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Plenary talks

EMISSIONS BEYOND GREENHOUSE GASES: EXPLORING HOW THEY SHAPE OUR ONE ATMOSPHERE

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Keywords: Emissions, Radiative Forcing, Aerosols

In this talk, we will discuss some key aspects characterizing the complexity of atmospheric emissions. Specifically, emissions into the atmosphere influence Earth's climate, with both aerosol particles and greenhouse gases being key drivers in the radiative balance. In total, aerosols have a net cooling effect, partly countering the warming effect of greenhouse gases.

As emissions are more than just greenhouse gases, changes in emissions can, and in most cases do, affect multiple atmospheric components simultaneously. The reduction of sulfur emissions from ship fuels serves as a case study: While this regulation is primarily targeted at reducing harmful environmental acidification, it also influences particle formation and consequently affects radiative forcing. When sulfur dioxide emissions decrease, fewer particles form in the atmosphere, reducing the cooling effect.

Particle emissions influence the Earth's radiative budget directly via light scattering and absorption, and indirectly by changing cloud properties. Both effects can even be observed from space via satellite imagery, for example as ship tracks, where water condenses on emitted or subsequently formed particles, creating clouds with a higher reflectivity. Even without cloud formation, particles scatter light directly, visible as an albedo increase over highly polluted regions.

The effects of greenhouse gases versus particles at any given time are of the same order of magnitude, yet their lifetimes are vastly different. While changes in greenhouse gas emissions typically manifest in atmospheric concentrations over decades, changes in emission of particles and their precursors show effects within days. While a quick reduction of aerosol and precursor emissions is desired from a health perspective, it also bears the risk of reducing the aerosol cooling which might lead to a temperature rise on a short timescale.

It matters where an emission takes place, both in terms of air quality and climate. This aspect is illustrated through aircraft emissions and subsequent contrail formation at different flight altitudes, which - contrary to ship tracks - have a net warming effect. Small flight altitude modifications can significantly alter the climate impact of aviation beyond its greenhouse gas emissions, helping to greatly decrease negative climate effects by air traffic even without changing fuels.

In this talk, we discuss recent findings regarding these key aspects of climate and air quality interactions by atmospheric emissions - both from international literature and from within the ACCC community research. Additionally, we show recent measurements by Tampere University comparing emissions from a fossil fuel and renewable biofuel. They provide insights into how a change driven by the goal of reducing greenhouse gases can additionally change other emissions - for a better air quality and human health. We will also discuss attempts to quantify the climatic effects of non-greenhouse gas emissions in different fields of emission research, and the challenges involved in trying to relate them to the health effects.

ACKNOWLEDGEMENTS

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CLIMATE CHANGE ATTRIBUTION OF EXTREMES AND THEIR IMPACTS IN FINLAND

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Keywords: Climate change attribution, Weather Extremes, Impact attribution, Science-to-service

INTRODUCTION

Climate change attribution investigates how observed local weather events are modified by climate change, informing risk assessments, insurance policies and adaptation planning. Attribution studies of extreme weather events inform also the public on the tangible impacts climate change has on weather. Thus they serve as powerful tool for raising public awareness on climate change as a phenomenon with real-life consequences. The studies often receive ample media coverage, creating also a platform for broader discussions of the far-reaching impacts of climate change on our planet.

World Weather Attribution (https://www.worldweatherattribution.org/) conducts rapid case studies of most impactful extreme weather events around the world. There is however an unmet need for more streamlined operational attribution services capable of focusing on more localized events, provided by e.g. by local meteorological institutes. Also, there is a need to bring together attribution studies with impact studies, where impacts and hazards can be followed up as they emerge (sometimes slowly) after an extreme weather event. Since early 2023 we have started developing such methods within ACCC.

These initiatives are now followed up in CLAIMS (from CLimate change to Attribution of extremes and their IMpactS in Finland and Northern Europe), a four-year project (2024-2028) funded by the Research Council of Finland. It aims to quantify how climate change is already affecting individual weather events in Finland and Northern Europe, how this effect will change in the future, and how these changes in weather conditions are translated to impacts in the Nordic forestry sector. A key part of the project is to develop an operational attribution service for Finland, provided by FMI .

METHODS AND SOME INITIAL RESULTS

CLAIMS approaches its goals using (1) high-resolution regional climate model simulations, (2) statistical analysis of observations and climate model simulations, and (3) climate impact modelling. To maximise the societal utility of its findings, the project also includes a strong (4) science-to-service component.

1. Multi-decadal regional climate model simulations will be conducted with the convection-permitting Harmonie Climate (HCLIM) model (Lind et al. 2023) at 2.5 km resolution using the pseudo-global-warming (PGW) approach (Brogli et al. 2023). In PGW, a regional climate model is repeatedly run with boundary conditions built on the same reanalysis data on real weather, but these boundary conditions are modified for the effects of climate change, so to represent (e.g.) the preindustrial past, true present-day climate (ca. 2024) or future climates. In contrast to freely running global climate model simulations, this makes it possible to study the climate change effect on individual weather events (see the example in Figure 1).

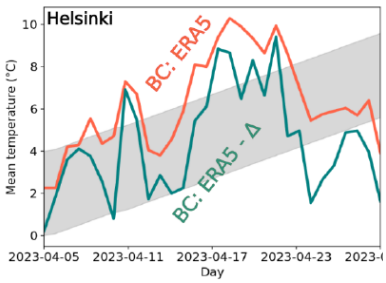

Figure 1. Daily mean temperatures in Helsinki in April 2023 in a present-day (red) and preindustrial (cyan) PGW simulation.

2. Combination of observed time series with model-based estimates of regional climate change also allows one to translate the former to "pseudo-observations", i.e., time series of weather that would have been observed in otherwise similar conditions at different levels of global warming. The method was introduced for monthly temperatures by Räisänen and Ruokolainen (2008) and further developed by Rantanen et al. (2024), and it is already in semi-operational use at the Finnish Meteorological Institute (e.g., FMI 2024). As an example, Figure 2 shows that the record-warm September 2023 in Helsinki (mean temperature +15.8°C) would have been 1.4°C colder in the beginning of the 20th century. In CLAIMS, this method will be extended to the daily time scale and other variables like precipitation.

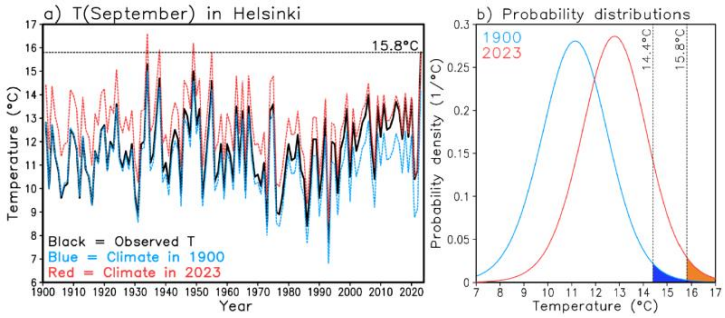

Figure 2. (a) Observed (black) September mean temperatures in Helsinki, together with pseudo-observations representing the climates in years 1900 (blue) and (2023). (b) The corresponding probability distributions for 1900 and 2023.

3. Both abiotic (windstorms, heavy snow loads, drought, forest fires) and biotic (e.g. bark beetle outbreaks) sources of forest damage are affected by climate change. The high-resolution meteorological time series from PGW simulations will be used as input to already existing impact models to quantify how climate change has already affected the risks of these hazards and how it is likely to affect them in the future.
4. A key expected outcome of the science-to-service component in CLAIMS is an operational tool, which will allow the meteorologists at the Finnish Meteorological Institute to quantify and communicate the impact of climate change on observed weather conditions in near real time. In addition, stakeholders in the forestry sector will be kept well-informed on the findings of the forest damage impact modelling, so to help their planning of climate change adaptation and mitigation.

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WHAT DO WE KNOW, AND DO NOT KNOW, ABOUT THE FATE OF PERMAFROST NITROGEN FOLLOWING THAW?

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Keywords: nitrogen cycle, Arctic, permafrost-affected soils, nitrous oxide

INTRODUCTION

Permafrost-affected soils host a vast stock of soil nitrogen (N), but most of it is poorly available for plants and microbes. With the strong warming in the Arctic region and associated permafrost thaw, permafrost N will become increasingly mobilised and can be redistributed between soils, plants, waterbodies and the atmosphere. This redistribution can feed back to the climate system indirectly via its diverse effects on carbon cycle and directly in the form of the emissions of the strong greenhouse gas nitrous oxide (N_2O) (Voigt *et al.*, 2020). Permafrost-derived N can be a valuable resource supporting enhanced plant growth and carbon sequestration, but how much of the released N can be caught by plants depends greatly on the magnitude, timing and location of this release, as well as the post-thaw soil conditions. Substantial N losses to the atmosphere or to waterbodies can be expected particularly with abrupt permafrost thaw and associated drastic changes in hydrology and vegetation cover. The fate of N in warming northern soils and its effects to C cycle are still very uncertain due to lack of experimental data and poor representation of permafrost processes in process models. In my talk, I discuss the recent advances in permafrost N cycling studies, identify knowledge gaps and suggest ways to address them.

CURRENT KNOWLEDGE ABOUT PERMAFROST NITROGEN

During the past decade, there have been important advances in the field of permafrost N science. The soil N stock in the top 3 m of the northern permafrost region has been estimated at 55 Pg (Palmtag *et al.*, 2022), comprising about one third of the global soil N stock. Additionally, detailed inventories have been published about N stocks of certain important N- and ice-rich landforms susceptible to abrupt thaw: permafrost-affected peatlands (7.1 Pg N; Hugelius et al., 2020) and Yedoma (41 Pg N in the whole Yedoma region; Strauss et al., 2022). Enhanced N_2O emissions with permafrost thaw have been observed from these landforms (Voigt *et al.*, 2017; Marushchak *et al.*, 2021), but also from other terrestrial ecosystems, including alpine meadows (Yang *et al.*, 2018) and polygonal tundra (Hashemi *et al.*, 2024). The first baseline estimate of the N_2O budget of the northern permafrost region suggests a negligible (top-down) to small source (bottom-up) of 3-4% of the global N_2O budget (Hugelius *et al.*, 2024). Syntheses of soil N pools indicate higher mineral N content in permafrost than in the seasonally thawing active layer, suggesting high bioavailability of permafrost N (Strauss *et al.*, 2022; Hansen and Elberling, 2023). Based on a meta-analysis of gross N transformation rates, the mineral N turnover in permafrost-affected soils is higher than could be expected based on the observations of low mineral N pools and low net turnover rates (Ramm *et al.*, 2022). Molecular studies have elucidated the role of various microbial groups as regulators of soil N cycling, for example, the role of ammonia oxidation as a bottle-neck process for N_2O production (Monteux *et al.*, 2018; Marushchak *et al.*, 2021).

KNOWLEDGE GAPS AND HOW THEY CAN BE ADDRESSED

There is still a dire lack of observational data and process understanding about N cycling in permafrost-affected soils, but the situation is improving due to increasing research interest and recent methodological advances. Portable N_2O analysers, automated chamber systems and eddy covariance set-ups can be used to produce more accurate and spatio-temporarily representative data on N_2O fluxes. The first study with air-borne N_2O flux measurements over an Arctic landscape (Wilkerson *et al.*, 2019) will hopefully inspire

similar efforts in the future, because it allows determination of regional emissions and identification of previously unknown hot-spots. Tracer studies based on the application of the rare heavy stable isotope of N, ^{15}N, can be used to resolve the gross rates of the numerous co-occurring microbial processes that produce and consume mineral N forms in permafrost-affected soils. Further, novel molecular tools allow better identification of microbes participating in soil N transformation despite their low abundance in permafrost-affected soils. These novel methods are utilized in the Thaw-N project (Academy of Finland, 2023-2028), which investigates the mineral N cycling and associated N_2O losses in two regions experiencing rapid permafrost thaw: the Alaskan Yedoma region and a palsa mire in northern Sweden.

ACKNOWLEDGEMENTS

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ATMOSPHERE-BIOSPHERE FEEDBACKS: MATCHING PUZZLE PIECES

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Keywords: feedback, climate, clouds, forest

Recently, we often hear about climate tipping points — thresholds of different Earth system components or variables that can trigger drastic and irreversible change of climate when reached or overcome. Tipping points can be global, such as potential release of greenhouse gases if permafrost thaws abruptly, or regional when changes in the climate system, for example, extreme temperatures, occur on a smaller spatial scale, affecting the regional climate system. Many of these tipping points are related to feedback loops - complex chains of interactions between different variables, which can enhance or dampen the response of the system to an external perturbation. Feedbacks often act across the geospheres and involve different time scales, which makes their understanding and quantification challenging.

In my talk, I will first introduce climate feedbacks, and explain their importance on a simple example. I will briefly discuss some existing feedback quantification methods and how they can possibly be compared. We proceed with an overview of different climate feedbacks so far identified, how many of them have been quantified – and how reliably. I will then introduce a current view on the biosphere-atmosphere-clouds-climate feedback, which I have been focusing my research efforts on. Finally, I will discuss several 'puzzle pieces' that INAR and ACCC scientists, including myself, have contributed to the quantification of this feedback, elaborate on how these pieces fit in a general picture, and outline the needs for future research.

Oral presentations

BARLEY MONOCULTURE VERSUS BARLEY WITH UNDERSOWN SPECIES: IMPACT OF DIVERSITY ON GHG EXCHANGE IN FINLAND

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Keywords: Barley monoculture, Undersown species, Greenhouse gases, Chamber technique.

ABSTRACT

Agricultural land use has a major impact on the environment by representing ca. 38% of the Earth's land surface and 17% of total anthropogenic greenhouse gas emissions (FAO, 2020). While the intensification of agriculture has improved food security, it has also harmed the environment in many aspects.

There are practices which could be less harmful for climate and biodiversity. For example, climate-friendly practices can help increase carbon sequestration and reduce CH4 and N2O emissions. However, there is a need 1) to quantify and verify the impact of these practices with traditional practices and 2) to estimate the size of the possible impact.

To bridge part of this knowledge gap, the TWINWIN experiment was established in Helsinki in June 2019. TWINWIN's goal was to study the impact of diversity on various soil-plant-atmosphere variables such as soil micro-organisms, greenhouse gases, plant diseases, and many more. The experiment consisted of 60 plots where barley was sown as monoculture or with 1 to 8 undersown species: Lolium perenne, Phleum pratense, Trifolium hybridum, Trifolium repens, Medicago sativa, Trifolium pratense, Festuca arundinacea and Cichorium intybus. The eight undersown species varied in functional traits, such as rooting depth and nitrogen-fixing properties. More details on the set-up can be found at Capelli *et al.* (2024).

GHG measurements were conducted on 26 plots, which included barley monoculture, barley + 1, barley + 4 and barley + 8 undersown species and bare fallow. CO2 fluxes (light response of net ecosystem exchange and total respiration), CH4 and N2O net fluxes were measured over three summers and two winters, with intervals varying between twice to once a month. In addition, various soil and vegetation parameters were measured simultaneously, such as soil temperature, soil moisture, green area index, above ground biomass and yield.

Here, we will present the TWINWIN experiment with a focus on CO2, CH4 and N2O fluxes measured with the chamber technique from 2019 to 2022. No significant differences were observed between treatments regarding CH4 and N2O fluxes, except for a few days with no distinct patterns. However, significant and notable differences were observed between barley monoculture and barley with undersown species regarding CO2 fluxes, especially outside the growing season.

ACKNOWLEDGEMENTS

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CAN'T SEE THE FOREST FOR THE TREES? REVIEW OF THE EUROPEAN UNION CARBON REMOVALS AND CARBON FARMING CERTIFICATION (CRCF) REGULATION

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Keywords: EU climate law, carbon removal, carbon sequestration, voluntary carbon market

INTRODUCTION

The European Union (EU) is a Party to the United Nations Framework Convention on Climate Change (UNFCCC). It is implementing its Nationally Determined Contribution (NDC) through a consolidated European Climate Law[1] which recognises the role of nature-based and technological carbon removals in achieving a Union-wide carbon neutrality by 2050 and a subsequent net negative scenario.[2] This goal is strengthened by a distinct target for land-use, land use change and forestry (LULUCF) sector including an aim to remove 310 megatons of carbon dioxide from the atmosphere by 2030.[3]

To accelerate action on this front, the European Union Carbon Removals and Carbon Farming Regulation (EU CRCF)[4] has been proposed. From a legal standpoint, it represents a substantial initiative necessitating further analysis. Carbon farming presents an interesting case as it involves actors that are primarily private entities operating on a voluntary-basis. This in and of itself is a feature of the Paris Agreement which aims to encourage implementation through its bottom-up orientation.[5] Additionally, despite the relative novelty of the term "carbon farming",[6] the history of land-based carbon sequestration is associated with many considerations.

The broad range of mitigation activities in the proposed regulation gives rise to questions not only regarding the role ascribed to the voluntary private climate action but also that of environmental integrity. This paper provides an overview of the EU CRCF and evaluates its potential in establishing a market for high-quality carbon removals, highlighting legal considerations and feasibility of carbon farming within the regulation.

METHODS

This paper employs a doctrinal legal method to evaluate the effectiveness of the EU CRCF in establishing robust quality standards. It will further draw upon an extensive literature regarding legal aspects of carbon sequestration and related international and EU environmental legislation, analysing the proposed regulation's alignment with some existing principles in its efforts to design a certification scheme for the pan-European voluntary carbon market.

RESULTS

Preliminary results suggest that while the EU CRCF sets out ambitious quality criteria for carbon removals, it may lack sufficient safeguards to ensure environmental integrity. The paper makes a preliminary suggestion that a

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[1] Regulation (EU) 2021/1119 of the European Parliament and of the Council of 30 June 2021 establishing the framework for achieving climate neutrality and amending Regulations (EC) No 401/2009 and (EU) 2018/1999 ('European Climate Law') OJ L243/1.

[2] Reg 2021/1119, paras 20, 22-23.

[3] Regulation (EU) 2018/841 of the European Parliament and of the Council of 30 May 2018 on the inclusion of greenhouse gas emissions and removals from land use, land use change and forestry in the 2030 climate and energy framework, and amending Regulation (EU) No 525/2013 and Decision No 529/2013/EU.

[4] Commission, 'Proposal for a Regulation of the European Parliament and of the Council establishing a Union certification framework (CRCF) for carbon removals' COM (2022) 672 final. Hereinafter EU CRCF.

[5] Charlotte Streck, 'Filling in for Governments? The Role of the Private Actors in the International Climate Regime' (2020) 17 *JEEPL* 5, 7.

[6] Commission, 'Carbon Removals and Carbon Farming' <https://climate.ec.europa.eu/eu-action/carbon-removals-and-carbon-farming_en> accessed 14 October 2024.

voluntary carbon certification scheme may not be the most suitable mechanism for incentivising nature-based climate mitigation, highlighting the need to explore alternative strategies to achieve high integrity outcomes in the LULUCF sector while providing sufficient financial rewards for land-owners.

CONCLUSIONS

This paper highlights the importance of robust quality standards in voluntary carbon certification schemes acknowledging the challenges linked to the inclusion of such a wide array of projects with differing mitigation impacts and sustainability outcomes. This can ultimately hinder the establishment of a truly high integrity voluntary carbon market. Collectively, this paper delivers insights to the EU's approach in incentivising voluntary private climate action, while questioning the multiple aims it is trying to achieve simultaneously.

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NEW PARTICLE FORMATION IN MILAN: AN INVESTIGATION ABOUT THE ROLE OF METEOROLOGICAL CONDITIONS AND URBAN POLLUTION

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Keywords: new particle formation, size distribution, urban environment.

INTRODUCTION

Studying the process of new particle formation (NPF) is crucial for protecting human health and addressing climate change. Ultrafine particles have the potential to harm the lungs, bloodstream, and brain. Additionally, these particles can undergo growth through condensation and coagulation, and interact with the solar radiation directly or as cloud condensation nuclei. Despite its significance, the NPF process has not been investigated in Milan using high-resolution instruments over an extended period yet. Our research aims to fill this gap, providing a comprehensive understanding of NPF in this city, which is, not only the most populated and polluted city in the Po Valley, but also a crucial hotspot for climate and air quality issues in Europe.

METHODS

The investigation of NPF is carried out through the analysis of particle number size distributions which were measured through advanced instrumentation, i.e., a Particle Size Magnifier (1.2-3nm), a Neutral Cluster and Air Ion Spectrometer (2.5-40nm), and a Scanning Mobility Particle Sizer (10-500nm). These instruments operated for about one year, between May 2023 and March 2024, at the Chemistry and Physics departments of the University of Milan, situated in an urban background area, as part of a collaboration within the European project RI-URBANS.

Upon classifying NPF days using both the conventional approach outlined by Dal Maso et al. (2005) and the ranking method proposed by Aliaga et al. (2023), the size distributions were analysed in conjunction with meteorological variables and pollutant concentration data, measured by the local environmental agency, ARPA Lombardia.

RESULTS

Preliminary analyses highlight that a cleaner and more mixed atmosphere – lower concentrations of black carbon, CO, SO_2, NO_2, PM_{10}, $PM_{2.5}$, lower condensation sink (CS) and higher atmospheric ventilation index – promote the formation of new particles (Figure 1). In particular, initial studies of the meteorological conditions and airmass trajectories through the NOAA HYSPLIT model suggest a link between NPF occurrences and episodes of Foehn winds, which are known to be characterized by the inflow of warm, dry air from the Alps through strong winds and sunny and warm weather conditions, even during winter months. Ongoing investigations are, therefore, focused on understanding more in detail the role of the airmass origin

and exposure to the NPF process through the application of Lagrangian particles dispersion model coupled with a high-resolution meteorological model.
Additional investigations will involve analysing particles' formation and growth rates, along with examining the size distributions of positive and negative ions. Lastly, we aim to quantify and compare the impacts of traffic and NPF on nanometric particle concentration, as they are the main contributors to ultrafine particles in Milan.

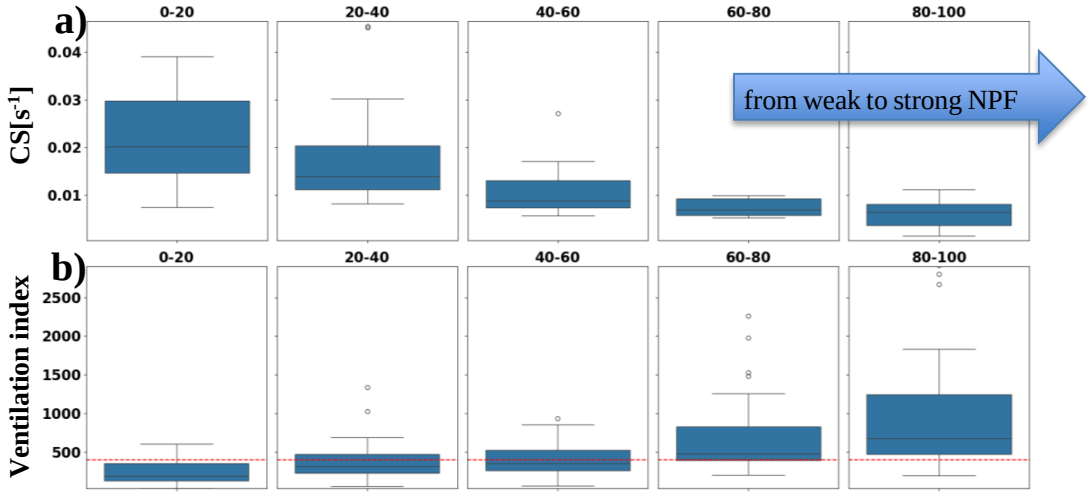

Figure 1. The figure reports a) the CS and b) the ventilation index through boxplots of 20-quantile of NPF ranking. Specifically, going from left to right each boxplot represents classes of stronger NPF intensity. Therefore, overall, the figure shows that stronger NPF happens at lower CS and higher ventilation index. The red line represents the threshold of ventilation index for stagnant days, provided by ARPA Lombardia.

CONCLUSION

To conclude, our study will allow the first high-resolution description of ultrafine particle size distributions and the first long-term analysis of the NPF process in Milan in relation to the meteorological conditions and pollution. Preliminary results show that a clean and mixed atmosphere promote NPF and suggest a link between NPF and Foehn wind events. Therefore, ongoing research explores deeper into the influence of atmospheric factors and air mass trajectory and exposure. Our analysis will include the quantification of traffic and NPF contributions to ultrafine aerosol particles.

ACKNOWLEDGEMENTS

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THE ROLE OF BARK IN TREE SURVIVAL UNDER DROUGHT STRESS

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Keywords: Bark, Climate change, Drought.

INTRODUCTION

In recent years, cases of widespread forest mortality have been recorded worldwide. Trees are more likely to die in hot and dry conditions, but the underlying mechanisms are not yet fully understood. In non-stressed conditions, majority of water loss from trees occurs through stomata in leaves. During drought, trees close their stomata or even drop leaves to prevent hydraulic failure, but water loss through bark should continue thus increasing the risk of hydraulic failure (Lintunen et al. 2021). Bark has static lenticels that intersperse the bark and allow exchange of gases between the stem and ambient air, and trees cannot control the opening and closing of the lenticels. On the other hand, stomatal closure in leaves also reduces photosynthesis during drought, but bark photosynthesis should continue and locally partly compensate decreasing leaf photosynthesis after stomatal closure. Bark covers large part of tree surface area through which tree interacts with the environment, but the role of bark in tree physiology during drought and tree mortality has been largely overlooked. Our main aim is to gain understanding of bark structure and function in different climatic and growing conditions and their responses to drought stress. This information is needed to reveal the role of bark in tree performance and survival in extreme conditions and future climate.

METHODS

The objectives are achieved by a unique combination of field and laboratory experiments on structural bark characteristics, gas exchange, tree hydraulics, non-structural carbohydrates, pigments, and their plasticity in response to climatic conditions. Experimental work will be combined with process-based modelling of tree hydraulics in the soil-plant-atmosphere continuum, and regional tree mortality modelling to allow improved estimates of species performance and survival in future climate scenarios.

The work is ongoing. By far, we have 1) analysed stem CO_2 exchange through bark and its main drivers from the unique long-term data collected at SMEAR II station (Dukat et al. 2024), 2) analysed transpiration through bark and its main drivers from the long-term data collected at SMEAR II station, 3) compared bark pigments, chlorophyl fluorescence of bark, transpiration through bark and its response to drought between various boreal tree species, and 4) conducted a massive drought experiment with bark manipulations in greenhouse conditions. Next, we will compare structural and functional bark characteristics between trees growing in contrasting climate conditions to study possible species adaptation to dry conditions. And finally, we will utilise the various measurements to assess the role of bark in tree survival under drought by modelling tree hydraulic failure under drought in different climate scenarios, and by simulating regional drought-induced mortality of the studied species in their distribution range. To further study the feedback of forests on climate, we plan to include bark processes into land surface modelling to simulate the role of bark in ecosystem-atmosphere interactions. This part will be done in collaboration with Finnish Meteorological Institute.

ACKNOWLEDGEMENTS

This work was supported by the Research Council of Finland Academy Fellow grant (no. 355142) and the ACCC Research Flagship grant (no. 337549, 357902).

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THE EFFECT OF EXTREME WEATHER ON PEATLAND GHG EXCHANGE IN FUTURE CLIMATE USING JSBACH-HIMMELI ECOSYSTEM MODEL

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Keywords: extreme weather, peatlands, greenhouse gas fluxes, ecosystem modelling.

INTRODUCTION

Extreme weather events affect Greenhouse Gas (GHG) exchange on peatlands. For example, 2018 heatwave in Europe caused prolonged drought reducing the carbon uptake of peatlands. While pristine peatlands are in normal conditions long-lived carbon sink, due to the heatwave the annual CO2 balance turned to source at some studied sites (Rinne et al., 2020). As extreme weather events are projected to increase due to the climate change, ecosystems including peatlands face a risk of turning into carbon source more often. Severe droughts can also revert the restoration measures done on drained peatlands (Kalhori et al., 2024). In this study, we utilize JSBACH-HIMMELI ecosystem model to simulate 30 pristine, restored and forestry-used peatland sites across Europe using climate change scenario weather forcing to support the creation of Tier 3 IPCC Emission Factors.

METHODS

The JSBACH-HIMMELI model (Raivonen et al., 2017; Susiluoto et al., 2018) is based on the land surface component of the Max Planck Institute Earth System Model (Reick et al., 2021). Our model includes the YASSO soil carbon model component (Goll et al., 2015) for organic matter decomposition which has been modified to account for anoxic conditions occurring in peat soil layers below the Water Table (WT) level (Kleinen et al., 2018).

For site simulations, we use single vegetation class at a time. For the different stages of ecosystem management – pristine, forested, and rewetted stage – different model versions are used. The conservation of ecosystem carbon has been accounted for at each change of the model version. For all simulations, we grow peat for 10 000 years in a pristine peatland stage and the changes to the drainage and restoration stages correspond to the actual management years. Parameters for each site are calibrated using Eddy covariance and chamber GHG measurements, WT measurements, and Sentinel 2 satellite-based Leaf Area Index. For climate change scenario simulations, we utilize three CORDEX-bias corrected models from CMIP5 project (Giorgi et al., 2009; Jones et al. 2011) and two ISIMIP3b-corrected models from CMIP6 (Lange et al., 2021). In total, we include RCP 2.6, 4.5 and 8.5 scenarios with mitigation pathways SSP 1 and 5.

RESULTS

In the simulation results using the climate scenarios, we see an increase in the variation of CO2 dynamics and increase in both CO2 sink and emission extreme years. On CH4, we see a strong increasing trend during the century due to warmer soil temperatures. Although the forcing scenarios predict an increase of drought events, especially in the RCP 8.5 case, the changes in simulated soil hydrology are relatively small on annual scale. The variance of WT, driving the CO2 emissions, is increasing the most in the Western and Northern Europe and the least in the Central Europe.

CONCLUSIONS

Peatlands are often thought to be resilient against extreme weather events, but as the severity of the events increases peatland face a risk of turning into net carbon source more often. This is highlighted by the notable increase of CH4 emissions. To finalize our analysis, we will look into the effects of drainage on the resilience against extreme events.

ACKNOWLEDGEMENTS

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Ecological restoration of low-productive peatlands drained for forestry

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Keywords: Peatland, ecological restoration, greenhouse gas fluxes, carbon, biodiversity, functional traits, vegetation, testate amoeba, peat

INTRODUCTION

Forest drainage in peatlands, which has resulted in a significant increase in tree growth in Northern Europe, has also led to the endangerment of several peatland habitats and reduced biodiversity and soil carbon storage of peatlands. In Finland where forest drainage has been particularly active, approximately EUR 0.8 million. ha of this drainage is economically unprofitable but had led to annual greenhouse gas emissions of €0.42 million t CO2 eq. On a European scale, nutrient poor peatlands are rare, and in many areas of Central Europe, restoration of these bogs to their natural state is highly demanding because of the species lost from the region and high nitrogen deposition. While these nutrient poor peatlands are well suited for restoration due high gains but also because of low risks related to increased methane emissions and societal resistance, large-scale restoration success requires greater knowledge and know-how than currently exist. Therefore, there is a current need to develop restoration methods and train forestry operators to plan and implement restoration successfully.

Our study that focuses on the restoration of nutrient poor, low productive peatland forests, aims to develop criteria for successful site selection and to bring together good practices for successful restoration.

METHODS

The success of restoration was defined as a slowdown in peat decomposition (heterotrophic respiration), recovery of the soil carbon sink, formation of new organic layer, and an increase in functional diversity. For this we sampled 28 sites in drained, restored and pristine conditions, located over a latitudinal gradient from Southern to Northern Boreal Finland.

Good practices were defined by gathering the experiences of restoration practitioners through interviews.

RESULTS AND CONCLUSIONS

In all studied sites the restoration of nutrient poor peatlands had decreased the carbon loss from peat to the atmosphere and supported the accumulation of new organic material. Also, the increase in methane emission following restoration was moderate in all sites. Restoration favoured the recovery of biodiversity, measured as the similarity of vegetation composition and the testate amoeba traits to natural peatlands. The positive response to restoration was favoured by increasing size of the catchment and decreasing distance to the nearest natural peatland.

Successful site selection and good practises are passed on to current and future practitioners responsible of planning operations and carrying out restoration work. We implemented this as workshops supported by digital mobile material, as well as restoration demonstration and self-contained demonstration sites, as well as by producing guided video and podcast series.

ACKNOWLEDGEMENTS

This work was supported by Recovery and Resilience Facility of European Union through Ministry of Agriculture and Forestry of Finland.

THE EFFECT OF URBANIZATION OF THE CHINESE GIGACITY ON THE WATER AND ENERGY BALANCES

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Keywords: PRECIPITATION, URBANIZATION, WATER BALANCE, ENERGY BALANCE.

INTRODUCTION

The urbanization of eastern China has been unprecedented in the human history, which causes many environmental problems and challenges. The cluster of megacities in northeast China could be classified as one huge continuous urban area – a Gigacity (Kulmala *et al*., 2021) – defined roughly by the lines Beijing–Xian–Shanghai–Beijing. There are already approximately 10 % of global population living in the Gigacity area and the population is projected to continue increasing in the coming decades. The Gigacity area is highly dependent on the local ground and surface water sources (Sun *et al*., 2014). Therefore, any disturbances on the precipitation in this area could cause severe consequences in terms of human wellbeing. It is known that individual megacities can bifurcate storm fronts (e.g., Dou *et al*., 2015). Similarly, it is known that the megacities cause enhanced frequency and intensity of extreme rainfall within and downwind of urban areas, and a decreased amount of cumulative rainfall (i.e., urban dry island) (Mahmood *et al*., 2014; Zhang *et al*., 2019). Therefore, the effect of the Gigacity could have substantial impact on the aquifer water levels and quality. The vast area of the Gigacity could even enhance these interactions, but the effects are still mostly unknown. In this study we examined the effect of the urbanization of the Gigacity on the precipitation within and downwind of the Gigacity.

METHODS

We utilized the ERA5-Land data (Munoz-Sabater *et al*., 2021) for the surface energy balance analyses. ERA5-Land provides a consistent view of the evolution of land and near surface variables covering the same period as ERA5 (Hersbach *et al*., 2020), but with enhanced spatial resolution. ERA5-Land has been produced by replaying the land component of the ERA5 climate reanalysis. The ERA5-Land data is provided in 1 h temporal resolution and 1° spatial resolution. For the precipitation, we used the Global Precipitation Climatology Centre's GPCC dataset (Schneider *et al*., 2013). The study period was from 1980–2020.

CONCLUSIONS

The volumetric water content of the deeper layers (100–289 cm) has been substantially decreasing within the gigacity area (Figure 1), especially after 2005 as the urbanization increased in early 2000s. This is indicating that the Gigacity area has already been drying substantially as the water balance of the area has been disturbed presumably due to the combined effect of urbanization, increased haze, and anthropogenic climate change.

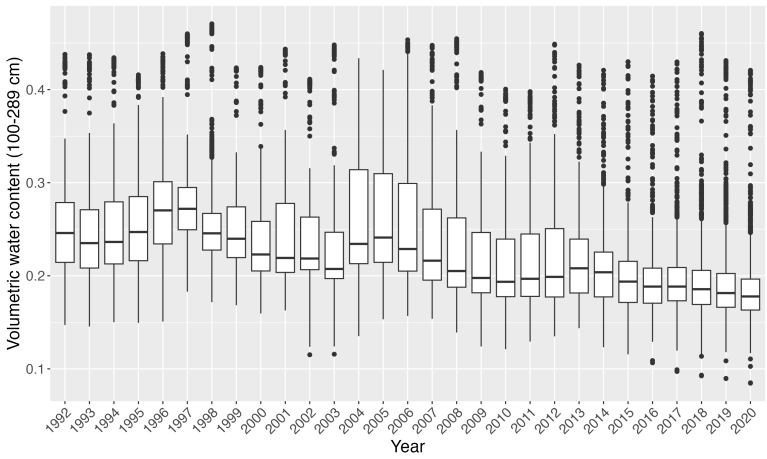

Figure 1. Boxplot showing the volumetric water content of soil for 100–289 cm layer within the Chinese gigacity area.

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QUANTIFYING UNCERTAINTY IN CARBON DIOXIDE REMOVAL WITH GAUSSIAN PROCESS EMULATORS AND MARKOV CHAIN MONTE CARLO

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Keywords: Carbon dioxide removal, Gaussian process emulators, MCMC, Climate models.

INTRODUCTION

Large-scale carbon dioxide removal (CDR) is crucial to meeting the Paris Agreement goal of limiting global warming well below two degrees Celsius, in addition to deep emission reductions (Smith et al., 2024). Solutions range from land-based approaches like reforestation to more technologically advanced options such as direct air carbon capture (DACCS). The potential for lowering the atmospheric CO_2 concentration and wider impacts on the climate and carbon cycle have been studied with Earth system models. However, full Earth system models are computationally very expensive and are not well suited for uncertainty analysis. Here, we describe a method for combining an Earth system model of intermediate complexity with Gaussian process emulation and Markov Chain Monte Carlo to quantify the uncertainty of temperature and carbon cycle response to reforestation and ocean alkalinization.

METHODS

As the basis of our analysis, we carried out 300-member perturbed parameter ensembles with the University of ensemble of Victoria Earth System Climate Model (UVic ESCM) (Mengis *et al.*, 2020). We perturbed 20 parameters to explore the Earth system uncertainty related to e.g., ocean and ocean biogeochemistry, carbon cycle, land vegetation, aerosols, non-CO_2 greenhouse gases. We chose SSP1-2.6 scenario as the control scenario and simulated two CDR scenarios: 1) Ocean alkalinization where 2 Pg $Ca(OH)_2$ yr^{-1} was added to ice-free oceans between between 70 °N and 60 °S and 2) reforestation where we assumed an idealized abrupt shift to vegan diet resulting in rewilding of pastures and part of croplands. Both CDR methods were started in year 2050.

To enable wider exploration of the parameter space, we trained Gaussian Process Emulators for the main outputs of the UVic ESCM for these scenarios. For annual time series spanning from 1850 to 2300, we used dimension reduction to make the emulation more cost effective. The emulators were used to run Markov Chain Monte Carlo to get posterior distributions for the 20 model parameters. We used Metropolis-Hastings algorithm with the proposal function based on the covariance of the parameters of the initial chain with 100,000 iterations. The emulator outputs were constrained by eight observation-based constraints including surface air temperature change from preindustrial climate, CO_2 concentration in 2020, permafrost and soil carbon content, historical atmosphere-to-ocean and atmosphere-to-land carbon fluxes, historical strength of Atlantic meridional overturning circulation, and ocean net primary production.

RESULTS

Gaussian process emulators were able to capture time evolution of most variables mostly well when tested with a randomly selected training set of 200 UVic ESCM simulations and about 40-80 runs left as test cases.

The posterior distributions of the emulated constraints were mostly matching well with the observations. Especially, the posterior distributions for surface temperature increase, atmospheric CO_2 concentration and permafrost carbon were very similar to observational uncertainty of those variables. Figure 1 shows emulated posterior time evolution of atmospheric CO_2 concentration and temperature. Even though these variables were constrained only in certain time points, the historical time evolution of them matches well with observational uncertainty.

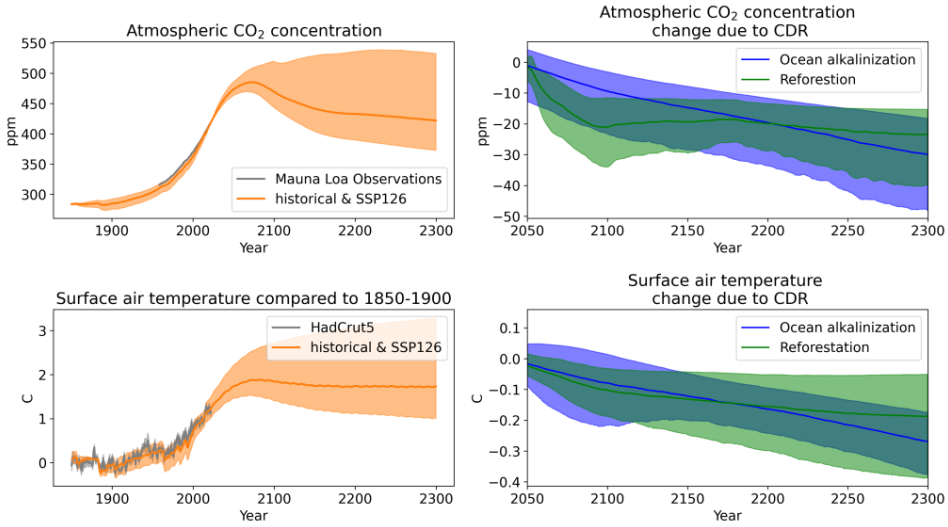

Figure 1. Atmospheric CO_2 concentration and surface air temperature based on the emulated posterior distribution. The right hand side shows the effect of ocean alkalinization and reforestation. The lines show mean of 10,000-member sample and shaded areas show the 95% credible intervals. The gray lines show observations.

CONCLUSIONS

Using Gaussian process emulators and MCMC based on a perturbed parameter ensemble with an intermediate complexity climate model offers computationally feasible way to quantify uncertainty related Earth system response to carbon dioxide removal. This kind of analysis is not possible with full Earth system models due to prohibitive computational cost. Although our modelling setup is computationally much more demanding than using simple climate models, the underlying simulations with an Earth system model enable us to capture mechanistic description of the full carbon cycle and interactions with different parts of the Earth system in a way that is impossible with simple climate models.

ACKNOWLEDGEMENTS

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OPTIMIZING FOREST CARBON SINKS WITH BECCS

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Keywords: Improved forest management, BECCS, optimization, reinforcement learning, forest carbon, soil carbon.

INTRODUCTION

According to IPCC (2014) it may be possible to eliminate 50% of global carbon emissions by applying bioenergy, carbon capture and storage (BECCS). However, cost efficient climate change mitigation cannot circumvent the possibilities to increase forest carbon storage if the unit costs are the same or lower compared to BECCS. Since BECCS tends to increase the demand for forest biomass there has been a concern for the effects of large scale application of BECCS on forest biodiversity. Together this implies a need to analyse improved forest management, BECCS and forest biodiversity in a unified framework. For this end we develop simultaneous optimization of wood production and carbon sinks by an age- and size structured model for mixed species forests. The model includes advanced model for soil carbon, wood production economy, forest deadwood accumulation and an intertemporal objective for the value of wood production and the value of carbon sinks net of emissions. Carbon stocks include aboveground biomass and carbon in forest soil and in wood products. Emissions from using forest biomass in bioenergy production can be captured and stored permanently. Our setup extends the economic research on forests carbon sequestration by including a mixed species age- and size structured stand, deadwood accumulation and optimization of carbon capture and storage together with wood production.

METHODS

In our high-dimensional model (ca. 4000 state variables) based on the individual-tree structure, both the continuous and binary decision variables and C sinks prevent the use of ordinary optimization methods (cf. the "curse of dimensionality"). However, the problem is a Markov Decision Process and can be solved using reinforcement learning (RL), explained in detail in Tahvonen et al (2022). In brief, RL solves optimal management actions as a function of a multidimensional system state (Sutton and Barto 2018). Besides other advantages (such as computation time and the possibility of adding stochasticity), our RL application allows specifying the problem without any explicit reference to rotation vs. continuous cover forestry, and e.g. a regime with equal successive rotations may emerge as optimal among any other admissible alternatives.

RESULTS

The inclusion of carbon sink and emissions lengthens optimal rotation, postpones thinning and decreases their intensity. High enough value of carbon removes thinning and leads to solutions with pure clearcuts and long rotation or to solutions with no harvesting. Tree species with lower commercial value are included only for carbon storage. As a side product of longer rotation and increased natural mortality, the stock of deadwood increases. Maximum average carbon stock in living trees, forest soil and wood products is obtained with long rotation and clearcut instead of “no human intervention” (cf. Roebroek et al. 2023).

BECCS is applied if the cost per tCO_2 falls below the social price of carbon. Given this condition is met, BECCS shifts emphasis toward wood production at the expense of carbon stock in trees and soil. Consequently optimal rotation length decreases, wood production increases but average C stock in trees and soil and the stock of deadwood decreases. BECCS produces a permanent annual CO_2 storage of 2.9-3.1

tCO_2 per hectare. BECCS always benefit wood production while the value of carbon storage may decrease. Surprisingly, with BECCS higher value of carbon may imply shorter rotation periods.

CONCLUSIONS

Including the value of carbon in optimizing the economic outcome of wood production increases the carbon stock in trees and forest soil. BECCS decreases this effect and shifts emphasis back to wood production. However, with BECCS it is still optimal to increase carbon stock in trees and forest soil compared to solutions with zero value of carbon. Consequently, also the deadwood stock remains clearly higher compared to solutions with zero carbon value. Economically efficient implementation of carbon storage in forests together with BECCS can be reached by subsidizing forest carbon sink net of soil emissions and by taxing industrial CO_2 emissions net of carbon capture and storage. Applying BECCS with business as usual forest harvesting is economically inefficient.

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SEVERE HAZE EPISODES IN BEIJING MAY HAVE ORIGINS AS FAR AS 2000 KM WEST

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Keywords: Air quality, Atmospheric modelling, Atmospheric chemistry, Haze

INTRODUCTION

Frequent air pollution episodes that occur in Beijing and the greater North China Plain during autumn and winter have significant impacts on health, the economy, and quality of life in the region. Being able to understand the origins, formation processes, and life cycles of severe haze episodes is imperative for developing air pollution mitigation strategies for a future of cleaner air.

This study applies SOSAA (the model to Simulate the concentration of Organic vapours, Sulfuric Acid, and Aerosols; developed at the University of Helsinki and the Atmospheric Modelling Centre Lahti) to a severe pollution episode in Beijing in November 2018. Although there are many atmospheric chemical transport models for regional air quality, SOSAA is unique because it has detailed chemical and aerosol dynamic processes and simulates concentrations of many more atmospheric species than regional models (Zhou et al., 2014; Boy et al., 2011). Moreover, SOSAA models aerosol size distribution rather than only mass concentrations, which is especially important from a health standpoint. Additionally, being able to analyse the chemical and physical processes along the backward trajectory leading up to the haze is a novelty that SOSAA can offer, which complements the measurements in Beijing.

After evaluating the SOSAA results, we simulated a few scenarios that could potentially reduce the severity of haze episodes in Beijing, and the results could be used for emission and air pollution mitigation strategies.

METHODS

In this study, SOSAA was run along 7-day back-trajectories using FLEXPART (Flexible Particle dispersion model) to investigate the origins of the severe haze episode. We started with the Environment-High Resolution Limited Area Model (Enviro-HIRLAM) to generate meteorology forecasts. The meteorological output was used to calculate the trajectories and as input to SOSAA. Details of the trajectory analysis can be found in Foreback et al. (2024). Next, we calculated emissions along the trajectories, based on Copernicus Atmosphere Monitoring Service (CAMS) for anthropogenic and biogenic gas emissions and Greenhouse Gas–Air Pollution Interactions and Synergies (GAINS) for primary particle emissions. Then we ran SOSAA along the trajectories using the emissions to simulate chemistry and aerosol dynamics. The drivers inside SOSAA include Atmospheric Cluster Dynamics Code (ACDC), the Master Chemical Mechanism (MCM), plus autoxidation chemistry. Then we created several scenarios to examine potential mitigation strategies for haze episodes. Examples of scenarios include switching to electric vehicles, reducing residential and industrial emissions, stricter controls on power plants, transitioning to renewable energy, and eliminating agricultural waste burning outside the city.

RESULTS

By analysing SOSAA results along the trajectories (an example shown in Fig. 1), we found that the haze observed in Beijing had origins far from the city, several days before arrival. We found that nearly 75% of particles arriving in Beijing originated outside the city. The heaviest haze in Beijing occurred when the

trajectories passed through southern Hebei province, which is a heavy emission area. Based on particle tracking that is done within SOSAA, we found that roughly 5% of primary particles and 8% of secondary organic aerosols arriving in Beijing originated as far as Xinjiang province in far western China, another region with heavy emissions, especially from coal.

By piecing together trajectories arriving every hour, we were able to take the SOSAA output at arrival time and create a stationary view of air quality in Beijing, which we compared to observations at Beijing Uni. of Chemical Technology (BUCT), shown in Fig. 1.

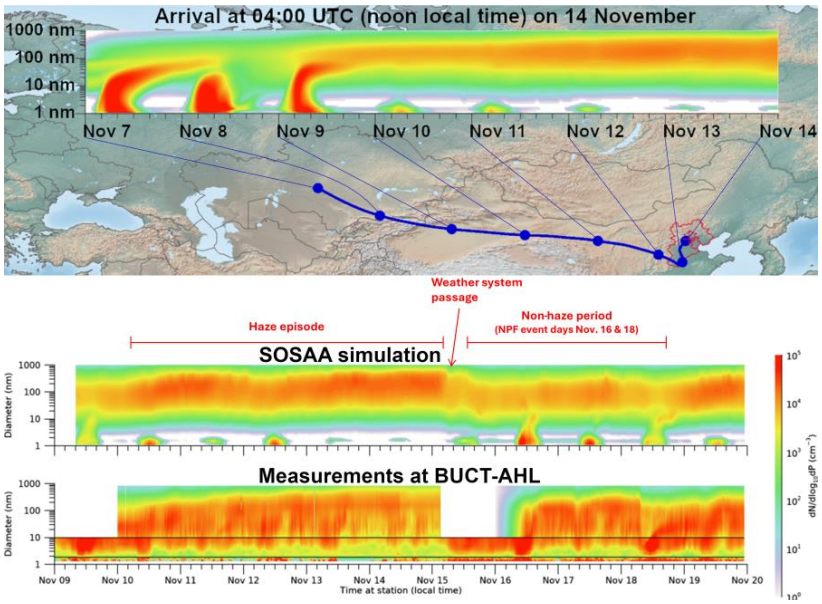

Figure 1. Top: Particle size distribution modelled along a trajectory arriving in Beijing during the peak of haze pollution. Bottom: Based on PSD along the trajectories, we simulated concentrations in Beijing, which are compared to DMPS, NAIS, and PSM measurements at BUCT.

Overall, SOSAA results agreed with the measurements, meeting the benchmark criteria of mean fractional bias < ±60% and mean fractional error <75%. Results of our scenario analysis showed that switching 25% of cars to electric, without any other emission control strategy, did not reduce PM with statistical significance, but it did reduce concentrations of gas pollutants. Likewise, introducing a comprehensive emission control strategy only within the city of Beijing decreased gas pollutant concentrations but did not improve PM. On the other hand, comprehensive emission control throughout the greater Beijing-Tianjin-Hebei (BTH) region reduced particle pollution by close to 15% and also reduced gas pollutant concentrations. However, comprehensive pollution reduction ended up increasing the smallest particle concentrations during particle formation events. Eliminating agricultural waste burning throughout China significantly reduced primary PM but did not significantly affect secondary aerosols or gas pollutants.

CONCLUSIONS

This study found that most of the haze during this episode was transported from outside Beijing, some of which originated as far as 2000 km west. We found that regional emission control is much more effective than regulations only in the city, and comprehensive emission controls are more effective than addressing only one emission source or sector. If haze is forecasted, a ban on agricultural burning in forecasted upwind directions of Beijing would also be an effective solution to help reduce haze pollution.

ACKNOWLEDGEMENTS

We would like to acknowledge the Center for Scientific Computing (CSC) for use of computing services for this project.

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SATELLITES CAPTURE SOCIOECONOMIC DISRUPTIONS DURING THE 2022 FULL-SCALE WAR IN UKRAINE

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Keywords: satellite data, nitrogen dioxide, Ukraine war, fires

INTRODUCTION

Since February 2022, the full-scale war in Ukraine has been strongly affecting society and economy in Ukraine and beyond. Satellite observations are crucial tools to objectively monitor and assess the impacts of the war. In this work we combine different satellite-based products such as tropospheric nitrogen dioxide (NO_2) and fire observations to detect and characterize changes in human activities linked to fossil fuel combustion processes.

METHODS

Nitrogen dioxide (NO_2) is a common air pollutant linked to fossil fuel combustion processes, and it is used as a proxy for human activities. Since NO_2 is short-lived in the lower atmosphere, it can be found in high concentrations near the emission sources and can therefore be used to assess changes in emissions. We use the Copernicus Sentinel 5-Precursor/TROPOspheric Monitoring Instrument (S5P/TROPOMI) NO_2 tropospheric column data available since April 2018 at spatial resolution of 3.5×5.5 km^2 (nadir) and daily global coverage, with overpass local time of 13:30. The TROPOMI NO_2 tropospheric columns were used to compile March-August average NO_2 maps for the analysis of persistent NO_2 enhancements and their year-to-year changes covering the period 2019–2022. TROPOMI NO_2 retrievals are gridded into a regular 1×1 km^2 grid using the area-weighted gridding method.

To identify the location of fires and thermal anomalies, we use the 375 m active fire data from the Visible Infrared Imaging Radiometer Suite (VIIRS) as well as the false colo imagery from Sentinel 2.

RESULTS

The results show significantly reduced NO_2 levels over the major Ukrainian cities, power plants and industrial areas: the NO_2 concentrations in the second quarter of 2022 were 15–46% lower than the same quarter during the reference period 2018–2021, which is well below the typical year-to-year variability (5–15%). In the Ukrainian capital Kyiv, the NO_2 tropospheric column monthly average in April 2022 was almost 60% smaller than 2019 and 2021, and about 40% smaller than 2020 (the period mostly affected by the COVID-19 restrictions). Such a decrease is consistent with the displacement of local population and corresponding emissions from the transport and commercial/residential sectors over the major Ukrainian cities. The NO_2 reductions observed in the industrial regions of eastern Ukraine reflect the decline in the Ukrainian industrial production during the war (40–50% lower than in 2021), especially from the metallurgic and chemical industry, which also led to a decrease in power demand and corresponding electricity production by thermal power plants (which was 35% lower in 2022 compared to 2021). In 2023 the air pollution partly rebounds closer to the pre-war levels, possibly due to a partial recovery in human activities.

Satellite observations of land properties and thermal anomalies indicate an anomalous distribution of fire detections along the front line in 2022, which are attributable to shelling or other intentional fires, rather than the typical homogeneously distributed fires related to crop harvesting.

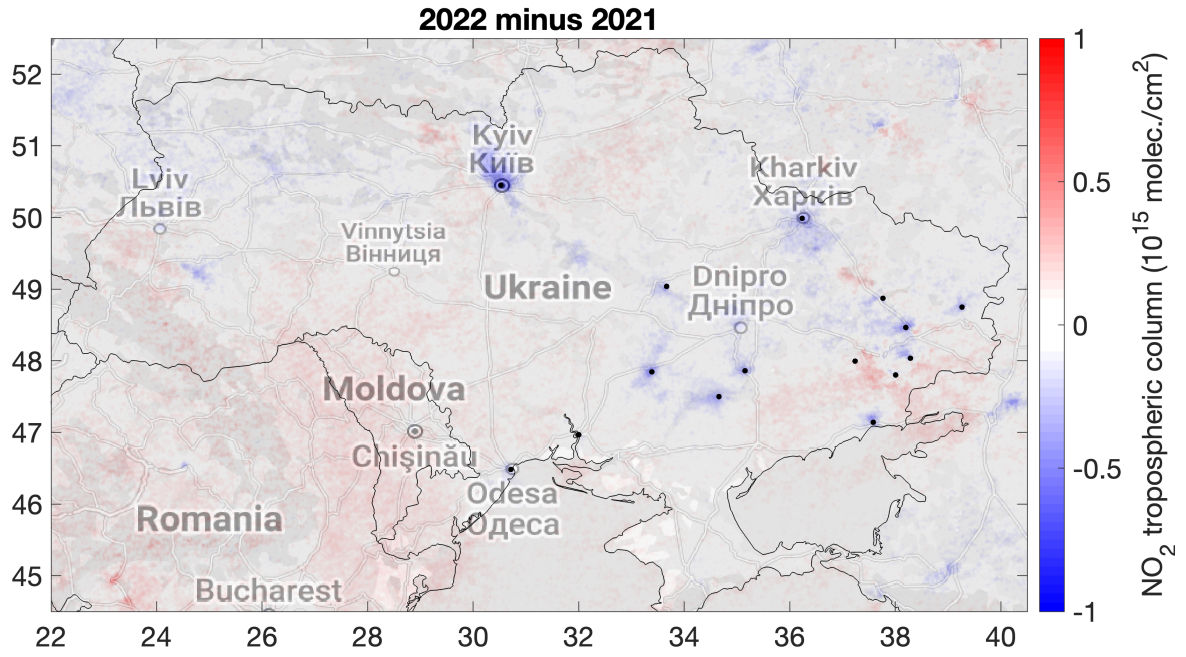

Figure 1. Difference of the March–August mean tropospheric NO_2 columns between 2022 and 2021 over Ukraine based on S5P/TROPOMI observations. Blue colors indicate reductions observed in 2022. Black dots correspond to the major cities, industrial areas and power plants.

CONCLUSIONS

The results provide timely insights into the impacts of the ongoing war on the Ukrainian society and illustrate how the synergic use of satellite observations from multiple platforms can be useful in monitoring significant societal changes. Satellite-based observations can mitigate the lack of monitoring capability during war and conflicts and enable the fast assessment of sudden changes in air pollutants and other relevant parameters. The results presented include an update to the paper by Ialongo et al. (2023) as well as considerations about additional military-related greenhouse gas emissions as described by Bun et al. (2024).

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MULTI-PRESSURE CHEMICAL IONIZATION MASS SPECTROMETRY FOR THE ANALYSIS OF COMPLEX GAS MIXTURES

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Chemical Ionization Mass Spectrometry (CIMS) is a well-established analytical method in atmospheric research, process monitoring, forensics, breathomics and food science. Despite significant advancements in procedural techniques, several instrument configurations, especially operating at different ionization pressures, are typically needed to analyze the full range of compounds from non-functionalized parent compounds to their functionalized reaction products. For polar, functionalized compounds, very sensitive detection schemes are provided by high-pressure adduct-forming chemical ionization techniques, whereas for non-functionalized, non-polar compounds, low pressure chemical ionization techniques have consistently demonstrated superior performance.

Here, using a MION2 chemical ionization inlet and an Orbitrap Exploris™ 120 mass spectrometer, we present multi-pressure chemical ionization mass spectrometry (MPCIMS), the combination of high- and low-pressure ionization schemes in a single instrument enabling quantification of the full distribution of precursor molecules and their oxidation reaction products from the same stream of gas without alterations. We demonstrate the performance of the new methodology in a laboratory experiment employing a-pinene, a monoterpene relevant to atmospheric particle formation, where MPCIMS allows to measure the spectrum of compounds ranging from the volatile precursor hydrocarbon to highly functionalized condensable reaction products. MPCIMS carries the potential as an all-in-one method for the analysis of complex gas mixtures, reducing technical complexities and the need for multiple instruments without compromise of sensitivity.

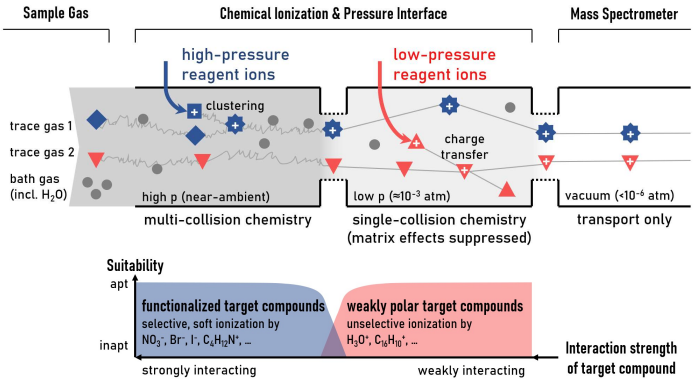

Figure 1. Principle of Multi-Pressure Chemical Ionisation Mass Spectrometry, where different ionization approaches are utilized at their required pressure within a single instrument.

ACKNOWLEDGEMENTS

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WINTERTIME BROWN CARBON CHARACTERIZATION: UNDERSTANDING CHEMICAL COMPOSITION AND LIGHT ABSORPTION IN RESIDENTIAL AND TRAFFIC AREAS

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Keywords: Brown carbon, Source apportionment, Chemical composition, Light absorption.

INTRODUCTION

Brown carbon (BrC) is a common component of organic aerosols (OA) that can influence climate due to its ability to absorb light in the near UV-visible spectrum (e.g., Laskin et al., 2015). Despite its potential climatic effects, our knowledge of the chemical composition and light-absorption characteristics of BrC remains limited. In this study, we performed real-time measurements of the chemical and light absorption properties of BrC during the winter/early spring at two different locations in Helsinki, Finland: a street canyon and a residential area. Our aim was to identify the sources of BrC, determine the mass absorption cross section (MAC) of different types of OA, and quantify the contribution of these OA types to light absorption across various wavelengths.

METHODS

A seven-wavelength aethalometer (AE33) was utilized to determine the light absorption of black carbon (BC) and BrC. Additionally, a soot particle aerosol mass spectrometer (SP-AMS) was employed to assess the concentration and composition of OA. We conducted a positive matrix factorization (PMF) analysis for the source apportionment of organics. Subsequently, a multiple regression analysis, following the approach of Qin et al. (2018), was conducted to determine the correlation factors for each type of OA with BrC light absorption across wavelengths of 370-660 nm, corresponding to their MAC_{BrC} values. The PMF factors at the traffic site were previously determined in Saarikoski et al. (2021).

RESULTS

Table 1. Contribution (%) of organic aerosol factors to brown carbon light absorption at the residential site.

	370 nm	**470 nm**	**520 nm**	**590 nm**	**660 nm**
LV-OOA-LRT	9.65	2.37	1.23	0.98	1.75
LV-OOA	9.72	12.79	13.88	15.88	17.45
BBOA	65.17	56.00	55.71	53.21	57.07
HOA	14.43	28.85	29.19	29.93	23.73
SV-OOA	1.02	0.00	0.00	0.00	0.00

Table 2. Contribution (%) of organic aerosol factors to brown carbon light absorption at the traffic site.

	370 nm	470 nm	520 nm	590 nm	660 nm
Tr-OOA	10.99	10.20	9.49	8.55	6.93
LV-OOA	23.66	21.85	18.12	15.50	8.84
HOA	4.09	7.12	6.53	6.58	2.80
BBOA	10.72	11.74	11.12	11.37	9.25
SV-OOA	0.00	4.65	5.72	7.80	4.47
LV-OOA (w/ BB)	44.44	49.03	50.19	67.71	67.71

CONCLUSIONS

The median contributions of BrC to light absorption were comparable in both the residential area and traffic sites, with peak contributions of around 20% at 370 nm. However, BrC in the residential area displayed intermittent spikes in absorption, while the traffic site demonstrated more consistent absorption trends. As anticipated, BrC absorption was predominantly at lower wavelengths (370 and 470 nm). The MAC_{BrC} was greater for the biomass burning organic aerosol (BBOA) factor, although the MAC_{BrC} values for low-volatility oxygenated organic aerosol (LV-OOA) were also elevated at the traffic site despite the potential effects of photobleaching. The BBOA PMF factor significantly dominated organic aerosol light absorption in the residential area, contributing between 53% and 65% across the measured wavelengths. In contrast, at the traffic site, both LV-OOA (w/BB) and LV-OOA were the primary contributors to light absorption. Adjusting the absorption Ångström exponent of BC (AAE_{BC}) between 0.8 and 1.2 caused significant changes in MAC_{BrC} of identified factors. Despite the observed variations, biomass burning consistently emerged as the dominant source of light-absorbing aerosols across all AAE_{BC} values, notably surpassing the contribution from traffic emissions. These results underscore the significant role of biomass burning and regional/long-range transport in BrC absorption during wintertime and highlight its potential relevance to climate warming.

ACKNOWLEDGEMENTS

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NUCLEAR OBSERVATIONS TO IMPROVE CLIMATE RESEARCH AND GHG EMISSION ESTIMATES – NUCLIM

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Keywords: Radon, GHG, Pollution, Climate.

INTRODUCTION

Greenhouse gases (GHGs) are the leading factors in global warming. Accurate estimates of baseline GHG levels permit a reliable assessment of the current climate state and a realistic prediction of climate change in the future, and they also provide a reference by which the magnitude of pollution events across Europe can be gauged. The Northern hemisphere is populated by about 90 % of humankind, where the GHG amount fractions have been profoundly influenced by various human activities since the Industrial Revolution. As a consequence, gaining accurate information of GHG baseline levels remains challenging in the Northern hemisphere. The Mauna Loa Observatory (MLO), located in the middle of the Pacific Ocean, offers the longest continuous carbon dioxide (CO_2) monitoring data of the Northern hemisphere. However, owing to its elevated location, the MLO data captures characteristics of the free troposphere instead of the boundary layer, where human beings reside, and the biosphere interacts with the atmosphere regulating the surface temperature. The Mace Head Atmospheric Research Station (MHD), on the west coast of Ireland, is a counterpart of the MLO site in monitoring North Atlantic background levels of GHGs. However, its location makes it prone to pollution from terrestrial sources. In NuClim, we will establish high quality long-term continuous GHG measurements following the protocols of Integrated Carbon Observation System (ICOS) at the Eastern North Atlantic site on Graciosa Island (ENA Graciosa) of the Portuguese Azores archipelago. The ENA Graciosa site is part of the Atmospheric Radiation Measurement (ARM) user facility. The remote location, low elevation, and small size of Graciosa Island as well as access to ARM infrastructure equip the measurement site with good baseline monitoring capability.

Different methods have been developed for GHG baseline determination, which include using meteorological data, statistical methods, transport models and atmospheric tracers (Chambers et al., 2016; Derwent et al., 1998; Henne et al., 2010; Wenger et al., 2019; Zanis et al., 2007). Many of these approaches are site-dependent, therefore posing limited applicability to other sites situated in distinct environments. For site-independent baseline air mass determination, Radon-222 has been recognised as the ideal tracer, for it is an inert gaseous radionuclide that undergoes radioactive decay with a half-life of approximately 3.8 days.

In this project, we will conduct high quality radon activity concentration measurements, calibrated traceable to national standards thanks to newly developed Radium-226 emanation sources, along with GHG monitoring aiming for accurate identification of baseline conditions of marine boundary layer. In addition, with the available data of meteorological parameters, trace gases and aerosols from ARM, the influences of local pollution episodes will be investigated and taken in consideration in determining the clean air masses for GHG baseline analysis. Furthermore, we also aim to quantify the emission and uptake of CO_2 by marine microbes and understand their interaction with global CO_2 budget as well as to explore aerosol properties and cloud microphysics in the marine environment and distinguish their responses to biogenic and anthropogenic effects.

METHODS AND EXPECTED RESULTS

By collecting high quality long-term continuous radon (measured by ANSTO 1500 L two-filter dual-flow-loop detector) and GHG (measured with a cavity ring-down spectrometer) data from the Graciosa ENA site, we will make air mass classification according to radon concentrations and identify GHG baselines from the 'cleanest' air masses with the least radon loading. The long-term data guarantees statistical reliability and enables the investigation of seasonality and interannual variability. As part of NuClim, the radon monitor at MHD will also be upgraded to an ANSTO 1500 L detector, which, together with the already available trace gas, meteorological, aerosol and cloud data, allow a unique opportunity to characterise the latitudinal gradient in atmospheric baseline conditions as well as in aerosol properties and cloud microphysics in the marine environment.

Refining GHG baseline determination is directly useful in reducing GHG uncertainties in predicting future climate and the project outcomes are also valuable in exploring the feedback of aerosol-cloud interactions on climate by gaining insights into anthropogenic effects on aerosol chemical compositions, cloud condensational nuclei activation, and low cloud formation in the marine environment.

ACKNOWLEDGEMENTS

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LINKING SO_2, SULFURIC ACID, CLUSTERS, AND SMALL PARTICLES: IMPLICATIONS FOR FUTURE PARTICLE FORMATION EVENTS

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Keywords: SO_2, NH_3, H_2SO_4-NH_3 clusters, New particle formation.

INTRODUCTION

Sulfur dioxide (SO_2) plays a crucial role in new particle formation (NPF) by being oxidized in the atmosphere to produce sulfuric acid (H_2SO_4), one of the most important compounds involved in the nucleation process. SO_2 emissions, primarily from volcanic eruptions, fossil fuel combustion, and industrial activities, contribute to atmospheric sulfuric acid levels, which in turn promote the growth of clusters into larger aerosol particles.

The Northern agricultural ecosystem and agricultural activities play a crucial role in atmospheric chemistry and climate regulation. Agricultural activities release ammonia (NH_3), which can react in the atmosphere with H_2SO_4 to form $(H_2SO_4)_m(NH_3)_n$ clusters that can grow to new particles. This new particle formation can subsequently exert significant impact on the production of cloud condensation nuclei (CCN) and, thus, the regulation of atmospheric temperature.

METHODS

We performed measurements of H_2SO_4, $(H_2SO_4)_m(NH_3)_n$ clusters, and highly oxidized organic molecules (HOMs) at an agricultural field site in Viikki, Helsinki (SMEAR Agri) from April to September 2023. Species were measured using a nitrate ion (NO_3^-)-based chemical ionization atmospheric pressure interface time-of-flight mass spectrometer (CI-APi-TOF, Aerodyne Research Inc. & Tofwerk AG) (Jokinen *et al*., 2012). Concentrations of ions in the range of 0.8–42 nm and particles in the range of 2.5–40 nm were measured using a neutral cluster and air ion spectrometer (NAIS; Airel Ltd) (Mirme and Mirme, 2013; Manninen *et al*., 2016).

RESULTS

Between April and May 2023, a wide range of SO_2 and NH_3 concentrations were captured, owing to sporadic power plant plumes and local fertilization events, while other factors (such as species and meteorological parameters) stayed relatively unchanged. We also observed neutral clusters, such as $(H_2SO_4)_3(NH_3)HSO_4^-$, $(H_2SO_4)_4(NH_3)HSO_4^-$, and $(H_2SO_4)_4(NH_3)_2HSO_4^-$, exhibited distinct diurnal variations, showing higher concentrations during the day and lower concentrations at night. NH_3 is almost always high enough to not influence the H_2SO_4-NH_3 cluster component proportion and concentrations, not limit the clusters and growth. SO_2 plumes are important tracers. We find a clear correlation between the following species, linking H_2SO_4 all the way the formation of clusters and small particles across a broad range of SO_2 and NH_3 concentrations: H_2SO_4 and its dimer, H_2SO_4 dimer and $(H_2SO_4)_m(NH_3)_n$ clusters, $(H_2SO_4)_m(NH_3)_n$ clusters and 2-2.3 nm negative ion number concentration, 2–2.3 nm negative ion and 3–5 nm particle number concentration.

Tuovinen *et al.* (2024) have found that the negative ions between 2.0 and 2.3 nm (2.16 size bin) are well suited for representing the NPF on a local scale. We investigated the relationship between these $(H_2SO_4)_m(NH_3)_n$ clusters and 2.16 size bin negative ions and found a linear correlation, indicating that $(H_2SO_4)_m(NH_3)_n$ clusters very likely contribute to the local NPF events at the Viikki station. Long-term measurement at a nearly measurement site in Kumpula shows that the SO_2 decrease will lead to the decrease in NPF frequencies. As global SO_2 concentrations gradually decline, giving implications for future particle formation events.

CONCLUSIONS

Our study highlights the significant role of $(H_2SO_4)_m(NH_3)_n$ clusters in NPF at the Viikki station, particularly during periods of elevated SO_2 concentrations. NH_3 levels were almost consistently high enough to not limit cluster formation or growth, indicating that SO_2 is a key tracer in this process. We observed clear correlations across species, from H_2SO_4 monomers and dimers to $(H_2SO_4)_m(NH_3)_n$ clusters, negative ions between 2-2.3 nm, and small particle number concentrations (3–5 nm). This progression indicates that $(H_2SO_4)_m(NH_3)_n$ clusters are crucial in connecting SO_2 emissions to the formation and growth of atmospheric particles in this region, with implications for future trends in new particle formation as global SO_2 concentrations decline.

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COULD CONTRAIL PROPERTIES CHANGE WHEN COMMERCIAL AIRCRAFT USE SUSTAINABLE AVIATION FUEL INSTEAD OF STANDARD JET A-1 FUEL?

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Keywords: sustainable aviation fuel, aircraft emissions, soot, ice nuclei, contrail

INTRODUCTION

Commercial aircraft engines emit hot gases, such as carbon dioxide (CO_2), water vapor (H_2O), nitrogen oxides (NO_x), sulfur oxides (SO_x), and hydrocarbons (HC), while also emitting primary particulates such as soot particles. For long-haul flights, commercial aircraft spend most of their flying time in the cruise phase (at altitudes between 9 and 12 km), where background particle concentrations are low and the residence time is long. Under specific conditions of temperature and humidity, aircraft emissions can trigger the formation of condensation trails (contrails) (Schumann 1996, 2005). Furthermore, these contrails can evolve into contrail cirrus that can last for a few hours, becoming indistinguishable from natural cirrus. Overall, these anthropogenic clouds increase the Earth's cloudiness and therefore could affect the climate.

Recently, Sustainable Aviation Fuel (SAF) has been introduced for commercial aircraft engines. SAF could be a possible alternate/complement of Jet A-1. However, the effect of the aerosol particles emitted from commercial aircraft engines using SAF on contrails is not well understood.

METHODS

The VOLCAN project (V*OL avec Carburants Alternatifs Nouveaux*) was launched to study the use of 100 % SAF without aromatic or sulphur content. One objective of the project is to measure the ice nucleation properties during an on-wing ground experiment behind an A321neo equipped with LEAP-1A engines and using four different fuels . During an extensive VOLCAN test campaign in Toulouse, France, in March 2023, a LEAP-1A engine was run in two different combustion modes: the standard, lean burn mode, and a forced rich-burn mode to achieve the nvPM level of engines equipped with Rich-Quench-Lean combustors. During the ground tests, four different fuels were used: a standard Jet- A-1 fuel, a 100% Hydroprocessed Esters and Fatty Acids (HEFA) fuel, a Synthetic Paraffinic Kerosene (SPK) fuel with high aromatic content and finally a SPK with low aromatic content.

The ice nucleation capacities of the generated particles was characterized using the PINCii (Portable Ice Nuclei Chamber 2) instrument. PINCii is a newly developed continuous flow diffusion chamber (CFDC) for

measuring ice nucleating particles (Castarède 2023). PINCii is a vertically oriented parallel-plate CFDC that has been engineered to improve upon the limitations of previous generations of CFDCs. After entering PINCii, the sampled particle aerosols are exposed to precisely controlled supersaturated humidity (typically here RHice=140%) and temperature (typically -50°C). The ratio of activated to total particles is computed by comparing the number of ice particles counted leaving PINCii to the total number of particles entering PINCii.

RESULTS

In this presentation, we present VOLCAN data showing how the different fuels and different engine regimes affect the ice nucleating capabilities of the emission aerosol particles. To our knowledge, these are the first INP measurements from SAF combustion.

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DEPOSITION ICE NUCLEATION ON SILICA PARTICLES VIA AN ADSORPTION-FREEZING MECHANISM

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Keywords: Ice nucleation, Insoluble aerosol, Silica, FHH adsorption theory, Classical nucleation theory

INTRODUCTION

Deposition ice nucleation is a process that has traditionally been thought to occur by direct deposition of water vapor molecules into critical sized ice clusters on dry, water insoluble particles. Despite the seeming simplicity of the process, deposition ice nucleation experiments have revealed features that have not been explained in a satisfactory manner. For example, the temperature dependence of the critical supersaturation often reveals a U-shaped curve (Hoose and Möhler, 2012): as temperature is lowered the critical supersaturation first decreases, then flattens out and then starts to increase. Hoose and Möhler noted that the low temperature behaviour (increasing critical supersaturation) is contrary to the common assumption that lower temperatures always facilitate ice nucleation. In fact, this strictly speaking applies to freezing only; vapor-to-ice nucleation theories (both the classical nucleation theory and the adsorption nucleation theory) predict monotonously increasing critical supersaturations as temperature is decreased.

During the past decade, an alternative mechanism has been suggested to explain deposition ice nucleation involving porous ice nuclei (Marcolli 2014, 2020; David et al. 2019). It is assumed that capillary condensation of water vapor in the pores is followed by homogeneous or heterogeneous freezing and growth of ice out of the pores. David et al. (2019) studied this pore condensation and freezing mechanism in the laboratory using both porous and nonporous silica particles and found that the porous particles nucleate ice at a considerably lower ice supersaturation at -55 °C than the nonporous particles.

In this work, we have developed a theoretical description of freezing of adsorbed water films on silica particles. We compare the results from our theoretical calculations to experimental ice nucleation data measured using the SPectrometer for Ice Nucleation (SPIN) chamber, and experimental data found in the literature.

METHODS

Multilayer adsorption of supercooled water on silica particles is modelled using the FHH adsorption theory accounting for a Kelvin correction due to the curvature of the sub-micron ice nuclei (Sorjamaa and Laaksonen, 2007). Freezing of the adsorbed film is modelled using classical nucleation theory. We assume homogeneous freezing since silica is a substance that induces ice pre-melting at its surface (David et al., 2019). For freezing to occur at a given temperature and humidity, there are three requirements: 1) the nucleation rate must be sufficiently high; 2) the adsorbed film must be thick enough to physically accommodate the critical nucleus; 3) the frozen, critical nucleus has to be stable against the supersaturated vapor.

The ice nucleation measurements were carried out at temperatures between -10 and -65 °C using the modified SPIN instrument (Welti et al, 2020) with polydisperse silica particles.

RESULTS

Our experimental results are in general agreement with those found in the literature and extend the experimental temperature range to ten degrees lower temperatures than previously. As temperature is

lowered from -10 °C, there is at first no ice formations. Close to the homogeneous freezing temperature of cloud droplets (-38 °C), ice is formed near the water saturation line and then the critical supersaturations drop quite abruptly from 145 % RH_i (relative humidity with respect to ice) to close to 110 % RH_i. As temperature is lowered further, the critical supersaturations increase again in parallel to the water saturation line. The U-shaped temperature dependence suggested by Hoose and Möhler (2012) is thus seen below -30 °C.

Our theoretical critical supersaturations match the experimental data well. Our model suggests that the drop of critical supersaturation close to -38 °C occurs because nucleation rate becomes sufficiently high at those temperatures for ice nucleation to occur below water saturation. However, critical supersaturation does not drop below 110 % RH_i because at lower humidities the adsorbed water film is not thick enough to accommodate the critical ice nucleus. At lower temperatures, the critical supersaturations increase in parallel to water saturation as the thickness of the water film stays constant at a fixed relative humidity with respect to water.

Interestingly, our experimental critical supersaturation at -55 °C coincides with that of the porous silica measured by David et al., 2019, whereas their nonporous silica nucleated ice at a substantially higher RH_i. We note that silicas can be quite hydrophilic or rather hydrophobic depending on the densities of surface silanol (SiOH), siloxide (SiO^-) and siloxane (Si-O-Si) groups. It appears that the silica used by David et al. was more hydrophobic than ours, and therefore their nonporous silica adsorbed sufficiently water to accommodate ice nucleation only at considerably higher RH_i than what we observed (140 % vs. 112%).

CONCLUSIONS

We have developed an adsorption-freezing model for predicting critical supersaturations of deposition ice nucleation with nonporous particles that nucleate ice homogeneously. The model reproduces experimental critical supersaturations measured using silica particles as ice nuclei, and thus explains the U-shaped temperature dependence suggested by Hoose and Möhler (2012). In the future, we aim to incorporate heterogeneous freezing into the model.

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ESTIMATING GLOBAL ACCUMULATION-MODE PARTICLE NUMBER CONCENTRATIONS WITH MACHINE LEARNING AND REANALYSIS DATA

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Keywords: Cloud condensation nuclei, Accumulation-mode particles, Machine learning.

INTRODUCTION

We trained machine learning models to estimate global accumulation-mode particle number concentrations. The accumulation-mode size range is important for understanding cloud condensation nuclei (CCN) but quantifying the global concentration of cloud-active aerosol is challenging (Rosenfeld *et al*., 2014). Our solution used machine learning methods and reanalysis data to extrapolate outside existing measurement stations.

METHODS

We taught our models to estimate the number concentration of particles larger than 100 nm (N100) using 1) in-situ N100 measurements from 35 stations and 2) CAMS and ERA5 reanalysis variables known to influence particle formation and growth. We trained two models: a simple Linear Regression model (LR) and a more complex XGBoost (XGB) model. Once the models were trained, we gave global reanalysis data fields as input for the trained models and generated daily N100 estimates.

RESULTS

We generated daily N100 estimates for 2013 both with LR and XGBoost (Figure 1a-b). The two models yielded similar results, and when we calculated the error value between the daily estimates at each grid cell, we saw that the estimates differed mainly in some emission hotspots as well as marine and remote regions (Figure 1c).

Comparing the estimated and observed N100 values at the measurement stations revealed the models' ability to capture the range of N100 values present in the training set. However, when we investigated excluding a station from the training set, the global model performance at that station clearly decreased unless similar stations remained in the training set. The decrease suggests potential unreliability in environments and conditions unrepresented by our measurement stations.

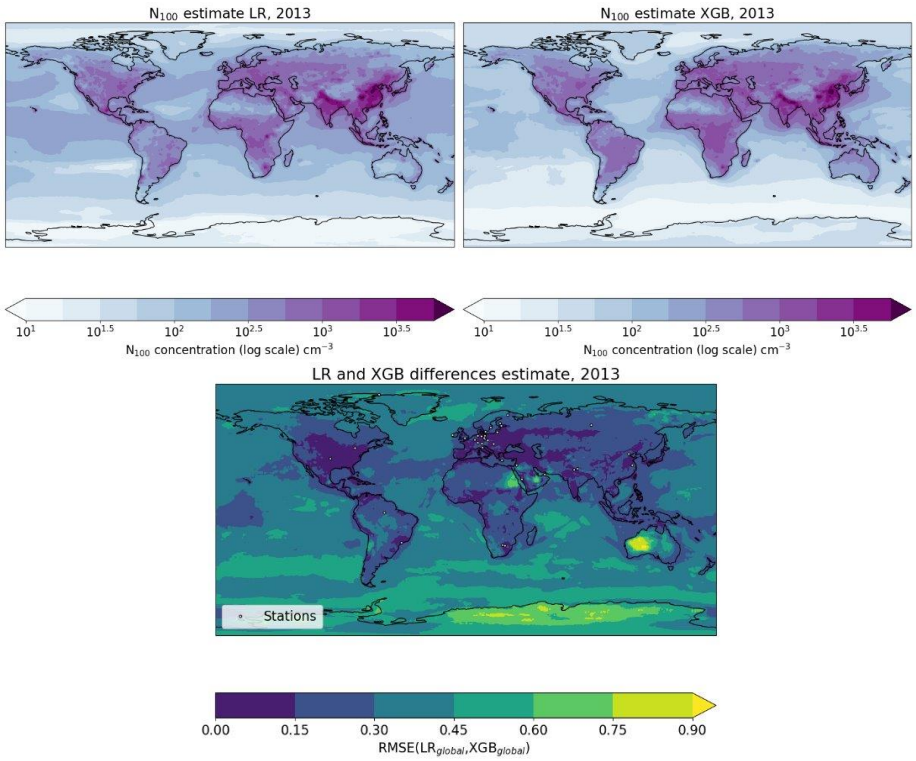

Figure 1. The 2013 average concentration calculated from daily N100 estimates generated with a) LR model and b) XGBoost model. Panel c) shows the comparison between the two models (root mean squared error of the daily log10-transformed N100 estimates at each grid cell), where higher values indicate a larger difference between the model estimates.

CONCLUSIONS

Our method can be used to produce global daily N100 estimates for the time-period covered by the reanalysis datasets. However, the model results can be unreliable in environments and conditions unrepresented in the model training. This challenge could be addressed by incorporating additional data, especially from outside of Europe, by including both new environments and longer time-series of data, covering several seasonal cycles in varying years. Shorter time-series of measurements could be utilized in investigating model performance in a wide scope of different environments.

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A NEW ATMOSPHERIC MEASUREMENT SITE IN NORTHERN BOTSWANA

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Keywords: size distribution, new particle formation, biomass burning, savanna.

INTRODUCTION

Continuous long-term measurements at several sites in South Africa have shown record-high frequency of new particle formation in grassland and savanna biomes (Nieminen *et al.*, 2018). Furthermore, the measurements in South Africa indicate substantial secondary aerosol formation in landscape fire emissions within the first few hours of atmospheric ageing (Vakkari *et al.*, 2018). However, measurements at the savanna and grassland sites in South Africa are affected by anthropogenic emissions from the Highveld region nearby Johannesburg, except for a clean sector towards the semi-arid Karoo region (Vakkari *et al.*, 2015). Therefore, seeking to minimise the anthropogenic influence on aerosol sources and processes in a savanna environment we set up a new atmospheric measurement site in northern Botswana.

METHODS

The new measurement site is located at 18.52°S, 21.94°E and 1007 m above sea level in northern Botswana in the Okavango delta area. The site is 20 km south of the town of Shakawe, located just outside the village of Xhaoga. The location is a compromise between as clean airmass footprint area as possible and logistical requirements of electricity, mobile network coverage and accessibility for operating the measurements. A 6 m long insulated and air-conditioned sea container was installed on site for the measurements.

Instrumentation at the site includes basic meteorological parameters, aerosol particle size distribution with a differential mobility particle sizer (DMPS), black carbon (BC) from a multi angle absorption photometer (MAAP), as well as CO and CO_2 concentrations. For an intensive campaign, an aerosol chemical speciation monitor (ACSM) for aerosol chemical composition, an online gas chromatograph coupled to an MS detector (GC-MS) for volatile organic compounds and a single particle soot photometer (SP2) for refractive BC have been installed at the site. Measurements commenced on 12 August 2024 and the intensive campaign is planned to continue until December 2024 with other measurements continuing even after this period.

RESULTS

The period from August to October is late dry season in northern Botswana and savanna fires are common in the region. Therefore, it is not surprising that chemical composition of the submicron aerosol is dominated by organic compounds. Also, the size distribution is generally dominated by accumulation mode particles, except when fresh smoke is observed. However, on days with lower pre-existing aerosol concentration also regional new particle formation is observed (Fig. 1). The frequency of new particle formation events appears much lower than in South Africa, though, since during the first two months only 10 such events were observed.

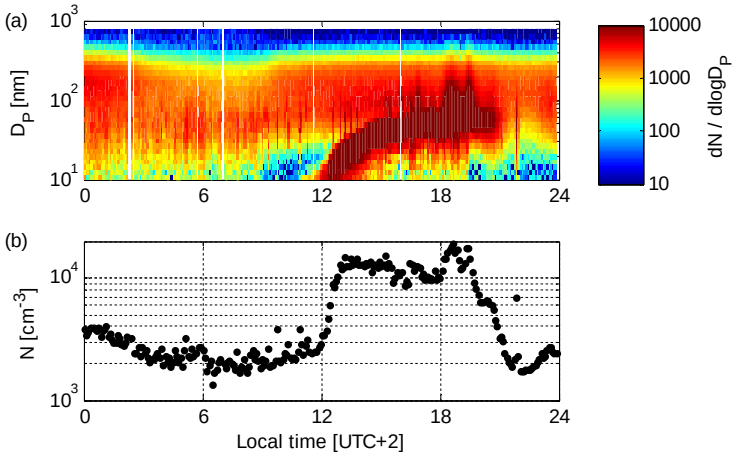

Figure 1. (a) Submicron number size distribution from DMPS measurements on 31 August 2024. (b) Total number concentration integrated from the size distribution.

CONCLUSIONS

We have launched a new atmospheric measurement site at the northern edge of the Okavango delta area in Botswana. The first weeks shown strong impact of savanna fire emissions, but also regional scale new particle formation is observed. Continuing the measurements, we expect to observe the effect of biogenic emissions on aerosol and trace gas budget with the onset of the wet season in late 2024.

ACKNOWLEDGEMENTS

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EFFECT OF NOISE BARRIERS ON AIR QUALITY USING PALM

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Keywords : Particle Emission, Noise Barrier, LES, Air Quality

INTRODUCTION

The air quality in cities is crucial for public health. The movement of air and dispersion of pollutants are influenced by urban structures. This study examines the impact of a noise barrier on road dust and traffic aerosols using the parallelized large eddy simulation model PALM (Maronga et al., 2020), which can resolve the turbulent motion and pollutant dispersion in a real urban canyon by carrying out high computational simulations and maintaining a sufficiently high grid resolution (Strömberg, et al. 2023).

METHODS

In this study, the sectional aerosol module (SALSA) embedded into the PALM has been used. This module can introduce aerosol processes such as coagulation and dry deposition into the simulation. In addition, the PALM model system features an LES core for atmospheric and oceanic boundary layer flows. Dynamic boundary conditions are provided by extracting data from numerical weather prediction data from the MetCoOp Ensemble Prediction System (MEPS data).

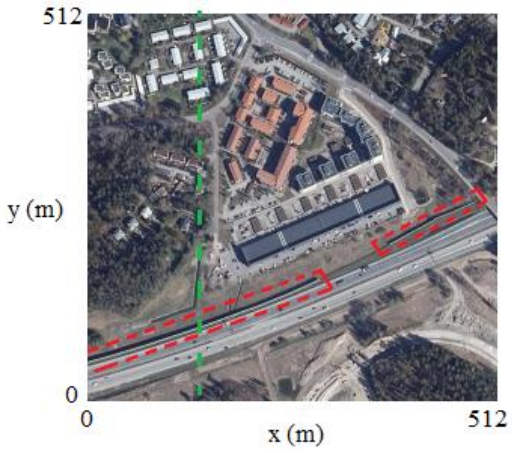

Fig. 1. Child domain of simulation including a noise barrier next to Turunväylä highway located in Espoo, Finland.

The information regarding topography is obtained from the archive of the National Land Survey of Finland with a 2 m grid resolution. It is important to choose a day when the wind direction is perpendicular to the road to see the highest impact of noise barrier on road dust dispersion next to the highway. The information about the wind direction during the air quality monitoring is obtained from the Finnish Meteorological Institute's Open Data. Aerosol emission values for each road in the domain are calculated using traffic volume data of different types of vehicles and the average emission factor. Two scenarios will be compared: one with noise barrier and one without it. The aim is to determine the influence of the noise barrier on roadside dust and traffic aerosol levels in the surrounding environment. To validate the simulation outcomes, data derived from a measurement campaign will be utilized. The measurement location is close to a noise barrier next to a highway called Turunväylä, in Espoo, Finland (Figure 1) as the main source of emissions.

RESULTS AND CONCLUSIONS

Results showed that noise barriers reduce the level of concentration on the downwind side of the barrier by 10% to 70% at some locations (See Fig. 2). This result aligns with the previous studies that highlight the positive effect of the noise barriers on air quality. However, noise barriers cause a high concentration plume on the source side, leading to increased concentrations on the highway. The strongest effect of the noise barrier is observed immediately behind it, and it diminishes as the distance from the barrier increases.

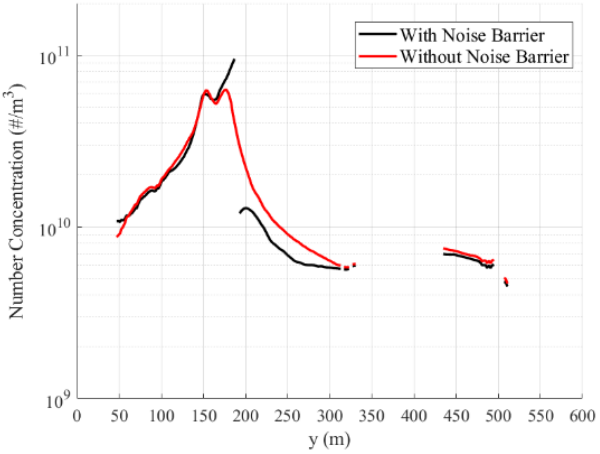

Fig. 2. The pollutant concentration along the domain (green dashed line in Fig. 1), with 3 m from the ground level

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QUANTIFYING THE CONTRIBUTIONS OF NEW PARTICLE FORMATION AND TRAFFIC EMISSIONS ON URBAN ULTRAFINE PARTICLE CONCENTRATIONS

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Keywords: Ultrafine particles, New particle formation, Traffic emissions,.

INTRODUCTION

Growth of nucleation mode particles (with initial diameter $D_P < 25$ nm) contributes strongly to accumulating aerosol pollution (e.g., $PM_{2.5}$) and cloud condensation nuclei concentrations in polluted urban and clean boreal terrestrial environments (Hakala *et al*., 2022; Räty *et al*., 2023). In addition to atmospheric new particle formation (NPF) process, occurring both in strong atmospheric NPF events (NPFEs) and with lower rate outside these discernible NPFEs, nucleation mode particles down to sub-3 nm sizes are emitted in large numbers from traffic combustion (Rönkkö *et al*., 2017). Distinguishing NPF and traffic sources in the observed urban particle number (PN) size distribution data is crucial to quantify their roles in urban air quality and climate.

METHODS

Here, we present methods that we are currently developing for distinguishing nucleation mode particles originating from NPF and traffic.

The first method is conducting a classification procedure for elevated PN concentration events in nucleation mode size range. This procedure is further developed from the NPFE classification scheme developed by Dal Maso et al. (2005). In addition to more detailed classes for NPFEs with different spatial connection to the observation site (NPFEs occurring both in situ and wide upwind area, NPFEs occurring in situ but limited upwind area and NPEs occurring in wide area upwind but not in situ), the procedure classifies different Undefined Events (UEs) as events that are likely related to nearby primary emissions, e.g., traffic.

In the second method we present, we utilise NOx concentration as a tracer for traffic emissions and develop further the methodologies developed by Rodrigues and Cuevas (2007), Okuljar et al. (2021), and Chen et al. (2023). We investigate long time series of PN and NOx concentrations in traffic-influenced environment, starting with data recorded at the HSY supersite at Mäkelänkatu in Helsinki (Kuuluvainen et al., 2018). The typical contribution of traffic to PN concentration under certain NOx concentration is estimated by a mode that forms the lower end of the probability distribution of PN concentrations in the investigated particle size ranges. With this method we can both determine the overall contribution of traffic on the observed particle concentration and estimate the probabilities of traffic and other (mainly NPF) contributions to the observed concentrations at each time step.

Finally, we describe how the above methods can be utilised for developing an estimated time series for NPF and traffic source of particles in different size ranges in the urban environment (Kulmala et al., 2024).

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NEW GUIDANCE DOCUMENTS ON ADVANCED AIR QUALITY PARAMETERS BY RI-URBANS

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Keywords: Air pollution, ultrafine particles, black carbon, ammonia, oxidative potential of PM.

INTRODUCTION

The scientific community has focused on many essential air quality parameters, such as ultrafine particles (UFP), black carbon (BC) and ammonia (NH3), already for decades recognizing their significant implications for public health and climate. Despite this attention, existing air quality regulations have largely overlooked these pollutants. However, with the anticipated release of the new Air Quality Directive (AQD) in late 2024, monitoring these parameters will become mandatory within the EU. The directive will also encourage monitoring additional pollutants, including the oxidative potential of particulate matter. For instance, in Finland, a designated urban background supersite will need to be established to measure UFP, their size distribution, BC, and various traditional air pollutants. Similar requirements will apply to rural supersites, and a separate focus is given on UFP and BC monitoring in areas with expected high concentrations.

RESULTS AND CONCLUSIONS

The AQD outlines the measurement methods that EU countries must adopt for monitoring these pollutants. However, it does not provide recommendations for new pollutants due to the absence of suitable European standards by CEN. To address this gap, the RI-URBANS project, in collaboration with ACTRIS, is developing new guidance documents in the form of Service Tools (STs). These STs will elucidate the various measurement methods available, their levels of standardization and harmonization, and the associated quality control and assurance (QA/QC) practices. Furthermore, they will emphasize the importance of these measurements and their added value. A summary of these guidance documents is presented in Table 1.

In addition to monitoring guidance for novel air quality parameters, the STs will encompass methodologies on various topics that benefit the scientific community and advanced air quality networks. This includes diverse source apportionment methods for both online and offline measurements, vertical profiling, emission inventories for new parameters, urban mapping, modelling, and health effect evaluations (Table 1).

While the finalization of these guidance documents is expected by 2024, draft versions currently under review are already accessible (RI-URBANS, 2024). These documents will be vital for air quality networks and national reference laboratories tasked with implementing new measurements within the forthcoming two-year transition period of the new AQD. Additionally, they will provide scientists with essential tools to harmonize measurements and methodologies across the EU and beyond.

Table 1. The new guidance documents prepared by the RI-URBANS project.

Number	Guidance document topic
ST1	Ultrafine-Particle Number Size Distributions (UFP-PNSD)
ST2	Black Carbon (BC)
ST3	Offline and Online particulate matter (PM) speciation
ST4	Oxidative potential of particulate matter (OP of PM)
ST5	Volatile Organic Compounds (VOCs)
ST6	Ammonia (NH3)
ST7	Measurements of boundary level height
ST8	Measurements of vertical profiles of aerosols
ST9	Measurements of vertical profiles by commercial aircrafts
ST10	Source apportionment of PM based on offline and online PM speciation
ST11	Source apportionment of UFP, BC, OP and VOCs using receptor modelling
ST12	Deterministic urban modelling of fine PM and PNC
ST13	Mapping ultrafine particles and citizen science
ST14	Evaluation of health effects of novel air quality parameters
ST15	Emission inventories for regional and urban scale modelling applications
ST16	UFP-PNSD multiscale modelling

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EXAMINING THE ROLE OF SEDIMENTATION IN MODULATING ICE NUCLEATION PATHWAYS IN CIRRUS CLOUDS

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Keywords: ATMOSPHERIC MODELLING, HETEROGENEOUS NUCLEATION, HOMOGENEOUS FREEZING CIRRUS CLOUD SIMULATION

INTRODUCTION

Cirrus clouds in the upper troposphere have a substantial impact on Earth's radiative balance, with their formation mechanisms closely tied to the presence and vertical distribution of ice-nucleating particles (INPs). This study investigates upper tropospheric cirrus clouds with a heavy emphasis on the the dynamics of dust transport, sedimentation, and their influence on heterogeneous and homogeneous nucleation processes. This study utilizes data from the MACPEX measurement campaign (Jensen *et al.*, 2013), with a particular focus on observations from the April 16th flight. The unique airmass flow trajectory on this day allowed for detailed modeling of changes in the vertical distribution of aerosols and ice particles, providing valuable insights into cirrus cloud formation dynamics.

METHODS

The simulations are conducted using UCLALES-SALSA (Tonttila *et al.*, 2017) model. Both heterogenoeus and homogeneous freezing are modeled. From known mechanisms of heterogeneous freezing, deposition nucleation is modeled. The data from NASA MACPEX (Jensen *et al.*, 2013) campaign is used to create suitable conditions for cirrus cloud formation. The simulations are conducted at high spatial and temporal resolutions. The simulation set up in this project is based on MACPEX science flight conducted on 16th of April 2011 where instruments on Nasa WB-57 measured synoptic cirrus clouds. Mineral dust is used as the sole type of insoluble INP, with concentration and size distribution based on measured values with PALMS instrument.

CONCLUSIONS

Simulations reveal that sedimentation of dust particles plays a critical role in shaping the vertical profile of INPs within cirrus clouds. Multiple repetitions of cirrus cloud formation lead to vertical shift of INPs through sedimentation of ice crystals and altered the freezing mechanisms that followed. Running the model with measured mineral dust concentration showed that homogeneous

freezing is mostly suppressed with majority ice forming via heterogeneous freezing. When the dust concentration was reduced to simulate conditions following multiple nucleation events, the impact of heterogeneous freezing on cirrus cloud formation was significantly diminished. Instead, homogeneous freezing became the primary contributor to the overall cloud structure. Figure 1 illustrates a model scenario with a lower INP concentration, where only a small amount of ice initially forms through heterogeneous freezing, followed by a high concentration of ice crystals generated by homogeneous nucleation. This study demonstrated the significance of local vertical transport of INPs and their impact on ice nucleation mechanisms present inside cirrus clouds. A manuscript on this study is currently under preparation. In future studies, langrarian large scale forcing will be used to alter the LES model domain to more accurately track the effects of real time atmospheric conditions on cirrus clouds.

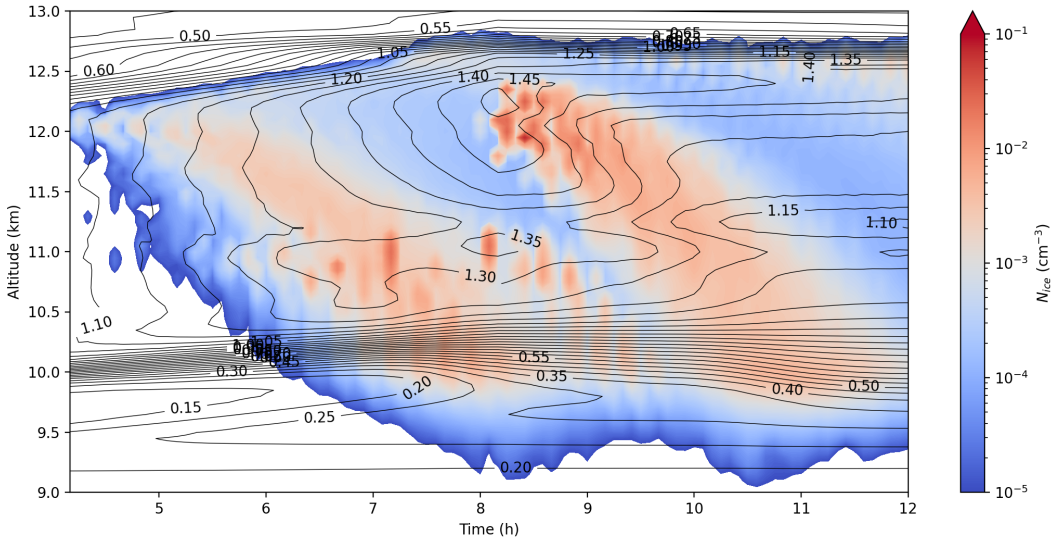

Figure 1: Ice crystal number concentration vertical profile over time. Black contours show the supersaturation over ice at 0.05 interval. As visible, homogeneous freezing requires high humidity to occur. Homogeneous freezing occurs around 8 hours into the simulation.

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ACCRETION PRODUCTS FOR PROBING RO2 CHEMISTRY

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Keywords: Oxidation, Radical chemistry, Mass spectrometry.

INTRODUCTION

Atmospheric oxidation of volatile organic compounds forms highly oxygenated organic compounds (HOMs), key precursors to secondary organic aerosol (SOA) (Ehn et al., 2014; Bianchi et al., 2019). HOMs form through reactions of organic peroxy radicals (RO_2). Especially potent group of HOMs are accretion products, formed in the self- and cross reactions of RO_2 radicals (Berndt et al., 2018).

METHODS

We conducted chamber experiments where we oxidised α-pinene, emitted in abundance by boreal forests, with ozone. We varied the oxidation rate, and measured oxidation products with a chemical ionisation mass spectrometer (CIMS). We operated the chamber in a continuous flow mode, so both RO_2 radicals and accretion products were in a steady state. In addition, we also added nitrogen oxides and seed particles to the chamber.

RESULTS

The accretion products could be grouped based on their responses to increasing oxidation rate. These responses reveal details about RO_2 lifetimes and reactivities, which have implications for oxidation chemistry in the atmosphere.

CONCLUSIONS

We studied α-pinene oxidation in the lab and revealed interesting insights into RO_2 chemistry through accretion product formation. The composition of accretion products was dependent on the α-pinene oxidation rate.

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PRELIMINARY SUMMARY OF URBAANI ILMANLAATU 2.0 -PROJECT

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Keywords: Air quality, New air quality directive, Spatial variability, Measurements, Modeling, Interactions with Stakeholders.

INTRODUCTION

Air pollution is one of the grand challenges the modern society is facing (Lelieveld et al., 2015). Currently, air quality monitoring heavily relies on fixed air quality monitoring stations operated by air quality authorities. Although the positioning of the observation sites is regulated and multiple sites provide harmonised data from individual cities, the spatial variability in the urban environment is not resolved in high enough detail (Petäjä et al. 2021). Particular challenges are connected to emerging air pollutants, such as ultrafine aerosol number concentrations (UFP) and black carbon (BC), which depend heavily on localised emission sources, such as traffic and wood burning (Kuula et al., 2020).

On October 14, 2024, the Council of the European Union formally adopted the revised Ambient Air Quality Directive. This is connected to the European Union's objective towards zero pollution by 2050 facilitating prevention of premature deaths due to air pollution. The new air quality directive responds to the World Health Organization recommendation (WHO, 2021) to monitor BC and UFP concentrations. Article 10 of the directive introduces the concept of air quality supersites that include a comprehensive analysis of air quality both in urban and rural background environments. The directive also addresses the need to measure air pollution concentrations near emission hot-spots.

The aim of this abstract is to give examples of the results and summarise the work done in a three-year project called “urbaani ilmanlaatu 2.0”, translated to English as “Urban Air Quality 2.0”. The project is funded by Technology Industries of Finland Centennial Foundation. The partners of the project include University of Helsinki with three research groups (atmospheric science, geography and computer science), Finnish Meteorological Institute and Helsinki Region Environmental Services Authority HSY. Tampere University contributed to measurements and modelling in an intensive measurement campaign.

RESULTS AND NEXT STEPS

The work of the project included components from urban air quality data management, quantifying and mapping emerging air pollutant concentrations in pilot activities, air quality modelling of the emerging air pollutants, estimations of pollution exposure of urban population and dissemination of results to targeted groups and the general public.

In fact, at the beginning of the project, Kuula et al. (2022) provided a joint voice of the consortium regarding, at that time, draft of the new air quality directive. We proposed a reassessment of specific features within the directive, focusing on: 1) Incorporating air quality sensors into a hierarchical observation network

(including supersites and indicative measurements), 2) Establishing the minimum number of sampling points and their siting criteria (contributing to the network design in air quality), and 3) considering new target air pollution parameters for future regulations (in particularly ultrafine aerosol particle number concentrations, size distributions and black carbon). Our opinion paper suggested enhancing the effectiveness of air quality management. The key suggestions were included in the new air quality directive.

In the project we performed several experimental campaigns addressing spatial variability of air pollution in the Helsinki metropolitan area. As an example, Elomaa et al. (2024) deployed a network of four types of small-scale filter-based BC sensors (AE51, MA200, MA350, Observair) with the objective to evaluate these sensors for monitoring ambient BC concentrations and to study variations in high resolution. Prior deployment, the sensor data was quality controlled against a reference BC instrument at SMEAR III observation site at the Campus. The results showed good correlation between the sensors and a reference instrument, confirming their suitability for deployment. The sensor network successfully captured small-scale variations in BC concentrations and demonstrated potential for source apportionment. High concentrations were observed at the surface level, particularly close to bus traffic.

The project will conclude at the end of 2024. The next step for the consortium is to prepare a summary of the results and conclusions of the project as a whole.

ACKNOWLEDGEMENTS

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CLUSTER ION COUNTER (CIC): A TOOL TO INVESTIGATE LOCAL NEW PARTICLE FORMATION AND CONDENSATION SINK

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Keywords: AIR IONS, CONDENSATION SINK, FORMATION AND GROWTH RATES

INTRODUCTION

Airborne production is an important source for number and mass concentrations of atmospheric aerosols. The airborne production is a very non-linear process and therefore hard to master. Atmospheric cluster ion (diameters below 2 nm) measurements can provide insight into ion source processes, such as the ion production rate associated with different atmospheric ionization pathways, as well as ion loss processes, such as ion-ion recombination or scavenging of ions by a pre-existing atmospheric aerosol population (e.g. Hirsikko et al., 2011; Kontkanen et al., 2013). Observations of intermediate ions (diameters between 2 and 7 nm) can be used to get information about atmospheric new particle formation (NPF) (e.g. Tammet et al., 2014), whereas small intermediate ions (approx. 2.0–2.3 nm) can be used to detect ”local” NPF, i.e. NPF taking place within a close proximity of a measurement site (Tuovinen et al., 2024).

Intermediate ions are sensitive to both occurrence and intensity of atmospheric NPF (e.g. Tammet et al., 2014). Recently, Kulmala et al. (2024a) and Tuovinen et al. (2024) found that the smallest sizes of intermediate ions describe relatively well the local production of new aerosol particles. These results were obtained using a Neutral Cluster and Air Ion Spectrometer (NAIS; Mirme and Mirme, 2013). The NAIS is, however, a sophisticated instrument that provides information not necessarily needed when investigating local NPF, such as detailed knowledge of both ion and particle number size distributions.

Utilising the recent paradigm shift (Kulmala et al., 2024b) we started to plan as simple methods as possible to observe local formation of intermediate ions (LFII) and condensation sink (Kulmala et al., 2024c).

METHODS

Here we have analyzed data obtained using a Cluster Ion Counter (CIC; Mirme et al., 2024), a recently developed and simple 3-channel instrument, and investigated how this instrument can be utilized to determine several variables important to NPF and small ion dynamics. We have derived equations that can be used to estimate condensation sink (CS), growth rate of newly formed particles and formation rate of 2 nm ions, quantifying the intensity of local new particle formation (actually local intermediate ion formation, LIIF) (Kulmala et al., 2024c), based on CIC measurements. We also compared ion concentrations between the CIC and NAIS, as measured at the SMEAR II station in Hyytiälä, Finland.

SUMMARY AND CONCLUSIONS

The recent progress on finding local NPF (e.g. Kulmala et al., 2024a; Tuovinen et al., 2024) has opened a question: are we able to utilize a simple ion counter to identify and quantify LIIF in a proper way? According to our results presented above, the answer is: yes (see Kulmala et al., 2024c).

We have developed a modified version of the CIC to measure sub-2 nm ion and 2.0–2.3 nm ion concentrations as accurately as possible (Mirme et al., 2024). From the former quantity we get information on the dynamics of small ions, including an estimate of the coagulation sink of ions and also condensation sink. Furthermore, the CIC makes it possible to estimate the growth rate from about 2 nm to 3 nm and, with this information, the formation rate of 2 nm ions, which we can use to quantify the intensity of LIIF. While we have focused on negative ions in this paper, the same principles are also valid for positive ions. LIIF is more sensitive to negative ions (Tuovinen et al., 2024), and thus negative ions were investigated.

Overall, we can conclude that the CIC is an effective instrument to observe LIIF and CS. Since CIC is ca seven times cheaper and requires less maintenance than the NAIS, with the CIC one can cover more observation locations and have wider data coverage than with the NAIS. However, if we want to investigate aerosol formation and growth rates for the nucleation mode (3–25 nm), as is usually the case in investigating regional NPF, NAIS measurements are needed.

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TRANSFORMATIVE CLIMATE CHANGE EDUCATION IN ART-SCIENCE COLLABORATION

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Keywords: Climate change education, transformative learning, art-science collaboration.

INTRODUCTION

To reach sustainable futures, transformations are needed in our minds as well as society at large. Transformative learning profoundly transforms learner's identity (Kegan, 2009), habits of mind and meaning perspectives (so called frames of reference) so that the learner can better generate opinions and beliefs to guide action (Mezirow, 2009). INAR has a long history of art-science collaboration (Juurola et al., 2014), that is recognised as one way to build transformative climate change education (Leite, 2024).

University of Helsinki and Helsinki University of the Arts started the planning of a joint climate change course in 2018. Ever since, the course has been organised every year. It is designed together by art and science teachers, and many of the activities, co-designed to support group work and social learning among the participants, are neither art nor science based, but transdisciplinary. Student engagement is enhanced by giving them time and space to design projects with freedom on how the outcomes are shared with the others as well as daily "Open spot" moments where students are encouraged to share their practice, knowledge or interest with others. The course is designed to support exploring art-science collaboration and learning in a head, hands and heart -pedagogical framework (Sipos et al., 2008): the daily schedule includes teaching activities based on knowledge, action and reflection/discussion.

Here, we explore if the co-designed intensive residential course on art-science collaboration can create learning conditions and processes that support transformative learning. We aim to understand better how to create transformative climate change education that can contribute to sustainability transformations in society.

METHODS

Qualitative content analysis was conducted following the framework by Rodríguez Aboytes and Barth (2020, Table 4). Final reflections by the students in art-science course held in Värriö in May 2024 were coded using Atlas.ti programme. All 12 students of the course gave permission to use their reflections for research purposes.

RESULTS

Elements of transformative learning were identified from the student reflections in the end of the course. Students' records on learning conditions that lead to transformative learning included educational experiences beyond formal settings, time and space for reflection and discourse, and social interaction among learners (Figure 1). Transformative learning often requires a disorienting dilemma. Here, three sources of dilemmas can be recognised: the context of art-science interface itself, the existential dread of climate change, and the special location in the Värriö Nature Strict Reserve next to Station for Measuring Earth Atmosphere Relations (SMEAR I) where continuous long-term observations of climate change are made. Participatory decision-making and collaborative work, where students and teachers from different

backgrounds seamlessly worked for common goals, were seen as “mind-shaking”, “healing” and “bringing hope”.

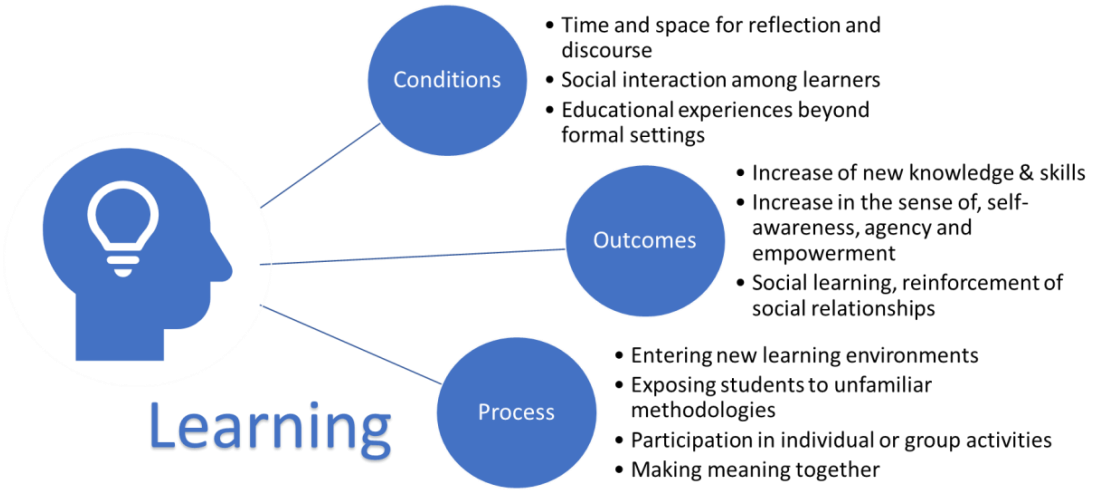

Figure 1. Learning process modified from Rodríguez Aboytes and Barth (2020, table 4) and examples of the elements of transformative learning observed from the course on art-science collaboration.

CONCLUSIONS

We conclude that an intensive residential course on art-science collaboration can create learning conditions and processes that support transformative learning.

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TARGETED METAGENOMICS USING PROBE CAPTURE DETECT A LARGER DIVERSITY OF NITROGEN AND METHANE CYCLING GENES THAN TRADITIONAL METAGENOMICS – DO NITROGEN CYCLING MICROBES PLAY A ROLE IN PLANT TISSUES?

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Keywords: microbiology, functional genes, targeted metagenomics, plant, host-microbiome.

INTRODUCTION

Microbes are the key players in the global cycling of nitrogen (N) and carbon (C), controlling the availability and fluxes of C and N in ecosystems, as well as being responsible for losses through the emissions of the powerful greenhouse gasses nitrous oxide (N_2O) and methane (CH_4). Thus, characterization of microbial functional guilds involved in these processes is high on the scientific agenda. Yet, standard sequence-based characterization methods often reveal only a minor fraction of their diversity in nature due to their frequent low relative abundance, insufficient sequencing depth of traditional metagenomes of complex communities, and limitations in coverage and efficiency of PCR-based assays.

METHODS

Here, we developed and tested a targeted metagenomic approach based on probe capture and hybridization to simultaneously characterize the diversity of multiple key metabolic genes involved in inorganic N and CH_4 cycling. We designed comprehensive probe libraries for each of 14 target marker genes, comprising 264,000 unique probes in total. These probes were used to selectively enrich the target genes in shotgun metagenomic libraries.

RESULTS

In validation experiments with mock communities of cultured microorganisms, the target gene profiles were similar to those of the original community when sequenced with targeted metagenomics. Furthermore, relative abundances of the marker genes obtained by targeted and shotgun metagenomics from agricultural and wetland soils correlated positively, indicating that the targeted approach did not introduce a significant quantitative bias. However, targeted metagenomics generated substantially higher diversity in terms of taxonomic coverage, and a larger number of sequence reads per sample, which allowed 41 or 1.2 times higher diversity estimates than when using shotgun metagenomics or targeted PCR amplification, respectively.

CONCLUSIONS

The targeted metagenomics tool has been used to study the nitrogen and methane cycling microbes successfully in tropical corals for N cyclers (Glaze et al. 2022) and boreal spruce phyllopsheric tissues for methane cyclers (Putkinen et al. 2021). However, the role of the nitrogen and N_2O cycling microbes within the plant and lichen-holobiont tissues are still relatively unknow. The results of seasonal study, labelling

and targeted metagenomic results in the plant tissues will be discussed. Thus, targeted metagenomics complements current approaches by enabling a targeted, more detailed characterization of the diversity (Siljanen et al. 2024) of key functional genes involved in N and CH_4 cycling within and between ecosystems.

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EVALUATING AND OPTIMISING INTEGRATION BETWEEN CLIMATE AND AIR POLLUTION POLICIES: THE CLIMAIRPATHWAYS APPROACH

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Keywords: climate change, air pollution, policy integration, transdisciplinary research.

ClimAirPathways is a project consortium consisting of legal scholars from UEF and atmospheric modellers from FMI jointly investigating pathways and obstacles to better integration of policies tackling climate change and air pollution. Integrating policies means realising synergies and avoiding trade-offs between them, which is particularly relevant to climate and pollution governance as these problems' sources and effects overlap. However, policy integration is a complex process politically, affecting priorities and power relations within government, and scientifically, due to remaining uncertainties regarding the climate-pollution interface. This is the rationale behind ClimAirPathways's transdisciplinary approach: Bringing together social and natural scientists allows us to investigate both institutional and scientific obstacles.

Since the project's launch one year ago, the UEF team has developed and applied an indicators-based framework for systematically evaluating the level of integration in existing policies. This presentation introduces said framework and presents initial evidence from case studies of national- and local-level climate and pollution governance in Italy. In our evaluations, we treat policy integration as a process encompassing both the formulation and implementation of policies and pay particular attention to the role of science throughout all this. As such, insights and data from our analysis are relevant not just from a political and legal perspective, but also to the scientific community, which plays a crucial role in informing and optimising the design of integrated policies.

Furthermore, the presentation anticipates the project's next steps: Conducting further case studies and comparing their underlying political and scientific processes in order to untangle what factors obstruct or enable policy integration. In a final phase, the legal and modelling teams will jointly develop scientifically informed legal pathways towards improved climate-pollution integration. The presentation thus also reflects on opportunities and modalities for collaboration across the disciplinary divides of legal and atmospheric science, our very own integration challenge in this project.

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THE EFFECTS OF A LONG-TERM WATER LEVEL DRAWDOWN ON PHOTOTROPHIC COMMUNITIES AND PHOTOSYNTHESIS IN BOREAL PEATLANDS

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Keywords: Peatland, Water-level drawdown, Phototrophic, Microbial photosynthesis

INTRODUCTION

The ongoing climatic and anthropogenic changes are suggested to lead to widespread drying of northern peatlands, seen as water table (WT) decline, reduced moisture availability in the moss layer (Gong *et al*. 2012) and, in a long-term, reduced cover and diversity of peat mosses (Kokkonen *et al*. 2019). However, moss photosynthesis has been found surprisingly resilient to these changes (e.g., Kokkonen *et al*. 2022). The reason for resilience might be the activity of the associated microbial communities affecting moss photosynthesis directly (Carrell *et al*. 2022), through nitrogen provision (Larmola *et al.* 2014), or compensating for the reduced photosynthetic activity in mosses by fixing carbon (Hamard *et al.* 2021).

Despite the acknowledged role of microbes as regulators of the peat carbon pool, the long-term effects of climate-driven WT decline on microbial carbon fixation or phototrophic communities have not been experimentally studied, and the link between the community composition of the *Sphagnum* microbiome and ecosystem functioning remains a pressing knowledge gap (Kostka *et al.* 2016). Here, we quantify phototrophic microbial communities and their photosynthetic capacity in a long term field experiment comprising pristine and experimentally drained water level drawdown (WLD) areas along a nutrient gradient from a bog to a mesotrophic fen and assess the drivers behind the observed patterns.

METHODS

The impact of water table was investigated using a 20-year old water-level drawdown experiment implemented on a mesotrophic fen, poor fen and nutrient poor bog in Lakkasuo, Finland. The community composition of phototrophic microbes was investigated by amplicon sequencing of microbial DNA in the peat moss layer; microbial photosynthesis was measured as ETR_{max} (electron transport rate) and F_V/F_M (the maximum potential quantum efficiency of Photosystem II; proxy for the condition of the photosynthetic machinery) using PhytoPAM. In addition, selected environmental variables were measured. We used two-way-ANOVA to assess the differences between the WLD areas and control areas. Non-metric multidimensional scaling (NMDS) was used to illustrate the differences in the community structure of phototrophic microbes. In addition, we used Spearman correlations to investigate the links between selected explaining variables and microbial and moss photosynthesis.

RESULTS

In the nutrient poor bog and the mesotrophic fen, the microbial communities were dominated by Cyanobacteria, whereas in the oligotrophic fen, Chlorophyta were most abundant phyla. We found that WLD enhanced the state of photosynthetic machinery (F_V/F_M rate)across all studied peatland types. Yet, the shifts in microbial communities and electron transport rates (ETR_{max}) displayed site-specific patterns. In the poor fen, we observed a simultaneous increase in Cyanobacteria and ETR_{max}, and could link these to both peat N content and moss photosynthesis.

CONCLUSIONS

Our study demonstrates that microbial communities have site-specific responses to the projected climate-induced drying in peatlands. The increased abundance of Cyanobacteria in poor fens, and its connection to nitrogen availability and microbial and moss photosynthesis adds evidence on the importance of nitrogen-fixing microbes for peatland functioning. It indicates the potential of Cyanobacteria to promote higher carbon fixation and counteract the carbon loss from increased decomposition.

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THE ROLE OF THE EUROPEAN SCIENTIFIC ADVISORY BOARD ON CLIMATE CHANGE

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Keywords: Climate change, Climate law, Climate governance, Scientific advisory bodies.

INTRODUCTION

The scientific basis of climate change has been widely accepted, but there still seems to be a significant gap between science and climate policy as governments are not enacting measures corresponding with the significance of the problem (Ghaleigh, 2016; Wagner *et al*., 2021). However, consensus exists on the need to involve scientific knowledge in decision-making to frame problems, provide evidence and engage in policy matters (Ibarra *et al*., 2022). Independent scientific advice is also an essential feature relating to the quality of climate governance (Kulovesi *et al*., 2024) and it is often provided by climate-specific scientific advisory bodies. For the advisory body's recommendations to be successfully considered in the policymaking process, certain key elements relating to the structure of the body and its mandate have been identified in previous studies (Evans and Duwe, 2021; Miljand and Bäckstrand, 2021; Averchenkova and Lazaro, 2020).

This study aims to assess the role of the European Scientific Advisory Board on Climate Change (ESABCC) in EU climate governance based on its legal mandate. The assessment covers both elements relating to the structure and operation of the body, but also to the scope of the mandate.

METHODS

The study is based on a literature review on scientific advisory bodies. To assess the role of the ESABCC, relevant legislation and policy documents were examined to determine the scope of the legal mandate, which is then assessed against the previous findings on successful scientific advisory bodies identified in the literature review.

RESULTS

The mandate should be enshrined in legislation as it provides authority and stability to the body's work (Elliott *et al*., 2021). A clear and specific mandate determines the degree of influence the body has on policy formulation (Evans and Duwe, 2021) and a legal requirement for the government to respond to the advisory body's recommendations has been found important (Averchenkova and Lazaro, 2020).

The European Climate Law (ECL) established the ESABCC to support the EU's climate action and efforts to reach climate neutrality by 2050 by scientific knowledge. The ECL refers to the ESABCC as point of reference for the EU on scientific knowledge relating to climate change. The main tasks of the ESABCC are listed in Art. 3 of the ECL and include e.g. considering the findings of the IPCC reports and scientific climate data, providing scientific advice and issuing reports on existing and proposed EU measures, climate targets and GHG budgets and their coherence with stated objectives.

The tasks and role in EU climate governance seem very general in nature. The ESABCC determines independently it's work programme, which includes some more specific tasks, but the body also retains freedom to pick up issues on an ad hoc basis. While this has proved useful, it remains unclear how the body operates e.g. when it needs external expertise. Neither the ECL nor the work programme determine the use of external expertise, which may hinder the ESABCC to pick up issues requiring expertise that the members

do not possess. In addition, the legal mandate of the ESABCC does not include any reference to the Commission to consider or to respond to the advice. This may hinder the recommendations from being successfully integrated in policymaking. It has also been found crucial to identify the points in the policymaking process where the advisory body's input is best utilised (Bandola-Gill, 2019). The legal mandate of the ESABCC does not say anything about the points of entry in the process for the body's input.

Advisory bodies' role in monitoring and evaluating progress is central (Zwar et al, 2023) and the legal mandate should explain the role in the independent assessment of progress made and the frequency of these assessments (Averchenkova and Lazaro, 2020). However, regarding the review of progress of both EU and member states, under the current mandate the ESABCC does not have any formal role in assessing progress.

CONCLUSIONS

While the institutional setup of the ESABCC is largely aligned with elements that support the success of a scientific advisory body, ambiguities remain especially in the role of the ESABCC in the policymaking process but also in how the operates in terms of external expertise. The lack of a legal obligation to the Commission to consider the advice and recommendations of the ESABCC may lead to a situation where the Commission simply ignores scientific advice from the ESABCC. The Commission has indicated that it is committed to following the ESABCC's recommendations, but it remains to be seen how well the scientific advice provided by the ESABCC is integrated in policymaking.

ACKNOWLEDGEMENTS

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XYLEM CONDUITS AND INTER-CONDUIT PITS OF SCOTS PINE, NORWAY SPRUCE AND SILVER BIRCH SCALE IN A COORDINATED WAY WITH DISTANCE FROM THE TREETOP

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Keywords: WOOD ANATOMY, BOREAL TREES, CONDUITS, PITS

INTRODUCTION

Ensuring sufficient water transport to the leaves is crucial for trees to survive under varying water availability (Adams et al., 2017; McDowell et al., 2008). Both hydraulic efficiency and safety depend highly on the anatomical structure of the conduits and particularly of their connections, the pits. On the one hand, wider conduits and pits enable higher water flow, on the other hand, they are more susceptible to air seeding (hydraulic failure) under stressed conditions (e. g., Domec et al., 2006; Jacobsen et al., 2019; Zimmermann, 1983). Several studies found that to counterbalance the resistance to water transport, which accumulates with the length of the water transport pathway, trees widen their conduits with distance from the treetop (e.g., Olson et al., 2021). Although pits represent the main resistance to water flow in the xylem (Domec et al., 2006), there are few studies on the relationship of pit dimensions and distance from the treetop (**Held et al., 2021**; Lazzarin et al., 2016; Losso et a., 2018; Zambonini et al., 2024). Trees exposed to stressful conditions may adjust their size or the conduit-widening pattern to increase their hydraulic safety. Our study aims to shed new light onto a) the coordination of conduit and pit dimensions along the water transport pathway, b) the plasticity of scaling patterns under varying growing conditions, and c) differences in hydraulic strategies between the studied species.

METHODS

We sampled the wood of Scots pine (*Pinus sylvestris* L.), Norway spruce (*Picea abies* (L.) Karst) and silver birch (*Betula pendula* Roth.) along the water transport pathway from the treetops to the coarse roots, and from two sites (labeled ‘limited’ and ‘favorable’) with different growth rates. Using light- and electron-microscopy, we analysed conduit and inter-conduit pit dimensions.

RESULTS

In all species we found that conduit and pit dimensions (Figure 1) scale with distance from the treetop. In the broad-leaf species birch, the scaling of conduits was steeper than in the conifers, whereas in the conifers, the scaling of pit dimensions and their coordination with conduits was stronger. The conifers exhibited different hydraulic strategies at pit level. In all species, we found small differences in scaling patterns between the sites.

CONCLUSIONS

Trees need to coordinate the widening of conduits and pits with distance from the treetop in order to ensure sufficient water supply of the canopy. Our results support the idea that trees can adjust their hydraulic architecture both *via* tree size and the scaling pattern of conduits and pits.

Species specific hydraulic strategies may thus affect the species composition of Eurasian boreal forests under climate change, which in turn may impact on their potential as carbon sinks, wood producers and providers of other important ecosystem services.

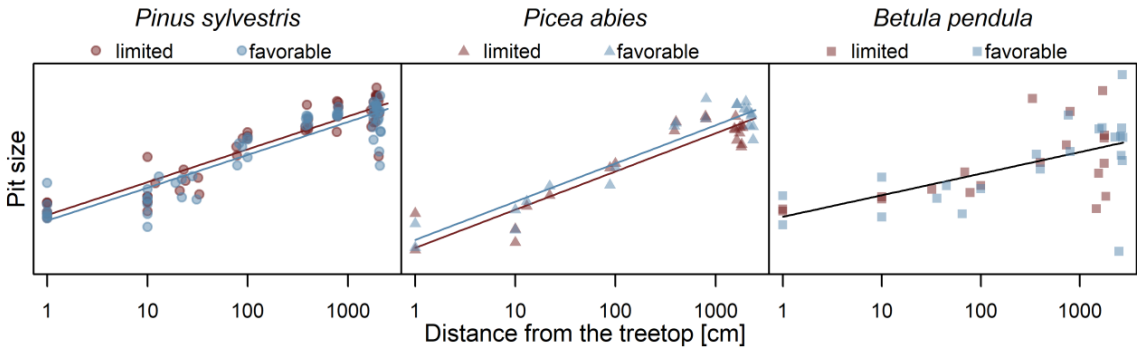

Figure 1: Scaling of pit size with distance from the treetop. Differently colored regression lines indicate site differences in scaling intercepts.

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CHARACTERIZATION OF WATER-SOLUBLE INORGANIC IONS AND CARBO-NACEOUS AEROSOLS IN THE URBAN ATMOSPHERE IN AMMAN, JORDAN

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Keywords: Urban air quality; particulate matter; inorganic ions; carbonaceous aerosols; SDS.

INTRODUCTION

The Mediterranean basin, where the northern Sahara of the African continent meets the southern coastal lands of southern Europe and the Levantine coast (i.e., the eastern Mediterranean), is considered a typical example of the long-range transport of many species of air pollutants carried by dust particles during sand and dust storm (SDS) episodes (Hussein et al. 2022). These SDS events have a substantial impact on the concentrations of the carbonaceous and non-carbonaceous aerosol species (Ghasemi et al., 2023; Tepe and Doğan, 2021). However, previous studies reporting the chemical characterization focusing on WSIIs did not include urban areas within the Levant. It was only recently when we previously considered an urban area in Jordan affected by SDS episodes originating from different major sources of dust and classified into three main categories: S (Sahara), SL (Saharan and Levant), SA (Sahara and Arabia), and SLA (Sahara, Levant, and Arabia) (Hussein et al. 2022 and 2020). In these previous two studies, we presented the $PM_{2.5}$ and PM_{10} concentrations during these SDS events with chemical characterization of carbonaceous aerosols. There is a clear gap in scientific knowledge about the WSIIs in the Levant. In this investigation, we present, for the first time the concentrations of OCEC and WSIIs as observed in $PM_{2.5}$ and PM_{10} collected at an urban site in Amman, Jordan (Al-Hunaiti et al. 2024). The characterization of WSIIs was investigated with respect to previously classified SDS episodes. We explore the sources of aerosol particles based on their chemical composition and provide an assessment of aerosol sources in the region.

METHODS

The particulate matter (PM_{10} and $PM_{2.5}$) was sampled with high volume samplers in the urban atmosphere of Amman, Jordan during May 2018 – March 2019. The sampling was collected over 24 hours every 6 days. In total, 51 and 48 valid samples of PM_{10} and $PM_{2.5}$ were collected. The gravimetric analysis was conducted according to the European directive EN1234-1. The water-soluble inorganic ions (WSII, F^-, Cl^-, NO_2^-, Br^-, NO_3^-, PO_4^{3-}, SO_4^{2-} and NH_4^+) was performed by ion chromatography (IC) and flow injection analysis (FIA). The OC and EC analysis according to the EUSAAR2 protocol employing a Sunset Laboratory Dual-Optical Carbonaceous Analyzer. The ambient conditions (T, P, RH, Wind Speed and Direction, and precipitation) were also monitored on site (WH-1080, Clas Ohlson: Art. no. 36-3242).

RESULTS

The $PM_{2.5}$ total carbon (TC) annual mean was 7.6±3.6 μg/m^3 (organic carbon (OC) 5.9±2.8 μg/m^3 and elemental carbon (EC) 1.7±1.1 μg/m^3), which was about 16.3% of the $PM_{2.5}$ (47±32 μg/m^3). The PM_{10} TC annual mean was 8.4±3.9 μg/m^3 (OC 6.5±3.1 μg/m^3 and elemental carbon (EC) 1.9±1.1μg/m^3), about 13.3% of the PM_{10} (63±39 μg/m^3). The $PM_{2.5}$ total water-soluble ions annual mean was 7.9±1.9 μg/m^3 (about 16.9%), and that of the PM_{10} was 10.1±2.8 μg/m^3 (about 16.0%). The minor ions (F^-, NO_2^-, Br^-, and PO_4^{3-}) constituted less than 1% in the PM fractions. The significant fraction was for SO_4^{2-} ($PM_{2.5}$ 4.7±1.6 μg/m^3 (10.0%) and PM_{10} 5.3±1.9 μg/m^3 (8.3%)). The NH_4^+ had higher amounts of $PM_{2.5}$ (1.3±0.6 μg/m3; 2.7%) than that PM_{10} (0.9±0.4 μg/m^3; 1.4%). During sand and dust storm (SDS) events, TC, Cl^-, and NO_3^- were doubled in PM, SO_4^{2-} did not increase significantly, and NH_4^+ slightly decreased.

CONCLUSIONS

Regression analysis revealed: (1) carbonaceous aerosols come equally from primary and secondary sources, (2) about 50% of the OC came from non-combustion sources, (3) traffic emissions dominate the PM, (4) agricultural sources have a negligible effect, (5) SO_4^{2-} is completely neutralized by NH_4^+ in the $PM_{2.5}$ but there could be additional reactions involved in the PM_{10}, and (6) $(NH_4)_2SO_4$, was the major species formed by $SO_4^{2-}$and NH_4^+ instead of NH_4HSO_4. It is recommended to perform long-term sampling and chemical speciation for the urban atmosphere in Jordan.

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EDUCATING CLIMATE CHANGE EXPERTS – EXPERIENCES FROM THE PILOT RUN OF THE SPECIALISATION PROGRAMME IN CLIMATE EXPERTISE

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Keywords: Climate change education, Student interactions, Student feedback, Student motivation.

INTRODUCTION

The **Specialisation programme in climate expertise** teaches professionals from different fields the skills, knowledges, and values necessary to drive systemic change towards a climate-resilient future. The first pilot run of the education program started in March 2024, with 42 students working in different professions within public and private sectors. The heterogeneity of the students provides an exceptional opportunity for students to learn in a setting where their varied expertise mirrors the complexity of climate change (Siponen et al. 2024), and through genuine interactions enforce their sense of agency as climate change experts (Salovaara and Hagolani-Albov 2024).

The goal of this presentation is to provide a first look at the extensive student feedback collected during and after the first compulsory course with a focus on the importance of different types of interaction influencing student motivation A more extensive analysis of the feedback and the effects of the education programme on student motivation, self-efficacy, and professional identity is underway.

METHODS

The education programme is being developed by University of Helsinki together with University of Eastern Finland and Finnish Meteorological Institute in collaboration with Climate University network and Climate Leadership Coalition. The programme lasts for 2 years consisting of 60 ECTS worth of courses (Figure 1). Feedback was collected during **I ERKO – Ilmastonmuutoksen tiede** course as part of weekly course assignments, and through the University of Helsinki's course feedback system Norppa, and HowULearn questionnaire (Parpala and Lindblom-Ylänne, 2012) with additional questions.

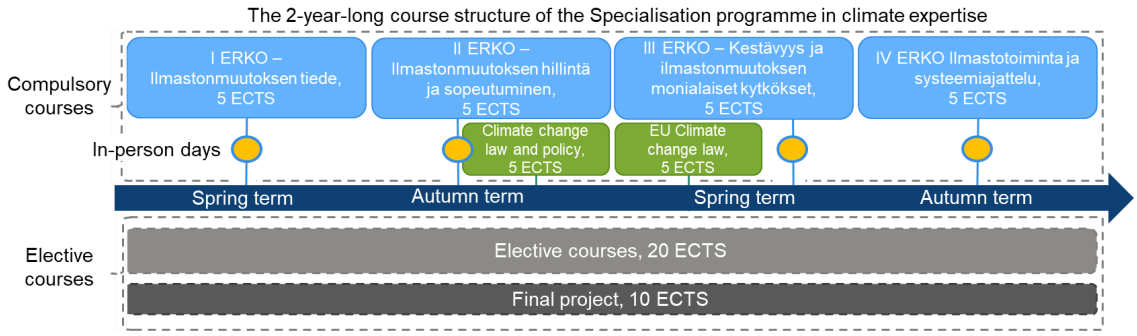

Figure 1. The overall course structure of the Specialisation programme in climate expertise: four core substance courses (blue) and two courses on climate law (green) provide the foundation of the education programme. Each student also chooses a total of 20 ECTS worth of elective courses (light grey) and prepares a final project (dark grey). All courses are online-only, but each term students participate in one two-to-three day-long in-person meeting (orange).

RESULTS

Based on student feedback, and our personal experiences teaching the students, the in-person meetings (Figure 1) are an integral part of maintaining student motivation through interactions (discussions and other related social activities) between students and teachers, lecturers, or other instructors, corroborating the findings of Alqurashi (2019). However, in our experience, student-student interactions have also been important (Kuo et al. 2014). Many students have mentioned peer support and networking as factors affecting their satisfaction both in case of in-person and online education. Social interactions were also interpreted to foster personal engagement with the presented subject material, which is known to increase student satisfaction (Sharif Nia et al. 2023). In general, the student satisfaction with the course materials and learning activities have been overwhelmingly positive despite the student heterogeneity and the complexity of climate change as an environmental and societal phenomenon.

CONCLUSIONS

The Specialisation programme in climate expertise brings together highly motivated experts from different sectors of society. As such, they are integral part of the programme by providing genuine perspectives to climate change and giving practical meaning to climate expertise. While transfer of knowledge is easily achieved through online courses it is important to foster student-student, student-instructor, and student-content interactions to keep students motivated and engaged throughout the programme. We hope that the success of the programme can inspire further climate action and create a model for future climate change education.

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PREDICTION OF DROPLET DISTRIBUTION RUPTURED FROM LUNG AIRWAYS USING NUMERICAL SIMULATIONS

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Keywords: Lung flows, Plug Rupture, Cough droplets, Aerosols.

INTRODUCTION

Pulmonary airways are coated with a mucus layer. Under certain conditions, this layer becomes thick enough to form liquid plugs due to Plateau-Rayleigh instability, blocking airways as a result. During inhalation, blocked airways can be reopened under particular circumstances (Muradoglu et al., 2019). This liquid plug rupture phenomenon results in the production of respiratory droplets. An accurate simulation of this process could help in a prediction of the droplet size distribution. Up until now, the accurate formation and tracking of these droplets have been computationally expensive with interface capturing approaches due to their relatively small size.

METHODS

In this abstract, we investigate different strategies to capture the droplet distribution during a rupture process. Simulations are performed using both algebraic and geometric volume of fluid (VOF) method solvers available in the OpenFOAM (Niethammer et al., 2024). Adaptive mesh refinement (AMR) has been widely used to focus on parts of interest and save computational cost. Therefore, the rupture process is simulated using AMR. In addition to that, Lagrangian particle tracking is used to track the cluster of particles resulting from the breakup of the mucus sheet. Sample results are presented in Fig. 1. These aspects are coupled with each other using a simple breakup relation based on a balance between stresses and surface tension.

RESULTS

Sample results are presented in Figs. 1 and 2. It can be shown that AMR performs partially in resolving the mucus droplets. In order to completely simulate the rupture, Lagrangian particle tracking is required. These two aspects can be coupled with each other using a simple breakup relation based on a balance between stresses and surface tension.

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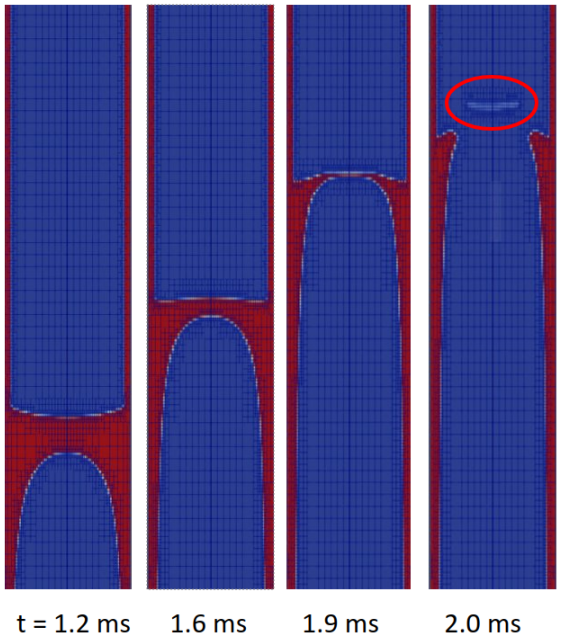

Figure 1: Snapshots of the reopening process simulated using VOF with AMR. The area of interest, i.e. the spray of droplets is enclosed by the red ellipse.

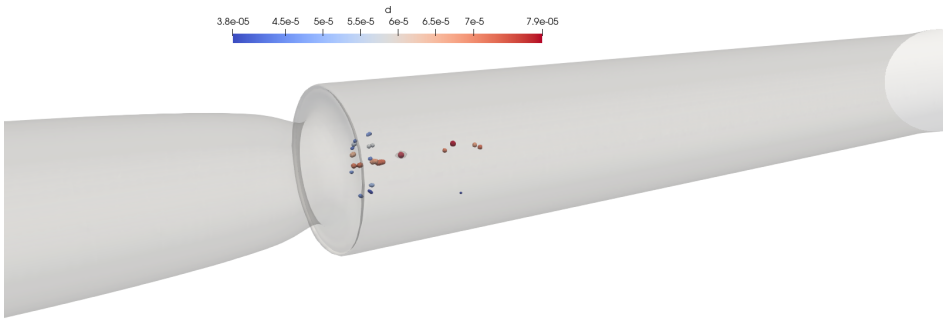

Figure 2: Conversion of VOF elements to small droplet particles

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SATELLITE OBSERVATIONS TO SUPPORT AIR QUALITY MONITORING IN EAST AFRICA

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Keywords: Air quality, satellite remote sensing, East Africa, Capacity building

INTRODUCTION

Significant advancements in space-based atmospheric composition monitoring have created new opportunities to utilize satellite data in various societal applications, such as supporting air quality monitoring or assessing impacts of air pollution on public health. To fully leverage the potential of satellite observations, active collaboration between the scientific community and stakeholders is essential. The role of satellite observations in supporting air quality monitoring is especially valuable in developing countries, where rapidly growing cities face increasing air pollution levels but ground-based air quality measurements are often very limited or unavailable.

The Finnish Meteorological Institute's project FINKERAT funded by the Ministry for Foreign Affairs of Finland aims to increase East African societies' preparedness for extreme weather events and to improve air quality monitoring in Kenya, Rwanda and Tanzania. Satellite observations play a key role in this project by providing e.g. information on atmospheric composition especially over those areas where ground-based observations are not available. Capacity building is also an essential part of the FINKERAT project, and several hands-on training sessions on satellite data analysis have been organized by the FMI in Kigali, Nairobi, and Dar Es Salaam as well as in Helsinki.

METHODS

Satellite observations from several instruments and variables were considered in the analysis over East Africa, including aerosol optical depth (AOD) from the two MODIS instruments and vertical distribution from Calipso, NO_2 from the TROPOMI and OMI satellite instruments, as well as active fire detections from VIIRS and MODIS. For hands on training courses jupyter notebooks and python codes were used, covering each of the analyzed variable. Where available, satellite observations were studied alongside ground-based measurements to evaluate whether similar conclusions about pollutant variability can be derived from both sources.

RESULTS AND DISCUSSION

Satellite observations of aerosols, fires, and trace gases provide valuable information on emission hotspots, seasonal pollutant variations, and long-term trends over East Africa where the main pollutant is often particulate matter. However, at the same time it is also crucial to recognize the key differences between satellite and ground-based measurements, their representativeness and potential uncertainties in both data. For aerosol satellite monitoring, in particular, evaluating vertical distribution is essential to understand potential long-range transport effects. In Rwanda, despite the frequent aerosol transport episodes in the upper atmosphere, analyses indicate that satellites can effectively capture seasonal aerosol patterns comparable to PM2.5 variations.

ACKNOWLEDGEMENTS

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THE POTENTIAL OF SATELLITE OBSERVATIONS TO ADVANCE OUR UNDERSTANDING OF ATMOSPHERIC METHANE IN THE ARCTIC

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Keywords: Methane, Validation, Inverse modelling, Benchmarking, Remote sensing

INTRODUCTION

The atmospheric concentration of methane – the second most important anthropogenic greenhouse gas – has increased with a record growth rate in recent years. While the sources of methane are mostly outside the Arctic region, the uncertainties of the high-latitude emissions are high (Saunois et al., 2020; Tsuruta et al., 2023). With the expansion of Earth Observations in the recent decade, total column methane (XCH_4) can now be observed from space using instruments such as the Japanese GOSAT mission and European Sentinel-5P TROPOMI. Space-based observations of methane have the potential to significantly increase our understanding of the distribution of atmospheric methane as well as the magnitude and variability of its sources and sinks at high latitudes. In this work, we report on recent and ongoing work towards benchmarking total-column methane datasets in the Arctic and boreal regions and present our most important findings.

METHODS

First, we evaluate satellite observations from both GOSAT (UoL-PR v9 product) and TROPOMI (OPER rpro and WFMD v1.8) using ground-based reference measurements from the Total Carbon Column Observing Network (TCCON) and Collaborative Carbon Column Observing Network (COCCON) high-latitude sites as well as AirCore profile measurements in Sodankylä, Finland. The results are detailed in Lindqvist et al. (2024) and are used to reflect the reliability of satellite observations at high latitudes.

Second, we compare satellite observations of methane to the optimized concentration fields from an increasing suite of atmospheric inverse modelling products that assimilate in-situ measurements and are resampled spatiotemporally to correspond to the satellite observations (including Carbon Tracker Europe-CH4, CAMS, and TOMCAT, complemented with other products). We explore the variability in the total-column methane between the inverse models, and quantify their differences to the satellite products. Our focus regions are different permafrost types (continuous, discontinuous, sporadic) as well as wetlands. We evaluate differences in seasonal variability, trends, and larger spatial features.

RESULTS

Time series analysis of individual GOSAT observations sampled at latitudes >50°N was carried out along with the resampled model time series from CAMS, CarbonTracker Europe, and TOMCAT. The linear growth rates have been quantified. The trends have also been evaluated spatially. We find that resampled models show a higher-level XCH_4 than GOSAT. We also find that GOSAT observations have a higher growth rate by 0.5–2.3 ppb/year than the models. Large model-to-model differences can be identified in the seasonal cycle of methane: GOSAT shows the largest seasonal variability. In addition, there are differences

in the spatial growth rate patterns with GOSAT showing a larger growth rate especially over Russia. Growth rate of methane at high latitudes shows significant model-to-model and regional variability.

Spatial patterns were studied with gridded TROPOMI satellite data throughout the Arctic. We find that TROPOMI shows a larger regional variability as compared to models. This may suggest a larger variability in local-scale emissions and calls for a detailed comparison of the prior emission information used in the models. We also find that patterns in the satellite-to-model differences are dominated by TROPOMI variability.

CONCLUSIONS

This work presents a parallel avenue for the evaluation of inverse modelling products far from ground-based measurements of methane at high latitudes, and lays groundwork on data-driven emission estimation approaches at high latitudes. The work contributes to the Esa-Nasa Arctic Methane and Permafrost Challenge (AMPAC) initiative and has been prepared in the ESA-funded MethaneCamp and AMPAC-net frameworks.

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Poster presentations

MESURING THE ATMOSPHERIC ION COMPOSITION IN THE BOREAL FOREST, HYYTÄLÄ, FINLAND

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Keywords: Atmospheric Ions, SMEAR II, APi-TOF, Mass spectrometer

INTRODUCTION

The SMEAR II Station, situated in the Finnish Boreal Forest, is a key research facility for atmospheric and environmental science. While it primarily focuses on the interactions between forest ecosystems and the atmosphere, the station holds cutting-edge instrumentations for long-term monitoring of atmospheric components, including precursors vapors and atmospheric ions clusters. Atmospheric ions have been investigated extensively for their ability of interacting with ambient molecules and triggering the formation of atmospheric aerosol particles. Ion-induced nucleation can initiate new particle formation (NPF) or amplify it by stabilizing charged molecular clusters that can further grow to large particles, possibly up to cloud condensation nuclei.

In the boreal forest, ion-induced nucleation (Kulmala et al., 2004) has been primarily characterized through the intervention of sulfuric acid, ammonia and highly oxygenated molecules (HOM, Bianchi et al., 2019) (Yan et al., 2018), the later originating from the oxidation of volatile organic compounds (VOC) emitted by the forest vegetation. HOMs were in fact first identified and measured as naturally charges ions in the same forest site, SMEAR II, back in 2010 (Ehn et al. 2010) with the first deployment of the Atmospheric Pressure interface Time Of Flight mass spectrometer (APi-TOF, Tofwerk A.G., Junninen et al., 2010). While technological advancement has enabled the quantification gas concentration through Chemical Ionization (CI) - provided with e.g., Eisele-type CI inlet (Eisele et al., 1993)-, semi-simultaneous measurement of both neutral molecules and charged ions are now possible through switching devices and multi-scheme chemical ionization (MION, Rissanen et al., 2019) inlets.

METHODS

Herein, we present an intercomparison the qualitative measurements of naturally charged ion clusters provided by 3 instrumental set ups supported by APi-TOF mass spectrometry. Three distinct APi-TOF were installed at the SMEAR II station, in Hyytiälä, Finland, (from which two are part of the instrumentation for continuous monitoring of precursor gases at site).

(1) A direct inlet tube (SN: APi-12)
(2) A Eisele-type chemical ionization inlet, with voltages and x-ray switched off (SN: APi-3)
(3) A multi-scheme ionization (MION) inlet, in the ambient ion mode (SN: APi-Cy)

The measurements were part of the Summer 2024 ACTRIS - CIMS intercomparison campaign, however the ambient ions measurement intercomparison occurred from August 8th to August 28th, 2024.

CONCLUSIONS

This work aims to assess the capability and the reproducibility of characterizing the atmospheric ion composition, qualitatively, in a well-defined forest site. Ultimately, we vouch for a harmonization of mass spectrometry measurements and highlight the need for operation guidelines to satisfy the need of intercomparable data set between operators, instruments and environment across the globe. While the analysis of the ion data is at its early stage, we hope to reveal preliminary results by the conference event.

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THINNING INDUCED MONOTERPENE EMISSIONS IN A BOREAL FOREST

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Keywords: Boreal forest, Thinning, Monoterpene emission, climate change.

INTRODUCTION

Forest ecosystems play a crucial role in counteracting climate warming by acting as carbon stocks and sinks. In addition, forests take a crucial role in atmospheric aerosol production that can mitigate climate warming. The emitted biogenic volatile organic compounds (BVOCs) by forests, particularly monoterpenes, can be further oxidized to highly oxygenated organic molecules (HOM) and then contribute to formation and growth of atmospheric aerosols. Recently, the impact of forest management on their climate cooling potential has attracted wide attention. Thinning, as one of the common management pathways, aims to produce socio-economic benefits and increase growth and quality of the remaining trees by decreasing tree density (Kuuluvainen et al., 2012). The thinning is known to influence forests' CO_2 uptake, carbon stocks, structure, and micrometeorology. In this context, it remains unclear that thinning will introduce change of the emission and further influence other related atmospheric processes.

METHODS

In SMEAR (Station for Measuring Ecosystem-Atmosphere Relations) II station in Hyytiälä boreal forest, long-term measurements of CO_2 fluxes, trace gases, monoterpene emissions and aerosol properties have been conducted. In the beginning of 2020, a thinning was conducted in the station, reducing the stand basal area by 40%. Majorly Scots pine trees were removed. In this study, we investigated the changes in ecosystem level BVOC flux due to the thinning. The BVOC concentration was measured through PTR-QMS (Proton Transfer Reaction – Quadrupole Mass Spectrometry) and the fluxes were calculated via a surface layer profile method. Moreover, we also looked into the CO_2 fluxes and HOM concentrations measured by eddy covariance and Atmospheric Pressure interface Time-Of-Flight mass spectrometer (Jokinen et al., 2012), respectively. We selected observations from 2016-2019 as pre-thinning years (reference year), the year 2020 as thinning year, and the period after 2021 as post-thinning year.

RESULTS

The ecosystem photosynthesis has been reported to recover to reference level within 1 to 2 years post-thinning (Aslan et al., 2024) in the forest. In contrast, the monoterpene emission displayed a decreasing trend over time since the thinning year. In springtime, monoterpene emissions in the thinning year were 2-3.5 times higher than any other years, possibly due to the decomposition of tree residues on the forest floor. The enhanced monoterpene emission continued until the 2nd post-thinning year. By the 3rd post-thinning year, the springtime increases in monoterpene emission had disappeared. In summertime, the monoterpene emission was higher in the 2nd post-thinning year compared to the 3rd year. However, both years displayed 12-31% lower monoterpene emissions than pre-thinning years. We will further investigate whether the enhanced monoterpene emissions will influence formation and growth of aerosol production.

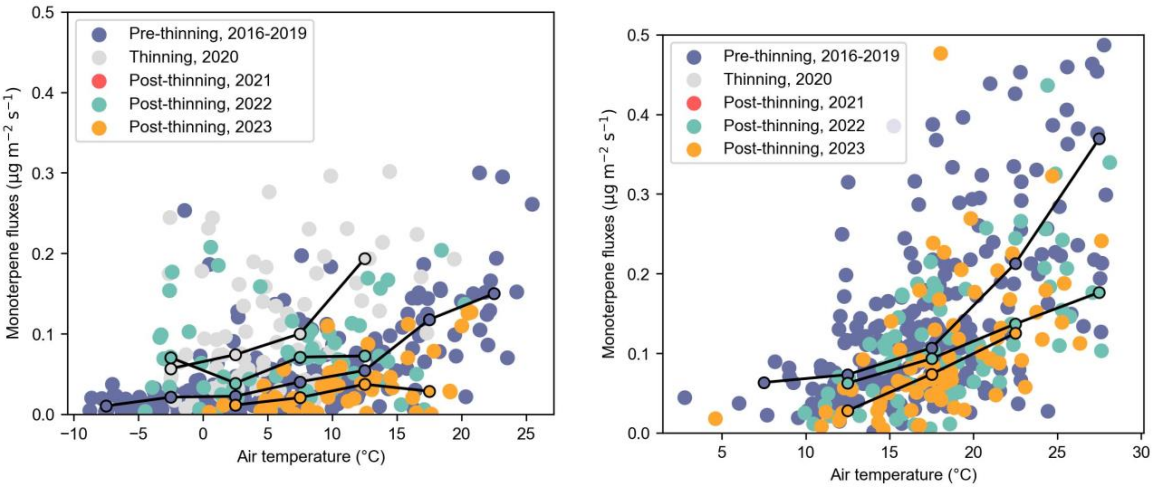

Figure 2. The influence of air temperature on monoterpe fluxes in spring (left) and summer (right) in pre-thining, thining, and post thinning years. Only daytime (10:00-16:00) data were presented. Note that the BVOCs emission data is missing in spring or summer of 2020 and 2021.

CONCLUSIONS

Different to the fast recovery of ecosystem photosynthesis after thinning, the monoterpene emissions decreased by years further to 2023. The thinning year presented enhanced monoterpene emissions, 2-3.5 times higher than the pre-thinning years. However, in summertime, the monoterpene emission in post-thinning years were 12-31% lower than the pre-thinning years. We will further investigate whether the enhanced monoterpene emissions will influence HOM formation and aerosol production.

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ASSESSING THE IMPACT OF TREE TRANSPIRATION ON PEATLAND RESTORATION IN FINLAND

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Keywords: climate change, greenhouse gases, restoration, mitigation

INTRODUCTION

Forestry-drained peatlands can be a major source of CO_2 emissions. About half of Finland's peatlands have been drained for forestry, threatening the country's carbon neutrality goal. Nevertheless, restoring drained peatland forests could reduce these CO_2 emissions.
The successful restoration of drained peatlands strongly depends on the water table after rewetting. The water table of peatlands is primarily driven by evapotranspiration (ET). Tree transpiration largely contributes to ET in drained peatland forests. However, it remains unclear how trees will respond to the rewetting and how they will affect the water table after rewetting.

METHODS

A peatland forest in Southern Finland is currently being rewetted. To study the response of the trees and the peatland ecosystem to rewetting, we monitor the tree transpiration before and after rewetting using sap flow techniques. Moreover, we measure ecosystem ET and net CO_2 fluxes by the eddy-covariance technique. Here, we will present the research site and some first results of the time before rewetting.

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Evaluating modelled carbon and nitrogen cycles using remote sensing-based leaf chlorophyll observations

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Keywords: carbon cycle modeling, Earth observation, terrestrial biosphere modeling.

INTRODUCTION

Terrestrial carbon sinks play pivotal role in slowing down anthropogenic climate change. Estimates of the size of natural carbon sinks necessitate detailed understanding of global carbon and nitrogen cycles. However, in certain regions, where the land carbon sink is nitrogen-limited, uncertainties in the nitrogen cycle result in inaccurate estimation of the scale of these carbon sinks. Terrestrial biosphere models (TBMs) are designed to study the carbon fluxes between the land surface and the atmosphere, and can be used to constrain the process-level uncertainties related to coupled carbon and nitrogen processes in the ecosystems.

Leaf chlorophyll (chl_{leaf}) is a photosynthetic pigment that facilitates the harvesting of light energy from solar radiation used in the photosynthesis. Chl_{leaf} can be used as a proxy for plants' photosynthetic capacity, as chl_{leaf} and leaf nitrogen allocated to photosynthetic fractions in the leaf are interconnected (Croft *et al.*, 2017). Harnessing chl_{leaf} as a proxy for both terrestrial nitrogen cycle and photosynthetic capacity crucially enables the accurate retrieval of chl_{leaf} from space-borne sensing data. The state-of-the-art remote sensing (RS) chl_{leaf} retrievals allow global scale evaluation of terrestrial nitrogen cycles, and thereby can advance the estimates of future carbon sink.

In this study, we employ a TBM to simulate the chl_{leaf} content for various ecosystems globally. We harness a global RS chl_{leaf} product for evaluating the modeled chl_{leaf} in both spatial and temporal dimension.

METHODS

We conducted site-level simulations with a TBM, QUantifying Interactions between terrestrial Nutrient CYcles and the climate system (QUINCY) (Thum *et al.*, 2019) for over 500 sites globally. QUINCY includes fully coupled carbon and nitrogen cycles, and provides diagnostics for chl_{leaf}. The QUINCY chl_{leaf} is evaluated against the global RS chl_{leaf} by (Croft *et al.*, 2020). Out of the 500 sites, there were 153 sites for which we further compared the simulated gross primary production (GPP) against the FLUXNET eddy covariance observations (Ukkola *et al.*, 2022). The QUINCY simulations were conducted with half-hourly meteorological forcing. In addition, the input data included atmospheric carbon dioxide concentration and nitrogen deposition for each site. The vegetation is categorized as eight different plant functional types.

RESULTS

On global scale, the QUINCY-simulated chl_{leaf} values correlate well the RS observations (r=0.5; $p < 1 \times 10^{-26}$). The strongest statistically significant correlation was observed for the temperate broad-leaved deciduous sites (r=0.71; $p < 1 \times 10^{-7}$). For some vegetation types, QUINCY chl_{leaf} tend to be constrained to much narrower numerical range than what the RS observations would indicate. For example, the QUINCY mean chl_{leaf} for C3 grasslands vary from 4 – 17 $\mu g\,cm^{-2}$, whereas the RS observations are in the range of 2 – 47 $\mu g\,cm^{-2}$. This suggests that the modeling routine is lacking factors that affect chl_{leaf} magnitudes. The seasonality of QUINCY chl_{leaf} seems to correspond to the RS chl_{leaf}, though for the deciduous trees QUINCY produced slightly delayed start and end of the growing season.

The mean annual GPP was in general in a good agreement with the FLUXNET observations (r=0.7 ; $p < 1 \times 10^{-23}$). However, QUINCY seems to underestimate the annual GPP for majority (58 %) of sites. The underestimation was on average $-408\,gC\,m^{-2}yr^{-1}$ ($\sim -27\,\%$) for the sites where QUINCY modelled lower annual GPP.

CONCLUSIONS

Utilizing RS-based chl_{leaf} allowed us to evaluate the QUINCY carbon and nitrogen cycles at global level, and detect which of the ecosystems would require further improvement in the model parametrization and process representation. Our study illustrates how the contemporary satellite products can benefit the process-based modeling, which in turn can allow more precise modeling of the terrestrial carbon budget.

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COVER CROP EFFECTS ON CARBON SEQUESTRATION AND YIELD IN VARIED CLIMATE SCENARIOS

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Keywords: carbon sequestration, cover crop , climate scenario, STICS

Agricultural fields represent both a great opportunity for climate change mitigation through soil carbon sequestration (Poeplau and Don, 2015) and an adaptation challenge under future climate scenarios (McKenzie and Williams, 2015). Cover crops have been shown to increase soil organic carbon content over time, and may improve resiliency of fields to increasingly likely weather extremes (Kaye and Quemada, 2017). However, their performance when intercropped with a cash crop is less studied than sequential applications. We investigate the impacts of intercropping cover crops with cash crops in varied climate scenarios, focusing on the cash crop yield and field-level carbon cycle, including net fluxes and soil carbon stocks. We will calibrate the STICS soil-crop model (Brisson et al., 2003) over two growing seasons (July 2022 – late 2024) using continuous eddy covariance fluxes, chamber flux measurements, yield observations, and satellite-derived LAI from an experimental farm on mineral soil in Southern Finland. We will then simulate several cropping scenarios including different cover crops such as Italian ryegrass (shallow rooting), clover (shallow rooting and nitrogen fixing), and fescue (deep rooting), with climate forcing from CMIP6 scenarios (Lange and Büchner, 2021; O'Neill et al., 2016). This procedure will then be extended to additional sites across Finland. The change in soil carbon stock and net ecosystem exchange will be evaluated alongside the effects on yield, particularly concerning yield stability and resilience to extreme weather conditions. These simulations and modelling capability will influence a monitoring, reporting, and verification system as well as a digital twin for agricultural fields, both under development at the Finnish Meteorological Institute. These are important tools for the planning and policy decisions surrounding agricultural land management, and how best to both reduce agricultural emissions and strengthen food security.

ACKNOWLEDGEMENTS

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THE EFFECT OF TWO DISTINCT HARVESTING TECHNIQUES ON CO2 EXCHANGE IN A NUTRIENT-RICH PEATLAND FOREST

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Keywords: flux, eddy covariance, photosynthesis, respiration.

INTRODUCTION

More than 50% of Finland's original 10 Mha peatland area has been drained for forestry (Päivänen and Hånell, 2012). Draining peatlands commonly turns them from carbon dioxide (CO_2) sinks to CO_2 sources due to lowered water table, exposing peat to oxygen that accelerates peat decomposition, especially in nutrient-rich soils (e.g. Ojanen *et al*. 2013). A growing tree stand may offset the CO_2 loss from peat, turning a peatland forest into a temporary CO_2 sink (Hommeltenberg *et al.*, 2014). However, in a commercial forest, the trees are harvested eventually. Thus, the carbon stored in wood is ultimately released back into the atmosphere. Therefore, cutting down the carbon emissions of peatland forestry in the long term must be done by reducing the emissions from peat soil. Wide-spread harvesting of peatland forests is foreseen to occur in Finland in the near future. The question is whether continuous cover forestry utilizing partial cuttings could be used to reduce CO_2 emissions and the consequent climatic impact of peatland forestry compared to traditional clear-cutting and even-aged forest management.

METHODS

The study was conducted in a mature, nutrient-rich peatland forest called Lettosuo in Tammela in southern Finland. The tree stand in 2015, before cuttings, was a mixture of Scots pine (180 $m^3\ ha^{-1}$), Norway spruce (34 $m^3\ ha^{-1}$) and Downy birch (48 $m^3\ ha^{-1}$). The cuttings were performed in early 2016. A small 2.4 ha area was clear-cut (CC) with traditional methods, including ditch cleaning, mounding and planting spruce seedlings. A larger portion of the site (13 ha) was partially cut (PC) by removing all overstory pine trees (74% of the stem volume), but in contrast to CC, no ditches were cleaned or seedlings planted.

Ecosystem-level CO_2 fluxes were measured with the eddy covariance technique for six years before the cuttings. The measurements continued after the cuttings in the same location, but only the PC area was considered during data analysis. An additional EC mast was installed at the CC site after clear-cutting in April 2016. The post-cut period in both areas has been measured for eight years. The pre-cut CO_2 balances were estimated separately for the PC and CC areas (Korkiakoski *et al.*, 2023). Tree growth was recorded before and after the cuttings to separate the contributions of tree stand and forest floor to net ecosystem CO_2 exchange.

RESULTS & CONCLUSIONS

Before the cuttings, the annual CO_2 exchange was about zero, but both cutting methods turned it into a CO_2 source. After the CC, the net CO_2 emissions increased drastically. The first post-CC NEE was 3100 g CO_2 $m^{-2}\ yr^{-1}$ but decreased markedly in the next four years. However, the decrease in emissions has slowed down in the following three years. The CC area is still a considerable source (1000 g CO_2 $m^{-2}\ yr^{-1}$) of CO_2 to the

atmosphere 8 years after the cutting. On the other hand, after the PC, the first post-cut NEE was 800 g CO_2 m^{-2} yr^{-1}, followed by two years of fluctuating annual NEEs. In the fourth post-cut year, the PC area became a net CO_2 sink on an annual level and has remained as such up to this date. GPP decreased by 30% and 80% after the cuttings at PC and CC sites, respectively. Changes in TER were not as significant as in GPP. The forest floor was losing carbon both before and after the cuttings.

Our research shows that partial cutting causes markedly less immediate CO_2 emissions than clear-cutting a nutrient-rich peatland forest, mainly due to changes in photosynthesis after cuttings (Korkiakoski *et al.*, 2023). However, changing the forest management method is not a long-term solution to mitigate the climatic impact of peatland forestry, as the soil keeps losing carbon after both cuttings.

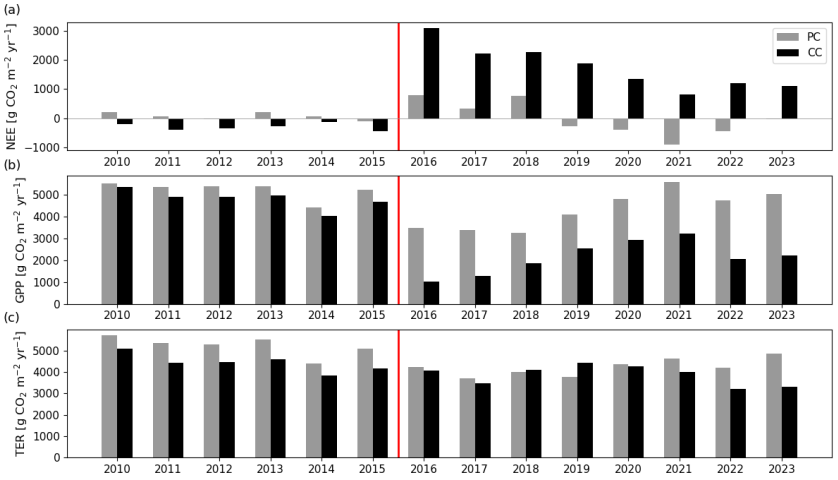

Figure 1. Net Ecosystem Exchange (NEE; top panel), Gross primary production (GPP; middle panel)) and Total ecosystem respiration (TER; bottom panel) at the partial-cut (grey) and clear-cut (black) areas for six years before and eight years after cuttings. The red vertical line separates the years to pre- and post-cut periods.

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CARBON ACCUMULATION RATES AND SEDIMENT CHARACTERISTICS IN NUTRIENT POOR NORTH BOREAL LAKES

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Keywords: C and N stable isotopes, climate, organic matter sources, end-member mixing model

INTRODUCTION

Organic matter (OM) in lake and pond sediments forms a globally significant long-term carbon (C) pool (Mulholland and Elwood 1982; Mendonca *et al.* 2017). That pool usually contain C from both allochthonous (terrestrial) and autochthonous (aquatic) sources and information of sediment C sink is needed when assessing components in both terrestrial and aquatic ecosystem C balances. The transport of terrestrial OM and its sedimentation in water bodies is considered a globally significant but still uncertain process due to its large spatial and temporal variability. For example, little is known of how sedimentation and sources of sediment C vary among oligotrophic high-latitude lakes, which are facing strong climate change impacts, including potential marked shifts in the catchment characteristics and lateral C transport.

METHODS

We studied well-dated lake sediment sequences spanning almost the entire Holocene (past ~10 kyr) from four oligotrophic lakes in northern Finland, with either peatland or forest dominated catchments (Fig. 1). We determined the contents of C and nitrogen (N), $\delta^{13}C$ and $\delta^{15}N$ of organic matter (OM), spectrally (visible near infrared spectroscopy) inferred lake-water organic C (TOC_{rec}) and chlorophyll *a* (Chl_{rec}), and diatom communities in sediment samples. Organic matter end-member data, i.e. $\delta^{13}C$ and C:N in soil, vegetation, POM, and algae samples collected from the catchments, were used for fingerprinting the OM sources.

RESULTS

The estimates of long-term mean CAR varied from 1.8 to 3.7 g C m^{-2} yr^{-1} being higher in the peatland lakes than in the forest lakes. Temporal variation in CAR over the Holocene was large and CAR was higher during the early and late Holocene when effective moisture and lake water levels were likely higher. The end-member analysis indicated discernible aquatic origin of OM in the forest lakes, while terrestrial OM made a larger contribution overall. In the late Holocene, aquatic productivity increased in the most oligotrophic lake while input from terrestrial sources increased in a peatland lake.

CONCLUSIONS

Our data with notable temporal variation in sediment CAR suggest that climate change can have far-reaching implications for catchment C budgets. In addition, our results show that water source and catchment properties impact sediment OM characteristics, rendering it even more important to understand how the hydroclimate controls the sources and quality of OM in future watersheds. These results provide a long-term temporal background for studying current and future responses of the sources and sedimentation of OM to changing conditions in hydrology, vegetation, and productivity at the northern margins of the boreal zone.

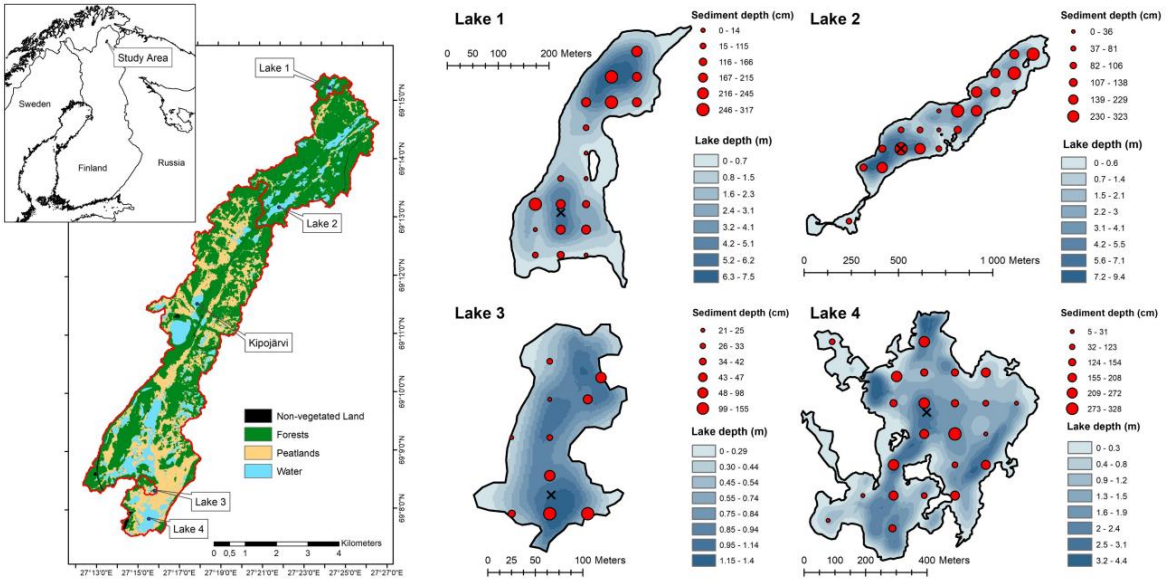

Figure 1. Locations of the study lakes (left) and the bathymetric maps with sediment depths (right).

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POST-FIRE CARBON DIOXIDE AND METHANE FLUXES FROM FORESTS SOILS DEPEND ON BURN SEVERITY

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Keywords: greenhouse gas, forest fire, climate change, boreal forest, prescribed burning

INTRODUCTION

Forest fires are arguably one of the most destructive natural disturbances in the boreal forest biome and can cause significant changes to the carbon balance in these ecosystems (Xu et al. 2022, Ribeiro-Kumara et al. 2015). Although the area of forests burned annually in Finland is currently small (<1000 ha), this area may increase both due to biodiversity directives to increase habitat diversity using prescribed burning and due to climate change intensifying wildfire regimes. Fire severity impacts the biological, chemical, and physical properties of soils which underlie greenhouse gas (GHG) fluxes (Köster et al. 2024; Xu et al. 2011). These can interact to cause complex dynamics in GHG emissions after fire (Köster et al. 2024; Ribeiro-Kumara et al. 2015). During active burning, there are very large emissions of carbon dioxide (CO_2) and methane (CH_4) from forest fires (Köster et al. 2024; Zheng et al. 2023). However, these emissions can even be surpassed by changes in GHG fluxes in the decades following fire as the ecosystem recovers its carbon sink function (Ribeiro-Kumara et al. 2015). Therefore, it is essential to understand the impact of fire on forest soil GHG fluxes as the annual area impacted by fire increases globally and fire behaviour becomes more extreme. To better understand these dynamics and what the future may hold, we must quantify GHG emissions in the early years after fire and explain the factors that impact these GHG flux rates, namely soil, vegetation, and fire characteristics.

METHODS

We aimed to measure CO_2 and CH_4 fluxes following prescribed restoration burning. Our research site was a ca. 40-year old thinned dry Scots pine (*Pinus sylvestris*) forest in Leppävirta, Finland. Soils on the site were sandy and the understorey was dominated by dwarf shrubs (*Vaccinium myrtillus, Vaccinium vitis-idaea, Calluna vulgaris*), mosses (*Pleurozium schreberi, Hylocomnium splendens*), and lichens (*Cladonia* sp.) with an intermittent cover of dry logging debris. In the spring of 2023, four permanent plots were established on the site, each containing four collars for GHG flux measurement. Three plots were located in the planned burned area (thinned) and one control plot was located adjacent to this area (unthinned). Metsähallitus conducted a prescribed restoration burn on 6 June 2024, which resulted in a medium to high fire severity surface fire across the site. Ground vegetation and logging debris were consumed across the site, but standing tree mortality varied between 0 and 100%. To ensure measurements were conducted in areas with varying burn severity (high, medium, and low), four additional plots, three burned and one control all containing four collars each, were established after burning. To measure CO_2 and CH_4 fluxes from the soils, we used a dark static chamber and a portable trace gas analyzer (Licor LI-7810). The duration of each flux measurement varied between two and three and a half minutes. To determine the impact of fire and time after fire on GHGs, we measured fluxes before fire (starting in the spring of 2023), daily immediately after fire, and at least monthly for the three months following fire until October 2024. With each measurement, we collected soil moisture and temperature data. We also measured the amount of litter and soil organic material consumed by the fire at each collar.

RESULTS

Early results indicate that fire decreased CO_2 emissions from soils, likely due to the mortality of vegetation (including trees) that contribute to soil CO_2 emissions through root respiration. On the other hand, CH_4 uptake increased following fire, but this was not equal on all plots and varied over time. In terms of burn severity, we found that plots with lower severity had greater fluxes; more CO_2 was emitted and more CH_4 was taken up in low-severity plots than in high-severity ones. Immediately following fire (i.e. when some active smoldering still present), we found that GHG fluxes were highly variable, with very high CO_2 and CH_4 emissions. Even though control areas were not thinned, there were no significant differences in soil CO_2 and CH_4 fluxes between control and treated plots prior to burning.

DISCUSSION AND CONCLUSIONS

Fire severity impacted GHG fluxes from boreal forest soils both immediately following fire as well as over the subsequent months by decreasing CO_2 emissions and CH_4 uptake with increasing fire severity. Changes in CO_2 fluxes can be generally well explained by changes in living biomass and temperature conditions (Ribeiro-Kumara et al. 2015; Köster et al. 2011). High CO_2 emissions in low severity plots are likely due to lower plant, tree, and microbe mortality in these areas, i.e. a combination of autotrophic and heterotrophic respiration (Ribeiro-Kumara et al. 2015). Increased CH_4 uptake in low severity plots is likely also linked to low microbe mortality, potential increases in microbe diversity, and soil temperature (Köster et al. 2011). However, the mechanisms and conditions that drive increases in CH_4 uptake in low-severity areas require further research.

ACKNOWLEDGEMENTS

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THE EFFECT OF YOUNG STAND MANAGEMENT ON CARBON BALANCE IN NORWAY SPRUCE SAPLINGS

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Keywords: Carbon balance, Forest management, Norway spruce, Eddy covariance.

INTRODUCTION

In final felling, the photosynthesising and carbon-sequestering trees are removed. After this, the area is regenerated, and the new growing forest begins to sequester carbon. However, carbon is quickly released into the atmosphere through soil respiration and the decomposition of logging residues, and the new tree generation and other surface vegetation are not able to sequester the same amount of carbon immediately. As a result, the regeneration area becomes a carbon source. How long it remains a carbon source depends on the characteristics of the regeneration area and the growth of the trees.

The effects of sapling stand management on the carbon balance are complex, and current knowledge does not allow for reliable predictions of the carbon balance; this requires experimental research. There has been limited research on the effects of sapling management on carbon flows in mineral soils (e.g. Kolari *et al*., 2004; Mäkipää *et al*., 2011). There is no known research in Finland that has monitored the carbon balance of the common method of mounding and planting spruce saplings in early-managed or unmanaged stands, taking into account the carbon sequestration and release of the entire ecosystem. Our hypothesis is that an early-managed spruce stand sequesters carbon less effectively in the short term than an unmanaged stand, but the difference is small and narrows quickly after the first thinning.

METHODS

In 2021, Luke (Natural Resources Institute Finland) established experimental plots on three mounded and spruce-planted stands on fresh heathland in Southern-Finland in Nastola, Karkkila, and Tammela to study the carbon balances of spruce saplings. At the time of establishment, 5–6 years had passed since the final felling and 4–5 years since planting. In the summer of 2022, early cleaning was conducted on half of the test plots, while the other half was left as an uncleaned control. In the early cleaning, all broadleaved trees that could potentially hinder the planted spruces were removed from the cleaned plots.

In the oldest sapling stand, located in Nastola on fine-textured sorted soil, the forest level carbon balance was measured using the eddy covariance method (EC) (Baldocchi 2003). In this sapling stand, five years had passed since planting. the EC measurement tower located in the middle of the experimental sapling stand continuously monitoring forest-level carbon dioxide flux above the saplings.

RESULTS

The forest-level carbon flux measurements conducted with the EC method indicate that the saplings sequestered carbon during the growing seasons and released it outside the growing season. Based on the cumulative development and observations over the course of a year, both treatments of the spruce saplings remain carbon sources nine growing seasons after felling. Early cleaning reduced carbon sequestration into biomass and increased carbon release into the atmosphere, especially during the growing season, compared to the uncleaned treatment. Annual net emissions showed no signs of reduction even in the uncleaned area. In the cleaned area, the cumulative carbon balance was 900 kg/ha higher in the first measurement year,

2 900 kg/ha higher in the second year, and 4 100 kg/ha higher in the third year than in the uncleaned area, meaning that more carbon was released from the cleaned spruce stand than from the uncleaned one. By the 2024 measurements, the difference in carbon balances between the treatments had not increased further.

From the beginning of the measurements, over a period of just over three years, approximately 3 000 kg/ha of carbon has been released into the atmosphere from the uncleaned sapling stand, and slightly over 7 000 kg/ha from the cleaned stand (Figure 1).

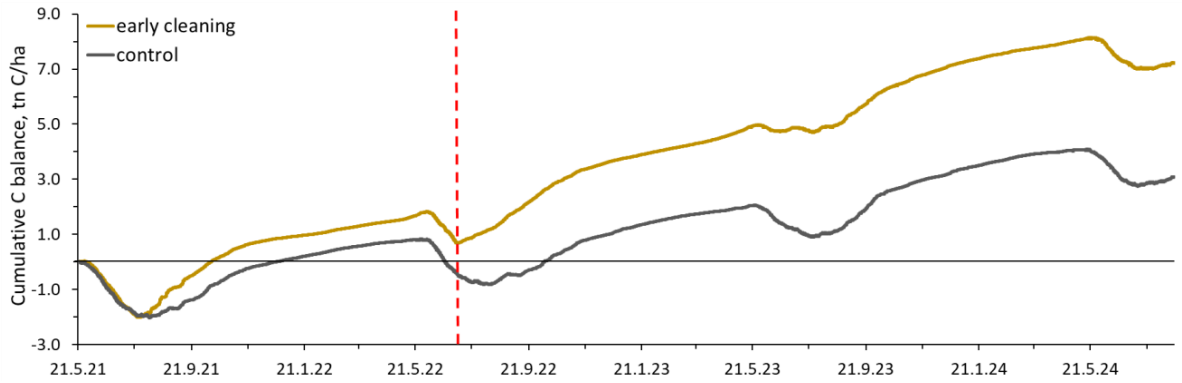

Figure 1. The cumulative carbon balance in the Nastola experimental seedling stand, from the start of the measurements on May 1, 2021, to July 31, 2024. Early thinning was carried out on the half of the experimental seedling stand in July 2022, indicated by the dashed line.

CONCLUSIONS

During the three-year project our measurements showed that a nine-year-old spruce seedling stand is still a carbon source. Early thinning increased the release of carbon into the atmosphere, but at the same time, it rapidly increased the biomass of the planted trees. The total biomass of the tree stand was still significantly higher in the untreated area. The effects of stand management treatments on tree growth and forest carbon balances will start to become apparent a few years delay, therefore further research is needed to examine how early thinning affects carbon sequestration and tree growth over the long term, also considering stand thinning.

ACKNOWLEDGEMENTS

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SHORT-TERM EFFECTS OF LOW-INTENSITY SURFACE FIRES ON DISSOLVED ORGANIC MATTER FROM BOREAL FOREST SOILS

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Keywords: Prescribed burning; Dissolved organic carbon; carbon flux; ^{13}C isotopic signature; DOM optical properties

INTRODUCTION

Boreal forest soils play a crucial role in long-term carbon (C) sequestration and storage helping to regulate the Earth's climate. Located in high northern latitudes, the boreal forest biome is warming faster than other global regions (Rantanen *et al.*, 2022). This leads to increasing fire frequency, intensity, and severity consequently threatening to turn boreal forest soils from C sinks into C sources (Walker *et al.*, 2019). Dissolved organic carbon (DOC) is a key active and labile C pool in forest soils, playing a pivotal role in soil organic C dynamics (Kalbitz and Kaiser, 2008). In boreal ecosystems, the dynamics of DOC in soil C cycling, turnover, and sequestration is still limited. Fire-induced effects on soil organic matter (SOM) are generally well understood. However, knowledge of how forest fires, especially low-intensity surface fires common in the boreal forest of Northern Europe, affect dissolved organic matter (DOM) quantity, composition, properties, and flux remains scarcely investigated. Our study aimed to improve the general understanding of how low-intensity surface fires affect DOC concentration and DOM quality in boreal forest soils immediately after the fire.

METHODS

To assess the short-term effects of low-intensity surface fires on DOC content and DOM properties in boreal forest soils, we conducted our investigation on a prescribed restoration burn site located near Ruunaa (Eastern Finland). This study site was an 18 ha stand of mature Scots pine forest on a sandy, well-drained podzol. The prescribed fire was carried out on June 30th, 2022, by the Finnish Forest Administration (*Metsähallitus*) as part of their restoration fire campaign. The burning resulted in a non-stand replacing surface fire of low intensity and severity and covered 12.03 ha.

We established three soil sampling plots, two throughfall samplers, and four zero-tension lysimeters in the burned area. As a control, we established one soil sampling plot and two zero-tension lysimeters in an adjacent unburned forest 200 m from the burned area. The burned area and the unburned control area are ecologically comparable and shared similar soils, elevation, vegetation, and microclimate. The sampling campaign took place from July to October 2022, which corresponded to the first growing season immediately following the burning. We collected soil water and throughfall samples once a month (July to October 2022) in both burned and unburned control areas. We measured post-fire litter and soil organic horizon thicknesses and collected two soil cores in each sampling plot in May 2023.

Soil water and throughfall samples from burned and unburned control areas were immediately filtered (0.45 µm) in the field. In the laboratory, we analysed these samples for DOC content and $\delta^{13}C_{DOC}$ isotope composition with a coupled elemental analyser and mass spectrometer (EA-IRMS). To identify post-fire changes in DOM chemical composition, we measured and compared the ultraviolet-visible absorbance spectra of the water samples. To further estimate the aromaticity, molecular weight, and humification of

DOM, we determined various spectroscopic indices derived from DOM absorbance properties such as the $SUVA_{254}$ index and the E_2/E_4 absorption ratio (Weishaar *et al.*, 2003; Helms *et al*., 2008). Each soil core was divided into subsamples based on soil horizon and depth. All subsamples were dried in an oven at 70°C for 24 hours, then sieved to 2 mm and ground. We determined the main physicochemical properties of SOM from burned and unburned control plots, including soil pH (pH_{H2O}), soil bulk density, soil C stocks, and $\delta^{13}C_{SOC}$ values (EA-IRMS).

RESULTS

We found that the low-intensity fire consumed the aboveground vegetation but only partially burned the first centimetres of the organic soil horizons, leading to the formation of a pyrogenic layer on the forest floor. Even though no significant losses of soil total C content were observed, the surface fire led to a decrease of soil DOC content, mirrored by an enrichment in ^{13}C in DOC from burned soils compared to unburned ones. This is likely due to the loss of soluble C caused by organic topsoil combustion and reduced microbial biomass, as well as inputs of newly formed pyrogenic C with a reduced proportion of lignin-derived ^{13}C. Soil DOM from burned soils was characterised by slightly higher degrees of aromaticity and molecular weights, suggesting the presence of a more recalcitrant and stable C pool in the soil water during the first months following fire.

CONCLUSIONS

Our results highlight the short-term effects of low-intensity surface fires on boreal forest soils through fire-induced changes in soil DOM content and chemical composition. Upland forest soils are hydrologically connected to boreal lakes and streams, meaning that post-fire fluxes of soil DOC are a key concern for the quality of surface water in burned boreal forest catchments and for regional C budgets. Owing to the importance of the boreal soil DOC pool for regional C balance and surface water quality, low-intensity surface fires should be considered in boreal forest management strategies.

ACKNOWLEDGEMENTS

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ASSESSING THE DIFFERENT CLIMATE IMPACTS OF MANAGED FORESTS

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Keywords: Forestry, Climate change, Albedo, Water budget, CO_2-equivalent

INTRODUCTION

Carbon sequestration is not the only way forests influence the Earth's climate. Accounting for the other impact pathways in forest management decision making is worth considering. Forests have relatively low albedo in comparison to other land cover types, which causes a local warming effect due to relatively high absorption of solar radiation (Betts, 2000). Water budget is also affected by forests, as their roots are capable of extracting water deep from the soil and canopy offers large area for evapotranspiration. This results in high flux of latent heat, which causes local cooling of the forest area when other land cover types are used as a baseline (Breil, 2024). Comparing the relative significance of these three impact pathways is not straightforward. Here we display the process of comparing the different climate impacts and present an example simulation with results. End goal is to analyze the total climate impact of a boreal Finnish pine forest under three different forest management scenarios (Lintunen, 2015) and multiple climate models. Land ecosystem model JSBACH-FOM (Tyystjärvi, 2024) is used in the simulations and it is calibrated to represent a boreal pine forest growing on a mineral soil, based on the climate and the soil properties present in Hyytiälä SMEAR II research station.

METHODS

Comparing the impact pathways is done by using a metric called Time-dependent emission equivalence or **TDEE** (Bright, 2016), which outputs a column vector producing the yearly CO_2 equivalent emissions reproducing a specific radiative forcing profile, resulting from for example an albedo difference between two areas over a time period. $\sum$**TDEE** is directly comparable with the carbon sequestration difference between two areas.

In the example scenario a pine forest is planted in 1900 and harvested in 1962. Sequestrated carbon, absorbed radiation and fluxes of latent and sensible heat are examined and compared to the same parameters from 1963 to 1967 where the pine forest has not yet grown again.

RESULTS

The comparison shows (table 1) that carbon sequestration is the most important factor in terms of climate change mitigation, since 80.73 kg of CO_2/m2 was sequestrated from 1900 to 1962. CO_2 equivalent values of other impacts were not insignificant, as the total climate impact in terms of CO_2 equivalent was reduced to 76.38 kg of CO_2/m2 after accounting for them. Difference in the absorbed radiation is largest and it is comparable to a reduction in carbon sequestration of 6.09 kg/m^2 of CO_2 equivalent. Latent heat release corresponds to cooling worth of 2.99 kg/m^2 CO_2 equivalent. Sensible heat flux is lower before the harvest, representing 1.25 kg/m^2 less CO_2 equivalent.

Table 1: The difference between absorbed radiation, latent heat flux, sensible heat flux and carbon sequestration and their total cumulative effect between forest growth (1900-1962) and initial years after harvest (1963-1967).

	Difference in radiative forcing before and after harvest	CO_2 equivalent
Absorbed radiation	2.73 W/m^2	-6.09 kg/m^2
Latent heat flux	-1,34 W/m^2	2.99 kg/m^2
Sensible heat flux	0.56 W/m^2	-1.25 kg/m^2
Carbon sequestration	-	80.73 kg/m^2
Total	-	76.38 kg/m^2

CONCLUSIONS

Results are in line with the initial assumption that lower albedo of the forest causes local warming. Albedo also appeared as the largest contributor after carbon sequestration. Cooling due to latent heat flux was also shown, but impact of this was reduced by the resulting decrease of sensible heat flux. Based on this simulation this methodology is proven to be efficient and can provide valuable insights in forest management. It will provide value when used to compare different harvest scenarios together with future climate scenarios in order to determine in which scenario the combination of these parameters leads to the highest possible CO_2 equivalent removal from the atmosphere.

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HOW DOES ROTATION FORESTRY AND CONTINUOUS-COVER FORESTRY AFFECT THE MICROCLIMATE AND THE MORPHOLOGY OF DWARF SHRUBS IN BOREAL FORESTS

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Keywords: Continuous-cover forestry, Rotation forestry, Dwarf shrub morphology, Microclimate in boreal forests, Ecosystem services

INTRODUCTION

Maintaining different forest ecosystem services face multiple challenges due to climate change and other anthropogenic disturbances (Thom et al., 2016). To enhance these ecosystem services in changing climate, the use of different forest management practices needs to be critically assessed (Pohjanmies et al., 2017). Since conventional rotation forestry (RF) has been shown to impact the forest soil structure, forest heterogeneity and reduce the biodiversity (Gauthier et al., 2015, Kim et al., 2021), alternative options have gained more interest in Fennoscandia during the last decades (Valonen et al., 2020). With continuous-cover forestry (CCF), a potentially suitable alternative, the aim is to mimic more natural disturbances (Kuuluvainen et al., 2012). As a result, CCF could maintain a more similar microclimate to unmanaged forests and gain a higher biodiversity compared to RF (Kim et. al., 2021). However, there is still lack of evidence on the impact of CCF on forest floor microclimate and its spatial variation. Several studies have shown that dwarf shrubs represent a suitable bioindicator to assess the effect of anthropogenic disturbances to ecosystem services of boreal forests. They provide a habitat for wildlife, contribute to biodiversity and to nutrient cycling (Nilsson and Wardle, 2005). We have found studies with contrasting results in the literature on how RF affects dwarf shrubs. While Atlegrim and Sjöberg (1996) demonstrated that the shoot-survival of bilberry shrubs declined in clear-cut sites managed by RF, a study carried out by Nybakken et al. (2013) showed that reproduction and defence of bilberry shrubs were enhanced in clear-cut sites compared to mature forest sites. To our knowledge, there is a lack of studies comparing the effects of RF and CCF in boreal forests on dwarf shrubs. We analyzed how the microclimate in forest stands was affected by RF and CCF, how morphological traits of bilberry (*Vaccinium myrtillus*) and lingonberry (*Vaccinium vitis-idaea*) were affected by RF and CCF, and to what extend the microclimate was suitable to explain the different morphological traits of bilberry and lingonberry.

METHODS

The study material was collected from two different experimental research areas that were managed by the Natural Resources Institute Finland (Luke). The first area was located in Padasjoki, Southern Finland (61° 26′ 00.4″ N, 25° 01′ 27.7″ E) and managed by CCF or RF. The CCF stands were part of the ERIKA research project plots that studies the forest development on tree and stand level in CCF (Valkonen et al., 2020). The RF stands were forest stands managed by RF and classified in four different age classes: recent clear-cut, young, immature, mature (Aalto et al., 2023). Further study material was collected from a second area, 27 km north from Padasjoki, in experimental plots of the Isojärvi research area in Kuhmoinen, Southern Finland (61° 40' 37.95" N, 24° 58' 1.1" E). The Isojärivi experimental plots were managed by gap-cuttings. The sites were established as part of the research project 'DISTDYN'. Aim of this project is to study how variation in temporal and spatial scales of felling affects forest structure and biota (Koivula et al., 2014). In total 59 TMS-3 automatic climatic stations (TOMST, Prague, Czech Republic; http://www.tomst.com/tms/TMS-3.html) were installed during April 2021 in the Padasjoski sites and 24 TMS-4 automatic climatic stations (TOMST, Prague, Czech Republic; https://tomst.com/web/en/systems/tms/tms-4) during November 2021 in the Isojärvi sites. In the Isojärvi sites, the sensors were installed in gaps (in distances 6.5m-19.5m to

forests) and in gap-surrounding forests. The sensors measured the air temperature (+12 cm from soil surface), surface temperature (± 0 cm from soil surface), soil temperature (- 6 cm from soil surface, and soil moisture (-6 cm from soil surface) in 15 minutes frequency. From the 02.08.2022-03.08.2022 one *V. myrtillus* (VM) and one *V. vitis-idaea* (VVI) dwarf shrub, adjacent to each climatic station, were sampled. We recorded the height, width, circumference at the base, and the elongation from all branches from the begin of 2022 until sampling day. In addition, we took stem samples to calculate the ring width and sampled the top five leaves of the top stem of each shrub to determine the specific leaf area (Garnier et al., 2001). Before sampling the shrubs, at the top of each shrub-canopy photographs were taken at 0° angle, oriented to the north by the smartphone front camera (iPhone SE 3rd generation, Apple Inc.). The pictures were analysed with a smartphone and tablet PC application (VitiCanopy2, Adelaide Research & Innovation Pty Ltd) and the plant area index and canopy cover calculated automatically (De Bei et al., 2016). All data analyses were proceeded with R 4.4.0 (R Core Team, 2024).

PRELIMINARY RESULTS

Clear-cut stands showed higher average soil temperatures during the growing season from May 2022-July 2022 compared to the other ages of RF and CCF in the Padasjoki area. Further, we measured higher total elongations (sum of the elongation from all branches per dwarf shrub) and higher specific leaf areas (SLA) for VM than for VVI in all treatments in both areas. Young forest stands responded with lower total elongations for VM, while the highest SLAs were measured these stands. In addition, we measured the highest plant area index (PAI) in young forest stands. In the Isojärvi plots, larger distance to forests resulted in higher soil temperatures. VM inside forests showed higher SLAs than VM in gaps (Figure 1).

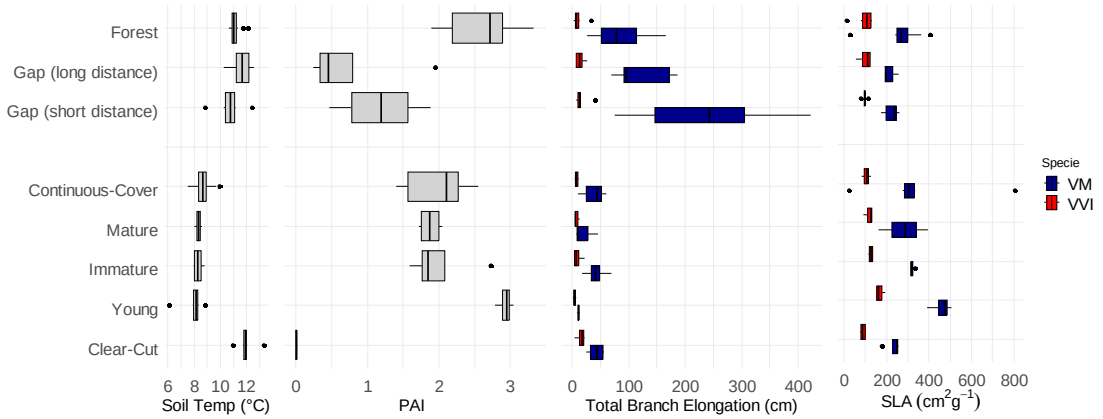

Figure 1. Average Soil Temperature in °C (from May-July 2022), Sum of elongation from all branches per dwarf shrub since begin 2022 in cm, PAI = plant area index (m^2*m^{-2}), and SLA = specific leaf area of dwarf shrubs in cm^2*g^{-1} (median ± quartile±min,max) in different forest management treatments in Isojärvi: Forest, n= 12; Gap (long distance =12.5-19.5m distance to forest), n=6; Gap (short distance = 6.5-9.5m distance to forest), n=6. and Padasjoki: Continuous-Cover, n=36, Mature, n=5, Immature, n=6, Young, n=6, Clear-Cut, n=6. VM= *V.myrtillus, VVI= V. vitis-idaea*.

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NEW PARTICLE FORMATION AT THE IZAÑA HIGH-ALTITUDE STATION: INSIGHTS INTO LOCAL CLUSTERING AND TRANSPORT

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Keywords: new particle formation, size distribution, high altitude

INTRODUCTION

New Particle Formation (NPF) affects climate and air quality. Secondary atmospheric particles formed during NPF can serve as cloud condensation nuclei if grown to larger sizes, affecting interactions with clouds and solar radiation. NPF, with characteristics varying by environment, remains not fully understood. Understanding NPF events in mountain sites and at high altitude is particularly difficult, not only due to the complicated maintenance of the instruments at low pressure, but also due to the complex topography that influences the phenomenon (i.e., Bianchi et al., 2022). At mountain sites, for example, the transport of particles and vapours from the lower altitudes is frequently observed (García et al., 2014).

METHODS

To study NPF in this kind of complex environment, we performed a three-month measurement campaign from March 28th to June 27th, 2022, at the Izaña Atmospheric Observatory (2367 m a.s.l.) on the island of Tenerife, Spain. At the site free tropospheric conditions and boundary layer influence alternate. This work focuses on the particles and ions number size distributions (1.2-500nm) measured with a Particle Size Magnifier, a Neutral cluster and Air Ion Spectrometer and a Scanning Mobility Particle Sizer.
NPF was analysed by applying the nanoparticle ranking method proposed by Aliaga et al. (2023). In particular, the concentration of 2-2.3 nm positive ions was used to rank the days exhibiting local clustering (Tuovinen et al., 2023), as the traditional regional NPF (e.g., Nieminen et al., 2014) is not observed at the site based on the particle number size distributions during our measurement period. The size distributions were also analysed together with meteorological variables and pollutant concentration data, measured at the Izaña Atmospheric Observatory.

RESULTS

Our preliminary results suggest that a combined mechanism of local clustering and transport from the boundary layer (BL) occurs during the daytime in Izaña. First, in fact, both the ions and the particles size distributions show a gap in concentration between ~ 2 nm and ~ 10 nm during most days, which is different from the patterns typically observed during regional NPF events. The transport from the BL is supported by the strong relationship between the increase in the number concentration of large particles and the increase in concentration of BL tracers (such as black carbon, CO, NO_x, water mixing ratio). Lastly, the correlation

between the concentration of 2-2.3 nm ions, which are representative of local clustering, and that of 10-30 nm particles, representative of transport, is not clear, supporting the hypothesis of them being two different processes, despite being deeply connected.
Indeed, our focus on the local clustering process points out that the transport from the BL is itself essential to have this phenomenon. In particular it is clear that high concentration of the precursor vapours sulfuric acid and Highly Oxygenated Organic Molecules (HOMs), together with low wind speed promote the formation of new particles (Figure 1).

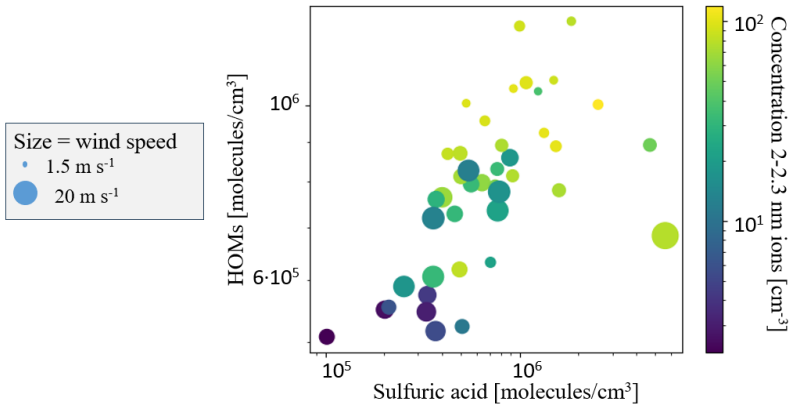

Figure 1. The relationship between the concentrations of the precursor vapors HOMs and sulfuric acid and the concentration of 2-2.3 nm positive ions, which is representative of local clustering. The marker size represents the wind speed.

CONCLUSIONS

Our study infers that local clustering and transport from the BL happen in Izaña and that they are deeply connected. The influence from the BL is, indeed, essential to have local clustering at this site. In particular, this phenomenon is observed when an increase in the precursor vapours concentrations and a decrease of the wind speed occurs. Considering that transport seems to play such a crucial role, Lagrangian particles dispersion model coupled with a high-resolution meteorological models will be applied to study the relationship between clustering and air mass origin.

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QUANTIFYING URBAN BIOGENIC CARBON SEQUESTRATION: CURRENT KNOWLEDGE AND FUTURE DIRECTIONS

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Keywords: PHOTOSYNTHESIS, RESPIRATION, PROCESS-BASED MODELLING, HEAT

INTRODUCTION

Cities worldwide are combating climate change by reducing emissions and aiming for carbon neutrality. Urban vegetation is increasingly used as a cost-effective way to offset some of the emissions in addition to providing many other ecosystem services. However, the diverse types of urban vegetation and variable environmental conditions make empirical carbon sequestration estimation challenging, and therefore models are needed for accurate quantification on the city scale and for guiding urban planning towards future climate. Although many models based on natural ecosystems exist, they are seldom tested in urban settings which have unique challenges, such as soil water limitations and increased temperatures, affecting ecosystem functioning and carbon sequestration.

METHODS

Since 2020, we have collected observations from various vegetation types (lawns, meadows, parks, roadside trees, an apple orchard, and an urban birch forest) in Helsinki, Southern Finland. While some sites were studied more intensively, the dataset includes both manual and automatic measurements of tree shoot CO_2 exchange, light response curves for grasses and herbs, shoot growth dynamics, soil CO_2 emissions, sap flow, soil carbon and nitrogen content, leaf water and chlorophyll content, green coverage, leaf area index (LAI), root growth dynamics, net ecosystem exchange of CO_2 and water, soil moisture, soil temperature, and micrometeorology. Additionally, we utilized solar-induced fluorescence (SIF) measurements from TROPOMI and OCO-2, along with LAI data derived from Sentinel-2. The data collected served as an important testing material for ecological research questions, but these measurements were also used to evaluate and advance process-based models simulating carbon cycle. We tested the urban SUEWS model, in addition to LPJ-GUESS, and JSBACH, which are land-surface modules in earth system models EC-EARTH and MPI-ESM, respectively.

RESULTS

During 2020-2022, the study sites experienced heat and drought conditions that were uncharacteristic for the region, but still not excessive enough to cause major limitations to ecosystem services provided by trees, such as cooling, even under extreme conditions (Ahongshangbam et al. 2023). However, intensively managed grasslands such as unirrigated lawns suffered from dry seasons and their photosynthetic production

decreased in contrast to irrigated lawns or meadows (Tremeau et al. 2024). Irrigation also has a significant effect on the carbon cycle in tree-covered systems as heterotrophic soil respiration responded more strongly to increased soil moisture than to the simulated urban heat island effect, especially during dry summers (Karvinen et al. 2024). Although tree planting is commonly seen as an attractive way to increase carbon sinks, Havu et al. (2022) showed that heterotrophic respiration from growing media after planting street trees hinders the carbon sequestration potential of the plantations for years. The successfully tested models replicated the observed component fluxes, such as seasonal changes in soil respiration and shoot photosynthesis, and the drivers, such as LAI, soil moisture and soil temperature (Thölix et al. 2024). However, the annual carbon sequestration varied considerably between the different models. The results were upscaled for the city of Helsinki using the SUEWS model (Havu et al. 2024) showing that urban vegetation in Helsinki sequesters 36.3 ± 7.7 kt C carbon annually and 47 % of that is by urban neighbourhoods i.e., outside forested areas.

FUTURE DIRECTIONS

It would be important that future urban biogenic GHG research focuses on accounting also for methane (CH_4) and nitrous oxide (N_2O) fluxes, as these are likely to play a significant role in fertile and irrigated vegetation types. Innovative climate-friendly soil media, such as circular materials, would improve the climatic impact of urban plantations. The performance of the models in future climates would benefit from further testing in different cities, the inclusion of new urban vegetation types, improved performance in extreme conditions and the integration of new data streams. Effective use of remote sensing data and model-data fusion techniques could improve scalability for new cities. Finally, the development of practical tools for urban planning will ensure that scientific knowledge is translated into actionable strategies for sustainable and climate-friendly construction and maintenance of urban nature.

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MODELLING OF BIOGENIC CO_2, HEAT FLUXES AND TEMPERATURE SPATIALLY IN ZÜRICH, SWITZERLAND

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Keywords: Urban, Modelling, CO2, Heat fluxes.

INTRODUCTION

A growing number of population lives in cities. Because of this, urban areas create a lot of greenhouse gas emissions, which enhance climate change. It is important for cities to reduce these emissions, but also find other solutions to mitigate their climate impact. One mean to reduce emissions is sequestrating carbon dioxide (CO_2), and urban green areas are key to this. Urban vegetation offers also other climate benefits such as enhancing cooling by proving shade and through evapotranspiration.

In this study, the combined effect of urban green areas on uptaking atmospheric CO_2 and cooling the local conditions is studied. Biogenic CO_2, heat fluxes and temperature are all studied together in the city of Zürich, Switzerland. It is one of the pilot cities in ICOS Cities project, which aims to develop tools and services based on science for cities to support their local climate action plans.

METHODS

The study is conducted with urban land surface model SUEWS (Surface Urban Energy and Water balance Scheme), which can simulate energy, water and CO_2 exchanges in urban neighbourhood scale (Järvi *et al.*, 2019). It also produces temperature profile in the roughness sublayer (RSL). For running the model, you need information about the land cover type fractions and parameters associated with each of those surface types. The land cover types are roads and paved surfaces, buildings, evergreen trees, deciduous trees, grass and water bodies. In addition, you need meteorological forcing data.

In this research, city of Zürich was modelled spatially by dividing the city area into 200 x 200 m^2 grids. Each of the grid had their own meteorological forcing data, which were the output of ICON-Art model (500x500 m^2) (Rieger *et al.*, 2015). The model run was done for one year, July 2022 to June 2023, and the Jan-June 2022 was used as a spin-up period.

The results of the model were compared against measurements conducted in the city as a part of the ICOS Cities project. Fluxes of CO_2, latent and sensible heat were compared to the eddy covariance (EC) measurements in the 111-meter tall Hardau II tower in the city center. Temperature variations in the city were tested against rooftop sensor network, which has approximately ten locations inside the city. For each site, temperature was compared against model output result selected from the same height as the rooftop.

RESULTS

From the results we see that the model can catch the spatial and temporal variations in temperature. Only in wintertime, especially during night, model underestimates temperatures slightly.

Comparison of fluxes of CO_2, latent and sensible heat between the measurements and the model show that further analysis on footprint is needed, since the model shows too large CO_2 emissions especially on the daytime. In addition, the sensible heat is not matching with the observations. Latent heat flux is modelled well.

The spatial biogenic CO_2 maps show that the forests surrounding the city are the biggest sinks of CO_2, but some green areas inside the city also act as a sink. In the forest, sinks are approximately 0.4 kg C m^{-2} $year^{-1}$, and in the urban green areas 0.1 kg C m^{-2} $year^{-1}$.

CONCLUSIONS

The SUEWS model is used in city of Zurich to study CO_2, heat fluxes and temperature. Results show that the model gives reasonable values for yearly CO_2 exchange, and the validation with temperature and EC data reveal that the model can simulate temperature and heat fluxes as well. Further work with the footprint analysis is needed.

ACKNOWLEDGEMENTS

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MIDDLE-LATE HOLOCENE COOLING INCREASED THE SOIL CARBON STOCKS IN AN ARCTIC-ALPINE ENVIRONMENT ON VARANGER PENINSULA (NORWAY)

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Keywords: Soil organic carbon stocks, Holocene, Carbon sink, Cold periglacial tundra.

INTRODUCTION

The climate is changing rapidly with increases in near surface air temperatures almost everywhere globally, and especially in the Arctic (Pörtner *et al*., 2022). A big contribution to the climatic changes of the current era comes from the anthropogenic emissions of atmospheric carbon in the form of CO_2, however, carbon is also stored in the Earth's crust, the oceans, and the terrestrial ecosystem. A particularly relevant carbon pool concerns the northern circumpolar permafrost region, and a series of recent reviews have been conducted with the purpose of estimating the current carbon stocks of its soils (Tarnocai *et al*., 2009; Hugelius *et al*., 2014). However, the focus there was purely on permafrost environments, leaving a gap on the soil organic carbon (SOC) stocks and distribution in non-permafrost cold periglacial landscapes. Kvitnesfjell, located in NW Varanger Peninsula (N Norway), is a hilly cold periglacial environment that lacks permafrost, but includes landforms such as wetlands, earth and peat hummocks, and solifluction. To our understanding, this is the first detailed SOC inventory of a cold periglacial area that lacks permafrost. The main objectives are to (1) conduct a detailed field SOC inventory and calculate the mean SOC stocks at landscape level, (2) identify the areas and landforms that store high amounts of SOC (carbon hotspots), (3) determine when these landforms were formed, and (4) discuss the potential vulnerability of these carbon hotspots to climate change.

METHODS

Five transects were selected and the sampling sites were placed along these transects at strictly equidistant intervals. Soil samples were collected, and a description of land cover was made in situ before sampling. Additionally, solifluction features were analysed in greater detail. The soil samples were then analysed for the parameters crucial for the estimation of SOC stocks. Some subsamples were also sent for elemental analyses to get C and N contents, while some were sent for ^{14}C dating for the paleoenvironmental reconstruction of the study area. A high-resolution satellite image was then used for a land cover classification of the 9 classes mentioned in Table 1, and the weighed mean SOC stock values of each class were upscaled to the whole study area of 21.7 km^2.

RESULTS

Wetlands hold the highest SOC values at full depth with 37.1 ± 21.3 kg C m^{-2}, however, they cover only 8.3% of the total study area (Table 1). Dry heath tundra dominates the landscape (33.7%), and the mean SOC is 5.46 ± 4.19 kg m^{-2}. The SOC stocks in Kvitnesfjell lie in between the values from other permafrost and periglacial mountainous and hilly areas. They are not so high to consider the area a carbon hotspot, however, in some cases, values even above 50 kg C m^{-2} are observed, with a maximum value found at a wetland site (97.5 kg C m^{-2}). Unique periglacial features like solifluction lobes and earth hummocks also hold significant amounts of carbon. Wetlands have basal dates ranging between 7088-119 cal yr BP, earth hummocks between 4363-1644 cal yr BP, and buried organic layers in solifluction lobes range in age between 5250-350 cal yr BP. These ^{14}C dates show that these landforms are all of Middle to Late Holocene age, a period associated with colder and wetter conditions based on proxy analyses of lake sediments in the

region (Huntley et al., 2013). This cooling and increased moisture of the climate increased the carbon sink capacity in Kvitnesfjell.

Table 1. Plant and soil attributes and SOC storage (kg C m^{-2}) for the 0-30 cm and 0-100 cm depth intervals for each land cover class (means and standard deviations), and for total study area (weighed means and confidence intervals).

Land Cover	% cover in study area	Sites (n)	% plant cover (mean ± sd)	% stones [a] (mean ± sd)	Soil depth in cm (mean ± sd)	SOC 0-30 in kg C m^{-2} (mean ± sd)	SOC 0-100 in kg C m^{-2} (mean ± sd)
Open Water	0.29	4	5 ± 12	72 ± 19	2.6 ± 2.7	0.17 ± 0.27	0.17 ± 0.27
Bare Grounds	7.09	4	10 ± 9	45 ± 34	23 ± 9	0.94 ± 0.79	0.94 ± 0.79
Sparse Tundra	25.1	5	66 ± 20	29 ± 12	19 ± 9	2.99 ± 0.71	3.01 ± 0.76
Dry Heath Tundra	33.7	13	114 ± 9	1 ± 2	38 ± 26	4.38 ± 2.23	5.46 ± 4.19
Mesic Tundra	5.62	2	130 ± 14	0 ± 0	55 ± 47	8.38 ± 3.25	11.5 ± 7.64
Earth Hummocks	13.4	6	119 ± 7	0 ± 0	34 ± 15	16.8 ± 9.90	18.0 ± 10.6
Grass Tundra	6.38	2	120 ± 0	0 ± 0	31 ± 4	7.11 ± 1.38	7.50 ± 1.94
Tall Shrub	0.15	1	130	0	82	6.57	16.8
Wetlands	8.30	4	109 ± 22	0 ± 0	61 ± 14	13.7 ± 5.94	37.1 ± 21.3
Study area	**100**	**41**				**6.61 ± 1.28[b]**	**9.31 ± 2.30[b]**

[a] Stones >4 cm diameter at surface, [b] Weighed averages with confidence intervals

CONCLUSIONS

This study is a detailed SOC inventory at landscape level in a cold periglacial tundra area without permafrost, something that has not been done before. The periglacial landforms found in Kvitnesfjell are of Middle to Late Holocene age, related to the cooling that took place after the Holocene Thermal Maximum. The results indicate that the cooling increased the carbon sink properties of the area. Considering the future climatic changes in the Arctic, with increased temperatures and precipitation, the carbon sink in the study area is expected to decrease.

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EDDY COVARIANCE FLUX MEASUREMENTS FOR UNDERSTANDING THE CLIMATE IMPACTS OF PEATLAND USE AND RESTORATION IN FINLAND

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Keywords: Greenhouse gas flux, drainage, carbon dioxide, methane, nitrous oxide, peatland rewetting, ICOS.

INTRODUCTION

While peatlands constitute a huge carbon storage globally, they also impact the atmosphere and climate in various other ways. More than half of the original peatland area of ca. 10 Mha in Finland has been drained, mostly for forestry. Drained peatlands constitute a large emission source in the land use sector, hindering Finland's way into carbon neutrality, pursued by 2035. To ensure the future of carbon sink and storage, and to mitigate the emissions from drained peatlands, one must understand the complex interactions between the biogeochemical cycles, greenhouse gas (GHG) fluxes, peatland processes and external pressures, such as climate and human impacts.

METHODS

The Finnish Meteorological Institute, University of Helsinki, University of Eastern Finland, University of Oulu and the Natural Resources Institute Finland have, during the past 25 years, established an eddy covariance (EC) measurement network to study ecosystem-atmosphere exchange of GHG's and energy. The network consists of nearly 20 peatland sites across the length and breadth of Finland with several land use or land cover types and provides continuous data on the GHG fluxes and climate impacts of peatland use, including that of the local biophysical forcing. More recently, the attention has been diverted to the impacts of peatland restoration by rewetting, allowing development towards mire functionality. In our EC sites, we also monitor numerous supporting parameters to better understand the ecosystem processes affecting the carbon and GHG balance.

RESULTS AND CONCLUSIONS

While the monitoring of drained peatlands has provided interesting insights into the dynamics of fluxes driven by the hydrometeorological conditions and management, the restored sites will allow us to understand the immediate, quickly developing response of the ecosystems following the rewetting. In this presentation, we will introduce the peatland flux measurement network in Finland. We will focus on the new sites that are yet to-be-rewetted, and show selected results from the other sites, including pristine mires, which provide a reference when estimating the climate impacts and feedbacks.

CHAMBER-MOBMESTA - AN AUTOMATED OFF-GRID GREENHOUSE GAS FLUX CHAMBER MEASUREMENT SYSTEM

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Keywords: Innovation, Instrument development, Solar-powered, Field measurement

INTRODUCTION

Direct measurements of greenhouse gas (GHG) exchange between ecosystems and the atmosphere are dominated by eddy covariance (EC) and chamber flux methods. EC is the most suitable for quantifying GHG balances on homogeneous ecosystems, whereas the strength of chamber measurements is in partitioning the fluxes and processes. The methods complement each other.

The INAR community is known for extensive studies at flagship stations. The purpose of MOBMESTA (MOBile MEasurement STAtion) is to extend the studies to new sites. The goal is to be able to conduct comprehensive measurements at sites with no access to electrical grid, and additionally no direct car access. The system is designed all-year-round operation in mind, but winter operation will require additional maintenance. MOBMESTA will consist of separate EC and chamber measurement stations with continuous meteorological and environmental measurements from the atmosphere and soil. An option to add site-specific ecological measurements is an important part of the specifications.

SPECIFICATIONS AND DESIGN

The chamber operation, i.e. closing and opening the chambers and transporting the gas to the analyser(s) is automated. However, as chambers require maintenance, the maintenance cycle of the system is designed to be 2 to 4 weeks. The system is designed such that chambers can operate pneumatically or electrically, including soil, stem and shoot chambers. chambers included in the system, custom chambers or both can be used. Both flow-through (dynamic) and closed loop (static) chambers will be supported.

MOBMESTA is a mobile system, meaning it should be possible to move it to a new site at relative ease. None of the parts of the system weighs more than 22kg, meaning that, if needed, a single person can install it. The system itself is built on a trolley (load area 1 x 0.6m, maximum load 400kg). The trolley acts as a stable 2-wheeled wheelbarrow, that allows easy balancing of the load.

The system (Fig. 1) has 16 sample lines, controlled by a Raspberry Pi, relay controllers and solenoid valves. The sample air is transported by a vacuum membrane pump, and the lines not being measured are flushed by a separate pump. The system is built around 4mm diameter (2.5mm inner diameter) tubing, that is smaller than the typically used 6mm (4mm) tubing. This allows small flow rates (up from 0.05L/min), that allows better signal for flow-through chambers, and less pressure effects for (static) closed-loop chambers.

The compressed air is designed to be used from industrial pressurized gas bottles. The system is designed to run from 1 to 6 months with one 20L (roughly 21kg when full) gas bottle, depending on the use case. The system is specified for LI-COR LI-870, LI-7810 and LI-7820, analysers with low power consumption (≤22W), but also other rack-sized or smaller analysers can be used.

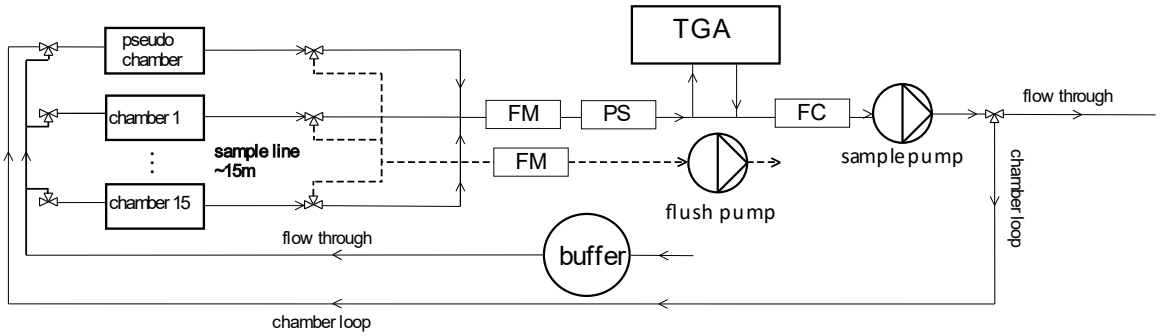

Figure 1. Schematic illustration of the gas flow in the system. Either flow through or chamber loop modes can be configured. Dashed line is for sample line flushing. One line is measured at a time while others are being flushed. Pseudo chamber sampling line is used to measure inflow to the chamber in flow through mode. TGA = trace gas analyzer, FM = flow meter, PS = pressure sensor, FC = flow controller.

POWER SYSTEM

The system is powered via solar panels and a lithium iron phosphate (LiFePO4) 25.6V batteries. The system consists of eight 100Ah 24V batteries, each weighing 19kg, and providing approximately 10 kWh of energy. LiFePO4 technology allows full battery capacity to be used without harming the batteries. A heating element enables battery charging also below 0°C. During cold periods, the power consumption and insulation keep the temperature inside the casing about 20°C higher than outside.

The solar panels consist of 10 JASOLAR 440W N-type glass-glass (22kg/panel) panels. The panels are suitable for vertical installation as they collect light from both sides. Vertical orientation reduces the need of snow removal from panels. Vertical installation is almost as efficient traditional tilting, as bi-facial panels collect efficiently reflected light and are not overly sensitive to compass point orientation.

Sample line heating is needed to avoid water vapor condensation inside tubing. The amount of energy needed for this is the most crucial factor for the total energy consumption and is associated with relatively large uncertainty. However, solutions like insulation of sample lines and toggling system on and off can reduce energy needs substantially. With Li-870, without heating, the total power of the system is <30W. During the darkest period in Finland, solar panels expected to produce electricity at approximately 40W on average (1% of nominal capacity). With full batteries, without solar panels, heating or power saving, the system would run approximately 2 weeks, after batteries need to be replaced with full ones.

THE NEXT STEPS

The Chamber-MOBMESTA is currently being built and tested, whereas EC-MOBMESTA is mostly designed, waiting to be constructed. The systems will be available to use within the INAR community based on needs and agreements for time periods of some months up to a few years in one location. According to the plan, Chamber-MOBMESTA will be ready for field-testing in spring 2025. If there is interest and funding, additional copies of the system may be constructed.

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AFFORESTATION TURNS CUTOVER PEATLAND INTO A CARBON SINK

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Keywords: peat, carbon dioxide, afforestation, carbon sink

INTRODUCTION

Rates of peat extraction have been rapidly declining in Finland, leaving thousands of hectares of formerly cutover peatlands which need to be managed. Unlike in some other regions, in Finland there is no obligation to restore former peat extraction sites to wetlands. While it is positive from a climate perspective that peat is no longer harvested for energy extraction, what happens after extraction ceases can still impact the climate. If these former cutover peatlands are abandoned without any remediation, they can remain as sources of carbon dioxide because hydrological and soil conditions are unfavourable to plant growth and often the peat is still exposed to oxygen (Tuittila et. al., 1999; Waddington et al., 2002). Afforestation is the most popular after use option of cutover peatlands by landholders in Finland (Laasasenaho et al., 2023), however it is unclear how the ecosystem will respond to afforestation, and whether the system can be turned into a carbon sink quickly. In this study, we present a 3-year record of eddy covariance measurements from an afforested cutover peatland site in Finland. We examined the CO_2 exchange dynamics of the site as it was afforested and calculated annual totals to determine whether it is a carbon source or sink.

METHODS

The study site, Naarasneva (62.86°N, 24.08°E), is located in Southern Ostrobothnia, Finland. Peat extraction ceased in 2020 and there is an average of 1 m depth of peat remaining. An eddy covariance system consisting of a Metek uSonic-3 Scientific sonic anemometer (Metek GmbH, Elmshorn, Germany) and LI-COR 7200RS gas analyser (LI-COR Biosciences, Lincoln NE, USA) was installed in August 2021 at 3 m above the ground surface which measured the turbulent exchange of heat, water and carbon dioxide. Wood ash fertilisation was done in January of 2022, followed by the planting of 2-year old *Pinus sylvestris* (Scots pine) saplings in June. The net ecosystem exchange (NEE) of CO_2 data were gapfilled using the marginal distribution sampling method (Reichstein et al., 2005). Sentinel-2 derived leaf area index (LAI) observations were used to investigate the revegetation of the site during afforestation. LAI was calculated using the satellitetools package (Nevalainen, 2022).

RESULTS

The timeseries of NEE (Fig. 1) shows the exchange of CO_2 increasing over time. The effect of fertilisation in 2022 is clearly visible, with a steady increase in the amount of CO_2 uptake throughout the mid-year compared to 2021. After fertilisation, the most dominant vegetation species growing were *Calamagrostis spp.* (reedgrass), *Epilobium spp.* (willow herb) and *Betula pubescens* (downy birch). The CO_2 uptake corresponds well with Sentinel-2 satellite derived observations of the leaf area index (LAI) (Fig. 1), which also show year on year increases over time.

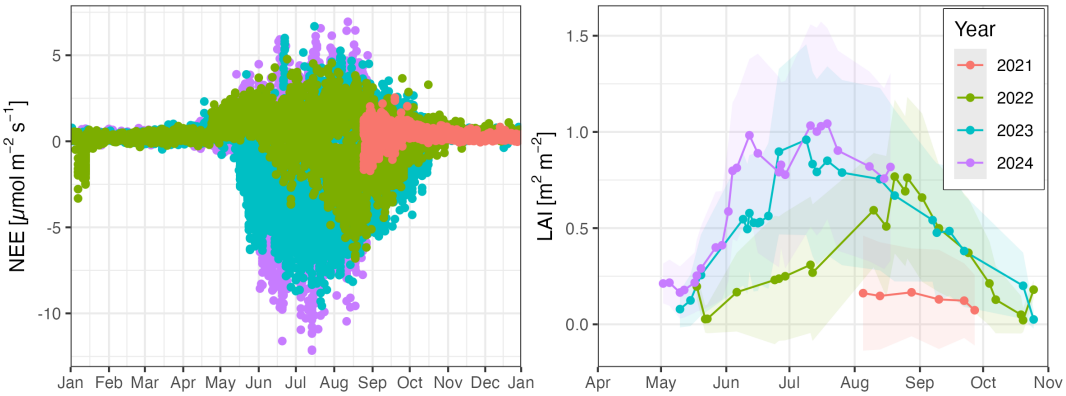

Figure 1. Left: 30-min average net ecosystem exchange (NEE) of carbon dioxide at Naarasneva. Positive values indicate a flux from the ecosystem into the atmosphere, negative a flux to the ecosystem. Right: remotely sensed observations of leaf area index (LAI) from days when Sentinel-2 data was available.

Annual totals of NEE calculated between Sep-Sep show the site was a net source of CO_2 between 2021-Sep to 2022-Sep with 5.3 ± 0.5 t CO_2 ha^{-1} yr^{-1} (mean ± 95% CI), followed by two years where it was a net sink at -0.9 ± 0.3 t CO_2 ha^{-1} yr^{-1} between 2022-Sep and 2023-Sep, and -0.6 ± 0.6 t CO_2 ha^{-1} yr^{-1} between 2023-Sep and 2024-Sep.

CONCLUSIONS

The results show that afforestation of a cutover peatland can turn the site into a carbon sink within two years. The decrease in carbon sink in 2024 is still being investigated, however it is likely that the rather warm and dry weather in spring and summer played a role. While it is positive that the carbon sink functionality of former peat extraction sites may be restored quickly, the long-term impact of afforestation is unclear due to the continued drainage of the peat and the uncertain fate of the carbon stored in wood.

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BELOWGROUND METHANE CYCLING ALONG A STREAM-TO-EDGE TRANSECT IN THE LOMPOLOJÄNKKÄ FEN

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Keywords: Methane Production, Methane Oxidation, Stable Isotopes.

INTRODUCTION

Lompolojänkkä is a nutrient-rich fen located in western Lapland. The site has been the focus of detailed methane flux measurements, which revealed high spatial variability along a transect from the central stream to the edge of the peatland. Surprisingly, the highest fluxes did not occur in the center of the peatlands, but rather at the halfway point between the center and the edge of the peatland, likely due greater oxygen transport by turbulent water flow at the center of the peatland (Zhang et al., 2020).

METHODS

In this study, we aim to quantify the contribution of hydrogenotrophic and acetoclastic methanogenesis, the fraction of methane oxidized prior to emission to the atmosphere, and the location (depth) of these processes in the peat profile. We further investigate if these processes differ in space along the stream-to-edge transect and time with the progress of the growth season. To quantify these processes, we collected pore water samples from 15 depth profiles at 20 to 100 cm depth. In these samples we quantified concentrations of dissolved methane, its carbon and hydrogen isotope values, and a suite of geochemical measures.

RESULTS

We find that locations close to the central stream are characterized by high methane concentrations at depth, which decrease steeply towards the surface, indicating that high rate of methane are produced at depth but oxidized prior to reaching the surface. Sites located at the edge of the peatland, in contrast, show low methane concentrations throughout the peat profiles, indicating that small amounts of methane are produced relatively close to the surface.

Stable carbon and hydrogen isotope values add additional complexity to our understanding of the methane dynamics. Methane oxidation is associated with strong increases in both $\delta^{13}C$ and $\delta^{2}H$ values in the residual methane and would therefore be indicated by an increase in both isotope values from deep to shallow peat layers. Such a pattern, however, was only detected close to the central stream, where approximately 50% of methane was oxidized prior to reaching the surface. In most other transect points, we found that $\delta^{13}C$ increased from deep to shallow layers, whereas $\delta^{2}H$ showed the opposite trend, indicating the mixing of hydrogenotrophic methane produced in deep peat layers with acetoclastic methane produced in the rooting zone.

An isotope mixing model indicated that that the fraction of hydrogenotrophic methane increased from center to edge of the site (from 45 to 30% at 100 cm depth in June) and with the advancing growth season (32 to

0% in September). In contrast, we typically find less than 15% hydrogenotrophic methane in shallow layers. We note that these numbers are associated with significant external uncertainty stemming from poor certainty about mixing model parameters.

CONCLUSIONS

Overall, our data demonstrates high and temporal spatial heterogeneity of methane production and oxidation within a single site. We demonstrate the additional information gained methane dual isotope analysis, and reveals how $\delta^{13}C$ profiles alone can be ambiguous and misleading.

ACKNOWLEDGEMENTS

This work was supported by the Research Council of Finland (grant number 354501) and the European Research Council (grant agreement number 757695). Lukas Kohl held a Marie Skłodowska-Curie Actions Individual Fellowship from the European Union's Horizon 2020 research and innovation program (grant agreement number 843511) and a fellowship by the University of Eastern Finland.

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GREENHOUSE GAS FLUXES FROM THE LITTORAL ZONES OF NORTH-BOREAL LAKES

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Keywords: Emergent vegetation, aquatic, carbon, plant mediated flux

INTRODUCTION

Vegetated littoral areas of northern lakes are understudied ecosystems in terms of their greenhouse gas (GHG) exchange. Boreal inland waters comprise a significant part of landscape level fluxes of CO_2 and CH_4 (Saunois et al. 2020). However, it is increasingly understood that GHG exchange is spatially heterogeneous in lakes. Microbial production of CO_2, CH_4 and N_2O all have temperature dependencies and have higher rates in sediments in shallower littoral areas. Additionally, littoral zones typically contain emergent macrophytes making them hotspots for ecosystem production, yet their role in fixing CO_2 is poorly understood (Larmola et al. 2003). Moreover, aerenchymous tissues are a common adaptation to waterlogging in littoral plant species and play an important role in CH4 transport, root exudates contribute to decomposition and there can be greater accumulation of allochthonous terrestrial carbon that acts as suitable substrate for methanogens (Juutinen et al. 2003, Bastviken et al. 2004, Burger et al. 2016). Lake-wide estimates including littoral zones remain few (Huttunen et al. 2003, Juutinen et al. 2003, Larmola et al. 2004, Kyzivat et al. 2022) and although vegetated shores can be relatively small in area, they likely play an outsize role in total lake GHG fluxes in northern lakes.

METHODS

We conducted the study in three lakes located within the Pallas Atmosphere-Ecosystem Supersite in Finnish Lapland. The lakes have contrasting physical and ecological characteristics. Greenhouse gas fluxes were measured using the manual chamber technique at 18 plots every two weeks during the ice-free seasons of 2023 and 2024. Additional measurements were conducted during the intervening winter. Flux measurements included concurrent measurements of CH_4, N_2O and net ecosystem exchange of CO_2 (in light) and ecosystem dark respiration (Rtot, in dark). Gross primary production (GPP) was estimated based on measured NEE and Rtot. Leaf area index measurements of emergent vegetation and other auxiliary measurements were made in order to understand drivers of flux rates.

RESULTS AND CONCLUSIONS

Early results indicated that littoral CH_4 fluxes were substantially larger than comparable open water fluxes and that sediment temperature and emergent plant leaf area were the principal drivers of temporal variation in CH4 flux. The rate of primary production was substantial in some densely vegetated shallow water areas, but it varied between species and sites. N_2O emissions were negligible at the sites in this study. In conclusion, littoral zones play an outsized role in contributing to CH4 emissions and have a role as a C sink in aquatic systems. However, lake-wide assessment needs to be verified including all flux components. It is important to understand further the scale and drivers of these fluxes, as well as the areal extent of the vegetated littoral zonesin boreal and subarctic lakes overall.

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IMPACT OF ELECTRIC VEHICLES ON AEROSOL PARTICLE CONCENTRATIONS IN FUTURE URBAN AIR QUALITY USING LARGE-EDDY SIMULATION. CASE STUDY: A PLANNED CITY BOULEVARD IN HELSINKI

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Keywords: LES, BEVs, Urban air quality, Pollutant dispersion.

INTRODUCTION

Urban areas, characterized by high population densities and poor air quality due to increased anthropogenic emissions and inadequate pollutant dispersion, face challenges. Traffic, a major contributor to urban air pollution, has prompted the adoption of electric vehicles (EVs) in both private and public transport to mitigate emissions. However, the impact of fleet electrification on local air quality and aerosol particle concentrations, particularly non-exhaust emissions from EVs, remains uncertain (Hooftman et al., 2018). A significant increase in Battery Electric Vehicles (BEVs) in Helsinki metropolitan areas has been anticipated (Viri et al., 2021). Therefore, this study aims to assess their impact on aerosol particle concentrations in a newly planned neighborhood in Helsinki by examining various traffic scenarios. The study utilizes a Large-Eddy Simulation (LES) model, PALM (Maronga et al., 2020), with a detailed aerosol module (SALSA) to realistically depict urban surface characteristics and aerosol dispersion in the target area.

METHODS

This study employs three distinct traffic scenarios: Scenario 1 (S1) serves as the baseline for the year 2022 (10% BEVs), while Scenario 2 (S2) and Scenario 3 (S3) project into the future, representing the years 2030 (60% BEVs) and 2040 (100% BEVs), respectively. All simulations are conducted over three domains including a root (1536 * 73072 * 64 cells), parent (768 * 1536 * 64 cells) and child (384 * 768 * 72 cells in x,y, and z directions) domain. The child domain covers the neighbourhood of interest, with a grid resolution of 1m, whereas the parent and root domain cover a larger area with a grid resolution of 3m and 9m, respectively. Within the child domain, detailed city boulevard layouts will be used to simulate the aerosol processes (i.e. dry deposition) by applying SALSA. The simulations The simulations were conducted for a typical winter morning rush hour (7:30 - 9:00, local time), using the Centre for Scientific Computing (CSC) Puhti super cluster. Each simulation required 72 hours of computing time.

RESULTS

The simulation results shows a significant difference in the magnitude of number and mass concentrations ($PM_{2.5}$) at pedestrian level (2 m) among the scenarios. In the baseline scenario, mean

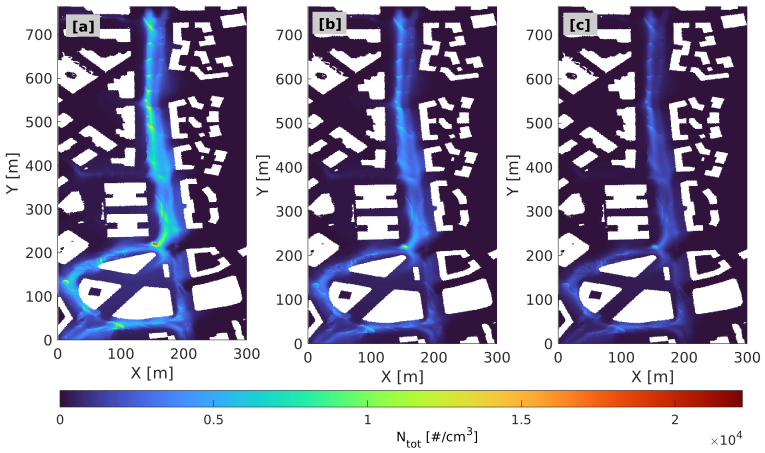

Figure 1: Spatial variability of the mean $PN_{2.5}$ concentration for a) the baseline scenario (S1), b) the difference between baseline and S2, and c) the difference between the baseline and S3 at 2 m height as calculated between 08:00 - 09:00. The prevailing wind direction is from the northeast.

concentrations near the traffic emission sources reaches 1250 cm^{-3}. However in S2, the mean $PN_{2.5}$ concentration is reduced by 20%, droping to 1100 cm^{-3}) in S2 and by 25%, to 1000 cm^{-3} in S3, compared to the baseline (Figure 1). This reduction is more pronounced in Ultra Fine Particles(UFPs). In contrast to PN, the average PM2.5 concentration increases significantly in both S2 and S3. Within the child domain, $PM_{2.5}$ rises by approximately 46%, from 17 $\mu g\ m^{-3}$ to 37 $\mu g\ m^{-3}$, relative to the baseline. Concentrations peak near traffic sources at the boulevard and roundabout, sharply decreasing in side streets and courtyards due to the canyon effect and stable weather conditions, limiting pollutant dispersion. Higher concentration levels are observed at street and pedestrian levels (1-2 m height), diminishing with increased height.

CONCLUSIONS

The study findings indicate that a higher proportion of BEVs will affect local air quality. Future scenarios, compared to the baseline, show increased mass and decreased number concentration. BEVs, by eliminating tailpipe emissions, significantly reduce total PN and UFPs. However, their larger size and weight result in increased emissions of larger particles, contributing to a rise in mass concentration. These findings provide valuable insights for urban planners and decision-makers, enabling them to anticipate and improve future local air quality within new city plans.

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EVALUATION OF PARAMETERIZATIONS FOR SEA-SPRAY EMISSIONS IN THE ARCTIC USING ENVIRO-HIRLAM SEAMLESS MODELLING

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Keywords: Arctic, Enviro-HIRLAM, seamless modelling, sea spray emission parameterizations, sea salt observations and modelled concentrations

INTRODUCTION AND METHODS

The application of seamless/ on-line approach in modelling is expected to be able to handle and study many existing processes and interactions on different spatiotemporal scales, including in the Arctic domain. The Enviro-HIRLAM (Environment - HIgh Resolution Limited Area Model) is seamless/ online integrated numerical weather prediction (NWP) and atmospheric chemical transport (ACT) modelling system capable to simulate simultaneously meteorology – atmospheric composition on multi-scales ranging from regional to subregional – urban scales (*Baklanov et al., 2017; Mahura et al., 2024*).

The seven sea spray emission parameterizations (from *Martensson et al., 2003; Monahan et al., 1986; Guelle et al., 2001; Gong, 2003; Zakey et al., 2008; Clarke et al., 2006; Vignati et al., 2001*) were evaluated in the Enviro-HIRLAM model. The model has been run over domain (Fig. 1a) at horizontal resolution of 15 km in 3 modes (reference run - REF; with included direct - DAE and indirect - IDAE aerosol effects) for the months of February, May, August, and October of year 2010 (with a 10 day spin-up from the previous months) including data assimilation, and with initial and boundary conditions for meteorology from ERA-5 and for gases/aerosols from the Copernicus Atmosphere Monitoring Service (CAMS). The studied domain covered the Arctic area with adjacent seas. February is characterised by the largest ice-covered area in the Arctic, August - by the lowest ice- covered area, May and October - as transitional periods when the ice is melting and building-up, respectively. Observations (at Irafoss, Zeppelin, Pallas, and Bredkalen sites; Fig. 1b), daily values of concentrations, were extracted from the EBAS (European Monitoring and Evaluation Programme Database).

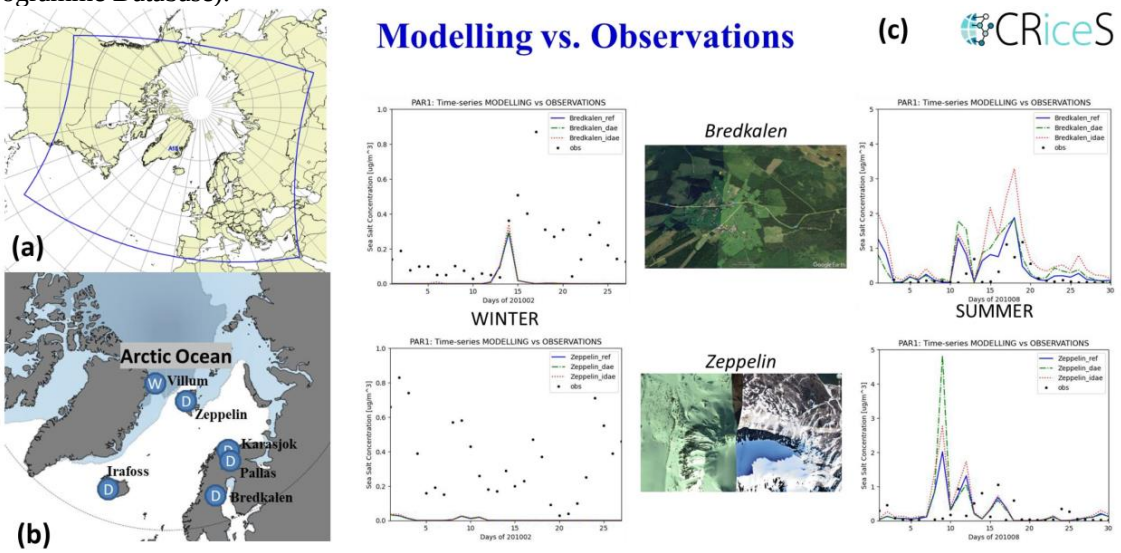

***Figure 1**: **(a)** A15 - modelling domain for Arctic; **(b)** Observational sites for model evaluation; **(c)** Example of time-series of Enviro-HIRLAM simulation vs. observations of sea salt concentrations for February and August.*

RESULTS AND CONCLUDING REMARKS

Analysis of observations vs. modelled results (Fig. 1c) for correlations (Mahura et al., 2024, in prep) showed that for 2 inland locations in Scandinavia - Bredkalen and Pallas - for all parameterizations positive correlations were identified. For Bredkalen, moderate to very strong positive correlations (ranging from 0.4 to 0.85) were identified for February and August, and positive negligible for May (around 0.2) and October (below 0.05). Similarly, for Pallas, moderate to very strong positive correlations (ranging from 0.35 to 0.85) were identified for February and August, but positive negligible for May (below 0.05) and October (around 0.2). Irafoss (location near seashore in Iceland) showed strong positive correlation (ranging from 0.55 to 0.75) for all parametrizations. It can be explained by the presence of large amounts of sea spray emissions all year around due to non-freezing surrounding waters and frequent passage of cyclones. For Zeppelin (all year ice/snow covered location), for the Martensson et al (2003) parameterization (developed on a large range of sea surface temperature variations, compared with other parameterizations), a moderate positive correlation (ranging from 0.5 to 0.6) was identified for February and October. For all other parametrizations, moderate to strong positive correlations (ranging from 0.40 to 0.65) were obtained for February and moderate correlation for October (up to 0.45; when IDAE effects are included in simulations). But, for all parameterizations, the negligible (less than 0.2) values were in May and August. It can be explained that during warm months an extension of ice/snow coverage is still large, and open waters (or sources of sea spray emission) are still far away from this Arctic station.

The output from Enviro-HIRLAM simulations (for months of February, May, August, and October of 2010 and for 7 parameterizations) has been post-processed and is stored at CSC's object-oriented storage system Allas. Such output varied between 156 (for February) -173 (for August) Gb.

ACKNOWLEDGEMENTS

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The Enviro-HIRLAM model is continuously developed and applied for the PEEX domain studies according to the PEEX Science Plan (PEEX, 2015) with emphasis on evaluation and testing of the online integrated approach for in-depth sensitivity analyses of mechanisms, relationships, feedbacks, interactions, etc. between chemistry-aerosols and meteorology and assessment studies in a changing climate.

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OFFLINE ANALYSIS OF PARTICULATE MATTER FROM SIMULATED BIOMASS BURNING USING FIGAERO-I-CIMS

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Keywords: Biomass burning, aerosol particles, offline filter sampler, FIGAERO-I-CIMS measurement.

INTRODUCTION

Secondary organic aerosol (SOA) plays a crucial role in both air quality and climate. Emissions from biomass burning significantly contribute to SOA formation, leading to increased particulate matter and, consequently, poor air quality. The Filter Inlet for Gases and AERosols (FIGAERO) coupled with a high-resolution time-of-flight iodide chemical ionization mass spectrometer (ToF-I-CIMS) is an advanced analytical technique that allows us to simultaneous sample and analyze both gas and particle phases of SOA (Lopez-Hilfiker *et al.*, 2014). In this study, we used a method similar to Cai et.al. (Cai *et al.*, 2023) using a separate filter sampler to collect the aerosol particles on specially designed filter cartridges. The collected samples were later analyzed with a modified FIGAERO inlet.

METHODS

Sampling was conducted at an environmental simulation chamber (ILMARI, UEF Kuopio), where biomass burning emissions were subjected to photochemical aging. The aerosol particles were collected on PTFE filters during various stages of the oxidative aging experiments and stored at –20 °C for four to five months prior to analysis using a modified FIGAERO-I-ToF-CIMS. The volatility of a detected ion can be derived from its thermal desorption behaviour in the FIGAERO inlet.

RESULTS

T_{max}, temperature at which the maximum of the signal is detected, reflects compound volatility. The overall volatility of a sample can be illustrated by the sum thermogram, the sum of all ion signals as a function of desorption temperature.

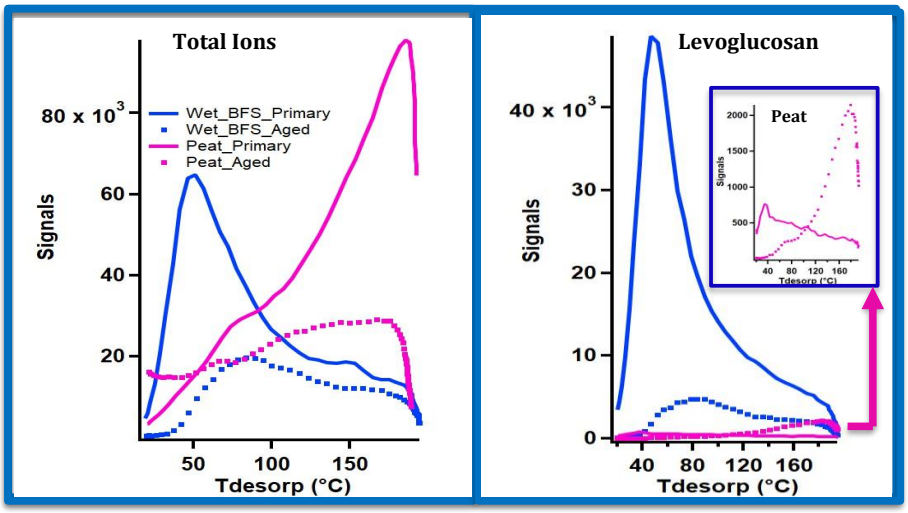

Figure 1. The sum thermogram of all ions (left) and levoglucosan (right)

Significant variability in T_{max} values and thermogram shapes was observed for burning products, including levoglucosan – a key tracer for biomass combustion derived from cellulose degradation (Figure 1). In the samples of primary emission, the ions from boreal forest surface (BFS) burning showed a T_{max} ~60 °C, while peat exhibited a higher T_{max} exceeding 150 °C, likely due to the different chemical composition of the biomass materials and possible contaminants. After 5 h of aging, T_{max} for BFS samples shifted to ~80 °C, while aged peat particles increased slightly to ~180 °C. For levoglucosan, a significant shift in T_{max} was observed in aged peat samples, suggesting potential interactions with other substances during aging or storage (Resch *et al.*, 2023) or the formation of oligomers that decompose during desorption.

CONCLUSIONS

The offline sampler effectively collected aerosol particles from biomass burning, enabling sampling from areas not accessible to the instrument. Aerosol particles from boreal forest surface and peat burning show distinct T*max* differences both before and after aging, indicating possible interactions with other substances due to the diverse chemical composition of reaction products caused by burning sources (biomass), prolonged oxidative aging, and extended storage of the samples. Future research should investigate the impact of different storage durations.

ACKNOWLEDGEMENTS

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INTERACTIONS BETWEEN BOUNDARY LAYER DYNAMICS AND NEW PARTICLE GROWTH IN MEGACITY

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Keywords: New Particle Growth, Boundary Layer Dynamics, PM, CCN, Climate.

INTRODUCTION

New particle formation (NPF) is a process in which gaseous molecules in the atmosphere cluster together to form aerosol particles (Kulmala et al., 2013). These particles contribute significantly to the total number of aerosols in the atmosphere, further influencing air quality and climate (Kerminen et al., 2018). The environmental and climate effects of NPF largely depend on the particle growth (NPG) process; however, it remains poorly understood, especially in urban (Stolzenburg et al., 2023). In this study, we performed simultaneous measurements of particle number size distributions (PNSD) and chemical compositions at the ground and at 260 m based on the 325 m meteorological tower in urban Beijing. By comparing the NPG process at the two heights, we provide new insights into the interactions between boundary layer dynamics and NPG in megacity(Du et al., 2021).

METHODS

The sampling site is located at the tower branch of the Institute of Atmospheric Physics (IAP), Chinese Academy of Sciences (39° 58′ N, 116° 22′ E), in Beijing, China. A platform with various instruments at 260 m was built based on the Beijing 325 m meteorological tower to measure the chemical and physical characteristics of aerosol particles using Scanning Mobility Particle Sizer (SMPS, TSI) and Aerosol Chemical Speciation Monitor (ACSM, Aerodyne) above the roughness sublayer, while another set of instruments was deployed at the ground level. In addition, gaseous pollutants, including CO, SO2, and O3, were also recorded at both heights. Meteorological variables (e.g. wind speed (WS), wind direction (WD), relative humidity (RH), and temperature (T)) at 15 heights were also obtained from the meteorological tower observation system.

RESULTS

Our results show that although NPG occurred at both heights, significant differences of NPG between 260 m and the ground level were observed in megacity. When vertical diffusion is sufficient, gaseous precursors from the surface could be transported to higher altitudes. The lower temperature and higher relative humidity aloft promoted gas-to-particle conversion, leading to stronger particle growth at higher altitudes. As a result, higher particle concentrations accompanied by stronger hygroscopicity led to >20% higher NPF-induced cloud condensation nuclei (CCN) formation aloft. However, when vertical mixing was suppressed, gaseous pollutants tended to accumulate near the surface. These pollutants then contributed to particle growth at ground level, exacerbating atmospheric haze pollution near ground. This, in turn, further reduced the boundary layer height (Figure 1). The valuable results provided novel information of the interactions between boundary layer dynamics and new particle growth, enhancing our understanding on the climate and environmental effects of NPF.

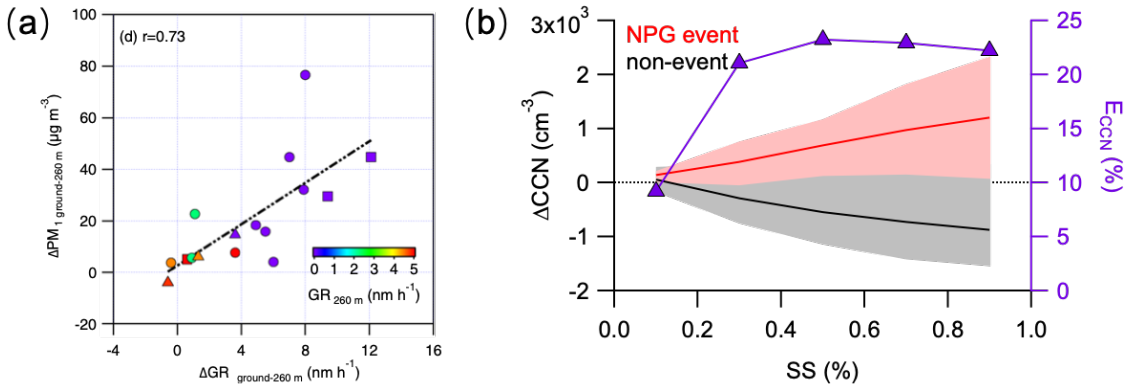

Figure 1. (a) The differences in PM1 between the ground and 260 m ($\Delta PM_{1\ ground-260\ m}$) versus the differences in GR between the two heights ($\Delta GR_{ground-260\ m}$) when vertical mixing is suppressed. (b) The differences in CCN concentrations between two heights (ΔCCN = CCN260 m – CCNground) and the changes of CCN due to enhanced NPG at 260 m (ECCN) when vertical diffusion is sufficient.

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PORTABLE GAS CHROMATOGRAPH WITH RESISTIVE COLUMN HEATING AND INTEGRATED ADSORBENT SAMPLING SYSTEM FOR AIR ANALYSIS

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Keywords: Portable gas chromatography, resistive column heating, adsorbent sampling, thermal desorption, air samples.

INTRODUCTION

Gas chromatography (GC) instruments are usually large in size due to the traditional oven heating of the separation column. For portable GC instruments, the column heating system is the most important part from where the size reduction can be obtained. One way to do this is the use of resistive column heating (Wang et al. (2012), Jacobs et al. (2013)). Miniaturized sampling and sample preconcentration can also be integrated to the portable GC system. Here it is practical to use in-tube extraction (ITEX) as it has been previously shown to work well for the analysis of organic volatile compounds (VOCs) from the air (Lan et al. (2019), Pusfitasari et al. (2023)). Detection in portable GC can be done in several ways. Photoionization detector (PID) is one good example where very small size PID sensors with good sensitivity are commercially available and they can be easily connected to the end of the GC column.

In this research, the portable GC prototype using resistive column heating and ITEX sampling was constructed, tested and utilized for the analysis of VOCs in different type of gaseous samples.

METHODS

Portable gas chromatograph prototype was designed that use MXT-5 metal capillary column from Restek with a length of 15 meters, an inner diameter of 250 µm and a film thickness of 0.5 µm. The stationary phase was 5% diphenyl-95% dimethylpolysiloxane. This column was coiled with the help of Teflon stands to avoid contact between the coils and insulated with the help of glass wool and aluminium foil. Resistive heating was used to heat the column by passing electric current through the column. In all cases, integrated ITEX tube packed with Tenax TA 80/100 were used for air sampling together with Gilian GilAir Plus pump. The ITEX trap was thermally desorbed to transfer the sample components into the separation column. A heated six port valve (VICI Valco) was used to switch between sampling and injection (desorption). Photoionization detector (MiniPID 2 sensor), mass spectrometer (Agilent 5973*Network* MSD) and ion mobility spectrometer (MaSaTech OEM Advanced IMS) were tested as a detector for the GC prototype.

Indoor air sampling was done from the analytical chemistry laboratory and outdoor air sampling from the laboratory window at Kumpula Campus in Helsinki, Finland. Candle flame gases were sampled by keeping the sampling line inlet above the flame.

RESULTS

When comparing with the conventional oven heating, the resistive column heating gave relatively good repeatability for the retention times and peak widths when standard hydrocarbon mixture was analysed. These comparative tests were made both with isothermal and programmed runs. Some temperatures and temperature programming seemed to be less repeatable. This is most likely due to the unoptimized heating

parameters and program. Different compounds (mainly various hydrocarbons) could be detected and identified from the indoor air, outdoor air and candle flame emissions when the GC column outlet was connected to the MS with a heated transfer capillary. Chromatograms obtained for these samples revealed, that the peaks were very nice and narrow especially at the beginning of the chromatogram. This shows that the resistive heating works well. However, peaks were broadened for the late eluting compounds that is most likely due to the nonefficient column or transfer capillary heating (should be improved to better go to higher temperatures).

CONCLUSIONS

Overall, the first portable GC prototype worked very well. Resistive column heating gave repeatable retention times and peak widths. The shapes of the chromatographic peaks were good. Both PID and MS detection seemed to work nicely. IMS was also briefly and successfully tested as a detector for the portable GC. The prototype GC was also successfully applied for the indoor, outdoor and candle flame emission analyses. Future development of the instrument will be focused to the improvement of the heating of the column and MS transfer capillary and the parameters (software) related to these. The sampling pump will be replaced with much smaller one and integrated as a part of the portable GC. Also the possibility of using compact photoacoustic spectrometry as a detector is worth of studying.

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Identifying Source Regions for Arctic Smoke Layers and Characterizing Their Optical Properties using CALIPSO observations

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Keywords: Arctic, fires, smoke, lidar.

INTRODUCTION

Wildfires are becoming more frequent and larger across various regions, driven by a combination of climate change and human activities with adverse effects in ecosystems and climate (Cunningham *et al.* 2024). Of particular interest are emissions from boreal fires located in the vicinity of the Arctic as they can be transported in this sensitive to climate change region contributing further to Arctic amplification (Rantanen *et al.* 2022). Depending on the fuel available, meteorological and burning conditions, their emission and aerosol characteristics may differ. Wildfires emit vast amounts of carbonaceous aerosols such as organic carbon and black carbon (BC) into the atmosphere. Currently, BC emissions, the second largest contributor to global warming after CO2 (Bond *et al.* 2013), rely heavily on model estimations due to lack of global-scale observations. Consequently, models significantly underestimate surface BC concentrations in the Arctic by one to two orders of magnitude.

Constraining the properties and amount of the smoke aerosols and attributing a source region for smoke transported over long distances to pristine regions is challenging due to the vastness of the boreal region since ground-based observations or/and flight campaigns are scarce. Space-borne remote sensing has the potential to provide useful information with a reasonable temporal resolution. In this study, we focus on identifying the source regions and optical characteristics of smoke layers in the Arctic utilizing a synergy of CALIPSO satellite observations, trajectory analysis from MERRA-2 and injection heights from CAMS Global Fire Assimilation System (GFAS) model.

METHODS

CALIPSO observations: The Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO) satellite has been providing observations on aerosols and clouds since June 2006. The Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP) instrument on board CALIPSO provides the vertical structure of aerosol and cloud properties. The CALIOP level 2 Version 4.51 5-km Aerosol Layer (ALay) product was used. Layers flagged as "elevated smoke" in the aerosol classification mask after quality control were considered only (Kim *et al.* 2018). Aerosol layers with horizontal averaging of 5, 20 and 80 km were analysed independently, and each layer was considered only once utilizing unique detection (Shang *et al.* 2024).

Trajectory analysis: We computed air parcel trajectories using a custom Lagrangian trajectory model following MERRA-2 wind fields (Gelaro *et al.* 2017). We linearly interpolated the MERRA-2 wind field information to get the wind components for the exact location and time of the air parcel. We used a 5-minute time step and simple forward Euler method in our trajectory computations.

Injection height of smoke: Daily estimated injection heights (mean altitude of maximum injection (MAMI)) were provided by the Plume Rise Model and IS4FIRES which are incorporated in CAMS Global Fire Assimilation System (GFAS) fire radiative power (FRP) (Rémy *et al.* 2017). The dataset combines satellite-based FRP observations with meteorological information from the ECMWF operational weather forecast to produce daily estimates of biomass burning emissions.

Smoke layer source identification: For each detected elevated smoke layer, a 10-day backward trajectory was considered. A source area for each smoke layer was appointed when the altitude of the trajectory point within 1°x1° was lower than the daily MAMI.

RESULTS

Six years of CALIPSO overpasses over the Arctic between 2018 and 2023 were used to depict elevated smoke layers and further attribute their source region and optical properties. The majority of the smoke layers were observed during the months of July and August. Of particular interest is August 2021 which exhibited exceptionally high occurrence of smoke layers compared to other years. The source identification method resulted to distinct areal clustering of the sources in Eurasia. Source regions for these elevated smoke layers have been identified for less than 10 % of the tropospheric smoke layers. Then, the optical properties corresponding to these distinct source regions were grouped and further reasoned depending on the time of travel to the Arctic and the type of burned area. It was found that smoke layers originating from regions in Central and East Russia had the highest Aerosol Optical Depth (AOD) compared to those originating from Europe in which the travel time of smoke layers was longer implying possible dilution of the smoke layer on the way to the Arctic region.

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COMPARING MEASUREMENT METHODS FOR PARTICLE LUNG DEPOSITED SURFACE AREA ($LDSA^{AL}$): THE ELECTRICAL SENSOR AND SIZE DISTRIBUTION METHODS

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Keywords: Urban air quality, Human respiratory tract, Particulate matter, Emission monitoring

INTRODUCTION

Additional metrics for fine particle pollution along with the particle mass are needed to better understand the health effects of ambient fine particles. For example, health effects associated with the fine particulate matter ($PM_{2.5}$, mass of sub-2.5 µm particles) seem to depend on the location, geographical region and near-source exposure, emphasising the need to study the spatial differences of particle pollution e.g. by utilising dense air quality monitoring networks with various metrics. Recently, particle health effects have been studied especially in terms of the particle composition and oxidative potential. In addition, the WHO has recommended monitoring of ultrafine particles (UFP) and black carbon (BC). However, many of the additional metrics often require challenging methodologies for dense air quality monitoring networks.

Particle lung deposited surface area ($LDSA^{al}$) is a popular health-relevant air pollution metric. It has been suggested that the surface area may be the most relevant dose metric, at least for the nanoparticles in the human lung (Schmid and Stoeger 2016). Also, $LDSA^{al}$ is sensitive to both UFP and BC, emphasising its potential health-relevance (Lepistö *et al.* 2023). $LDSA^{al}$ can be measured cost-efficiently with electrical particle sensors, which makes it a tempting metric for dense air quality monitoring in cities. $LDSA^{al}$ can be measured with size-distribution devices like the electrical low pressure impactor (ELPI+) and the differential/scanning mobility particle sizers (DMPS/SMPS).

$LDSA^{al}$ as a metric however has some challenges. First, it is not known, how well the different measurement methods (electrical sensors vs size distribution devices) compare with each other. Also, particle lung deposition depends on various parameters related to particle morphology, size and composition as well as human activity and anatomy. All these parameters cannot be considered in the measurement, and some necessary approximations are needed. However, different devices or studies may use varying assumptions for the lung deposition. Overall, the effect of different assumptions on the $LDSA^{al}$ measurement with different methods is not understood. To better understand the potential of $LDSA^{al}$ as a health-relevant pollution metric, it should be better understood how different measurement methods with their typical assumptions affect the measurement in different countries and urban environments.

METHODS

In this study (Lepistö *et al.* 2024), $LDSA^{al}$ measurements of an electrical particle sensor (Partector), ELPI+, DMPS and SMPS were compared in ambient measurements, which were conducted in road traffic sites in Helsinki (Finland, Jan–Feb 2022) and Prague (Czechia, Mar–Apr 2022). $LDSA^{al}$ was calculated by 1. assuming spherical hydrophobic particles, 2. correcting particle effective density, 3. correcting both effective density and particle hygroscopic growth. The corrections were done only for the ELPI+, DMPS and SMPS data, because Partector results cannot be corrected. Additionally, the Partector and ELPI+ were compared in various urban areas in Tampere (Finland, Dec 2021) and Düsseldorf (Germany, Mar 2022).

RESULTS

In Helsinki, average LDSA^{al} concentrations with the DMPS and Partector were 69 %–74 % and 76 %–91 % of the ELPI+ result, respectively. In Prague, the SMPS and Partector measured 54 % and 67 % of the ELPI+ concentration. The differences were especially related to larger accumulation mode particles (> 200 nm). After the effective density correction, LDSA^{al} with the DMPS and SMPS was 66 %–79 % of the ELPI+ value, whereas with Partector the difference was less than 23 % compared to the ELPI+. The results show that the ELPI+ may overestimate LDSA^{al} of larger accumulation mode particles if effective density is not considered. In general, the DMPS and SMPS measured considerably lower concentrations than the electrical methods, likely related to the agglomerated structures of particles. Also, the performance of the Partector dropped clearly as the $PM_{2.5}$ concentration increased (Fig. 1), explained by the effective measurement range of electrical sensors (20–400 nm). The hygroscopicity correction did not considerably affect the measured concentration, but still changed the shapes of the size distribution with the ELPI+, DMPS and SMPS.

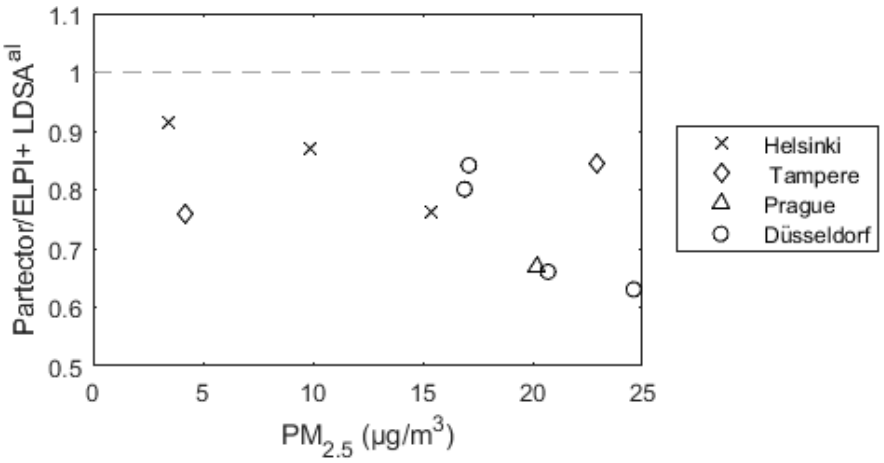

Figure 1. Partector LDSA^{al} compared to the ELPI+ LDSA^{al} as a function of the average $PM_{2.5}$ of the measurement period. Each dot represents separate measurement periods or locations in the studied cities.

CONCLUSIONS

The study shows that LDSA^{al} measurement has challenges, but still holds potential. The observed differences with the instruments were mainly related to larger accumulation mode particles, whereas the accuracies were better with ultrafine particles. Therefore, LDSA^{al} should be well suitable metric to measure spatial differences of locally emitted particles near pollution hotspots. Overall, the study highlights the need for proper definition for LDSA^{al} as well as careful interpretation of LDSA^{al} results with different methods.

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FORMATION OF HIGHLY OXYGENATED ORGANIC MOLECULES (HOM) FROM FURAN AUTOXIDATION: INSIGHTS FROM LABORATORY EXPERIMENTS

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Keywords: Aerosol, SOA, HOM, Autoxidation, Furan

INTRODUCTION

Furan is a five-membered heterocyclic compound, widely present in biomass and is generated during the atmospheric oxidation of biogenic compounds such as isoprene and butadiene (Francisco-Marquez, 2005). It is considered an important volatile organic compound (VOC) due to its reactivity and significant presence in the wildfire plumes (Koss, 2016). Its atmospheric oxidation can lead to the formation of secondary organic aerosols (SOA), with highly oxygenated organic molecules (HOM) being key intermediates in this process. The oxidation pathways of furan and its derivatives are not well understood, making it essential to investigate their behaviour under different environmental conditions. This research explores the formation of HOM from the oxidation of furan under various experimental setups to better understand its atmospheric implications.

Furan's atmospheric relevance lies in its ability to produce reactive radicals upon oxidation, leading to the formation of low-volatility compounds, such as HOM, that can contribute to SOA formation. The atmospheric oxidation reactions can involve OH addition to the furan ring, H atom abstraction from the ring, or, in the case of substituted furans, H atom abstraction from substituent groups (Charlotte, 2020). While much of the focus in atmospheric chemistry has been on other VOCs such as monoterpenes, furan offers a unique structure with high reactivity, providing a different pathway for HOM and SOA formation. Studying furan allows us to expand the understanding of aerosol formation from less-studied VOCs, potentially filling gaps in atmospheric models.

METHODS

In the experimental exploration of Furan OH oxidation, a laboratory setup integrating a flow reactor system and a multi-scheme chemical ionization inlet (MION) orbitrap mass spectrometer was implemented (Rissanen, 2019; Iyer, 2021). The reactions were conducted under standard conditions of 1 atm and room temperature, with air used as the bath gas. OH radicals were generated in situ within the flow reactor through the ozonolysis of tetramethylethylene (TME) which simulates atmospheric oxidation. Product detection was achieved through a nitrate (NO_3^-) ionization scheme in the orbitrap mass spectrometer. This setup enabled the manipulation of key variables, such as VOC concentrations, ozone levels, and residence times, to simulate various atmospheric conditions. Different combinations of reactants, including furan, ozone (O_3), nitrogen oxide (NO), and deuterated water (D_2O), were introduced to simulate various atmospheric conditions and observe the formation of HOM from furan oxidation.

RESULTS

The experiments explored a range of conditions, varying the residence times from as short as 400 milliseconds to as long as 10 seconds. Longer residence times resulted in increased HOM formation, while shorter residence times limited oxidation but still allowed for the detection of HOM. The introduction of NO examined the influence of NO_x chemistry on peroxy radical behavior. Adding NO led to a higher formation of organonitrates and a reduction in peroxy radicals, demonstrating a correlation between NO

addition and the precursor compound behavior. The use of D_2O enabled the observation of hydrogen-deuterium exchange in reaction intermediates, providing further insights into the pathways involved in furan oxidation.

CONCLUSIONS

Across all tested conditions, HOMs were consistently detected, supporting the hypothesis that furan oxidation plays a significant role in atmospheric SOA formation in the atmosphere. This ongoing research aims to advance our understanding of furan's role in atmospheric chemistry and to address environmental concerns associated with it.

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CLIMAIRPATHWAYS: INTEGRATED MODELING OF AIR QUALITY IN FUTURE CLIMATE SCENARIOS

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Keywords: Climate Modeling, Urban Air Quality, Machine Learning, Downscaling

INTRODUCTION

Climate change and urban air quality are two interrelated topics. However, air quality, and the modeling related to it, is a phenomenon that is more regional in scale compared to the global scale of climate and global climate modeling (GCMs). Thus these issues are often treated separately both in the scientific community and in policies that address these issues. The downside of this disconnect is that possible co-benefits of mitigation efforts are not being attained and the most cost-effective solutions are not utilized.

To address this issue, the work package of "Scientific Modeling" of the ClimAirPathways project aims to provide an integrated modeling approach to accurately estimate urban air quality within a GCM simulation, and apply this to simulations of future emission and climate scenarios. This would allow to evaluate the effects of policies on both of these targets in a scientifically consistent and flexible manner, which is necessary to inform decisions on these policies.

METHODS

A run of a global climate model provides estimates for various pollutant concentrations, such as black carbon (BC), organic carbon (OC), dust (DU), sea salt (SS) and sulfate (S04). However, these values are averages over a model grid box, and due to the coarse resolution of the model grid, are generally poor estimates for the pollutant concentrations in cities. Additionally, the GCM does not accurately take into account the effect of local emissions, such as those from traffic and residential combustion. The emissions of BC are of particular interest, since, as an aerosol component, it also has properties which contribute to a warming of the atmosphere and surface. This is particularly noticeable in the Arctic regions.

To correct for this model error, we use data from measurement stations to train a machine learning regression model. Previous research (Miinalainen *et al.*, 2023) has shown that this method can substantially improve the estimate at locations where measurement data is available. We will investigate this method also for other locations in the European Union and in China. An interesting question for the future is also whether this method can be generalized to allow for error correction also at other locations, and whether other additional datasets can be incorporated into the machine learning model to further improve the correction.

ACKNOWLEDGEMENTS

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APPLYING BLACK CARBON SENSORS IN HIGH RESOLUTION SPATIAL MONITORING

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Keywords: air quality, small scale sensors

INTRODUCTION

Black carbon (BC) has an emerging role in air quality monitoring (WHO, 2021). BC is emitted as a by-product of combustion, such as traffic and biomass combustion. In urban areas, the spatiotemporal variation of BC is high according to the anthropogenic activities (Luoma et al., 2021). BC is typically monitored only at well-equipped air quality stations or atmospheric research sites, that do not necessarily reveal the high spatial variation of BC. Monitoring BC in better spatial resolution is possible with small scale sensors, which are typically cheaper and easier to deploy compared to the reference type instruments.

The aim of this study was to test the applicability of several BC sensors for high resolution monitoring.

METHODS

In summer 2022, we deployed four different types of BC sensors (AE51, MA200, and MA350 by Aethlabs, and ObservAir by DST) around the Kumpula campus area in Helsinki, Finland. The multi-angle absorption photometer (MAAP; by Thermo Fisher Scientific) at SMEAR III station in Kumpula campus was used as a reference instrument. As all the BC measurements were based on optical detection and filter sampling, the BC concentration is hereon referred as equivalent BC (eBC).

Before and after the field deployment, we performed an intercomparison between the sensors and the MAAP at SMEAR III. For the deployment phase, the BC sensors were set up in slightly insulated boxes to cover them from rain and vandalism. Only the AE51s were located indoors and sampling the air through a window. The sensors were deployed in five locations: one at more background location in botanical garden, two at ground level and two at building roofs. The aim was to see whether there is vertical variation in the eBC concentration and if we see the effect by the local construction site close to one of the locations. At three of the locations, the sensors were deployed as pairs (i.e., two AE51s and two ObservAirs) to operate at two different flow rates to test the suitability of the so-called dual-spot correction for sensor measurements.

RESULTS

The intercomparison between the sensors and the MAAP showed good correlation ($r > 0.8$). The sensors could be adjusted against MAAP with a simple orthogonal regression and the slopes of the regression lines varied between 0.84-1.13. During the intercomparison periods, the sensors were deployed at SMEAR III where the environmental conditions were stable.

During the field measurements, the MA200 and MA350 sensors showed occasionally very high variation or unrealistic values due to rapidly varying temperature and relative humidity in the mornings and evenings. For the ObservAir-sensors, we did not see similar behaviour as it applied an inbuild correction scheme for the variation in temperature. Because the AE51 sensors were deployed indoors, they were not exposed to similar changes in temperature.

Especially the dual-spot correction, which the MA200 and MA350 apply automatically, was sensitive for the changes in the temperature and the measurements without the correction were more stable. At the sites, where the sensors were deployed as pairs with two different flow rates, the dual-spot correction did not improve the measurements. Therefore, in this study we applied the not dual-spot corrected data.

Spatially, the eBC concentration levels within the Kumpula campus area only varied slightly. We did not observe significant differences between the ground and the rooftop measurements. Also, we did not see any signal from the nearby construction site. However, we did see some interesting short-term peaks at the different sites probably due to passing buses or nearby wood burning activities.

The results of the study are presented in detail in Elomaa et al., (2024, in discussion).

CONCLUSIONS

Based on this study:

- In controlled environments, the BC sensors correlate well with reference grade instruments.
- The BC sensors can be used to observe variations in eBC concentration in high spatial resolution.
- The BC sensors should be installed in stable environments, for example, in temperature-controlled boxes.
- If it is not possible to install the BC sensors in a stable environment, their response in varying temperature and relative humidity should be measured to form a correction algorithm.
- Especially the dual-spot correction algorithm is sensitive to the environmental changes and should be used with caution.
- For comparable measurements, the sensors should be intercompared and adjusted before and after the field deployment.

ACKNOWLEDGEMENTS

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MONITORING NEW PARTICLE FORMATION AND CONDENSABLE VAPOURS IN AN ARCTIC SITE: NY-ÅLESUND

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Keywords: New Particle Formation, Condensable Vapours, Mass Spectrometry

INTRODUCTION

The whole Arctic region is rapidly undergoing environmental transformations due to climate change. Among these changes, marine and terrestrial emission patterns are evolving, altering the natural processes forming new aerosol particles which further impact the Earth's global energy balance. Therefore, monitoring the atmospheric composition of aerosol particles and their precursor gases is crucial for comprehending the complex Arctic climate system.

The Svalbard archipelago is mapped by snow- ice- and permafrost-covered land, limited vegetation, and a strong marine influence of the sea-ice. Besides sulfuric acid (SA), methane sulfonic acid (MSA), and iodic acid (IA) – the concentrations of which are interlinked with the activity of ocean/sea ice –, the terrestrial Arctic ecosystem can greatly impact the emissions of precursors gases. For example, the vegetation emits volatile organic compounds (VOC) resulting in highly oxygenated organic molecules (HOM, Bianchi et al., 2019), and the fauna acts as a strong source of nitrogen-rich chemicals, such as ammonia. Altogether, these molecules are crucial for New Particle Formation (NPF).

Due to flourishing vegetation and thawing permafrost, there is an increase in VOC - and therefore HOM - concentrations. On the other hand, disturbance in bird migration patterns results in extended bird settlement over the Arctic coast which leads to an increase in ammonia concentrations. Finally, we expect increased emissions originating from the warmer – and therefore more biologically active – Arctic Ocean. These and other ecosystem responses to climate change can critically impact the gas emissions in the region and therefore alter the local NPF frequency and/or intensity.

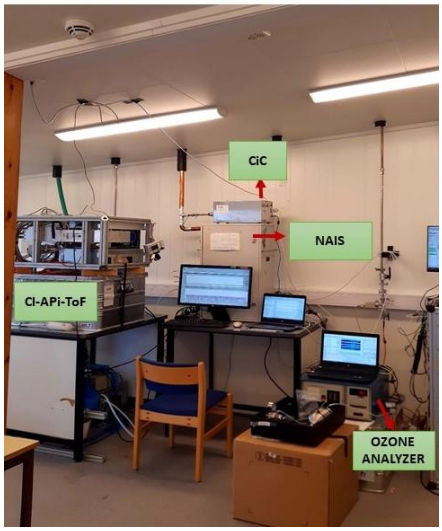
METHODS

With this work, we build upon the previous results (e.g. Beck et al., 2021; Xavier et al., 2022) gathered by our instrumental setup to monitor NPF in the Arctic, in the Ny-Ålesund research station, Svalbard. Originally started in 2017, the observations retrieved from the station represent the longest time series of data measured with mass spectrometry in the Arctic. The latest deployment (starting from May 2024) is scheduled to continue over the year 2025, and possibly further.

The instrument setup consists of:

- A neutral cluster and air ion spectrometer (NAIS, Airel Ltd) and a cluster ion counter (CIC, Airel Ltd) to monitor the size distribution of neutral particles and positive and negative ion clusters.

- A nitrate-based chemical ionisation atmospheric pressure interface time-of-flight mass spectrometer (CI-APi-TOF, Tofwerk, AG.) to assess the concentration of precursor vapor (CI-mode) and identify ion clusters in the ambient air (ambient-mode). In the latest deployment, we implemented a switching system to automatically enable the chemical ionisation on and off at regular intervals (10-minute cycle) to obtain quasi-simultaneous CI and ambient mode data.
- An ozone analyser (Thermo Environmental), to quantify the concentration of ozone periodically depleted during the Arctic Spring.



Figures 1 and 2: Instrumental setup to understand aerosol formation pathways in Ny-Ålesund (left); The cabin housing the instruments in Gruvebadet, Ny-Ålesund (right).

This extensive instrumental set up, accompanied with the supporting particle size distribution data from a scanning mobility particle sizer (SMPS), as well as meteorological data, gathered by the CNR-Italy Arctic station, significantly contribute to the aim of obtaining a holistic picture of the NPF processes in Ny-Ålesund. To achieve this aim, we will analyse both specific nucleation events, and long-term trends in aerosol concentrations and nucleation patterns.

CONCLUSIONS

While the analysis of this recent arctic data set is at its early stages, we aim to reveal preliminary results by the conference event, with selected study cases from this year's NPF observations at site.

ACKNOWLEDGEMENTS

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RENEWABLE FUEL: ASSESSING THE POTENTIAL FOR VOC AND PARTICLE EMISSION REDUCTION IN A HYBRID DIESEL ENGINE

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Keywords: diesel emissions, renewable fuel, volatile organic compounds, mass spectrometry

INTRODUCTION

Transportation and vehicles are responsible for a large portion of global CO_2 emissions, with road transport being the largest contributor (IEA, 2020; Masson-Delmotte et al., 2021). Despite strides in electrification, progress falls short of emission reduction targets. Thus, mitigation techniques are implemented, such as hybrid engines to reduce fuel consumption and renewable fuels to avoid burning fossil fuels in combustion engines. Renewable fuels aim to burn fast-carbon-storing materials, in contrast to fossil fuels, which emit CO_2 stored over millennia.

In terms of vehicle emissions beyond CO_2, regulations focus on particles and some trace gases. Scientific interest has recently additionally focussed on volatile organic compounds (VOCs), both for their own effect and their potential to contribute to particulate matter. Wong et al. (2020) found that emissions of VOCs and PM2.5 from diesel engines contributed more to air pollution in urban environments than those from gasoline engines.

That poses the question of how particle and trace gas emissions change when using a renewable fuel, compared to a fossil fuel. In this study, we access that in the controlled environment of a hybrid diesel engine.

METHODS

Measurements were conducted at the Hybrid Engine Research Platform (HERPA) of the Aerosol Physics Lab in Tampere. It is a research engine coupled to a state-of-the-art instrument fleet.

We used a renewable diesel from waste and scraps such as industry waste fats, animal fat and vegetable oils. It achieves a 90% reduction in CO_2 emissions, as in attributing emissions to previous use of the input materials and using 10% for the preparation of the diesel. As a fossil fuel reference, a conventional diesel was used. The engine was run in various operating conditions, including stable operation points, the RMC-C1 cycle, cold starts and hot starts.

The instrument fleet used to measure emissions includes an FTIR for trace gases (CO_2, H_2O, CO, CH_4, N_2O, NO, NO_2, SO_2), a microsoot sensor for black carbon mass concentration, a condensation particle counter for particle number concentration, an engine exhaust particle sizer for particle size distribution, a trace gas analyzer for CO2 and H2O, as well as a Vocus PTR mass spectrometer for volatile organic compounds (VOCs).

RESULTS

Emissions from both fuels differ significantly. During the RMC-C1 cycle, the renewable fuel yieldes approximately a 30% reduction in particle emissions. Furthermore, the renewable fuel results in mostly lower trace gas levels, including a threefold reduction in SO_2 emissions due to less sulphur content, reduced aromatic VOC emissions, yet an increase in water emissions due to higher hydrogen content.

Qualitative emission behaviour is similar for both fuels. Particle number concentrations increase rapidly during engine transition states to a higher 10^7 cm^{-3} range. During stable operation points, mostly a single mode of 45 nm is observed, but concentrations do not settle to constant values. Trace gases level quickly for each motor setting, making gas phase emissions mostly dependent on the current state of the motor, while particle emission a matter of its change.

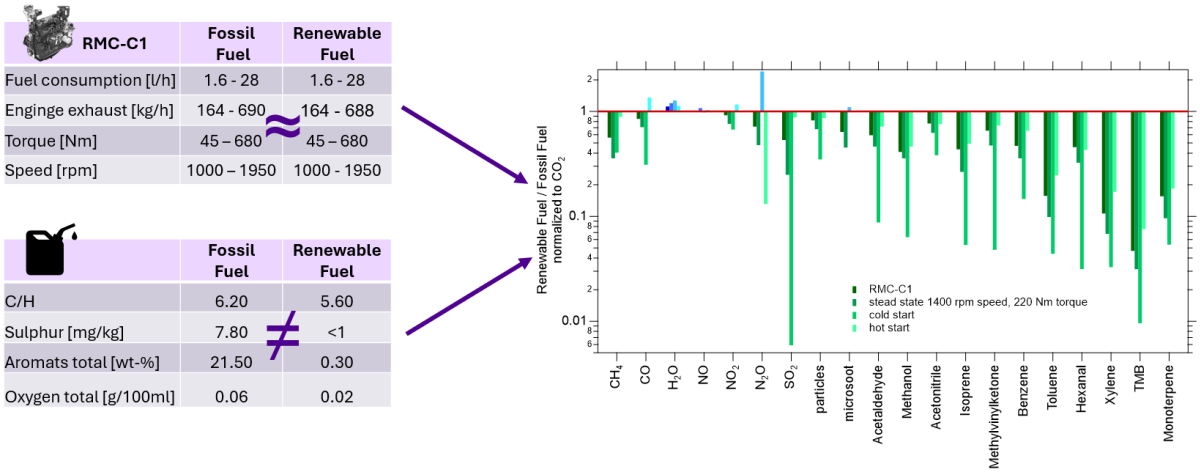

Figure 1. Emission factor comparison for steady state motor operation: Values <1 indicate lower emissions from renewable fuel compared to fossil fuel.

CONCLUSIONS

Two different fuels were burned in a hybrid diesel engine: A fossil and a renewable fuel. Overall, the renewable fuel burned cleaner than the fossil fuel, making it an opportunity for emission reduction beyond CO_2.

ACKNOWLEDGEMENTS

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We thank AGCO Power for providing the engine and extensive support in building the HERPA facility, as well as Neste for providing the fuels.

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INSIGHTS INTO POLLUTION EPISODES FROM SAWMILLS IN THE NEAR VICINITY OF SMEAR II, FINLAND

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Keywords: air pollution, monoterpenes, tree emissions, sawmill.

INTRODUCTION

Volatile organic compounds (VOC) are most importantly emitted from the biosphere (Guenther et al. 2012). In some cases, however, anthropogenic activities can modulate the naturally occurring emissions. One of such example are sawmills, which can produce 10 to 1000 times higher VOC concentrations compared to the natural background levels (Ingram et al. 1995). The emissions are caused by VOCs gradually evaporating from special storage structures of wood stored, sawn, and dried at the sawmills (Ingram et al. 1995, Ghirardo et al. 2010).

Station for Measuring Ecosystem-Atmosphere Relations (SMEAR) II, aiming for comprehensive understanding of ecosystem-atmosphere interactions, is located near three large sawmills; two in Korkeakoski (6 km southeast from the station; JPJ 2004, UPM 2004) and one in Vilppula (21 km northeast from the station; Metsä Group 2004). Influence of the sawmills in Korkeakoski on the measurements at SMEAR II have been noticed already earlier (Eerdekens et al. 2009, Liao et al. 2011), but in this study we continue the analysis utilizing multiple variables and using wind direction as an indicator for sawmill influenced time periods. Moreover, we expand the analysis to include the sawmill in Vilppula, which alone is the size of the two sawmills in Korkeakoski. In the analysis we aim to identify the influence of sawmills in naturally emitted VOCs, in order to separate the sawmill effect from natural ecosystem-atmosphere processes, but also in trace gases and aerosol population.

RESULTS

Clear increase in monoterpene concentration were observed every time wind crossed even briefly the Korkeakoski sawmill sector. Simultaneously NO_x increased and O_3 decreased. Additionally, many other VOCs, such as benzene, toluene+p-cymene, methyl ethyl ketone, isoprene+methylbutenol fragment, and acetaldehyde, showed increased concentrations during sawmill events. Concentrations of highly oxygenated organic molecules (HOMs) and aerosol particles were more variant, likely affected by atmospheric chemistry and preexisting particle concentrations. The signals from the Vilppula sawmill direction were similar, but considerably smaller.

To separate sawmill emissions from long-range transported pollution, we used air mass back trajectories. We noticed that wind direction is good approximation of sawmill emissions from the Korkeakoski

direction, while trace gas concentrations from Vilppula direction correlated more with back trajectories. This may also be due to the fact that also northeastern winds measured at SMEAR II actually originate in eastern Europe and Russia. While polar plots of monoterpenes showed clear signal from Korkeakoski direction, trace gases showed more diverse emission patterns, indicating that they have also other sources than the sawmills. Even though the impact of at least the sawmills in Korkeakoski seems evident, the unambiguous separation between sawmill emissions and long-range transport pollution remains difficult to solve.

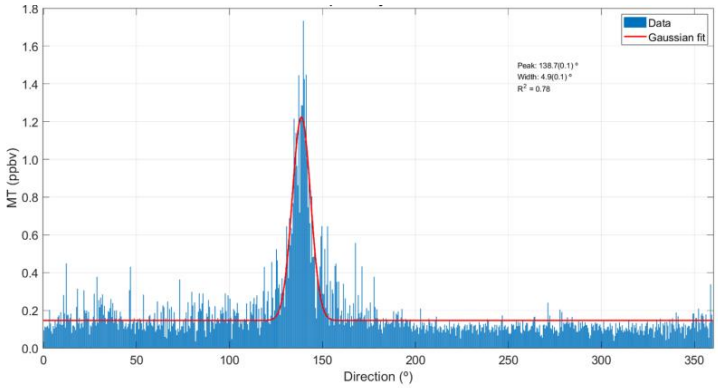

Figure 1. Monoterpene concentration as a function of wind direction. Peak in Korkeakoski sawmill is evident while signal from Vilppula direction (29°) is not clear.

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A SEMI-MOBILE MEASUREMENT UNIT FOR AIR QUALITY OBSERVATIONS INCLUDING NON-REGULATED AND EMERGING POLLUTANTS

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Keywords: Air Quality, Monitoring, Aerosol

INTRODUCTION

In populated areas, the concentrations of harmful trace gases and aerosol particles may vary greatly even over short distances. To understand the causes of this variance, data at high spatial resolution is needed for different areas, and for the many types of emission sources that can be found (eg. Diesch et al., 2011; Gurney et al., 2012). Typically, atmospheric observation and monitoring data is obtained from measurement stations which are point measurement and thus less than optimal spatial coverage of the area of interest. Often, more interesting measurement spots can be envisioned but it is not feasible to build a measurement station at these locations. For such situations, a semi-mobile measurement system is a good solution.

Air pollution studies require simultaneous observation data on gas phase pollutants, aerosol mass and number concentration, and information on the meteorological conditions and solar irradiation. To produce such data, a measurement system consisting of several instruments is required (Drewnick et al., 2012), and if longer time coverage is needed, the system needs to be able operate without constant supervision. To achieve this, we are constructing a measurement unit that allows high-quality observations while simultaneously allowing easy transport and deployment of the whole observation setup. The main purposes of the unit are roadside observation campaign measurements near urban sources of air pollution emissions and field observations of atmospheric trace gases and aerosols coupled with mobile chamber observations. Here, we will present the characteristics of the measurement unit.

METHODS

Here, an overview of the system is given. A special focus in the unit is to enable measurement of non-regulated air quality components and emission, including different emerging pollutants. For this, the sampling system is such that even the smallest particles can be measured, and the sampling lines of individual instruments are designed to enable as little losses as possible for the relevant characteristic (e.g. ultrafine particle number).

The semi-mobile air quality measuring station is built inside a modified marine container, providing a compact and transportable platform. Sample air is collected from the roof of the container via a PM10 or PM2.5 inlet, which draws air into a vertical metal pipe. A Nafion™ dryer is installed to remove moisture before the air is distributed isokinetically to the various measurement devices. Devices measuring larger particle ranges are positioned closer to the inlet to minimize inertial and gravitational losses.

The station's initial focus is on aerosol particle measurements, with plans to integrate gas compound analyzers in future upgrades. As of now, the measuring station will be equipped with a Condensation Particle

Counter (CPC) to measure total particle number concentration. Particle size distributions are determined using an Electrical Low-Pressure Impactor (ELPI+) and an APS Spectrometer, covering ranges of 0.006-10 µm and 0.5-20 µm, respectively. The Neutral Cluster and Air Ion Spectrometer (NAIS) detects particles in the nanoscale (2-40 nm) and ions in the size range of 0.8-40 nm. Carbon-containing particles are analysed using the CASS system, which includes an aethalometer (AE33) for black carbon detection via optical analysis of aerosol filter samples and a total carbon analyzer (TCA08) that combusts aerosol samples to quantify the resulting CO2 and determine total carbon content. Additionally, a meteorological sensor records air temperature, relative humidity, wind speed, and wind direction.

Data from all instruments is collected through a local network, backed up on-site and automatically transmitted over a cellular connection to a remote server at an interval of 3 minutes for near real-time visualization and independent operation of the station. The setup allows for automated status and error messages over SMS in the case of connectivity issues or the disruption of data collection from one or more instruments.

ACKNOWLEDGEMENTS

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SECONDARY AEROSOL FORMATION POTENTIAL OF ASPHALT EVAPORATES

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Keywords: Air Quality, Secondary Aerosol, VOC

INTRODUCTION

Secondary aerosol (SA), which includes both organic (SOA) and inorganic (SIA) aerosol, formation in the atmosphere from natural and anthropogenic precursor sources is still poorly understood on a quantitative level. One reason for this is a lack of understanding of the different sources of SA precursors, which can originate also from sources not generally considered in traditional air quality studies. One such source is evaporated organic compounds from asphalt used in road paving, which has been proposed to be a source of organic compounds, which in bottom-up estimations have been calculated to present a significant contribution to the SOA burden in some parts of the world (Khare et al., 2020).

Such emissions are strongly temperature dependent. With the ongoing climate change and the concerning increment in the global surface temperature, the emissions could be expected to increase further. Furthermore, when traditional aerosol emissions are decreasing due to the tightening emission and air quality regulations, there is a following increasement in overall contribution of the asphalt secondary and other non-traditional emission sources in the total emission scale.

However, as of now, the estimations of asphalt SOA have been based on the measurements of gaseous aerosol precursor VOCs, volatile organic compounds, and literature-based SOA yields. Therefore, the true formation potential of secondary aerosol from a VOC mixture is typically different than that from single or multiple identified compounds (McFiggans et al., 2019). Thus, measuring the potential SOA (pSOA) directly from a realistic matrix is considered to be a better estimate to the atmospheric SOA formation than what literature-based methods result in (see also e.g. Mentel et al., 2007).

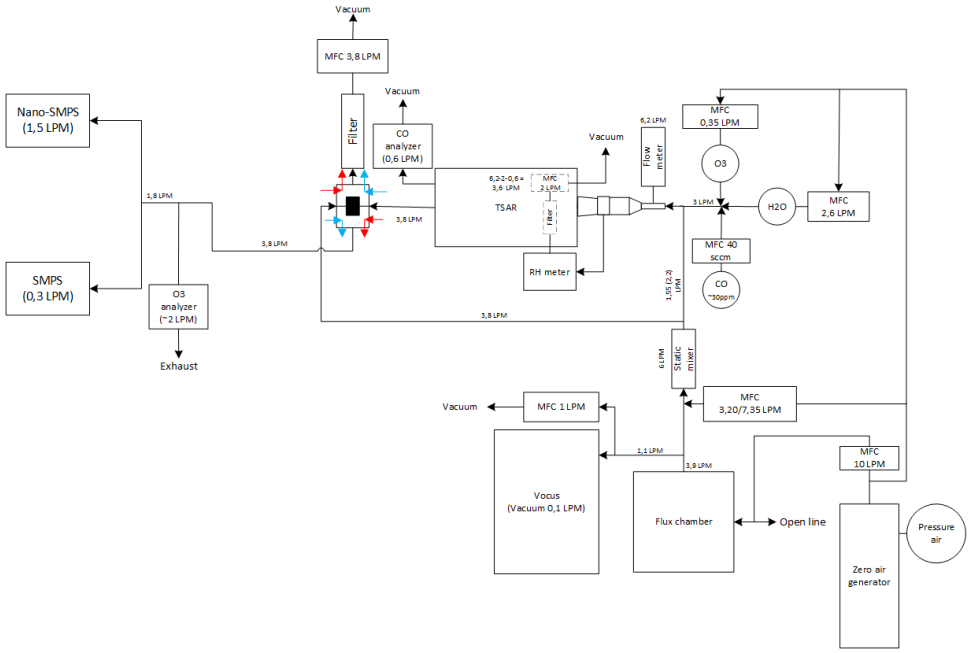
Here, we have performed laboratory measurement of the evaporation temperature-dependent pSOA from asphalt-emitted evaporate precursors using the TSAR oxidation flow reactor (Simonen et al., 2017), measuring both the gas-phase precursors and the formed secondary aerosol mass as a function of temperature. We present the measurement system as well as the initial results of the measurement.

METHODS

VOC and SOA emissions from an asphalt sample were measured using a flux chamber setup. The asphalt piece was placed on a heating plate, with surface temperatures adjusted between 30°C and 60°C. VOCs emitted from the asphalt were carried by an air flow through the flux chamber to downstream measuring instruments.

The sample air was then directed into the oxidation flow reactor (TSAR), where it underwent aging to simulate atmospheric oxidation processes. TSAR used UV photolysis of O_3 to produce OH radicals, with CO as a tracer gas, simulating an approximate atmospheric aging of 3 days. This aging corresponds to the peak of SOA formation.

Two scanning mobility particle sizers (SMPS) were employed to measure particle size distributions, both upstream (primary particles) and downstream (secondary particles) of TSAR, covering a size range of 2-60 nm and 20-700 nm. VOC concentrations were quantified using a VOCUS PTR-TOF-MS, sampling directly from the chamber before TSAR to analyze the VOC emissions.



INITIAL RESULTS

Data analysis is still ongoing, but we were able to detects bigger total SOA masses with higher asphalt surface temperatures. Initial trend indicates a temperature-dependent effect of observed potential SOA; this is in line with the assumed increased emission of precursors. The data can be used to estimate SOA emission factors to add to the pSOA precursors estimates in various modelling approcaches.

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UPTAKE OF SEDIMENT-DERIVED CARBON INTO AQUATIC PLANTS: IMPLICATIONS FOR TRANSFER OF ^{14}C FROM BELOW-GROUND SOURCES.

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Keywords: Radiocarbon, aquatic plants, sediment-derived carbon, mixing model

INTRODUCTION

Nuclear power is considered an alternative energy source in the global transition from fossil fuels to mitigate the climate change crisis. However, radionuclide discharges from nuclear power plants and waste repositories into the biosphere remain a major concern for the nuclear power industries. Among all the radionuclides released ^{14}C is one of great importance, due to its high atmospheric mobility (Pérez-Sánchez et al., 2009) , long half-life (5730 years), and identical biochemical characteristics to stable carbon (C) isotopes (^{12}C, and ^{13}C). This allows ^{14}C to integrate into aquatic ecosystems and enter the C cycle through aquatic plant uptake as CO_2 or bicarbonate species. While plants primarily assimilate C from the atmosphere via their shoots, a smaller amount of C (<2%) can also be absorbed through roots (Amiro et al., 1991; Amiro and Ewing, 1992; Mobbs et al., 2014). Despite the proportionally lower uptake of C through roots, many studies emphasize the importance of root C uptake, especially in environments where soil ^{14}C concentration exceeds the atmosphere level due to continuous or accidental releases from the repositories (Majlesi et al., 2019; Ota and Tanaka, 2019). Yet the extent to which sediment-derived ^{14}C enters biota remains unclear, and the current model lacks comprehensive data on this process.

This study investigated the uptake and transfer of sediment-derived C (^{14}C and ^{13}C) into roots and leaves of various aquatic plants in microcosm settings. The selected plants used in this study included three categories of common aquatic plants: submergent (*Littorella uniflora*), emergent (*Lysimachia nummularia* and *Stachys palustris*), and free-floating (*Lemna minor* or common duckweed). The ^{13}C signature was used as a proxy for ^{14}C to understand the behavior of sediment-derived C. These species are ecologically significant and widely distributed across northern ecosystems, including Finland's freshwater environments. The findings of this study provide essential data to refine the radioecological model and enhance understanding of ^{14}C behavior in aquatic ecosystems offering valuable insights for biosphere safety assessment.

METHOD

The selected aquatic plant species were cultivated in a plastic aquarium containing peat sediment as a substrate, to investigate the possible transfer of sediment-derived C into the plants. The idea of using cutaway peatland was based on the significant natural difference in ^{14}C/total C between modern atmosphere level (100pMC) to 8000 years of old leftover peat after peat extraction (38 pMC). The peats were highly depleted in ^{14}C due to the lower atmospheric concentration of ^{14}C before nuclear weapon testing started in the 1950s and the radioactive decay of ^{14}C over time (Biasi et al., 2011). At the end experiment plant and sediment were collected and analyzed for ^{14}C and ^{13}C content. Two pool isotopic mixing models were used to calculate the relative contribution of two sources (sediment and atmosphere).

$$f1 = (pMC\ sample - pMC\ source\ 2)/(pMC\ source\ 1 - pMC\ source\ 2)$$

RESULTS

The mixing model results indicated that free-floating (*L. minor*) showed the highest contribution of sediment-derived C, 57.1% ± 8.11. Among the submerged species (*L. uniflora*) exhibited the sediment-derived contribution of 13.1%±2 in roots, and 13.9% ±2.1 in the leaves. Emergent species had the lowest incorporation with *S. palustris* showing a contribution of 1.25% ± 0.65 in the roots and 1.41% ± 0.54 in the leaves, and *L. nummularia* showing 2.59% ± 0.16 in the roots and 1.46 ± 0.37 in the leaves. The contribution of sediment-derived C in these species was significantly different from zero. The statistical analyses revealed no significant difference in the transfer of sediment-derived C between the roots and the leaves of each species ($p<0.05$).

The results derived from ^{13}C datasets showed a similar trend with the ^{14}C data in the transfer of sediment-derived C into the plants. *L. minor* had the highest uptake of 36.6 % ± 0.21, followed by submerged (L. unfloral) 17.15 %±0.92 and 16.60 %±0.80 in roots and leaves. Emergent showed lower transfer with S. palustris at 5.61% ± 0.61 in roots and 7.11% ± 0.75 in the leaves, and *L. nummularia* (8.46% ± 1.78 in roots and 7.21% ± 0.73 in leaves.

CONCLUSION

This study demonstrates significant sediment-derived C uptake across different aquatic plant species with free-floating showing the highest uptake. The results suggest that ^{13}C can serve as a proxy for ^{14}C uptake on a plant species basis supporting its use in the radioecological model. These findings highlight the potential risk of aquatic food web from radionuclide contamination, however further research is recommended.

ACKNOWLEDGMENTS

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DECALIN AUTOXIDATION STUDY IN A FLOW REACTOR WITH CHEMICAL IONIZATION MASS SPECTROMETRY DETECTION

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Keywords: secondary organic aerosol, autoxidation, decalin, highly oxygenated organic molecules

WHAT DECALIN IS

Decalin ($C_{10}H_{18}$), also known as decahydronaphthalene, is a fully hydrogenated naphthalene derivative and represents the cycloalkanes chemical class. Decalin exists in *cis* and *trans* isomeric forms. It is commonly used as an industrial solvent for resins and additives in commercial jet and diesel fuels. It was also reported to be significant in the new generation of fuels derived from oil shale and oil sand.

WHAT DECALIN UNDERGOES IN THE ATMOSPHERE

Cycloalkanes represent an important fraction of the total volatile organic compounds (VOCs) in the urban atmosphere contributing significantly to tropospheric secondary organic aerosol (SOA). Atmospheric oxidation of decalin with the commonly available oxidant OH radical is initiated by H-abstraction reactions, forming three distinct C10H17 radicals via successive isomerization. The process of OH-initiated oxidation accompanied by O_2-addition is followed by H-migration switching the radical center from one carbon atom to another in the decalin moiety. This allows more O_2 intake successively which is known as autoxidation. These autoxidation reactions produce highly oxygenated organic molecules (HOMs), which play a key role in the formation of SOA.

WHAT WE HAVE DONE ON DECALIN IN OUR LAB

A multi-scheme chemical ionization inlet (MION2, Karsa Inc.) coupled with an orbitrap mass spectrometer (Exploris 240, ThermoFisher) was employed to explore the *cis*-decalin OH oxidation in a borosilicate glass flow tube reactor. The OH radicals were generated in situ through tetramethylethylene (TME) ozonolysis. Nitrate reagent ion (NO_3^-) was used to ionize the oxidation products as corresponding adduct ions. We studied the oxidation reaction by varying the reaction time to track how fast HOMs form in the OH-initiated oxidation of decalin.

In the present study, the decalin OH reaction produced a wide distribution of oxygenated products with HOM monomers up to 9 oxygen atoms and accretion products (formed by alkylperoxy $RO_2 + RO_2 \rightarrow ROOR + O2$ reaction) up to 10 oxygen atoms in 10 s reaction time. The same distribution of HOM monomers was observed within 5 s reaction time while the number of accretion products decreased in that timescale. Experiments at further short reaction times are on the go to explore more the autoxidation of decalin and its importance in atmospheric SOA formation.

WHY PROCEED WITH DECALIN REACTIONS

The forthcoming Decalin-NO_x experiments aim to assess the oxidation state of the products in the presence of NO_x. This investigation is crucial due to conflicting reports regarding the impact of NO on autoxidation and HOM formation.

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INTERACTIONS BETWEEN BOUNDARY LAYER DYNAMICS AND NEW PARTICLE GROWTH IN MEGACITY

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Keywords: New Particle Growth, Boundary Layer Dynamics, PM, CCN, Climate.

INTRODUCTION

New particle formation (NPF) is a process in which gaseous molecules in the atmosphere cluster together to form aerosol particles (Kulmala et al., 2013). These particles contribute significantly to the total number of aerosols in the atmosphere, further influencing air quality and climate (Kerminen et al., 2018). The environmental and climate effects of NPF largely depend on the particle growth (NPG) process; however, it remains poorly understood, especially in urban (Stolzenburg et al., 2023). In this study, we performed simultaneous measurements of particle number size distributions (PNSD) and chemical compositions at the ground and at 260 m based on the 325 m meteorological tower in urban Beijing. By comparing the NPG process at the two heights, we provide new insights into the interactions between boundary layer dynamics and NPG in megacity(Du et al., 2021).

METHODS

The sampling site is located at the tower branch of the Institute of Atmospheric Physics (IAP), Chinese Academy of Sciences (39° 58′ N, 116° 22′ E), in Beijing, China. A platform with various instruments at 260 m was built based on the Beijing 325 m meteorological tower to measure the chemical and physical characteristics of aerosol particles using Scanning Mobility Particle Sizer (SMPS, TSI) and Aerosol Chemical Speciation Monitor (ACSM, Aerodyne) above the roughness sublayer, while another set of instruments was deployed at the ground level. In addition, gaseous pollutants, including CO, SO2, and O3, were also recorded at both heights. Meteorological variables (e.g. wind speed (WS), wind direction (WD), relative humidity (RH), and temperature (T)) at 15 heights were also obtained from the meteorological tower observation system.

RESULTS

Our results show that although NPG occurred at both heights, significant differences of NPG between 260 m and the ground level were observed in megacity. When vertical diffusion is sufficient, gaseous precursors from the surface could be transported to higher altitudes. The lower temperature and higher relative humidity aloft promoted gas-to-particle conversion, leading to stronger particle growth at higher altitudes. As a result, higher particle concentrations accompanied by stronger hygroscopicity led to >20% higher NPF-induced cloud condensation nuclei (CCN) formation aloft. However, when vertical mixing was suppressed, gaseous pollutants tended to accumulate near the surface. These pollutants then contributed to particle growth at ground level, exacerbating atmospheric haze pollution near ground. This, in turn, further reduced the boundary layer height (Figure 1). The valuable results provided novel information of the interactions between boundary layer dynamics and new particle growth, enhancing our understanding on the climate and environmental effects of NPF.

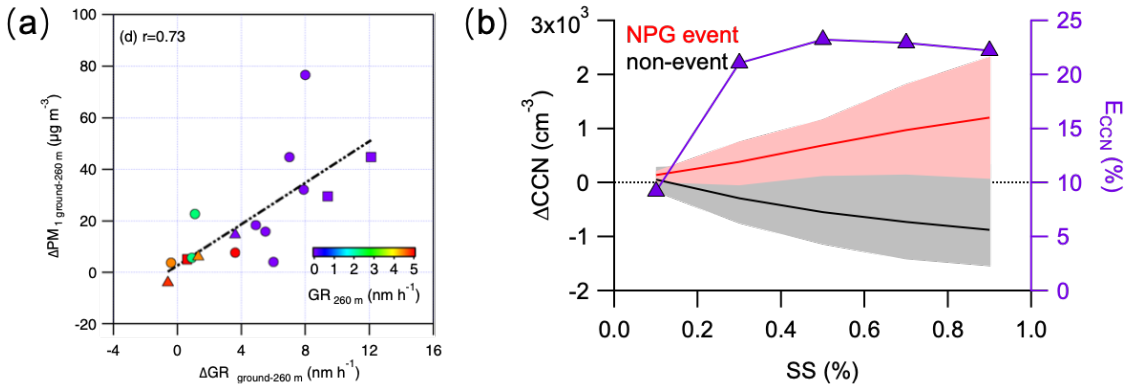

Figure 1. (a) The differences in PM1 between the ground and 260 m ($\Delta PM_{1\ ground-260\ m}$) versus the differences in GR between the two heights ($\Delta GR_{ground-260\ m}$) when vertical mixing is suppressed. (b) The differences in CCN concentrations between two heights (ΔCCN = CCN260 m – CCNground) and the changes of CCN due to enhanced NPG at 260 m (ECCN) when vertical diffusion is sufficient.

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STUDYING THE SENSITIVITY OF EVAPORATION MODELLING TO VOLATILITY PROPERTIES

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Keywords: Aerosol volatility, evaporation, aerosol modelling.

INTRODUCTION

Understanding the evolution of aerosols is key to model their impacts on environment and human health. Large fraction of the particulate matter present in the environment is organic. Organic particulate matter contains both non-volatile, semi-volatile and volatile compounds, and it is well known that the partitioning of organic matter between gas and particle phases depends on the volatility of the aerosol and may change as the aerosol dilutes and ages (e.g. Saha et al, 2018). It has been shown to be effective for modelling purposes to represent the volatility range of an aerosol using a discrete volatility distribution (Donahue et al, 2006). A volatility distribution can then be used to model the behaviour of an aerosol in different temperatures and concentrations.

A volatility distribution usually depicts organic mass divided to bins based on their effective saturation concentrations. In addition to the effective saturation concentration, the evaporation of an aerosol depends on several other variables. The most important ones are usually assumed to be the vaporization enthalpy and the mass accommodation coefficient. All three of these variables are often uncertain, which makes it challenging to accurately estimate aerosol volatility. This is especially problematic when trying to define a volatility distribution based on observed evaporation since several combinations of these three variables can produce similar behaviour. In many cases, vaporization enthalpy is assumed to be a constants for all organic matter, when in reality it tends to be larger for less volatile species. Mass accommodation coefficient is generally assumed to be unity, but studies have suggested several values for organic aerosols going as low as 0.01.

METHODS

Genetic optimization algorithm can be used to find a volatility distribution that reproduces observed data such as how much organic mass evaporates in different temperatures (Tikkanen et al, 2019). It is a method imitating evolution, where an initial population of individuals, in this case volatility distributions, is generated and compared to some fitness criteria. The population then starts producing offspring favouring better individuals thus improving the overall quality of the whole population. This allows for the optimization of several variables simultaneously.

Aerosol evaporation can be modelled by solving the saturation concentration driven mass transfer between particle and gas phases. This can be combined with the genetic optimization algorithm to obtain a volatility distribution matching target evaporation data. Various scenarios based on real and artificial data can be run using different estimates for vaporization enthalpy and mass accommodation coefficient to study the sensitivity of both the mass transfer model and the genetic optimization algorithm to these variables.

RESULTS

The input values for vaporization enthalpy and mass accommodation coefficient used in the volatility simulations have an impact on both the modelled evaporation and the optimized initial volatility distribution. Figure 1 shows how an emission from traffic behaves using different vaporization enthalpy values. The volatility distribution was obtained by optimizing both the effective saturation concentration and the vaporization enthalpy of the sample. Using different vaporization enthalpy values can clearly lead to very different simulated behaviour.

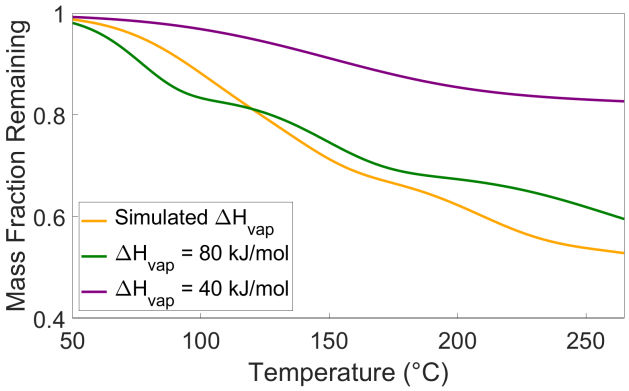

Figure 1: Figure 1. Evaporation of an aerosol solved using a vaporization enthalpy ΔH_{vap} solved for each volatility bin separately or using two different constant values.

CONCLUSIONS

Modelling the evaporation of organic aerosols accurately depends on effective saturation concentrations, vaporization enthalpies and mass accommodation coefficients. Often all three are unknown which can lead to inaccurate results or optimization problems that are difficult to resolve. Whenever possible, these values should be estimated or constrained as well as possible for reliable results.

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ACTRIS (AEROSOL, CLOUDS AND TRACE GASES RESEARCH INFRASTRUCTURE) – UNIVERSITY OF HELSINKI TOPICAL CENTRE UNITS

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Keywords: Aerosol, Clouds, Trace Gases, Research Infrastructure, Nanoparticles, Condensable vapours, Standardization.

INTRODUCTION

ACTRIS is a European distributed research infrastructure producing high-quality data on short-lived atmospheric constituents and providing free access to this high-class long-term atmospheric data through a single-entry point. ACTRIS offers also e.g., access to its world-class facilities, measurement guidelines, instrument calibrations, training possibilities and technology development for users from academia as well as from the private sector and general public. ACTRIS consists of an extensive network of National Facilities (observational and exploratory platforms), and Central Facilities: Head Office, Data Centre and six Topical Centres. The leadership of the pan-European ACTRIS is in Finland; ACTRIS Head Office and the statutory seat of ACTRIS ERIC (est. 2023) are located in Helsinki. ACTRIS ERIC has currently 17 member countries. University of Helsinki (UH), in the forefront of nanoparticle and cluster measurements and research, is hosting two ACTRIS Topical Centre Units to standardizing measurements of secondary aerosol formation. The Cluster Calibration Centre (CCC) is part of the ACTRIS Centre for Aerosol In Situ Measurements (CAIS-ECAC), focusing on sub-10nm aerosol particle concentration and size distribution measurements. CiGas-UHEL unit is part of ACTRIS Centre for Reactive Trace Gases In Situ Measurements (CiGas), focusing on condensable trace gases, which can serve as aerosol precursors.

ACTRIS TOPICAL CENTRE MAIN TASKS

ACTRIS Topical Centres are in a key role in sustaining high level of ACTRIS performance and stimulating the advancement of new measurement techniques and methodologies in atmospheric research. ACTRIS Topical Centres aim to ensure accurate, reliable, and thus, comparable and harmonized data from different measurement sites / mobile facilities (incl. chambers, mobile platforms) at European level and contribute to the harmonization at the global level. Topical Centres provide operation support to ACTRIS National Facilities and services to external users.

The main tasks of the UHEL Topical Centre Units, related to measurements of sub-10 nm particles and aerosol precursors, are to 1) link with associated communities e.g., facilitating close collaboration with the instrument manufacturers, 2) provide training and consultancy, 3) produce and provide measurement and data procedures and tools (e.g. measurement guidelines and recommendations, see *SOPs for NAIS and PSM/nCNC and ACTRIS standard procedures for aerosol in situ measurements*), 4) monitor measurement and data quality e.g., via organizing instrument calibration and intercomparison workshops, 5) contribute to ACTRIS National Facility labelling process and 6) carry out measurement and calibration method and instrument development.

ACTRIS TOPICAL CENTRE IMPLEMENTATION AND RECENT ACTIVITIES

The CCC and CiGas-UHEL are currently implementing their functions. Full operative capacity of these Units is expected in 2026. The CCC and CiGas-UHEL continue the work towards standardizing and

validating the methods for measuring sub-10 nm particle concentration and size distribution, and condensable vapours and develop their measurement quality monitoring processes (calibration/validation processes) and in collaboration with ACTRIS Data Centre the implementation of the instrument data flow and the data QA/QC processes. The CCC has successfully organized two pilot instrument intercomparison workshops for nanoparticle instruments. One for ion spectrometers in May 2023 and one for other nano-particle instruments in November 2023. The CCC has been active in developing nanoparticle (sub-10 nm) instrument performance and evaluation criteria for ACTRIS calibration workshops and compatibility and providing training (e.g., ACTRIS training course organized annually in Finland and Aerosol in-situ course organized by CAIS-ECAC annually in Kosetice, CZ). The CiGas-UHEL has organized two intercomparison workshops for chemical ionization mass spectrometers: one workshop in controlled chambers in spring 2023 in Leipzig, Germany and one field workshop in summer 2024 in Hyytiälä, Finland. CiGas-UHEL is working on developing CI-APi-TOF (Chemical Ionization–Atmospheric Pressure interface–Time Of Flight mass spectrometer) measurement guidelines and methods related to transmission calibration improving the quantification of other condensable vapours such as highly oxygenated organic molecules (HOMs).

ACKNOWLEDGEMENTS

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ATMOSPHERIC BIOGENIC VOLATILE ORGANIC COMPOUNDS IN EUROPEAN RURAL REGIONS

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Keywords: VOCs, terpenes, ambient air, rural, Europe

INTRODUCTION

Europe is one of the most studied areas related to biogenic volatile organic compounds (BVOCs). However, our knowledge of these atmospheric reactive compounds remains quite limited, even here. Total hydroxyl radical (OH) reactivity studies indicate that half of the atmospheric reactive compounds are still unknown, especially in the forested areas (Yang et al. 2016). Studies of OH and ozone reactivity by our group have shown that significant fractions of reactivity comes from biogenic emissions (Praplan et al. 2020 and Thomas et al. 2023).

Globally, isoprene is the most emitted BVOC. While boreal forests in Northern Europe are mainly monoterpene emitters, Central Europe is expected to be dominated by isoprene (e.g., Messina et al., 2016). Current atmospheric models are not fully able to explain observed ozone concentrations and secondary organic aerosol (SOA) formation in Europe, which may be partly due to insufficient knowledge of BVOCs. Although isoprene is routinely measured at many European measurement stations, there is much less data available on the mixing ratios of mono- and sesquiterpenes. In summer 2022, we conducted an intensive VOC measurement campaign under the EMEP Task Force on Measurement and Modelling at 17 stations across Europe.

METHODS

Samples were collected on Tenax TA-Carbopack B sorbent tubes on July 12-19, 2022, at 17 stations across Europe. Species-speicific analyses were later conducted at the Finnish Meteorological Institute using a thermal desoprtion-gas chromatograph-mass spectrometer. Most of the stations were regional background sites.

RESULTS

Our ambient air mixing ratio measurements revealed that, in addition to anthropogenic aromatic hydrocarbons and alkanes, there were high fractions of isoprene and monoterpenes at all sites (Figure 1). When we calculated the OH reactivities of these compounds to assess their impact on local chemistry, isoprene and monoterpenes accounted for an average of 88% of the OH reactivity.

For monoterpenes, the highest concentrations were observed at forest-adjacent sites, and at several stations, monoterpene mixing ratios even in Central Europe exceeded those of isoprene. Although α-pinene is often used to represent all monoterpenes, each monoterpene has different reactivities and atmospheric impacts

and in many cases, α-pinene represented only a minor fraction of total monoterpenes, highlighting the need for species-specific terpene measurements. We also detected several sesquiterpenes and even with very low mixing ratios they may have significant emissions since their atmospheric lifetimes are often very short (for β-caryophyllene ~2 min).

Our results show that BVOC mixing ratios are highly variable, but they contribute significantly to the total reactivity of C5-C15 VOCs, which is the main VOC fraction impacting the secondary organic aerosol formation. Results also indicate that in some regions, monoterpenes may dominate over isoprene.

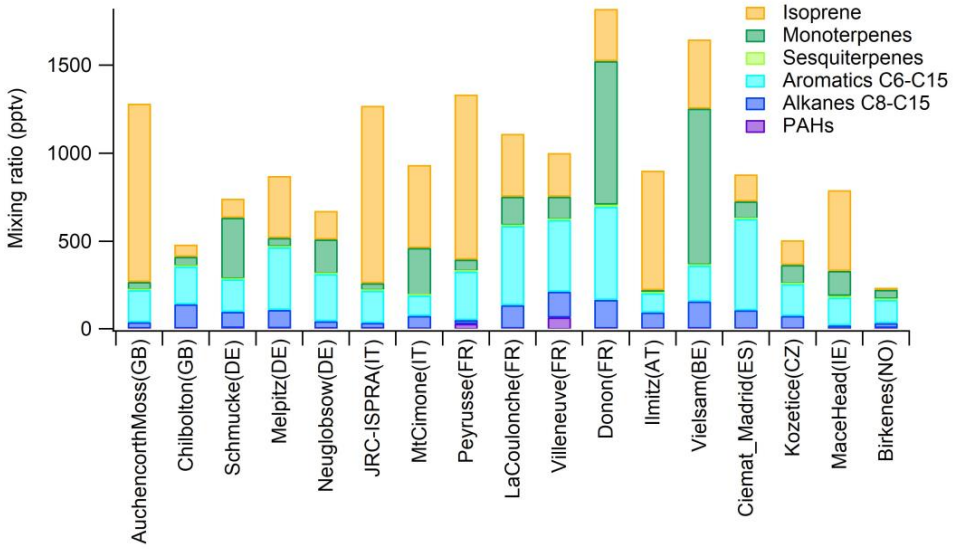

Figure 1. Mean mixing ratios (pptv) of different VOC groups during the campaign

ACKNOWLEDGEMENTS

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GASEOUS EMISSIONS AND CHEMICAL COMPOSITION OF PARTICLES FROM AUXILIARY HEATERS OF CARS

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Keywords: Vehicle emission, Auxiliary heater, Gaseous exhaust emissions, Chemical composition.

INTRODUCTION

In recent decades, the automotive industry has witnessed a significant shift towards the integration of various auxiliary heating systems aimed at enhancing the comfort and functionality of vehicles in cold climates. One such prominent innovation is an auxiliary heater (AH), a technology designed to provide supplementary heating to the vehicle cabin and engine. AHs are used to improve thermal comfort within vehicles. Cold weather causes discomfort for occupants and challenges in the efficiency and emissions of internal combustion engines. The need to strike a balance between passenger comfort and environmental impact has brought AHs into the spotlight of automotive engineering.

Significant reductions of internal combustion engine emissions have been achieved through emission regulation and implementation of emission aftertreatment technologies. Despite the focus on reducing vehicle emissions, the AH emissions have not been considered in the vehicle emission regulations. Thus, emissions from them remain significant under realistic operating conditions, as shown in Oikarinen *et al.* (2022). AH emissions regulations are also lax when compared to engine emissions, with only CO, NOx and THC concentrations being regulated. Due to lax regulation there has been no need for manufacturers of AHs to implement similiar emission aftertreatment devices that have been applied to engine emissions which could mitigate adverse environmental and health impacts of AH use.

METHODS

To improve the understanding of the composition of AH emissions, two measurement campaigns were conducted. First in outdoor winter conditions at around –20 oC outdoor temperatures and later in indoor laboratory conditions at 25 oC to determine whether the operating temperature affects the emissions from AHs. We measured gaseous emissions and the chemical composition of the particles emitted from AHs. Gaseous emissions from AHs were measured with a Fourier Transform InfraRed (FTIR) spectrometer and detailed chemical composition of emitted particles with a Soot Particle Aerosol Mass Spectrometer (SP-AMS). NOx emissions were measured with a NOx analyzer. SP-AMS measurements were made for fresh sample directly from the AH exhaust line and for aged sample where fresh sample was aged photochemically using oxidation flow reactor.

RESULTS

Analyzed gaseous compounds, NOx and total carbon content (TC), exhibited significant dependence on the operating temperature. This effect is presented in Table 1. NOx emissions are notably higher for both fuel types in subzero winter conditions. For TC emissions, the effect of the temperature depends on fuel type. The particle chemical composition was dominated by black carbon for the fresh sample, whereas for the aged sample, organic carbon was the dominant form of emissions, as seen in Figure 1. Especialy for Diesel AH for which primary emissions are low the secondary particles are dominant fraction of total particle emission which are not properly detected by measuring only primary emissions.

Table 1. Operating conditions (C) and NOx and TC emissions from single 30 min preheating cycle.

Quantity	Gasoline AH		Diesel AH	
C	Winter	Indoor	Winter	Indoor
NOx (mg/30min)	1100 (41)	650 (0.19)	940 (30)	690 (28)
THC/OGC (mg/30 min)	200 (32)	300 (230)	270 (9.5)	210 (59)

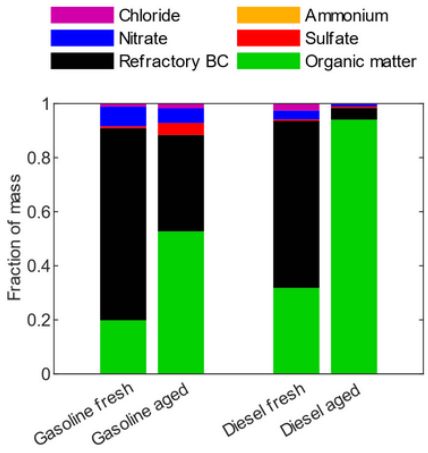

Figure 1. Chemical composition of both fresh and aged particles.

CONCLUSIONS

Gaseous emissions of AHs mostly stay within regulation limits for THC and CO during stable operating period, but emission limits are systematicly ignition and shutdown periods of AH operation and for CO emissions of gasoline AH even during the stable operating period. NOx emissions were found to stay within their respective emission limits for whole preheating period.

Due to significant the effects of operating temperature to measured emissions AH emissions measured in cold temperatures are expected to be more representative to reality than laboratory assessments. Also secondary particle formation should be accounted for when determining particle emissions from AHs.

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STANDARDIZATION OF THE SULFURIC ACID CALIBRATION OF CHEMICAL IONIZATION MASS SPECTROMETERS

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Keywords: Calibration, Sulfuric acid, Chemical Ionization, Mass Spectrometry.

INTRODUCTION

The study of condensable vapors involved in atmospheric new particle formation (NPF) relies critically on the use of instruments with remarkable sensitivity and selectivity. In parallel, achieving consistent results across different studies - promoting meaningful data comparison - is challenging unless standardized measurement practices are implemented. Atmospheric Pressure interface Time-of-Flight (APi-ToF) mass spectrometers combined with Chemical Ionization (CI) inlets have long demonstrated their effectiveness in detecting condensable vapors that are crucial to NPF, including sulfuric acid (SA) and highly oxygenated organic molecules (HOMs). The first step toward obtaining high-quality data lies in the proper calibration of these instruments.
At sites like the Hyytiälä Forest Station (Finland), where SA and HOMs are acknowledged as key players in the nucleation and growth of aerosol particles (Sulo, 2021), CI-APi-ToFs are routinely calibrated using SA. Therefore, a systematic study was conducted on the SA calibration procedure using two CI-APi-ToFs at the ACTRIS Laboratory of the University of Helsinki, with the aim of defining general best practices. The insights gained from this research were subsequently applied to two additional CI-APi-ToFs used for long-term measurements in Hyytiälä, which underwent monthly calibration from January to September 2024. At present, the same calibration procedure is also used at two other Finnish stations, in Tvärminne and Värriö, and it will be implemented in future measurements at the SMEAR III station. Given the promising results obtained from the two CI-APi-ToFs operating in Hyytiälä, the next steps include establishing an optimal calibration frequency for instruments deployed at field sites and defining some criteria to calculate a mean calibration factor from all the values collected.

METHODS

The calibration setup employed (Figure 1) reproduces in its essential features the one presented by Kürten (2012). Synthetic air, sulfur dioxide (SO_2), pure nitrogen (N_2), and water vapor (H_2O) are injected into the calibrator box, where a Pen-Ray mercury (Hg) lamp photolyzes H_2O, triggering the in-situ production of SA. By varying the amount of H_2O introduced into the box, the quantity of SA produced at different steps of the calibration is adjusted as needed. Alongside the measurement of SA signals with the instrument, the theoretical concentrations of SA generated within the calibration box are calculated using a dedicated model. The calibration factor for each step is finally calculated as the ratio of the theoretical SA concentration to the corresponding measured SA signal, normalized to that of the reagent ion.
The calibration procedure was systematically studied in the laboratory by varying the injected flow rates and modifying the setup configuration to observe how these changes influenced the calibration outcomes. The optimized procedure established based on these findings was subsequently applied to the calibration of two additional instruments in Hyytiälä without further adjustments.

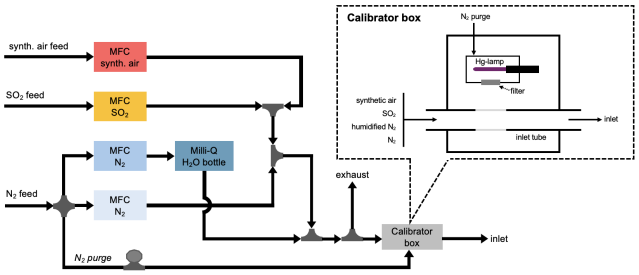

Figure 1: Schematic representation of the calibration setup.

RESULTS

In the laboratory study, the defined protocols enabled the calculation of average calibration factors for the two instruments considered, with associated uncertainties - expressed as standard deviations - of 30% and 31%, respectively, which are in good agreement with values reported in the literature (Kürten, 2012; Heinritzi, 2016).
Similarly, the calibration experiments conducted monthly in Hyytiälä resulted in calibration factors with associated uncertainties of 24% and 21%, indicating that the rigorous procedure developed in the laboratory can be effectively implemented in field settings.

CONCLUSIONS

At present, the number of calibration factors calculated for the two instruments operating in Hyytiälä does not allow for statistically significant hypotheses regarding a reasonable frequency for conducting calibrations. Nonetheless, it can be inferred that monthly calibrations may not be necessary, as the calibration factor does not appear to vary significantly over such a short time frame. A more comprehensive evaluation in this regard will be feasible by considering the calibration experiments performed on the instruments in Tvärminne and Värriö. Finally, one important question yet to be addressed is whether the calibration results are influenced by varying environmental conditions, particularly temperature, but more data are required to support this analysis.

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TRENDS OF INORGANIC AND ORGANIC POLLUTANTS AT PALLAS STATION, NORTHERN FINLAND

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Keywords: Air pollution, Trends, Arctic.

INTRODUCTION

Finnish Meteorological Institute has a long history of atmospheric monitoring at Pallas, a subarctic site in Northern Finland. The measured air pollution concentrations are among the lowest in the Northern Hemisphere, but even in this remote location, detectable concentrations of harmful and even toxic pollutants are observed. Pollution sources can be natural, like thawing soil, or anthropogenic, like emissions from industrial activities. Especially Nornickel metal smelters in Kola Peninsula have been a major pollution source in the area for decades, affecting the otherwise excellent air quality. Here we estimate the long-term trends of an extensive set of air pollution variables measured at Pallas, including e.g., sulphur dioxide, ozone, particulate matter, black carbon, atmospheric heavy metals, inorganic compounds, polyaromatic hydrocarbons (PAHs) and volatile organic compounds (VOCs).

METHODS

Pallas research station, compromising of multiple measurement sites, is located in Northern Finland, 170 km north from the Arctic Circle. The station is unique in Europe, in terms of the number of measured variables and the northern, isolated location (Lohila et al., 2015). Air pollutants have been measured in two sites, Sammaltunturi (67°58.400' N, 24°06.939' E) and Matorova (67°59.237'N, 24°14.579'E), since the 1990s. Most of the measurements presented here are based on on-site sampling (e.g., filter) and later analysis in the laboratory. Also online techniques have been utilised with several air pollutants, e.g., gaseous compounds. The measurement techniques are based on European standards and international guidance documents, such as those from ACTRIS and EMEP. Trend analysis was done with a statistical model of Generalized Least Squares (GLS) regression with autoregressive moving average (ARMA) errors (Anttila and Tuovinen, 2010). The trend calculations were performed for monthly averaged datasets of different lengths, one containing all available measurements for each variable, and one containing only the last ten years.

RESULTS

Our results indicate a low level of total pollution, as the concentrations are among the lowest observed in Europe. The concentrations place far below most of the regulatory limit values, e.g. by EU or WHO. Compared to EU target values, the averages of 2023 for arsenic, cadmium, nickel, lead, and benzo(a)pyrene in PM_{10} were only 0.3–1.3 % of the respective standard. Respectively, annual average of the measured $PM_{2.5}$ was 6.0%, PM_{10} was 6.5%, and NO_2 was 2.0% of the limit values. The long-term trends showed that air pollution concentrations have steadily declined since the mid 1990s. This is as expected, since anthropogenic emissions have been decreasing in the whole EU. Most of the studied pollutants had decreasing trends also for the last 10 years, only with few exceptions. Measurements of chlorine showed a statistically significant increasing trend, and additionally, increasing but statistically nonsignificant trends were found for sodium, calcium and magnesium. Lastly, we studied in more detail the concentrations from recent years for pollutants associated with emissions from the metal smelters in Kola Peninsula, as media reports have stated that a large nickel smelter had a staged shutdown during 2019-2020 (e.g. High North

News, 2020). Our results show that annual and monthly average concentrations of sulphur dioxide and relevant atmospheric heavy metals, like copper, nickel and arsenic, have declined after the shutdown.

CONCLUSIONS

Here we present a trend analysis applied for a large set of atmospheric pollutants measured at Pallas, an atmospheric composition monitoring supersite in a pristine, subarctic environment in Northern Finland. The measurements represent background air quality in a remote, northern environment. We found statistically significant decreasing trends for pollutants with long-term measurements, for some the first observations starting in the mid 1990s. The trends mostly continued to decrease during the last decade. The atmospheric ions that had the increasing trends have a common main source, natural sea salt, that can be transported to Pallas with the air masses coming from the Arctic Ocean. The increasing trends in these concentrations might be connected to the ongoing environmental changes in the Arctic, e.g. the declining extent of the sea ice, or changes in wind patterns. This underlines the fact that atmospheric composition monitoring in the Arctic is now more important ever, as the climate warming is advancing there faster compared to anywhere else on the Earth (Rantanen et al., 2022), and environmental changes can be rapid.

The measurements from the very recent years indicated that the closure of the Nornickel metal smelters possibly have affected the average concentrations of several air pollutants, like atmospheric heavy metals and sulphur dioxide. A more detailed source apportionment study will be done to analyse the effects of the closure.

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EMISSION FACTORS OF SECONDARY ORGANIC AEROSOL FROM LABORATORY BIOMASS BURNING: PHOTOCHEMICAL AND DARK OXIDATION

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Keywords: BIOMASS-BURNING EMISSIONS, SECONDARY ORGANIC AEROSOLS, CHEMICAL COMPOSITION.

INTRODUCTION

Biomass burning (BB) is one of the largest sources of aerosols in the atmosphere. Aerosols emitted from biomass burning affect human health and the climate system (Andreae, 2019). The properties of BB aerosols depend on burning conditions (smoldering/flaming) and biomass fuel type. Organic aerosols emitted from fresh BB are referred to as primary/fresh aerosols (POA). Additionally, secondary organic aerosols (SOA) are formed from the oxidation of the gaseous BB emissions contributing to the particle mass (Hodshire et al., 2019). Due to global warming and climate change, wildfires and the corresponding BB emissions are becoming more frequent thus enhancing their impact on aerosol properties. Understanding the evolution of BB emissions during atmospheric aging is, therefore, crucial. In this study, we characterized fresh and aged aerosols stemming from burning three different biomass samples followed by photochemical or dark oxidation in an environmental simulation chamber.

METHODS

The measurements took place at the ILMARI chamber facility at the University of Eastern Finland in Kuopio, Finland from May to June 2022. We studied the burning emissions from three different biomass types (African Savannah grass, African Savannah wood, and biomass collected from the Finnish Boreal Forest surface) at different burning conditions. For each sample and burning condition, the fresh emissions were fed into the chamber where oxidation was initiated by $OH^{\bullet}$ radicals (from photolysis of H_2O_2) and/or O_3 addition. $OH^{\bullet}$/Photo-oxidation experiments correspond to ~24 h of atmospheric aging at [OH] = 1×10^6 molec/cm^3. To represent the burning condition of each experiment the modified combustion efficiency (MCE) was determined from the CO and CO_2 concentrations in the chamber as $MCE = \Delta CO_2 / (\Delta CO_2 + \Delta CO)$.

The aerosol particles and gases emitted from BB were characterized by a wide range of online and offline instruments. Here, we present the bulk chemical composition of NR-PM_1 (non-refractory particulate matter < 1µm) particles measured with a High-Resolution Time-of-Flight Aerosol Mass Spectrometer (HR-ToF-AMS). Positive matrix factorization (PMF) analysis was performed for the HR organic mass spectra data to

separate the POA and SOA for each experiment. The emission factors (EF) of SOA are determined after correcting the AMS data for wall losses (Wang et al., 2018).

RESULTS

The initial total mass of NR-PM_1 in the chamber varied between ~20 and 80 µg/m^3 for different experiments depending on the biomass type, burning conditions, and feeding times for the chamber. For all experiments, organic compounds dominated the primary aerosol mass by contributing ~ 94 % of the total NR-PM_1 mass. The composition of organics was different for different biomass fuels: for example, a higher contribution of biomass-burning tracer (levoglucosan) was observed for Savannah grass compared to the other two biomass fuels.

Emission factors of formed SOA exhibited a decreasing trend with increasing MCE for all photochemical and O_3/dark aging experiments irrespective of the biomass fuels. The SOA emission factors in dark aging experiments were lower compared to those in photochemical aging at similar MCE conditions.

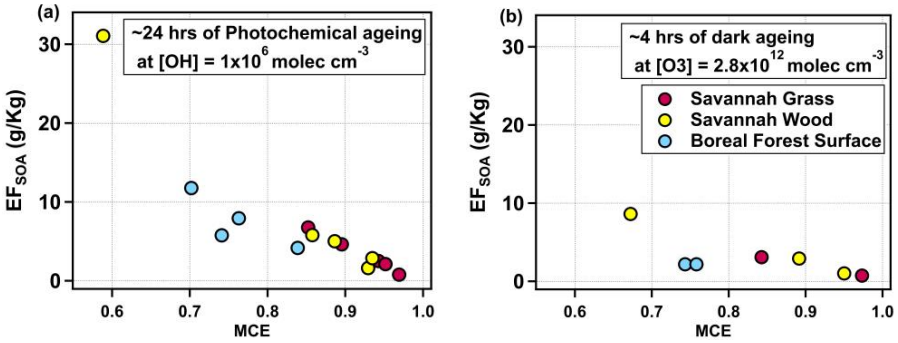

Figure 1. Emission factors for SOA formed at different burning conditions (MCE) for (a) Photochemical and (b) dark oxidation experiments.

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DRIVERS OF VOLATILE SOIL EMISSIONS IN THE BOREAL FOREST

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Keywords: volatile organic compounds (VOCs), forest soil, emissions, tree stand properties.

INTRODUCTION

Volatile organic compounds (VOCs) are present in soils and can be emitted into the atmosphere . Living roots, microorganisms, and above- and below-ground litter (e.g., roots, fallen tree branches, leaves, needles, and dying parts of the ground vegetation) produce VOCs, which influence microbial processes of carbon (C) and nitrogen (N) cycles and thus decomposition and nutrient availability and can also promote plant growth. However, the drivers of soil VOC emissions are complex and not fully understood, so that such emissions are not included in global climate models (Tang et al. 2019). To study the drivers of VOC emissions from boreal forest soil emissions, soil samples and soil VOC emissions were collected at two forest sites from Luke's long-term and well documented experiments in Finland from May to October 2023. We analyzed correlations between VOC emissions and site characteristics (e.g. tree species, nitrogen availability, soil pH, microbial biomass) as well as environmental conditions (e.g. soil temperature and moisture, ambient air temperature and relative humidity, photosynthetically active radiation).

METHODS

Two sites were selected for this study: a spruce dominated stand with a N-fertilization experiment (Karkkila, 60.577°N, 24.261°E), and a forest with a tree species experiment (Taivalkoski, 65.316°N, 28.161°E) with individual plots with either silver birch, Scots pine, or Norway spruce, grown on originally similar soil. We collected soil VOC emissions on multi-bed adsorbent tubes from three locations in each plot (control and N-fertilized in Karkkila, and different tree species in Taivalkoski) The collected samples were then analysed with a thermal desorption gas chromatograph coupled to mass spectrometry (TD-GC-MS). During sampling of BVOC emissions, the air temperature and moisture both inside and outside the sampling enclosure were recorded with sensors. In addition, soil moisture was measured and a visual estimate of vegetation cover was conducted after each BVOC emission sampling. In addition, 15 to 20 soil cores were systematically taken by a soil auger around 1-2 m of each VOC sampling location twice at each site (early and late growing season) and the organic layer separated. Sampled organic layers were combined to make one composite sample for each sampling location. Pretreatments and analysis were performed as described in literature (Soronen et al. 2024) to derive soil parameters, including microbial properties. We also used a microdialysis sampling technique to determine induced diffusive fluxes of plant-available N

compounds in the organic layer (Soronen et al. 2024). Fluxes were measured twice during the growing season at each site (early and late season).

RESULTS

Soil emissions varied in quantity and composition. For a given plot, emissions collected on the same day show relatively similar compositions but with varying quantities. However, seasonal variations influenced the composition of the emissions, reflecting different underlying processes occurring throughout the growing season. Soil and environmental factors effects were compound-dependent. Overall, environmental variables correlating to α-pinene were different from other terpenes For instance, moss cover increased α-pinene emissions. Also, the nitrogen fertilized plot emitted more limonene than other forest stands and the plots in Karkkila emitted more camphene than the ones in Taivalkoski. Chloroform was also found to be emitted, in particular from the N-fertilized plot. Chloroform is most likely related to soil microbiota. Increased moss cover reduced chloroform emissions. In general, it seems that the dominant tree species, moss cover, and shrub cover are vegetation factors that had most effect on VOC emissions. From soil properties, increasing dissolved organic carbon, organic matter, and the microbial biomass C-to-N ratio increased BVOC emissions. N-fertilization of the forest floor increased camphene and chloroform emissions.

CONCLUSIONS

The relationships between stand properties, soil properties, environmental conditions and VOC emissions were explored using multiple linear regressions, highlighting differences in the processes involved in the emissions of different VOCs. We found that individual compounds are affected differently, emphasizing the importance of speciation when considering soil VOC emissions. Environmental properties can have both direct and indirect effects on VOC emissions. Furthermore, with increasing global temperatures causing heat stress to vegetation, it is also estimated that the biomass in boreal areas will increase, and so will litter and organic soil matter. These factors will affect soil microbiota and forest floor vegetation and cause increased emission and shifts in forest floor vegetation emissions alongside an extending growing season and increased biomass in boreal forests. Without a comprehensive knowledge of current total emissions of the boreal forest, future changes in BVOC emissions and their effects on local air chemistry are difficult to predict. The presented analysis can be used in models of biogenic VOC emissions from boreal forest soils in order to investigate future scenarios.

ACKNOWLEDGEMENTS

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NANOPARTICLE RANKING ANALYSIS APPLIED TO NEW PARTICLE FORMATION IN SIBERIAN BOREAL FOREST

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Keywords: New Particle Formation, Boreal Forest, Siberia.

INTRODUCTION

New Particle Formation (NPF) plays an important role in atmospheric processes and influences the climate. Its mechanisms are poorly understood in remote regions like Siberian taiga. Previous studies showed that in Siberia, NPF is less frequent than at other boreal forest sites (Lampilahti et al., 2023, Wiedensohler et al., 2019). To understand the phenomena of Siberian NPF, we analysed data from a long-term measurement campaign (2019 - 2021). We classified NPF events in a traditional way, described in Dal Maso et al., 2005; and also performed nanoparticle ranking analysis (Aliaga et al., 2023). We compared the outcome of the two methods, and investigated how different atmospheric parameters influence NPF using nanoparticle ranking analysis.

METHODS

In this study, we used data collected at Fonovaya station (56°25”N, 84°04”E) in Tomsk region, West Siberia (Antonovich et al., 2018). The site is surrounded by boreal forest, and the closest cities are Tomsk (60 km east from the station) and Novosibirsk (170 km south–south–west from the station). At the station, long-term monitoring of atmospheric parameters is conducted. To study NPF, we used particle number size distribution measured by Neutral cluster Air Ion Spectrometer (NAIS) during 2019 - 2021. We did traditional NPF classification, dividing all measurement days into three categories (Dal Maso et al., 2005): events, non-events, and undefined days based on visual assessment of aerosol number size distribution. The same data set was used for nanoparticle ranking analysis (Aliaga et al., 2023). The method is based on analysis of a variable derived from the number concentration at particle diameters from 2.5 to 5 nm ($\Delta N_{2.5-5}$). Particles in this size range are sensitive to the occurrence of atmospheric NPF, and $\Delta N_{2.5-5}$ can be linked to the probability and strength of NPF events. To investigate factors that influence NPF, we studied the correlations between $\Delta N_{2.5-5}$ and different atmospheric parameters, such as concentrations of SO_2, NO_x, and ozone, global solar radiation, temperature, relative humidity (RH), wind speed, wind direction, condensation sink (CS) and particle formation rate (J_3).

RESULTS

A strong link between NPF and $\Delta N_{2.5-5}$ was observed for Siberian forest similar to Finnish boreal forest (Aliaga et al., 2023). As expected, NPF events occurred more often at higher $\Delta N_{2.5-5}$ values, and low values corresponded to nonevents. We also studied the correlations between $\Delta N_{2.5-5}$ and atmospheric variables for different seasons. Solar radiation has a strong positive link to NPF, and its influence is especially significant in autumn and winter. Temperature also plays a very important role in NPF processes, and the negative

correlation with $\Delta N_{2.5\text{-}5}$ is strongest in spring. Those parameters are driving photochemical reactions that enhance NPF. The strongest correlation between SO_2, which is crucial for sulfuric acid production promoting aerosol formation and growth, and $\Delta N_{2.5\text{-}5}$ was most significant in summer though SO_2 concentrations are usually the lowest in summer. Ozone also showed a correlation with $\Delta N_{2.5\text{-}5}$, especially in spring and summer, possibly due to playing a key role in oxidizing VOCs, which contribute to nucleation. RH had a negative correlation with $\Delta N_{2.5\text{-}5}$, especially in winter and autumn, likely due to its effect on condensation processes. Wind speed showed weaker but notable seasonal connection to NPF, with wind speed positively correlating with $\Delta N_{2.5\text{-}5}$ in spring and summer.

CONCLUSIONS

In this study, we investigated NPF at Fonovaya station in Siberia, focusing on the processes and factors influencing it. We used both traditional event classification and nanoparticle ranking methods, finding that NPF events are associated with higher $\Delta N_{2.5\text{-}5}$, while non-events occur on low $\Delta N_{2.5\text{-}5}$. Our analysis revealed positive correlations with SO_2, O_3, NO_x, global radiation, and wind speed, and negative with temperature and RH with a strong seasonal impact. No significant correlation was found for the condensation sink. These findings align with the results of previous studies on spring NPF at Fonovaya (Lampilahti et al., 2023, Garmash et al., 2024), and further contribute to our understanding on the meteorological factors important for NPF events at Fonovaya station.

ACKNOWLEDGEMENTS

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SECONDARY ICE PRODUCTION IN ARCTIC MIXED-PHASE CLOUDS

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Keywords: large-eddy simulation, mixed-phase clouds, secondary ice production.

INTRODUCTION

Shallow mixed-phase clouds are common over high-latitude marine regions. Simulating mixed-phase clouds is challenging because the equilibrium between liquid and glaciated cloud states is sensitive to ice crystal number concentration (ICNC). Ice-nucleating particles (INPs) such as dust are needed to initiate primary droplet freezing. Measurements show that INP concentrations in moderately supercooled (temperatures above -10 °C) pristine marine clouds are in the order of 1 #/kg but the observed ICNCs can easily exceed 1000 #/kg. Most of the ice crystals are thus related to secondary ice production (SIP) such as rime splintering often called as the Hallett-Mossop process.

METHODS

UCLALES-SALSA (Tonttila *et al.*, 2017; Ahola *et al.,* 2020) is a large-eddy simulator (LES) coupled with sectional aerosol-cloud microphysics module SALSA (Kokkola *et al.*, 2008). The model contains the large-eddy simulator UCLA-LES (Stevens *et al.,* 1999) as well as the two-moment mixed-phase cloud microphysics originally developed by Seifert and Beheng (2006), which can be used instead of SALSA. For this study, we have implemented the same Hallett-Mossop SIP process for both SB (Seifert and Beheng) and SALSA microphysics. The highly detailed sectional SALSA accounts for aerosol-cloud interactions while the two-moment SB microphysics assumes a fixed cloud droplet number concentration. Understandably, the details of SALSA come with significant computational costs, so one of our aims is to see how much SALSA and SB predictions differ and why.

Our LES simulations are based on observations from the ACLOUD (Arctic CLoud Observations Using airborne measurements during polar Day) campaign (Ehrlich et al., 2019). The observations examined in detail by Järvinen *et al.* (2023) show that ICNCs are in the order of 1000 #/kg while the expected INP concentration is smaller by three orders of magnitude. This and the high cloud top temperatures suggest that secondary ice production has an important role in producing ice crystals.

RESULTS

Our first aim is to see if the simulations can reproduce the observed ICNC, and if not, then how to adjust the ice production so that observed ice concentration is reached. The first tests showed that the default SIP parameterization could not produce enough ice, so we adjusted the production rate. A factor of ten increase seemed to be enough for this case. Figure 1 shows the time series of simulated ICNC from three simulations. The dashed line shows the base-case simulation where primary ICNC is set to match with the expected INP concentration of 1 #/kg. With the default setup, ICNC stays at about 1 #/kg, but when SIP rate is increased by a factor of ten (solid line), ICNC of 1000 #/kg is reached in about 8 hours. Interestingly, the same factor of ten increase is valid for the SALSA simulation (grey solid line).

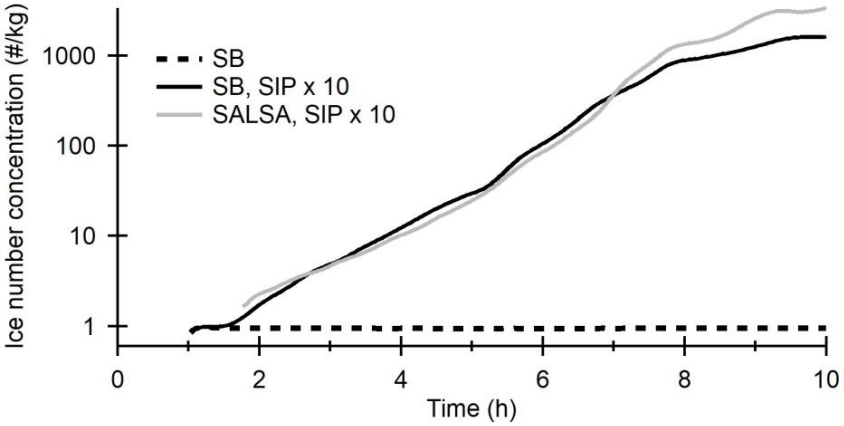

Figure 1.Domain mean ice crystal number concentration from three UCLALES-SALSA simulations: SB microhysics without any adjustmets (dashed line) and when SIP rate is increased by a factor of ten (solid line), and SALSA simulation with the same adjustment (grey solid line).

CONCLUSIONS

Simulating secondary ice production is challenging because the process is sensitive on the conditions and parameterizations being used. For the current observation-based conditions and with the slightly modified SIP parameterization, our LES simulations produced realistic ice crystal concentrations. Moreover, the results are similar for both the simple SB and the detailed SALSA microphysics.

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QUANTIFICATION OF PURE LEVOGLUCOSAN AND PHOTOOXIDIZED LEVOGLUCOSAN AEROSOL BY AEROSOL MASS SPECTROMETRY

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Keywords: biomass burning, levoglucosan, secondary organic aerosol, mark compounds

INTRODUCTION

Emissions from biomass combustion are the largest sources of primary organic aerosol on a global scale and a potentially large source of secondary organic aerosol precursors (Andreae, 2019). Understanding the impacts of biomass burning on local, regional, and global aerosol budgets is therefore curcial. Levoglucosan is one of the most used molecular markers for biomass burning. Chemical receptor models and source-apportionment studies extensively use it to quantify the contribution of biomass burning to ambient aerosols. Given its importance, it is essential to quantify levoglucosan under ambient conditions in a reliable, accurate and convenient way. The research will investigate the response of aerosol mass spectrometer (AMS) to the pure levoglucosan aerosol particles subject to aging and mixing with other inorganic/organic particles. The goal is to establish an approach to quantity levoglucosan based on AMS measurement.

METHODS

The experiments were carried out using an oxidation flow tube reactor (OFR). The operation procedure of this OFR has been described previously (Buchholz et al., 2019). Briefly, a commercial levoglucosan compound (Sigma-Aldrich) in water solution was atomized and then mixed with a humidified flow of synthetic air and O_3. After entering OFR, the evoglucosan aerosol particles were photooxidized by hydroxyl radicals (OH), which were produced by photolyzing O_3 with 254nm UV lamps in the presence of water vapor. Six types of experiments were performed:

(1) pure levoglucosan aerosol experiments without aging
(2) mixture of levoglucosan aerosol with inorganic aerosol particle without aging.
(3) mixture of levoglucosan aerosol with organic aerosol particle without aging.
(4) photoaging experiments of pure levoglucosan aerosol by OH
(5) photoaging experiments of mixed levoglucosan and other organic aerosols by OH
(6) photoaging experiments of mixed levoglucosan and other inorganic aerosol by OH

The chemical composition of bulk aerosol particles was measured by an Aerodyne high resolution time-of-flight aerosol mass spectrometer (AMS, DeCarlo et al., 2006). The volume concentration and size distribution of aerosol particles were measured by a scanning mobility particle sizer (SMPS). The ion molecular composition and volatility of aerosol constituents were characterized using a chemical ionization mass spectrometer (CIMS) coupled to filter inlet for gases and aerosols (FIGAERO) (Lopez-Hilfiker *et al.* 2014).

RESULTS

When using AMS to quantify specific organic aerosol particles, the default relative ionization efficiency (RIE) of 1.4 for organic aerosol may not always apply and vary depending on the organic component (Xu et al., 2018). In the pure experiments with levoglucosan aerosol, we first determined the RIE of levoglucosan aerosol. The combined CE*RIE (where CE stands for collection efficiency) for levoglucosan was found to be 1.11, where. The value is lower than the value of 1.4 reported by Xu et al. (2018).

After applying the new CE*RIE value, the levoglucosan mass concentrations quantified by AMS showed strong agreement with the volume concentration measured from SMPS across five levels of levoglucosan concentrations (r2=0.9) (Figure 1).

$C_2H_4O_2$ (m/z60) and $C_3H_5O_2$ (m/z73) are recognized as known marker fragments for levoglucosan, accounting for 11% and 2% of its mass, respectively (Fig. 2). Additionally, the study attempted to identify two potential marker fragments for levoglucosan: $C_6H_4O_3$(m/z124) and $C_6H_6O_3$ (m/z126), though further confirmation is needed (Fig.2). Using data from pure levoglucosan experiments and these marker fragments, further analysis is going on to quantify levoglucosan in the mixtures with inorganic/organic aerosols and in the photoaging experiments.

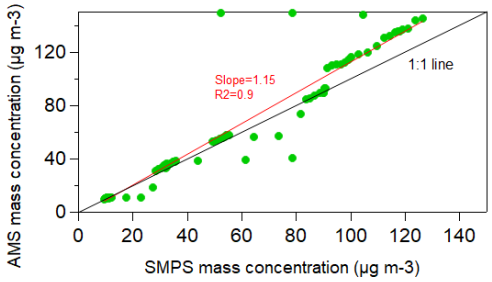

Figure 1. The mass concentration of pure levoglucosan aerosol particles as determined by AMS vs the measurement from SMPS after applying a density of 1.69 g cm^{-3} for levoglucosan in the pure levoglucosan experiments.

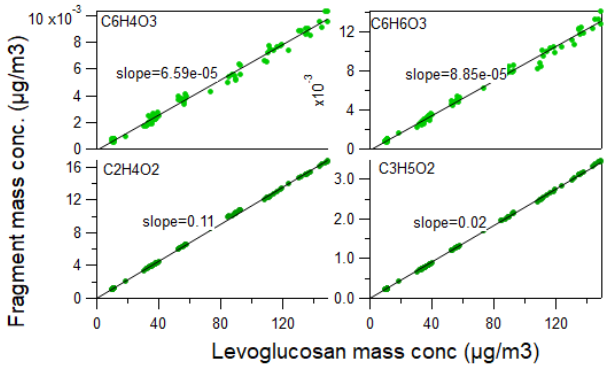

Figure 2. The response of fragment marker compounds of levoglucosan to the parental compound levoglucosan at five different mass concentration levels.

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MONITORING URBAN MICROCLIMATE IN THE CITY OF TAMPERE

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Keywords: Urban heat island, urban microclimate, high resolution climate data.

INTRODUCTION

In the TAPSI project (Localised climate service for Finland, https://www.ilmatieteenlaitos.fi/tapsi), new services are being developed to provide more regionally detailed climate information to support climate change adaptation and understanding in Finland. As part of the project, urban measurement networks are being designed and implemented in four Finnish cities, Tampere, Helsinki, Rovaniemi and Oulu. The measurement networks will provide higher-resolution temperature and humidity data within the city, allowing for a more detailed analysis and modelling of urban microclimatic features, such as the urban heat island effect. Further, the urban measurement networks aim to address key questions related to urban climate, including how the built environment affects climate conditions in urban areas, how the urban environment and its green and blue infrastructure influence local climate conditions, and how these effects can be observed in different parts of the city. In this abstract, we present the urban measurement network installed in the city of Tampere during the summer of 2023 and preliminary results of the first measurements.

METHODS

As part of the TAPSI project, 19 measurement devices were installed in the city of Tampere during the summer of 2023 to measure temperature and relative humidity, with an additional 2 installed in the summer of 2024. Figure 1 shows the locations of the measurement stations (yellow points) in the City of Tampere. The sensors have been primarily placed in built environments, including apartment building and residential areas, as well as parks and recreational areas. All of the devices have been installed at the same height of 3 m above ground.

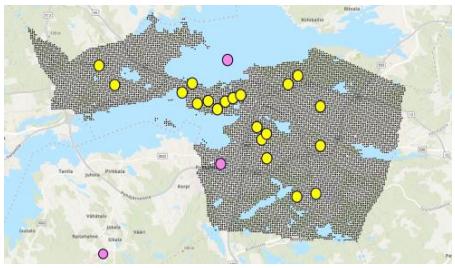

Figure 1. The measurement stations (yellow points) in Tampere. Three measurement stations from the Finnish Meteorological Institute (pink points) were also included in the interpolation calculations. The hatched area in the figure marks the interpolation area for the Kriging interpolation used.

Temperature observations from the urban measurement network in Tampere and three measurement stations from the Finnish Meteorological Institute (Pirkkala, Härmälä, and Siilinkari) were interpolated to a 100 m resolution using Kriging interpolation (e.g., Aalto et al. 2016) over the area hatched in Figure 1. In our application of the Kriging method, the explanatory variables included elevation, the percentage of lake coverage, the percentage of forest cover, the percentage of apartment buildings, and location (lat and lon coordinates).

RESULTS

Figure 2 shows the areas where, during June-July 2024, the daily minimum temperatures (Figure 2a) and maximum temperatures (Figure 2b) were, on average, higher (reddish areas) or lower (greenish areas) than the mean of the whole interpolation area. When comparing temperature anomalies with the percentage of forest cover (Figure 2c), topography (Figure 2d), and lake coverage (blue in Figures 2a-c), higher minimum temperatures were observed near water bodies compared to the regional mean, and lower maximum temperatures were found in more forested areas compared to the regional average.

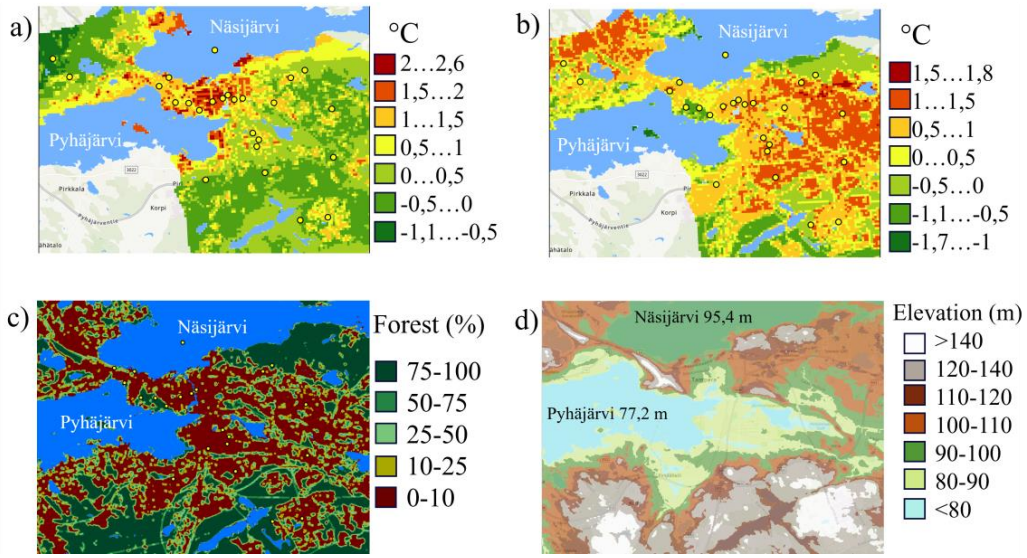

Figure 2. Upper row: the Kriging-interpolated average daily a) minimum, and b) maximum temperature anomaly (°C) from the regional mean over the City of Tampere during June-July 2024. Bottom row: c) the percentage of forested area and d) the elevation (meters above the mean sea level) of the grid point. In Figures a)-c) the yellow points on the maps show the locations of the measurement stations, and the blue areas depict water bodies.

CONCLUSIONS

Based on preliminary results, the effects of water bodies and forest cover on local temperature are already noticeable in some areas during the short two-month period of June-July 2024. More accurate results will be obtained as more data is gathered and the analysis is refined. For instance, the results shown here did not include analysis of how prevailing large-scale weather patterns affect temperature distributions in the area.

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DROUGHT STRESS IN URBAN GREEN AREAS IN SOUTHERN FINLAND

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Keywords: Carbon cycle, Urban, Green spaces, Ecosystem modelling.

INTRODUCTION

More than half of the world's population lives in urban areas, and urban settlements contribute around 70% of the global CO_2 emissions. Enhancing the carbon sequestration of urban green infrastructure has been identified as an option for mitigating climate change. In addition, urban green areas can also help to manage run-off water, reduce the urban heat island effect, and have further health related co-benefits. Climate change-related risks are increasing, and urban green areas are subjected to stress factors such as heat, drought and pollution. We studied carbon cycle components of urban green areas focusing on the impact of drought. The study area is a semi-urban area situated in Helsinki, Southern Finland.

METHODS

We used the JSBACH ecosystem model (Reick *et al.*, 2013) together with observations related to the soil conditions, water balance, plant phenology, soil respiration and carbon sequestration. Details are given in Tremeau *et al.* (2024), Karvinen *et al.* (2024) and Thölix *et al.* (2024). The site consists of a park area with lawns and linden trees (*Tilia cordata*) and an urban forest dominated by birch (*Betula pendula*). Some parts of the park site were irrigated. Climate indices were used for describing the drought stress of the study area: The Standardized Precipitation Evapotranspiration Index (SPEI); Standardized Precipitation Index (SPI); and Potential Evapotranspiration. The indices were calculated at 3-months timescale, with monthly temporal resolution. We used the ERA5-Land (Muñoz Sabater, 2019) data both to drive the model and to derive the climate indices.

RESULTS

During the study period, 2005–2023, there were two summers with significant drought periods (2006 and 2018). The drought stress in 2006 was mostly due to deficiency in precipitation, while in 2018 it was strongly driven by the temperature, as seen in the evapotranspiration (Fig. 1). The drought response was seen in the leaf area index, as well as in the carbon assimilation of the lawns. The trees mainly showed a decrease in carbon assimilation.

CONCLUSIONS

In a changing climate drought may become more common. Several factors may promote more frequent droughts in the future: higher temperatures; higher variability in precipitation; and earlier

snowmelt. In this study the deeper roots of the trees, compared to grasses, decreased the effects of drought on the trees. Furthermore, the effect of irrigation requires further studies.

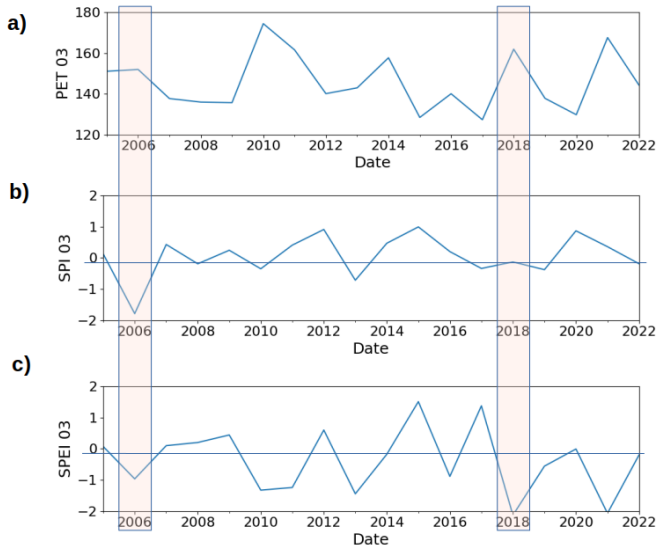

Figure 1: Drought stress in the Kumpula area (Helsinki), as described by climate indices, which are cumulated over three months. The figure shows timeseries for July: a) Potential evapotranspiration (PET); b) Standardized Precipitation Index (SPI); and c) Standardized Precipitation-Evapotranspiration Index (SPEI).

ACKNOWLEDGEMENTS

This work is part of two projects 'CO-CARBON: Individuals, communities and municipalities mitigating climate change by carbon smart green space' (grant no: 335204) and 'CarboCity: Urban green space solutions in carbon neutral cities' (grant no: 325549) funded by the Academy of Finland. We also acknowledge the support through the Flagship program for Atmospheric and Climate Competence Center (ACCC, Grant no 337552).

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CLIMATE CHANGE IMPACT TO FOREST FIRE SEASON, NUMBER OF FIRES AND BURNT AREA IN FENNOSCANDIA

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Keywords: Forest fire, Climate change, Ecosystem model, Carbon cycle.

INTRODUCTION

Forest fires are significant disturbances to ecosystems. Climate change is altering the dynamics of boreal forests, with disturbances expected to become more frequent by the end of the century. An increase in forest fire frequency creates risks to both ecosystem resilience and societal well-being. However, forecasting the future impacts of climate change on forest disturbances remains uncertain due to the inherent limitations of global climate models.

METHODS

Here, we study the impact of climate change on forest fire season, number of fires and burnt area using ecosystem model JSBACH-SPITFIRE (Thonicke *et al.*, 2010; Lasslop *et al.* 2017; Lasslop *et al.* 2016). The simulations are driven by output from three global climate driver models (CNRM-CM5, MIROC5 and CanESM2) that have been bias-corrected and downscaled (CORDEX EUR-44 domain). The global models from CMIP5 were run under two forcing scenarios, RCP 4.5 and RCP 8.5. To tackle the uncertainty of climate change projections, we used six climate projections.

In the model, forest fires are caused by human activities or lightning. The probability of fires depends on factors such as fuel characteristics and weather conditions. Warmer temperatures increase the risk of fires by drying out vegetation, although higher precipitation can reduce this risk to some extent.

RESULTS

In our simulations (Kinnunen *et al.* 2024) the fire season in Fennosscandia is projected to extend in both spring and autumn. The fire season is estimated to lengthen from 20±7 days to 52±12 days, starting from 10±9 days to 23±11 days earlier and ending from 10±10 days to 30±16 days later, by the end of the century. It is expected that the number of fires and burnt area are projected to increase from the reference period (1981-2010) to the end of the century (2071-2100) due to rising temperatures, despite increases in precipitation (table 1). However, the amount of change varies significantly between climate projections and locations.

Climate projection	Forest fire season [day]	Number of fires [km^{-2} y^{-1}]	Burnt area [km^2 y^{-1}]
RCP 4.5 CNRM-CM5	19.9 ± 6.8	0.0006 ± 0.0007	0.004 ± 0.006
RCP 8.5 CNRM-CM5	46.4 ± 9.8	0.0024 ± 0.0020	0.014 ± 0.014
RCP 4.5 MIROC5	21.6 ± 6.6	0.0013 ± 0.0011	0.009 ± 0.010
RCP 8.5 MIROC5	52.1 ± 11.6	0.0034 ± 0.0029	0.021 ± 0.021
RCP 4.5 CanESM2	33.8 ± 9.1	0.0010 ± 0.0010	0.006 ± 0.007
RCP 8.5 CanESM2	33.0 ± 8.3	0.0016 ± 0.0013	0.009 ± 0.008

Table 1: Change from reference period to the end of the century.

CONCLUSIONS

There is large variation in results. However, the forest fire season is projected to become longer, with an increase in the number of fires and a larger area burned by the end of the century.

One potential improvement could be to include specific properties of peatland vegetation into the model. Peatlands are unique ecosystems with vegetation that is highly combustible under dry conditions, contributing to intense and long-lasting fires. By including details such as the moisture content, organic material composition, and decay rates of peatland vegetation, the model could more accurately predict fire behavior and risk in these areas. This enhancement would increase the overall accuracy of the model, particularly in areas where peatlands are common.

ACKNOWLEDGEMENTS

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RESTORATION INDUCED LONG-TERM VEGETATION CHANGE IN OLIGOTROPHIC PEATLANDS

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Keywords: Forestry Drainage, Functional Diversity, Rewetting, Tree Stand Removal.

INTRODUCTION

Peatlands are facing growing pressure from both land use and climate change (UN Environment Programme, 2022). In Europe this is seen as increased exploitation and drainage since the 1800s (Swindles et al., 2019), where about 60% of peatlands have been subjected to agricultural use, forestry, and peat extraction (UN Environment Programme, 2022). These actions have compromised biodiversity and nature conservation values and contributed to the ongoing global biodiversity crisis (e.g. Fraixedas et al., 2017, Carroll et al., 2011). Thus, ecological restoration, aiming to return communities and functions characteristic of undisturbed peatlands is urgently needed to enhance biodiversity, and safeguard peatland functions and services (Aapala et al., 2013, Gann et al., 2019). However, little is known on the long-term responses of vegetation – hindering us to judge the success of various restoration measures.

METHODS

We followed vegetation changes in oligotrophic pine fens over 12 years starting a year before restoration actions (rewetting and tree stand removal). In addition to standard tree harvesting where only stems are removed from the sites, we assessed the impact of whole tree removal where stems but also branches are taken from the sites. We combined plant cover data with plant functional trait data which was obtained from earlier studies and TRY database (Laine et al., 2021a, Laine et al., 2021b, Kattge et al. 2020).

RESULTS

The restoration trajectory of vegetation was non-linear in both restoration approaches, and the recovery time differed between plant functional groups. We first observed an initial loss of species indicative of drained peatlands, followed later by increases in species indicative of undrained peatlands and an increase in trait heterogeneity. Additionally, we observed that the sedges responded to restoration faster than *Sphagnum* mosses.

CONCLUSIONS

Resemblance to undrained peatlands increased in both harvesting methods, giving support for the use of both restoration measures. Furthermore, our results highlight that predictions based on short-term vegetation monitoring can be improved with a long-term monitoring approach, especially for species responding slowly, and that, due to the co-occurrence of traits characteristics of forest and peatland species, restoration is likely to result in heterogeneity of ecosystem functions.

ACKNOWLEDGEMENTS

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QUANTITATIVE QUANTIFICATION OF DOWNSCALED CLIMATE DATA IN REPRESENTING EUROPEAN CLIMATE EXTREMES

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Keywords: extremes, regional climate, downscaling.

INTRODUCTION

Temperature and precipitation extremes are estimated to intensify with an increase in number of events (Fischer *et al.*, 2021). This will impact the society on different levels. There is a plethora of climate datasets available from various climate models, but it is not yet clear which of these datasets are suitable for reliable estimation of the impacts of extreme weather events on society. General circulation models (GCMs) have a coarse spatial resolution thus, downscaled datasets (i.e., statistical and dynamical) are needed for regional analyses and representation of small-scale processes. It is expected that downscaled datasets will also improve the description of extreme events. In this study, we compare observed extremes related to temperature and precipitation with GCMs and downscaled datasets. The primary objective of the research is to understand which datasets could be used as a basis for decision making on a regional level.

DATA and METHODS

Climate extreme indices were calculated based on four different climate model datasets: both CMIP5 and CMIP6 simulations, dynamically downscaled simulations for Europe, i.e., CORDEX simulations, and statistically downscaled NASA Earth Exchange Global Daily Downscaled Projections (NEX-GDDP-CMIP6) and as averages for the historical period (1990-2019) and for the future based on RCP4.5/SSP2-4.5 scenarios. Climate extreme indices for the former period were compared with climate indices based on ERA5 reanalysis and E-OBS daily gridded meteorological data for Europe. We analyze the number of heavy precipitation days (P>10mm (R10mm)) and the annual maximum consecutive 5-day total precipitation (Rx5day). For temperature, we analyze the annual maximum of daily maximum temperature (TXx) and the number of days in a year when temperature cross the 0°C throughout that day defined as Zero crossing days (ZCD).

RESULTS

Figure 1 illustrates the mean of the maximum 5-day precipitation for the period 1990-2019, based on CMIP5, CMIP6, CORDEX, NEX-GDDP-CMIP6, ERA5, and E-OBS. The GCMs in CMIP5 and CMIP6 have coarse spatial resolution, which limits their ability to accurately capture finer regional details, especially in complex terrain where local factors heavily influence precipitation patterns. This coarse resolution is particularly evident in the underrepresentation of extreme precipitation events at smaller spatial scales, which can be critical for assessing local climate impacts. Statistically downscaled dataset NEX-GDDP-CMIP6, provide an improvement by reproducing Rx5day

more accurately in regions where heavy precipitation is most common, such as mountainous areas. However, despite this improvement, these datasets often underestimate Rx5day in other regions, indicating that the statistical downscaling process does not always fully capture the spatial complexity and dynamics behind precipitation extremes. Dynamically downscaled CORDEX simulations show the better agreement with observation, offering high spatial accuracy. This improved performance is due to the higher resolution of the regional climate models, which better capture local topographic and atmospheric features that influence extreme precipitation events. Despite the strengths of CORDEX in representing precipitation, biases remain in its temperature simulations. When compared to observational datasets, CORDEX models exhibit temperature discrepancies, both in terms of absolute values and in the projected temperature changes under a warming climate. These temperature biases can, in turn, affect the accuracy of indices related to climate extremes.

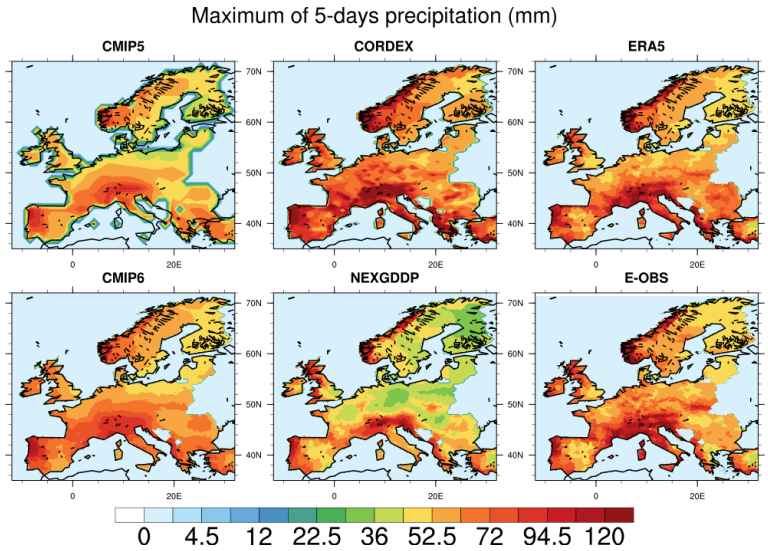

Figure 1: Maximum of 5-day precipitation from 1990 to 2019.

CONCLUSIONS

Utilizing climate model projections to inform adaptation policies and strategies is complex due to the variability and limitations inherent in different climate model datasets. Each dataset has unique characteristics and potential weaknesses, necessitating two key actions: (1) a thorough understanding of the differences between these datasets, including the underlying causes of these discrepancies, along with the development of improved methodologies for generating more accurate and reliable climate projections; and (2) the effective communication of climate change information, tailored to the needs of specific data users, in an accessible and actionable format.

ACKNOWLEDGEMENTS

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Carbon sequestration in different urban vegetation types in Kumpula

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Keywords: Urban, Carbon sequestration.

INTRODUCTION

Many cities aim for carbon neutrality, which has increased interest in the carbon sequestration potential of urban vegetation. However, the diverse nature of urban vegetation and varying environmental conditions make comprehensive measurements challenging, setting expectations for carbon cycle modeling. Most models have been developed to describe natural ecosystems, so models must also be developed to describe urban vegetation with challenges, such as limited water supply and space.

METHODS

In this study, we evaluated the performance of three models – JSBACH, LPJ-GUESS, and SUEWS – in estimating photosynthesis, respiration, and carbon sequestration. We examined both irrigated and non-irrigated lawns, park trees (*Tilia cordata*), and urban forests (*Betula pendula*) in Kumpula, Helsinki.

The model results were compared to observations of soil moisture and temperature, sap flow, leaf area index (LAI), gross primary production (GPP), soil respiration, and net ecosystem exchange (NEE).

RESULTS

Our analysis showed that the models accurately captured seasonal and annual variations, as well as the effects of weather on carbon fluxes and related parameters. However, validating the absolute levels of fluxes was challenging due to limitations in observations, and the fact that net ecosystem exchange measurements in urban areas include some anthropogenic emissions. Tree-covered areas sequestered more carbon annually compared to lawns. Irrigation turn out to be a significant factor, often enhancing carbon sequestration.

All models produced similar average net ecosystem exchange across the urban vegetation area over the study period. However, LPJ-GUESS predicted higher carbon sequestration in tree-covered areas but lower rates in grasslands compared to JSBACH. The models also indicated considerable year-to-year variability in carbon sequestration rates, but since factors like temperature and soil moisture influence both carbon uptake and release processes, it was difficult to link high or low sequestration years to specific meteorological events.

This study highlights the need to account for diverse vegetation types and the role of irrigation in urban carbon modelling, offering valuable insights for sustainable urban planning and climate change mitigation.

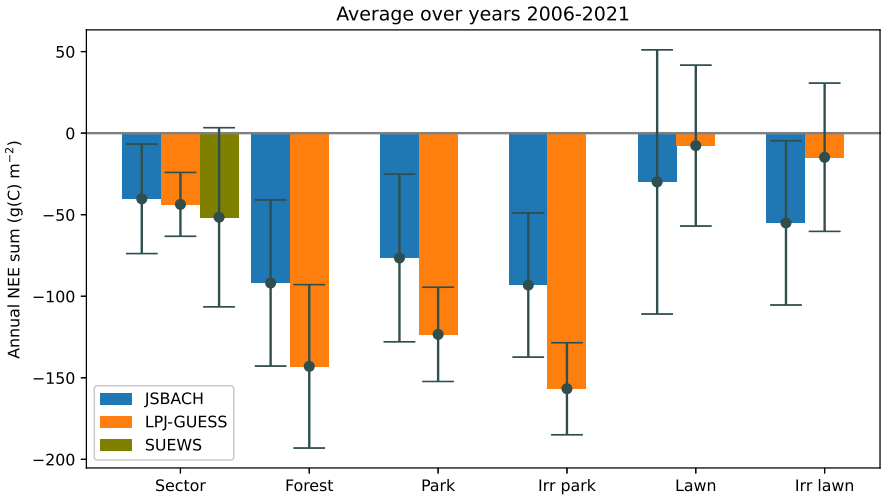

Figure 1: Mean carbon sequestration (NEE) in the diverse target area and for the separate vegetation types in the different models over 2006–2021. The error bar represents the standard deviation over the years.

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ARCTIC OCEAN EXPEDITION 2001: IMMERSION FREEZING ANALYSIS ON PRESERVED FILTERS

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Keywords: ice nucleation, immersion freezing, arctic clouds.

INTRODUCTION

The arctic ocean expedition (AOE-2001) was an interdisciplinary expedition that produced observational data for the purposes of marine biology, atmospheric chemistry, aerosol chemistry and physics, meteorology, oceanography, and seismology. The ship-based expedition on the Swedish ice-breaker *Oden*, gathered data from June 29th to August 26th from Gothenburg (Sweden) to Svalbard and the North Pole (Leck *et al*., 2004).

During the expedition, the ice nucleating particle concentration (N_{INP}) at 258 K was measured on board by Keith Bigg, using a filter-based (Millipore membrane filter) sampling method and a thermal gradient diffusion chamber (Bigg, 1996) for observing the N_{INP}. The data was published in Welti *et al.* (2020).

In this study, we investigate if preserved filters from the AOE-2001 expedition can be used for droplet freezing experiments to reproduce the observations of Bigg and further characterize the INP concentrations at different temperatures.

METHODS

Two types of filters have been preserved from the AOE-2001 cruise: glass and quartz fibre filters, originally collected for radionuclide analysis described in Paatero *et al.* (2004).

To analyze the filter for N_{INP} we apply the "filter punching technique" that uses 96, 1 mm diameter circles extracted from each AOE-2001 filter. The punched-out circles are submerged in 50 µl aliquots of water on a PCR-plate. To measure the N_{INP} as a function of temperature $N_{INP}(T)$, the PCR plate is immersed into a temperature-controlled ethanol bath and subjected to decreasing temperatures at 1K/min. From the fraction of frozen aliquots at each temperature $f_{ice}(T)$, the cumulative N_{INP} at the respective temperatures can be calculated following Vali (1971).

$$N_{INP}(T) = -\frac{\ln\left(1 - f_{ice}(T)\right)}{V}$$

The volume normalization factor V is determined from the punched circle $d_{punchout}$ and filter d_{filter} diameters and the sampled volume through the filter V_{filter}.

$$V = \frac{(0.5 \cdot d_{punchout})^2}{\left(0.5 \cdot d_{filter}\right)^2} V_{filter}$$

We determined the substrate background by performing experiments on portions of blank filters, where no air was sampled through. The substrate freezing temperature of quartz fibre filters is low enough to allow

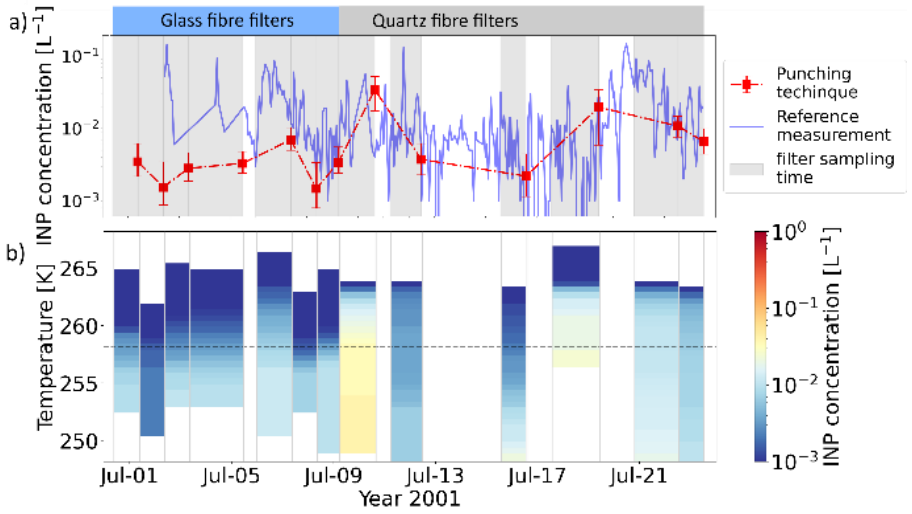

Figure 1. a) comparison of N_{INP} from on-board measurements to filter punching measurements at 258K. b) time-series of N_{INP} temperature spectra. Width of the bar indicates the sampling time of each filter and dashed line marks the temperature 258K.

the detection of N_{INP} down to 250 K. The freezing temperature of glass fibre filters however is considerably higher, close to 258 K.

RESULTS

the detection of N_{INP} down to 250 K. The freezing temperature of glass fibre filters however is considerably higher, close to 258 K.A comparison of the newly measured N_{INP} time-series at 258 K to the previous dataset is shown in Fig. 1. Measurements from quartz fibre filters showed better correlation to Bigg's on-board measurements than the ones from glass fibre filters (Fig. 1a). On filters with higher N_{INP} at 258 K, the most active INPs were found at temperatures 253K, 259K and even at 263K (Fig. 1b).

These results from a pristine environment such as the Arctic indicate that reusing preserved quartz fibre filters with the filter punching technique could be applied to obtain N_{INP} from areas and time periods where filters were collected for other purposes. Additional tests and analysis need to be performed to evaluate the statistical correlation with reference measurements and establish homogenized INP concentration datasets.

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MODELLING RESILIENCE TO WIND DISTURBANCES IN PRODUCTION FORESTS: A CASE STUDY FROM SOUTH-WESTERN FINLAND

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Keywords: Wind disturbances, Forest management, Carbon balance,

INTRODUCTION

In Europe, the frequency and intensity of disturbances has been increasing in recent decades (Seidl et al. 2014). In the light of expanding demand for a variety of ecosystem services provided by forests, the resistance and/or resilience of these ecosystems and production systems is of growing interest. In the case of intensively managed production forests in Finland, the effect of both pre- and post-disturbance forest management is of high importance: forest management affects forest structure and hence influences susceptibility to wind disturbances, and in itself temporarily affects susceptibility; the management reaction to disturbances (salvage logging as well as disturbance-induced extended management reactions) can heavily influence the mid- to long-term effects of the disturbances themselves on timber production, carbon stocks and biodiversity.

METHODS

In this study, we apply the process-based forest model PREBAS in a 60.000 km^2 region in south-western Finland for the period 2001–2100. The model is initialised with field data from 2616 national forest inventory (NFI) plots which serve as simulation units. Wind disturbances are simulated using an empirical stand-scale model based on Finnish NFI data which estimates wind susceptibility based on forest structure, localised maximum wind speeds, soil properties and recent forest management (Suvanto et al. 2019), providing stand-level projections of wind disturbances. We applied historical, RCP4.5 and RCP8.5 climate scenarios based on MRI-ESM2-0 projections, and 4 management scenarios:

- *business as usual*: recorded harvest levels until 2022, constant thereafter
- *bioeconomy*: harvest levels +15% after 2022
- *set-aside protection*: area of unmanaged forests increased by 300% to meet EU goals, BAU harvest levels in remaining managed forests
- *multi-purpose forest management*: prioritise harvests from fertile sites, de-prioritise harvests from infertile old forests, leave retention trees when clear-cutting; harvest levels decreased by 25% after 2022

In addition, we used three scenarios of management reactions to wind disturbances: none, extensive salvage logging and extended management reactions to wind disturbances (corresponding to current practices), and a 'medium' scenario where wind disturbances are met with a management reaction in 50% of severely disturbed sites.

RESULTS

Our results show that wind disturbances are relatively stable under current climatic conditions across all management scenarios, but increase substantially with increasing climate change intensity. This can largely be attributed to increasing growing stock and hence susceptibility to and impact of wind disturbances.

However, even when wind disturbances increase under climate change, the management reaction to wind disturbances (salvage logging and prioritisation for regular management) is very efficient in mediating the impact of wind disturbances on growing stock and C stocks at larger scales: the management reactions in effect reallocate harvests from undisturbed sites to disturbed sites, reducing the impact on biomass and C stocks. At high harvest levels, salvage logging has partially positive effects on biodiversity indicators, as it alleviates harvest pressure from undisturbed forests. Under climate change scenarios, increases in wind disturbance occurrence and intensity are overcompensated by increased forest growth.

CONCLUSIONS

In the intensively managed forests in south-western Finland, the medium- and long-term effects of wind disturbances on timber availability, C stocks and biodiversity heavily depend on forest management; in pre-disturbance management, the harvest level affects wind disturbance more than different management approaches, especially under climate change (cf. also Mäkelä et al. 2023). Management reactions to disturbances can heavily reduce the impact of wind disturbances on most ecosystem services, first and foremost on C storage. Under climate change scenarios, increases in wind disturbance occurrence and intensity are overcompensated by higher forest growth. Our modelling approach, however, does not yet consider spruce bark beetle as a secondary damage agent, and hence likely underestimates the total impact of wind disturbances (Seidl & Rammer 2017).

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Ice sheets: what's going on underneath and how important is it for future sea-level rise?

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Keywords: Ice sheet, Sea level rise, Uncertainties, Basal friction.

INTRODUCTION

The Antarctic and Greenland Ice Sheets (AIS and GrIS) play a critical role in shaping future sea-level rise (SLR), but their contributions remain the largest sources of uncertainty in SLR projections under future human-driven climate change (Edwards et al., 2021). This uncertainty, along with the risk of potential tipping points leading to rapid ice loss, arises from limited understanding of key processes that govern ice-sheet behavior (Fox-Kemper et al., 2021). In the Ice Sheet Model Intercomparison for CMIP6 (ISMIP6), 55% of the total uncertainty of AIS is due to differences between the simulations of various ice-sheet models (Seroussi et al., 2023). While modeling the AIS's and GrIS's complex interactions with the climate is difficult (Seroussi et al., 2023), one other uncertain process is basal sliding over bedrock. Because this process is not directly observed due to the large thickness (typically 3 km of ice), its representation in current models remains rudimentary. The primary goals of *Combining Coupled Modelling and Machine Learning to Constrain Antarctica's Uncertain Future* (ICEMAP) include (i) better quantification of uncertainties related to basal sliding, (ii) comparison of these uncertainties to other sources of variability, and (iii) exploration of how satellite data can help reduce these uncertainties.

METHODS

To achieve these goals, we employ the Elmer/Ice model, co-developed by CSC – IT Center for Science in Espoo and the Institut des Geosciences de l'Environnement in Grenoble (Gagliardini et al., 2013). Elmer/Ice is an open source finite element software for ice sheets, glaciers and ice flow modelling, and was one of the participants in ISMIP6. It belongs to the family of "complex models", which are characterised by higher-order approximations (full-stokes, intermediate-order model, SSA), adaptive grids (finite element method or finite volume method) to model complex geometries and uses data assimilation methods to calibrate the many unknown parameters. Here we take into account various physical and numerical uncertainties to perform multiple calibrations using remote-sensing velocity data to compute basal sliding. Subsequently, these values and their spatial variations can be compared with the diverse existing theories that have been developed from small-scale physical and numerical experiments.

RESULTS

We noticed significant differences between the basal sliding fields of the Greenland and Antarctic ice sheets. We show that the influence of subglacial hydrology, i.e., the presence of water at the

base, seems to play a much more important role for Greenland than for Antarctica. Indeed, due to surface melting, the quantity of water that can infiltrate and reach the base is greater, even at great distances from contact with the ocean. This melting seems to explain these low-friction zones in Greenland. In Antarctica, on the other hand, there is little to none surface melting. It is therefore more difficult to explain these low-friction zones upstream of the grounding line, i.e. the line at which the ice begins to float. This can potentially be explained by several phenomena, but further research is needed to determine their influence.

CONCLUSIONS

In this work, we address the first objective of ICEMAP, which is to better quantify uncertainties related to basal sliding. We then show that subglacial hydrology appears to play a dominant role for both the Greenland and Antarctic ice sheets.

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MODELLING ^{15}N TRACER EXPERIMENT IN A MIXED FOREST WITH A TERRESTRIAL BIOSPHERE MODEL

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Keywords: The QUINCY model, nitrogen cycle, isotopes, carbon cycle

INTRODUCTION

Nitrogen cycle is an important biogeochemical cycle, as it is closely coupled to the carbon cycle and can therefore influence the amount of carbon that is taken up from the atmosphere and stored by the terrestrial vegetation. Changing climatic conditions are influencing the biogeochemical cycles and to understand their responses to these changes, we need to have a good process-level understanding of their interactions with the climate. Terrestrial biosphere models (TBMs) are tools that can incorporate this understanding and allow us to make predictions to the future.

However, modelling of the nitrogen cycle is a challenging task and datasets suitable for model evaluation are scarce. Ecosystem manipulation experiments, such as fertilization and tracer addition experiments, provide a promising source of data. Fertilization experiments have some issues, as they are influencing the ecosystems. Isotopic tracer experiments circumvent these issues, as the amount of input is so small that it does not impact the ecosystem state and the tracer signal can be traced to different ecosystem pools.

In this study we have data from a long-term ^{15}N tracer experiment at a temperate mixed deciduous forest and used a TBM including the ^{15}N cycle to simulate what happens to the signal once it has entered the ecosystem. We're interested in the pathways of the nitrogen entering the system, on the retention of the nitrogen and realism of our modelled turnover rates of different ecosystem pools.

METHODS

The tracer addition experiment was done at the Arnot Forest, the U.S. (42° 17' N, 76° 38' W), a mixed temperate forest. The ^{15}N tracer was applied as 99 % atom ^{15}N-KNO_3 in 2007 three times across the season. The plant and soil pools were measured in 2006 and 2008. Later measurements were taken in 2012-2013 and the last measurement in 2017. More information on the site and the measurements can be found in Goodale et al. (2017).

We used a TBM called QUantifying Interactions between terrestrial Nutrient CYcles and the climate system (QUINCY) (Thum et al., 2019). This model has fully coupled carbon, nitrogen, energy and water fluxes as well as the ^{15}N cycle. We added the ^{15}N tracer in the NO_3 solute in the upmost soil layer. We run the model simulation with meteorological data until 2018, additionally we made a simulation to further 30 years.

RESULTS

The total amount of recovery of the tracer was close to 100 % in the simulation. The observations showed a recovery rate of 79 % in the end of 2007, after which it decreased to 70 %, a typical value in these kinds of experiments. The model is therefore not releasing enough tracer away from the system.

Comparison of the temporal evolution of the ^{15}N in different ecosystem pools showed that the fine roots, leaves and sapwood had a quick response to the tracer input, which was quite similar to the observations. However, for the coarse roots and heartwood pools the response of the model was much slower than what was observed.

CONCLUSIONS

The modelling study on the ^{15}N tracer experiment revealed interesting aspects of the nitrogen cycle that will further help in improving the model. Information on the pathways of the ^{15}N tracer elucidates the turnover rates of the different ecosystem pools. Having an explicit ^{15}N cycle described in the model facilitates making best use of the tracer experiments.

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FUTURE NEEDS OF INDOOR AIR RESEARCH

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Keywords: Indoor air quality, buildings, climate change.

INTRODUCTION

Air pollution is one of the most significant threats to human health with 8.8 million people estimated to die prematurely every year due to air pollution including both indoors and outdoors (Lelieveld et al., 2020). Even though most people spend 90% of their time indoors (Klepeis et al., 2001) and many chemicals are more abundant indoors than outdoors (Cometto-Muñiz and Abraham, 2015), majority of comprehensive air quality research has focused on outdoor air. For example, the Institute for Atmospheric and Earth System Research (INAR) and the Atmosphere and Climate Competence Centre (ACCC) have a long history in investigating the interactions between outdoor air, ecosystems, and climate, using comprehensive long-term measurements (see e.g., Kulmala et al., 2023), but there is still plenty of unharnessed potential to use this capacity for indoor air. This year at ACCC we have worked to prepare a new Indoor Air Research Programme that would maximise the use of this potential and the impact of our future research to the society.

Indoor air quality can in many ways be more complex than outdoor air quality. Unlike outdoor air, indoor air is largely influenced by people, surfaces, building physics, heating and cooling, ventilation, outdoor air, and many other factors. Indoor surfaces can act as sources, sinks, and storages for different chemicals and partitioning and reactions between air and surfaces make comprehensive understanding of indoor air challenging. The air quality in a confined space is also sensitive to different human activities, such as cooking, cleaning, and smoking and largely influenced by choices in ventilation etc. All this information needs to then be brought together in exposure studies, which can subsequently define the total burden that the different environments pose on human health and further inform decisionmakers and the public in their choices.

Climate change makes matters even more complicated, since temperature and relative humidity are expected to increase in indoor spaces, which speeds up many reactions. Other challenges brought to us by climate change include increased numbers of wildfires and flooding events as well as challenges with energy consumption and more crowded indoor spaces. On the other hand, adapting to climate change means a need for new solutions, such as creating new sustainable building materials.

The pressing need for more research on the chemical complexity of the indoor environment, its challenges in the future climate and the importance of communicating this work was also highlighted in a recent review published by the National Academies of Sciences, Engineering, and Medicine (2022). We believe that our community can be a significant player in bringing new understanding to the indoor air research field since we have decades of research experience in comprehensive understanding of the biosphere-atmosphere interactions and many of our tools are applicable for indoor studies.

Here, we will present our pre-study addressing the need for a holistic view to tackle indoor air challenges, outlining both the challenges and the existing capabilities that enable us to address them. We have experience in the continuous measurements of over thousand variables in outdoor air, as well as the many time-dependencies and processes that determine outdoor air quality and its interactions. The same approach allows us to better understand the dynamic nature of indoor air chemistry.

METHODS

To maximise the impact of our research efforts, we have done comprehensive background work. This work has included evaluating the current state of research and the capabilities of our scientific community as well as actively communicating with industrial stakeholders, companies and decision makers.

In 2024 we have also actively participated in several Finnish and international indoor air events, including two international conferences where we presented the project to diverse audiences. We also organised a full day of indoor air related programme at the 3rd ACCC Impact week, including presentations from renowned indoor air experts and workshops bringing together industry experts and researchers.

Some of the focus areas for the programme include the green transition, influence of climate change, and novel health research. We want to generate scientific data that can be used by experts improving design, construction and renovation methods of buildings, as well as emission standards for building materials and consumer products. Eventually we strive to produce knowledge to support the decisions of policymakers as well as to inform the public.

CONCLUSIONS

Indoor air quality is an emerging challenge, and it will be even more prominent with challenges brought up by climate change. In 2024 we have worked towards a new programme for indoor air research in Finland. This work has included mapping the capabilities of our research network and the most important research questions as well as interactions with different stakeholders to maximise the impact that our future research can have on the society. Currently we are applying for funding for the programme.

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GAS-PHASE OXIDATION OF ATMOSPHERICALLY RELEVANT UNSATURATED HYDROCARBONS BY ACYL PEROXY RADICALS

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Keywords: acyl peroxy radicals, quantum chemistry, monoterpene

INTRODUCTION

Atmospheric volatile organic compounds (VOCs) are directly emitted from anthropogenic and biogenic sources into the atmosphere and play an important role in the chemistry of aerosols and the global carbon cycle. A reaction class of particular interest is the subset of VOC oxidation pathways leading to (extremely) low-volatility organic compounds ((E)LVOCs) which can participate in the formation and growth of aerosol particles. Isoprene and monoterpenes are two major representatives of VOCs from biological sources. Moreover, the atmosphere contains on the order of 10^7-10^8 molecules cm^{-3} of short-chain acyl peroxy radicals (R(O)OO•, APR).

METHODS

We investigated the kinetics of the accretion reaction between atmospherically relevant unsaturated hydrocarbons and various functionalized peroxy radicals. Drawing on the benchmarking studies conducted by Pasik et al. (2024), we employed this methodology to investigate this kind of reactions. The research involves quantum-mechanical calculations for the accretion reaction between isoprene and peroxy radicals following the pathway shown in Figure 1.

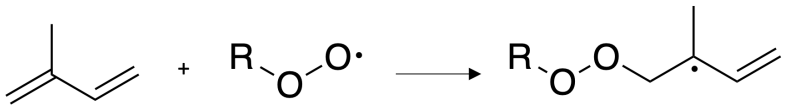

Figure 1. Investigated reaction pathway of isoprene and peroxy radicals.

RESULTS

Among all tested functional peroxy radicals, only acyl peroxy radicals (APRs) gave small energy barriers (from negative up to 1kcal/mol) and sufficiently fast reaction rates to be competitive in the atmosphere.

Furthermore, we tested other atmospheric-relevant compounds, such as limonene, α-pinene, β-pinene, and toluene, in reaction with APRs. Results show that for monoterpenes these reactions are feasible as minor sources of accretion products under atmospheric conditions and should not be omitted. The addition of APR to toluene occurs through a fairly high barrier (5.07 kcal/mol), resulting in a low reaction rate coefficient ($2.5*10^{-20}$ cm^3s^{-1}). For these reasons, we would not consider this or other APR + aromatic reactions to be significant for atmospheric chemistry.

Moreover, the reaction between unsaturated hydrocarbons and acyl peroxy radicals leads to an alkyl radical to which molecular oxygen rapidly adds. The formed perester peroxy radical may either undergo further H-shift reactions or react bimolecularly. These reactions were also considered in this study.

Table 1. *Zero-point energy corrected barriers (ΔE) and bimolecular reaction rate coefficients (k) for reactions between acetyl peroxy radical and unsaturated hydrocarbon calculated at the DLPNO-CCSD(T)/aug-cc-pVTZ//ωB97X-D/6-31+G* level of theory at 298 K.*

Unsaturated hydrocarbon	ΔE [kcal/mol]	k [cm^3s^{-1}]
isoprene	1.5	$3.0*10^{-16}$
limonene	1.1	$1.2*10^{-15}$
α-pinene	3.1	$5.1*10^{-18}$
β-pinene	2.4	$4.0*10^{-17}$
toluene	6.1	$7.1*10^{-21}$

CONCLUSIONS

The multi-functional oxygenated compounds formed through acyl peroxy radical + alkene reactions are potentially important contributors to particle formation and growth. Thus, acyl peroxy radical-initiated oxidation chemistry may need to be included in atmospheric models.

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LICHENCLIMATE PROJECT:

MICROBIAL INTERACTIONS AND GHG DYNAMICS IN BOREAL ECOSYSTEMS

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Keywords: Nitrogen, Nitrous Oxide, Nitrous Oxide Consumption, nosZ gene, Lichen, Boreal Forest, Greenhouse Gases (GHG).

INTRODUCTION

In the context of growing concern about climate change, understanding greenhouse gas (GHG) dynamics in boreal forests is crucial. While most research has focused on carbon dioxide (CO2) emissions, the roles of nitrous oxide (N2O) and methane (CH4) remain underexplored. The LichenClimate project aims to investigate how lichens and their microbiome influence GHG consumption and emission in these ecosystems. The main goal of the project is to identify lichen species that significantly contribute to GHG dynamics in boreal forests. By sampling common species across different seasons and environments, we will analyse metabolic activities related to GHGs and the variations in N2O, CH4, and CO2 fluxes. Using gas chromatography, mass spectrometry and stable isotope techniques, we will quantify gas fluxes and link them to microbial community activities. An innovative aspect of the project is the analysis of lichen microstructure, which includes tracking enzymatic activities using FISH-probes. Additionally, the project will enhance our understanding about the microbiomes of different lichens through microbiological analyzes with the aid of PCR, Targeted Sequencing, and Amplicon Sequencing. These methodologies will help us locate microbial communities and understand their interactions within the diverse structures of lichens. Identifying active functional genes through metatranscriptomics will help clarify the enzymatic pathways involved in GHG metabolism. Currently, the project has achieved a significant milestone by identifying the nosZ gene in a lichen species, Platismatia glauca. Furthermore, in mesocosm tests, we have observed that this lichen consumes nitrous oxide. Through this project, it will be possible to better understand the pathways of GHG consumption and emission, thus valuing forests and areas generally covered by cryptogamic coverings. Studying these pathways could lead to future technological solutions for GHG mitigation. The results of this study will be used to model GHG dynamics at a landscape level and to assess how future climatic conditions may influence the distribution and activity of lichens.

CONCLUSIONS

The LichenClimate project will not only contribute to a better understanding about the ecological roles of lichens in the GHG cycle but also provide valuable information for developing climate change mitigation strategies, highlighting the potential of natural ecosystems in combating the rise of greenhouse gas emissions.

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Citizen comprehension of climate change mitigation and sustainability transition

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Keywords: Sustainability agency, climate democracy, citizen science

INTRODUCTION

Climate change mitigation and adaptation, among various other conceptualisations and strategies to tackle the complex sustainability crisis, can be seen predominantly centralised (Lange et al., 2013). Although, sustainability—specifically in its action—is typically said to be democratic and a responsibility for us all, be it for individuals or different communities (Hügel & Davies, 2020), how it commonly gets addressed, is authored by a selected few; such as scientific cohorts as those authoring the IPCC reports, or intergovernmental coalitions like those settling things in Paris, or most closest to the everyday life of individuals; corporations and their collaborators like those developing different environmental or sustainability certificates and those applying them to their goods and services. Undoubtedly, such elites have the expertise and authority to take leadership in the needed processes (Oikarinen & Lauri [in preparation]), however—as the outcomes of those leadership strategies predominantly address individual citizens, the engagement through which the viable knowledge would best get to use, ought to be collaborative. For example, various government or local municipality campaigns related to the application of SDGs, or corporations communicating to—and with their part also educating the consumers on green production (and consumption), are ultimately meant to assist the individual to take part in the sustainability transition, such acts ultimately defines the individual to have a certain role; mainly that of a consumer, and simultaneously tightly limits the agency of their participation to the change (Salovaara & Hagolani-Albov, 2024). Regardless of whether the concurrent conceptualisations and strategies to further sustainability are going to be deemed correct in and for the future, what seems evident to us is that in order to best further the transformation, a dialogue between the scientific and societal rhetoric of sustainability and the citizen comprehension and relevance to these issues is direly needed.

METHODOLOGY

To bridge the possible differences or potential contradictions, both approaches are needed; incorporating what could be *citizen-led sustainability* to the rhetoric(s), and to translate the conceptualisations and strategies—predominantly through the worries causing them—to the citizen in a relevant manner. In order to do so, the citizen-led sustainability needs to be collaboratively defined. While our project is still in its planning stages, the initiation to the process is set. A Likert-scale questionnaire, sent out to a large random selection sample group (Bryman, 2016), will be utilised to gather data, for example, on the current citizen comprehension on their understanding, role, capacities to participate and potential disconnects between the rhetoric and their everyday life. While this questionnaire will most likely, for the vastness of the data, be utilised in a few publications, the project itself will be extended to further develop the citizen comprehensions towards more of a fleshed out in developing future-narratives (Kallis & March, 2018) on what the citizen-led sustainability ought to be about in certain contexts. To continue, these narratives could be further workshopped with varying expert and stakeholder groups, such as academics, educators, journalists, decision and policymakers, artists, and so forth, to employ the citizen-led sustainability in their contexts and processes to fully utilise the narratives. Thus, apart from resulting in a massive data set to be opened to the public and scientific and potentially also public audience publications, the narratives are meant to become rhetorical tools of sort (Flyvbjerg, 2012), that are meant to find use in numerous contexts, fields, and processes, that to date have carried forward the more centralised message sustainability.

RELEVANCE

While the relevance of our research speaks to a vast academic audience, from coordinators of sustainability education to transition researchers to climate change scientists, the broader impact it aims for comes from the planned multisectoral collaboration. The first academic contribution comes from the massive data set brought about through this project and shared publicly through an open data repository. The project will further develop the data in collaborative transdisciplinary workshops, through which the citizen comprehensions on sustainability are contextualised to different perspectives and contexts. For example, further exploring what could these comprehensions mean to grassroots activities, or exploring what could be the educational implications of the citizen comprehension, all adding to the definition of what citizen-led sustainability could be about—and all with aims to explore a broader array of perhaps current yet untapped or here-emerging citizen roles beyond that of being *serviced for sustainability*. The immediate societal relevance comes through further multisectoral collaborations, where the definition of citizen-led sustainability—or sustainabilities (Kothari et al., 2019)—are workshopped with actors from such fields as arts, media, decision and policy making. This collaboration is of high importance in further employing the citizen-led sustainability as a rhetorical tool, in bringing forward the narrative and its implications throughout the society in transition.

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COMMUNITY OF INQUIRY AND SENSE OF BELONGING ON A HYBRID MULTISITE FIELD COURSE

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Keywords: Blended learning, Community of Inquiry, Sense of Belonging, Education

INTRODUCTION

Blended learning, which combines online and face-to-face teaching, has become an everyday practice in higher education, especially since the COVID-19 pandemic (Adel & Dayan, 2021). Considerable effort has been dedicated to understanding how students can form social relationships and learning communities in these hybrid environments. Among various findings, a sense of belonging has been identified as a crucial factor in students' active engagement, learning outcomes and course retention rates (Mendoza & Venables, 2023). However, the focus of these studies has been mostly on traditional on-campus and online courses, whereas in natural sciences, field courses, often combined with online periods, are a crucial part of the education (Gerhart et al., 2021). Therefore, it seems timely to explore how students could better form learning communities in so-called hybrid field site courses.

In this study, we analysed various dimensions of a learning community, at a piloted blended learning setup: a hybrid multisite field course. The course focused on greenhouse gas exchange across the sub-Arctic with simultaneous hands-on measurements and scaling at different sites. The course design combined online sessions with a research station visit, where three clusters of students each travelled to their nearest field site to minimize travel-related impacts.

By utilising an adapted framework of community of inquiry (Garrison et al., 2000), we analysed how the course was designed, how the social relationships and sense of belonging of students evolved, how they managed to form a critical co-learning community and how they found the multisite setup beneficial for their learning.

METHODS

We utilized various methods of inquiry and sources of data for our case study. A questionnaire consisting of Likert-scale statements and open-ended questions was used to study the forming of community of inquiry. The questionnaire included a modified Sense of course community belonging measure (Jeng et al., 2023) to measure students' sense of belonging on the course, and a question pattern to measure the cognitive presence of students' community of inquiry based on a framing of designing online learning by Peacock & Cowan (2019). Students also filled an anonymous post-course feedback which was partially utilised to bolster our analysis. We observed the field course at one research site and recorded observations, in the style of a thick description approach (Geertz, 1973). Lastly, the responsible teachers' views on the course design and execution were also studied at a reflection workshop post-course.

RESULTS

The students' sense of belonging differed between sites with one site scoring comparatively low. A lower sense of belonging was associated with students' perceptions of insufficient support from teachers and the absence of a clear research plan. The PhD students reported a lower sense of belonging, which however was

largely attributed to their location at the research site with the lowest overall sense of belonging. Observations and survey results indicated that inter-site comparisons were negatively affected by limited communication and collaboration between sites, as well as insufficient time allocated to each component of the course. However, students still found the multi-site setup promising, as they reported having had meaningful interactions with peers while doing field work and appreciated the effort to cut emissions through less travelling on such courses. Teachers reported feeling that they did not manage to facilitate the interaction between research sites, and wondered whether traditional everyone-on-same-site setup would in the end be more beneficial for students' interactions and thus learning.

CONCLUSIONS

A hybrid multisite field course can bring about a community of inquiry, if appropriate effort is put into the design and execution of the course, for example, by allocating sufficient time for given tasks, by ensuring active and functional community communication modes, and by being active in facilitating meaningful discussion within the whole group of students and teachers.

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MATRIX-ISOLATION INFRA-RED SPECTROSCOPIC STUDY OF ELECTRONICALLY EXCITED SO_2 REACTING WITH ETHANOL

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Keywords: matrix-isolation, sulfur dioxide, ethanol, argon, IR

INTRODUCTION

Sulfur-containing compounds undergo a wide range of photochemical processes under the influence of sunlight and play an important role in planetary atmospheres. Apart from the traditional understanding of sulfur compounds forming highly hygroscopic sulfuric acid via oxidation in the atmosphere, there is a unique chemical reaction associated with sulfur dioxide that can lead to new particle formation (Donaldson, 2016; Kroll, 2018a, 2018b). Sulfur dioxide absorbs UV radiation which causes SO_2 molecules to enter an excited singlet state ($^1A_2$ and $^1B_1$). The singlet excited states can relax to a triplet state ($^3B_1$) through intersystem crossing or collisional relaxation (Heicklen,1980). This triplet-electronically excited state of SO_2 can react with water (Kroll, 2018a), unsaturated hydrocarbons, and alkanes (Kroll, 2018b). Kroll et al. (2018b) provided rate constants for the reaction of $^3SO_2$ with different sets of alkanes proceeded via H-abstraction from the hydrocarbon (RH) to form HOSO. and R. radicals.

METHODS

In this work, the reaction between electronically excited $^3SO_2$ and ethanol was investigated in cryogenic matrices. Complexes of SO_2 and ethanol were prepared in an argon matrix and their structures were identified by infrared spectroscopy. The reaction between $^3SO_2$ and ethanol was promoted by irradiating the matrix-isolated complex structures with a 280 nm laser. The assignment of the complex structures and putative reaction products was supported with quantum chemical calculations.

RESULTS

This study demonstrates the presence of complex formation between ethanol and SO_2, which is essential for the photochemical reaction to occur. The result is corroborated by the complex bands being increased upon deposition and annealing at higher temperatures. Subsequently, after the irradiation of the matrix at 280 nm, there are new peaks arise, while there is a clear indication of the consumption of complex bands. This confirms that the photochemical reaction has occurred between these two monomers. Identification of the new peaks resulting from photo-chemical products is being carried out.

CONCLUSIONS

The results will broaden the understanding of the reactivity of $^3SO_2$ with molecules containing labile hydrogen such as ethanol, in both the gas and condensed phase. Moreover, this reaction can produce an additional route for particle formation, which is a key step in the aerosol formation process.

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STATUS OF SMEAR IV PUIJO TOWER MEASUREMENT FACILITIES IN ACTRIS MEASUREMENT NETWORK

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Keywords: ACTRIS, Measurement station, monitoring

INTRODUCTION

Puijo SMEAR IV is semi-urban aerosol, air quality and cloud microphysics measurement station situated at top of Puijo Observatory Tower, Kuopio, Finland, operated co-jointly by University of Eastern Finland (UEF) and Finnish Meteorological Institute (FMI). The station has been operational since 2008 with measurements for both standard air quality variables (O3, NOx, SO2, PM2.5, ect.) and aerosol properties (size distribution, total number concentration, scattering and absorption properties), see the full listing at the website. The unique feature of the station is two separate sampling lines with whole air and interstitial air inlets. The whole air inlet has cut-off of 50 µm and interstitial inlet at 1.5 µm. The dual inlet system is designed for observations of aerosol-cloud interactions, as the observatory tower is frequently covered with low-altitude clouds, annually approximately 10% of the time. The initiation of ACTRIS (Aerosols, Clouds and Trace Gases Research Infrastructure, see website) measurement network aims to harmonize aerosol measurement activities across Europe. To fulfil the ACTRIS measurement standards, measurement infrastructure of Puijo SMEAR IV were upgraded.

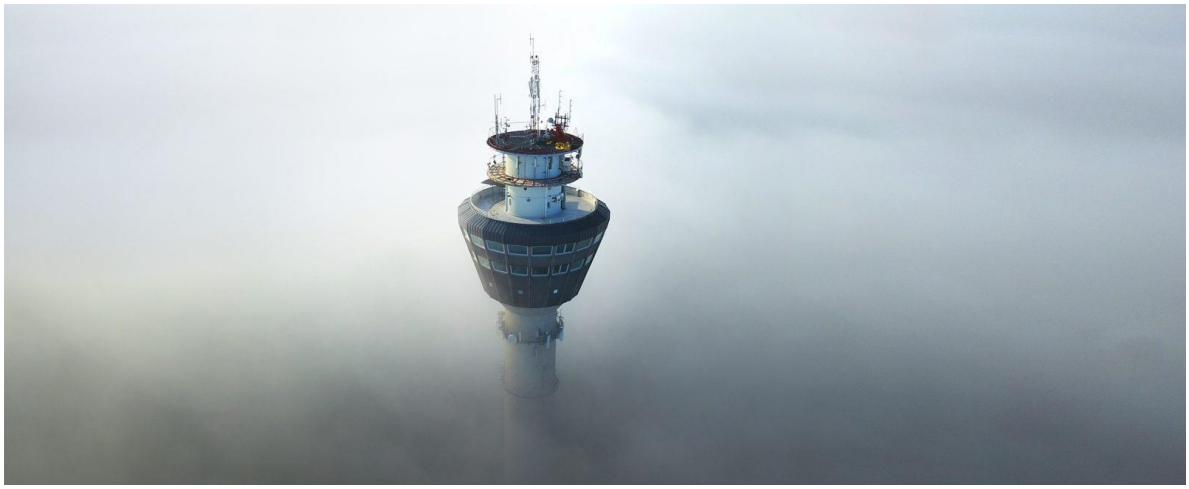

Figure 1. Puijo tower inside low-level clouds.

METHODS

Currently, the application of the Puijo SMEAR IV station for ACTRIS measurement networks is in initial acceptance stage with following aerosol parameters and instrumentations. The instrument used to measure each parameter is indicated in brackets. Particle number concentration > 10 nm (TSI CPC model 3750),

Particle number size distribution – mobility diameter 10 – 800 nm (Custom built DMPS with closed loop Vienna type DMA and Airmodus A20 CPC), Particle light scattering and backscattering coefficient (Ecotech Aurora 3000 integrating nephelometer), Particle light absorption coefficient and equivalent black carbon concentration (Magee Scientific AE33 aethalometer), Particle number size distribution – aerodynamic diameter 0.8 – 10 µm (TSI APS 3321) and Mass concentration of non-refractory particulate organics and inorganics within PM1 fraction (Aerodyne ToF-ACSM).

The total air inlet sampling line has total of 2.5m long with sample flow of 50 LPM. The flow is divided into four subsampling lines with isokinetic flow splitter. After the flow splitter, sample flow is dried with nafion drier before sample air reaches instruments.

The interstitial measurement line is 2.5m long with 14 LPM flow. On top of the sample line is a impactor with cut-off of 1.4 µm (Digitel AG). The sample flow is then divided into three ports which each has nafion drier before instrumentations. The connected instruments in the interstitial line are DMPS (identical to mentioned above), TSI integrating nephelometer 5363 for light scattering properties and Thermo Fisher Scientific MAAP 5012 for particle absorption measurement. Data from these instruments is currently not planned to be uploaded to ACTRIS database but is available upon request.

CONCLUSIONS

Puijo SMEAR IV atmospheric measurement station has provided valuable information about air quality and aerosol particles for 15 years. The upcoming upgrade to ACTRIS measurement network standards will harmonize the data products produced in the station compared to other atmospheric measurement stations across Europe. Once the station is fully operation in the ACTRIS network, the stations data-availability will also improve as data available through ACTRIS network is free to use without need for additional input from measurement station staff. The updates taking place in the Puijo SMEAR IV station will ensure that the station stays operational and produces high quality data also for the next 15 years.

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CLIMED: CLIMATE-ORIENTED TRANINGS

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Keywords: ClimEd; PEEX; approaches in online/ onsite/ hybrid trainings; Group Work – Small-Scale Research Projects; climate change, services, adaptation, mitigation

INTRODUCTION

The Erasmus+ ClimEd ("*Multilevel Local, Nation- and Regionwide Education and Training in Climate Services, Climate Change Adaptation and Mitigation*"; 2021-2025; http://climed.network) project aim is to develop a competency-based curricula for continuous comprehensive training of specialists in the field of climate services and additional education in climate change for decision-makers, experts in climate-dependent economic sectors, and public. It should be noted that some of the ClimEd goals and objectives are closely related to the Pan-Eurasian EXperiment (PEEX; www.atm.helsinki.fi/peex) programme, and especially with multi-disciplinary, -scale and -component study climate change at resolving major uncertainties in the Earth system science and global sustainability issues. The ClimEd project plans 7 trainings (http://climed.network/events/climed-trainings), which are carried out during project lifetime and will be focused on training the faculty/ teaching/ research staff and postgraduates at the ClimEd partner institutions and collaborating organizations in advanced educational and information-and-communication technologies for building a flexible multi-level integrated practice-based education system in the field of Climate Services, Climate Change Adaptation and Mitigation.

METHODS

Although all trainings were planned to be carried out as face-to-face/onsite events, but because COVID pandemic situation, firs several trainings (in Estonia, Ukraine, and Finland) were converted into virtual/online training. Program of such online trainings was divided into 3 consecutive blocks: (i) online lecturing, (ii) home-work-assignments (HWAs) as Group Work/Projects (as Small-Scale Research Projects, SSRPs) with established internal communication between the member of the groups and with an option of zoom-consulting during remote work, and (iii) final oral presentations (projects' defences) of HWAs with evaluation and feedbacks, discussions, and awarding certificates (corresponding to ECTS credits) with achieved learning outcomes and obtained skills. The majority of HWAs is based on the ClimEd main themes linking climate change vs. agriculture, energy, technical design and construction, urban economy, water management, health care; although other themes of interest can be selected by groups. Trainings also include questionnaires distributed among participants: evaluation of the training, and evaluation of own learning outcomes. Technically, the Moodle system, Zoom-hosting, e-evaluations, etc. are actively utilized in such trainings. All materials of the trainings are always publicly accessible online at the ClimEd project website as well as long-term stored at the Moodle system for each training. Since spring 2024, the trainings, taking a similar approach, were arranged as hybrid events (with both onsite/online participation) in Spain (4th trainings) and Estonia (5th).

RESULTS AND OUTCOMES OF TRAININGS

The outcomes/ summaries – including the lecture topics and learning outcomes, information resources, themes of group projects, feedbacks, and training results, established network-community of the training participants (trainees and lecturers and teachers of HWAs) – of the online training approach will be presented for the ClimEd Trainings. Summaries are available for online: 1st training "Competence-Based Approach to Curriculum Development for Climate Education"; 19 Apr – 12 May 2021;

http://climed.network/events/climed-trainings/climed-training-1-online); 2nd – "Adaptation of the Competency Framework for Climate Services to conditions of Ukraine" (29 Jun – 26 Aug 2021; http://climed.network/events/climed-trainings/climed-training-2-online); 3rd – "Digital tools and datasets for climate change education" (26 Oct – 12 Nov 2021; http://climed.network/events/climed-trainings/climed-training-3-online); and for hybrid: 4th "Developing learning courses in climate services considering needs of different users" (6–10 May 2024, Spain; http://climed.network/events/climed-trainings/climed-training-4); and 5th "Blended/ Online Learning for Climate Change: Bridging Theory, Technology, and Practical Application" (30 Sep – 4 Oct 2024, Estonia; http://climed.network/events/climed-trainings/climed-training-5) trainings.

Participants of the last completed ClimEd 5th training had obtained an understanding of climate education through advanced educational technologies, examining climate policy and objectives, and how blended and online learning can enhance teaching effectiveness. They learned to design and implement blended learning strategies that combine online and traditional teaching methods to enhance climate education. Practical workshops provided them with hands-on experience in creating interactive learning modules on climate topics. Additionally, participants mastered the use of Moodle for developing online exam questionnaires, enabling them to effectively assess blended learning experiences. The SSRPs' focus was on mastering Moodle for creating online exam questionnaires to arm educators with the expertise to design, deliver, and assess blended learning experiences. Main goal for each Group working on own SSRPs was developing Exam Questionnaires for the Moodle Environment for Climate Change educational programs.

The e-evaluation of the recent ClimEd 5th Training was done using 2 questionnaires distributed among participants. Following the 1st questionnaire – (Evaluation of the Training) – 100% of the participants estimated overall rating for this course as" very good" and "good"; training materials were of "excellent" (75%), and "very good" (25%) quality and information about the training was sufficient (100%), and participants will recommend such training to colleagues (100 %). Following the 2nd questionnaire – (Self-Evaluation of the Obtained Competencies and Skills) – about 98% of participants "fully agreed" and "mostly agreed" that they have obtained/ improved their competencies and got skills working as groups.

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D5.2: ClimEd Training N2: Adaptation of the Competency Framework for Climate Services to conditions of Ukraine, 16 p, 2021

D5.3: ClimEd Training N3: Digital tools and datasets for climate change education, 17 p, 2021

D5.4: ClimEd Training N4: Developing learning courses in climate services considering needs of different users, 17 p, 2024

D5.5. ClimEd Training N5: Applying Different Technologies of Blended/Online Learning in Education, 2024, (in preparation)

TREE PHYSIOLOGY ACROSS VARYING URBAN ENVIRONMENTS

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Keywords: urban forest, tree physiology, leaf traits.

INTRODUCTION

Cities seek to resolve environmental problems and mitigate climate change impacts with ecosystem services provided by trees and other green infrastructure. Many of trees' ecosystem services are directly related to their physiological processes such as photosynthesis or transpiration, thus, to be able to provide the desired services trees need to function optimally. However, urban environments contain unique stress factors such as the urban heat island and paved impermeable surfaces that may negatively affect tree functions (Czaja et al., 2020). Yet, other characteristics of cities, such as high nutrient or CO_2 concentrations, may benefit tree functions (Gregg et al., 2003). The stress-inducing or beneficial environmental conditions may vary sharply across the urban mosaic of land uses, constituting large intra-city differences in the ability of trees to function optimally and act as a solution to cities' environmental questions.

In this study, we aim to describe the effects of differing urban environments on tree physiological processes and stress signals. As trees can acclimate to their growth conditions through plastic changes in structures and functions, we also explored variations in their leaf traits.

METHODS

We selected a total of 30 mature trees, silver birches (*Betula pendula* Roth.) and Norway maples (*Acer platanoides* L.), from streets, managed parks and forest patches (site types) within central Helsinki. The site types covered a gradient from strongest to smallest impact of urban stress factors including urban heat island, paved surfaces, potential for mechanical damage.

In May 2024, we installed point dendrometers in three trees per species per site type to detect stem diameter variations and sap flow sensors in two birch trees per site type to follow tree water transport. In June—August 2024, we also conducted monthly point measurements of photosynthesis and transpiration in standard conditions (conditions set to 30°C temperature, 40% relative humidity and 1000 µmol m^{-2} s^{-1} photosynthetically active radiation), along with measurements of stress signals: leaf water potential and chlorophyll fluorescence Fv/Fm parameter (maximal efficiency of photosystem II) for all study trees.

In addition, we sampled 10 leaves from each tree for measurements of leaf traits: leaf area, mass and thickness, specific leaf area, relative water content and dry matter content, 8 leaves for analysis of stomatal density and 6 leaves for analysis of turgor loss point using osmotic potential (Bartlett et al., 2012).

RESULTS

In preliminary analysis of the stress signals, we found that leaf water potential among Norway maple was on average lower in forest and park trees than in street trees, when environmental impacts (soil humidity and vapour pressure deficit) were accounted for (Figure 1 a). Norway maples on streets were thus less likely to experience drought. No significant site-type differences appeared in silver birch leaf water potential (Figure 1 a) or Fv/Fm in either species (Figure 1 b).

Leaf traits showed tentative, not statistically significant, differences between the site types. Among Norway maples, street trees tended to have smaller, thinner and lighter leaves than park and forest trees (Figure 1 c). In contrast, silver birch leaves tended to be heavier and larger in street trees than in park and forest trees (Figure 1 d).

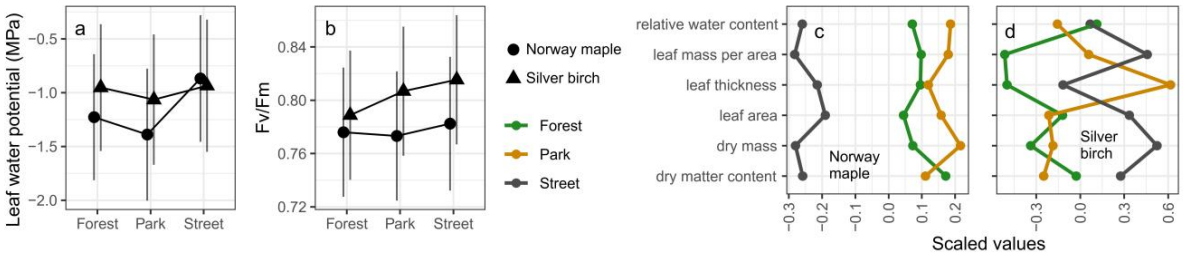

Figure 1. Site and species-specific mean leaf water potential (a) and chlorophyll fluorescence Fv/Fm parameter (b), along with scaled site-specific leaf trait values of Norway maple (c) and silver birch (d).

CONCLUSIONS

In the analysed stress signals, tree-to-tree variation was large and the differences between site types appeared generally small. The tentative differences in leaf traits suggest that larger-scale sampling with more individual trees and species would be interesting. Next, we will add to the analysis photosynthesis and transpiration estimates to gain a comprehensive view of the urban tree physiology and their ecosystem services.

ACKNOWLEDGEMENTS

This work was supported by the Kone Foundation grant 202204755. We thank the City of Helsinki and Juha Raisio from the public works department for their collaboration in the project, and Elina Syrjälä for the assistance in field work.

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MACHINE LEARNING BASED UPDRAFT EMULATOR FOR CLIMATE MODELS

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Keywords: Large-Eddy simulation, Gaussian Process Emulator, vertical velocity.

INTRODUCTION

Despite numerous efforts, aerosol-cloud-interactions are still the most uncertain component of the climate forcing by anthropogenic aerosols. Global circulation models (GCMs) cannot afford the computational cost needed to accurately represent changes in cloud droplet formation induced by aerosol perturbations. GCMs employ a computationally feasible scheme that greatly simplify how cloud droplet activation is driven by vertical wind velocities (updrafts) through the water saturation ratio during the adiabatic cooling of ascending air masses. Gaussian process emulators (GPEs) have been recently presented as an alternative to close the gap between meter-scale and kilometer-scale resolutions.

In this study, we present a machine learning based emulator to predict the variance in updrafts using meter-scale descriptions of cloud droplet dynamics generated by Large-Eddy-Simulations performed with UCLALES-SALSA (Tonttila *et al.*, 2017). This emulator will offer an improved alternative for GCMs to include turbulence effects in the boundary layer on the formation and lifetime of stratus and stratocumulus clouds. Our approach is based on an emulator previously developed by Ahola *et al.* (2022) for marine stratocumuli and that has been already implemented in the ECHAM climate model by Nordling *et al.* (2024). Here, we aim to capture also cloud dynamics for stratocumuli formed over land.

METHODS

Figure 1 shows the workflow of the development of the updraft emulator. First, initial conditions for the Large-Eddy simulations (LES) are taken from a 1-year climate model (OpenIFS) simulation. Conditions corresponding to single layer stratocumulus clouds are filtered from the whole dataset. The updraft is then modeled using the UCLALES-SALSA model. Model outputs comprising the most important indicators of cloud formation are used as training data of a GPE. These variables include horizontal averages of potential temperature (θ), specific humidity, liquid water path (LWP), cloud droplet number concentration (CDNC), sensible heat, solar zenith angle, boundary layer height and pressure at ground level. These variables have been shown to predict LES-derived updraft (Ahola *et al.*, 2022). The final updraft emulator is implemented into the OpenIFS model to improve the simulation of stratocumulus clouds.

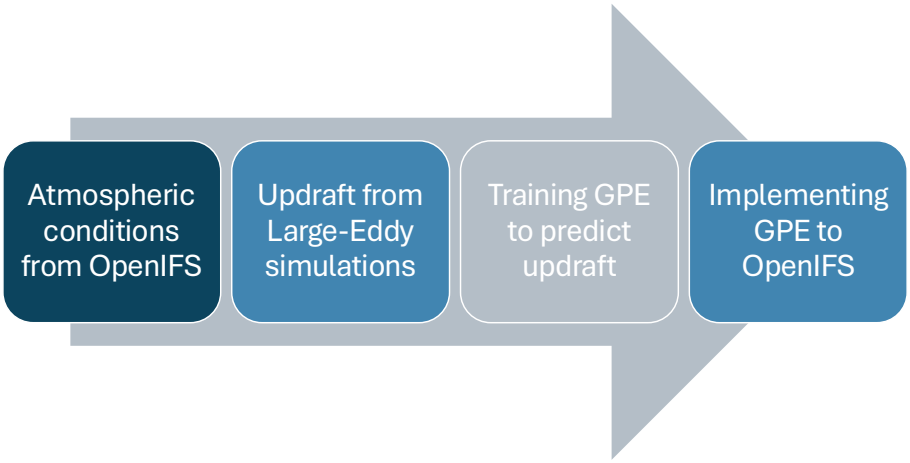

Figure 1: Development of the updraft emulator.

ACKNOWLEDGEMENTS

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ON THE MEAN DIAMETER OF ATMOSPHERIC SMALL IONS

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Keywords: small ions, mobility diameter, cluster growth, coagulation sink.

INTRODUCTION

Small ions, consisting of charged clusters and large molecules with mobility diameters below 2 nm, are continuously existing in the atmosphere (Hirsikko et al., 2011). Small ions can grow by coagulation with other neutral or charged clusters and by uptake of condensable vapors, such as sulfuric acid and organics. In addition to growth, coagulation scavenging by larger particles can impact the size of small ions as their lifetimes are shorter, suppressing their growth. Coagulation scavenging could also modify the size distribution of small ions through the size dependency of the scavenging rates. In this work, we studied the mean mobility diameter (d_{mean}) of small ions in Hyytiälä, Finland and Beijing, China. The correlation of d_{mean} with other variables such as condensation sink (CS) was investigated.

METHODS

Ion number size distribution data measured with Neutral cluster and Air Ion Spectrometer, or NAIS (Mirme & Mirme, 2013), was used for both sites. The average small ion diameter d_{mean} was determined for both polarities using weighted mean with the number concentrations used as weights.

Condensation sink (CS) data was used to parameterize the coagulation scavenging of small ions. For Hyytiälä, sulfuric acid and highly oxidized organic molecule (HOM) concentrations were used due to their strong connection with cluster formation and growth. For Beijing, sulfuric acid dimer concentration was used instead for this purpose. Sulfuric acid and HOM concentrations, denoted as [SA] and [HOM], were measured with Chemical Ionization Atmospheric Pressure interface Time-Of-Flight (CI-APi-TOF) mass spectrometer. Sulfuric acid dimer concentration ([SA_2]) was measured with a nitrate based – long time-of-flight chemical ionization mass spectrometer (CIMS). New particle formation (NPF) ranking (Aliaga et al., 2023) data was also used.

RESULTS AND CONCLUSIONS

We found that in Hyytiälä, d_{mean} was highly correlated with [SA][HOM] with Spearman correlation coefficient of $r \approx 0.65$ for both polarities. This indicates that in Hyytiälä d_{mean} has significant variation depending on how much the clusters are growing by vapor uptake. In Beijing, however, d_{mean} had a weaker correlation with [SA_2] with r=0.08 (0.26) for negative (positive) ions, which was possibly due to the higher coagulation scavenging rates in Beijing than in Hyytiälä suppressing the growth of the ions. We also investigated the values of d_{mean} for different NPF ranking and a clear positive correlation was found in both locations. These results show that when NPF is more intense, small ions are larger. Therefore, while the correlation between d_{mean} and [SA_2] was weak in Beijing, cluster growth, potentially leading to NPF, arguably impacts the size of small ions in both locations.

In Beijing, d_{mean} was found to have negative correlation with CS. The correlation coefficient between CS and d_{mean} was r=-0.16 and r=-0.24 for negative and positive small ions, respectively. However, the variation in the values of d_{mean} was low. In Hyytiälä, d_{mean} of positive small ions did not have clear correlation with CS while d_{mean} of negative ions was negatively correlated with CS. The correlation between CS and d_{mean} of negative ions was the highest during winter with r=-0.44.

To investigate the joint impact of growth and coagulation scavenging, we looked into the values of d_{mean} grouped by the different co-occurrent values of CS and [SA][HOM] or [SA_2]. It was found that for positive ions in Hyytiälä, the correlation between d_{mean} and CS was always positive, regardless of the value of [SA][HOM]. For negative ions, the correlation turned positive when [SA][HOM] was high. The correlation coefficient was r=0.22 when [SA][HOM] was above the 75th percentile. In Beijing, the correlation between d_{mean} and CS was negative, regardless of [SA_2]. However, both in Beijing and Hyytiälä, the correlation between d_{mean} and CS seemed to shift towards positive correlation with increasing [SA_2] or [SA][HOM], respectively. These results imply that when there is more cluster growth, the relative impact of more effective scavenging of the smaller ions on the total impact of CS on d_{mean} increases, while the relative impact of the shorter lifetimes, which suppress growth, decreases. Our results have shown how the impact of coagulation scavenging on the average size of small ions is non-linear and depends on the cluster growth.

ACKNOWLEDGEMENTS

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RIVER WATERS AS A SOURCE OF ICE NUCLEATING PARTICLES

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Keywords: Ice nucleation, Bubble bursting, Aerosol-cloud interaction, Immersion freezing.

INTRODUCTION

Bursting bubbles, breaking waves, and splashing waterfalls release various aerosols into the atmosphere (Fuentes *et al.,* 2010). In this project, we conduct field measurements to characterise the particle flux generated by waterfalls and to investigate whether these particles have the potential to influence the formation of ice clouds.

Figure 1: Overview of the measurement site at Vanhankaupunginkoski, Helsinki. The left panel displays the primary filter sampler and sonic anemometer. The right panel highlights the close proximity of the waterfall, with the sampling equipment visible to the left.

METHODS

A seven-week-long measurement campaign was conducted by the Vanhankaupunginkoski waterfall in the Vantaa river (coordinates: 60.2°N, 25.0°E) between 26.6. and 16.8. 2024. During the campaign, 12 h filter samples (flow 16.6 L/min) were collected atop of the waterfall for ice nucleation analysis. River water samples in the same spot were collected daily on weekdays. Ancillary data includes particle concentration measurements (CPC, TSI Model 3772), wind speed and direction (sonic anemometer, METEK uSonic-3 Scientific). The measurement site and the primary, 12h filter sampler setup is shown in figure 1. A second filter sampler (Comde Derenda PNS 31T-DM-6.1) was set up on the opposite side of the waterfall, along with a weather station (Vaisala WXT536) to collect basic weather data.

Filters were used to obtain the ice nucleating particle (INP) concentrations of the air sampled at the measurement site. For the analysis, filters were immersed in 10 mL of filtered Milli-Q water to suspend the collected aerosol. Freezing spectra of the suspensions were evaluated using FrESH (Freezing Experiment Setup Helsinki). In each experiment, 50 µL aliquots were dosed into a 96-well PCR plate and exposed to decreasing temperatures (1 °C/min) until all droplets were frozen. The fraction of frozen droplets as a function of temperature is obtained from pictures taken during the experiment, and the concentration of INPs is subsequently derived. The same type of analysis was performed with the river

water samples. Dilutions to extend the freezing spectra of water samples to lower temperatures were prepared when needed.

The ambient particle size distribution at the sampling site was evaluated during one visit to the site, providing insight into the size range of particles present. To better understand spatial variations in water properties along the river that could affect the amount of INP released, we collected water samples from both upstream and downstream of the waterfall. In order to explore the aerosolization mechanisms of particles from the river water into air, bubble tank experiments were performed in the lab. The released particles were collected onto filters, and their concentration and size distributions were measured for comparison to the ambient data. The ice nucleation ability of these water samples and the bubble tank generated particles was also investigated.

RESULTS

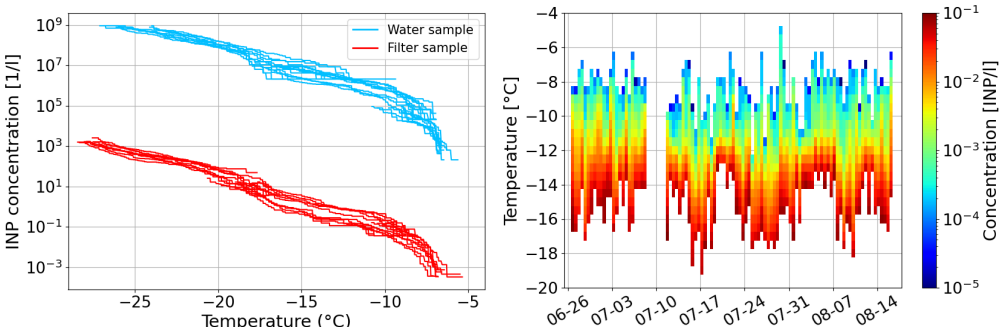

Figure 2: (a) INP concentration as a function of temperature for water and filter sample from the bubble tank experiments . Water samples: INP per litre of water, and filter samples: INP per litre of sampled air. The plot includes undiluted (1/1), 1/100, and 1/10,000 dilutions for both water and filter samples. (b) A time series of the INP concentrations of the 12h samples at different temperatures over the course of the campaign.

The results from the bubble tank experiment reveal little variability among the different samples (Figure 2a). The temperature spectra have a similar shape and only a small spread in observed INP concentrations at all temperatures. This suggests that bubble bursting is capable of emitting INPs from the river water into the air. Furthermore, the bubble tank results provide a reference point to assess whether the INP concentrations measured on-site originate from the river water or are affected by other sources. The comparative analysis will enhance our understanding of the mechanisms at play.

A time series of the INP concentration at the site is shown in Figure 2b. The majority of freezing events occur below -8°C, but periods of heightened activity can be identified, with notable peaks in early July and mid-August. However, these events have yet to be linked to specific atmospheric or environmental conditions. Ion and carbon content measurements and processing the site weather data will give us more insight into connections between specific atmospheric events and variations in ice nucleating particle activity.

ACKNOWLEDGEMENTS

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ATMOSPHERIC OBSERVATORY AT THE COAST OF THE BALTIC SEA

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Keywords: coastal, SMEAR, Baltic Sea, new particle formation.

INTRODUCTION

The SMEAR (Station for Measuring Earth surface – Atmosphere Relations) concept offers an observation platform that provides continuous, comprehensive environmental information from local level up-to the global Grand Challenges including carbon sink and emissions (Kulmala et al., 2023). To find practical solutions to these challenges, a deep understanding based on new scientific knowledge through advanced data is needed. The coastal environment is a hot spot ecological area having the potential of not only being an important greenhouse gas sink/source but also a climatically relevant ecosystem to study the emissions of volatile organic compounds, other trace gases and marine aerosols (Thakur et al., 2022). Based on the SMEAR II station's integrated approach a permanent atmospheric laboratory at the Tvärminne Zoological Station on the Finnish coast of the Baltic Sea has been setup in 2022, in the "CoastClim" centre (https://coastclim.org) as the basis of coastal SMEAR.

METHODS

The station uses state-of-the-art instruments like Multischeme Chemical Ionization inlet-atmospheric pressure interface- time of flight mass spectrometer and Vocus Proton Transfer reaction mass spectrometer, aerosol size distribution instruments like Particle Size Magnifier, Neutral Air Ion Spectrometer, Differential Mobility Particle Sizer and Aerodynamic Particle Sizer, trace gas analyzers (SO_2, NOx, CO, O_3), eddy covariance mast (fluxes, heat, momentum, CO_2, H_2O and CH_4) and the weather system. The aim is to study the climate change impact on the coastal atmosphere integrated with ecosystem processes of the Baltic Sea.

Additionally, campaign-based experiments to study the emission of VOC, especially monoterpenes from the coastal water and biota, were carried out in the summer of 2022. The VOC fluxes were measured using manual steady-state flow-through flux chambers floating on the seawater surface. Emissions were sampled through Tenax TA adsorbent tubes and analysed via Gas Chromatography technique. Spots was sampled in the morning, afternoon, and evening over the sampling days.

RESULTS

Various new particle formation (NPF) events were observed with burst events mostly when the wind is coming mostly marine and regional events during continental air mass (Fig 1). Campaign based studies done in May-June 2022, using the flux chamber-Tenax system showed Increase in the signals of isoprene during the afternoons (Fig. 2), when the sun radiation is the highest and most of the NPF events occur. Our results that Median flux values for a -pinene in the mornings were higher than afternoon and evening, This location was enriched with macroalage. The data would be further interpreted considering the effect of chamber temperatures, water temperature and photosynthetically active radiation which play a major role in driving emissions from the water into the overlying atmosphere.

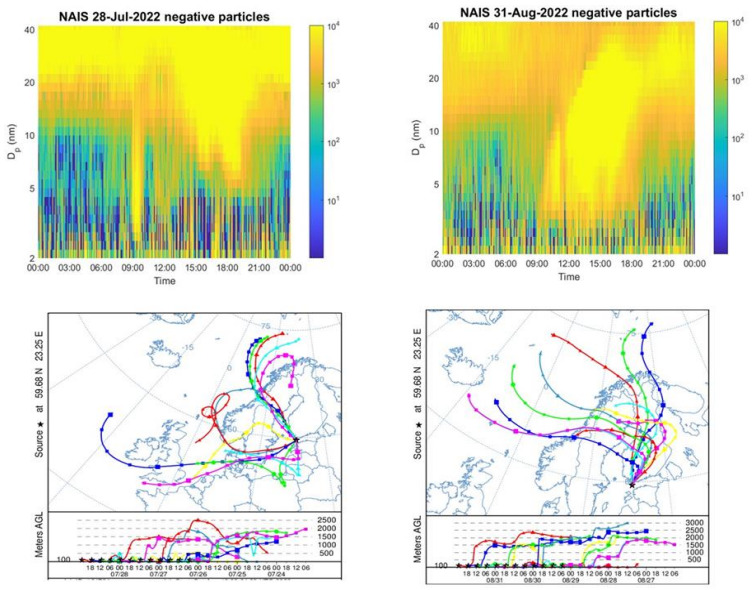

Figure1 : Different types of aerosol formation events when air masses are coming from marine and continental sectors.

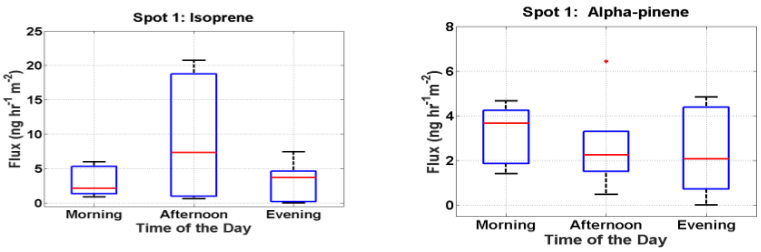

Figure 2. Dirunal variability of Isoprene and a-pinene fluxes at the shore of the atmospheric observatory. The red line shows the median flux value, the upper end and lower end of the box demonstrates the 75th and 25th percentile, respectively. The whiskers show the variability in the data.

CONCLUSIONS

The first results highlight the need for more long-term measurements supported by campaign-based measurements to understand the coastal atmospheric chemistry, identify the sources of specific monoterpenes, which can be precursors to highly oxidized organic molecules that play an important role in NPF. Connecting the coastal emissions to aerosol formation is crucial for understanding the impacts of climate change and is one of the core aims of our multidisciplinary project "CoastClim".

ACKNOWLEDGEMENTS

We acknowledge funding from Jane and Aatos Erkko Foundation and Ella and Georg Ehrnrooth Foundation.

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INTO THE FIRE: CHARACTERISING BIOMASS BURNING AEROSOL AT THE SOURCE

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Keywords: Biomass burning aerosol, AMS, wild fires.

INTRODUCTION

Wildfires are an important source of ambient aerosol both directly (Primary Organic Aerosol, POA) and indirectly (Secondary Organic Aerosol, SOA) affecting both climate and air quality in large areas. Studying the emission strength and properties of such biomass burning (BB) aerosol is vital for understanding their impact on the atmosphere on the regional and global scale. Such studies become even more important as both the frequency and the severity of wildfires have increased in the past decade, especially in the high latitudes (Jolly et al., 2015; Tyukavina et al., 2022). Due to the low background aerosol loading in most boreal and polar regions, even small fires can have a large impact on aerosol population and significantly change, e.g., the concentration of Cloud Condensation Nuclei (CCN) in a region.

However, conducting in-situ studies near active wildfires is difficult due to their unpredictability and complex spreading behaviour. Typically, real-world fire emissions are characterised with airplane-based measurements high above the burning areas. Stationary ground-based platforms are usually located at some distance of the active fire area and struggle to really capture the fresh fire emissions as the plumes usually quickly lift to higher altitudes. Additionally, the spread of a fire plume strongly depends on the complex wind conditions near a fire. I.e., it is easy to miss a plume of a nearby fire with a stationary platform if the wind is in the wrong direction.

METHODS

Here, we present a study of a controlled burn of a selected 8 ha forest area in Finland (Pohjois Savo) which represents the typical summer-time brushwood fires in Northern European countries. The controlled burn is part of the forest management program of the Finnish Forestry Service (Metsähallitus). To mimic a slow-moving brush fire typical for the Finnish boreal forest, the area around the measurement location was strip burned. I.e., a small area was manually ignited and burned with visible flaming. Consecutively, the adjacent areas were ignited to maintain a steady and controlled burn front moving through the whole area.

We placed a container with measurement instruments in a “safe zone” inside the dedicated burn area to obtain data from the fresh emissions of the active fire. Measurements were also conducted for several days before the burning event as well as after the active flaming period was over to fully characterise the impact of the fire on the aerosol population in this area before, during, and after a fire occurred. By placing the instruments inside the burned area, we were able to determine emission factors as close to the source as possible under atmospherically relevant conditions. Additionally, gas and particle phase instruments mounted to a drone were deployed providing a mobile platform to further sample the fresh plumes.

The chemical composition of the aerosol particles was characterised with a High-Resolution Time-of-Flight Soot-Particle Aerosol Mass Spectrometer (SP-AMS) and offline filter samples which were thermally

desorbed into a Chemical Ionisation Mass Spectrometry (CIMS). Black-carbon content of the aerosol particles was measured with a Multi-Angle Absorption Photometer (MAAP) and an aethalometer. We determined the CCN activity of the aerosol with a Cloud Condensation Nuclei Counter (CCN-C). CO and CO2 concentrations were monitored with a Cavity Ring-Down Spectrometer and a Fourier Transform IR spectrometer.

RESULTS

We used the modified combustion efficiency (MCE) to classify the burning conditions into flaming or smouldering dominated time periods (Yokelson et al., 1999; Ward and Radke, 1993). The observed emissions fell into the flaming dominated category only when the actively burned area was near the measurement station. For most of the time, the emissions exhibited MCE values characteristic for smouldering burning conditions. The highest concentrations of aerosol particles in general and black carbon specifically were observed during the flaming periods with values up to 1000-fold higher than the usual background values at this location. During the smouldering periods, the observed concentrations were still over 100 times higher than usual. These high particle concentrations persisted for at least 12 h after the active burning period. The AMS data suggests that the particles were dominated by organic compounds with less than 5 % black carbon and inorganic compounds in the particles.

CONCLUSIONS

Flaming conditions produced higher aerosol particle concentrations than smouldering conditions in this controlled boreal brushwood fire. However, the smouldering phase persisted much longer after the initial open flames thus potentially contributing significantly to the overall emissions associated with such fires. This study provides important insights into the characteristics of aerosols close to the source in wildfires typical for the boreal region. Additionally, it provides answers to the question of how typical forest fires affect the aerosol population and its properties in the European boreal regions.

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MACHINE LEARNING APPROACHES TO UNDERSTAND AEROSOL-CLOUD INTERACTIONS IN MARINE STRATOCUMULUS CLOUDS

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Keywords: Aerosols, Cloud droplets, updraft velocity, statistical analysis.

INTRODUCTION

Aerosol-cloud interactions are crucial for understanding Earth's climate system, as aerosols influence cloud droplet number concentration (CDNC) and broader atmospheric dynamics. However, accurately quantifying the effect of cloud condensation nuclei (CCN) on CDNC is challenging due to the complexity of atmospheric processes and uncertainties in observations. In this study, we use a machine learning approach to isolate aerosol effects on CDNC in marine stratocumulus clouds. By integrating satellite data and climate model simulations, we evaluate different regression techniques and explore machine learning methods to better capture the CCN-CDNC relationship.

METHODS

In this study, we employed a comprehensive methodology to investigate the relationship between CCN and CDNC through the analysis of satellite-retrieved aerosol and cloud properties. This analysis was further enhanced by simulations conducted with the global aerosol-climate model ECHAM-HAMMOZ, incorporating the Sectional Aerosol Module for Large Scale Applications (SALSA), hereafter referred to as ECHAM-SALSA (Kokkola et al., 2018) climate model simulations. Our research focused on two distinct regions of the Pacific Ocean, known for their prevalence of low-level marine clouds. We utilized cloud products from the Moderate Resolution Imaging Spectroradiometer (MODIS) onboard Aqua and Terra satellites to extract key cloud characteristics. The cloud base updraft velocity (Wb) was estimated using the libRadtran radiative transfer model (RTM) using the linear fit between cloud top radiative cooling and Wb formulated by Zheng et al., 2016. To further investigate CDNC variability, we employed a cloud parcel model to simulate the adiabatic ascent of air parcels, analyzing how CCN concentrations and updraft velocities affect droplet formation and growth. By integrating these diverse data sources and methodologies, we aimed to enhance our understanding of aerosol-cloud interactions and their implications for cloud microphysics in marine environments.

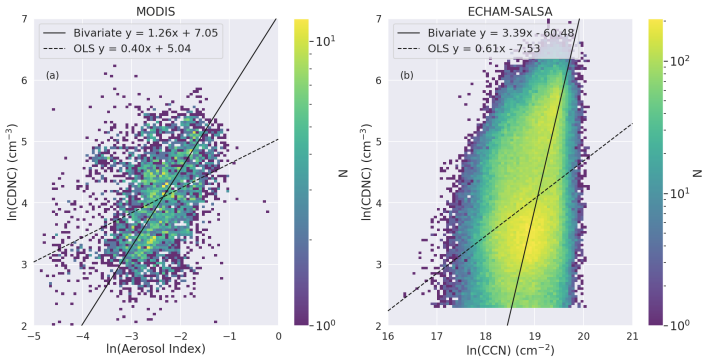

Figure 1: Susceptibility of cloud-top CDNC to changes in CCN burden using Bivariate fit and OLS from (a) satellite observation and (b) climate model simulation, with colors representing the number of data points.

RESULTS

The relationship between CCN and CDNC was assessed using Ordinary Least Squares (OLS) regression and bivariate fitting. OLS regression showed a poor fit to satellite observations and climate model simulations, confirming the limitations noted in prior research by Pitkänen., et al 2016. Bivariate fitting yielded a better alignment with the data visually, but it consistently produced slopes greater than 1, which is unphysical since CDNC should not exceed CCN concentrations (See Fig. 1). This suggests that CCN is not the sole factor influencing CDNC. To investigate this further, we employed Random Forest (RF) for feature importance analysis, identifying that updraft velocity, CCN burden, and liquid water path (LWP) significantly contribute to CDNC variability in both satellite and climate model data. This underscores the need for a comprehensive approach that considers multiple factors influencing the CCN-CDNC relationship, highlighting the complexities of aerosol-cloud interactions. To address this, we show the machine learning based Elastic Net Regression (ENR), effectively accounts for multiple factors influencing CDNC while addressing over-fitting ad feature selection. The ENR slope estimates were significantly lower than those from bivariate fitting, aligning more closely with cloud parcel model simulations. Our findings underscore the complexity of aerosol-cloud interactions, emphasizing the need for advanced modeling approaches like ENR to capture the nuanced relationships between CCN and CDNC accurately.

ACKNOWLEDGEMENTS

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CLOUD FORMING POTENTIAL OF AEROSOL FROM BOREAL FOREST SURFACE FIRES

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Keywords: CCN activity, prescribed burn, boreal forest.

INTRODUCTION

Wildfires emit large amounts of gaseous compounds and particulate matter such as organic aerosol (OA) and black carbon (BC) (Andreae, 2019). The particulate emissions have a potential to alter the radiation balance of the earth via scattering and absorbing of solar radiation as well as activating as cloud condensation nuclei (CCN). Changes in the abundance of CCN will change the properties of clouds and thus their impact on the radiation budget (aerosol-cloud interaction). The CCN activity of aerosol particles depend on their chemical properties, size, mixing state as well as the environmental conditions. An increase in the rate and intensity of forest fires has been observed in the arctic during recent decades, making biomass burning (BB) aerosol a matter of interest (Tyukavina et al., 2022).

METHODS

Field measurements of a prescribed fire were conducted in summer 2024 to study the emissions from a boreal forest surface fire. An 8-ha area of forest was burned by the Finnish Forest Administration (Metsähallitus) and the properties of the emitted smoke were measured with a container located in the middle of the burned area. In addition to the forest fire smoke, the background concentrations and aerosol properties were measured before the prescribed burn. The measurements included characterization of the concentration and chemical composition of the gaseous and particulate species in the smoke as well as CCN activity, size distribution and optical properties of the aerosol. During the fire, the burning condition was characterized with the modified combustion efficiency ($MCE = \Delta CO_2 / (\Delta CO_2 + \Delta CO)$) which is calculated with background corrected CO_2 and CO concentrations.

For this study, size resolved CCN activity measurements were performed with a Cloud Condensation Nuclei Counter (Droplet Measurement Technologies). During the burning period, the properties of the sampled aerosol showed high temporal variability due to the complex dynamic of the air movements. Plumes of smoke mixed with cleaner air creating order of magnitude changes in particle concentration within less than a minute which presents a great challenge for the size resolved CCN measurements. Therefore, the hygroscopicity parameter κ (Petters and Kreidenweis, 2007) was calculated for each measured supersaturation by dividing the CCN data into subsets based on MCE. An activation curve was fitted into each of these datasets and the average κ values within each MCE range were derived.

RESULTS

In total, the open flame burning of the forest and the subsequent smoldering was measured for almost 22 hours. During this period, the measured smoke was mostly from the smoldering phase. Overall, the mean MCE was 0.84 suggesting the dominance of smoldering in boreal forest surface fires. However, the changing wind directions and the fixed location of the container may have affected the amount of smoldering and flaming combustion captured by the measurements.

For this study, we measured the CCN activity of both background and BB aerosol. The median background aerosol κ value was 0.19 and 0.16 for supersaturation of 0.32 % and 0.49 %, respectively. For the same supersaturations, the κ values for the burn aerosol varied from 0.09 to 0.13 and from 0.1 to 0.14 as seen in Fig 1. This suggests that the emissions from boreal forest surface fires decrease the hygroscopicity of the ambient aerosol. Despite the decrease in hygroscopicity, the CCN number concentration is still higher due to the increased total aerosol concentration. The hygroscopicity of the aerosol measured in this study are comparable to our previous measurements in the laboratory with boreal forest surface samples.

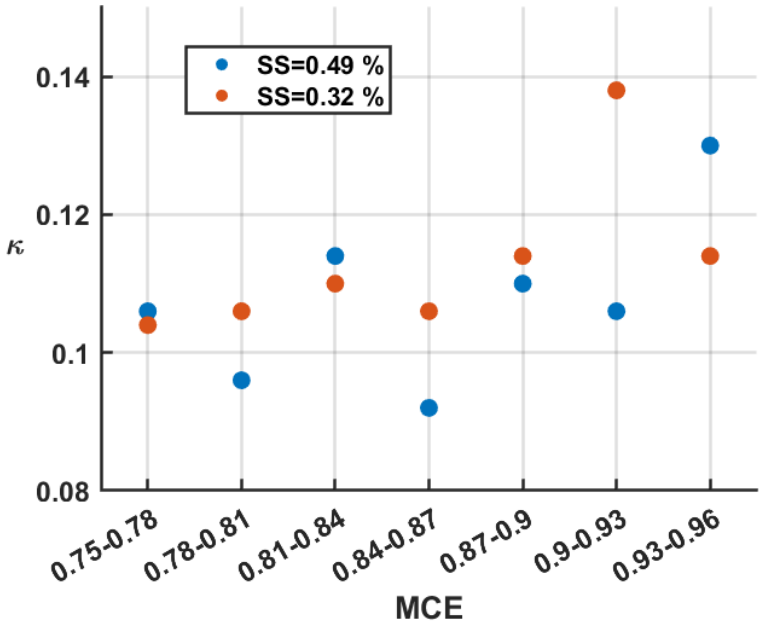

Figure 1. The hygroscopicity parameter κ of aerosol particles emitted by the prescribed burning as a function of modified combustion efficiency (MCE) for supersaturations (SS) of 0.32 % and 0.49 %.

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Thinning in boreal forest and Carbonyl Sulfide fluxes

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Keywords: Carbonyl sulfide, Ecosystem fluxes, GPP, Eddy covariance.

INTRODUCTION

Carbonyl sulfide (COS) is a gas found in the atmosphere at concentrations of ~ 500 parts per trillion (ppt) (Montzka et al., 2007). The major sources are marine regions, followed by anthropogenic sources like industrial activities and biomass burning. The biosphere is the main sink of COS (Berry et al., 2013). COS and CO_2 share the same diffusive pathway from the atmosphere to the chloroplasts in the plant leaves. Therefore, COS has gained considerable attention in biogeochemical research as it provides insight into the gross primary productivity (GPP) of an ecosystem and its carbon sink (Sandoval-Soto et al., 2005; Wohlfahrt et al., 2012). In this study, we measure and analyze three years (2020-2022) of COS flux measurements at the Hyytiälä boreal forest site following a thinning conducted in 2019-2020 to quantify the changes in the ecosystem COS uptake after thinning.

METHODS

The COS flux measurements were conducted in Hyytiälä forest station (61°51' N, 24°17' E, elevation:181m a.s.l.). The fluxes were measured at 23m height using an eddy covariance setup that includes a 3-D ultrasonic anemometer (uSonic-3 Class A, METEK Meteorologische Messtechnik GmbH, Elmshorn, Germany) and an Aerodyne quantum cascade laser spectrometer (QCLS; Aerodyne Research Inc., Billerica, MA, USA) for measuring the concentration of COS. The measurement site is surrounded by Scots pine stand, sown in 1962 and thinned in 2002. The latest thinning happened between January and March 2020, and the stem density was reduced by 40% (Aslan et al., 2024). The COS fluxes around the periods before (2013-17) and after (2020-22) thinning are compared to analyze the changes in the uptake of COS by the forest stand.

RESULTS

To understand the ecosystem level responses, F_{COS} during the June and July months is presented as a function of PAR, T_a, and VPD (Fig. 1). The relationships between F_{COS} and environmental variables during 2020 and 2022 were similar to those reported in the pre-thinning years (Vesala et al., 2022), with COS uptake decreasing under increases in T_a and VPD. The year 2021 was anomalous as positive fluxes were observed at high T_a, and VPD conditions.

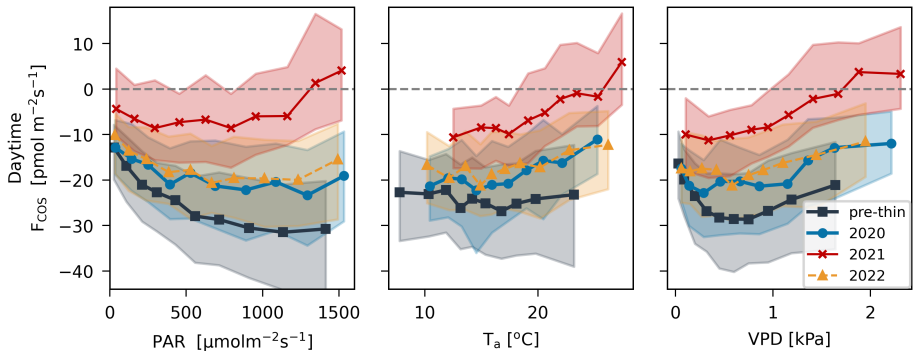

Figure 1: Binned median correlation between daytime FCOS and environmental variables during June-July for pre-thinning years (2013-17) and each year after thinning (2020,21 and 22). The data is sorted equally into 10 bins, and the shaded regions represent 25th and 75th percentiles

CONCLUSIONS

The positive fluxes in the 2021 summer point towards the emission of COS within the footprint area of the EC tower. The lack of understanding of such a spontaneous yet significant source of COS within the boreal forest warrants more research to understand the processes behind this emission and find the environmental factors that can affect it.

ACKNOWLEDGEMENTS

This study has received financial support from the University of Helsinki via Integrated Carbon Observation System - Hyytiälä (ICOS-HY), the Research Council of Finland project N-PERM (Grant No. 341348), and project ForClimate (Grant No. 347780), and the EU Horizon Europe-Framework Programme for Research and Innovation (Grant No. 101056921-GreenFeedBack).

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THE MOLECULAR SCALE MECHANISM OF ADSORPTION AND DEPOSITION FREEZING OF ACTIVE ICE NUCLEATING PARTICLES

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Keywords: Heterogeneous ice nucleation, Deposition ice nucleation, Metal oxides, Molecular dynamics simulation.

INTRODUCTION

Deposition ice nucleation describes the process in which water vapor deposits onto critical-sized ice clusters on insoluble particles. Modeling indicates that deposition ice nucleation is the dominant mode at cirrus cloud temperature. Despite its importance, the mechanism of deposition freezing remains poorly understood, and experimental observations have uncovered aspects that lack satisfactory explanation. For instance, it is shown that the critical supersaturation (S^*) and temperature depends to each other as a U-shape curve (Hoose and Möhler, 2012). When temperature decreases from approximately 250 K, the S^* initially decreases, levels off around 230-220 K, and then begins to rise again. This behaviour contradicts the common assumption that lower temperatures consistently promote ice nucleation. Laboratory measurements show that ice nucleation activity and the temperature dependence of critical supersaturation S^* vary significantly depending on the materials that act as ice nucleating particles (INP)s. For example, it is shown that in the case of silver iodide (AgI), there is a notable increase in the dependence of a parameter S^* on temperature as the temperature decreases continuing down to -65 °C. Additionally, it has been shown that when water molecules are adsorbed to a surface, such as AgI, they undergo a rapid transition into an ice-like state as the temperature falls below the freezing point, especially when the water concentration is below saturation. However, the similar measurements for copper oxide (CuO) particles exhibit a distinct temperature dependence for ice nucleation, contrasting with the behaviour of AgI. Specifically, under conditions of ice supersaturation, water vapor initially condenses onto the adsorbed liquid phase, followed by ice nucleation in the experiment. A similar behavior is observed for titanium dioxide (TiO_2) (Kanji *et al.*, 2017). This study investigates the phase behavior of adsorbed water on diverse INPs under upper tropospheric temperatures through molecular modeling.

METHODS

We employ molecular dynamics (MD) simulations and a hybrid of grand canonical Monte Carlo and MD (GCMC/MD) to provide adsorption isotherms and explore deposition ice nucleation using

LAMMPS 2022 software. We investigate the adsorption behavior of water at various levels of supercooling, including 213, 223, 233, 243, 253, and 263 K, while examining different active INPs such as AgI, TiO_2, CuO.

RESULTS

Our simulation results on AgI surface shows that water initially adsorbs in clusters which merge and grow over time to form layers of supercooled water. Ice nucleation on silver iodide requires a minimum the adsorption of four molecular layers of water. Guided by the simulations, we propose the following fundamental freezing steps: 1. water molecules adsorb on the surface, forming nanodroplets. 2. the supercooled water nanodroplets merge into a continuous multilayer when they grow to about three molecular layers thick. 3. the layer continues to grow until the critical thickness for freezing is reached. 4. the critical ice cluster continues to grow (Roudsari *et al.*, 2017).

Our preliminary results of MD simulations on CuO and TiO_2 show that the formation of water on the surface does not occur as a monolayer; instead, multilayers develop through the coalescence of water droplets. Initially, water molecules are chemisorped, and then physisorbed water clustering around specific chemisorption sites on the surface.

CONCLUSIONS

In conclusion, on AgI surface, water molecules initially adsorb onto the surface by forming nanodroplets, which coalesce into a continuous multilayer once they reach approximately three molecular layers in thickness. These layers continue to grow until they achieve the critical thickness for freezing, after which the ice cluster expands further.

The adsorption isotherm derived from GCMC/MD simulations of water on CuO surfaces closely aligns with experimental observations, confirming the accuracy of the modeled structure. Across all cases, the adsorption process begins with a droplet formation phase, preceding the development of a multilayer where freezing can occur.

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PRELIMINARY ANALYSIS OF SIZE DISTRIBUTIONS AND PROPERTIES OF PLANT-DERIVED EXTRACELLULAR VESICLES

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Keywords: Bioaerosols, Extracellular vesicles, Ice nucleating particles, Spruce, Bilberry

INTRODUCTION

Extracellular vesicles (EVs) are natural nano-sized, lipid membrane bound particles which provide promising biomaterial source for medical applications and aerosol research. Owing to their biocompatibility and size-scale, EVs can serve as natural carriers for therapeutic agents and drugs (Du *et al*. 2023, Herrmann *et al.* 2021). In environmental perspective, plant-based airborne bioaerosols can be ice nucleation-active and thus, have potential to contribute to biosphere-climate feedback mechanisms (Brent, 2008; Maki, 2023).

In addition to bacteria, viruses, fungal spores etc., EVs may play an important role in different atmospheric processes. For example, in marine environment, the cyanobacteria biomass has been suggested to be regulated by airborne biological agents such as EVs associated with atmospheric aerosols (Rahav, 2020). Despite their potential contribution to atmospheric processes, plant-based EVs properties have remained poorly understood. In this study, we investigate EVs size-distribution in liquid and aerosol phase as well as their ice nucleation properties using samples isolated from Norway spruce (*Picea abies*) and bilberry (*Vaccinium myrtillus L*).

METHODS

EV samples suspended in Phosphate-buffered saline (PBS) and Milli-Q water were prepared for aerosol and ice nucleation studies by melting samples in 17 ml of Milli-Q water and further diluting by 1/10 volume in Milli-Q water. An atomizer aerosol generator was employed to produce EVs in aerosol phase. Particles were charged via an ^{241}Am bipolar diffusion charger and particle number size distribution in aerosol phase was classified by the electrical mobility with the Vienna-type Differential Mobility Particle Sizer (DMPS) up to 300 nm size range while the concentration of sampled particles was measured by a Condensation Particle Counter (TSI 3010, USA). Nanoparticle Tracking Analysis (NTA, Malvern Panalytical Ltd, UK) was employed to characterize particle size distribution in liquid phase and a cold stage, which design was based on the µL-NIPI (Whale et al., 2015), was used for the ice nucleation experiments.

PRELIMINARY RESULTS

Samples diluted in pure Milli-Q water were chosen as the final set of samples for aerosol studies as the PBS solution was observed to produce salt particles overlapping with the EVs signal. EVs size-distribution obtained with NTA analysis is based on the hydrodynamic size measurements in liquid phase and EVs appeared at larger sizes compared to the measurements in aerosol phase. Preliminary analysis on the ice nucleation activity will be discussed.

ACKNOWLEDGEMENTS

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ASSESSING LAKE 2.0 MODEL PERFORMANCE IN SIMULATING THERMAL AND GREENHOUSE GASES DYNAMICS IN A SMALL BOREAL LAKE IN SOUTHERN FINLAND

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Keywords: Lake modeling, Greenhouse gases, Climate change.

INTRODUCTION

Lakes are significant sources of carbon dioxide (CO_2), methane (CH_4) and other greenhouse gases (GHGs) to the atmosphere. Recent research of CO_2 emissions estimated that these ecosystems release an amount of CO_2 equal to about 20% of emissions from fossil fuels and that these releases have global implications (Desai et al., 2015). In addition, the lake mixing regimes and carbon budget are changing rapidly in response to the influence of climate change (Golub et al., 2023). Being able to accurately simulate thermal and gas related dynamics thus turns out to be a relevant task because it enables the prediction of future shifts in temperature patterns and gas exchange rates between lakes and the atmosphere. Despite this, however, most field and modeling studies that have investigated this topic refer to sampling limited to the open-water season or summer with limited consideration of interannual variability (Desai et al., 2015). In particular, in lake GHG's related research, ice cover is poorly investigated. This is critical because the ice cover prevents the release of greenhouse gases by causing them to accumulate under it and then be released when the ice breaks up. This dynamic significantly affects the seasonal variability of GHGs concentrations and fluxes in lakes that freeze seasonally (Kiuru et al., 2018).

METHODS

Here we investigate the ability of the LAKE 2.0 model (Stepanenko et al., 2016) to accurately simulate the surface energy balance and GHGs exchange between lakes and the atmosphere. Special attention is devoted to the model´s ability to predict lake mixing regimes and concentration of dissolved gases (oxygen, carbon dioxide and methane) during shoulder seasons (spring and fall turnover periods) and during the wintertime. LAKE 2.0 is a one-dimensional model that allows coupled simulation of thermodynamics and biogeochemical characteristics in lakes and reproduces profiles and time series of water temperature, and concentrations of O_2, CO_2 and CH_4. The model is forced using a meteorological data set from Lake Kuivajärvi, a small boreal lake in located in Southern Finland. Results from the LAKE 2.0 model are compared to 30 minutes water temperature and weekly gas concentrations measurements from the lake (Miettinen et al., 2015; Miettinen et al., 2020).

RESULTS

The model effectively reproduces the observed seasonal temperature pattern in the lake throughout the entire year. The Root Mean Square Error (RMSE) for water temperature is between 1.8 and 2.4 °C over the entire water column. Overall, seasonal dynamics of gases are well represented. Considering the surface layer of the water column, the RMSE for the dissolved CO_2 concentration is between 0.7 and 1.3 mg/L and the RMSE for the dissolved CH_4 concentration is about 3.3 µg/L. Focusing on shoulder seasons, the model is able to reproduce temperature and gases dynamics fairly well. Short and long spring and fall mixing periods are adequately simulated.

Nevertheless, there are some shifts in gas accumulation amount and timing. In the model, CO_2 accumulation in the deeper layers is underestimated during spring and the decrease in concentration before the autumn mixing period is delayed. CH_4 accumulation at the bottom is underestimated both in the wintertime and under the stratification in summer. Finally, biases are also evident in early warm winters when the presence of thin and intermittent ice cover delays the accumulation of gases at the bottom of the lake.

CONCLUSIONS

The LAKE 2.0 model effectively reproduces seasonal and interannual dynamics of water temperature and gases throughout the entire year. Biases related to modeled gas concentration and release are highly dependent on the model's ability to accurately simulate the water temperature. This is particularly relevant considering that thermal dynamics in lakes are predicted to shift due to climate change. Overall, the good performance in simulating thermal and gas dynamics makes the LAKE 2.0 model a valid tool to help reduce the uncertainties in GHG trends in lakes.

ACKNOWLEDGEMENTS

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YEAR OF SMEAR II

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Keywords: Field station, Field measurements, Societal interaction.

INTRODUCTION

Versatile work at field stations goes on year round. At SMEAR II (Station for Measuring Earth surface – Atmosphere Relations) this includes at least:

- Maintaining and developing measurements and basic infra
- Hosting and collaborating with scientific visitors
- Introducing SMEAR II to wide variety of visitor groups and implementing societal interaction
- Arranging and helping with ATM field courses

These activities are spread unevenly throughout the year, thus there´s a yearly rhythm in work conducted at a field station by local staff.

METHODS

SMEAR II is located at Hyytiälä Forest Station in Juupajoki, Central Finland and is led by INAR. The core part of the work at the station is maintainig continuous long-term measurements (ca. 1200 parameters) about ecosystems, atmosphere and their interactions. The site is also part of ICOS, ACTRIS, eLTER and AnAEE infrastructures. Most of the work and observations continue uninterruptedly throughout the seasons, with additional summertime ecosystem measurements and samplings. To maintain these measurements, in addition to the permanent staff, the station hosts yearly four summer students for 3–5 months. Other season-dependent supplemental tasks are maintaining cabin temperatures meticulously during cold and hot periods, snow work throughout winters, coppice clearing in autumns, etc.

Data of research visits has been archived since 2011. The number includes visits of which main purpose was related to data collection in some manner (no courses, meeting etc.), either by UH internal group or other groups from Finland and abroad. For campaign visitors we provide:

- Help with planning, installation, maintenance and sampling
- Basic infra (internet, data transfer, electricity, vacuum, exhaust)
- Ancillary data
- Accommodation and food

The main components of societal interaction are school collaboration and Pirkanmaa Climate Action Lab (PIK). PIK aims to promote climate related discussion and solutions among municipalities, parishes, companies and universities.

INAR hosts yearly two intensive courses at the station and three courses are arranged every second year. Additionally, some courses have only shorter visits to the station or are organized intermittently with collaborators.

We arrange introductory tours around the station for groups with wide variety of backgrounds: scientific groups, financiers, politicians, stakeholders or any other group interested in SMEAR II research.

DISCUSSION

At SMEAR II we don´t have as clear active field season related to measurement activities as stations concentrating mostly on manual field measurements, and the timing of hectic periods depend more on developmental needs or occurring issues with on-going measurements.

Summer students help with manual samplings, make an important addition to the number of staff at the site and create a clear rhythm to the year. Summer students quite often continue within the group and make master´s or PhD theses of INAR topics.

The number of scientific visitors at the site varies between years, especially due to long campaigns. The number of visitors from Finnish institutes has decreased during the last 13 years while the permanent staff at the site has increased. For scientific visitors, the active season is Mar-Sep while Oct-Feb are much quieter.

Societal interaction is distributed throughout the year, except for Jun-Jul. Most frequently school visits are one day trips from Pirkanmaa area, but longer visits are done by schools from also other parts of Finland and occasionally from abroad. PIK workshops take place four times per year with 30–50 participants.

INAR courses are quite evenly distributed within March-Oct period but as also for many other activities the mid-winter months are quieter.

Over 1000 visitors per year, altogether from over 70 countries visit SMEAR II tours arranged by our staff, spring and autumn seasons being the most active visiting seasons.

ACKNOWLEDGEMENTS

This work was supported by the Research Council of Finland (grant 357902).

VIRTUAL EXCHANGES AS A TOOL FOR YOUTH-DRIVEN GLOBAL PARTNERSHIP DEVELOPMENT FOR SDGS

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Keywords: Virtual Exchange Climate University, UnaEuropa

INTRODUCTION

Traditional concept of on-site education is changing. Alongside traditional teaching, distance education is increasingly becoming available. Virtual Exchange (VE) is a tool with which students' interest in distance education can be increased and the element of interaction can be added (O'Dowd, & O'Rourke 2019, O'Dowd 2021, Schenker 2013). UHEL is currently coordinating two European Union ERASMUS+ VE projects. Climate University for Virtual Exchanges (CLUVEX, www.atm.helsinki.fi/cluvex) and UnaEuropa for Virtual Exchanges (UnaVEx, www.atm.helsinki.fi/unavex) will be implemented during the years of 2023-2026. The projects focus on the challenges of climate change and sustainable development. The goal of these projects is to bring a total up to 5,000 university students to VEs within three years. The projects support the continuation of studies in the subject area through existing MOOCs. The CLUVEX project is based on the Climate University (CU, climateuniversity.fi) MOOCs, developed and coordinated by UHEL while the UnaVEx project is based on sustainable development MOOC of the UnaEuropa network (www.una-europa.eu). UHEL, together with the projects' partners from Europe, Europe Neighbourhood East (e.g., Ukraine, Armenia), and Africa (e.g., South Africa, Republic of the Congo, and Kenya), is developing and researching the VE concept as a part of distance learning.

METHODS

During VEs, university students from different countries receive science, based information related to the SDG themes e.g. climate change, sustainable development and exchange ideas in small groups working online (in virtual environment). After the VE, the students will submit reports for the 1 credit point granted by University of Helsinki's Open University and VE Certificate given by the projects (in CLUVEX – so-called the Climate Messenger certificate, and in UnaVEx – so-called the Climate Advocate certificate). Both projects will collect necessary information on students' motivations before the start of each VE and feedback after VE completed.

RESULTS

In CLUVEX, since summer 2023, preparatory steps were taken for developing concept, elaborating guidebooks such as VE Guidebook, Climate Literacy Guidebook, Climate Messenger Code of Conduct, and other supporting educational materials. In May and Sep of 2024, a series of trainings (TR) for moderators was successfully carried out. These included: TR1 - CLUVEX concept and technical skills, TR2 - Climate University MOOCs, TR3 - Soft skills, TR4 - CLUVEX guidebooks and materials, and TR5 - CLUVEX Group Exercise "Climate Horizon" and tools for climate-related data visualisation and analysis. The 1st CLUVEX VE Week will take place online during 14-18 Oct 2024. In recent months it has been actively advertised and promoted through participating in the project Universities, as well as their collaborators, students' local and international various networks, etc. Students successfully completed the VE Week, in

addition to 1 credit and certificate, will have an opportunity to attend free of charge the CU MOOCs related to climate change themes.

In UnaVEx, since spring 2024, preparatory work has been taken for developing concept and the exercise for the virtual exchange week. We will start Nov 2024 and Feb of 2025, a series of trainings (TRs1-5) for moderators. The UnaVEx Group Exercise will be based on the "Introduction to Sustainability" (https://courses.mooc.fi/org/uh-inar/courses/introduction-to-sustainability). The 1st UnaVEx VE Week will take place online during five days ("week") on 24 Feb, 7 Mar, 14 Mar, 21 Mar, 28 Mar in 2025.

CONCLUSIONS

Base on the preliminary results of the 1st virtual week of the CLUVEX project, it seems that the virtual week can act as a low-threshold motivator in distance learning of climate competences. At the same time, the virtual exchange also promotes students' skills, such as remote working e.g. related technical skills and working in small groups and interaction skills.

ACKNOWLEDGEMENTS

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ORANSSI LUMI: AN EXPLORATORY JOURNEY THROUGH ATMOSPHERIC EVENTS

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Keywords: Education, Atmospheric dust, Art-Science, Outreach.

Oranssi Lumi: an exploratory journey through atmospheric events is a set of educational materials focused on atmospheric dust, created at the Finnish Meteorological Institute, and inspired by the Saharan dust deposition event that affected Finland in 2021 (Meinander *et al.,* 2023). In the educational materials' pages, educators and students can explore together the processes that occur along the dust's journey. They will learn how deserts become deserts, types of interaction between dust and clouds, and how dust can land in such far away regions, among other topics.

This digital resource is structured into three thematic blocks corresponding to the stages of the dust's journey: its *origin*, *transport* and *deposition*. The stages connect with an adjacent topic: dust, wind and snow, respectively. All the concepts are explored from multiple angles, allowing teachers from various fields -such as music, physics, language, and more- to implement them, fostering a connection between scientific and artistic disciplines in their classrooms, and enabling discussions about climate and climate change.

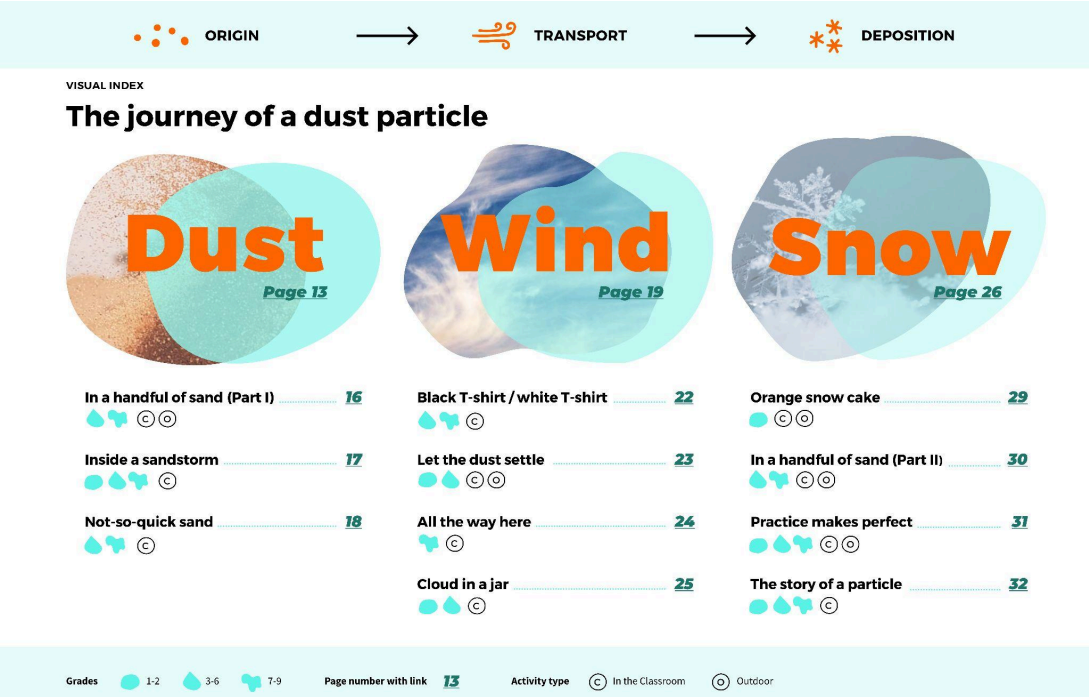

Figure 1. Educational materials' visual index containing the set of newly designed activities by chapter. The shape code indicates the target audience's age group.

Using an exploratory learning approach, these materials include a set of ready-made activities that directly address students. Each activity is supported by background information to assist educators in facilitating it. For ease of implementation, we have included curriculum connections based on the Finnish National Education Curriculum for grades 1-9. An extensive list of additional resources is available for a deeper exploration of the concepts covered. Additionally, the materials include simple guidelines for snow sample collection.

Are you ready to join a dust particle on its adventure from the Sahara's arid lands all the way to Finland? You can download these educational resources in English from https://en.ilmatieteenlaitos.fi/oranssi-lumi.

Find more information about the initiative on the project website and Instagram profile (@oranssi_lumi).

Figure 2. Oranssi Lumi's wordmark.

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The project "Learning through atmospheric events: Citizen science and citizen arts educational material" was made possible thanks to the support of the Kone Foundation.

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FINITE ELEMENT-BASED EXTENDED KALMAN FILTER AND SMOOTHER FOR RETRIEVAL OF AEROSOL SIZE DISTRIBUTIONS AND PROCESS RATES

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Keywords: Aerosol process rate estimation, Bayesian state-space estimation, General dynamic Equation, Finite element method.

INTRODUCTION

Aerosol particles have a major effect on the climate as they reflect and absorb incoming solar radiation and act as cloud condensing nuclei, thus both directly and indirectly affecting the albedo of the Earth. However, the magnitude of these effects is highly uncertain due to uncertainties in aerosol dynamics modelling in global climate models as both aerosol process rate approximations and the applied aerosol dynamics models are typically rather crude. Currently, accurate modelling of aerosol dynamics in global climate models is infeasible due to the high computational cost (Schultze and Rockel, 2018).

Temporal evolution of an aerosol size distribution can be described with the General Dynamic Equation of aerosols (GDE), which accounts for particle growth, nucleation and other particle sources, removal processes and coagulation (Seinfeld & Pandis, 2016). To be able to model the evolution of aerosol number distributions accurately with the GDE, we need to have the means to estimate these process rates as accurately as possible.

In our research, we apply Bayesian state-space estimation methods, the Extended Kalman Filter (EKF) and Extended Kalman Smoother (EKS) for estimating the evolution of the aerosol size distribution and process rates, with credibility intervals.

METHODS

The EKF estimates the state of the system, i.e., the expected values of the size distribution and process rates. Along with the state, the EKF also estimates the uncertainty (posterior covariance) of the state, providing credibility intervals for the estimate. Uncertainties related to the evolution parameters and measurement devices can be accounted for in the EKF. At each step, the EKF predicts the next state based on a nonlinear model of the system dynamics (the evolution step) and updates this prediction with new measurements (the update step) (Gelb et. al 1974). In the evolution step, a finite element approximation of the GDE is used to predict the state of the system at the next time step (Salminen et. al 2022). The vector autoregressive 2 (VAR2) model is used to predict the process rates. During the update step, predictions for the evolution parameters and covariances are corrected with measurements obtained with a differential mobility particle sizer (DMPS) or a scanning mobility particle sizer (SMPS).

The EKS improves the EKF estimates by incorporating both past and future measurements. After a forward pass using the EKF, a backward pass refines the estimates using future data, reducing uncertainty.

We simulate the DMPS measurements by transforming a known aerosol distribution evolution to the output of DMPS with a system matrix which maps particle number concentrations to counts measured by a condensation particle counter. The obtained counts are corrupted by Poisson distributed noise to mimic a real measurement.

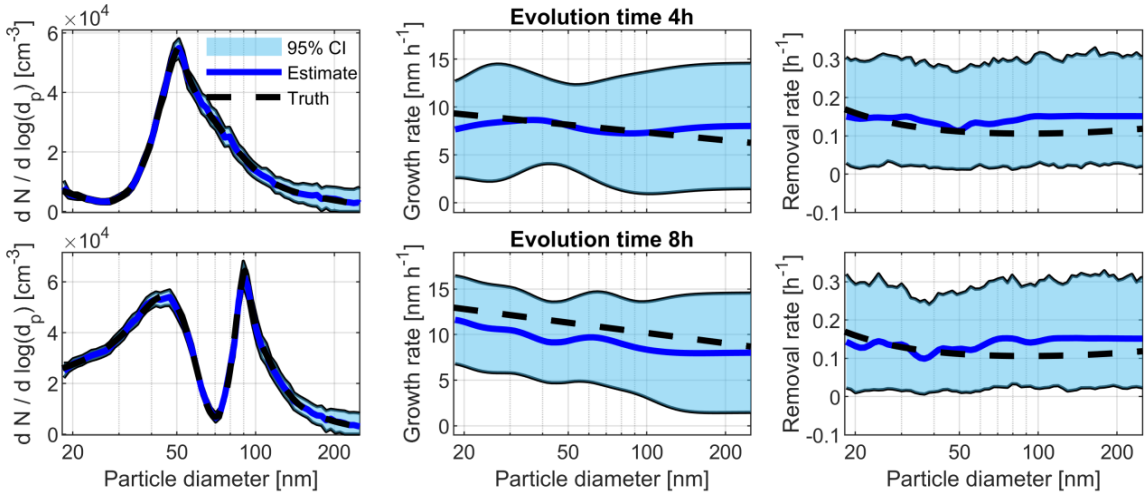

Figure 1: EKS estimates for the size distribution, growth rate and removal rate with credibility intervals at the time instants 4 h and 8 h after beginning of the simulation. The light blue area is the 95 % credibility interval, the blue line is the expected value of the estimate, and the black dashed line is the true value.

RESULTS

An example case is presented, in which the aerosol size distribution is driven by known process rates that vary with respect to time and particle size. Then the measurement is simulated as described in the Methods section. In Figure 1, the EKS estimates and uncertainties are presented for the aerosol size distribution and process rates at time instants 4 h and 8 h. The true values of the size distribution and process rates are inside the 95 % credibility intervals for the duration of the simulation. Note that the credibility intervals are narrower when there are a lot of particles, as the signal-to-noise ratio is larger.

CONCLUSIONS

The EKF and EKS can be used to estimate the aerosol size distribution evolution and process rates from simulated DMPS data, with credibility intervals. We are currently investigating the application of the EKF to real measurement data, with promising preliminary results.

ACKNOWLEDGEMENTS

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Assessing Methane Emission Estimates in Finland Using an Atmospheric Inversion Model

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Keywords: methane, inversion modelling, greenhouse gas, national greenhouse gas inventory.

INTRODUCTION

Independent verification of national greenhouse gas (GHG) inventories is highly needed, and atmospheric inversion models, which use observations of atmospheric methane (CH_4), offer a potential way to estimate the reported GHG emissions, including CH_4. An important part of the inversion models is their prior emissions and their spatial distributions. In this study, we assess how well CarbonTracker Europe - CH_4 (CTE-CH_4), a global atmospheric inversion model, is able to estimate CH_4 emissions in Finland. To do this, we compare modelled estimates using two different anthropogenic inventories, EDGAR and CAMS-REG, as anthropogenic priors over the period from 2000 to 2021. In addition, wetland emission estimates from two process-based models (JSBACH-HIMMELI and LPX Bern DYPTOP) and their impact on optimised emissions are investigated. We analyse the differences between these estimates and validate the emission estimates using auxiliary datasets, trying to identify which inversion model setup gives the most realistic estimates.

METHODS

We estimate CH_4 emissions using the atmospheric inversion model CTE-CH_4 (Tsuruta et al., 2017) in Finland during the last two decades, 2000-2021. At the core of the model is TM5, an Eulerian atmospheric chemistry transport model, which is used to transform CH_4 fluxes into atmospheric mole fractions. Measurement of CH_4 mole fractions from in situ stations to revise the assumed prior emission. As the prior emissions, two different anthropogenic emissions are used: EDGAR v6 (Crippa et al., 2021) and CAMS-REG (Kuenen et al., 2022), which is based on the national inventories, as well as estimates from two different process-based models (JSBACH-HIMMELI (Raivonen et al., 2017) and LPX Bern DYPTOP (Lienert and Joos, 2018)).

RESULTS

Our results showed significant differences in the methane emission estimates studied. In particular, EDGAR CH_4 emissions in Finland were four times higher than the national inventory estimate. Inversion modelling decreased the emissions from EDGAR, but increased them from the national

inventory estimates, bringing the estimates closer together. In addition, the optimised natural CH_4 emissions were larger than both process-based model estimates (JSBACH-HIMMELI and LPX Bern DYPTOP), suggesting that process-based models may underestimate CH_4 emissions from wetlands in Finland, though, this discrepancy could also be due to unaccounted sources such as other freshwater systems.

CONCLUSIONS

We found that while the total CH_4 budget is better constrained, the partitioning between anthropogenic and natural sources remained uncertain and requires further improvement. The choice of priors was shown to significantly affect the posterior emission estimates in Finland. However, the inversion model helped to reconcile anthropogenic and natural emission trends and improved the seasonal cycle of natural emissions. Importantly, while the prior emissions had a large range, this range was reduced in the optimised emissions. All things considered, our study demonstrated how a global inversion model can be used to estimate emissions in a single country, highlighting both its potential and the challenges in refining source partitioning at this scale.

ACKNOWLEDGEMENTS

We thank the teams behind the LPX-Bern DYPTOP v1.4. We are grateful for all the PIs performing high-quality CH_4 measurements at global sites and making them available through the GAW-WDCGG, ICOS and personal communications. For financial support, we thank the European Union's project FPCUP Action 2019-2-49 (219/SI2.818795/07 (CLIMA), the EU-H2020 VERIFY (776810), EU-Horizon EYE-CLIMA (101081395), Academy of Finland Center of Excellence (272041), FIRI - ICOS Finland (345531), and GHGSUPER (351311), Flagships ACCC and FAME (337552 and 359196), CSC (FICOCOSS) and JTF-VISIO.

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ICE NUCLEATION ACTIVE POTASSIUM SALT FROM BIOMASS-BURNING SMOKE

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Keywords: Ice nucleation, cirrus clouds, biomass-burning.

INTRODUCTION

The highest concentration of ice nucleating particles (INPs) in biomass-burning smoke is observed during intense, flaming fires (Schaefer, 1952; Prenni, 2012). Evidence that INPs can be generated by the burning process itself is sparse, and a more accepted assumption on their origin is the lofting of dust and soil from the ground by intensive convection. Potassium containing particles are common in smoke plumes and serve as a marker for biomass burning. Inorganic potassium compounds include KCl, KNO_3, and K_2SO_4. Crystalline KCl is detected in fresh smoke from flaming fires and converts to KNO_3 and K_2SO_4 by reacting with HNO_3 and H_2SO_4 in the smoke plume during aging (Freney, 2009).
We present experimental evidence that crystalline K_2SO_4 can serve as ice nucleating substrate, whereas on KCl ice forms only above its deliquescence relative humidity (DRH) by homogeneous ice nucleation in the solution droplet.

METHODS

Salt particles were generated from an atomizer and dried with a silica diffusion dryer before 200 nm particles were selected with a differential mobility analyzer. Ice nucleation experiments on the monodisperse particles were conducted using a modified version of the SPectrometer for Ice Nucleation (SPIN) chamber (Welti, 2020), in which the test particles are exposed to temperatures down to 208 K and well defined humidity. Salt particles introduced into the SPIN equilibrate to the thermodynamic conditions inside the chamber and can either adsorb water onto their surface or deliquesce. The formation of ice is detected optically after a residence time of 10 s from the growth of ice crystals.

RESULTS

Ice nucleation occurs at temperatures below 235 K, relevant for the formation of cirrus clouds. Fig. 1 shows the ice saturation (S_{ice}) and temperature conditions where a 1% fraction of particles triggers ice formation. (a) KCl particles deliquesce at approx. 85% relative humidity and their solution droplets freeze homogeneously. Below 223 K the DRH of KCl crosses the homogeneous freezing threshold of solution droplets (Koop, 2000), shifting ice formation to higher S_{ice} coinciding with the DRH. (b) K_2SO_4 particles trigger ice formation already at S_{ice} below the threshold of homogeneous freezing in solution droplets and its DRH. We suggest the ice nucleation mechanism at play is homogeneous ice nucleation within very thin layers of adsorbed water.

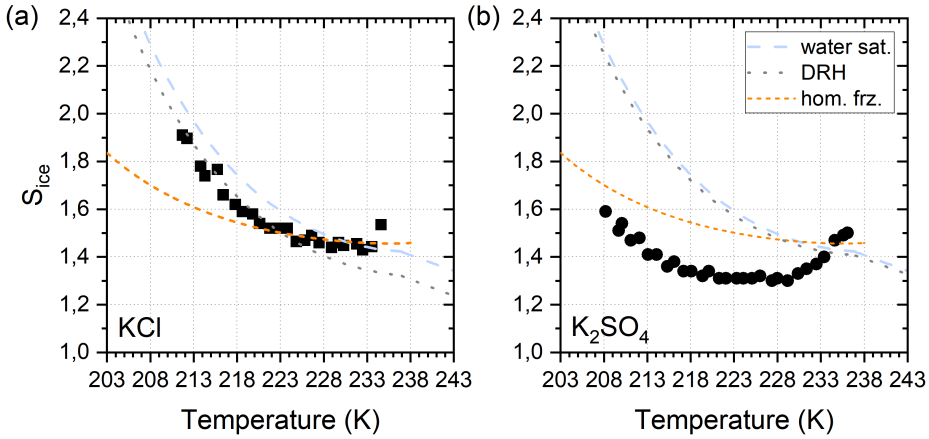

Figure 1: Ice nucleation conditions on (a) 200 nm KCl particles, and (b) 200 nm K_2SO_4 particles are shown as black symbols. Homogeneous ice nucleation conditions in solution droplets are indicated as dashed orange line, water saturation is shown as dashed blue line and the salt specific deliquescence relative humidity as function of temperature is shown in gray.

CONCLUSIONS

We demonstrate that K_2SO_4 can be a pyrogenic INP. However, most biomass-burning aerosol occur as mixed particles with the potassium salt either coated by organics or attached to an organic particle. In both scenarios, ice formation could be inhibited by migration of water molecules into the organic material, preventing the formation of a thin layer of water on the K_2SO_4.

ACKNOWLEDGEMENTS

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Only abstracts

CONTINUOUS COVER FORESTRY IN DRAINED PEATLAND FOREST: EFFECT OF SELECTION HARVESTING ON FOREST CO_2 FLUXES

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Keywords: peatland forest, carbon dioxide, forestry, harvesting.

INTRODUCTION

Greenhouse gas emissions of drained peatlands have received attention in recent years as countries aim to minimize land-use emissions as part of their climate change mitigation actions. In Finland, drained peatland forests are actively used for forestry and there is a pressure to reduce peatland forest soil emissions while still being able to use the wood for commercial purposes. Continuous cover forestry (CCF) has been suggested as one solution to minimize carbon dioxide (CO_2) emissions from peatland forests (Leppä *et al.*, 2020; Lehtonen *et al.*, 2023). Information about the effects of harvesting is needed, especially from nutrient-rich peatland forests that hold the largest potential for forestry but also have the highest soil emissions.

METHODS

The impact of selection harvest on CO_2 budget of drained peatland forest was studied using recent eddy covariance (EC) data measured in a nutrient-rich peatland forest site Ränskälänkorpi in Southern Finland. EC tower (height 29 m) was located in the border of the CCF treatment and control and measured CO_2 flux from both treatments depending on the wind direction. CO_2 flux data (Oct 2019 – Apr 2024) was gapfilled (data coverage 28 % and 12 % for CCF and control after filtering, respectively) using extreme gradient boosting (Vekuri *et al.*, 2023). Effects of selection harvest (Mach 2021) on CO_2 budget, gross primary productivity (GPP) and total ecosystem respiration (TER) of CCF treatment were estimated by comparing pre- and post-harvest years of the CCF site and using the control site as a comparison for the harvested treatment.

RESULTS

CCF was a net source of CO_2 of 310±80 g C m^{-2} y^{-1} before harvesting (Fig. 1). Net CO_2 flux was 390±70 g C m^{-2} y^{-1} first year after harvesting and decreased to 320±30 g C m^{-2} y^{-1} in the second year after harvesting. During the third year after harvesting, net flux further decreased 120±60 g C m^{-2} y^{-1}. During the same years control was a net source of CO_2 with CO_2 budget varying between 430±130 and 710±120 g C m^{-2} y^{-1}. GPP decreased from 1390 to 950 g C m^{-2} y^{-1} first year after harvest but increased after that reaching 1230 g C m^{-2} y^{-1} third year after harvest. TER of CCF decreased from 1670 to 1330 g C m^{-2} y^{-1} in the harvesting year and stayed close to that the two following years.

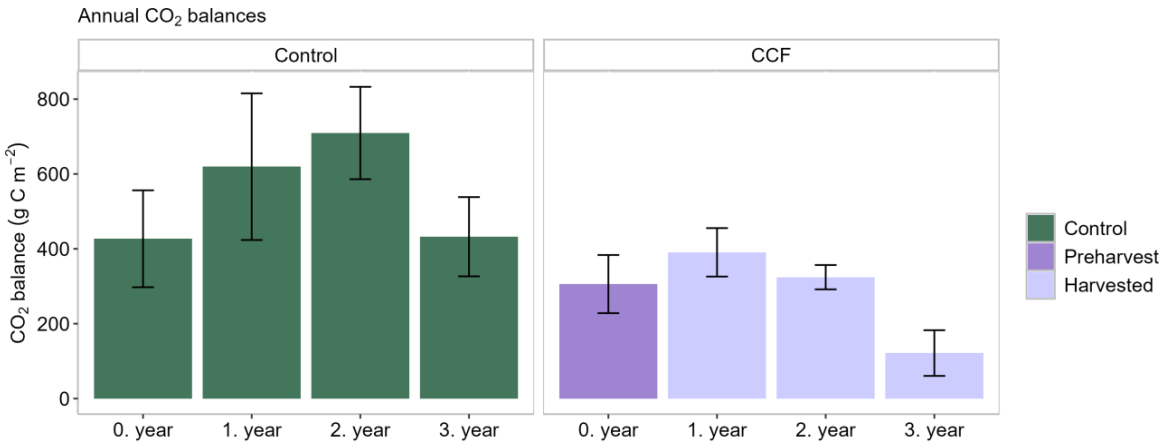

Figure 1. Annual net CO_2 balances of control and the continuous cover forestry (CCF) treatment. Harvesting was done in CCF in March 2021. Budgets are calculated for each year starting from April (0. year = 04/2020 – 03/2021, 1. year = 04/2021 – 03/2022, 2. year = 04/2022 – 03/2023, 3. year = 04/2023 – 03/2024).

CONCLUSIONS

Peatland forest site was a large source of CO_2 before harvesting, but the net source of CO_2 has decreased second and third year after selection harvest. The decrease in the net annual CO_2 emissions in the CCF treatment second and third year after harvest can be explained by increasing GPP while TER remained relatively stable between postharvest years. Since CO_2 budget greatly varied between years in the control, year-to-year variation in environmental conditions may affect the annual CO_2 budget also in CCF.

ACKNOWLEDGEMENTS

The work was funded by Academy of Finland (Biogeochemical and biophysical feedbacks from forest harvesting to climate change – BiBiFe, Grant no. 324259; Managing Forests for Climate Change Mitigation – FORCLIMATE, Grant no. 715 347794). We also thank for the support of ACCC Flagship funded by the Academy of Finland (Grant no. 337552).

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CORRECTING THE BIAS BETWEEN SIMPLE AND COMPLEX MONOTERPENE OXIDATION SCHEMES WITH NEURAL NETWORKS - DEFINING THE VARIABLE SPACE

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Keywords: α-pinene, oxidation, neural network, climate model, VBS.

INTRODUCTION

An important step in the formation of secondary organic aerosol (SOA) is the oxidation of volatile organic compounds (VOC), which produce compounds capable of condensing into the particle phase. One VOC group affecting SOA formation are monoterpenes emitted from vegetation, often modelled using properties of α-pinene. The VOC emissions from vegetation have been found to be temperature dependent, creating a climate feedback through SOA-induced aerosol climate effects (Yli-Juuti *et al.*, 2021). To simulate SOA in a changing climate more accurately, the volatility of the products from monoterpene oxidation under varying conditions should be represented in climate models. In current climate models, VOC oxidation is either extremely simplified or nonexistent. One example of a model with a simplified VOC oxidation scheme is the sectional aerosol module SALSA, which can be used in global-scale simulations (Kokkola *et al.*, 2018; Irfan *et al.*, 2024).

In recent years, experimental research has lead to an improved understanding of α-pinene oxidation chemistry, and its description in process-scale models has also become more accurate. The use of such detailed models in global-scale simulations is inhibited by their high computational cost. In our study, we aim to train a neural network (NN) to predict the difference in the volatility distribution of the α-pinene oxidation products from a detailed chemistry model and from the simple scheme in SALSA, accounting for the variation in atmospheric conditions. Ultimately, our objective is to combine the NN with SALSA to correct the biases caused by the simplified formulation, and implement this revised parametrization into a global climate model, such as ECHAM-HAMMOZ (Schultz *et al.*, 2018). The oxidation conditions which form the NN training data will be generated by sampling from ranges decided based on an ECHAM-HAMMOZ simulation. As a first phase, we investigate the variable space required for training the NN.

METHODS AND RESULTS

We use the ADCHAM model (Roldin *et al.*, 2014), which includes MCM and the near-explicit oxidation chemistry model PRAM developed by Roldin *et al.* (2019), to simulate the training set for the NN. As SALSA calculates aerosol processes independently at each grid box within the framework of ECHAM-HAMMOZ, we have similarly run ADCHAM as a box model. To select which variables should be included as inputs to the NN, their impact on the resulting volatility distribution was analyzed by changing their values in ADCHAM simulations individually, while setting other variables

to atmospherically realistic values (Fig. 1a). The effects of atmospheric pressure, relative humidity, and SO_2 on the resulting volatility distribution were found to be relatively small. On the other hand, NO, NO_2, NO_3, and CO had a more significant effect, based on which their concentrations are included as inputs to the NN, in addition to temperature, OH, O_3, and α-pinene.

To define the atmospherically relevant range for each input parameter for the NN training set generation, their variation in the atmosphere is investigated from ECHAM simulations. An example of the analysis on the vertical distribution of α-pinene according to ECHAM-HAMMOZ simulations is seen in Figure 1b. In both the boreal region and the Amazon, α-pinene concentrations were found to be potentially relevant for oxidation in at least 3–4 model levels above surface, indicating the importance of accounting also for model levels other than the surface. To finalize the sampling ranges for each input variable, an additional climate simulation incorporating more detailed chemistry will be run to define the atmospheric conditions of significant α-pinene oxidation. Based on this, we will select the range from which to sample each of the input variables. Then, the training data can be generated and the NN models trained. Finally, different NN architectures and other model variants will be evaluated in the box model configuration against the ADCHAM simulations.

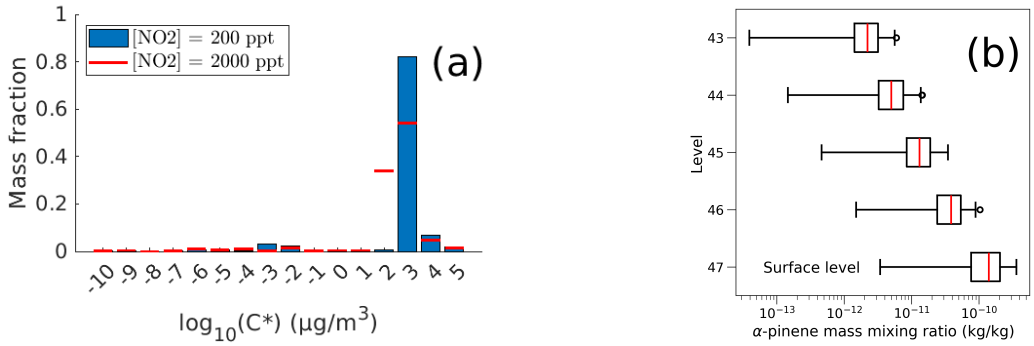

Figure 1: (a) Volatility distributions of the oxidation products in two ADCHAM simulations. C* stands for the saturation mass concentration of the compounds. (b) Vertical profile of α-pinene across the boreal region according to ECHAM-HAMMOZ based on yearly averages.

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RESULTS AND INSIGHTS FROM THE FIRST ANNUAL ACTRIS SUB-10NM INSTRUMENT INTERCOMPARISON WORKSHOP

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Keywords: ACTRIS, Calibration, Instrumentation, Intercomparison.

INTRODUCTION

The investigation of aerosol properties, associated phenomena, and nanoscale processes, such as new particle formation, has gained significance in the light of climate research (Lee, 2023). Integrating localized data into synoptic measurement networks aids in understanding the relationships influencing climate and atmospheric aerosol dynamics, enhancing comparability among various studies. The ACTRIS (Aerosol, Clouds, and Trace Gases Research Infrastructure) network is a key initiative addressing this need. As a pan-European research platform it is dedicated to advance atmospheric sciences and climate research by providing standardized measurement approaches, state-of-the-art facilities, and high-quality data adhering to strict standards. These regulations cover the methodologies for measurements and data processing, along with a curated list of approved measurement systems meeting minimum performance criteria. To ensure relevance within the ever-evolving field of instrumentation, ACTRIS is bound to regularly update this list.

In this context the Cluster Calibration Center (CCC) – located at the university of Helsinki, Finland - part of the ACTRIS Center for Aerosol In-Situ Measurements - European Center for Aerosol Calibration (CAIS-ECAC) organized its first inaugural sub-10nm instrument intercomparison workshop in November 2023.

METHODS

The objective of the ACTRIS CAIS-ECAC instrument intercomparison workshop was to assess and compare the effectiveness of various aerosol particle size spectrometers designed for measuring sub-10 nm aerosol particle-size-distributions, -concentrations and overall performances. The workshop featured various instruments, including the Airmodus A11 (Vanhanen et al., 2011) its upgraded version the A12 retrofit (Sulo et al., 2023), a Grimm PSMPS, a TSI 3756, a TSI 1nm-SMPS, and a TSI 3789. These were tested on different measurement arrangements such as the Hauke- (Winklmayr, 1991) and Half-Mini-Setup (Fernández de la Mora, 2013), utilizing tungsten oxide (WO_x) particles. Furthermore, the instruments were

compared on their response for measurements conducted on a custom-made aerosol injection tank and on environmental conditions.

RESULTS

For most of the parameters investigated the participants showed reasonable alignment with the claims of the manufacturers. Moreover, the measurements revealed a lower concentration detection limit for the activation-based systems (Airmodus A11 and A12). Both these instruments alongside the GRIMM PSMPS showed a lower size detection limit compared to the remaining mobility-based devices (TSI 3756, TSI 1nm-SMPS, and TSI 3789). In terms of sizing performance, a difference was observed between the two instrument classes as was for the average size distributions measured within the custom-made chamber (see Figure 1). Additionally, we were able to verify a systematic size shift for 4-way-cross WO_x particle generators.

CONCLUSIONS

The workshop provided valuable insights into instrument performances, highlighting best practices and areas for improvement. These findings will also influence the planning of future workshops significantly, ensuring more effective evaluations of aerosol measurement techniques and intercomparisons.

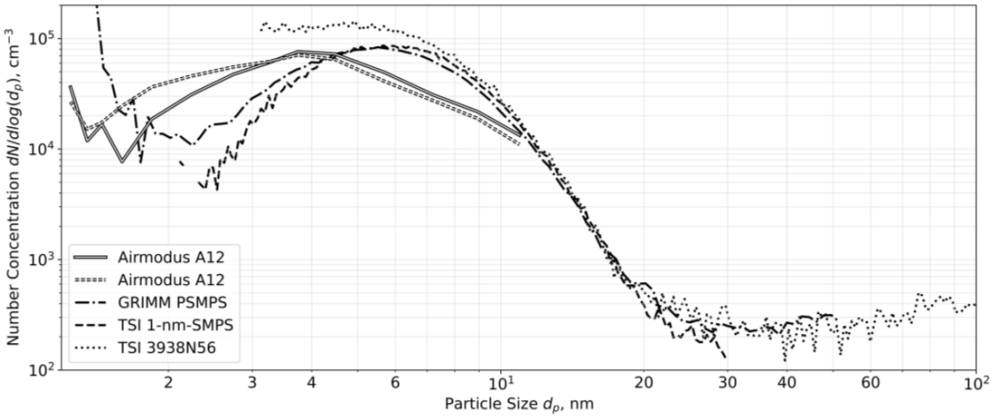

Figure 1. Comparison of the average number size distribution for different particle sizer instruments measuring on the custom-made aerosol injection tank.

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AN ALGORITHM FOR AUTOMATED PEAK IDENTIFICATION IN ATMOSPHERIC MASS SPECTRA

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Keywords: Volatile organic compounds, Instrument development, Mass spectrometry.

INTRODUCTION

Mass spectrometers are a key class of instruments for studying the chemistry of the atmosphere and of atmospheric aerosol (Pratt and Prather, 2012; Junninen et al., 2010; Huey, 2007). One significant challenge when utilizing mass spectrometry to study the atmosphere is the vast amounts of different compounds present within ambient air. These thousands of compounds in combination with the limited mass resolving power of commonly used mass spectrometers, such as those utilizing time of flight to determine masses of measured molecules, makes identifying the chemical formulas of observed molecules a time consuming process. Often the signals from several different compounds overlap within mass spectra, and the underlying individual compounds are deduced using peak fitting (Stark et al., 2015; Junninen et al., 2010). However, identifying all the compounds present in a dataset may take researchers anywhere between days and months, depending on desired accuracy and the size of the dataset.

This work intends to cut down this time significantly, by providing an algorithm for fitting and identifying peaks in datasets completely automatically. In doing so a large fraction of time currently spent on peak identification can be allotted to more meaningful analysis of results.

METHODS

The algorithm works by uncertainty weighted peak fitting. The key challenge of automating peak identification is determining the number of peaks to fit, which this algorithm accomplishes by comparing fits containing different numbers of peaks using a slightly modified Bayesian Information Criterion (Neath and Cavanaugh, 2012). The algorithm used a list of potential compounds for identifying fitted peaks as specific chemical formulas. This list was generated combinatorially, by allowing reasonable combinations of the elements C, H, O, N and F.

The algorithm was tested and optimized using synthetic data, in order to have precise knowledge of the peaks contained in the spectra. Finally, the performance of the algorithm was evaluated by applying it to previously analyzed and published data from chamber experiments and ambient aerosol chemical composition measurements (Peräkylä et al., 2020; Graeffe et al., 2023). The results provided by the algorithm were compared against the results of the previously conducted thorough manual analysis.

CONCLUSIONS

The main findings of this work has already been submitted to Atmospheric Measurement Techniques (Mickwitz et al., 2024). Comparison between algorithm and manual results for the both datasets

showed that algorithm was in agreement with manual analysis for over 97% of the signal area, and was able to locate 75% of the peaks that had been identified during manual analysis. These results show that the algorithm is certainly good enough to provide an excellent starting point for further analysis, although manual revision is still required. By automatically identifying the source of a vast majority of the signal, the time required to go through and verify algorithm results is expected to be far shorter than the time required to conduct the analysis from scratch.

Sensitivity tests conducted using synthetic data showed that the algorithm is rigorous enough to to be implemented in a large variety of realistic scenarios for atmospheric mass spectrometry. By implementing this algorithm to established analysis software the goal of significantly reducing peak assignment time will certainly be achieved, and with increased usage additional improvements are likely to further increase the usefulness of this method. Currently, work is being done in close collaboration with Aerodyne Research Inc. to incorporate the algorithm into the widely used analysis software Tofware.The algorithm code will also be provided as open access upon publication.

ACKNOWLEDGEMENTS

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COMPARISON OF SULFATE AND NITRATE IN AIR PARTICULATE MATTERS DURING 4 YEARS IN BEIJING, CHINA AND HYYTIÄLÄ, FINLAND

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Keywords: Sulphate, Nitrate, Air pollution, Aerosol.

INTRODUCTION

Atmospheric sulphate (SO_4) and nitrate (NO_3) are critical components in understanding the dynamics of air pollution, particularly in regions impacted by both natural and anthropogenic emissions (Reiss et al., 2007). The oxidation processes of sulphur dioxide (SO_2) and nitrogen oxides (NO_x), which lead to the formation of SO_4 and NO_3, are influenced by several factors, including meteorological conditions and local emissions (Liu, Chan, & Abbatt, 2021; Orel & Seinfeld, 1977). This study investigates the concentration distributions of SO_4 and NO_3 at two contrasting sites: Hyytiälä, a rural location with limited anthropogenic influence (Heikkinen et al., 2020), and Beijing, a major urban centre with significant pollution sources (Y. Liu et al., 2021). The research explores how these pollutants vary seasonally, diurnally, accumulating time over land and pollution land and under different humidity conditions, providing insights into the effectiveness of pollution control measures and the influence of natural and anthropogenic factors on air quality.

METHODS

The sulphate and nitrate concentration data were retrieved from 2 Aerosol Chemical Speciation Monitor (ACSM, Ng et al., 2011) located in Beijing University of Chemical Technology (BUCT; 39.9428° N, 119.2966° E), and SMEAR II station, Hyytiälä, Finland (Hari et al., 2013). Other meteorology variables are measured with an Automatic Weather Station. The concentration was provided in 1 hour temporal resolution, study period was form 2018-2021. The Time over Land (ToL) and Time over Polluted Land (ToPL) in short, was the time of airmass arrived when measuring travelled above land or polluted land, it was calculated based on back trajectory calculated by HYSPILT model.

RESULTS

SO_4 and NO_3 concentrations at Hyytiälä follow a normal distribution, indicating several simple point emissions, while in Beijing, the broader distribution reflects both natural and dominant anthropogenic sources. Over time, Beijing's pollutant levels became more normally distributed, due to pollution control efforts. Seasonal variations show NO_3 peaking in the evening during winter and fall in Beijing, while Hyytiälä consistently peaks in the morning. SO_4 concentrations in Beijing peak in the afternoon, especially in summer, with Hyytiälä showing higher concentrations in winter.

In terms of oxidation processes, the sulphate oxidation ratio (SOR) in Hyytiälä remains consistent at around 0.84, while in Beijing it fluctuates around 0.65, with higher values observed from Thursday to Sunday. NO_3 concentrations in both locations peak on weekends. Relative humidity (RH) plays a crucial role in Beijing, where higher RH levels enhance the formation of SO_4 and NO_3. At RH levels above 60%, SOR reaches 0.9 in Beijing, while in Hyytiälä, SOR remains stable across varying RH levels. The nitrate oxidation ratio (NOR) in Beijing also rises with RH, indicating enhanced NO_3 formation via aerosol surface reactions.

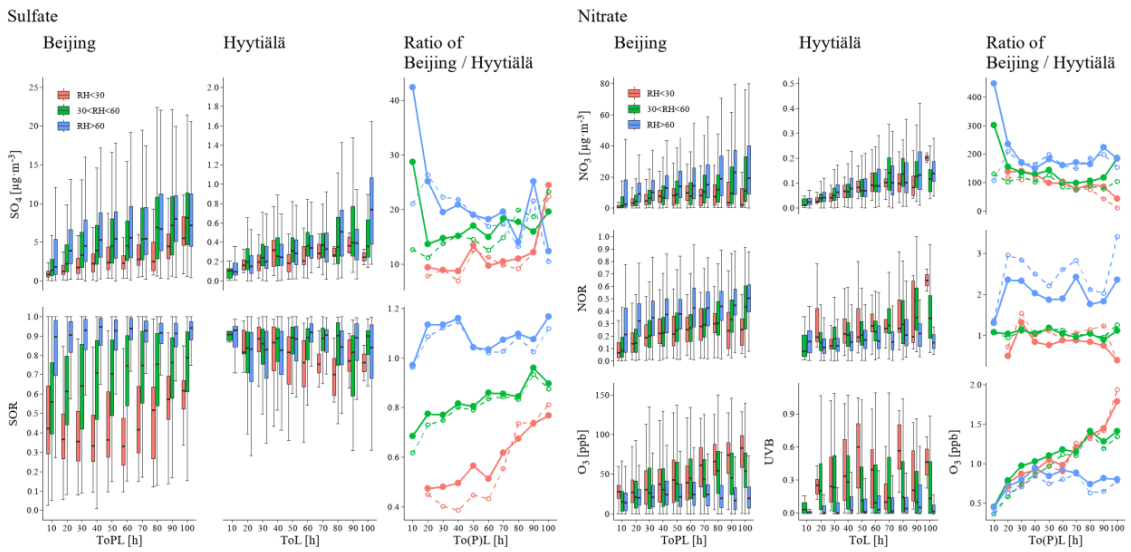

Figure 1. The concentration of nitrate, sulphate, and their oxidation ratio changing with Time over Land (ToL) and Time over Polluted Land (ToPL) at different relative humidity levels.

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EVALUATING THE APPLICABILITY OF A REAL-TIME HIGHLY OXYGENATED ORGANIC MOLECULE (HOM)-BASED INDICATOR FOR OZONE FORMATION SENSITIVITY AT A BOREAL FOREST STATION

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Keywords: ozone pollution, ozone formation sensitivity, highly oxygenated molecules (HOMs), real-time HOM-based indicator, boreal forest.

INTRODUCTION

Ozone (O_3), formed via complex photochemistry involving nitrogen oxides (NO_x) and volatile organic compounds (VOCs), acts as a critical secondary pollutant and oxidant in the troposphere (Wang *et al*., 2017). Therefore, understanding the O_3 formation sensitivity, whether NO_x-limited or VOC-limited, is essential for effective air quality management. Recently, we proposed using the distribution of highly oxygenated organic molecules (HOMs) as a potential real-time indicator to determine O_3 formation sensitivity regimes in chamber studies (Zhang *et al.*, 2024). The key reactions that form O_3, namely those between peroxy radicals and NO, also determine the branching between nitrate-containing and non-nitrate HOM species. However, validation of this indicator outside of laboratory conditions is still lacking. In this study, we evaluate the atmospheric applicability of the HOM-based indicator at a boreal forest station in Hyytiälä, Finland. Using model scenarios where either NO_x or VOC emissions were doubled as references, we find that the ratio of non-nitrate HOMs to HOM organic nitrates from monoterpene oxidation is able to determine O_3 formation sensitivity regimes also in ambient air at this site. Our observations indicate that our rural background station is primarily NO_x-limited, especially during elevated temperatures with high VOC concentrations, but is often also in a transition region between the two limit regions. While our HOM-based indicator for ozone sensitivity regimes was successful at a monoterpene-dominated site, the main challenge in other areas will likely be to identify suitable nitrate and non-nitrate HOM products to replace the monoterpene-derived HOMs used here.

METHODS

The ambient measurements were conducted at the Station for Measuring Ecosystem-Atmosphere Relations (SMEAR) II station, a boreal forest station situated in Hyytiälä, southern Finland (61°51'N, 24°17'E). Gas-phase HOMs were measured using a nitrate-adduct chemical ionization mass spectrometer (NO_3-CIMS, Tofwerk AG/Aerodyne Research, Inc.) with high selectivity. Consistent with our laboratory study (Zhang *et al.*, 2024), species with more than 8 oxygen atoms were used for the Indicating Ratio, IR_{HOM} (the ratio between non-nitrate HOM monomers and HOM organic nitrates, $\frac{\sum HOM_{Mono,O>8}}{\sum HOM_{ON,O>8}}$). VOCs were measured using a proton-transfer-reaction quadrupole mass spectrometer (PTR-MS, Ionicon Analytik GmbH) at 14 different *m/z* values. In order to quantify the sensitivity in the O_3 formation to changes in the ambient NO_x and VOC concentration, we utilize the chemical transport model for Aerosol Dynamics, gas phase CHEMistry and radiative transfer calculations (ADCHEM). Besides the base simulation, two sensitivity runs were performed: One scaling the emissions of NO_x by a factor of two ('2×NO_x') and one scaling the emissions of VOCs by a factor of two ('2×VOCs').

RESULTS

We compared the indicating ratio against the change in absolute O_3 concentration (ΔO_3) under the '2×NO_x' and '2×VOCs' scenarios. The HOM-based IR_{HOM} showed strong correlation with the modeled ΔO_3 (Figure 1A): larger values for IR_{HOM} corresponded to larger ΔO_3 for '2×NO_x' [R^2=0.60 (0.76)] and lower ΔO_3 for '2×VOCs' [R^2=0.21 (0.51)], consistently suggesting an increasing likelihood of the Hyytiälä station being NO_x-limited. Although VOCs and NO_x serve as precursors for O_3 and their ratio ($\frac{\text{VOCs}}{\text{NO}_x}$) has traditionally been used to determine the limiting regimes for O_3 formation, this ratio exhibited a much weaker correlation with the model results compared to the IR_{HOM} (Figure 1B). Substituting total measured VOCs in the indicating ratio for MTs, which are the dominant VOCs at this station[38] and the precursors for HOMs used in IR_{HOM}, did not improve the correlation (Figure 1C). Compared to precursor-based indicating ratios (i.e., $\frac{\text{VOCs}}{\text{NO}_x}$ and $\frac{\text{MTs}}{\text{NO}_x}$), the HOM-based IR_{HOM} exhibits better performance under various conditions, suggesting that it is a robust parameter (Figure 1).

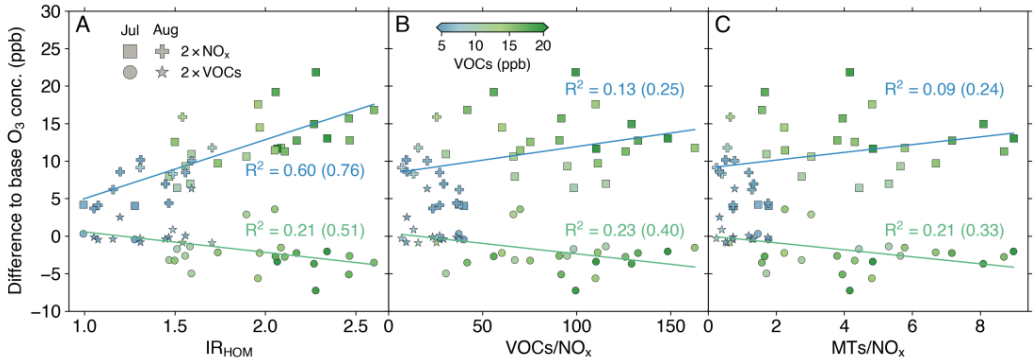

Figure 1. Comparison of modeled O_3 concentration changes from doubled NO_x (2×NO_x) or VOCs (2×VOCs) with different indicating ratios for O_3 formation sensitivity. R^2 values in parentheses represent recalculations after excluding the 5 largest outliers.

CONCLUSIONS

In summary, we evaluated a real-time HOM-based indicator (IR_{HOM}) for O_3 formation sensitivity regimes, using both modeled results and observational data. We conclude that the proposed indicator works effectively also in an atmosphere characterized by high monoterpene concentrations. For conditions where monoterpene HOM are not abundant enough to be used for the indicating ratio, other HOM species would need to be used. The principle behind the HOM-based indicating ratios remains valid across most conditions: HOM and O_3 formation are intrinsically connected through RO_2 chemistry.

ACKNOWLEDGEMENTS

This work was supported by the Jane ja Aatos Erkon Säätiö (the Jane and Aatos Erkko Foundation), and the University of Helsinki through university-funded doctoral researcher positions. R.W. and P.R. received funding from the Swedish Research Council Formas (project no. 2018-01745-COBACCA), the Swedish Research Council VR (project no. 2019-05006), and the Crafoord foundation (project no. 20210969).

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QUANTIFICATION OF PARTICLE-PHASE HIGHLY OXYGENATED ORGANIC MOLECULES (HOMS) IN AMBIENT AIR

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Keywords: Highly oxygenated organic molecules, Monoterpene, Chemical ionization mass spectrometer, Vaporization inlet for aerosols.

INTRODUCTION

Highly oxygenated organic molecules (HOMs) are key contributors to secondary organic aerosol (SOA) in the atmosphere (Ehn et al., 2014). However, research has primarily focused on gas-phase HOM formation due to the lack of analytical techniques capable of detecting particle-phase HOMs. The recently developed Vaporization Inlet for Aerosols (VIA), coupling with a nitrate Chemical Ionization Mass Spectrometer (NO_3-CIMS) has shown the ability to measure particle-phase HOMs in real time (Häkkinen et al., 2023; Zhao et al., 2024). In this study, we present the first ambient application of this novel system for measuring particle-phase HOMs in Helsinki.

METHODS

The VIA−NO_3-CIMS system is the main instrument for detecting and quantifying low-volatile "sticky" HOM species in the particle phase. First, a honeycomb-activated carbon denuder was used to remove gaseous compounds while allowing particles to pass through. The particle stream was then directed into a heated desorption tube to continuously evaporate the particles into the gas phase. A sheath flow unit cooled the hot vapors and minimized wall losses before ionization and analysis by the mass spectrometer. The VIA−NO_3-CIMS system sampled ambient air from the fourth-floor window of the Physicum Building at the University of Helsinki's Kumpula campus (60.20° N, 24.96° E) between August 9 and 14, 2023, using a silica gel dryer and a 5-m long, 10-mm tube.

RESULTS

The VIA−NO_3-CIMS measurements correlate surprisingly well with the Aerodyne Aerosol Mass Spectrometer (AMS). In particular, the trends in sulfate tracked almost perfectly, although the sulfate mass concentration from the VIA was four times lower than the AMS, suggesting higher losses than expected of vapors after evaporation, or alternatively particle losses in the sampling lines leading up to the VIA. For organics, the discrepancy was even larger, with the VIA underestimating mass by a factor of 24. After accounting for the same factor of 4 (assuming a universal vapor and/or particle loss of all species), HOMs were found to contribute approximately 1/6 of total organics, consistent with laboratory-observed particle-phase HOM fractions (14−29%). However, the VIA missed some AMS-detected increases in organics, particularly during the morning of August 13, when hydrogen-to-carbon ratios (H/C) peaked, but oxygen-to-carbon ratios (O/C) dropped, possibly related to a fresh emission plume (Figure 1).

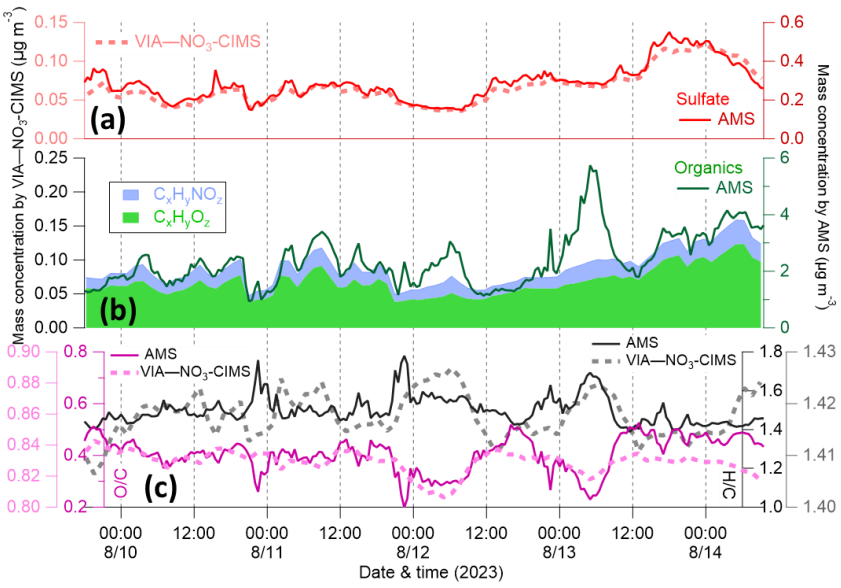

Figure 1. Time series of (a) sulfate, (b) organics, and (c) oxygen-tocarbon (O/C) and hydrogen-to-carbon (H/C) ratios measured by the VIA−NO_3-CIMS and AMS. Note that in panel c, the y-axes do not start from zero.

CONCLUSIONS

This study demonstrates that the VIA-NO3-CIMS system shows great potential as a powerful tool for real-time, quantitative measurements of particle-phase HOMs in ambient organic particles, providing new insights into atmospheric chemistry.

ACKNOWLEDGEMENTS

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UNIVERSITIES, ORGANIZATIONS AND PROFESSIONALS AS CLIMATE CHANGE CO-AGENTS

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Keywords: climate change education, sustainability, agency.

INTRODUCTION

As the need for urgent society-wide action to address sustainability crises grows, it becomes increasingly apparent that current workforce, potentially still active on 40 years from now, is in need of environmental re-education. While the need to reform education systems and policies for continuing education has been acknowledged (Delors, 1998)–often talked about to match technological or economic developments–the continued learning processes associated to sustainability transformations have been seldomly studied (Van Mierlo & Beers 2020). Here, we utilize theories of agency to understand the process in which educated "change-agents" encounter the structural realities of working life.

By observing professional agency (e.g. Eteläpelto et al. 2013), this study builds on the theory of *structuration* on the interplay between individual agents, organizational structures, and the university as an enabler of individual *knowledgeable agency* (Gidden's, 1984). To emphasize the need for this view, Karvinen (2024) found that graduates' agency to promote sustainability in their work was often restricted by organizational constraints, highlighting the need for university education to better address this challenge. Likewise, our hypothesis suggests that educated agency is likely to encounter structural constraints, underscoring the importance of fostering co-agency in the potentially transformative construct of individual agents and the educational and organizational dimensions.

Assessing the climate change specialization program's processes and interplay with the involved agency and its actualization in different contexts, we attain insight for further developing professional sustainability training. This in turn contributes to a deeper understanding and provides recommendations for reforms that reflect the needs and potential of lifelong learning across the entire educational system. The main research question for our study is: *How does climate change agency actualize in professional contexts?* We will explore several sub-questions, including: What promotes or prevents (transformative) agency in organizations? Are there teachable strategies to manage challenges, faced regardless of seemingly given authority to enact changes? How can co-agency between universities, professionals, and organizations be best nurtured and without it, will the vast efforts of sustainability and climate change education ever surmount to the impact we expect?

METHODS

To answer the research questions, we will collect the data during the *Climate Expert Specialization* -training, organized by Institute for Atmospheric and Earth System Research (INAR), University of Helsinki. The data consists of pre- and post-education questionnaires and interviews. Both the pre-education questionnaire and semi-structured interviews have already been conducted. The qualitative data will be analyzed using inductive qualitative content analysis (Drisko & Maschi 2015) using ATLAS.ti software.

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EXPLORATION OF A-PINENE OZONOLYSIS AND AUTOXIDATION USING SELECTIVE DEUTERATION

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Keywords: α-pinene ozonolysis, Autoxidation, Selective deuteration, CI-orbitrap.

INTRODUCTION

Secondary organic aerosol is formed from low-volatile vapours in the atmosphere. These vapours can form from gaseous volatile organic compounds (VOC) undergoing oxidation, which results in the vapours' low volatilities. Upon oxidation, some VOCs have been shown to go through a rapid process called autoxidation (Crounse *et al.,* 2013) forming highly oxygenated organic molecules (HOMs) (Bianchi *et al.*, 2019). The exact autoxidation pathway taken affects the formation rates and the properties of the resulting HOMs, yet a comprehensive step-by-step mechanism of HOM formation has not been described for any system of atmospheric relevance. Due to their generally low volatility, HOMs readily condense on available surfaces, promoting growth and formation of aerosol particles. However, the significance of these compounds is not yet fully understood, hence, it is important to study the intricacies of the autoxidation process.

METHODS

In this work, we studied the initial formation pathways of HOMs in reactions initiated by the ozonolysis of the most abundant monoterpene α-pinene. Following the method described by Meder et al. (2023), we monitored whether hydrogen atoms were lost and at what step in the oxidation process from carbons at positions 1, 3, 4, 5, 7, 8, 9, and 10 using the eight corresponding selectively deuterated α-pinene analogues. We reacted the precursors with ozone to produce oxidation products and HOMs in a flow tube. We monitored the products with the CI-Orbitrap (Riva *et al.,* 2020) where a high mass resolving power (up to 280 000 Th/Th at m/z=200 Th) Orbitrap mass spectrometer is coupled to an Eisele-type chemical ionisation (CI) inlet (Jokinen *et at.,* 2012). We used both nitrate (negative mode, selective towards HOMs) and N-butylammonium (positive mode, broader selectivity range) as reagent ions. Additionally, we ran quantum chemical calculations to determine what could be forming the observed C10H16O3 signal, and tested simple "linear" and "non-linear" oxidation models.

RESULTS AND CONCLUSIONS

We found that the Master Chemical Mechanism (MCM; Saunders *et al.* 2003) seems to underestimate the formation of the first-generation peroxy radical (O_4-RO_2) which has lost a hydrogen atom from carbon position 10 (RO_2-Kb). Furthermore, our data indicates that the ring-breaking mechanism proposed by Iyer *et al.* (2021) explains most of the observed peroxy radical signal with eight oxygen atoms (O_8-RO_2), though we do see indication of other O_8-RO_2 forming from the accretion product signals. Surprisingly, our data shows that $C_{10}H_{16}O_3$ signal cannot be pinonic acid as is commonly assumed (Saunders *et al.* 2003, Capouet *et al.* 2008). Based on quantum chemical calculations, we found that the signal could be explained by secondary ozonide and dioxirane, as the latter was found to be more stable than previously thought (Cremer *et al.* 1998). Our data also highlighted the fact that α-pinene ozonolysis and autoxidation has multiple

branching pathways where some products though they are formed, are not observed or are much less abundant in the mass spectra as they react quickly to form other products. This "non-linearity" is not accounted for when modelling the oxidation of α-pinene, as it is assumed that the observed less-oxygenated products form the observed more-oxygenated products (Fig. 1). We tested using linear and non-linear approaches on cyclohexene data from Berndt *et al.* (2015) and found the non-linear model could explain the behaviour better than the linear model. It is important to accurately model the oxidation processes as it enables better predictions in the changing climate.

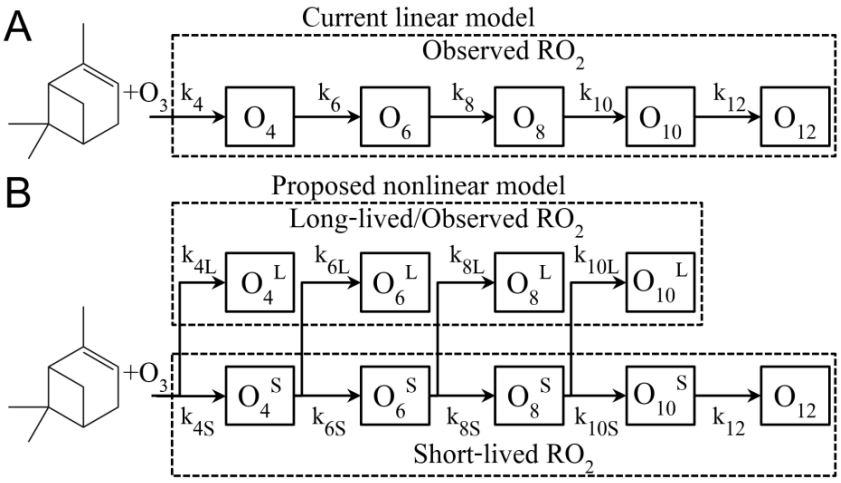

Figure 1. **Current and proposed improved autoxidation modelling schemes.** (**A**) The current linear modelling scheme for autoxidation where peroxy radicals with n oxygen atoms (O_n) produce the next peroxy radicals with added oxygen (O_{n+2}) at reaction rates k_n that are the same for all O_n. (**B**) A nonlinear modelling scheme where the peroxy radicals are separated in short-lived peroxy radicals (O_n^S), and long-lived and thus observable peroxy radicals (O_n^L). The short-lived RO_2 continue to autoxidize forming the basis for the formation of the more oxygenated peroxy radicals. Contrastingly, autoxidation does not continue for the long-lived RO_2 leading to their longer lifetimes. The reaction rates forming short-lived O_n-RO_2 are k_{nS}, and the long-lived are k_{nL}. In both schemes, the subsequent reactions are not shown for clarity.

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DIFFERENTIAL CHARACTERIZATION OF AIR IONS IN BOREAL FOREST OF FINLAND AND MEGACITY OF EASTERN CHINA

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Keywords: Air ions, new particle formation, SMEAR II, SORPES.

INTRODUCTION

Air ions can play an important role in new particle formation (NPF) process and consequently influence the atmospheric aerosols, which affect climate and air quality as potential cloud condensation nuclei (Kulmala et al., 2007; Yu and Turco, 2008). However, the air ions and their role in NPF have not been comprehensively investigated yet, especially in polluted area. To explore the air ions in polluted environment, we compared the air ions at SORPES site, a suburban site in polluted eastern China, with those at SMEAR II, a well-studied boreal forest site in Finland, based on the air ion number size distribution (0.8-42 nm) measured with Neutral Cluster and Air Ion Spectrometer (NAIS) during 7 June 2019 to 31 August 2020. In this study, according to the protocol of the atmospheric electricity measurement community, air ions were mobility-classified as cluster or small ions (3.2-0.5 $cm^2\ V^{-1}s^{-1}$), intermediate (0.5-0.034 $cm^2\ V^{-1}s^{-1}$), and large ions (0.034-0.0042 $cm^2\ V^{-1}s^{-1}$), which correspond to mobility diameters of 0.8-2, 2-7, 7-20 nm, respectively. We first compared the ion concentration and their diurnality and seasonality between SMEAR II and SORPES sites. Subsequently, we analyzed the correlation between ion concentration and related factors. we next compared the NPF characteristic at two sites, including the frequency of NPF, formation rate and growth rate of ions. In parallel, the role of ions in the new particle formation were analyzed at two sites. In this work, we aim to characterize the similarities and differences in ion characteristics and contribution of ion to NPF between more pristine boreal forests and complex urban polluted environments.

METHODS

In this work, all the measurements for the comparison in SMEAR II and SORPES were conducted during a year period between June 2019 to August 2020. The SMEAR II station is located in Hyytiälä, southern Finland. This station is a boreal forest site in a pristine rural environment. SMEAR II has carried out the world's longest, continuous measurements of aerosol particle-number concentration and size distribution since 1996. The SORPES station is located about 20 km east of downtown Nanjing in eastern China. With few local emission sources within 2−3 km surrounding. Under the prevailing eastly wind throughout the year, the site primarily measures background air in well-developed Yangtze River Delta (YRD) metropolitan region, which is practically a gigacity that many megacities clustered along the Nanjing to Shanghai axis. Ambient air ion size distribution data employed in this study were all measured by NAIS.

RESULTS

Median concentration of cluster ions at SORPES (217 cm^{-3}) was about 6 times lower than that at SMEAR II (1268 cm^{-3}) due to the high CS and pre-existing particle loading in polluted area, whereas the median large ion concentration at SORPES (197 cm^{-3}) was about 3 times higher than that of SMEAR II (67 cm^{-3}). Seasonal variations of ion concentration differed with ion sizes and ion polarity at two sites. High concentration of cluster ions was observed in the evening in the spring and autumn at SMEAR II, while the cluster ion concentration remained at a high level all day in the same seasons. The NPF events occurred more frequently at SORPES site (SMEAR II 16%; SORPES: 39%), and the highest values of NPF frequency at both sites were in spring ((SMEAR II: spring: 43%; SORPES: spring: 56%).

CONCLUSIONS

The median ion-induced fractions were estimated to be 19.9% at SMEAR II and 1.3% at SORPES, suggesting that the contribution of ions to NPF, especially in polluted environment. However, our findings indicate that the contribution of ions to NPF is not negligible. The charged particles were activated earlier than neutral particles at SORPES, suggesting charged particles were more readily activated than neutral particles in polluted urban environment. Overall, this study presented a comprehensive comparison of air ions in completely different environments and highlighted the need for long-term ion measurements to improve the understanding of air ions and their role in NPF in polluted area like eastern China.

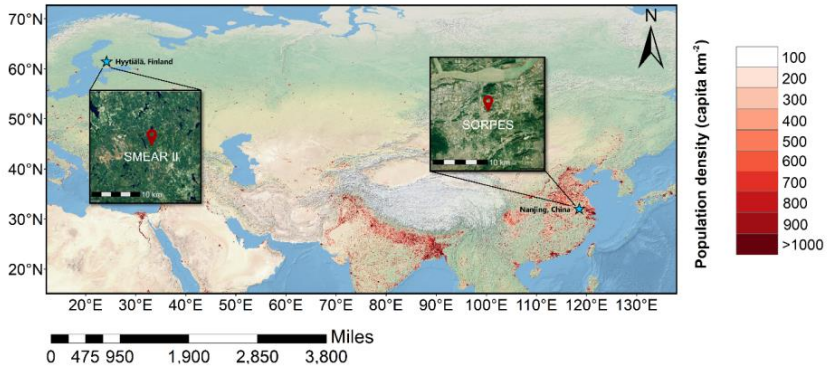

Figure 1. Locations of SMEAR II in Hyytiälä, Finland and SORPES in Nanjing, eastern China on the map with population density.

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UNDERSTANDING AEROSOL PARAMETRIC UNCERTAINTY IN CLIMATE MODELLING: FIRST INSIGHTS FROM ONE-AT-A-TIME SENSITIVITY STUDIES ON THE CHEMICAL TRANSPORT MODEL TM5

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Keywords: Aerosols, PPEs, Emulator, Radiative forcing.

INTRODUCTION

Parametric aerosol uncertainty in global scale climate models can be as large as intermodal uncertainty (Johnson et al., 2020). To improve climate predictions, we need to understand and reduce this uncertainty. This study focuses on TM5, a chemical transport model (CTM) used in EC-Earth3 an Earth System Model (ESM) that contributes to the Coupled Model intercomparison Projects (CMIPs). Conducting a parametric uncertainty study with TM5 has never been done before. Thus, improving aerosol uncertainties in TM5 is necessary to reduce CMIP's aerosol related uncertainties.

METHODS

Aerosol parameters (table 1) are inputs to TM5 that describe the aerosol sources, sinks, transformations, physical, chemical and optical properties.

Table 1: select aerosol parameters with their uncertainty ranges to be used in TM5 PPE. * R indicates range, F indicates scaling factor.

Parameter	Uncertainty *	Source
Sea spray emission	F 0.2 - 5	(Lee et al., 2013)
Black carbon emission	F 0.5 - 2	(Yoshioka et al., 2019)
DMS emission	F 0.5 - 2	(Lee et al., 2013)
Aging rate	R 0.3 - 5	(Lee et al., 2013)
SO4 primary emission diameter	R 3-100nm	(Yoshioka et al., 2019)

We have performed one-at-a-time sensitivity studies which involves varying one aerosol parameter at a time across its uncertainty range and analyzing TM5's climate-relevant outputs, such as cloud condensation nuclei concentration and ambient aerosol absorption optical thickness at 550nm, to measure the impact.

RESULTS

The preliminary results (Figure1) show increase of absorption in TM5 when ELVOCs molar yield from isoprene oxidation (OH and O3) are increased, opposed to increased emission of sea spray.

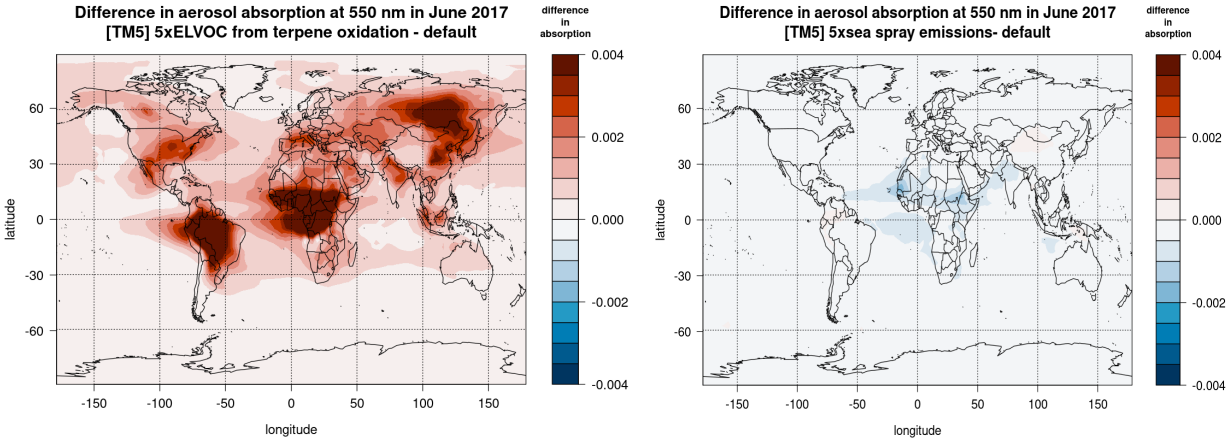

Figure 1. Difference in ambient aerosol absorption optical thickness at 550nm in June 20167 from scaling ELVOC from terpene oxidation by a factor 5 (a) and sea spray emission by a factor 5 (b).

CONCLUSIONS

Based on these results, we aim to conduct a perturbed parameter ensemble (PPE) study on the aerosol parameters that have the greatest impact on climate relevant outputs. A PPE is a set of simulations created by perturbing multiple uncertain parameters in a model simultaneously. It is used to understand how parameter uncertainties affect uncertainties in model outputs, such as aerosol radiative forcing (yoshioka et al., 2019).

Due to high computational cost of running the PPE, I will use an emulator as a statistical surrogate of my CTM model (TM5). The emulator aims to provide denser output data across the parameter space, identifying influential parameter combinations and accurately measuring uncertainties in climate- relevant outputs.

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