality is particularly difficult for non-primary species. In this case, the design of effective abatement measures should rely on the understanding of the O_3 – NOx – VOC system. In this contribution, we perform a source apportionment analysis for summer ground-level O_3 in the Madrid region.

Methodology and Results
The complexity of O_3 dynamics, including the interaction with meteorological variables and other chemical species, requires the application of multi-scale, multi-pollutant models such as the WRF-SMOKE-CMAQ system, used in this study. We applied the CMAQ Integrated Source Apportionment Method (CMAQ ISAM) method (Kwok et al., 2015) to understand the sources of O_3 as a first step to define effective options to tackle photochemical pollution in the Madrid region. This tool keeps track of VOC and NO_X emissions for selected sectors in addition to the influence of initial and boundary conditions. Road traffic is the main contributor to NO_X emissions (69%) in our modelling domain (Fig. 1) while solvent and other product use is the main origin of VOC emissions (48% of anthropogenic sources).
The period simulated corresponds to an experimental campaign carried out in July 2016 (Querol, 2018). In general, local O_3 levels were dominated by external contributions. During this period, several accumulation episodes, associated to very weak synoptic forcing and high atmospheric stability, took place. In some days, e.g. July 27th, contributions from the previous days may reach 15% of total predicted O_3. As for local sources, road traffic is the main source of O_3, followed by biogenic emissions (domain-averaged 34% and 24% respectively during July 27th, illustrated as an example in Fig. 1).

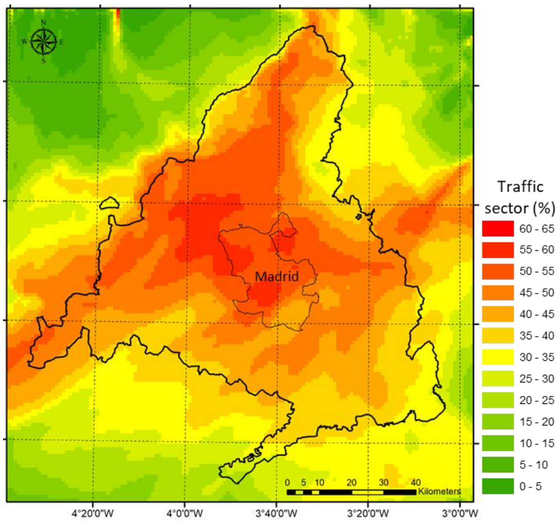

Fig.1 Road traffic contribution to daily average ground-level O_3 in our modelling study according to CMAQ-ISAM

Conclusions
The source apportionment study performed shows that reducing NO_X emissions from road traffic may be the best option to reduce O_3 ambient concentration in the Madrid region. Of note, external contributions, represented by boundary conditions in our study may represent up to 82% of total O_3. This points out that effective policies to tackle O_3 problems should consider a larger geographic scope.

Acknowledgement
This study was carried out within the AIRTEC-CM (urban air quality and climate change integral assessment) scientific programme funded by the Directorate General for Universities and Research of the Greater Madrid Region (S2018/EMT-4329).

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COMPARISON OF SENTINEL5 PRECURSOR/TROPOMI NO2 OBSERVATIONS WITH LOTOS-EUROS SIMULATIONS AND GROUND BASED IN SITU MEASUREMENTS

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Summary

In this study, we present the setup of the chemical transport model LOTOS-EUROS in the AUTH "Aristotelis" cluster and a comparison of tropospheric NO_2 columns derived from LOTOS-EUROS chemical transport model simulations against S5P/TROPOMI satellite measurements and in-situ observations.

Introduction

Nitrogen oxides play an important role in the production of tropospheric ozone and secondary aerosol formation while the deposition of nitrogen leads to eutrophication and changes in the biodiversity. Sources of NO_x emissions can be both anthropogenic and natural since they are associated with fossil fuel combustion, burning biomass, lightening and biogenic emissions from soils (Cooper et al., 2017). Chemical Transport Models (CTM) and satellite observations can be essential tools for studying the NO_2 emissions, concentrations and dynamics in high spatial and temporal resolution with a global coverage.

Methodology and Results

In this study, the regional air quality model LOTOS-EUROS v2.2 is employed for the estimation of NO_2 concentrations over Europe with a spatial resolution of 0.25°x0.25° for the year 2018 [*Figure 8*, left for November 2018]. The anthropogenic emission inventory is based on the CAMS inventory, while the initial and boundary conditions are retrieved from the CAMS Near-real-time dataset. Finally, LOTOS-EUROS is fed with meteorological data from the operational dataset of ECMWF.

Higher spatial resolution runs (0.1°x0.1°) are conducted for dedicated regions of interest within the previous domain in which case the simulations from the coarser run are used as initial and boundary conditions. The higher resolution concentrations are then compared to the level 2 S5P/TROPOMI daily tropospheric NO_2 data extracted from the TEMIS repository (November is shown in *Figure 8*, right).

We further present comparisons of the modelled NO_2 concentrations with ground-based in situ measurements.

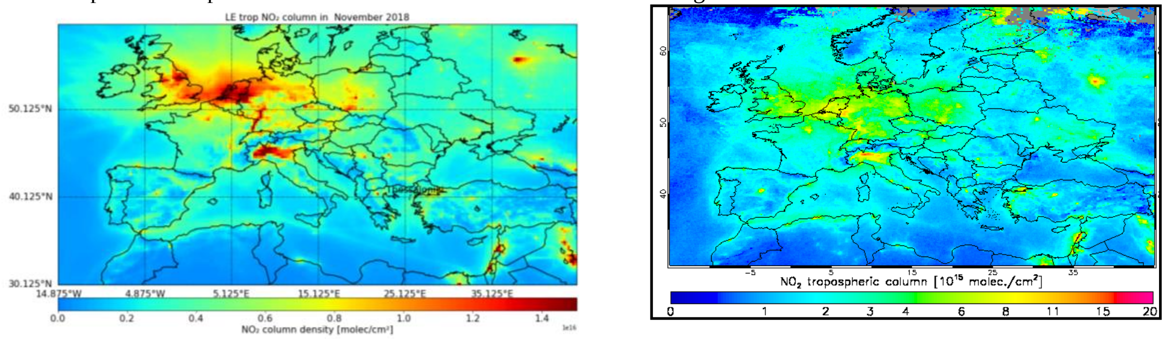

Figure 8 Mean LOTOS-EUROS [left] and S5P/TROPOMI [right] tropospheric NO_2 columns in November 2018 over Europe

Conclusions

Changes of NO_2 emissions over the years can be attributed to distinct reasons, such as policy measures and economic crisis (Castellanos and Boersma, 2012). Hence, long-term high spatial resolution satellite observations and dedicated model simulations play an indispensable part in keeping up with these changes and providing updated emissions estimates.

Acknowledgement

This research has been co-financed by the European Union and Greek national funds through the Operational Program Competitiveness, Entrepreneurship and Innovation (call RESEARCH-CREATE-INNOVATE) by the project with code T1EDK-01697 and the project "PANhellenic infrastructure for Atmospheric Composition and climatE change" (MIS 5021516). Results presented in this work have been produced using the Aristotle University of Thessaloniki (AUTh) High Performance Computing Infrastructure and Resources.

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ULAANBAATAR / MONGOLIA SMOG RESULTS OF PM10, PAH, BTX, NO_2 AND SO_2 MEASUREMENTS IN GER AREAS - TEMPORAL VARIATION AND SPATIAL DISTRIBUTION

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Summary
Subject of this presentation are results of pollutant measurements in Ulaanbaatar, the capital of Mongolia, and in it's surrounding so called Ger areas where many people are living. The temporal variation of the smog is shown by evaluation of PM, SO_2 and NOx measurement results of the existing monitoring stations. The spatial distribution has been investigated by additional measurements with gravimetric PM samplings and subsequent PAH analyses, by mobile PM measurements with low-cost instruments and by passive sampling of SO_2, NO_2 and BTX at different sites in the Ger areas.

Introduction
At the last Air Quality Conference in Barcelona we reported about the smog problem in Ulaanbaatar /Mongolia, the coldest and most polluted capital city of the world. The winter smog is caused mainly from the Ger areas with their yurtes and little huts where in around 185.000 traditional stoves and in 2700 heat only boilers raw coal and wood is burned. These Ger areas are located in valleys and slopes surrounding the city, see Figure 1 as an example. During the recent years the traffic density is strongly increasing causing additional pollution directly in the city, especially from old diesel buses.
At 11 existing automatic monitoring stations the temporal variation of the smog can be followed. The results from these monitoring stations show also differences of different areas of the city. But to get more information about the spatial pollutant distribution, especially in the Ger areas where many people are living and exposed to the smog additional measurements have been carried out supported by the German project "Further development of air quality management and monitoring of air quality in Ulaanbaatar (Mongolia)" [1]. This presentation shows results of these measurements.

Measurement Results
The results of the existing automatic monitoring stations have been evaluated to show temporal daily variations and wind direction and wind velocity dependencies in pollution roses. In addition to these permanent measurements at several sites additional measurements and samplings have been carried out from February to April 2019. At four sites PM10 samplings have been taken for further PAH analysis. In Figure 2 [2] the determined PM10 concentrations of 10 sampling periods are depicted (line). According to the collected PM samples the analysed PAH concentrations adsorbed at PM are shown in this figure as total number of detected different multi-ring PAHs (bars). The determined BaP equivalents of 32±17 ng/m^3 are very high compared to values of other cities in the world. Only from Tianjin in China similar values are reported [2].
With new low-cost PM instruments mobile measurements were carried out on a car driving along roads. From that horizontal PM distributions and indication of hot pollution spots are shown. Passive samplers for SO_2, NO_2 and BTX were exposed at 14 sites in the valley and at the adjacent slopes. As an example, in Figure 3 results of SO_2 passive sampling are depicted as temporal averages at different sites. The highest values have been determined in the Ger area valley north of the city. In the presentation also the results of NO_2 and BTX (Benzene, Toluene, Xylenes) passive samplings will be presented.
It can be summarized that with this measurement program a valuable insight into the pollutant load the people in the Ger areas are exposed to could be given. Followed by simulation activities the transport of the pollutants from the Ger areas into the city shall be investigated.

Fig.1: PM measurement in a Ger area

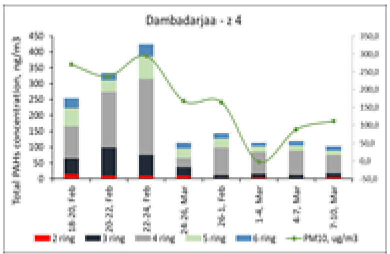

Fig.2: PM10 concentrations and adsorbed PAHs

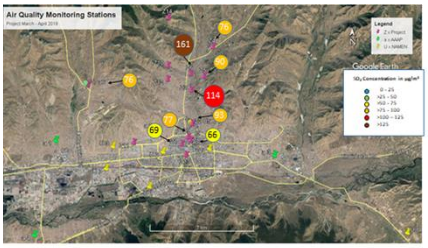

Fig.3: Results of passive SO_2 averages, Feb.2019

1) Acknowledgement
This project is financed by the German Federal Environment Ministry's Advisory Assistance Programme for environmental protection in the countries of Central and Eastern Europe, the Caucasus and Central Asia.

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NOVEL METHODOLOGIES FOR CLIMATE CHANGE IMPACT TO URBAN AIR QUALITY FOR EUROPEAN CITIES. THE CASE OF THESSALONIKI

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Summary

This study aims to quantify the climate change impact on air quality trends in European urban environments. The present focus is on Thessaloniki, a city with relatively high air pollution levels. Our methodology is based on proper weather clustering utilizing existing fine scale EURO CORDEX Regional Climate Model (RCM) simulation data, according to the moderate climatic scenario RCP4.5. Three regional climate model simulations have been considered, quantifying to a certain extent meteorology-related uncertainty. Local air quality modelling intercomparison in a 2km x 2km grid has been performed for selected past and future days using the WRF/WRFChem modelling system.

Introduction

Trying to model future climatic change impact on local scale air quality one should be aware of the inherent difficulties to mathematically describe the associated phenomena and quantify the relevant input due mainly to lack of knowledge and missing accurate input data. For results that require high temporal and spatial resolution one should consider also the issue of computational capacity. Consideration should be given also to the additional difficulty due to high temporal variability of the defining parameters not only on the level of hour and day but also on the level of the year and even beyond. On the other hand, independently of the methodology adopted, important relevant uncertainties need to be quantitatively addressed.

Methodology and Results

In the frame of the EU project ICARUS, a novel approach have been coined based on weather clustering to study the climate change effect on urban air quality in selected European cities (Bartzis et al, 2019). The approach consists of classifying daily weather data of 50-year period (from 2001 to 2050) into an appropriate number of clusters using Principal Components Analysis and k-means cluster analysis, following the moderate climatic scenario RCP4.5 (van Vuuren et al., 2011). In the present study the focus in on Thessaloniki, covered by an area of 50km x 50km around the city center. The EURO CORDEX regional climate model simulations data at the finer resolution of 0.11 degree (~12.5km) have been utilized. Three RCM simulations have been found to fulfil the present study requirements i.e. INERIS-WRF331F, SMHI-RCA4 and KNMI-RACM022E. The cluster interpretation methodology includes (a) cluster characterization with respect to weather parameters, (b) cluster frequency of occurrence along the 50-year period as a climatic change indicator, (c) frequency of occurrence of heat waves as an additional climatic change indicator and (d) clusters associated with elevated observed concentrations in the city area for NO_2, O_3, and PM pollutants in the historical period 2001-2015 and (d) selection of proper representative days for detailed air quality modeling. Air quality modeling has been performed on the WRF and WRF-chem modeling system, on cluster defined representative past and future days. The results are intercompared including the available observation data.

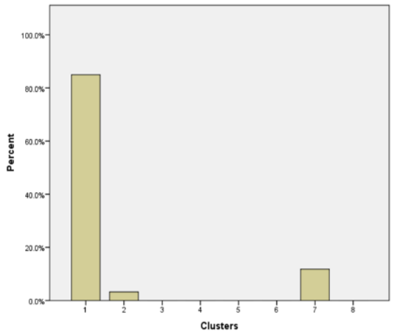

Fig.1 Heat Waves per cluster

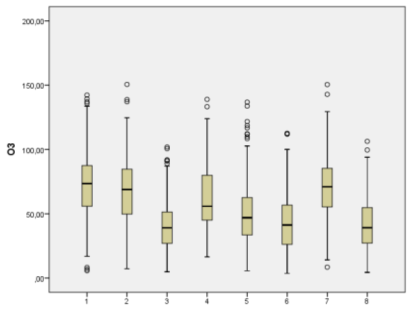

Fig.2 O_3 concentration statistics per cluster

Conclusions

A new approach has been developed to study air quality trends under specific climatic scenarios using local scale weather clustering and air quality modeling efficiently. By putting future and past days in the 'same pot' and dividing them into 'individual seamless clusters' new capabilities have been generated to study future days by relating them 'meteorologically' with past days in which the meteorological and air quality behaviour under the given emission inventory is observed and known. Using more than one RCM we obtain the measure of meteorology-related uncertainties.

Acknowledgement

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MODELING OF ATMOSPHERIC TRANSPORT OF POLLUTANTS RELEASED FROM IZMIR WILDFIRE IN 2019

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Summary

A big wildfire happened in Izmir the summer of 2019 and a large forest area was destroyed. In addition to its deforestation impacts, this forest fire caused air pollution due to combustion of natural vegetation. This study aims to model the atmospheric transport of smoke released from this fire. For this purpose, a long-range atmospheric dispersion model, FLEXPART, was used. The new ECMWF dataset - ERA-5 was used as the meteorological input. The area influenced from the fire was detected from satellite data for defining the source term of the model. The analysis of satellite images also demonstrated that atmospheric transport of the smoke from the wildfire travelled towards south-west direction and effected mostly the Greek islands in the Aegean Sea. The model results were compared with data from air quality monitoring stations in Greece and in Turkey to assess the performance of the model.

Introduction

Wildfires cause various environmental problems such as air pollution, carbon releases and soil erosion. Pollutants that originate from forest fires are mostly smoke, NO_2 and CO, which influence air quality along the flow path of the event in the atmosphere. These parameters are dispersed, transported and transformed with various atmospheric mechanisms. A wildfire in Izmir, Turkey happened in August 2019 and destroyed more than 5000 ha of forest. The fire was one of the biggest wildfires of Turkey in recent years. Satellite images demonstrated that smokes from the fire moved predominantly towards south-western direction towards the Aegean Sea and Greece, which was opposite to the city centre. Thus, the air pollution effects of the fire did not mostly influence the metropolitan centre of the City of Izmir but rather effected sparsely populated areas of the coastline and the Greek Islands. Based on this premise, this study focussed on predicting the air pollution impacts of this wildfire and demonstrate the influence of the source term on the simulated results using atmospheric dispersion modeling.

Methodology and Results

A long-ranged atmospheric dispersion model, FLEXPART, was used to simulate the atmospheric dispersion of pollutants released from Izmir Wildfire in 2019. FLEXPART is a commonly used Lagrangian particle dispersion model for the transport of atmospheric pollutants. It is also used to simulate the pollutants originating from forest fires. NO_2 and CO are selected as the two characteristic species to investigate the impact of the wildfire. Release rates of NO_2 and CO were defined from satellite data assisted emission factors available from the literature. Further, the newly released high resolution ERA5 dataset of ECMWF was used as meteorological input. Alternative source term definitions were made to better characterize the emissions released from the fire. The simulation results were then compared with air quality monitoring data along the downwind direction of the fire. The results revealed a fairly long-ranged transport of the contaminants as wet deposition mechanism was not available during the time of the fire.

Conclusions

The simulation of air pollutants originating from forest fires provides valuable information on the extend and magnitude of the contamination within short and long ranged vicinity of the event. Comparative simulations also reveal the influence of the source terms on the dispersion and deposition patterns of air pollutants along the downwind direction of the fire.

Short Presentations

PROJECT URBI PRAGENSI - URBANIZATION OF WEATHER FORECAST, AIR-QUALITY PREDICTION AND CLIMATE SCENARIOS

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Summary

The ratio of population living in cities is growing and this is especially true for the largest ones, megacities. However, even smaller cities like the City of Prague (about 1.5 M) can suffer significantly and the night time temperature difference can achieve more than 5°C. Moreover, such cities are significant sources of anthropogenic emmisions, not only of GHG, but other air-quality precursors as well, including aerosols. To assess the impact of cities and urban structures on weather, climate and air-quality, modelling approach is commonly used and the inclusion of urban parameterization in land-surface interactions is of primary importance to capture the urban effects properly. It is especially important when going to higher resolution, which is common trend in operational weather forecast, air-quality prediction as well as regional climate modeling. This represents the rapidly developing research, motivated by specific risks in urban environment, with strong impacts on vulnerable communities there, leading to the tools to assess properly impacts within the cities and of the effectiveness of adaptation and mitigation options applied there by the city authorities. Under the action towards the Smart Cities and within the framework for developing adequate climate services, such supporting tools for decision making are inevitable. It is valid not only for extreme heat waves impact prediction, but as well in air-quality forecast and in long term perspective in connection to climate change impacts assessment. This provides the background for the project within Operational Program Prague - The Pole of Growth "Urbanization of weather forecast, air-quality prediction and climate scenarios for Prague", shortly URBI PRAGENSI.

Introduction

The role of cities is increasing and will continue to increase in future, as the population within the urban areas is growing faster. Urban areas exert strong influence on human health through several different but partly cooperating ways. In term of direct effect of urban heat island, especially within episodes of heat waves the urban environment can cause the health risks as heart attack, especially to the specific groups of vulnerable people (elderly). Such events can be combined with smog episodes in summer, under specific adverse dispersion conditions this is typical for winter. The cities are significant sources of air-pollution emissions and following chemical reactions can be affected by the temperature and humidity, which are typically specific characteristics of UHI.

Methodology

There are four main tasks within the project. First, urbanization of weather forecast, i.e. involving and testing the urban parameterization scheme in the weather prediction model can provide in very high resolution localized weather prediction and especially under the heat wave condition it can well capture the temperature differences in the city center with respect to the remote areas, which can achieved in the midsize city like Prague more than 5°C. There are applications, which can use such localized prediction for planning and decision making on e.g. public services for some specific groups of population in risks. Further, air-quality forecast based on such urbanized weather condition forecast can benefit from better estimates of temperature for chemical reactions, mixing height for dispersion conditions etc. Third, urbanized scenarios of climate change can provide better description of future conditions in the city for adaptation and mitigation options, moreover, in connection to urban heat island urbanized regional climate model in very high resolution is good tool for estimates of efficiency of potential adaptation or mitigation measures which might be applied by the city administration. Last, but not least, microscale simulations using LES methods are supposed to be used for selected local hot-spots to solve them.

WRF model is used for weather prediction with urban effects parameterization included in multiple nested domains of 9 km for Central Europe region through 3 km resolution domain and 1 km resolution domain of central Bohemia region for the City of Prague, coupled with CTM model CAMx, which covers the first two items.

Results and Conclusions

Effects of the City of Prague are clearly seen in weather forecast with urbanization included, the model is well capable to reproduce typical urban heat island during heat wave episodes, really achieving the intensity of about 5°C. Hindcast series of weather forecasts shows the added value of urbanized weather prediction for the City of Prague both in summer heat wave events as well as during winter as a result of anthropogenic heating. The effect of urbanization on air quality prediction is slightly positive due to higher surface roughness and mostly increase of mixing layer above the city, however, the main task in the area of air quality forecast is to provide quasi-operative tool for eventual mitigation measures assessment, i.e. in case of potential predicted smog episode to simulate measures of regulations defined in advance and to assess their effects.

Acknowledgement

The authors wish to thank for support under Programme OP PPR with the project URBI PRAGENSI, CZ.07.1.02/0.0/0.0/16_040/0000383, as well as local support of Charles University in Programme Progress, Q16-Environmental Research.

VALIDATION OF THE AIR QUALITY AND METEOROLOGICAL VALUES MODELLED BY PALM-4U MODEL AGAINST OBSERVATION CAMPAIGN IN PRAGUE-DEJVICE

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Summary

The PALM-4U urban climate model allows to simulate detailed street level meteorological and air quality values in very fine resolution for large urban areas. Results from a modelling domain in Prague-Dejvice quarter were compared against values obtained from two observation campaigns in the summer and winter of 2018. The comparison has been used for validation and calibration of the model and its inputs.

Introduction

The newly developed urban climate model PALM-4U (www.palm4u.org) which is based on a well known LES model PALM enables high-resolution simulations of meteorological and air quality conditions in urban areas, mainly with respect to the phenomena of urban heat island and air quality in street canyons. The recent development significantly enhanced model's capabilities and our team has strongly contributed to the development. The PALM-4U model can be used to evaluate the efficiency of micro or local scale urban development strategies.

Observations

To validate model performance, observation campaigns took place in different cities. This work presents results from a detailed validation of the model against an observation campaign carried out in Prague-Dejvice area. The campaign was accomplished within the UrbiPragensi project and spanned two fourteen-day episodes; one in typical summer conditions and the other in the winter of 2018. The campaign was carried out by Czech Hydrometeorological Institute (CHMI) specialists in collaboration with the modelling team. It utilized three vehicles fully equipped for measurements of air quality and meteorology, infrared cameras, a drone for vertical profile measurement, and instruments for measurement of heat fluxes through building envelopes. A wide range of meteorological and air quality measurement data has been collected. Apart from this measurement campaign, meteorological data from CHMI's professional background stations in Prague, including vertical profiles measurement and mixing height, are available. This allows us to compare a wide range of the modelled and observed values of meteorological and air quality characteristics.

Model setup

The model has been configured in two nested domains. The coarse domain has horizontal extent of 4 × 4 km, height of 3 km and 10-m resolution and serves for modelling of the effects of the surroundings with respect to the area of interest. The observations were compared against modelling results from the fine inner domain. This domain has an extent of 1440 × 1440 m, height of 260 m and 2-m resolution. Initial and boundary meteorological conditions for coarse domain were taken from a simulation of WRF model in 1-km resolution configured with urban canopy model. The initial and boundary concentrations were obtained from a simulation of CAMx model. The PALM-4U model needs a detailed description of the urban canopy layer, e.g. buildings including characteristics of the particular walls and roofs, streets and pavements, natural areas, trees, etc. as well as a precise charakterization of the emission flows. This represents a significant challenge. We process our input data from a combination of multiple sources, e.g. Prague OpenData, Open Street Maps, national and Prague geodatabases and we supplement them with data obtained by terrain mapping campaign.

Results

The results show very good agreement of the meteorological data, particularly surface temperatures. The concentrations of air pollution evince larger variability. The comparison of the border values with nearby background observation stations allows us to split the contribution of the transported emissions from the local ones and partially calibrate the model results. The remaining differences can be attributed to the uncertainties in the local emissions as well as to imperfection in turbulent flow description.

Acknowledgement

This work was supported by project UrbiPragensi financed from operational programme "Prague – the Pole of the Growth", CZ.07.1.02/0.0/0.0/16_040/0000383. Matthias Suhring and Johannes Schwenkel were supported by project MOSAIK, 01LP1601A. The simulations were performed in IT4Innovations Czech National Supercomputing Center supported by project LM2015070 and at the supercomputers of The North-German Supercomputing Alliance (HLRN).

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AIR QUALITY MODELING STUDY USING WRF-CHEM OVER BARCELONA

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Summary
The WRF-Chem model with a multi-layer canopy model was used in this study to simulate the air quality over the city of Barcelona at high resolution. The model is run with detailed information (urban morphology and emissions). Our results show that using detailed land-use information, characteristics regarding building configuration and high resolution emissions inventories improve the model performance.

Introduction
Currently, around 54% of the world's population is living in urban areas and this number is projected to increase by 66% by 2050. Air pollution mainly from transport mobility, heating and cooling in cities, is considered the single largest environmental health hazard in Europe and is responsible for 467,000 premature deaths per year. Air quality has been identified as a major threat to human health and ecosystem, especially in urban areas, where exposure to air pollution is the highest. Urban air quality modeling has been the focus of considerable development during recent decades, driven by this concern. Numerous air quality models have been developed by different research groups and are being used for designing emission control policies. The Weather and Research Forecasting model (WRF) coupled with chemical transport (WRF-Chem) with multi-layer canopy model offers the ability to simulate the air quality at urban scale.

Methodology and Results
Methodology and ResultsThe WRF-Chem model is used in this study. WRF has three different urban canopy schemes designed to represent city morphology (e.g. building and street canyon geometry) and surface characteristics (e.g. albedo, heat capacity, emissivity, urban/vegetation fraction). Here we used a multi-layer layer scheme, the Building Effect Parameterization (BEP) coupled with the Building Energy Model (BEP+BEM, Salamanca and Martilli, 2010) to take into account the energy consumption of buildings and anthropogenic heat generated by air conditioning systems. The Local Climate Zones (LCZ) classification is used for the metropolitan area of Barcelona (MAB). The LCZ is a detailed urban land classification developed for the city of Barcelona by the Cartographic and Geological Institut of Catalonia (ICGC). Specific values for each LCZ for thermal, radiative and geometric parameters of the buildings and ground are used by the BEP+BEM scheme to compute the heat and momentum fluxes in the urban areas. Our results suggest that detailed input data (land-use information, urban morphology and emissions) is needed to model the air quality over Barcelona.

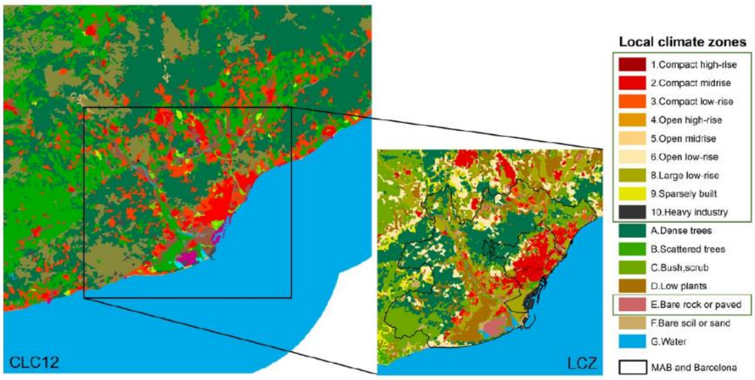

Fig.1 Land use in MAB domain: Corine Land Cover 2012 at the left and Local Climate Zones at the right. The LCZ used are the ones inside the green rectangles.

Conclusions
Here we present the first results of a study aimed to model the air quality over the city of Barcelona at high resolution using the WRF-Chem model with urban canopy models. Future steps will be to study how the green infrastructures (in various forms from peri-urban agriculture to green roofs) impact the urban atmosphere (e.g. humidity, temperature, and air quality).

Acknowledgement
This project has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (grant agreement No 818002)". The EU project, entitled Integrated System Analysis of Urban Vegetation and Agriculture (URBAG, https://urbag.eu/), aims to find out how urban green infrastructures can be most efficient in contributing to urban sustainability.

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BIOGENIC EMISSIONS FROM URBAN VEGETATION: IMPACT OF DETAILED INVENTORIES IN DIFFERENT EUROPEAN CITIES

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Summary
Many cities are planning to increase "urban forestry" to mitigate heat island effects and improve air quality. Since isoprenoid emissions from vegetation can affect ozone and secondary organic aerosol, it is important to know their impact on air quality for selecting the appropriate trees species, location and extension where to be planted. The availability of digital inventories of the trees species within urban areas can support a detailed evaluation of biogenic volatile organic compounds (BVOC) emissions. Urban vegetation inventories have been gathered from Bologna, Madrid and Milan municipalities and integrated with forest cover maps available at regional and national levels. The resulting vegetation maps have been compared with CORINE land cover highlighting the improved description of tree species. Biogenic emissions have been then computed starting from the tree species emission factors and high-resolution meteorological model simulations fields.

Introduction
The increase of urban vegetation is one of the solutions proposed to improve the quality of life in cities starting from air quality and thermal comfort, basic elements of the citizens' health and well-being. Many cities are planning or realizing urban forestation as a joint tool to achieve climate change resilience and air pollution reduction. In this framework, the LIFE+ Preparatory project VEG-GAP has been funded to investigate the interactions between air pollution and urban vegetation starting from an in-depth knowledge of the current state of urban green in the target cities. Meteorological and air quality models will be used to describe the complex interaction between anthropogenic and biogenic emissions, considering transport, formation and deposition of pollutants in the atmosphere from the continental to the urban scale.

Methodology and Results
Municipal administrations of the major European cities developed digital vegetation inventories including the main features of trees located along the roads and within parks. Similar inventories have been provided by Bologna, Madrid and Milan. Those data have been processed and transformed in fractional cover of each species within pixels of the raster landcover maps that have been built to support biogenic emissions computation and air quality modelling. Urban vegetation data have been integrated with forest cover and land-use maps available at regional scale to cover air quality model domains and integrate information concerning other land cover types, (e.g. agriculture and urban structures). The all-species overall trees cover (see Fig.1 for Milan area) confirms the improvement obtained with respect to the areas covered by forest and trees plantations described by CORINE Landcover (Fig.2). A general coherence of areas covered by the largest forest fraction is observed over hills and nearby riverbeds, while an increment of trees cover over urban and agricultural areas is obtained. High resolution BVOC emissions have been then computed for present vegetation of Bologna, Madrid and Milan. A Plant-Specific Emission Model (Silibello et al., 2017) has been applied to derive biogenic emissions for each plant species. The emissions computed over a year-long period provided a first indication of the tree species having the larger potential impact on the ozone cycle and on the secondary aerosols production.

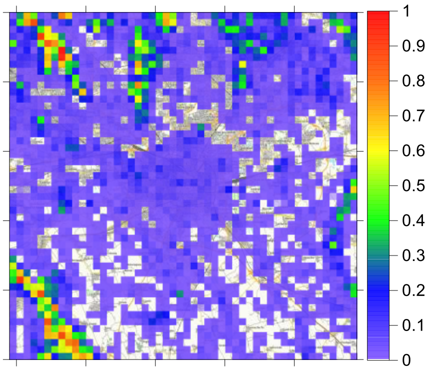

Fig.1 Trees fraction cover (local inventory)

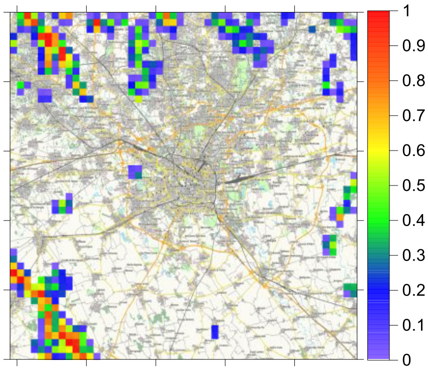

Fig.2 Trees fraction cover (CORINE Landcover)

Conclusions
Improved vegetation cover maps have been built for the cities of Bologna, Madrid and Milan, including municipal trees inventories and regional scale forest maps. These maps proved to improve available landcover datasets at national and European level. Tree species dependent BVOC emissions have been calculated for the three cities providing an improved input to air quality models and allowing a preliminary identification of the species with potentially larger impact on concentrations of secondary air pollutants.

Acknowledgement
This work was supported by the VEG-GAP Project - LIFE18 PRE IT 003.

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TROPOSPHERIC NO_2 AND HCHO DERIVED FROM THE DUAL-SCAN MAX-DOAS INSTRUMENT IN UCCLE, BRUSSELS

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Summary

This study focuses on the seasonal variation of tropospheric nitrogen dioxide (NO_2) and formaldehyde (HCHO) in Uccle, Brussels. Ground-based Multi-Axis Differential Optical Absorption Spectroscopy (MAX-DOAS) measurements of aerosols, NO_2 and HCHO have been carried out in Uccle during one and a half year (March 2018 – October 2020). The MAX-DOAS instrument is operating in dual-scan configuration in the UV and Visible wavelength ranges. During one scan, the instrument performs a vertical scan in a fixed azimuthal direction and an azimuthal scan in 10 different directions in a fixed low elevation angle (2^{o}). This measurement sequence allows to study the seasonal vertical and horizontal distribution of NO_2 and HCHO in Brussels. The observations show a clear seasonal cycle of these trace gases around the measurement site. Important applications are (1) the validation of satellite missions with high spatial resolution, such as TROPOMI/S5P and (2) an improved understanding of the trace gas distribution based on the link between MAX-DOAS remote sensing measurements and in-situ measurements in Brussels.

Introduction

Tropospheric NO_2 is an important anthropogenic pollutant emitted by combustion processes associated to traffic, industrial activity and domestic heating. NO_2 has a direct health impact and is a proxy of air pollution, as its high concentration are often associated with high concentration of tropospheric ozone (O_3) and aerosols. Tropospheric O_3 is linked to air quality by a nonlinear photochemical mechanism involving Volatile Organic Compounds (VOCs) such as HCHO, which is the most abundant organic carbonyl compound in the atmosphere. For these reasons, the monitoring of aerosols, NO_2 and HCHO is highly relevant, especially in urban areas, such as Brussels.

Methodology and Results

The dual-scan MAX-DOAS retrieval strategy refers to a NO_2 and HCHO near-surface concentration and vertical column density retrieval over one complete MAX-DOAS scan. We use (1) a parameterization approach as introduced by Sinreich et al. (2013) and (2) an OEM-based profile retrieval. The basic principle of the approach is that the lower the elevation angle, the higher the absorption of a trace gas located close to the ground. During one scan, we apply first an Optimal Estimation Method (OEM) - based profile retrieval, then Radiative Transfer Model (RTM) simulations and finally, the parameterization technique. One and a half year of NO_2 and HCHO near-surface concentrations revealed a clear seasonal cycle concerning the horizontal distribution of these trace gases around the measurement site. Major role play the seasonal variation of the meteorological conditions and the anthropogenic activity (changes in traffic volume and heating). The use of in-situ NO_2 measurements revealed that the agreement between both datasets depends on the location of the in-situ station and the meteorological conditions.

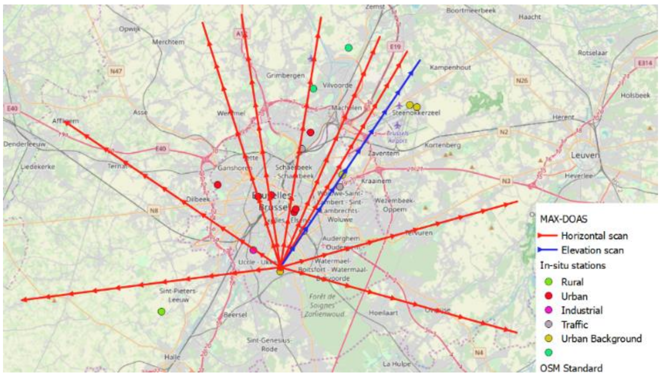

Fig.1 The dual-scan experimental set-up of the BIRA-IASB MAX-DOAS instrument

Conclusions

Dual-scan MAX-DOAS observations in urban areas, such as Brussels, are very valuable in order to monitor continuously the near-surface concentration of important pollutants that influence air-quality and human health. The measurements in more than one azimuthal direction allow the study of the seasonal horizontal distribution of NO_2 and HCHO and the identification of hot spots around the city. Except this utility, they can be used for the validation of satellite missions dedicated to air-quality monitoring.

Acknowledgement

We would like to acknowledge the Belgian Federal Science Policy Office (BELSPO) for funding this study.

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ASSESSMENT OF THE SPATIAL REPRESENTATIVENESS OF PM MASS CONCENTRATION MEASUREMENTS PERFORMED AT THE GROUND LEVEL ON THE LILLE OBSERVATION PLATFORM

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Summary
This study aims to assess the spatial representativeness of PM mass concentrations measured at the ground level a research supersite (Lille Observation Platform), compared to measurements performed on a routine basis by the regional air quality monitoring network. We have systematically evaluated the spatial (within ~80 km) and temporal (from hourly to annual resolutions) differences between the supersite and monitoring stations in urban background or rural areas over the period October 2016- June 2019.

Introduction
Assessing the spatial representativeness of the measurements performed at an observation site is of tremendous importance for exposure studies, model validation and data assimilation. Ground-level mass concentrations of Particulate Matter (PM) are strongly affected by emissions, dispersion and deposition, and therefore local phenomena can reduce the temporal and/or spatial range of representativeness of such measurements.

Methodology and Results
The Lille Observation Platform is located on the rooftop of a building on the University campus. It has been equipped for decades with a large panel of active/passive remote sensing instruments including Sun/sky photometer and Lidar dedicated to aerosol property retrievals as part of several networks (AERONET, EARLINET, ACTRIS, etc.). Recently (since October 2016), additional routine near-real time measurements of the fine (submicron or PM_1) fraction of aerosols at the ground level have been deployed, in order to better assess the temporal variability of the chemical composition of aerosols at the ground level (Table 1). These remote sensing and in situ instruments are complementary to provide robust assessment of their impacts on climate change as well as on air quality. The observation site is located in a suburban area, only 4 km apart from the closest monitoring station defined as an urban background site. It is also about 80 km apart from two rural sites.

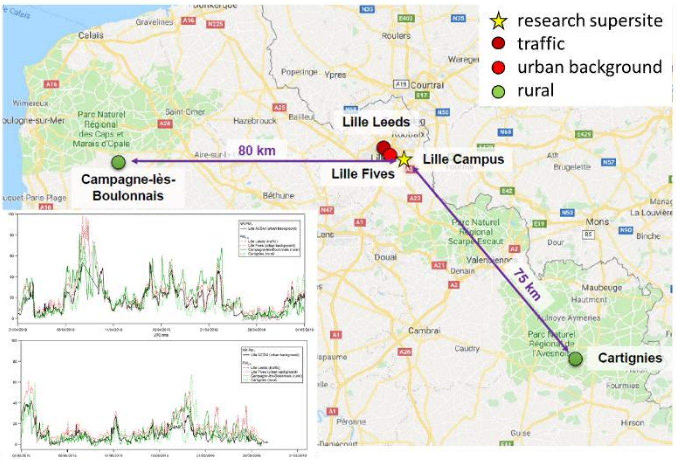

Fig.1 Map of the sites considered in the representativeness study

Table 1: Parameters routinely measured in situ at the ground level on the Lille observation platform since Oct. 2016

Instrument	Time resol.	Measured parameters
Aerosol Chemical Speciation Monitor (Q-ACSM, Aerodyne Research Inc.)	30 min	Mass concentrations of non-refractory submicron aerosols (organics, sulfate, nitrate, ammonium, chloride)
7-wavelength aethalometer (AE33, Aerosol d.o.o.)	1 min	Black carbon mass concentrations and absorption coefficients of submicron aerosols
Optical particle counter (FIDAS 200S, Palas GmbH)	1 min	Aerosol number concentration with diameters smaller than 10, 2.5 and 1 µm (PM_{10}, $PM_{2.5}$ and PM_1, respectively)

Conclusions
This work investigated the representativeness of ground level PM measurements at the Lille Observation Platform over a wider spatial scale. Further studies are ongoing to (i) apportion the organic aerosol and Black Carbon sources in order to deconvolve primary from secondary sources, and (ii) link optical properties to chemical composition in the finer fraction.

Acknowledgement
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ANALYSIS OF NO_2 SPATIAL VARIABILITY IN A CARIBBEAN CITY

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Summary
This research aimed to understand the distribution and spatial variability of NO_2 during the study period in Barranquilla a Caribbean city in the North of Colombia. In order to obtain the concentration of the contaminant in an adequate resolution, 137 diffusion passive tubes from Gradko© were installed. Results showed an average of 19.92 ±11.50 µg/m^3. Critical points of the city that may urgently need management plans were determined for serving as a tool for environmental and health authorities.

Introduction
Nitrogen dioxide (NO_2), one of the main air pollutants, may contribute to the formation of atmospheric particles through various photochemical reactions, including nitrate particles, which form an important fraction of $PM_{2.5}$ and, in the presence of ultraviolet light, ozone. Epidemiological studies have shown that bronchitis symptoms in asthmatic children increase in association with long-term exposure to NO_2 and reduced lung function growth (Achakulwisut, 2019). Diffusion passive tubes are lightweight, economical and need no maintenance, on-site energy and pumping. Recent studies indicate increasing concentrations of NO_2 in developing countries, despite declining trends in developed countries, probably as a result of environmental regulation policies in the latter (Geddes et al., 2016). Cities like Barranquilla, driven by unprecedented economic growth, the explosive increase in urbanization and population, can experience severe air pollution problems by NO_2. Moreover, the study area has a deficiency in the number of monitoring points for NO_2. Therefore, this research aimed to understand the distribution and spatial variability of NO_2 during the study period in Barranquilla a Caribbean city in the North of Colombia.

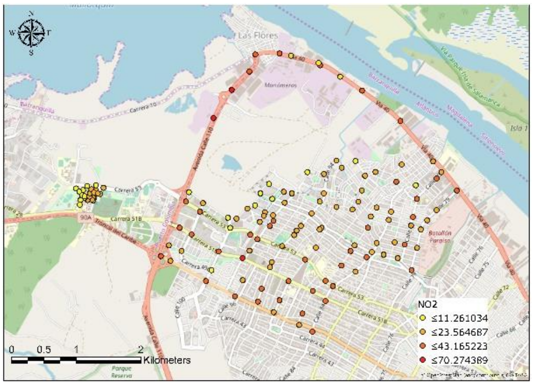

Fig.1 Location of diffusion passive tubes and NO_2 concentration

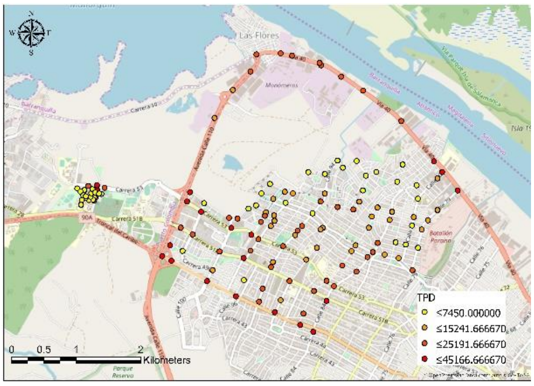

Fig.2 Mean traffic load per day

Methodology and Results
Diffusion passive tubes prepared with 20% TEA/water from Gradko © Environmental were used for measure NO_2 in 137 points at a height of 2-4 m in a lamppost, road sign or traffic light (Fig 1.). Diffusion tubes were located at the roadside between 1 and 5 m from the kerb edge. Barranquilla is a Caribbean city located in the North of Colombia that has approximately 1.200.000 inhabitants and possesses a warm humid climate. Sampling period was two weeks from 3/16/2019 to 3/30/2019. Samples were analysed on UV CARY1 spectrophotometer by Gradko. Detection limit of the method was 1.11 ug/m^3. Results showed an average of 19.92 ±11.50 µg/m^3, with a maximum and minimum value of 70.27 and 0.57 µg/m^3, respectively. 35%, 26% and 17% of the results were in these ranges 8.4-16.2 µg/m^3, 16.2-24.0 and 24.0-31.8 µg/m^3, respectively, summing 78% of data. Moreover, just 6 samples were higher than the WHO guideline value of 40 µg/m^3. Highest values corresponded to industries, ports and 4-lines vehicular intersections. Also, high values were obtained for downwind points near the roadway. Although, these are astounding results because values were lower than WHO standards for all points, even though the study area has several stationary sources, ports and high traffic. Probably, emitted NO and transformed to NO_2, reacts rapidly with other air pollutants such as organic compounds or ozone. High ozone levels are typical in the coastal cities, including the study area. Traffic data was estimated, too. Correlation between NO2 and traffic was 0.35 indicating that other variables may be influencing, such as turbulence, distance from the edge and chemical reactions with other air pollutants.

Conclusions
Critical points of the study area included stationary sources, ports and a highly traffic impacted intersection. These results may help in management plans, and thus subsidize the knowledge to serve as a tool for environmental and health authorities.

Acknowledgement
This work was supported by Universidad del Norte. We acknowledge all grad students for their help during sampling.

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ESTIMATING DAILY $PM_{2.5}$ CONCENTRATIONS AT CITY OF SÃO PAULO, BRAZIL

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Summary

Using meteorological and land use variables we applied Linear Mixed Model (LMM, Laird and Ware, 1982) to predict daily ground-based $PM_{2.5}$ concentrations across the city of São Paulo (SP), Brazil, for the period between 2012 and 2017. LMM demonstrated a good performance (cross-validation R^2 above 0.65) to predict $PM_{2.5}$ concentrations in SP. This methodology enables epidemiological studies to assess the effects of both acute and chronic exposure to air pollutants on human health.

Introduction

In urban areas, such as SP, inhabitants are daily exposed to high air pollutants levels. The negative association between high levels of fine particulate matter ($PM_{2.5}$, particles smaller than 2.5µm in diameter) and issues related to human health are well documented (WHO, 2006). However, few and sparse air quality networks monitor the levels of air pollutants, being them representative of inhabitants that live nearby those networks. Thus, the developing of methodologies to estimate $PM_{2.5}$ concentrations in regions where air quality networks are lacking is needed.

Methods and Results

We used the LMM to estimate $PM_{2.5}$ concentrations across SP from 2012 to 2017. This methodology allows us to take into account the daily variability of meteorological conditions that influence $PM_{2.5}$ concentrations and also gives us daily $PM_{2.5}$ estimates. *Variables:* hourly $PM_{2.5}$ concentration data were obtained from 28 automatic air quality monitoring stations of the Environmental Company of São Paulo State (CETESB). The explanatory variables used for the LMM were air temperature (Temp), relative humidity (RH), precipitation (Precip), speed wind (WS) (meteorological variables) and road density (land use variable). Since in SP the main source of air pollution is vehicular emissions, we used the road density variable as *proxy* for emissions. It represents the total length of high traffic streets (trunk, motorway, primary and secondary roads) per cell (km/km^2) and was calculated using roadway data downloaded from OpenStreetMap (OSM, http://www.openstreetmap.org) and the line density tool from ArcGIS software (www.arcgis.com). Nearest neighbor method were used to interpolate the meteorological variables in a grid with 1 x 1 km^2 cells comprising SP territory. Planetary boundary layer height (PBLH) estimates were obtained from Climate Forecast System Reanalysis version 2 (CFSRv2) developed by the National Centers for Environmental Prediction (NCEP) (https://rda.ucar.edu). *Model:* first, using grid cells containing monitoring stations, we fit the model presented in equation (1), where PM_{ij} is the $PM_{2.5}$ concentration observed at cell i on day j; α and $u_j \sim Normal(0; \sigma_u^2)$ are the fixed and random daily intercepts, respectively; β'_s are the fixed effects related to the explanatory variables; $\varepsilon_{ij} \sim Normal(0; \sigma^2)$ are the random errors.

$$(1)\ PM_{ij} = \alpha + u_j + \beta_1 Temp_{ij} + \beta_2 RH_{ij} + \beta_3 PBLH_{ij} + \beta_4 Precip_{ij} + \beta_6 WS_{ij} + \beta_6 Road\ Density_i + \varepsilon_{ij}$$

We selected the subgroup of variables that best predicted $PM_{2.5}$ concentrations using the Akaike Information Criteria (AIC). To evaluate the performance of the model, Leave-One-Monitor-Out Cross-Validation (LOMO CV) R^2 and square root of mean squared prediction errors (RMSPE) were calculated. Then, using the model selected earlier, we estimated $PM_{2.5}$ concentrations in cells with no monitoring stations for the entire period of the study. R software (www.r-cran.org) was used in the analyses. *Results:* We fitted models considering diurnal (average of the 6am-18pm period measurements) and daily (average of the 24-hour measurements) $PM_{2.5}$ concentrations, because they are used in epidemiological studies. All variables in equation (1) were important for $PM_{2.5}$ prediction, in both models. Diurnal and daily models presented 0.67 and 0.76 LOMO CV R^2, respectively, showing a fair performance of the model. RMSPE were 5.2 µg/m^3 and 4.9 µg/m^3 for diurnal and daily, respectively. The overall mean of diurnal $PM_{2.5}$ concentrations predictions ranged from 16.0 and 19.4 µg/m^3 (see Fig. 1) and the overall mean of daily $PM_{2.5}$ concentrations predictions ranged between 17.9 and 19.6 µg/m^3.

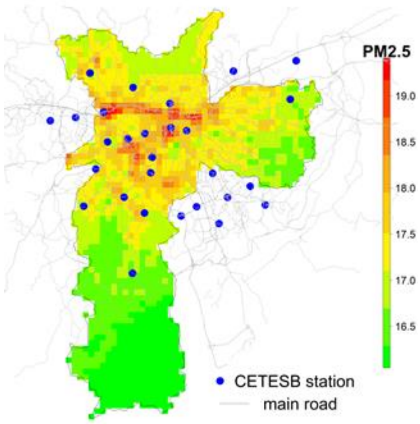

Fig. 1: Overall mean of diurnal PM2.5 predictions over SP in 2012-2017 period

Conclusions

The good performance of the LMM demonstrate that it can be used to predict ground-based $PM_{2.5}$ over SP, a region where many studies have pointed out the effects of high air pollution levels on SP citizens' health (e.g. Saldiva et al., 1995), but few studies have tried to predict ground-based $PM_{2.5}$ concentrations.

Acknowledgement

This work was funded by FAPESP (grant #2016/09411-1) and by CAPES. We acknowledge CGE, IAG-USP and DAEE for providing the meteorological data. We also thank CETESB, OSM and NCEP teams for providing air quality data, roadway data and PBLH data, respectively.

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USING SMALL SENSORS TO TAKE HIGH RESOLUTION MEASUREMENTS OF NITROGEN DIOXIDE AND OZONE IN VARIOUS URBAN ENVIRONMENTS

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Summary: This study uses small sensors for air quality measurements to investigate differences in urban air pollution on a local scale. Experiments using EarthSense Zephyrs were conducted to measure NO_2 and O_3 in urban street canyons, at street level as well as at various heights. Field co-locations were conducted to calibrate the instruments and provide an in-situ calibration for subsequent post-processing used to convert raw voltage data output by the sensor components to air pollutant concentration. Differences in concentrations of NO_2 and O_3 between the street level and at various heights within the street canyon were observed. Such high resolution data is useful for validation of urban scale air quality models, as well as to inform our understanding of exposure to air pollution in urban micro-environments. Future experiments will seek to directly connect such measurements to transport policy to assess their impact on urban air pollution.

Introduction: Air pollution was linked to ca. nine million premature deaths worldwide in 2015 (Landrigan et al., 2018), about half of which could be attributed to ambient air pollution and the other to indoor air pollution. The classical view of urban air pollution monitoring is based on well-established and well-characterized, yet expensive, reference methods installed in limited and static monitoring stations. The use of small sensors as a complementary tool for air quality monitoring could give us high spatial density and temporal resolution relevant for city scale measurements and more information related to air pollution exposure of the population. At the Institute for Advanced Sustainability Studies e.V. (IASS), the Climate Change and Air Pollution (ClimPol) project is working on deploying small sensors in a variety of urban environments to better understand the patterns of air quality in cities and provide valuable information to decision-makers on the impacts of measures, specifically those linked to transport policy.

Methodology and results: Since 2017, ClimPol has deployed EarthSense Zephyrs in local urban environments, including vertical profiles within street canyons and in mobile bicycle measurements in Berlin, Germany to measure ozone (O_3) and nitrogen dioxide (NO_2). The Zephyr prototype units use a combination of metal oxide sensors (MOS) and electrochemical sensors (EC) to measure O_3 and NO_2. To calibrate the devices during the experiments, field co-locations were performed before and after each deployment with reference instruments either at measurement stations within the Berlin air quality measurement network (BLUME) or at the field site itself. Various statistical models such as multiple linear regression (MLR) and random forest (RF) were tested for their accuracy at transforming raw voltage data from the sensors into pollutant concentrations, as well as to quantify uncertainty to see if the devices would fit the Air Quality Directive requirement for indicative measurements. Preliminary results indicate that these units are able to detect variation in concentrations of NO_2 and O_3 between street level and various vertical heights within a street canyon. Median concentrations over a month of measurements in the summer of 2017 of NO_2 in a street canyon were found to be ~2.5 ppb higher in the middle of the street than at the 1st floor of a building and ~4ppb higher than at the 3rd floor of a building, but at greater heights beyond the 3rd floor NO_2 appeared to be well-mixed. For O_3 the concentrations were about ~3ppb lower in the middle of the street than at the 1st floor, but for all other heights appear to be well-mixed. The same experiment in the winter revealed larger differences in concentrations between street level and the various heights of a building, with a median concentration of NO_2 at street level ~6ppb higher than the 1st floor with significant decreases in concentrations for each subsequent height. For O_3 in the winter, concentrations at street level were ~4ppb lower than at the 1st floor and ~8ppb lower than at the 3rd floor, reflecting the lower O_3 production and higher NO_2 emissions in the winter.

Conclusions: As small sensor technologies improve, their usefulness in investigating differences in air quality in local urban micro-environments will multiply. Utilizing these devices to conduct future experiments to better understand human exposure to and the impact of transport policy on air pollution is a key next step in their development.

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Accepted Abstracts but not presented at the Online Conference[1]

[1] Arranged in alphabetical order by submitter surname

FROM URBAN AIR QUALITY FORECASTING AND INFORMATION SYSTEMS TO INTEGRATED URBAN HYDROMETEOROLOGY, CLIMATE AND ENVIRONMENT SYSTEMS AND SERVICES FOR SMART CITIES

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Summary
This presentation is analysing a modern evolution in research and development from specific urban air quality systems to multi-hazard and integrated urban weather, environment and climate systems and services and provides an overview of joint results of large international WMO GURME, IUS, and EU FP FUMAPEX, MEGAPOLI and MarcoPolo projects teams.

Introduction
Urban air pollution is still one of the key environmental issues for many cities around the world. A number of recent and previous international studies have been initiated to explore these issues. In particular relevant experience from the European projects FUMAPEX, MEGAPOLI, MarcoPolo will be demonstrated. MEGAPOLI studies aimed to assess the impacts of megacities and large air-pollution hotspots on local, regional and global air quality; to quantify feedback mechanisms linking megacity air quality, local and regional climates, and global climate change; and to develop improved tools for predicting air pollution levels in megacities (Baklanov et al., 2010). FUMAPEX developed for the first time an integrated system encompassing emissions, urban meteorology and population exposure for urban air pollution episode forecasting, for assessment of urban air quality and health effects, and for emergency preparedness issues in urban areas (UAQIFS: Urban Air Quality Forecasting and Information System; Baklanov, 2006; Baklanov et al., 2007).

Resent evolution and results
While important advances have been made, new interdisciplinary research studies are needed to increase our understanding of the interactions between emissions, air quality, and regional and global climates. Studies need to address both basic and applied research and bridge the spatial and temporal scales connecting local emissions, air quality and weather with climate and global atmospheric chemistry. WMO has established the Global Atmosphere Watch (GAW) Urban Research Meteorology and Environment (GURME) project (http://mce2.org/wmogurme/) which provides an important research contribution to the integrated urban services.
It is also important to remember that most (about 90%) of the disasters affecting urban areas are of a hydro-meteorological nature and these have increased due to climate change (Habitat-III, 2016). Cities are also responsible not only for air pollution emissions, but also for generating up to 70% of the Greenhouse Gas emissions that drive large scale climate change. Thus, there is a strong feedback between contributions of cities to environmental health, climate change and the impacts of climate change on cities and these phases of the problem should not be considered separately. Further, a single extreme event can lead to a cascading effect that generates new hazards and to a broad breakdown of a city's infrastructure. There is a critical need to consider the problem in a complex manner with interactions of climate change and disaster risk reduction for urban areas (Grimmond et al., 2014, 2015; Baklanov et al., 2016, 2018).
WMO is promoting safe, healthy and resilient cities through the development of Integrated Urban Weather, Environment and Climate Services. The aim is to build urban services that meet the special needs of cities through a combination of dense observation networks, high-resolution forecasts, multi-hazard early warning systems, disaster management plans and climate services. This approach gives cities the tools they need to reduce emissions, build thriving and resilient communities and implement the UN Sustainable Development Goals.

Conclusions
The Guidance on Integrated Urban Hydro-Meteorological, Climate and Environmental Services (IUS), developed by a WMO inter-programme working group and the Commission for Atmospheric Sciences and Commission for Basic Systems, documents and shares the good practices that will allow countries and cities to improve the resilience of urban areas to a great variety of natural and other hazards (WMO, 2018, 2019).

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THE USE OF HYPNUM CUPRESSIFORME HEDW. AS BIOMONITORS OF TRACE ELEMENTS AND RADIONUCLIDES IN GREECE

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Summary

This study aims to show the atmospheric deposition of trace elements and radionuclides in the North part of Greece using mosses as biomonitors. More specifically, ninety-five (95) samples of *Hypnum cupressiforme* Hedw. were collected in the region of Northern Greece during the end of summer 2016. Samples were collected according to the requirements of the Protocol of the European Survey ICP Vegetation and were analysed to the content of trace elements using Neutron Activation Analysis (NAA), while the concentrations of the radioactive nuclides were determined using gamma ray spectrometry. The elemental characteristics of each moss sample was further analysed via the application of the source apportionment by Positive Matrix Factorization (PMF) and specifically by the EPA PMF 5.0 model. The source apportionment results revealed the contribution from five sources: Soil Dust, Aged Sea Salt, Vehicular Traffic, Heavy Oil Combustion and Mining Activities, with Soil Dust displaying the highest contribution to the measured metal concentrations among all other sources.

Introduction

Moss biomonitoring technique has been used for more than 40 years in Europe, with the Scandinavian countries being the first who introduced it based on the numerous advantages that they offer. Mosses have the ability to retain particles from the air. They receive all the nutrients from rain and dry deposition with no elemental uptake from the substrate (Berg and Steinnes, 1997; Harmens et al., 2013). Within the framework of UNECE ICP Vegetation programme (Harmens et al., 2013) the current study was carried out in Northern Greece, and the results are included in the European database for the Atmospheric Heavy Metal Deposition. Attention should also be paid to the fact that this is the first study in Greece which shows the simultaneous atmospheric deposition of trace elements and radionuclides in the whole territory of Northern Greece using biomonitors and recognise the most influenced areas.

Methodology and Results

After the sampling, mosses were prepared in the lab and analysed using the gamma ray spectrometry for the determination of the activity concentrations of the radionuclides. The activity concentrations of ^{137}Cs, ^{40}K, ^{7}Be and ^{210}Pb were determined. Some differences have been observed in the activity concentrations between mosses collected from ground surface, rocks, branches and roots. ^{7}Be and ^{210}Pb activity concentrations are higher in moss samples from the ground surface and rocks. ^{137}Cs concentrations are higher in mosses collected near roots and rocks.

Mosses were also analysed for the determination of trace elements using NAA, at the reactor IBR-2 of FLNP, JINR in Dubna, Russia. The elemental characteristics of each moss sample was further analysed via the application of the source apportionment by Positive Matrix Factorization (PMF) and specifically by the EPA PMF 5.0 model. In total 30 species were used for source apportionment (Na, Mg, Al, Si, Cl, K, Ca, Sc, Ti, V, Cr, Mn, Fe, Co, Ni, As, Br, Rb, Sr, Mo, Cd, Sb, Cs, Ba, La, Ce, Tb, Hf, Ta and Th). According to PMF analysis, the five sources that contribute the most in the elemental concentrations are the Soil Dust, the Aged Sea Salt, the Vehicular Traffic, the Heavy Oil Combustion and the Mining Activities. The Soil Dust source contributes the most in the measured concentrations.

Conclusions

A high sampling density was achieved, providing information about the elemental and radionuclides deposition from the atmosphere to terrestrial systems over the region of Northern Greece. The source apportionment results revealed contribution from five sources: Soil Dust, Aged Sea Salt, Vehicular Traffic, Heavy Oil Combustion and Mining Activities, with Soil Dust displaying the highest contribution to the measured metal concentrations among all other sources.

Acknowledgement

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CORONA: CITY OBSERVATORY RESEARCH PLATFORM FOR INNOVATION AND ANALYTICS

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Summary
The City Observatory Research platfOrm for iNnovation and Analytics (CORONA) brings together a team of internationally recognised researchers and stakeholders to deliver early research outputs from the £8m UK Collaboratorium for research on infrastructure and cities (UKCRIC) Urban Observatories (UOs) equipment grant. CORONA is demonstrating how UOs provide new understanding about urban processes, and their interactions across sectors and scales and therefore improve engineering and planning decisions. The research outputs from the first wave of UKCRIC's UOs (Newcastle[1,2], Bristol, Sheffield) are being used to inform processes (governance, standards, entrepreneurship) and the technological instruments (data standards, technology, integrating quantitative and qualitative urban monitoring data) essential to the second wave of UKCRIC UOs and overall UKCRIC research objectives.

Introduction
CORONA has four key work packages: (1) *Technology and urban data architectures* for assimilation of best practice from research activities in the themes of data storage and communication infrastructure, (2) *Observational framework for urban observatories*, a review of best practice in of human and organisational processes to develop a comprehensive manual to support cities developing UO platforms, (3) *Experimentation within the city,* to develop guidance for urban baselines, temporal and special scales, experimental design, reproducibility and provenance, and (4) *Place-based societal city case studies* such as evaluation of recommended interventions and mitigations e.g. Air quality (AQ) monitoring and source appointment for Newcastle to develop high resolution source apportionment for AQ in cities across multiple scales using integrated UO data.

Methodology
To model Newcastle's air quality we utilised UKCRIC and other investments in air quality monitoring systems in Newcastle (see Fig.1). Measurements across the city are compared with ADMS model outputs. Non-local contributions to local AQ can be estimated by reviewing minimum measurements across the city when local emissions are at their lowest. A Newcastle City Centre flux tower provides physical and chemical properties of atmosphere-related processes such as humidity, wind and reactive nitrogen to investigate the vertical profiles of pollution in the city (see Fig.2). Topas optical particle analysis units have been installed across cross sections of traffic, industrial, coastal, residential, shipping and busy urban food takeaway areas to investigate the chemical characterisation of particulate matter (PM) in these zones. AQ variations have been assessed by time of day, day of week, season, wind direction, weather conditions, cultural events, changes in traffic management. AQ sensors at schools are promoting a change from the culture of driving children to school and replacing this with walking and cycling.

Results & Conclusions
An overview of learnings from the CORONA project in Newcastle, including the practicalities, will be presented including daily, weekly, and seasonal differences in Newcastle AQ, ground-truthing of ADMS model outputs and UK National atmospheric emissions inventory data, effectiveness road closures for AQ improvements, e.g. for Newcastle Pride events, the Great North Run, Ride Newcastle and the Great Exhibition of the North. We will also present effectiveness of schools AQ monitoring for changing the driving school run culture, non-local pollution contributions to local AQ, a comparison of chemical characteristics of PM in different urban zones and initial findings from the flux tower data.

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References
[1]urbanobservatory.ac.uk/corona, [2]newcastle.urbanobservatory.ac.uk

Locations:	• 180
Type:	• 4 x precision AQ monitoring kit, • 180 low cost AQ sensors
Pollutants:	• NO_2, NO, NO_x, O_3 • PM10, PM2.5, PM_1, PM_4, total particle counts • CO, SO_2, VOCs, volatile and non- volatile PM10 & PM2.5
Weather:	• 4 precision stations + radar • wind speed & direction, temperature and humidity
Traffic:	• UO 6 + 100 NCC cameras – machine learning to ID vehicle type • UTMC data such as journey times and counts (using ANPR)

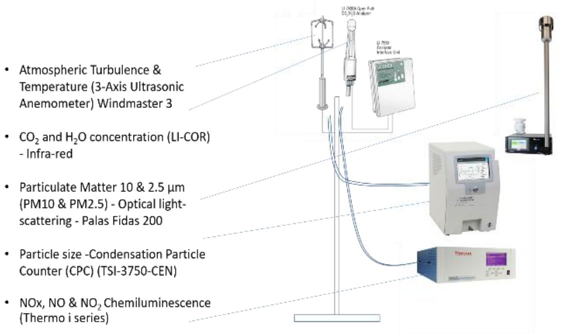

Fig.1 Urban Observatory Air Pollution Monitoring *Fig.2 Flux Tower Equipment*

NEIGHBORHOOD SCALE AIR QUALITY SIMULATIONS WITH STREET NETWORK MODEL AND CFD

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Summary
In this study we present a comparison of air quality simulations performed at neighbourhood scale with two different level of modelling together with observations. The first is a street network subgrid scale model that is applied inside a Chemistry Transport Model (CTM). The second is a Computational Fluid Dynamics (CFD) model adapted for obstacle resolving micro-meteorological simulations

Introduction
Air pollution can be very localized (hot spots) and these details are not seen by standard regional models. Several approaches have been developed in the literature to address this issue. Here we present a nested models approach to zoom on the air quality at local scale remaining in connection with the regional scale simulations. These neighbourhood scale air quality simulations are important in highly polluted zones near main roads and industries.

Methodology and Results
To address these issues the CEREA has developed a Street in Grid (SinG) approach that is coupled with its regional scale air quality model (Polyphemus)(Kim et al. 2018). If further refinements in space and time are required we have also developed a nested CFD approach where both the meteorology and air quality are simulated at neighbourhood scale (Gao et al. 2018, Thouron et al. 2019).
After presenting in more details the two tools mentioned, we present detailed validation results and present applications to several French cities: a neighbourhood in Toulouse and two neighbourhood in Paris.

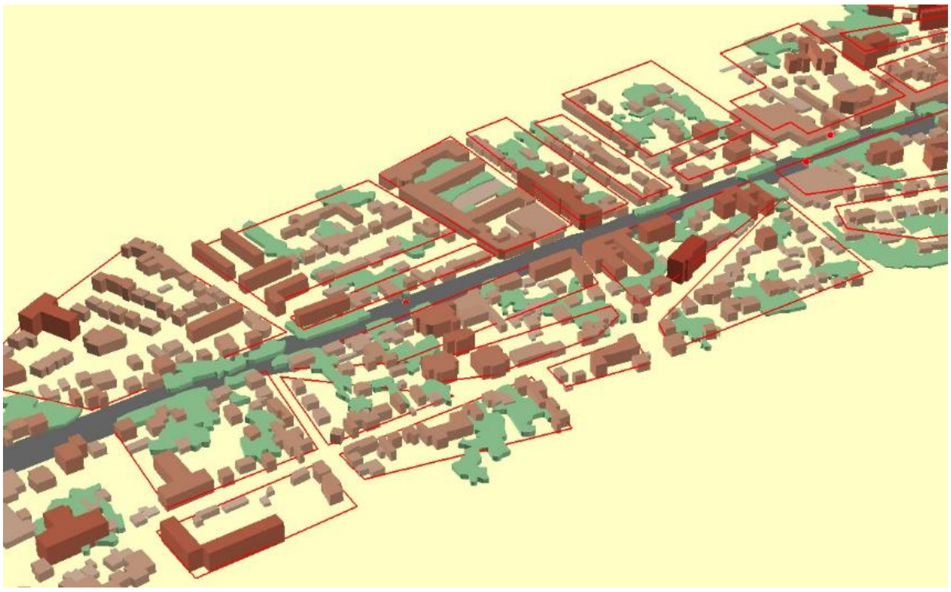

Fig. 9 : An example of a city neighbourhood (East of Paris) with detailed building and vegetation area together with simplified canyon geometry (red polygones)

Conclusions
For the neighborhhod scale simulation of air quality hot spots, the comparison with experimental field campaign have shown that the two approaches can simulate the average increase of concentrations observed in street with traffic. However a more detailed localization of pollution hot spots (dependant on the meteorological conditions) can only be obtained with a CFD.

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MOSS BIOMONITORING OF AIR POLLUTION IN GEORGIA, CAUCASUS

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Summary

The purpose of this study is to check the possibility of moss biomonitoring of air pollution in the Transcaucasus, in Georgia. The most commonly used moss species for biomonitoring (*Pleurozium schreberi, Hypnum cupressiforme* and *Hylocomium splendens*) were selected for the study. A total of 120 moss samples growing in different landscapes were collected during the summer time of 2014-2017. Using neutron activation analysis and atomic absorption spectrometry, the concentrations of 41 elements were determined. Multivariate statistics was applied to find associations of chemical elements and to characterize the sources of elements detected in the samples.

Introduction

Nowadays air pollution is a serious worldwide problem caused by anthropogenic activities and is closely related to the environmental situation, economics, and human health. Air pollution monitoring is continuously performed only in several cities in Georgia (Tbilisi, Kutaisi, Chiatura, and Batumi) and the maximal permissible concentration of element-pollutants in air are often exceeded. The advantage of the moss biomonitoring technique is that it is inexpensive and can be easily used for investigations of large territories with diverse habitat, that increases the confidence and precision in assessment of pollution.

Methodology and Results

To assess atmospheric deposition of heavy metals in Georgia, the moss biomonitoring method was used in combination with epithermal neutron activation analysis (ENAA) and atomic absorption spectrometry (AAS). For the study 3 moss species *Pleurozium schreberi, Hypnum cupressiforme* and *Hylocomium splendens* were used. In total, during 2014–2017, 120 moss samples were collected. The sampling altitudes range from 161 m to 2763 m. Sampling was carried out in accordance with the recommendations of the UNECE ICP Vegetation (Frontasyeva & Harmens, 2020). Using ENAA and AAS, the concentrations of 41 elements were determined (Na, Mg, Al, Cl, K, Ca, Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Se, Br, Sr, Zr, Cd, Mo, Pb, Sb, I, Cs, Ba, La, Ce, Nd, Sm, Eu, Tb, Yb, Hf, Ta, W, Au, Th, and U). The Principal Component Analysis helped to identify the main emission sources, such as crust, industrial, and marine components. To visualize the main sources of air pollution, maps were created using GIS technologies. A comparison of median values of elements with the corresponding data from the other Europe countries showed that the concentrations of heavy metals in most of moss samples collected in Georgia are much higher than in Europe. The mining industry has the most significant environmental impact, namely, the manganese deposit in Chiatura, the abandoned arsenic deposits in Tsan and Uravi, the gold deposits in Kazreti and the coal deposits in Tkibuli.

Conclusion

The moss biomonitoring combined with the statistical methods of data analysis and depicting the areas affected by element-pollutants are important tools for the evaluation of air quality.

Acknowledgement

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CASE STUDIES ON USING EARTH OBSERVATIONS ADDRESSING DUST IMPACTS IN DIFFERENT KEY ENVIRONMENTAL CHALLENGES ALONG THE SUSTAINABLE DEVELOPMENT GOALS

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Summary

Earth Observation (EO) data provides the capability to integrate data from multiple sources and helps to produce more relevant, frequent, and accurate information about complex processes. EO, empowered by methodologies from Artificial Intelligence (AI), supports various aspects of the UN's Sustainable Development Goals (SDGs). This work presents author's major studies using EO to investigate the dust impacts to the SDGs and fill in knowledge gaps and develop methodologies and cloud-based applications in selected SDGs, including SDG 7 (Affordable and Clean Energy), SDG 11 (Sustainable Cities and Communities), SDG 13 (Climate Action) and SDG 14 (Life below Water).

Introduction

On the historical 70th anniversary of the United Nations (UN) in September 2015, the heads of state and delegates gathered and adopted the 2030 Agenda for Sustainable Development in three dimensions — economic, social, and environmental— in a balanced and integrated manner, which represents a milestone in our progress towards international development cooperation. Meanwhile, according to World Health Organization (WHO), cities of the Middle East and North Africa (MENA) fared among the worst in terms of air quality (WHO, 2016) and active dust actives. As an important aspect of technological innovation today, the Earth Observation (EO) plays an important role to mitigate the shortage of in-situ data availability by providing reliable, updated and cost-effective data as solutions in a global or regional scales. It is suggested that EO should be widely used in the dust and air quality investigations to assist SDGs goals in the MENA region.

Methodology and Results

This work reports our collective investigations of aforementioned four SDG goals related to the dust and its impacts in the hotspot Middle East and North Africa (MENA) region, using synergistic approaches of earth observations (EO) and modelling. We show EO capacities to quantify the solar energy losses from extreme dust conditions in sun-privileged locations such as Egypt. We also urge immediate mitigation actions to be taken in Egypt and the Greater Delta regions, for its severe situation of air pollution and dust storms. The dust storm is proved to be closely connected with vegetation and underground water losses. Its impacts, along with food shortage and seawater inundation, threatening human livings of both urban and rural residents in the MENA region. Our studies also focus on the air quality situation in MENA particularly in Egypt. Utilizing EO datasets, the annual geographical and population weighted PM 2.5 level in Egypt are analysed in 18 years. In addition, multiple machine learning models are developed to predict the PM10 and AOD (El-Nadry et al. 2019) (see Fig. 1) levels in the MEAN region. We also demonstrate the applications of cloud computing and big data analysis to the climate studies in the MENA region including the Red Sea and the Gulf, such as the use machine learning models in classification and change detection of marine habitats (e.g. mangrove, coral reefs and salt marshes), time series analysis of chlorophyll-a and its possible relationship with the dust deposition, as well as transfer learning approaches for precision agriculture to mitigate the impacts from the dust storms.

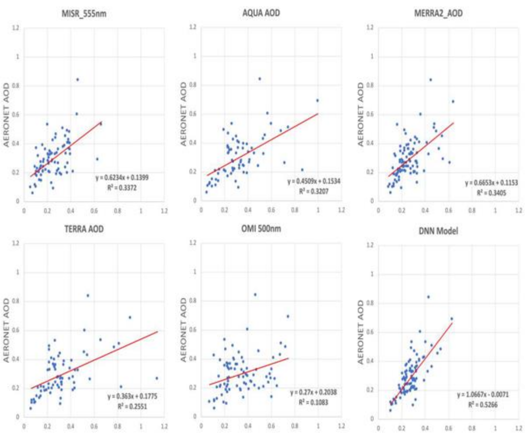

Fig.1 Hatfield Tunnel and its sketch map

Conclusions

These results emphasize the promising usage of EO data analysis to study the dust and its impacts, in order to achieve SDGs. We also suggest the considerable effort should be made to address data gaps to ensure that adequate data are available to inform decision-making on all aspects of the 2030 Agenda.

Acknowledgement

This research was partly funded by the COST Action "InDust" under grant agreement CA16202, supported by COST (European Cooperation in Science and Technology) and more specifically the Short Term Scientific Mission project "Finding".

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QUANTIFICATION OF EXPOSURE TO BLACK CARBON AND NO_X INSIDE VEHICLES WHEN DRIVING THROUGH A ROAD TUNNEL

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Summary

Simultaneous measurements of NO_x, black carbon (BC) and CO_2 inside cars and in ambient air outside the windows of the vehicles showed the importance of air ventilation and penetration efficiency for drivers' exposure when travelling through road tunnels. Cabin air exchange could be quantified using the rate of decline in concentrations after exiting the tunnel. Penetration efficiencies for the ten cars varied between 12% and 53% for BC and 48% and 72% for NO_x. Immediately after exiting the tunnel concentrations inside vehicles were higher than outside vehicles. The share of the total tunnel induced BC exposure that occurred after leaving the tunnel was between 21% and 44% for the ten cars.

Methods

NO_x, BC and CO_2 was measured inside and outside vehicle cabins when driving through a 3.85 km road tunnel in Stockholm. NO_x was measured using Model 405 nm NO_2/NO/NO_x Monitor™ (2B Technologies, 2100 Central Ave., Suite 105, Boulder, Colorado 80301, USA), BC using (Aethalometer, microAeth® Model AE51, AethLabs San Francisco, California, USA) and CO_2 (SENSEAIR K33 LP T/RH, Senseair AB, Delsbo, Sweden). All instruments were battery operated. Measurements were performed in ten different cars; 4 from 2018, 4 from 2019 and 2 from 2017. Cabin ventilation was set on automatic with air condition turned on and temperature at 20°C. The decline in concentrations during the first minute after exiting the tunnel was used to estimate the rate of exchange of cabin air.

Results

Concentrations of both NO_x and BC were lower inside cabins compared to outside when travelling in the tunnel, but as the concentrations outside the cabin dropped drastically when exiting the tunnel, concentrations inside were higher than outside during some minutes right after exiting the tunnel (Figure 1). The share of the total tunnel induced BC exposure that occurred after leaving the tunnel was between 21% and 44%. On average for the 10 cars studied the cabin air was exchanged approximately 3 times inside the tunnel. Penetration efficiencies estimated based on inside outside concentration ratios, varied between 12% and 53% for BC and 48% and 72% for NO_x (Figure 2).

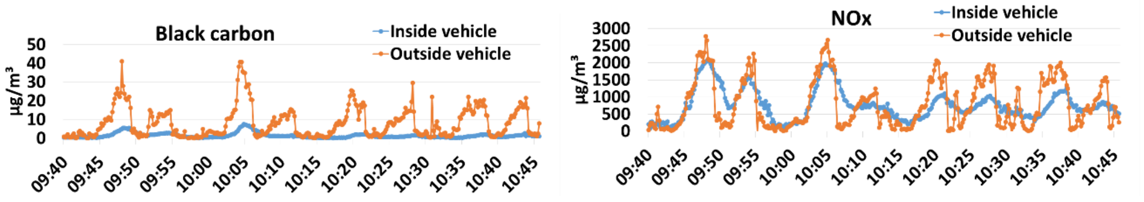

Figure 1. Example of variation in BC and NO_x inside and outside of a vehicle (BMW525) when driving 8 times back and forth of a road tunnel in Stockholm.

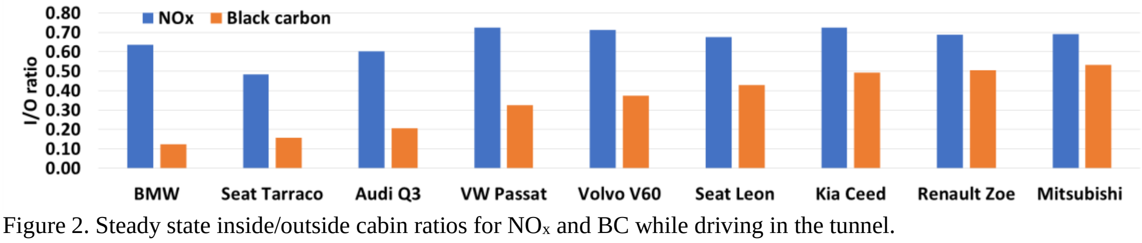

Figure 2. Steady state inside/outside cabin ratios for NO_x and BC while driving in the tunnel.

Discussion

Several factors affect drivers' exposure in vehicles, e g concentrations in ambient air, vehicle ventilation, pollutants' penetration efficiency, vehicle age, size, model and speed. Simultaneous measurements inside and outside ten cars showed large variability in cabin concentrations depending on car model and ambient concentrations. Inside/outside concentrations of BC were lower than NO_x due to the uptake in air ventilation filters. In-vehicle exposure due to the penetration of tunnel air does not immediately cease when exiting the tunnel; the importance of the exposure outside the tunnel for the total tunnel induced exposure varied between 21% and 44% for BC.

Acknowledgement

This study was financed by the Swedish Transport Administration.

MOSS BIOMONITORING IN RUSSIA: PAST, PRESENT AND FUTURE

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Summary
A brief historical review is given on the development and milestones of the moss biomonitoring technique used to study atmospheric deposition of trace elements, nitrogen, persistent organic pollutants (POPs) and radionuclides of technogenic and natural origin in Europe. The relevance of these studies to the UN Convention on Long-range Transboundary Air Pollution (LRTAP) is emphasised. Examples of the long-term activity of the UNECE ICP Vegetation (International Cooperative Programme on Effects of Air Pollution on Natural Vegetation and Crops) established in 1987 (https://icpvegetation.ceh.ac.uk/) are given to illustrate the tendencies in behaviour on a large scale of air pollutants such as heavy metals, nitrogen and persistent organic pollutants. A review on application of the moss biomonitoring technique in Russia over a large period of time starting from the late 60-es of the XX century until present is given. Nowadays Russia is a participant of the UNECE ICP Vegetation and contributes to this programme. The perspectives of applying moss techniques in the coming moss survey 2020/2021 in Russia are described.

Introduction
The use of mosses as biomonitors of atmosphertic deposition of heavy metals and radionuclides in Russia started more than 40 years ago in connection with the development and problems of the nuclear and military-industrial complexes in Siberia and the Urals. In the 1990s, within the framework of UNECE ICP Vegetation programme, systematic studies using moss were carried on in north-western Russia (Karelia, Kola Peninsula, Kaliningrad, Pskov and Leningrad regions), and the results were presented in the European Atlas Atmospheric Heavy Metal Deposition in Europe – Estimations Based on Moss Analysis. In 1998–2002, JINR participated in the IAEA-coordinated research project “Biomonitoring of air pollution in the Chelyabinsk region (South Ural Mountains, Russia) through trace elements” in one of the most contaminated areas of the world experiencing strong ecological stress from heavy metals and radionuclides.

Methodology and Results
A combination of instrumental ENAA at the IBR-2 reactor at JINR, Dubna [2], and AAS provides data on concentrations of about 40 chemical elements (Al, As, Au, Ba, Br, Ca, Cd, Ce, Cl, Co, Cr, Cs, Cu, Dy, Eu, Fe, Hf, Hg, I, In, La, Lu, Mg, Mn, Na, Nd, Ni, Pb, Rb, Sb, S, Sc, Se, Sm, Ta, Tb, Ti, Th, V, W, Yb, Zn), which substantially exceeds the number of elements requested by the European Atlas (given in bold). Distribution of the determined elements over the sampled areas is illustrated by the contour maps produced by the Russian software package GIS-INTEGRO with raster and vector graphics. Starting from 1995, JINR takes part in the European moss surveys reporting data on some areas of Central Russia (Moscow, Tula, Yaroslavl, Ivanovo, Kostroma, Leningrad and Tver regions), as well as on the Republic of Udmurtia, Yekaterinburg (the Urals), Crimea and Yamal peninsulas). It was shown that moss as natural planchette can be used for tracing deposition of cosmic dust in peat bog cores in Western Siberia and some mountainous areas of Russia. There was an attempt to apply moss technique for assessing the sequences of the Fukushima disaster in the Far East of Russia by means of a low background gamma spectrometry of moss samples collected in Kamchatka. Besides passive (terrestrial) moss biomonitoring, the active moss biomonitoring (moss-bag technique) was used to study air pollution in street canyons of the intensely growing megalopolis of Moscow.

Conclusions
In agreement with the long-term strategy of the LRTAP Convention to enhance participation and improve air quality in Eastern Europe, the Caucasus, Central Asia, and South Eastern Europe, efforts to extend the moss survey to former republics of the USSR such as Armenia, Azerbaijan, Georgia, Moldova, Kazakhstan, and Uzbekistan were successfully undertaken. Around 15 teams were formed in Russia to cover moss sampling in Northern and Central Russia, Western Siberia, Caucasus, and the Far East of Russia (Kamchatka and Sakhalin) in the coming moss survey 2020/2021.

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INFLUENCE OF HIGH GRID RESOLUTION IN AEROSOL USING A GLOBAL NON-HYDROSTATIC ATMOSPHERIC MODEL

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Summary
We exploit a high-performance computer such as K computer at RIKEN in Japan to perform a global non-hydrostatic atmospheric model with aerosol components using horizontal grid spacing high enough to resolve the cloud-system. We simulate aerosols using a global model, NICAM, with 14-km grid spacing. To evaluate the influence of grid resolution, we also perform the NICAM with 56-km grid spacing. As a result, the simulated aerosol optical thickness (AOT) in both resolutions are generally comparable to the observed ones in the major industrial regions, desert, and biomass burning areas, but the differences are found in specific components such as black carbon and sulfate by up to 32% in the annual averages. The subgrid variabilities of the simulated aerosol and cloud optical thickness are investigated by comparing 1°×1° global domain and are estimated to be 28.5% and 80.0%, respectively, in 14-km grid, whereas the corresponding differences are 16.6% and 22.9% in 56-km grid. Although the differences in the global annual aerosol averages between NICAM with 14-km and 56-km grid spacings are small, those become large in the regional or subgrid scales. It clearly indicates the high-resolution simulation is important to properly simulate aerosols.

Introduction
The atmospheric aerosols affect not only the air quality but also climate change due to interactions of aerosols, cloud, precipitation and radiation. Especially, the relationship between aerosols and clouds is still uncertain. The uncertainty may be caused by the grid resolution, which are generally coarse to resolve cloud and cloud-system using global climate models. To more accurately represent aerosol and clouds, we need to simulate aerosols with high resolutions, which allows us to explicitly resolve the cloud-system without conventional parameterizations of clouds.

Methodology
We execute a Non-hydrostatic Icosahedral Atmospheric Model (NICAM; e.g., Satoh et al., 2014), which is one of the cloud-system resolving models with aerosol components (e.g., Suzuki et al., 2008). The global distributions of the NICAM-simulated aerosols, i.e., mass concentrations and optical thickness, with global 14-km grid spacing for 3 years integrations are compared to satellites such as MODIS and in-situ measurements such as AERONET. To evaluate the influence of the model grid spacing, we also conduct numerical experiments using NICAM with 56-km grid spacing. In this study, 14-km and 56-km simulations are called high-resolution model (HRM) and low-resolution model (LRM).

Results
The simulated aerosol optical thickness (AOT) in both HRM and LRM are generally comparable to the observed ones in the major industrial regions, desert, and biomass burning areas. The difference in the aerosol components, especially water-insoluble black carbon (WIBC) and sulfate, between HRM and LRM are large by up to 32% even in the annual averages. This is attributed to the differences in the column burden of the wet deposition of WIBC over the outflow areas and in the sulfate formation associated to clouds. In a global scale, subgrid variabilities of the simulated aerosol and cloud optical thickness in the 1°×1° domain using 6-hourly data are estimated to be 28.5% and 80.0%, respectively, in HRM, whereas the corresponding differences are 16.6% and 22.9% in LRM.

Conclusions
Although the differences in the global annual aerosol averages between NICAM with 14-km and 56-km grid spacings are small, those become large in the regional or subgrid scales. Our results clearly indicate the high-resolution simulation is important to properly simulate aerosols.

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AIR POLLUTION DISPERSION MODELLING IN INTERGRATED RADIOLOGICAL EMERGENCY SYSTEM FOR POPULATION PROTECTION IN CASE OF A NUCLEAR POWER PLANT ACCIDENT

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Summary

Nuclear power plant accidents in Chernobly and Fukushima made an important impact on development of radiological emergency systems for population protection. One of the most important component is the air pollution dispersion modelling because the radiological polution reaches the population first trough the atmosphere. A significant improvement in the air pollution modelling for radiological emergency systems that occurred in recent years is presented in this abstract.

Introduction

Radiological emergency systems for population protection must be reliable, robust and resistant to different disturbances. To achieve this they must be operating automatically, online and in real time all the time before the emergency events occur. The results of this systems must present the current state of radioactive pollution in the atmosphere and forecast the dispersion in recent (3-hours) and far (up to 7 days) future. This presentations for the decision makers resposible during the emergency events must be made in graphical forms where all the information is presented in simple, intuitive and condensed form.

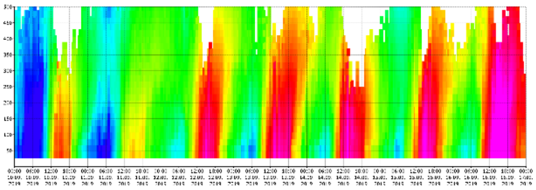

Fig.1 RASS measurements of air temperature profile (one week example)

Methodology and Results

Methodology for design and construction of such an emergency system is described in detail in paper by Mlakar et al. (2019a). The quality of system depends on the measured and forecasted meteorological inputs (Grašič et al., 2019). To acieved best quality also air pollution dispersion model must be carefully selected according to complexity of the domain and then also validated on the appropriate field data set (Mlakar et al., 2014). In the paper by Mlakar et al. (2019) and this abstract an implementation is presented on the example of the Measuring and Modelling System at the Krško Nuclear Power Plant in Slovenia.

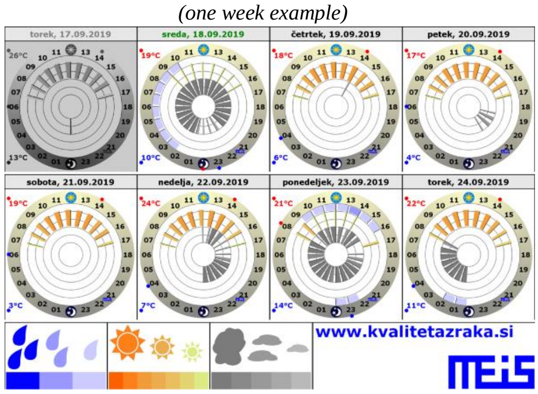

Fig.2 Example of 7-day weather forecast using sunflower diagrams (Božnar et al., 2015)

Conclusions

Presented methodology and implementation at NPP Krško is the result of years of development and effective planning and adaptation to new technologies and increased technological capabilities.

Acknowledgement

The authors acknowledge that the projects ("Method for the forecasting of local radiological pollution of atmosphere using Gaussian process models", ID L7-8268, and "STRAP - Sources, TRAnsport and fate of persistent air Pollutants in the environment of Slovenia", ID J1-1716) were financially supported by the Slovenian Research Agency. We are grateful to the Krško NPP for the continuous funding of system development and maintenance.

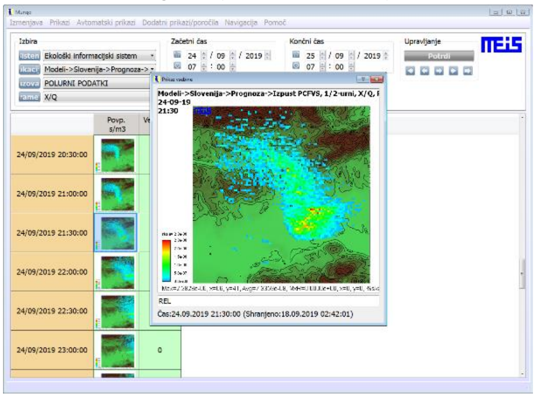

Fig.3 Modelling results of relative concentrations (Mlakar et al., 2019b) of radionuclides released into atmosphere

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DIFFERENCE IN AMBIENT-PERSONAL EXPOSURE TO $PM_{2.5}$ IN LOCAL RESIDENTS IN URBAN AND RURAL BEIJING, CHINA: RESULTS OF THE AIRLESS PROJECT

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Summary:

Taking advantage of a validated personal sensor, this study examined the difference in personal and ambient exposure to $PM_{2.5}$ in 251 non-smoking participants and quantify the difference in diverse pollution settings.

Introduction:

A key limitation in epidemiological studies lies in the accuracy of exposure assessment, where most studies are based on ambient data from monitoring stations, satellites or modelling, which is assumed to be different from the actual personal exposure and may bias the previous findings in health responses. However, the evidence is scarce to understand the uncertainties of the difference between personal and ambient exposure. Hence, based on a validated personal sensor and the measurements from stationary monitors, we aim to quantify and compare the personal and ambient exposure to fine particulate matter ($PM_{2.5}$) among residents from urban and rural Beijing across two seasons, winter and summer.

Methods and Results:

In total, 123 urban and 128 rural non-smoking participants aged 50-75 years were recruited from two well-established cohorts in Beijing to allow a panel-study (AIRLESS*). During Nov-Dec 2016 and May-Jun 2017, each participant was instructed to carry a validated personal air monitor (PAM)[1] to measure $PM_{2.5}$ concentration at high spatiotemporal resolution for consecutive seven days in each campaign. Personal dataset was then matched with ambient $PM_{2.5}$ measured at the same time using reference instruments in the urban and rural fixed sites within 10 km to residential communities.

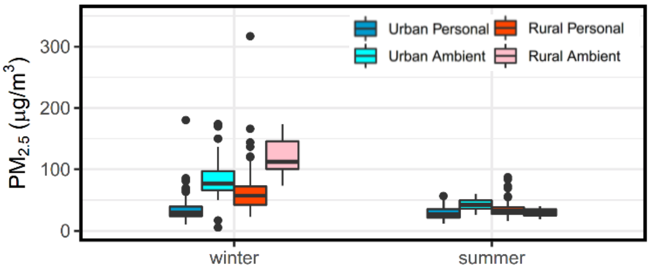

Figure 1: Comparison of weekly personal and ambient exposure to $PM_{2.5}$ among urban and rural residents in Beijing

On average, in winter, the weekly concentration of personal exposure to $PM_{2.5}$ among rural residents was 63.2±34.6 µg/m³ (mean±sd), which was significantly lower than the ambient exposure of 119.6±23.0 µg/m³. A similar trend was also observed for urban residents with personal and ambient exposure as 33.8±19.6 µg/m³ and 84.3.6±30.0 µg/m³ respectively. In summer, both personal and ambient exposure decreased, and the exposure difference became smaller. However, although personal exposure was still lower compared to ambient exposure for urban residents, the trend was opposite for rural residents. Larger variation and more extreme cases were observed in personal than ambient exposure in both seasons.

From the diurnal pattern of exposure in rural residents, we observed that the higher personal exposure in summer was attributed to both lowered ambient concentration and pronounced peaks of personal exposure at morning (8:00-10:00) and evening hours (18:00-22:00), indicating potential local sources, such as cooking. On the other hand, in urban residents, extreme exposure scenarios appeared along the main road, indicating a potential high exposure from traffic sources. Classification of time-activity mode is ongoing to understand the cause of the difference in personal-ambient exposure.

Conclusions:

This study showed a clear difference between personal and ambient exposure to $PM_{2.5}$ in various pollution settings. The difference might be attributed to diverse air pollution sources, socio-economic and personal activity patterns.

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SOURCE APPORTIONMENT OF $PM_{2.5}$ AND PM_{10} FRACTION AT THE PUNTIJARKA STATION

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Summary
In this study, concentrations of inorganic ions and PAHs in $PM_{2.5}$ and PM_{10} fractions at the Puntijarka station are presented, and main sources of pollution and their contributions to the concentration of PM in ambient air are estimated. In order to get a deeper insight into atmospheric data and assess the contribution of pollution sources, positive matrix factorization and backward trajectories analysis were applied.

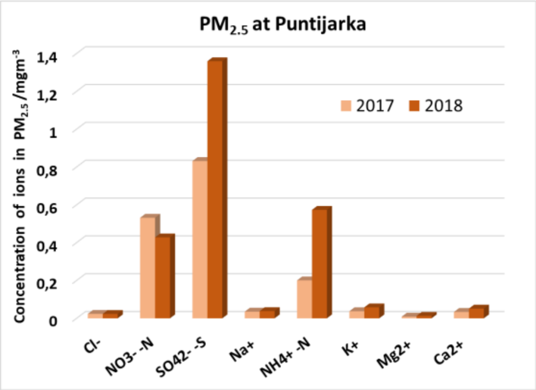

Fig.1 Annual average concentration of inorganic ions in $PM_{2.5}$ fraction.

Background
The monitoring and analysis of the chemical composition of precipitation and air in combination with source-receptor modelling enables the understanding and linking of emission sources with pollutants pathways and the discernment of local and regional impacts on air quality. Thus, source apportionment studies also help assess the relative importance of natural and anthropogenic sources affecting the air quality of a region.

Methodology
The Puntijarka station (988 m a.s.l.) is a background station on the mountain Medvednica situated north from the Croatian capital Zagreb and representative for monitoring of long-range transboundary transport of atmospheric pollution and tracking the effectiveness of implementation of international emissions reduction agreements as well for the evaluation of the local impact of the city to the mountain ecosystem. The 24-h records of polycyclic aromatic hydrocarbons (PAHs) concentrations in the particulate phase PM_{10} and inorganic ions in $PM_{2.5}$ for 2017 and 2018 at the Puntjarka station were analysed. PM samples were collected on teflon filters with LV samplers and all analysed in accordance with standard procedures. Ion-exchange chromatography (IC) and gas chromatography coupled to a mass spectrometer (GC-MS) were used to identify the inorganic ions and PAH composition of $PM_{2.5}$ and PM_{10}, respectively. For the source apportionment EPA PMF 5.0 software was used, while the backward trajectories were calculated using HYSPLIT Trajectory Model.

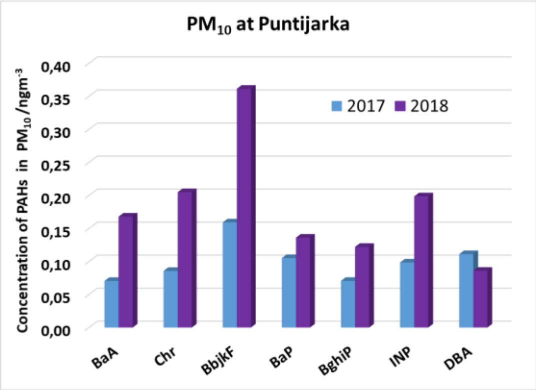

Fig.2 Annual average concentration of PAHs in PM_{10} fraction.

Results and Conclusions
The mass concentrations of polycyclic aromatic hydrocarbons in the PM_{10} fraction are higher in winter indicating local source of these pollutants. The annual average (0.11 ng/m^3 in 2017 and 0.14 ng/m^3 in 2018) for benzo(a)pyrene is much lower than the annual target value for the protection of human health (1 ng/m^3). The $PM_{2.5}$ composition is mainly dominated by the acidic components SO_4^{2-} and NO_3^-.
Results of PMF show that major health related chemical species of PM_{10}, in winter period, originate from domestic combustion while in the hot period from traffic exhaust. For the $PM_{2.5}$ fraction the prevalent sources are natural degradation and combustion evidencing combined effects of natural sources and anthropogenic activities.

Acknowledgement
This work was supported through the state budget allocated to Croatian Meteorological and Hydrological Service.

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ASSIMILATING SENSOR DATA IN A NEAR-REAL-TIME MAPPING APPLICATION

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Summary
The Dencity study demonstrated the potential of using information from an air quality sensor network to improve the quality of a modelled near real time urban air quality map. In addition the methodology provides relevant information about specific updates of the underlying traffic emission inventory. The model-sensor combination fits within a smart city context and opens a wide range of new City of Things applications.

Introduction
A fundamental ingredient for building a smart city is having access to accurate, relevant and real-time data. The Dencity project (2017-2019) which was setup as a City of Things demonstrator, aimed to identify the potential as well as current shortcomings and obstacles of such a smart city air quality application relying both on sensor network data as well as a near real time high resolution modelling application.

Methodology and Results
Within the smart zone of the city of Antwerp, Belgium an air quality sensor network was deployed and generated a continuous stream of near real time air quality data. In parallel a near real time application of the ATMO-Street model (Lefebvre et al, 2013) was setup to provide high resolution air quality maps at an hourly basis (Fig 1). The modelled maps take into account near real meteorology as well as data from the fixed monitoring network of the Flemish Environment agency. However, at every road link no real time traffic information is currently available. As an alternative, use is made of modelled annual averaged traffic volumes which are modulated by seasonal, weekly and daily time profiles. In this way local and accidental traffic events are not picked up by the modelling chain and as such not reflected in the air quality maps.
Within the Dencity project, it was demonstrated how sensor network data collected within the smart zone has the potential to mitigate this problem via a data assimilation methodology. Sensor network data and the modelled map are fused by an ensemble Kalman filter.

Fig.1 Hourly ATMO-Street output for the city of Antwerp.

In this data assimilation procedure the traffic emissions are taken as input variables with a given uncertainty. Subsequently this input is translated by the model into a concentration field respecting model characteristics such as street canyon effects and inter-street dependency (Fig 2). By applying this methodology, is was demonstrated than an updated are quality map can be produced taking into account local sensor data, in the same time providing updated information about the underlying emission strengths.

Fig.2 Changes in the updated AMTO-Street map due to assimilation of the sensor data. Demonstration case with 3 sensors.

Conclusions
The near real time ATMO-Street application developed within the Dencity project illustrated the potential of a combined use of a model applications and sensor network data to provided more accurate air quality maps and in the same time provide updated information about the underlying emission inventories. This demonstrator opens a wide range of new applications in the context of smart city programs which are being developed in many places worldwide.

Acknowledgement
This work was supported by the Dencity project funded by VLAIO, Flanders Innovation & Entrepreneurship.

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COMPARISON OF MEASURED RESIDENTIAL BLACK CARBON LEVELS OUTDOORS AND INDOORS WITH FIXED-SITE MONITORING DATA AND WITH DISPERSION MODELLING

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Summary

Epidemiologic studies on health effects of air pollution usually rely on ambient monitoring data or modelled residential levels. Little is known how well these data estimate residential outdoor and indoor levels. This study investigated the agreement of measured residential black carbon (BC) levels outdoors and indoors with levels calculated using modelled by dispersion modelling, and with fixed-site monitoring data.

Residential outdoor and indoor real-time BC measurements were conducted for 15 families living in central Stockholm over 1 week time. Urban background monitoring station predicted half of the outdoor BC day-to-day variation at residential addresses. Long-term dispersion modelling explained half of the spatial differences in residential outdoor BC levels. Outdoor BC levels were comparable with indoor levels.

Methods

Residential outdoor and indoor real-time BC measurements were conducted in for 15 families living in central Stockholm at addresses predicted to be more exposed to traffic-related air pollution (N=7) or less exposed (N=8). The measurements were performed over one week. The, which average concentrations were also standardized adjusted by using urban background monitoring levels to reflect an annual average. Dispersion modelling was applied to estimate long-term outdoor residential BC levels. In addition, BC concentrations were retrieved from urban background and street-level routine monitors. Pearson correlation test, and linear regression were applied to study the relationship between measured and modeled BC concentrations at homes and at the fixed-site stations.

Results

Outdoor BC levels were on average 533 ng/m3 (range 404-797 ng/m3) at highly exposed addresses, and 400 ng/m3 (261-526) at the less exposed. The corresponding average fixed-site urban background and street levels were 317 and 998 ng/m3, respectively. Urban background BC levels explained 50.5% of the variation in residential outdoor measured home levels averaged over 24-hours. Modeled annual outdoor BC levels at the home addresses were on average 98% of the standardized adjusted measured home outdoor levels, and explained 49% of the spatial variability. Indoor BC levels were on average 90% (SD=0.63 for 1-hour observations) of those measured outdoors.

Discussion & Conclusions

Common exposure estimation approaches in the epidemiology of health effects related to BC displayed high validity for residencies in central Stockholm. Urban background monitored levels explained half of the outdoor BC day-to-day variability at residential addresses. Long-term dispersion modelling explained half of the spatial differences in outdoor BC levels. Indoor BC concentrations were similar to outdoor levels. BC exposure levels modelled with dispersion modelling can be used as surrogates of population exposures in long-term studies based on spatial differences.

Acknowledgement

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CAN POST-PROCESSING TECHNIQUES OF HIGH RESOLUTION URBAN PARTICULATE MATTER FORECASTS ACCOUNT FOR INACCURATE EMISSIONS AND/OR PROCESSES?

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Summary

Fine atmospheric particulate matter (PM) is currently the most important air quality problem in both Greece and Europe. It is estimated that high concentrations of fine PM lead to a few thousand excess deaths in Greece every year and two to three hundred thousand deaths in Europe. Despite its importance especially in urban areas, its spatial and temporal distribution is not well understood. Particulate matter forecasts from state-of-the-art air quality models only achieve moderate skill scores.
This study aims to quantify the extent of PM forecast improvement in an urban area and its surroundings on the basis of a state-of-the-art high-resolution chemical weather forecasting system, historical observations and a post-processing algorithm.

Introduction

Uncertainties in air quality model (AQ) simulations (Vautard et al., 2012; Kukkonen et al., 2012) basically arise from three main classes of processes: (1) chemistry and aerosol physics; (2) fluxes (emissions, deposition, boundary fluxes); and (3) meteorological processes affecting transport and diffusion, chemistry and surface fluxes. Those uncertainties do not affect equally the forecast quality of all prognostic species. Rather, some are predicted with better skill (e.g. ozone) than others (e.g. PM) (Kioutsioukis et al., 2016). Considering this, we quantified the PM forecast improvement from a high-resolution AQ model through a dynamic statistical post-processing algorithm.

Methodology and Results

The Analogue Ensemble (AnEn) technique utilizes a historical dataset of deterministic air quality predictions and observations. The hourly AnEn predictions for different pollutants and measurement sites are based on a subset of past deterministic forecasts which demonstrate similarity to the current forecast. The technique is compared against the raw forecasts of the three-dimensional Eulerian photochemical grid model CAMx (Comprehensive Air Quality Model with Extensions). The CAMx simulations are performed on a 2-km spatial resolution grid that covers the entire Greece. In this study, PM10 and PM2.5 hourly simulations are used for four months i.e., January, April, July and October of the year 2012. Both original and corrected forecasts are evaluated against observations at 4 monitoring stations (2 urban traffic stations, 1 suburban industrial and 1 rural background station). Compared to the original forecasts, the corrected forecasts have smaller Mean-Square-Error and Mean Bias and higher Correlation Coefficient independently on the station type. The improvement is higher in the stations where the AQ model does not perform well. Besides the better overall statistics, the AnEn is not so successful in the range of concentrations that exhibit low representativity in the sample.

Conclusions

Air quality (AQ) modeling has progressed significantly over the past decade. However, many uncertainties still remain and need to be reduced in order to improve the performance of such modeling systems so they would have high societal utility. Besides the progress in the representation of the physical, chemical and dynamical processes in the modelling systems, statistical techniques can provide essential improvement in the forecast skill and therefore, they can be integrated in the operational forecasting flow, once the pitfalls of their applicability are isolated. This was clearly demonstrated for the case of particulate matter, a pollutant with moderate forecast skill.

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INVESTIGATION OF THE DISPERSION OF FINE PARTICULATE MATTER IN THE ATMOSPHERE OF A CAREER FOR INERT MATERIALS

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Summary
Wind erosion breaks down toxic impurities and enables their transport over long distances and polluting air, soils and water over vast areas around mines and in surrounding settlements. The purpose of this study is to investigate and analyse the atmospheric air and the concentrations of fine particulate matter in open pits and quarries, and to analyse different types of pollutants. The studies will take into account the pit geometry and the type of the underlying substrate defined by the mined minerals. Specific weather parameters, such as wind pattern defining the direction of transfer, and the temperature profiles defining the temperature inversions retaining pollution over the region, will be considered as well. The expected results are to track the overall process of emission, transmission and sedimentation of aerosol impurities and fine particulate matter concentration in the mine area and in nearby settlements.

Intruduction

The concentration of fine particulates in the atmosphere is a complex function of many variables, such as the intensity of the sources, the distance to them, the atmospheric conditions, the topography of the area, etc. The main meteorological parameters affecting the dispersion are the direction and velocity of the wind and the temperature stratification of the atmosphere. The paper presents and discusses the results of an experimental study of the dispersion of fine particulate matter in the quarry area of inert materials around the village of Balsha.

Methodology and Results

To determine the dispersion and concentration of aerosol impurities in space and time, four laser particle counters were located around the main source of dust in the area - road transport and working excavators and pneumatic hammers. A mobile meteorological station was used to determine the main meteorological parameters. Experimental studies have shown that the concentration of fine particulate matter rapidly decreases with distance from the source under these weather conditions (relatively light wind and intense thermal turbulence). At distances of several hundred meters, the concentration of aerosol impurities in the quarry atmosphere decreases to background levels. On the basis of the experimental data, a Gaussian model for the dispersion of impurities was tested with the real initial and boundary conditions of the experiment. When the initial parameters are well adjusted, the model shows relatively good results. Laser particle counters were used during the experimental campaign – one six-channel HHPC-6 (MetOne) with particle size channels at 0.3 μm, 0.5 μm, 0.7 μm, 1 μm, 2 μm, 5 μm and three two-channel BQ20 (TROTEC) with particle size channels at 2.5 μm and 10 μm for particle number and mass concentration measurements. The meteorological data were obtained from the multi-functional weather station with four sensors (temperature, precipitation, relative humidity, air pressure, wind direction and speed).

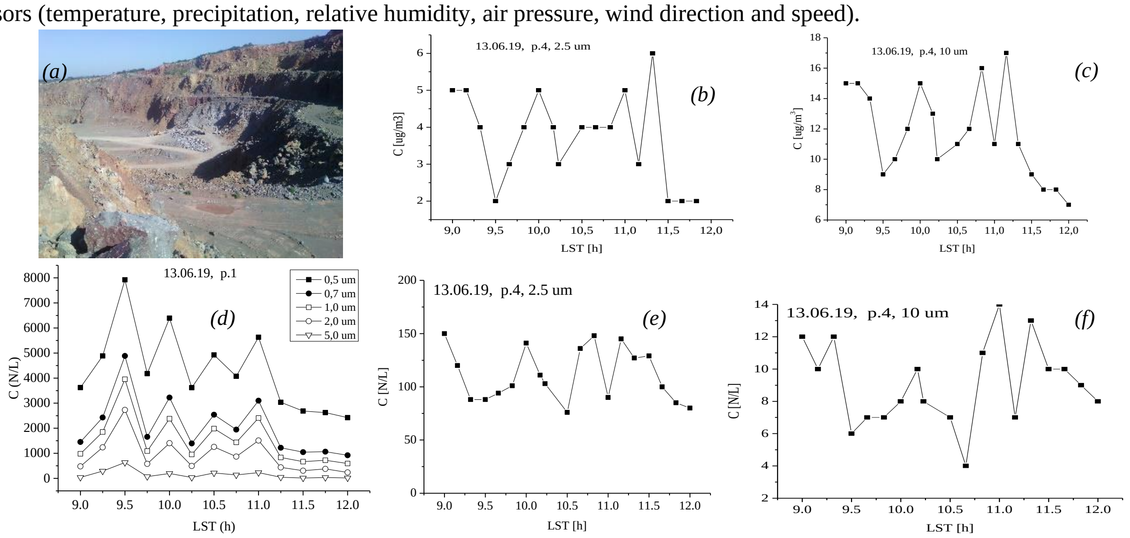

Fig. 1. The open quarry for extraction of ballast materials at Mining Company (a), mass concentration of 2.5 and 10 μm fine particulate matter at points 4 on the *13.06.2019(b, c), and* numerical concentration of 2.5 and 10 μm FPM at point 1, 4 on the *13.09.2018(d, e, f).*

Conclusions

The measurements of fine particulate matter in air in the Balsha quarry lead to the following conclusions: Horizontal and height re-distribution of impurities is caused by the specific orography of the region. A clear vertical stratification of aerosol impurities is present and, therefore, dispersion is affected more by the vertical positioning of FPM sources within the quarry than the horizontal movement of machines. Given the particular weather (a clear summer day with a relatively light wind), the concentration of aerosol impurities several hundred meters from the source was not above the admissible air pollution limit values, which, according to the EU directive apply to average daily concentration of particulate matter with a radius of up to 10 μm – 50 μg/m^3 and 2.5 μm – 40 μg/m^3.

Acknowledgement
This work has been carried out in the framework of the National Science Program "Environmental Protection and Reduction of Risks of Adverse Events and Natural Disasters", approved by the Resolution of the Council of Ministers № 577/17.08.2018 and supported by the (MES) of Bulgaria (Agreement № D01-230/06.12.2018).

AIR POLLUTION FROM CRUISE SHIPS IN COPENHAGEN PORT IN DENMARK

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Summary
Activity data on cruise ships in the Copenhagen Port and Port of Aarhus, Denmark and an emission inventory were established as input for air quality calculations of the contribution of the cruise ships to the concentrations in the vicinity of the quays at different heights. The limit value for the 19th highest hourly value of NO_2 was significantly exceeded in the examined heights of 25 m, 50 m and 70 m.

Introduction
The purpose of the study was is to assess the number of cruise ships and their emissions in Copenhagen Port and Port of Aarhus, and how this affects air quality. Air quality calculations are carried out in the nearby urban areas in Copenhagen and Aarhus and on a more detailed scale in the vicinity of the quays to assess air quality at the nearby dwellings. The presentation will focus on the results for Copenhagen. The study attracted a lot of media attention and subsequent debate on abatement with focus on shore power.

Methodology and Results
Detailed information on cruise ships calling into port in 2017, berthing slots and quay locations were obtained from the administrations of Copenhagen Port and Port of Aarhus. The location of the quays have been digitized based on maps provided by the ports.

By internet lookups (marinetraffic.com, cruiseline's homepage, ship yards etc.) using the ship's name or IMO code (International Maritime Organization), it is possible to determine a number of parameters for the ship such as construction year, engine type, total installed engine power, scrubber installation, etc. These data makes it possible to determine the fuel consumption and emission factors for the precise calculation of the emissions. Similarly, a number of physical parameters has been determined such as height of ship hull above the water line, chimney height above the water line, volume flow and exhaust gas temperature.

Air quality calculations have been carried out with the OML-model for 2017 based on the emission inventory and the physical parameters. In addition to emissions, meteorological data and background concentrations are also included in the OML-calculations. Firstly, air quality calculations are performed for a larger grid for each city on a spatial resolution of 200 m x 200 m in order to assess how cruise ships affect air quality in the urban area around the ports. Secondly, air quality calculations are carried out on a smaller grid with a finer spatial resolution to assess the air quality in the vicinity of the quays. The spatial resolution is 100 m x 100 m for Copenhagen Port and 50 m x 50 m for Port of Aarhus. Calculations are carried out for the annual mean of NO_2 (nitrogen dioxide) and of $PM_{2.5}$ (mass of particles less than 2.5 micrometers), as well as for the 19th highest hourly value of NO_2 to represent peak values. Limit values exist for all these indicators. The geographic variation in concentrations is shown with isoline on aerial photos.

A meteorological year with more frequent easterly wind was identified to assess the impact to air quality. More frequent wind directions from East will transport air pollution from the cruise ships towards the urban areas in both Copenhagen and Aarhus due to their location. The selected meteorological year is 2002.

The concentration contribution of the cruise ships has moreover been calculated at different heights for the small grids in the ports to assess the exposure of high-rise buildings. Calculations have been performed for 25 m, 50 m and 70 m.

Conclusions
A comparison of the emissions from an average cruise ship with the emissions from an average passenger car in city traffic shows, that emissions from a cruise ship is equivalent to emissions from about 3,500 cars for NO_x and around 5,000 cars for $PM_{2,5}$ exhaust calculated per time unit (g/s).

The limit value was not exceeded for calculations of the 19th highest hourly value for NO_2 at ground level. However, the limit value is reached at a height of 25 m and significantly exceeded at heights of 50 m and 70 m. The maximum values exceed the limit value of 200 $\mu g/m^3$ several times. Hence, the cruise ships contribute significantly to exceedances of the limit value of the 19th highest hourly value for NO_2 above 25 m in Copenhagen Port in the vicinity of the quays.

Acknowledgement
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INFLUENCE OF ELEVATED INVERSIONS ON AIR POLLUTION LEVELS IN MOSCOW

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Summary
Morning elevated inversions clearly influence on the air pollution dynamics so at the moment of their destruction NO_2 begins to fall whereas a growth of O_3 is accelerated. Unlike them, an influence of subsidence inversions didn't be detected.

Introduction
Influence of elevated inversions on the surface concentrations of minor air gases is studied in details. As one knows elevated inversions strongly influence on the dynamics of the air pollution in big cities as barriers which prevent the vertical turbulent exchange. They were detected by the data of 'ECHO-1' (GDR production) sodar which operates at the Meteorological observatory of MSU since 1988. Vertical range of these data is from 25 to 800 m; vertical resolution is fine (12.5 m) that allows detecting of even thin inversion layers. Measurements of the air composition were carried out at the same location at joint Ecological station of the Obukhov IAP and Lomonosov MSU from 2002 to 2014. Surface concentrations of ozone were measured by use of Dasibi 1008-RS and 1008-AN gas analyzers with an accuracy ±1 ppb; nitrogen oxides were measured by TE42C-TL gas analyzer with the same accuracy. Temporal resolution of these measurements was equal to 1 min. All instruments at the station were of the same types as those used in the GAW WMO network and were regularly calibrated.

Results and conclusions
Two types of elevated inversions were investigated separately: morning (inertial) inversions which are remains of former nocturnal surface ones, and long-living subsidence inversions. Morning inversions are observed as a rule in warm and transitional seasons (from April to October) whereas subsidence inversions exist usually in cold season (from November to February). The dynamics of minor air gases was analyzed before and after a moment of final disappearing of morning inversion. Its disappearing is observed on the sodar record from 07 to 12 a.m. at different days but all data series were normalized to this moment as to 'zero' moment. As a result it was found that just at this moment NO_2 begins quickly fall whereas a growth of O_3 (which is started under the inversion yet) suddenly accelerated. An average rate of O_3 change before inversion destruction was equal to $+0.2 \cdot 10^{-3}$ mg/(m$^3 \cdot$ min) whereas during the first hour after this moment it became $+0.5 \cdot 10^{-3}$ mg/(m$^3 \cdot$ min). Similar result was received before (Lokoshchenko et al., 2004). A probable reason is dynamic factor: strengthening of downward transport of O_3 to the ground from upper air layers after disappearing of inversion.

Unlike morning inversions, clear influence of subsidence inversions on the air pollution levels didn't be detected. A sampling of 40 long-living inversions which existed continuously 20 hours or longer (record long inversion existed 119 hours) during the Ecological station operation from 2002 to 2014 was analyzed. A time of each case (from 20 to 119 h) was divided into six equal parts from the appearance of subsidence inversion to its vanishing on the 'ECHO-1' sodar record. As a result of analysis, statistically significant tendencies neither to gradual accumulation of NO_2, nor, vice versa, to gradual decrease of O_3 was detected (Fig.1). Additional account of wind speed V in the air layer from 40 to 200 m by the data of Doppler 'MODOS' sodar (METEK, Germany) which also operates at the University partially explains the dynamics of air pollutants: a growth of V before inversion destruction leads to expected decrease of NO_2.

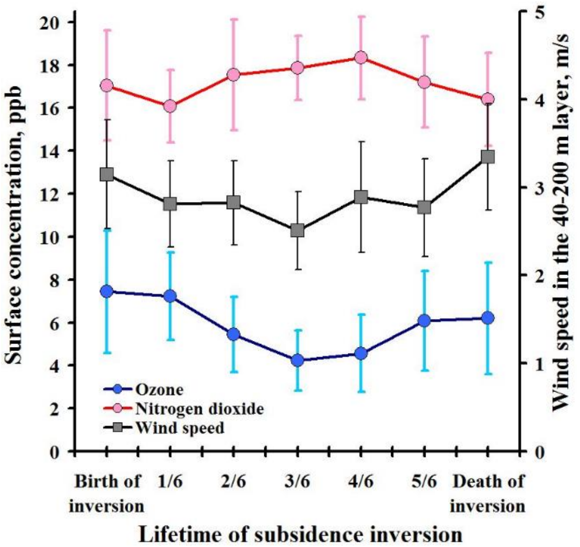

Fig.1. Air pollution dynamic during symbolic time of subsidence inversion existence. Moscow, 2002–2014. Confidence intervals are calculated with the 0.95 confidence probability.

Thus, an existence of subsidence inversion, taken by itself without account of other factors, does not leads to clear changes of the air pollution levels. Possible explanations of this result are: subsidence inversion base often is too high which reduces its influence on the air pollution in the ground air layer; irregular function of pollution sources; influence of additional factors such as wind speed, solution of some minor gases at precipitation, etc.

Acknowledgement
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AIR POLLUTION IN RUSSIAN AND INDIAN CITIES

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Summary
The dynamics of main air pollutants (ozone, nitrogen oxides, sulfur dioxide and others) is studied for conditions of Moscow and Bangalore. Their annual and diurnal courses as well as long-term changes at both places are discussed and compared.

Introduction
The regular air pollution measurements are carried out during last several decades in the most of big cities all over the World. Accumulated long-term data allows comparing of conditions of the air quality with the account of climate specific and a difference of pollution sources (intensity of traffic, urban industry, predominant type of used fuel, etc.) at different places. Networks of stations measuring surface concentrations of the main minor air gases (ozone, nitrogen oxides, carbon oxide, sulfur dioxide and so on) exist and operate both in Russian (e.g., Moscow) and in Indian cities (Delhi, Bangalore). The detailed analysis of the air pollution in these cities will be presented in their comparison with each other. Firstly, the annual course of all main pollutants will be discussed. Secondly, the daily course will be analyzed as well. Besides, long-term dynamics will be studied which indicates total tendencies in time.

Results and conclusions
In Moscow city the long-term data of joint Ecological station which was founded by common efforts of Obukhov IAP and Lomonosov MSU and operated during 12 years from 2002 to 2014 are used for the analysis. According them, the annual course of ozone is noted by wide maximum in spring and summer (from March to August) as a result of, firstly, more intensive photochemical formation of O_3 at this time and, besides, of ozone influx to the land surface from the middle and upper troposphere. Unlike ozone, nitrogen oxide, nitrogen dioxide and carbon oxide do not have statistically significant changes in their annual cycles, except for only a slight decrease in the content of NO in the early warm season (May–June). Regarding long-term changes, gradual increase of the surface O_3 (on the order of 1% during each year) was detected. Vice versa, the content of carbon oxide slowly decreases, while the content of nitrogen dioxide remains almost unchanged in Moscow (Elansky et al., 2015). Sulfur dioxide levels in Moscow are extremely low (about 1 ppb) and sometimes grow only in conditions of strong frosts in winter when the city heating system operated using reserve fuel (black oil) with a high content of sulfur (Lokoshchenko et al., 2008).

Ambient air quality and air pollution status of major Indian cities including Delhi (northern India) and Bangalore (Southern India) are covered by a national programme called ambient air quality (AAQ) monitoring network. As per the monitoring protocol daily six measurements are made for gaseous components (nitrogen oxides, carbon oxide, sulfur dioxide, ozone etc.) and three readings for particulate matter (SPM2.5 and SPM10). Using this data, the preliminary analysis is being carried out over Delhi and Bangalore at daily, monthly and annual time scale. Location specific Air quality indices are computed and the pollution status are categorized as good, bad and poor and presented. The comparison of pollution dynamics in Indian and Russian cities are evaluated.

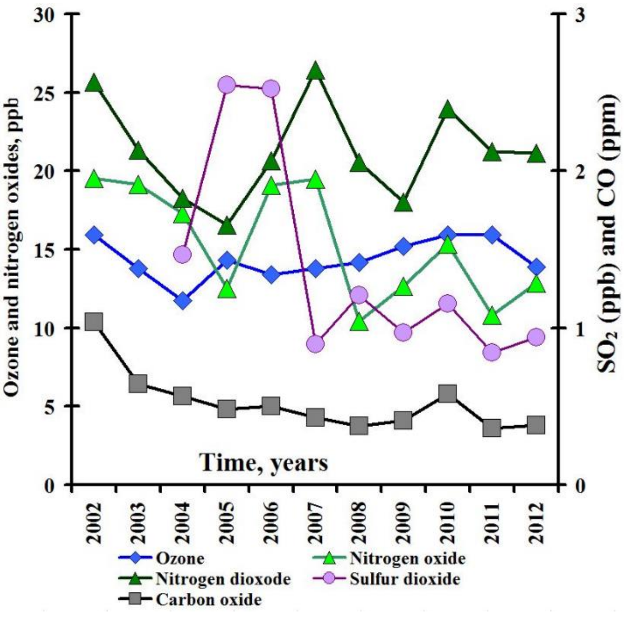

Fig.1. Annual means of the surface concentrations of minor air gases over Moscow for 2002–2012.

Acknowledgement
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IS SUBSIDISED STOVE EXCHANGE AN EFFECTIVE EMISSION REDUCTION POLICY? – THE CASE OF OSLO

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Summary
We evaluate the potential effect of a subsidy programme for stove exchange, which has been in place for over 20 years in Oslo (Norway). The subsidy programme provides economic support to the inhabitants for substituting old stoves for residential wood combustion (RWC) for new and cleaner ones as a measure to reduce PM emissions. First, we evaluated the potential reduction in emissions and pollution levels by emission and dispersion modelling. Then we assess the reductions associated with the stoves already replaced with the subsidy and the time variation in emissions, wood consumption and emission factors from 2005 to 2018. The trends were evaluated in municipalities with and without subsidy. The results from emission and dispersion modelling show that a replacement of wood stoves for new ones would have a significant effect on the reduction of emission (up to 46%) and $PM_{2.5}$ levels (up to 21%). However, emission and wood consumption trends (2005-2018) show a low reduction, and no discernible differences in municipalities with and without subsidy programmes.

Introduction
RWC is an extensive heating source in Nordic countries, and a concern for local $PM_{2.5}$ in winter. Emissions from residential heating in the Nordic area are dominated by RWC, which is responsible for >50% of the $PM_{2.5}$ levels. Consequently, different types of regulatory instruments are being implemented to reduce emissions. Oslo Municipality has had a subsidy programme to promote the replacement of old stoves produced before 1998 for new ones, and increase in that way the share of clean burning appliances. The subsidy programme was implemented in 1998 and since then, Oslo residents have been able to apply for economic support to replace old stoves. The aim of our study is to assess the impact that the existing subsidy programme has had on $PM_{2.5}$ emissions and the further potential for reducing pollution levels in Oslo.

Methodology and Results
We selected three different approaches. First, we perform emission and dispersion modelling to assess three scenarios of introduction of new stoves technologies. Emissions are estimated with the MetVed model (Grythe et al., 2019) and $PM_{2.5}$ levels are estimated with the EPISODE model (Hamer et al., 2019). The scenarios were designed to consider a complete substitution of stoves and the continuous introduction of new improved stove technology over time. Secondly, we estimate the emission reduction associated with the stoves already replaced with subsidy support. Then, we evaluate emissions, wood consumption and emission factors trends from 2005 to 2018 in Norwegian municipalities with and without subsidy.

$PM_{2.5}$ emissions and concentration levels were modelled to be reduced by an average 18-46% and 3-9%, respectively, depending on the assumed emission factor of the new stoves in each scenario. The largest concentration reduction, 8 and 21% depending on the scenario, were modelled in the areas with the highest $PM_{2.5}$ concentrations. The number of stoves replaced with the subsidy was estimated to be around 8% of all the stoves in Oslo. Emission reductions obtained from the exchanged stoves show increased effect in reducing emissions over time and reach a reduction in 2018 of 3-6% regarding emissions in 2005. The comparison between municipalities with and without subsidies shows no discernible differences. Oslo shows a somewhat stronger reduction in emission factors compared with national values. However, it also shows the lowest reduction in RWC emissions and wood consumption at 1.7% and 1% per year, respectively. Available observations of $PM_{2.5}$ concentrations in Oslo indicate a declining trend 3-5% per year between 2010 and 2018. During winter and the heating season, concentration reductions in urban background are similar to those at traffic stations, and the reductions appear similar to the reductions obtained during the remainder of the year (i.e., non-heating season). This indicates that the reductions are mainly caused by the other main emitting source, i.e., traffic, which have emissions throughout the year.

Conclusions
We have assessed both the potential of emissions reduction and to what extend the subsidy programme to exchange wood stoves, implemented over 20 years ago, has succeeded in reducing emissions of $PM_{2.5}$ from RWC in Oslo. Based on the results from our study it is not possible to see that the subsidy programme has had any significant effect in reducing $PM_{2.5}$ concentrations in Oslo. We furthermore see no evidence that municipalities with subsidies reduce emissions faster than other municipalities. Therefore, additional measures targeted at reducing pollution from RWC activity are needed.

Acknowledgement
This study was financed by the Climate Agency in Oslo Municipality.

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AIR QUALITY AND ELEMENT DEPOSITION IN URBAN AREAS: ASSESSMENT BY LICHEN BIOMONITORING - A CASE STUDY FROM MILAN (ITALY)

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Summary
Air quality monitoring in many urban areas is based on sophisticated and costly equipment to check for the respect of environmental quality standards, but capillary monitoring is often not feasible due to economic constraints. In such cases, the use of living organisms may be very useful to complement the sparse data obtained by physico-chemical measurements. In this study, the bioaccumulation of selected trace elements (Al, As, Cd, Cr, Cu, Fe, Pb, Sb, Zn) in lichen samples (*Evernia prunastri*) transplanted for three months in Milan (Italy) was investigated to assess the main environmental contaminants, their sources, and the fluxes of element depositions. The results pinpointed Cr, Cu, Fe and Sb as the main contaminants and suggested a common origin for these elements from non-exhaust sources of vehicular traffic, such as brake abrasion. Ranges of estimated mean annual element deposition rates in the study area were fairly high.

Introduction
More than 80% of the EU population lives in urban areas, and as a consequence urban air pollution affects the quality of life of most citizens. Notwithstanding some improvement to complement the sparse data obtained by physico-chemical measurements, essentially induced by the implementation of EU legislation on emissions of air pollutants, key EU air quality standards for the protection of human health, especially the concentration of PM, are currently not being met in more than 80% of urban areas. According to WHO, long-term exposure to PM is linked to cardiovascular and lung diseases, heart attacks and arrhythmias, disorder of the central nervous and the reproductive systems, and can cause cancer. In urban areas, high levels of PM are mainly caused by emissions from road traffic, which thus will require further action for improvement.
Nowadays, many urban areas have an air quality monitoring network to check whether the set environmental standards are met or not, but capillary monitoring is currently not feasible in all cities due to economic constraints related to the establishment and maintenance of sophisticated and costly equipment. It is therefore necessary to use different approaches to achieve a high spatial resolution of atmospheric pollution and to understand dispersion of pollutants within urban areas. In such cases, the use of living organisms may be very useful to complement the sparse data obtained by physico-chemical measurements. The use of lichens for assessing atmospheric levels and deposition patterns of trace elements is well-established, and there is evidence that lichen biomonitoring may also be profitably used in environmental forensics and environmental justice. This study reports the results of a lichen biomonitoring survey of air quality and element deposition fluxes carried out in the city of Milan (Italy).

Methods
Samples of the fruticose lichen species *Evernia prunastri* were collected in a rural area of Tuscany (C Italy), far removed from local sources of air pollution, and exposed at a control site 50 km from Milan and at 50 sites in Milan for three months (December 2018 - February 2019). A stratified random sampling design was selected to represent the 9 administrative city districts and also the central, semi-peripheral and peripheral portions of the city. The bioaccumulation of selected trace elements (Al, As, Cd, Cr, Cu, Fe, Pb, Sb, Zn) was investigated by ICP-MS. The results were expressed in terms of Exposed-to-Control (EC) ratios, and an overall Contamination Index (CI) was calculated. Maps of element deposition were obtained by GIS and interpolation algorithms. Based on a weight/area ratio of the lichen species *E. prunastri* of ~160 g/m^2, a known exposure time of 3 months and assuming that the final concentrations represent an equilibrium with the new environment, it was possible to convert element concentrations in lichens into estimates of average annual element deposition rates.

Results
Significant bioaccumulation emerged only for Cr, Cu, Fe and Sb, which were all strongly intercorrelated, suggesting a common origin. All these elements showed a clear decreasing pattern moving from the city centre to the periphery. Trends were not evident for the 9 administrative districts. The Contamination Index highlighted significant air pollution for all the 50 sites investigated. The 95% confidence interval for the estimated average annual element deposition rates showed values in the range 2.1-2.7, 483-579, 8.6-12.5, 0.42-0.54 $kg/km^2/y$ for Cr, Cu, Fe and Sb, respectively.

Conclusions
The results clearly pinpoint to non-exhaust emissions of vehicular traffic, such as brake abrasion, as the main source of air pollution in Milan, which is a polluted city, subjected to severe element deposition.

MULTIVARIATE ANALYSIS ON PERCEIVED ANNOYANCE CAUSED BY AIR POLLUTION AND THEIR DETERMINANTS

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Summary

This study aims to investigate variables that determine the perceived annoyance caused by air pollution, especially sedimented dust, by applying the multivariate ordinal logistic regression model. This study also intends to compare survey's results on the perceived annoyance before and after an intervention at the industrial activities of a pelletizing plant located in southern region of Espirito Santo, Brazil. The use of multivariate analysis made it possible to draw the probable annoyed individuals' profile and their determinant variables.

Introduction

Perceived annoyance caused by air pollution has been identified as an useful signal for potential health effects and community life quality loss. Previous studies have shown that there is a complex relationship between perceived annoyance and perception of air pollution, health problems, concentration levels of air pollutants, individual and location within the urban sprawl (e.g. Egondi et al. 2013, Machado et al., 2018). Considering this, we proposed a comparative study, to analyse individuals' perceptions, before and after an environmental accident which caused the interruption of industrial activities at a palletizing plan in 2015t. A multivariate analysis was used to identify the determinants factors of perceived annoyance caused by dust.

Methodology and Results

The studied region is an industrialized urban area located in the Southeast coast of Brazil. The main air pollutants sources in the region includes ports and steel, pellet making, quarry, cement, chemical, among others. The surveys were conducted in 2014 (sample size n=280) and 2017(n=534) to investigate, thus analyse and compare respondents' opinions Pearson's chi-square test was applied. Anderson (1984), defined the stereotype logit model with categorical references as:

$$\log\frac{\pi_j}{\pi_c} = \alpha_j + \phi_j\beta'X, \quad j = 1, \dots, c-1. \quad (\alpha_c = \phi_c = 0) \qquad \text{(Eq.1.)}$$

Table 1 shows the comparison between the two surveys. The percentage of not annoyed with air pollution is higher in 2017 (38%), after the main industrial source of pollution was intervened. The percentage of extremely annoyed is higher in 2014 (before the intervention) than 2017. When people were asked about the re-start up the main industry, more than 89% answered to be favourable to the industry activities return. More than 80% affirmed the industry is important to improve the local economy.

Table I. The main questions about perceived annoyance and the p-value

Question	Answers options	2014		2017		p-value
How do you feel annoyed by air pollution	*Not annoyed*	23	(8%)	203	(38%)	<0.05
	Little annoyed	50	(18%)	120	(22%)	
	Moderate	71	(26%)	105	(20%)	
	Very annoyed	98	(36%)	81	(15%)	
	Extremely annoyed	27	(10%)	24	(4%)	
	Not know	2	(1%)	1	(0%)	
At home, how do you feel annoyed by dust from outside?	*Not annoyed*	59	(22%)	30	(6%)	<0.05
	Little annoyed	27	(10%)	74	(14%)	
	Moderate	58	(21%)	91	(17%)	
	Very annoyed	94	(35%)	131	(25%)	
	Extremely annoyed	32	(12%)	21	(4%)	
	Not know	1	(0%)	187	(35%)	

Conclusions

The regression model results confirmed the hypothesis to reduce the perceived annoyance caused by air pollution complains after the interruption of industrial activities. Chi-Square tests showed that in 2017 there was an improvement in air quality assessment, reduced the sedimented dust at homes and reduction in perceived annoyance caused by air pollution.

Acknowledgement

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UNDERSTANDING THE PROCESS OF SETTING AIR QUALITY LIMIT VALUES AND THE ASSOCIATED COMPLIANCE CHALLENGE

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Summary
Related to the on-going EU AAQD fitness check (EC, 2017), this study assesses how the risks associated with air pollutants should be managed, and highlights this as being just as important as quantifying the environmental and human health impacts, when binding air quality limit values (AQLVs) are set. Through a modelling approach, the study examines how annual average PM and NO_2 concentrations would vary under different emission reduction scenarios, and assesses the cost and practicability of achieving compliance with the current EU AQLVs, as well as lower limit values.

Introduction
In 2018, the European Commission (EC) initiated a fitness check to evaluate the relevance, effectiveness, efficiency, coherence, and added value to the EU of the Ambient Air Quality Directive (AAQD) (EC, 2008). The results of the fitness check will be used to assess if the AAQD remains the appropriate legislative instrument to protect the environment and the European population from adverse impacts on human health associated with air pollutants.
One item which the EC will need to determine is if the current AQLVs should be revised. It is the long-term objective for air quality in the EU to achieve no exceedances of the World Health Organisation (WHO) guideline levels for human health.
The WHO guidelines (WHO, 2006) state:
'…it should be emphasised, however, that the guidelines are health-based or based on environmental effects, and are not standards per se. In setting legally binding standards, considerations such as prevailing exposure levels, technical feasibility, source control measures, abatement strategies, and social, economic and cultural conditions should be taken into account.'
As a consequence the fitness check, and the Directive revision process that ensues should follow a two-step process of firstly assessing the environmental and human health risks presented by concentrations of air pollutants (risk assessment step) and secondly, assessing how these risks may be managed (risk management step).
In order to assess the cost and the practicability of achieving compliance with current and lower AQLVs, a modelling study was carried out that examines how annual average air concentrations of PM and NO_2 would vary under some potential emission reductions scenarios.

Methodology and Results
A suite of modelling tools was applied to predict NO_2 and PM concentrations under different emissions scenarios. The cost of certain emission reduction scenarios was calculated using an in-house integrated assessment model (IAM) which takes its values from the IIASA GAINS model (IIASA, 2006). The starting point was the emissions under a current legislation (CLE) scenario as described in (TSAP) Report #16 (IIASA, 2015). Predicted results under the Maximum Technically Feasible Reductions (MTFR) scenario were also evaluated. In addition to the CLE and MTFR scenarios, emissions scenarios that involve measures that are not included as technical measures in GAINS were examined. These include the electrification of different fleet segments, the substitution of domestic solid fuel, as well as removal of agriculture NH_3 emissions.
The results show that under CLE, $PM_{2.5}$ and NO_2 concentrations will be significantly reduced from 2025 onwards. However, full compliance with the existing EU AQLVs will not necessarily be achieved in all EU countries, as country variation is significant for both pollutants. In Poland for example, approximately 25% of $PM_{2.5}$ stations would remain non-compliant in 2030 under CLE, while in France around 3% of NO_2 stations are still above the limits.
Alternative non-technical emission reduction scenarios, such as the substitution of solid fuels in the domestic sector with gas or liquid alternatives, reduce $PM_{2.5}$ concentrations significantly and improve compliance (less than 10% of $PM_{2.5}$ stations remain non-compliant in Poland in 2030). On the contrary, the electrification of road transport is not expected to have a significant effect on PM levels, regardless of the vehicle categories or proportion of the vehicles substituted.
The electrification of the road transport sector is predicted to have the most significant impact in reducing NO_2 concentrations. However, even forcing the electrification of all vehicles, some EU monitoring stations will still fail to achieve compliance by 2030 (e.g., France) indicating that other sources need to be addressed.

Conclusions
The process of assessing how emissions of pollutants can be controlled, at what cost, and how successful these are in reducing air concentrations of pollutants has shown to be an important factor to consider when you assess compliance with binding AQLVs. Reductions beyond the already legislated emission reduction measures will require a substantial economic investment for only a small impact on the subsequent compliance improvement, while ambitious non-technical measures are not in themselves predicted to be effective for achieving full compliance with the current EU AQLVs.

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IMPACT OF EMISSION INVENTORY UNCERTAINTIES ON OZONE CONTRIBUTIONS OF LAND TRANSPORT EMISSIONS

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Summary
This study aims to quantify the impact of the uncertainties of land transport emission inventories onto the quantification of ozone contributions. For this we performed simulations with the global-regional model system MECO(n), including a source apportionment method. In these simulations we varied the land transport emissions systematically between 25 % and 175 % and analysed the impact of these changes on ozone and the ozone contributions. Our results suggest a strong impact of the uncertainties of the land transport emission inventories onto the simulated ozone contributions. The ozone mixing ratios themselves, however, are only slightly influenced. This implies that the analysis of contributions rather than solely the ozone mixing ratio is essential for the evaluation of mitigation options based on emission reductions.

Introduction
Land transport emissions are one of the most important sources of nitrogen oxides (NO_x) and thus influence air quality and contribute to the formation of tropospheric ozone. An increase of tropospheric ozone further contributes to global warming. The contribution of land transport emissions onto NO_x and ozone cannot be directly measured. Instead models, equipped with complex source apportionment methods, are needed to estimate these contributions. This contribution analysis, however, is complicated by the large uncertainties of the emission inventories. As the formation of ozone is strongly non-linear, the response of ozone and the ozone contributions on perturbations of the emissions within these uncertainties is not necessarily linear. This study aims to improve our understanding of the influence of the uncertainty of the land transport emission inventories onto the estimated ozone contributions by performing simulations with systematically varied emissions.

Fig.1: Set-Up of the MECO(3)

Methodology and Results
We applied the MECO(n) model system with a source apportionment method for ozone. The model system combines the global chemistry-climate model EMAC together with regional chemistry-climate model COSMO-CLM/MESSy (Kerkweg & Jöckel, 2012, Mertens et al., 2016). For the current study we apply a MECO(3) set-up with three refinements over Europe with resolutions of 50 km, 12 km and 7 km (Fig. 1). The source apportionment is applied in all model instances with 12 distinct emission categories, including specific categories for European land transport and other European emissions. To account for the uncertainties of the land transport emission inventories we performed seven simulations in which we scaled the European NO_x emissions from land transport systematically between 25 % and 175 %. For our analysis we focus on July 2010. Our results show that the relative contribution of the unscaled European land transport emissions on ozone is between 6 % and 20 %. The lowest values are simulated over the British Islands, while the largest values are simulated in the Western part of the Po Valley (Fig. 2). These values, however, are strongly altered when the emissions are varied. Averaged over the Po Valley the ozone contribution of land transport emissions ranges between 9 % and 23 % in the different simulations. Compared to the ozone contributions, ozone itself is only slightly altered. This is caused by a change of the ozone production efficiency of other emission sectors, if the land transport emissions are varied. As an example, the contribution of other anthropogenic emissions ranges between 14 % and 20 % in the different simulation results, although the corresponding primary emissions themselves are not changed between the simulations.

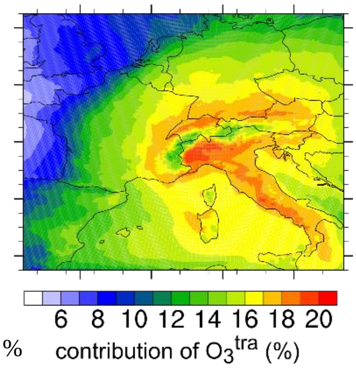

Fig.2 Relative contribution of European land transport emissions to ground level ozone.

Conclusions
Uncertainties of land transport emission inventories strongly influence the diagnosed ozone contributions, while in most European regions ozone itself is only slightly altered. This has important implications for the assessment of mitigation options. The success of mitigation options should not only be measured by the change of the ozone mixing ratios, but should consider the change of the ozone contributions of all relevant emission sectors, to understand changes of the ozone production efficiency.

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HIGH-RESOLUTION MAPPING OF URBAN AIR QUALITY WITH HETEROGENEOUS OBSERVATIONS: A NEW METHODOLOGY

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Summary

In this study, we present a practical approach to producing high spatiotemporal resolution maps of urban air pollution , which is capable of assimilating air quality data from heterogeneous data streams. The methodology, called Retina, has been applied and evaluated for nitrogen dioxide (NO_2) in Amsterdam, the Netherlands, and Barcelona and Madrid, Spain. Based on open data, the approach can easily be applied to other pollutants such as particulate matter. Retina enhances the understanding of reference measurements, and acts as a framework to integrate additional low-cost measurements and satellite observations (e.g. from Sentinel 5P/TROPOMI) in order to get better localized air quality information.

Introduction

In many cities the population is exposed to elevated levels of air pollution. Often local air quality is not well known due to the sparseness of official monitoring networks, or unrealistic assumptions being made in urban air quality models. Low-cost sensor technology, which has become available in recent years, has the potential to provide complementary information (see Fig. 1). Unfortunately, an integrated inter-pretation of urban air pollution based on different sources is not straight-forward because of the localized nature of air pollution concentrations, and the large uncertainties associated with measurements of low-cost sensors.

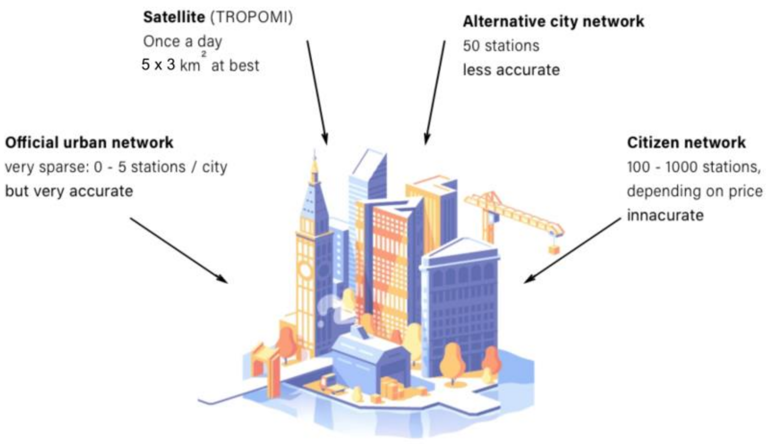

Fig. 1: New trends in air quality monitoring ask for smart systems to make optimal use of the heterogeneous data sources.

Methodology and Results

Retina uses a two-stage approach. It runs an Gaussian dispersion model (AERMOD) to account for hourly variability in urban emissions and meteorological conditions. The model is periodically re-calibrated with recent historic measurements. In the second stage it assimilates near-real time measurements using a statistical interpolation scheme. Its main system design considerations are:

- Observation driven
- Able to assimilate observations of different accuracy
- Potential near-real time and forecasting application
- Versatile / portable to other domains
- Based on open data
- Reasonable computer power

The assimilation of reference measurements results in hourly maps with a typical accuracy of 35% within 2 km of an observation location, and 50% at larger distances. When low-cost measurements are included, e.g. from the Urban AirQ campaign (Mijling et al., 2018), the maps reveal more detailed concentration patterns in areas which are under-sampled by the official network. Current work focusses on the incorporation of tropospheric NO_2 column satellite retrievals from Sentinel 5P/TROPOMI.

Conclusions

Retina enhances the understanding of hourly reference measurements by statistical interpolation to street-level resolution. It also acts as a framework to integrate additional low-cost measurements and satellite observations, which facilitates application in cities which lack a strong official monitoring network.

Acknowledgement

This work was supported by KNMI-DataLab and the EU H2020 project AirQast.

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TRENDS IN AIR QUALITY, SANTA CRUZ DE TENERIFE (CANARY ISLANDS)

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Summary
Concentrations of nitrogen dioxide (NO_2) have been assessed for a medium sized city (Santa Cruz de Tenerife, Spain) for a six-year period (2012-2017). The air quality of the city is affected by both local anthropogenic emissions and longer-range natural emissions such as Saharan dust outbreaks. There is only a small overall decline in NO_2 concentrations at the urban background site and a small increase in averaged NO_2 concentrations is observed at the remaining urban sites. This is in contrast to observed declines in NO_2 concentrations in many other Spanish and European cities. The ongoing measurement and assessment of NO_2 and other ambient air concentrations constitutes a necessary tool to monitor the expected benefit of policies to reduce on-road traffic emissions and to identify improvements in ambient air quality.

Introduction
Santa Cruz de Tenerife is the capital of Tenerife (Canary Islands) and has 204,000 inhabitants, it has a complex mixture of anthropogenic sources (on-road and maritime traffic and an oil refinery) and being close to the African continent (~300 km) it experiences frequent desert dust outbreaks. In recent years there have been various policies introduced at both a national and European level to reduce on-road traffic emissions. However, there have been other factors affecting emissions, for example Spain experienced a marked dieselisation of the on-road vehicle fleet in the last decades, its percentage share of diesel cars in its total passenger car fleet rose from 27% in 2000 to 57% in 2015. Consequently, a study was undertaken to assess the trends in NO_2 concentrations in Santa Cruz de Tenerife for the years 2012-2017 and to evaluate the response of air quality in this city to real-life emission changes.

Methodology and Results
Concentrations of nitrogen dioxide (NO_2) were assessed for various measurement stations of the Air Quality Network of Santa Cruz de Tenerife. The EU air quality standards set a limit concentration value of 40 $\mu g\ m^{-3}$ for NO_2 concentrations for a one-year averaging period (EC, 2008). The World Health Organisation Air Quality Guidelines for NO_2 concentration coincide with the EU air quality standards. NO_2 monthly mean concentrations for the period 2012-2017 for five of the measurement stations in Santa Cruz de Tenerife are shown in Fig. 1. NO_2 annual mean concentrations averaged for five urban sites are shown in Fig. 2 alongside annual mean concentrations at the urban background site (Parque de la Granja). There is only a small overall decline in NO_2 annual mean concentrations at the urban background site and an overall small increase in NO_2 averaged annual mean concentrations is observed for the remaining five urban sites. This is in contrast to observed declines in NO_2 concentrations in many other Spanish and European cities (e.g. Grange et al, 2017). There has been a progressive increase in traffic intensity in Santa Cruz de Tenerife since 2013. This increase in traffic intensity, along with the potential contribution of excess diesel-related NO_x emissions could help to explain the increase or slow decline in NO_2 annual mean values observed here.

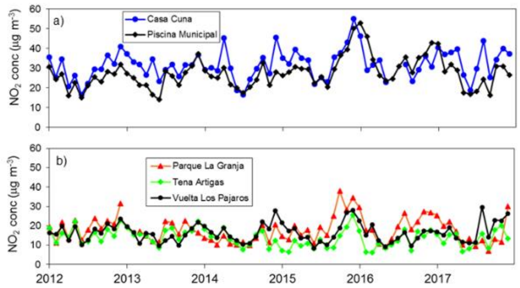

Fig.1 NO_2 monthly mean concentrations, 2012-2017.

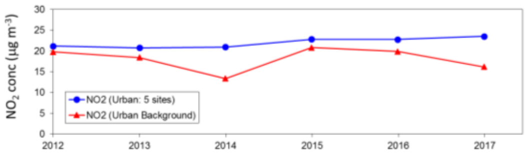

Fig.2 NO_2 annual mean concentrations, 2012-2017.

Conclusions
There is only a small decline in NO_2 concentrations at the urban background site and a small increase in averaged NO_2 concentrations is observed for the remaining urban sites. This is in contrast to observed declines in NO_2 concentrations in many other Spanish and European cities. This requires ongoing measurements and evaluation to monitor the expected benefit of policies to reduce on-road traffic emissions and to identify improvements in ambient air quality.

Acknowledgement
The authors would like to thank the Canary Government for data from their Air Quality Monitoring Network. This activity has been undertaken in the framework of the World Meteorological Organisation Global Atmosphere Watch Urban Research Meteorology and Environment (GUERME) project.

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AIR POLLUTION EMISSION EVOLUTION INDUCE BY ROAD IN PORT-AU-PRINCE

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Summary

In order to quantify the evolution of the air pollution produce by car traffic in Port au Prince metropole, two emission inventories have been performed. Using the vehicles count on a major thoroughfare of the capital in May 2012 and at the same place in May 2019 the emission of NOx and CO2 evolution have been evaluated. During the last seven years, the population increase for 14% following by vehicles number 13%, lead to the decreased by 38% of NO_X emission rate per km, obtained from emission inventories. On se same time and for the same portion of the road, an increase of CO_2 emission (9%) has been observed. Thus, the exhaust gas standards applied over the past decade help to protect the health of the population but not avoid the climate change.

Introduction

It is now well established that air pollution in megacities and medium sized cities is an important cause of excess mortality and greenhouse gas emission (Baklanov et al., 2016). In developing countries this problem is aggravated by the lack of air pollution rules and regulations. The metropolitan area of Port au Prince, with 2.6 million inhabitants, is one of the biggest Caribbean conurbations. In this town, the lack of official public transportation induces the increase of the use of individual transport and the presence of traffic jam. The road is the main polluter of this urban area. In order to determine the evolution of the pollution related to car traffic, two emission inventories have been done seven years apart. We can analyse the vehicle fleet evolution and its impact on air quality.

Methodology and Results

In order to obtain the evolution of pollution from roads, we counted on an important street of the capital, vehicles at two times separated by an interval of seven years. The number and types of vehicles (cars, heavy vehicles, Bus and Minibus) has been considering. The number of vehicles observed on a mean street show an evolution between 2012 and 2019, of 13%. This increase is close to the evolution of the population on the same period (14%).

Mean engine power, fuel type and age of the fleet have been extracted from data provided by the Office of Vehicle Insurance Third-cons (OAVCT). Using the American-European exhaust emission mean standards for NO_X, we obtained the results presented on Table 1. The decreases observed for all types of vehicle was expected because the regulation on pollutants require by the different standards, Euro4, Euro5 and the last Euro6 induce a drastic limitation of pollution emission.

NO_X	Emission in 2012 (kg/km)	Emission in 2019 (kg/km)	Evolution In (%)
Car & pick-up	1,343	0,652	-51,74
van	0,621	0,529	-14,76
Bus & Lorry	0,164	0,127	-44,02
Total	2,129	1,308	-38,55

Table1: NO_X emission calculated for three types of vehicle

An opposite behavior has been observed on CO_2 emission calculated with the vehicles count of 2012 and 2019 (Table2). Car and pick-up number for both years was approximatively the same but the evolution of engine standard related with the date of the first time the vehicle was put in circulation was different. This fact explains the decrease in CO_2 product presented in Table2.

During the last seven years Van number had doubled because numerous pick-ups used to person transportation arrived in end of life have been replaced by Van. Most of them are second hands imported from USA or Europe. Taken in account the engine age evolution and the increase of van number, we obtained and CO2 emission increase of 64%. Its obscure the good results of car and pick-up. The heavy vehicles emission evolution is mechanically related to the age of the fleet.

CO_2	Emission in 2012	Emission In 2019	Evolution
Car & pick-up	1227,706	1129,755	-7,97
Van	431,821	710,278	64,48
Bus & Lorry	2327,074	2519,270	8,26
Total	3986,605	4359,302	9,35

Table2: CO_2 emission calculated for three types of vehicle

Conclusions

The evolution of exhaust emission between 2012 and 2019, deduce from count of vehicles on a main street of Port au Prince shows a decrease in the NO_X level related with the engine evolution. This result will be confirmed with field campaign results performed in 2019. At the opposite, the CO2 emission increase but less than the increase of the population on the same period. By the road impact, the participation of developing countries on climate change, is of the same magnitude as population increase.

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THE INFLUENCE OF LONG-RANGE AIR POLLUTANTS IN FLUCTUATIONS OF FINE AND COARSE PARTICLE CONCENTRATIONS IN URBAN AREAS

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Abstract
The urbanisation and population growth, together with the consequential of the anthropogenic activities are the key reasons for the increased air pollution in an urban environment. Beside the anthropogenic activities an additional significant factor that enhance the air pollution in these areas, is the long-range pollution dispersion such desert dust storms. Given that, urban air quality is currently drawing the attention of the political and scientific community aiming to improve the human health and quality of life. The aim of this study is to assess the contribution of long-range transport of air pollutants in the urban air pollution, in the combination of the local emissions and the urban microclimatic conditions. This will be achieved through a combination of use of (i) long-term field measurements of particulate matter, and (ii) predictions from a dust regional model.

Introduction
Particulate Matter (PM) has a significant impact on human health since it has been associated with increased hospital admissions for cardiovascular (e.g. Middleton et al., 2008) and respiratory diseases, as well as mortality (e.g. Ortiz et al., 2017) in many cities worldwide. More specifically, these studies suggest that the size of airborne particles appear to have a greater negative impact on human health than particle mass concentration (PMC). Also, it is known that during dust episodes, the largest proportion of PM concentrations consists by coarse particles. Bearing this in mind, we quantified the $PM_{2.5}/PM_{10}$ ratio, under different conditions: (i) during severe desert dust days or non-dust days, (ii) considering the effect of precipitation nearby the study areas. This classification aims to study how the dynamic interaction between the local emissions and the long-range transport of PM affect the concentration of fine and coarse particles in the urban areas. The conclusions of such a study can be used for the evaluation of effects on human health.

Methodology and Results
In this study, we use hourly averaged data from May of 2010 to May of 2018. Continuous PM_{10} and $PM_{2.5}$ concentrations were recorded by Tapered Element Oscillating Microbalance (TEOM) analysers. Data were collected from three air quality monitoring stations which are part of the Air Quality Monitoring Network operated by the Air Quality and Strategic Planning Section, Department of Labor Inspection of Cyprus (Fig. 1). The first station is located in Ayia Marina-Xyliatos and it is considered as a background station for the region of Cyprus. Also, data from the Nicosia and Larnaca traffic stations, were used. The Nicosia station is located in the middle of the island Cyprus. The Larnaca station is also considered as an urban traffic station and it was chosen to be used on the grounds that the city is coastal, and it is affected by the transportation of sea salt particles. Filters of the recording analysers were analysed in order to examine the chemical composition of the particles.

Fig.1: The Air Quality Monitoring Station Network of Cyprus

In addition, we obtained 3-hourly Multi-Model Median surface concentration predictions, which were generated from different regional forecast models (https://sds-was.aemet.es). The forecasting data and chemical analysis was used in order to identify the severe dust days during the study period (Fig. 2). Furthermore, data analysis is used to quantify (i) the relationship between the $PM_{2.5}$ and PM_{10} concentrations during the desert - dust or non dust - days, and (ii) how this relationship is affected by the presence of local emissions in the urban atmosphere or the precipitation.

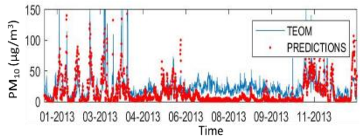

Fig.2: Comparison between on-ground measurements and model predictions

Concluding Remarks
The scientific questions addressed in this paper are driven by the needs of the Life + MEDEA research project, which aims to implement a strategic plan to reduce the exposure of vulnerable populations to desert dust. Therefore, we apply data analysis on PM concentrations in order to:

- estimate the association between the fine and the coarse size particles, and how this relationship varies under the effect of transboundary air pollution.
- assess the impact of precipitation on the variation of the $PM_{2.5}/PM_{10}$ ratio.

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SIMULTANEOUS DETECTION OF POLYCYCLIC AROMATIC HYDROCARBONS AS WELL AS INORGANIC IONS IN SINGLE PARTICLE MASS SPECTROMETRY.

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Summary

Polycyclic aromatic hydrocarbons (PAHs) are toxic trace components in atmospheric aerosols with strong impacts on climate and human health. They are bound to airborne particles and transported over long distances. Estimates of their health risks, transport pathways and degradation would benefit from on-line detection of PAHs along with analysis of the carrying particles to identify the source. We report a new and field-deployable technique that yields the single-particle PAH composition along with both positive and negative inorganic ions via LDI.

Introduction

Inhalation of Polycyclic Aromatic Hydrocarbons (PAHs) is a well-known cause of morbidity and mortality, while data on the PAHs distribution in aerosols is limited (Ravindra et al. 2008). However, details about the PAHs mixing state are crucial to assess potential health effects. PAHs may either be equally distributed over a large number of particles (internally mixed) or could be highly increased within a specific sub-population (external mixture), inducing strong local effects upon particle-in-lung deposition. Besides, PAHs are considered for taking a key role in secondary aerosol formation (Shrivastava et al. 2017). Consequently, novel on-line characterization techniques that address PAHs on a single-particle scale while providing information on their potential source are highly desired.

Methodology and Results

Our approach for on-line single particle profiling is based Single Particle Mass Spectrometry (SPMS) (e.g. Murphy 2007), where particles are introduced through an aerodynamic lens and detected via laser velocimetry using a pair of cw-lasers. In our technique, the particles are than heated by an IR-laser pulse (10.6 µm CO_2-laser), a few microseconds before the combined ionization step of Resonance-Enhanced Multi-Photon Ionization (REMPI) and Laser Desorption/Ionization (LDI) takes place (Fig. 1). With this approach, we present a novel route to obtain the full LDI-information of both positive and negative inorganic ions needed for particle source apportionment in combination with health-relevant PAHs by REMPI (Schade et al. 2019).

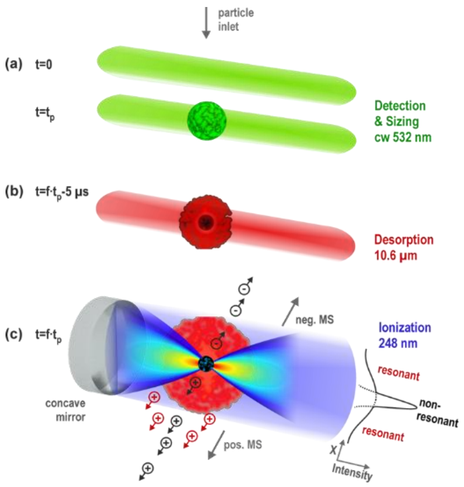

Figure 1. Schematic of the sizing (top) and new ionization procedure (bottom) using an unfocused laser beam of 248 nm wavelength for REMPI and a focused laser beam of the same wavelength for LDI.

Conclusions

In contrast to previous methods, we are now able to address ions from LDI and REMPI in one combined ionization step, acquiring source- and aging information. The method has been applied for several combustion aerosols and allows a deepened insight into the mixing state of PAHs. On-line experiments on combustion aerosols demonstrate the methods capabilities to unravel the distribution of health-critical PAHs in the particle phase in real time. We also present field study results, where PAHs from ships and biomass combustion in marine and terrestrial aerosols were determined on a single-particle level for the first time.

Acknowledgement

This work was supported by the German Research Foundation under grant ZI 764/6-1, by the German Federal Ministry for Economic Affairs and Energy (ZF4402101 ZG7), by the Helmholtz International Lab AeroHealth and by Photonion GmbH,

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REMOTE DETECTION AND EVALUATION OF SHIP EMISSIONS USING NOVEL PARTICLE MASS SPECTROMETRY TECHNIQUES.

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Summary
Novel ionization technologies in single particle mass spectrometry (SPMS) allow a unique view into the chemical composition of individual particles in real-time. We demonstrate the detection of ship emission particles at long distances from shipping lanes. Our technology reveals both the heavy-metal content of individual particles as well as traces of toxic Polycyclic Aromatic Hydrocarbons (PAHs) carried by the particles. First results from a study on long-range transported marine and terrestrial aerosols allow a comparison of the exposure to PAHs from ships, urban traffic and residential wood combustion.

Introduction
Ship emissions play a pivotal role in global air pollution with strong climate and health effects. Huge amounts of particulate matter loaded with organic pollutants, sulphur and heavy metals are emitted. Novel fuel types and exhaust cleaning devices are entering the market to meet the new sulphur limits in 2020. However, little is known about the current and future contributions of ship emissions to regional air pollution and long-range transported aerosols. To evolve efficient risk assessment and mitigation strategies, innovative on-line analyzation methods are needed.

Methodology and Results
We developed a new laser ionization method for individual particles based on resonant light absorption of metal atoms in laser desorption/ionization (LDI) combined with Resonance-Enhanced Multiphoton Ionization (REMPI) of aromatic molecules (Schade et al., 2019). The technique detects traces of particle-bound transition metals and yields full-fledged PAH-spectra from individual particles. The high sensitivity for metals, sulphur and PAHs fits perfectly for the detection of ship emissions in ambient air. We demonstrate that ship engines can emit residual metals even hours after switching from heavy fuel oil to diesel operation. Based on this findings, we developed a method to detect ship plumes from many km distance using freely available data from air trajectories and automatic identification system (AIS) to attribute them to ship passages. Our approach indicates violations against sulphur limits in emission control areas (SECAs) from a large distance. Furthermore, we demonstrate the source apportionment of PAHs to ship emissions and show first results from a field study comparing the PAH pollution from ships, from road traffic and wood combustion in northern Europe.

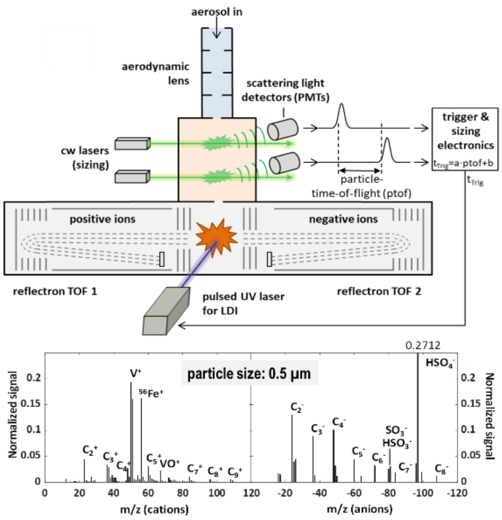

Figure 10. (top) Schematic of the single particle mass spectrometer (SPMS). Individual particles are exposed to accurately triggered UV-laser pulses for ionization and analysis of the components. (bottom) An exemplary single-particle mass spectrum from distant ship emissions, showing strong signals for V/Fe and C-clusters for the cations in addition to high amounts of HSO_4^- and C-clusters for the anions.

Conclusions
The impact of air pollution from ships on human health and ecosystems is not well understood and will change with the new fuels that are introduced to comply with the new global sulphur regulations. Our single-particle approach provides new insights into the chemical composition of long-range transported particles, with emphasis on the health-relevant metals and aromatic molecules. Thus, it paves the way to more sophistically estimates of the exposure to pollutants from different distant sources, including ships.

Acknowledgement
This work was supported by the German Research Foundation under grant ZI 764/6-1, by the German Federal Ministry for Economic Affairs and Energy (ZF4402101 ZG7), by the Helmholtz International Lab AeroHealth and by Photonion GmbH,

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Schade J., Passig J., Irsig R., Ehlert S., Sklorz M., Adam T., Li C., Rudich Y., Zimmermann R., 2019 Spatially Shaped Laser Pulses for the Simultaneous Detection of Polycyclic Aromatic Hydrocarbons as well as Positive and Negative Inorganic Ions in Single Particle Mass Spectrometry. Anal. Chem. 91, 15.

PARTICULATE MATTER IN INDOOR ACADEMIC ENVIRONMENTS: CHEMICAL COMPOSITION, SOURCES, INFILTRATION FROM OUTDOOR.

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Summary

This study was aimed to evaluate the chemical composition and the main sources of indoor PM_{10} in an academic environment. Samplings were carried out for one year in six environments of the same university building. Chemical characterization and source evaluation were performed. Indoor PM_{10} increase was observed for soil components and for organics (mainly bioaerosol) during class hours, while other chemical components of PM mostly infiltrated from outdoor air.

Introduction

It is well known that atmospheric particulate matter (PM) causes a number of adverse effects upon health, although there is still considerable uncertainty about the chemical characteristics of PM that are the main determinants of health. Increasing interest is addressed towards indoor environments, where people spend most of their time. The chemical composition of PM in these environments, which is related to both indoor sources and the infiltration of outdoor air, possibly influences the state of health of citizens much more than the much more studied outdoor atmosphere.

We present the results of an experimental study carried out in academic environments ranging from small laboratories to very wide classrooms. University represents the place where many young people spend most of their time away from home, and is characterized by the absence of some of the PM sources that are typically found inside homes (cooking, biomass burning for domestic heating, pets, among others). The study was aimed to evaluate the concentration and chemical composition of indoor PM_{10} and their relationship with outdoor particles, volume of the classroom, presence/absence of the students, season.

Methodology

Samplings were carried out inside the Physics Department of the Sapienza University of Rome. Two sampling schedules were simultaneously applied: - short samplings carried out during working days, working nights and week-ends of a winter and a summer period, aimed to highlight the differences due to the presence/absence of students and teachers; - 1-month samplings for the duration of 1 year, envisaged to obtain a general picture of PM indoor sources during a long period.

Both sampling schedules were applied to four classrooms of different sizes, a research laboratory and a computer room, located at the ground, 2nd and 4th floor of the same building. Outdoor sampling points were located as close as possible to each indoor area, at the same height from the ground. At each site and for both schedules PM_{10} samplings were simultaneously carried out on Teflon, quartz and polycarbonate filters, for the determination of the total, bioavailable and residual fractions of elements (ED-XRF and ICP-MS), anions and cations (IC), elemental carbon and organic carbon (thermo-optical analysis), bioaerosol content (PI staining and epifluorescence microscopy observation) and PM mass.

Results

The determination of all the main chemical components of PM allowed us to obtain a satisfactory mass closure for both indoor and outdoor samples. The composition of PM in all the indoor environments was dominated by the organic fraction and by soil components (Fig.1). Bioaerosol was found to give a relevant contribution to the organic fraction. A significant decrease of PM concentration and of these main contributes was observed during the night, week-ends and holiday periods with respect to class hours. A main role of people, who directly release bioparticles and bring/re-suspend soil components, was highlighted. The analysis of bioaerosol showed relevant differences in the shape and type of particles between indoor and outdoor samples.

The infiltration from outside constituted the main source of many inorganic species. Significant differences in the infiltration factors were detected, depending on the size and chemical composition of the particles. The possibility to determine the extractable (bioavailable) and residual fraction of each elements improved our ability to speculate about their toxicity and to trace outdoor sources. A relationship between the concentration and composition of indoor PM_{10} and the occupancy rate of the classroom, height from the ground, distance from the street, use of air conditioners and season was highlighted.

Conclusions

University classrooms constitute a peculiar indoor environment where many typical indoor PM sources are missing. During the class hours, indoor PM_{10} concentrations were much higher than outdoor values. Significant indoor sources were detected for soil components (re-suspension) and for organics (bioaerosol). For many other sources (biomass burning for domestic heating, exhaust and non-exhaust traffic emission, sea spray, secondary species) outdoor air was the main source and the indoor/outdoor ratio mostly depended on particle dimensions.

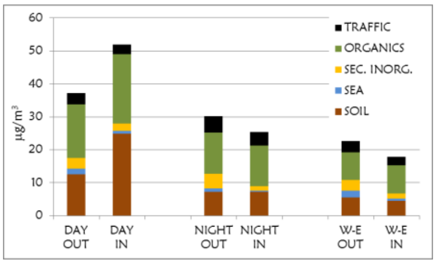

Fig.1 Main sources of indoor and outdoor PM_{10} in a university classroom.

Acknowledgement

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DYNAMICS IN TRENDS OF ATMOSPHERIC COMPOSITION IN URBAN AND BACKGROUND EURASIAN REGIONS ACCORDING GROUND-BASED AND SATELLITE DATA

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Summary

Results of ground-based spectroscopic measurements of CO and CH_4 atmospheric total content (TC) in Moscow, Beijing, Zvenigorod (ZSS station, Moscow province) and the station ZOTTO (Central Siberia) are analyzed as well as data of Eurasian NDACC stations. Also AOD data of AERONET sites are analyzed. Estimates of CO and CH_4 TC and AOD trends obtained with use of ground-based and satellite AIRS v6 and MODIS/Terra data are in agreement between themselves.
A decrease of magnitude of seasonal CO variations was found for different sites. Total decrease of CO TC for 2003-2018 for different Eurasian regions was found; but for summer and autumn months of 2008-2018 CO TC trends in North Europe and middle- and polar latitudes of Asia became positive. The response of surface CO in Eastern Siberia on anthropogenic emission of South-East Asia was found as insignificant. An increase of CO in warm seasons after 2007-2008 can not be explained by growth of anthropogenic or wild-fires emissions.

Introduction

Global climate changes always accompanied by regional and local changes in atmospheric composition. The relationships between them are important especially in urban regions and different for different time-periods and sites. This work continues a series of previous works devoted to the study of air pollution in different regions of Eurasia (Rakitin et al., 2017, Wang et al., 2018, Rakitin et al., 2018). Trends distributions for CO, CH4 and AOD for different time-periods and seasons are presented. Before it we had provided a comparison between orbital and ground-based trends values with use of data simultaneous measurements for every site.

Results

The decrease of CO TC in Moscow and Beijing was observed in 1998-2018 (2.9±0.6%/yr and 1.2±0.1%/yr respectively). Global decrease of CO TC in Eurasia in 2003-2018 was observed. For summer and autumn months of 2007-2018 CO TC has increased in almost all of studied sites (Fig.1) in spite of reduction of anthropogenic emissions and decrease of emission from wild fires (in domain Central North Eurasia, 10º−90º E., 42º−75º N).
A growth of CH_4 TC after 2007 over different Eurasian regions was found.
Decrease of AOD over Central and Southern Europe as well as over China (1−5%/yr) was observed after 2007. Positive AOD trends in Siberia can be explained by wild-fires of last years in this region.

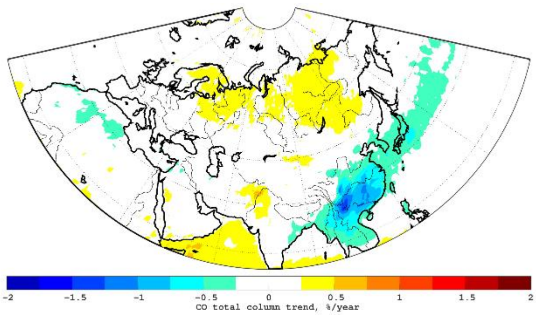

Fig.1. CO TC trends over Eurasia for autumn months of 2007-2018

Conclusions

According ground-based and satellite spectroscopic observations after 2007-2008 CO TC trends over North Eurasia changed their sign from decrease to increase in summer and autumn seasons. These changes can not be explained by growth of wild-fires or anthropogenic emissions. Since 2007 an increase in CH_4 TC trends over Northern Europe as well as for tropical belt of Eurasia has been obtained. Analysis of satellite observations AIRS v6 of CO and CH_4 TC and MODIS/Terra AOD data confirmed the ground-based estimates of trends.
Such pattern of changes in atmospheric composition especially in CO trends can not be explained by growth of anthropogenic and/or wild-fires emissions. Possible reason of beginning of CO growth could be the change in the ratio of the natural sources and sinks with a significant role of atmospheric photochemical mechanisms.

Acknowledgement

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CARBON MONOXIDE IN ABL OF MOSCOW ARIA: TRENDS, VARIATIONS, EMISSIONS

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Summary

Analysis of the long-term CO total column (TC) and surface concentration measurements and meteorological data in Moscow and surrounding provinces for different time-periods and seasons from 2000 to 2018 years is presented. Additionally averaged surface concentrations of key pollutants and characteristics of their inter-annual variability for Moscow territory based on Mosecomonitoring (MEM) network were used to estimate the changes in air quality. Trend estimates based on spectroscopic ground-based datasets of OIAP were compared with changes in wind speed and temperature trends obtained by use of Obninsk meteorological mast (OMM) data and datasets of sounding station no. 27612 (Dolgoprudny) as well as life-time of temperature inversions in Moscow and Zvenigorod obtained using acoustic sounding (SODAR) data.

Methods

CO emissions estimates were provided using different methods such as simple box model and characteristics of concentration variations in Moscow ABL according MEM data as well as variations of CO total column during “accumulation” episodes i.e. during calm days according spectroscopic measurements in Moscow center. Both estimates are in good agreement: 638±136 Gg yr-1 for 2014 (MEM data, Elansky et. al., 2018) and 664±340 Gg yr -1 for 2018 (CO TC data, present work).

Results

Positive trends (0.2-1.2 %/yr depending on time-period) of wind speed in boundary layer of Moscow (Dolgoprudny, Moscow outskirts, sounding station no. 27612, layers 0-500 and 500-1000 m) were obtained for winter months of 2000-2017. In Obninsk (small town of Kaluga province) changes in wind speed were insignificant for all of seasons and time-periods after 2000. The decrease in recurrence of calm days (– 7%/yr) and anthropogenic CO column (– 6.8 %/yr) in Moscow was found for time-period 2007-2017.

Conclusions

Significant increase of air quality in Moscow in last decade due to not only emissions of pollutants reduction but also impact of “climatic factor” such as improvement of boundary layer ventilation.

Trends of CO TC in Moscow and in surrounding regions differ in their sign after 2007: decrease with the rate 1.0-2.9 %/yr for Moscow for different seasons of 2007-2018 and increase in Zvenigorod and Obninsk with the rate 0.3-0.7 %/yr for summer and autumn months were found.

Acknowledgement

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HOW MUCH IS TOURISM CONTRIBUTING TO AIR POLLUTANT EMISSIONS?

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Summary

Data on atmospheric pollutant emissions from tourism activities was identified as a critical knowledge gap. At a European level, emission inventories are developed using the standard Nomenclature for Reporting (NFR sectors). However, none of the NFR are exclusively for tourism or explicitly include it. This work presents a methodology to estimate the emissions from main touristic activities, focusing on Portugal as a case study. The emissions were distributed using tourism data as a proxy, namely the contribution of tourism to characteristic industries, as well as the nights spent in tourism establishments by non-residents. The proxy data was used to distribute emissions throughout the municipalities, using the national reported emissions data as a starting point. An analysis of the spatial distribution of tourism emissions was performed, highlighting that tourism has a significant impact on atmospheric emissions over specific areas (up to 40%), and contributing to areas where air pollution is already an environmental stress factor (urban centres of Porto and Lisbon).

Introduction

Tourism has only recently been investigated as a potential cause for air pollution environmental issues. To date, the majority of studies have focused on translating tourism into CO_2 emissions as a way of quantifying its environmental impact. For an extensive air quality analysis, detailed emissions for atmospheric pollutants are required for each activity sector. Currently, there are no studies where an emissions inventory was built specifically for tourism. Nowadays, Portugal is one of the most important tourism worldwide destinations. According to the World Travel & Tourism Council, the total contribution of travel and tourism to Gross Domestic Product (GDP) was of 17.3%, and 20.4% of the total employment generated, directly and indirectly, by the tourism industry. Therefore, the main objective of the paper is to quantify direct emissions from tourism in each municipality in Portugal, as a first step to develop the data required for an in-depth air quality analysis.

Methodology and Results

To estimate the impact of tourism on air quality, 2015 data from the Portuguese Tourism Satellite Account and Tourism Statistics were used as it is the most up to date data available. In order to analyse the direct economic relevance of tourism, the Gross Value Added (GVA) together with the GVA generated by tourism characteristic activities (GVAGT) were used.

The NFR sectors, recommended for emissions inventories reporting at EU level, were used, in particular the ones that have a direct link to tourism: road and off-road transport, stationary combustion, aviation and shipping activities. The Gross Added Value for characteristic tourism industries was used as proxy data to estimate the contribution of tourism to each economic activity (and corresponding NFR sector). Then, using a specific methodology to each of the four sectors (where tourism have impact), the total emissions and their distribution throughout the municipalities in the country was achieved (see Fig. 1).

Emissions from tourism were then compared in terms of the contribution of tourism to each of these sectors, and their spatial and temporal distribution also analysed and discussed.

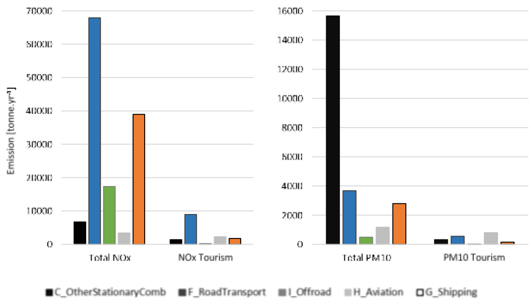

Fig.1 Total and tourism emissions for C_OtherStationaryComb, F_RoadTransport I_Offroad, H_Aviation and G_Shipping, in tonnes/year.

Conclusions

The analysis of the total emissions suggests that tourism activity is responsible for maximums of 67.6% (both NOx and PM10 for aviation), followed by 20.6% (for NOx in the stationary combustion sector) and 15.1% (for PM10 in the transport sector) of total emissions. The analysis of the spatial distribution of tourism emissions highlighted that tourism has a significant impact on atmospheric emissions over specific areas (up to 40.1%) and contributing to areas where air pollution is already an environmental stress factor (urban centres of Porto and Lisbon). While this methodological framework was developed specifically for Portugal (including the time variations shown, which are specifically for Portugal), the case study may be relevant for many other areas in Europe.

Acknowledgement

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MAPPING URBAN AIR QUALITY USING LOW-COST SENSOR NETWORKS

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Summary
We present an approach for exploiting the information from a heterogeneous network of low-cost air quality sensor systems for mapping urban air quality by combining sensor observations with data from an urban-scale air quality model. Specific focus lies on properly characterizing and propagating the uncertainties of each individual sensor system. Results indicate that the method is capable of providing realistic up-to-date maps of urban air quality at high spatio-temporal resolution.

Introduction
One of the most promising applications of low-cost sensor systems for air quality is the possibility to deploy them in relatively dense networks and to use this information for mapping urban air quality at unprecedented spatial detail. More and more such dense sensor networks are being set up worldwide, particularly for relatively inexpensive nephelometers that provide $PM_{2.5}$ observations with often quite reasonable accuracy. However, air pollutants typically exhibit significant spatial variability in urban areas, so using data from sensor networks alone often results in maps that show somewhat unrealistic spatial patterns. One solution is to use the output from an air quality model as an *a priori* and as such to use the combined knowledge of both model and sensor network to provide improved maps of urban air quality. Here we present our latest work on combining the observations from low-cost sensor systems with data form urban-scale air quality models, with the goal of providing realistic, high-resolution, and up-to-date maps of urban air quality.

Methodology and Results
In previous years we have used a geostatistical approach for mapping air quality (Schneider et al., 2017), exploiting both low-cost sensors and model information. The system has now been upgraded to a data assimilation approach that integrates the observations from a heterogeneous sensor network into an urban-scale air quality model while taking into account the sensor-specific uncertainties. The approach further ensures that the spatial representativity of each observation is automatically derived as a combination of a model climatology and a function of distance. We demonstrate the methodology using examples from Oslo and other cities in Norway. Initial results indicate that the method is robust and provides realistic spatial patterns of air quality for the main air pollutants that were evaluated, even in areas where only limited observations were available. Conversely, the model output is constrained by the sensor data, thus adding value to both input datasets.

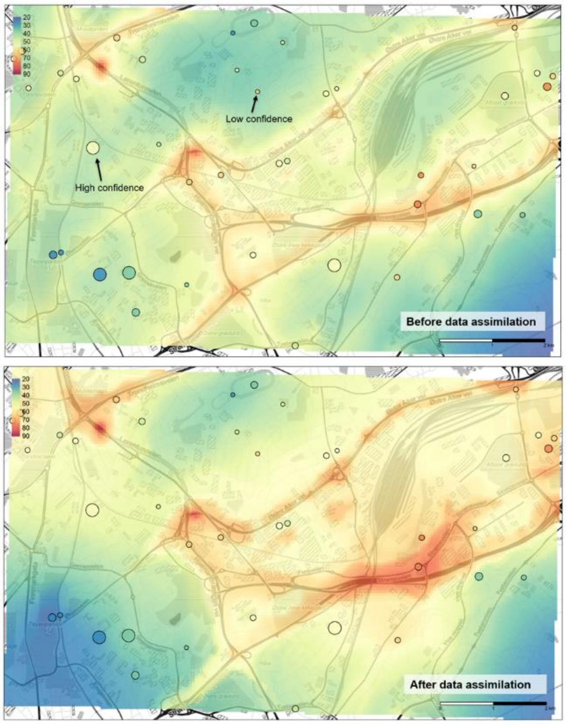

Figure 11: Example of mapping urban air quality through the combination of sensor networks and models. The top panel shows the NO_2 concentration field before assimilation, the bottom panel after assimilation. Circles indicate the observations with colour representing concentration and size representing the accuracy.

Conclusions
While several challenging issues remain, modern air quality sensor systems and particularly those for measuring $PM_{2.5}$ have reached a maturity level at which some of them can provide an intra-sensor consistency and robustness that makes it in some cases feasible to use networks of such systems as a data source for mapping urban air quality at high spatial resolution. We present our current approach for mapping urban air quality with the help of low-cost sensor networks and demonstrate both that it can provide realistic results and that the uncertainty of each individual sensor system can be taken into account in a robust and meaningful manner.

Acknowledgement
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TOWARD A UNIFIED TERMINOLOGY OF PROCESSING LEVELS FOR LOW-COST AIR-QUALITY SENSORS

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Summary
We present a set of strictly defined levels describing the amount and type of processing applied to the data acquired by low-cost air quality sensors. The objective is to help the low-cost air quality sensor community to communicate more clearly and thus to make the use of this new technology more transparent and efficient.

Introduction
The use of low-cost sensors for measuring air quality has proliferated in recent years, allowing for the deployment of dense monitoring networks, which are able to provide unprecedented information on the spatial patterns of air pollutants in the urban environment and thus enable applications such as high-resolution urban-scale air quality mapping as well as personal exposure assessment. However, the raw data supplied by such sensors is in need of processing to various degrees in order for allowing exploitation for air quality applications, and substantial confusion exists with the low-cost sensor community regarding what type of dataset has been processed to what extent and by what methods. In addition, there has been significant concern recently regarding at what point a measurement can no longer be considered a true measurement but is more akin to a statistical model (Hagler et al. 2018). In order to address both of these issues we propose a set of strictly defined harmonized processing levels.

Methodology and Results
Adapting a very successful and widely used system of processing levels within the satellite remote sensing community, we propose a set of five processing levels specific to low-cost air quality sensors. They allow for classifying the amount and type of processing applied to a dataset and as such can act as labels to better describe the data. The levels to some extent mirror those used in the satellite remote sensing community but differ substantially in the details. Level-0 describes the raw data coming out of a sensor system (e.g. voltage or similar), Level-1 represent an intermediate product in concentration units with only minimal processing applied, and Level-2 describes the most frequently used standard product with various corrections applied. Beyond Level-2 we see the boundary between actual measurements and modelling. Level-3 describes a heavily processed product using a wider variety of predictor variables and finally Level-4 represents a spatially continuous map product, which is often a combination of a sensor network with model data. Detailed level definitions and examples are given in Schneider et al. (2019).

Conclusions
The proposed set of processing levels to be used for low-cost air quality sensors aims at improving and simplifying the communication between manufacturers, researchers and users. We believe that a unified terminology of sensor processing levels represents a step towards improved data integrity and transparency and that it will ultimately lead to a better use of this new technology.

Acknowledgement
This work has been carried out with partial funding provided by the Norwegian Research Council within the iFLINK project.

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COMPOSITION OF SURFACE AEROSOLS AS AN INDICATOR OF URBAN ATMOSPHERIC POLLUTION

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Summary
The results of field observations of elemental and dispersed composition and mass concentration of aerosol particles up to 5-10 μm in the surface layer of the atmosphere of Moscow in June 2019 were analyzed in order to determine local urban sources and estimate aerosol emissions in the Moscow region. It was established that under conditions of "calm" atmosphere, the total mass concentration of particles up to 5 μm in the surface air layer of Moscow was characterized by low values and in average did not exceed 6-8 μg/m^3. It was shown that surface aerosols are most enriched by such elements as Cu, Zn, Ti, Pb, Mn, P, S, as well as by Ca, Na, K, Fe, Al, Mg. The calculated aerosol concentration coefficients showed a high degree of accumulation of heavy metals and sulfur entering atmospheric aerosols from anthropogenic sources, mainly from traffic.

Introduction
The active participation of aerosol particles in atmospheric physicochemical processes, as well as the spatiotemporal variability of aerosol properties, determine their strong influence on the ambient air composition and, as a consequence, on ecological state. The contribution of aerosol particles to air quality worsening grows in large cities with a large number of local sources of pollution. With a large anthropogenic load, the chemical and dispersed composition of aerosol particles are an indicator of the air quality of the urban environment. The aim of this work was to determine the elemental composition, microphysical parameters and mass concentration of surface aerosol particles up to 5-10 μm in size to assess their contribution to the atmospheric pollution of large cities (for example, Moscow) and determine their main local sources.

Results
Based on the results of observations in June 2019, the elemental composition of aerosol particles in the surface air layer of Moscow is analyzed taking into account their microphysical parameters, as well as meteorological and synoptic conditions. The period of the field experiment was characterized by the dominance of the northern and northwestern Arctic air masses, the absence of extreme weather events, and occasionally cyclonic activity. The total mass concentration of aerosol particles up to 5 μm in size on average did not exceed 6-8 μm/m^3. The calculated aerosol concentration coefficients CCa (Dobrovol'skii, 2009) showed a strong enrichment of surface aerosols in Moscow with a number of elements, which are associated not only with the soil in the background landscape of Moscow megacity, but also with regional anthropogenic sources. In particular, a high accumulation of heavy metals (Cu, Zn, Ti, Pb, Mn), phosphorus and sulfur in aerosols of surface air was revealed. Aerosol particles are also enriched with metals Ca, Na, K, Fe, Al, Mg. The diagram of the percentage mass distribution of elements over fractions of aerosol particles of various sizes and the mass concentration (μg/m^3) of elements whose content in aerosol particles is significant (solid line) are shown on Fig. 1. Noteworthy are S, Zn, and Pb, concentrated mainly in PM2.5 particles which are the most hazardous to human health. The main anthropogenic source of identified heavy metals and metalloids in the Moscow megacity is road transport. The data on the elemental composition of surface aerosols in Moscow are in good agreement with the results published in (Vlasov et al., 2015).

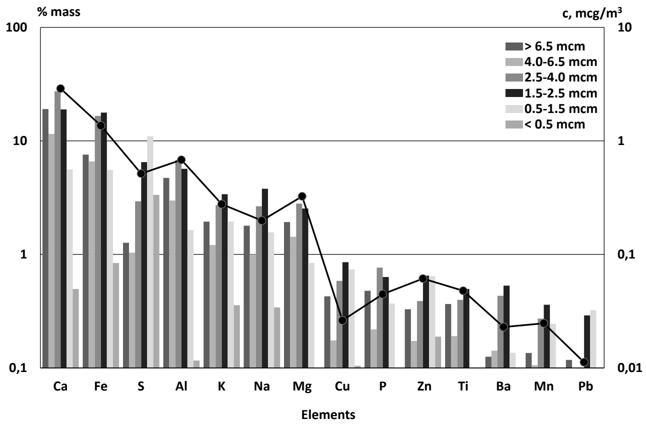

Fig. 1. Mass distribution of elements by fractions of surface aerosols in Moscow. June 2019

Conclusions
Observational data obtained during field experiment in June 2019 showed that the chemical and dispersed composition of atmospheric aerosols is an indicator of urban air quality. During that period in the surface layer of the atmosphere of Moscow aerosol particles up to 10 μm in size were highly enriched with some heavy metals, phosphorus and sulfur. It has been confirmed that in "calm" atmosphere, automobile transport makes the main contribution to air pollution in large cities.

Acknowledgement
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SIMPLE SOFTWARE FOR PREPARATION OF CTM EMISSION INPUTS: EMPY

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Summary
A simple software for preparation of emission inputs for chemical-transport (CTM) model was developed. This software consists of three main subprograms that subsequently import various emissions inputs to the model domain, make the speciation of $PM_{2.5}$ and NMVOC pollutants, and dis-aggregate the annual emissions to the hourly profiles. Final outputs of the program are the CMAQ-ready emission inputs files in standard netCDF format.

Introduction
The emission inventories are prepared by experts often aggregated on national, regional, or district levels. Usually, they only provide annual sums with very rough speciation - e.g. only values of all non-methane volatile organic compounds NMVOC and fine particles $PM_{2.5}$ and are available. However, chemical-transport models require emissions: a) in specific gridded domain, b) speciated according to the chemistry mechanism used in the model (e.g. instead NMVOC it requires emissions in more verbose form like isoprene, ethane etc.) c) with hourly time variation d) in model-ready format. The presented software emPY fully solves the steps b), c), and d). The step a) is partially solved, the emPY allocates emissions in specific gridded domain specified by arbitrary projection and resolution, but does not provide so called top-down spatial dis-aggregation.

Description of emPY software
The emPY software was developed at Slovak Hydrometeorological Institute (SHMU) for the preparation of the emission inputs for the CMAQ chemical-transport model. It is fully written in Python programming language and is structured in easily-extensible way- it means that user can easily add some new functionality. It consists of the three main subprograms and some preprocessors. The schematic description of the emPY software is shown in Fig 1. The software is available on GitHub page https://github.com/dusssaaan/SHMU/tree/master/emPY/, where the documentation is also presented.

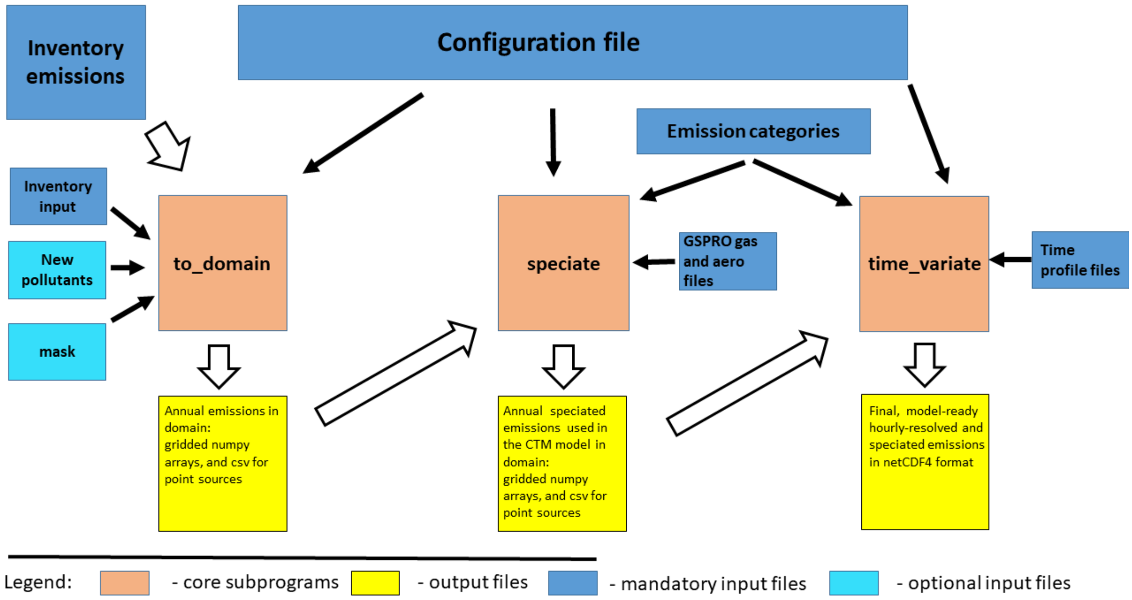

Fig.1 Schema of the emPY software

Conclusions
The software for preparation of CTM emission inputs - emPY is presented. emPY is an open-source product developed at SHMU for internal purposes, but is available free on GitHub for any user. It prepares CMAQ-ready emission files. The software is written in Python 3 programming language. The emPY software has already been used for the preparation of the emission inputs for CMAQ model for several projects: Air Protection Strategy of Slovak Republic; LIFE-IP Integrated Project “Implementation of Air Quality Plan for Malopolska Region Malopolska in a healthy atmosphere“; Drivers and health impacts of the ambient air pollution in Slovakia.

Acknowledgement
We would like to express gratitude to Nina Benešová and Ondrej Vlček from the Czech Hydrometeorological Institute, Peter Huszár and Michal Belda from the Charles University, Prague for their detailed explanation of general features of emission processors.

USING SENSOR DATA AND INVERSION TECHNIQUES TO REDUCE ATMOSPHERIC DISPERSION MODELLING ERROR

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Summary
An optimisation scheme has been developed that applies a Bayesian inversion technique to a high resolution (street-level) atmospheric dispersion model to modify pollution emission rates based on sensor data. The scheme minimises a cost function using a non-negative least squares solver. For the required covariance matrices, assumptions are made regarding the magnitude of the uncertainties in source emissions and measurements and the correlation in uncertainties between different source emissions and different measurement sites. The scheme has been applied in London using measured data from the existing reference-standard London Air Quality Network and from the Breathe London network of AQMesh sensors.

Introduction
Compiling an accurate air pollution emissions inventory for an urban area is a challenging and time consuming task. Even where comprehensive and detailed emissions inventories exist, emissions errors account for a significant proportion of dispersion model error; in particular, there is high uncertainty in published NO_X emission factors for light-duty diesel vehicles (Anenberg *et al.*, 2017). Traditionally, air pollution dispersion models are validated by comparing measured and modelled concentrations at well-established monitoring sites; at best, modellers manually refine the dispersion modelling to minimise error at these locations; at worst, modellers calculate 'adjustment factors' and apply these to modelled concentrations. Meanwhile, the increasing availability of relatively low cost air pollution sensors that are easy to install and to maintain is allowing networks of such sensors to be installed across urban areas (Kumar *et al*., 2015, Reis *et al*., 2015). Although these sensors typically have reduced reliability and accuracy compared with traditional monitors they allow much greater spatial coverage. A systematic method that integrates data from these low cost sensors with models could deliver real benefits in terms of understanding emissions and improving model estimates.

Methodology and Results
Using a probabilistic approach (e.g. Webster *et al*., 2016), we have defined a cost function with two terms: one that represents model error taking into account observation uncertainty; and one that represents emissions error taking into account emissions uncertainty. Given an initial set of emissions data, we minimise this cost function using a non-negative least squares solver to find a revised set of emissions data that reduces model error. The system has been tested in Cambridge (Carruthers *et al*., 2019) using data output from the urban air quality model ADMS-Urban (Owen *et al*., 2000; Hood *et al*., 2018) together with observed data from AQMesh sensor pods. In London, as part of the Breathe London project (www.breathelondon.org), the system has been further developed and applied using ADMS-Urban modelled data and measured data from the existing reference-standard London Air Quality Network and from the new Breathe London network of AQMesh sensors.

The results of this analysis (e.g. changes in hourly and average emission rates across the domain and on individual roads, changes in diurnal emissions profiles) and the impact of the AQMesh sensor data will be discussed in the paper. A key challenge with this inversion technique is to quantify the emissions error and its covariance between sources of the same type, between sources of different types and between pollutants; similarly, to quantify the observation error and its covariance between monitoring sites and between pollutants. The effect of the error covariance matrix on the solution achieved will be discussed in the paper.

Acknowledgement
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ASSESSMENT OF S-5P TROPOSPHERIC NO_2 MAPPING AND IMPACT OF SPATIAL SMEARING OVER HIGHLY POLLUTED REGIONS BASED ON COINCIDENT AIRBORNE APEX DATA

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Summary
In the presented study, the S-5P/TROPOMI tropospheric nitrogen dioxide (NO_2) product (3.5 x 7 km^2 at nadir observations) has been validated over strongly polluted urban regions based on comparison with coincident high-resolution airborne remote sensing observations (~100 m). Airborne imagers are able to map the horizontal distribution of tropospheric NO_2, as well as its strong spatio-temporal variability, at high resolution and with high accuracy. Additionally, such data sets allow to study the TROPOMI subpixel variability and impact of signal smoothing due to its finite satellite pixel size, typically coarser than fine-scale gradients in the urban NO_2 field. Results of the comparison and assessment of the TROPOMI tropospheric NO_2 product will be discussed.

Introduction
Sentinel-5 Precursor (S-5P), launched in October 2017, is the first mission of the Copernicus Programme dedicated to the monitoring of air quality, climate and ozone. Its characteristics, such as the fine spatial resolution, introduce many new opportunities and challenges, requiring to carefully assess the quality and validity of the generated data products by comparison with independent observations, i.e. aircraft remote sensing reference data in this study. Tropospheric NO_2 is one of the principal trace gas products of TROPOMI and is a key pollutant with a direct impact on human health and an important precursor of tropospheric ozone and particulate matter.

Methodology and Results
In the framework of the S5PVAL-BE campaign, the Airborne Prism EXperiment (APEX) imaging spectrometer has been deployed during four mapping flights (26-29 June 2019) over the two largest urban regions in Belgium, i.e. Brussels and Antwerp, in order to map the horizontal distribution of tropospheric NO_2. Mapping flights and ancillary ground-based measurements (car-mobile DOAS, MAX-DOAS, CIMEL, ceilometer, etc.) were conducted in coincidence with the overpass of TROPOMI (typically between noon and 2 PM UTC). The TROPOMI and APEX NO_2 vertical column density (VCD) retrieval schemes are similar in concept and based on 1) Differential Optical Absorption Spectroscopy (DOAS) fitting of the pre-processed spectra in the visible wavelength region, 2) the calculation of appropriate air mass factors (AMFs) by a radiative transfer model in order to account for enhancements in the optical path length due to the surface albedo, aerosol and NO_2 profile shapes and viewing and sun geometry. Finally, retrieved NO_2 VCDs were georeferenced, gridded and intercompared. In Antwerp, main NOx sources are related to (petro)chemical industry in the harbour, while traffic emissions are dominant in Brussels. The NO_2 VCDs observed by APEX range between 3 and 35 x 10^{15} and 1 and 20 x 10^{15} molec cm^{-2} in Antwerp and in Brussels, respectively. Per flight, 15 to 20 TROPOMI pixels were fully covered by approximately 5000 APEX measurements for each TROPOMI pixel. Averaging the APEX VCDs within a TROPOMI pixel reduces its uncertainty to 3.1 $x10^{13}$, a reduction by a factor of 22 when compared to the TROPOMI random uncertainty.

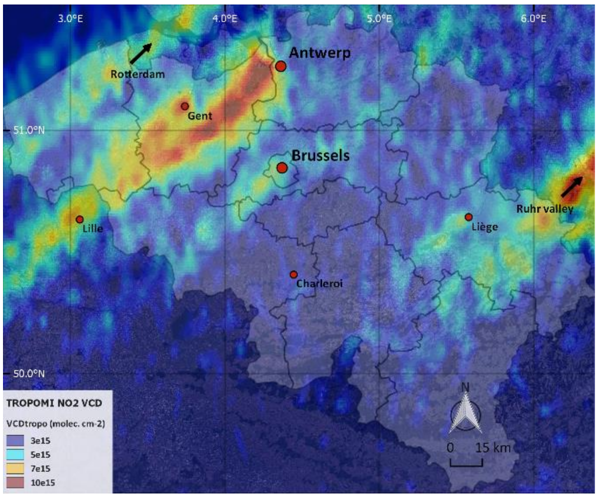

Fig. 1 Tropospheric NO_2 hotspots, observed over Belgium by TROPOMI based on an early afternoon S-5P orbit on 27 June 2019 (Google, TerraMetrics).

Conclusions
The study demonstrates that the urban NO_2 distribution, and its fine scale variability, can be mapped accurately based on airborne mapping observations. It provides a unique data set for air quality studies, as well as a set of reference data for validation of the S-5P data quality and quantification of the retrieval uncertainties in polluted regions. The presented validation strategy for TROPOMI tropospheric NO_2 retrievals based on airborne mapping data can be valuable for validation of future satellite missions, such as S-5, S-4, TEMPO and GEMS.

Acknowledgements
The Belgian Federal Science Policy Office is gratefully appreciated for funding the APEX aircraft activities in the framework of the STEREO III programme.

LONG-TERM EXPOSURE TO AIR POLLUTION, $PM_{2.5}$ AND ITS CONSTITUENTS AND RISK OF NON-HODGKIN LYMPHOMA IN DENMARK: A POPULATION-BASED CASE–CONTROL STUDY

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Summary:
Known risk factors of NHL account for only a small percentage of the NHL incidence. There are only few studies on outdoor air pollution and NHL incidence. Our study found an association between carbonaceous and secondary organic PM at the residence and overall risk of NHL. Air pollution was also associated with higher risk of follicular lymphoma and lower risk for diffuse large B-cell lymphoma.

Introduction:
There is limited evidence regarding a possible association between exposure to ambient air pollutants and the risk of non-Hodgkin lymphoma (NHL). Previous epidemiological studies have relied on crude estimations for air pollution exposure and/or small numbers of NHL cases. Particulate matter (PM) air pollution is a complex mixture and the various PM constituent probably affect health differently. The literature on specific PM constituents and the risk of cancer is sparse. In this study, we aimed to evaluate the association between air pollution modeled at the address level, $PM_{2.5}$ and its constituents and incidence of non-Hodgkin lymphoma (NHL) and its two main subtypes identified from the nation-wide Danish Cancer Registry.

Main Body:
Methodology:
We undertook a nationwide register-based case-control study including 20,847 cases registered in the Danish Cancer Registry with non-Hodgkin lymphoma between 1989 and 2014. Among the entire Danish population, we selected 41,749 age and sex-matched controls randomly from the Civil Registration System. We assessed outdoor PM concentrations at addresses of cases and controls with a state-of-the-art dispersion modelling system. Conditional logistic regression was used to estimate odds ratios (ORs) and adjusted for individual and neighborhood level socio-demographic variables

Table 1. Associations between 10-year mean exposure of air pollution and risk for Non-Hodgkin lymphoma and its subtypes

	All types of Non-Hodgkin lymphoma	**Follicular Lymhoma**	**Diffuse large B Cell Lymphoma**
Cases/control	19650/35222	3469/6139	6638/11843
Exposure (µg/m^3)	Model[a] OR (95% CI)	Model[a] OR (95% CI)	Model[a] OR (95% CI)
$PM_{2.5}$ (IQR =5.44)	1.00 (0.93 – 1.70)	1.16 (0.98 – 1.38)	0.91 (0.81 – 1.03)
BC/OC (IQR = 1.15)	1.03 (1.00 – 1.07)	1.05 (0.97 – 1.14)	0.98 (0.92 – 1.04)
SIA (IQR = 3.98)	0.93 (0.83 – 1.04)	1.44 (0.80 – 1.08)	0.82 (0.67 – 1.00)
SOA (IQR =0.05)	1.54 (1.13 – 2.09)	4.52 (0.86 – 23.83)	0.51 (0.21 – 1.22)
Sea-salt (IQR =0.88)	0.96 (0.93 – 0.98)	0.92 (0.86 – 0.99)	1.02 (0.98 – 1.08)

[a] adjusted for sex, age and calendar time, by matched design additionally adjusted for marital status, country of origin, personal income, and labor market attachment, neighborhood level socio-demographic characteristics
Abbreviations: PM, particulate matter; SIA/SOA, secondary inorganic/organic aerosols; BC/OC, sum of primary emitted black carbon (BC) and organic carbon (OC), NHL, non-Hodgkin lymphoma;

Results:
The results showed associations between risk for NHL and exposure to carbonaceous (OR=1.03; 95% CI: 1.00, 1.07) and secondary organic particles (OR=1.54; 95% CI: 1.13, 2.09). The results indicated a higher risk for Follicular lymphoma in association with several PM components. There was no association between exposure to $PM_{2.5}$, BC, O_3, SO_2 or NO_2 and overall risk of NHL but several air pollutants were associated with higher risk of follicular lymphoma, e.g. $PM_{2.5}$ (OR=1.15 per 5 µg/m^3; 95% CI: 0.98-1.34) and lower risk for diffuse large B-cell lymphoma (OR=0.92 per 5 µg/m^3; 95% CI: 0.82-1.03).

Conclusions:
This is the first study on PM constituents and the risk of NHL. The results indicated an association with carbonaceous and secondary organic PM and overall NHL cases, higher risk of follicular lymphoma and lower risk for diffuse large B-cell lymphoma was also observed. The results need replication in other settings before any firm conclusion can be reached.

SOURCE APPORTIONMENT OF BLACK CARBON AT RESIDENTIAL AND TRAFFIC ENVIRONMENTS

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Summary

Black carbon (BC) has impacts on air quality, health and climate. All incomplete combustion processes, in urban areas typically traffic and biomass combustion, produce BC. In this study, we investigated the sources of BC at two locations in Helsinki, Finland, by using multi-wavelength aethalometer data and statistical method to the aerosol mass spectrometry data. In residential area and traffic site, approximately 47% and 13% of BC was related to biomass combustion, respectively. In general, source apportionment of BC based on aethalometer and SP-AMS gave similar results.

Introduction

Climate change is currently one of the major global challenges with huge yearly costs to societies. Black carbon (BC) with direct impacts on climate, snow albedo, and human health, is considered to be the most important light absorbing aerosol component in the atmosphere in respect of global warming. In tightly populated cities, BC sources include typically transportation, industry and residential combustion (Timonen et al., 2019). Due to technology advancements and legislation, there is a declining trend in BC emissions from vehicular traffic. In contrast, the emissions from residential combustion are not currently regulated in most European countries. Therefore, there is a growing interest to identify BC sources and quantify their impacts on air quality at different urban locations. In this study, we investigated the sources of BC at two different environments in Helsinki, Finland.

Methodology and Results

BC was measured by using a dual-spot Aethalometer (AE33; Drinovec et al., 2105) and Soot Particle Aerosol Mass Spectrometer (SP-AMS; Onasch et al., 2012). Measurements were conducted at a residential area with a lot of wood burning and at roadside characterized with heavy traffic. Measurements were performed in winter (Jan–Apr 2019) at the residential site and in late summer (Aug–Sep 2019) and autumn (Oct 2015) at the traffic site. To distinguish BC to traffic and biomass burning BC, two different pairs of the absorption Ångström exponent values (α) for wood burning and fossil fuel were tested for AE33 data (Helin et al., 2018). Mass spectra of organics and rBC acquired from the SP-AMS were analysed statistically by using Positive Matrix Factorization (PMF). At the residential site, PMF resolved three factors for organics and rBC; hydrocarbon like organic aerosol (HOA), oxygenated OA (OOA) and biomass burning OA (BBOA), while at the traffic site, an additional OOA factors was found.

Conclusions

According to the PMF, 47% of BC was related to biomass burning and 40% to traffic at the residential site. The rest was assumed to be regional background or long-range transported. At the traffic site, 47% of BC was from traffic and 39% from regional/long-range transport while only 13% was from biomass burning. By comparing the biomass burning contribution of BC (BC-BB%) from the SP-AMS to that from the aethalometer, AE33 gave typically slightly larger BB%. However, it was found that more than one PMF factor might be required to explain the BB% given by the AE33. Additionally, Ångström exponent values need to be fine-tuned for each site.

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ASSESSMENT OF INDOOR AND OUTDOOR AIR QUALITY IN A SCHOOL IN STUTTGART

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Summary

With the aim of assessing the indoor and outdoor air quality in a German elementary school in Stuttgart; a diffusive sampling technique along with mobile and continuous measurements was applied. Measurements were done using NO_2 diffusive samplers along with mobile measurements to measure O_3, NO_x, Particulate Matter (PM) (size range 0.01 µm to 32 µm) and Black Carbon. Apart from that, NO_x was monitored continuously in the ventilation system of the school. The measurements were divided into two periods, summer (29.05. – 17.07.2017) and winter (16.10.2017 – 12.01.2018). In general, the pollution levels measured in and outside the school were not high enough to be considered harmful to the health of the children. However, a clear correlation between the level of pollutants and the proximity to the main road was identified. The problem was located in the isolation of the double windows that face the main road. In order to improve the air quality in that part of the building, the isolation of the windows was improved and a second field campaign with NO_2 passive samplers was performed in 2019 to verify the improvement of the air quality.

Introduction

Children spend most of the time per day inside the school building and therefore assuring low concentration of pollutants in schools is a priority. The sources of pollution in school buildings have been widely studied (Csobod, 2014). Although most of the pollutants have been found to be mainly emitted from indoor sources (Indoor/Outdoor ratio > 1), NO_2 and O_3 come predominantly from outdoor sources (in average I/O < 0.8 and I/O < 0.1 respectively). Considering this fact, traffic-related pollutants (NO_x, PM and black carbon) as well as ozone were measured to investigate the effect of a busy road on the air quality of the school.

Methodology and Results

Mobile measurements were performed during 8 days in summer and 12 days in winter. In parallel, NO_2 passive samplers from the company Passam Ag were installed during 7 weeks in summer and 9 weeks in winter in 25 different locations: 20 indoor locations on different floors and 5 outdoor locations in playground and at the street as well as one passive sampler in a reference station located 150 m away from the school and facing the same busy road. In general, the NO_2 concentrations obtained from passive samplers inside the school were less than 20 µg/m³ and relatively higher in the playground but below the annual limit value of 40 µg/m³. This limit was only exceeded at sites located at the busy road (59 ± 11 µg/m³). An aerosol spectrometer working on scattering light principle was used to measure PM concentrations. In both seasons, high PM10 concentration was found when the kids were present in the classrooms. During the winter term an elevated number of ultrafine particles were detected with a Condenser Particle Counter in one of the classrooms when candles were used. The Black Carbon concentration was measured with microAeth® AE51. During the winter campaign it showed concentrations from 1.500 up to 2.000 ng/m³ in the playground which was more than three times higher compared to the summer results. The highest concentration of Black Carbon was found in the winter term at the road (average of about 3.000 ng/m³). Continuous measurements of NO and NO_2 (see Fig.1) as well as O_3 helped to identify the influence of the rush hours in a room facing the main road in the ground floor even though the windows remain closed.

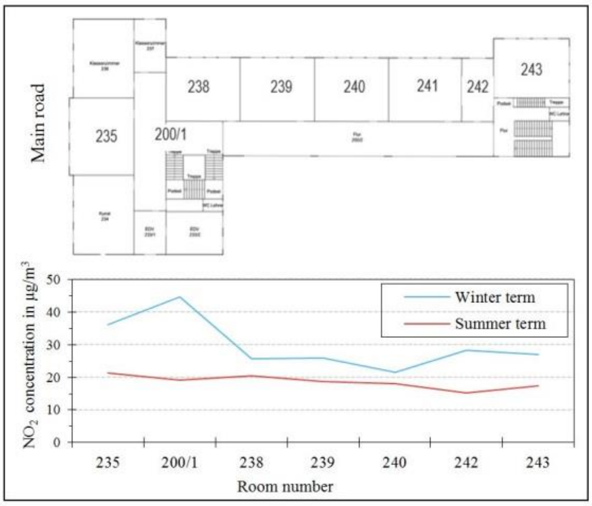

Fig.1 Average concentration of NO_2 in different classrooms of the second floor. The main road is indicated on the left side of the building.

Conclusions

The influence of the outdoor traffic to the air pollution in the classrooms facing the busy road was verified, especially in the ground floor. The classrooms with the lowest concentration of pollutants were found in the third floor, due to the vertical dilution. An improvement of the isolation of the windows was recommended to avoid air exchange through the windows in the rooms facing the busy road.

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ENVIRONMENTAL SPEED LIMITS

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Summary

In this study, we establish the effects related to the implementation of Environmental Speed Limits (ESLs) as a measure to mitigate air pollution and associated health effects. Studies published in the literature on the effects of reducing the maximum speed limit on emissions and pollutant concentration levels are controversial, showing a wide range of results. This reflects an uncertainty that may be related to variations in the methodology and scope of the studies. We present detailed emissions (i.e., NO_x, $PM_{2.5}$ and PM_{10}), concentration levels from dispersion modelling (i.e., $PM_{2.5}$ and PM_{10}) and population exposure to $PM_{2.5}$ and PM_{10} under three scenarios; 1) the ESL is not implemented (baseline scenario); 2) the ESL is implemented and we use real vehicle speed as input data; and 3) the ESL is implemented and we assume speed sign compliance.

Introduction

In Oslo, since 2004, the Norwegian Road Administration has implemented ESLs over certain roads in an attempt to reduce the production and dispersion of non-exhaust PM. The ESLs have been implemented over roads, which are considered main arterial roads with high traffic volume due to people commuting from residences in the city outskirts to work in the city centre. For these roads, signed speed limits are reduced from 70 or 80 to 60 km/h during the winter season (i.e., November 1st to April), when studded tyres are allowed due to winter meteorological conditions and slippery road surfaces.

Methodology

Emissions were developed for 2013 based on high-resolution input data, that thereafter are aggregated to 1 km grid, and combined with time variation functions to result in hourly emissions at 1 km^2 resolution. The main contributing sectors to PM and NO_x emissions and pollution levels are traffic and residential wood combustion (RWC), both estimated at high resolution based on the high detailed data on traffic, the NORTRIP model (Denby et al., 2013) to account for the road dust contribution and the MetVed model (Grythe et al., 2019) for RWC. Emissions were developed for the three scenarios previously described, and thereafter used as input data in the EPISODE model (Hamer et al., 2019). Population exposure is calculated by combining the modelled PM concentration at specific residential addresses with the number of people registered for each building point.

Results and Conclusions

The roads, where ESLs are implemented, contribute to PM_{10} levels by over 20% in the vicinities of the roads, mainly characterized by residential areas (Fig 1) if ESLs are not implemented. The results indicate that changes in NO_x emissions are negligible between the scenarios: Reductions in $PM_{2.5}$ and PM_{10} emissions may be achieved by up to 6% and 12%, respectively. Dispersion modelling shows that changes in annual $PM_{2.5}$ mean concentration are negligible (i.e., <1%) as there are several other significant sources of these particles (e.g., RWC), whereas we obtain a reduction in annual PM_{10} mean concentration of up to 8%. When evaluating changes in population exposure, the ESL have the highest impact on reducing high daily PM_{10} concentrations, i.e., in the range 65-85 µg/m^3. The results from our study show that the most significant effects are obtained when drivers fully complied with the speed limit, indicating the need for enforcement of the signed speed in order to effectively reduce PM_{10} levels by this measure.

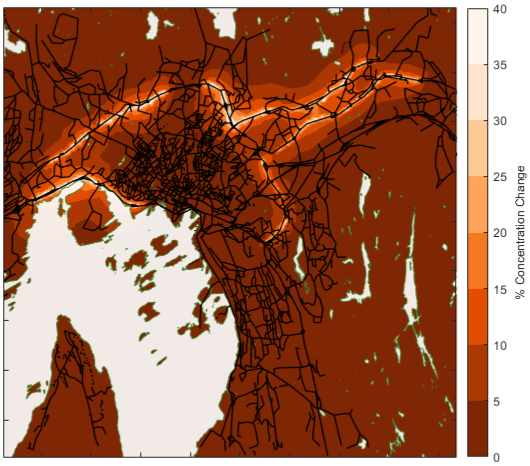

Fig.1 Contribution to PM_{10} levels from the roads where ESL is implemented in the baseline Scenario (Without ESL).

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