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PEATLAND RESTORATION AS A NATURE BASED SOLUTION TO TACKLE CLIMATE CHANGE AND BIODIVERSITY LOSS

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Keywords: peatland, rewetting, ecosystem services, biodiversity.

INTRODUCTION

We are facing multiple interlinked crisis such as biodiversity loss and climate change. Environmental crisis don't come without consequences to societies, but are interconnected with food, energy, and water availability, and to economy. Several national (e.g. Maankäyttösektorin ilmastosuunnitelma (MISU)), European (Biodiversity strategy for 2030, Nature restoration law) and international (Rio Conventions, the Ramsar Convention on Wetlands, the United Nations (UN) 2030 Agenda for Sustainable Development and the UN Decade 2021-2030 on Ecosystem Restoration) acts call for action to tackle the crises. As "high-carbon" ecosystems the protection, restoration, and sustainable management of wetlands and particularly peatlands receive specific attention.

Peatlands produce several ecosystem services, with significant importance in areas where they cover large extents such as boreal zone and countries like Finland (~30% of land area covered by organic soils). The most recognized ecosystem services provided by peatlands are "biodiversity, habitat provision and nature conservation", "global climate regulation" and "water quality and nutrient regulation". Europe has a long history of peatland land use, starting from drainage for agricultural purposes, peat extraction for farm animal bedding and heating, and drainage for forestry. This has led to 10% of Europe's peatlands completely lost, while 46% are at degraded condition (UNEP 2022). Consequently, several peatland habitats and peatland dwelling species are red listed also in Finland (Hyvärinen et al. 2019; Kontula & Raunio 2019). More so, peatland drainage has led to significant GHG emissions, estimated at 582 Mt CO_2 e a^{-1} for Europe (UNEP 2022). Expectedly, peatland rewetting and restoration has been suggested as an efficient nature-based solution (NbS) to tackle the environmental crises (e.g. Humpenöder et al. 2020; Leifeld & Menichetti 2018). Peatlands, neither the drained ones or the restored or pristine ones, do not form a uniform group with similar functions and impacts on ecosystem service provision. Efficient use of peatland management as NbS requires detailed understanding on the variability of functions of different peatland types.

PEATLAND RETORATION AND RESEARCH IN FINLAND

In Finland peatland restoration has been focused on forestry drained peatlands, with first experiments performed in the 1970s and 1980s to protect exceptionally valuable species and habitats. Currently the restored peatland area exceeds 55 000 ha (Metsähallitus 2023, personal communication). With the upcoming nature restoration law, the volume of restoration is likely to continue to increase. In Finland we have good understanding and skills on forestry drained peatland restoration (Aapala & Similä 2014).. The method of rewetting and (partial) removal of trees developed by Metsähallitus has proved effective in restoring water table and general peatland vegetation rather quickly (Kareksela et al. 2021). Yet, there are still several knowledge gaps that make use of peatland restoration as an efficient NbS uncertain.

When considering climate change mitigation potential, the starting point of restoration has great impact. The GHG emission of peatlands under different land uses are rather well quantified, and choosing sites with higher emissions could be expected to have best climate change mitigation potential (Ojanen & Minkkinen, 2020). However, restoration or rewetting of "the best" options namely organic croplands and grasslands is still little studied in Finland and has consequences on farmers and food security. Paludiculture is suggested

as a prominent way for just transition, but markets for products are not yet developed and even the impacts on GHG emissions are not widely studied. In Finland it is more likely that most of the peatland restoration, also in the future, will be targeted on forestry drained peatlands. To support provisioning of different ecosystem services, the site selection becomes an important tool. It is well known that nutrient poor and nutrient rich forestry drained peatlands vary in their GHG emissions, but we still have very little data to estimate the development of GHG sinks and sources after the restoration.

CONCLUSIONS

To use peatland restoration as an efficient NbS, we need to investigate what are the potential restoration pathways, i.e. what kind of vegetation communities occur following restoration. In addition, we need to quantify the ecosystem functions related to each of these successional stage after restoration. This requires more field measurements and modelling. More so, we cannot forget people and society, but we need to find ways to make peatland rewetting and restoration socio-economically sustainable. Search for the answers to these questions has seen a rise of several research projects on the field, such as University of Eastern Finland based projects WaterLANDS (Water-based solutions for carbon storage, people, and wilderness, , coordinated by University of Dublin, Ireland), TurvaHiili (Restoration of Low-productive Drained Peatlands - With Well Targeted Site Selection and Good Practices Towards Safeguarding of Soil Carbon Storage and Improved Functional Biodiversity, coordinated by UEF and Return of Sphagnum.

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THE ROLE OF TAILORED CLIMATE SCENARIO INFORMATION FOR THE PSYCHOLOGICAL DISTANCE TO CLIMATE CHANGE AND THE PERCEIVED LEGITIMACY OF CLIMATE POLICY PATHS

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Keywords: Climate communication, climate model downscaling, climate policy, psychological distance.

INTRODUCTION

Implementation of climate policies requires broad public support. The perception of climate change risks has been considered an important factor explaining climate policy attitudes and the varying level of support for climate policy (Smith and Mayer, 2018). It has been argued that climate impacts remain psychologically distant to many people, which affects the way they perceive the necessity of emission reductions (Spence *et al.*, 2012). Greater perceived distance to climate change consequences has been observed to be linked with less public engagement in climate change issues and less support for climate policies (Singh *et al*., 2017). In addition, lack of knowledge regarding the variety of consequences that different strategies have leads to tunnel vision (narrow focus e.g., on immediate costs instead of the full spectrum of impacts), which distorts the process of forming an opinion about the fairness of those strategies.

In this study, the effect of personally tailored climate impact information (scenarios for 2040) on the opinions and attitudes of the Finnish public regarding climate strategies was studied. The work addresses the following research questions: 1) How do Finnish people regard their knowledge level about local climate impacts in different emission scenarios? What is the actual level of knowledge and is it linked to attitudes?; 2) What is the level of psychological distance (PD) to climate change in Finland and is there differences between demographic groups?; and 3) Does personally tailored climate scenario information affect the PD and attitudes about climate policies?

METHODS

An interactive online tool to depict the outcomes of downscaled climate models and a personalized vulnerability estimate (Fig. 1) were developed to bring the information close to people: to consider people like them and their local environment. For local climate scenarios, we applied downscaled global climate model data produced as part of the Climate Impact Lab Global Downscaled Projections for Climate Impacts Research (CIL GDPCIR) project (Gergel, 2023). Two scenarios were considered: SSP1-2.6 ('decreasing emissions'), and SSP2-4.5 ('increasing emissions') for variables precipitation and daily minimum and maximum near-surface air temperature. From the ensemble output, the following metrics were derived: number of heat wave days, duration of winter and number of heavy rain days. For projected air quality in the two emission scenarios, we applied the ECHAM-HAMMOZ model. Electricity consumption in the scenarios was derived based on simulations regarding the need for heating by Ruosteenoja and Jylhä 2021.

A survey (n=1017) representing Finnish public was conducted to find out the level of knowledge, attitudes towards climate policies and psychological distance (PD) to climate change among different demographic groups before and after using the tool. The survey consisted of claims (responses at a 5-step Likert scale: from “fully disagree” to “fully agree”), a knowledge test, and open questions.

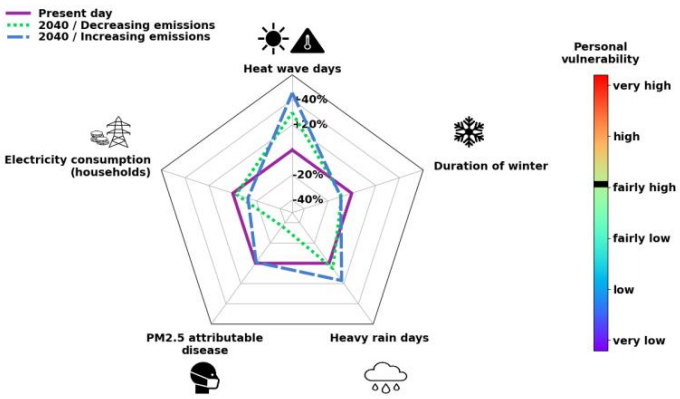

Figure 1. An example output of the interactive tool showing changes in five metrics for a given location by year 2040 as compared to the level of present day in two scenarios, and a person's vulnerability level.

RESULTS

The knowledge level about local impacts in climate scenarios was low, but the respondents' confidence in their own knowledge increased after using the tool and opinions about climate policy became clearer. The potential of climate policies to alleviate changes in the living environment was perceived as higher after obtaining the tailored information. No polarization in attitudes towards climate science and policy was found between respondents with urban and rural domicile. Age and income level, however, were associated with differences in attitudes and PD to climate impacts. The Finnish public perceived climate impacts as spatially proximal, while the temporal and social dimensions of distance indicated more variation. For those with low vulnerability, climate impacts appeared as more distant after obtaining personally tailored information. To form an opinion about the fairness of climate strategies, the respondents were most keen to have global information and possibilities to compare the impacts and actions in Finland with other countries.

CONCLUSIONS

Local and tailored information about climate scenarios increases knowledge, but its effect on PD, attitudes and the perceived fairness of policy paths depends on demographic group and personal vulnerability to climatic risks. For those without such attributes that increase their vulnerability, tailored scenario information may increase the PD to climate change impacts and cause an attitudinal shift towards more negative, while for others the opposite may occur. This should be considered in climate communication.

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EARTH SYSTEM IMPACTS OF A REALISTIC OCEAN ALKALINIZATION DEPLOYMENT SCENARIO

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Keywords: ocean, alkalinity enhancement, CO2 removal, earth system model.

INTRODUCTION

Negative emission technologies (NETs) are an integral part of most climate change mitigation scenarios limiting global warming to 1.5 °C above preindustrial levels. Several different NETs have been proposed, including ocean alkalinization that has been considered as one method with high carbon removal potential (IPCC, 2018). To date, most studies on NETs with Earth System Models have been based on idealized scenarios where atmospheric carbon is either simply removed by prescribed amount or some NET is deployed at magnitudes that would be extremely challenging to reach if any economic, technical, or political constraints were considered (Keller et al., 2014).

METHODS

Here, we present a more realistic global deployment scenario for ocean alkalinization with CaO dispersed at ocean surface in the exclusive economic zones of US, Europe, and China, based on their respective production capacities. The dispersion scenario is based on current excess capacities in the lime and cement industries, and high-end projections on how they could evolve until 2100. We use the high-overshoot SSP5-3.4-OS as the socioeconomic background scenario. We simulate the deployment scenarios with two different Earth System Models: EC-Earth and NorESM2-LM. We will show results from two simulations with alkalinity enhancement deployment initiated in 2030 and 2040.

RESULTS

The preliminary results from NorESM2-LM show that the CO_2 is being removed from the atmosphere to oceans after the alkalinity deployment. When comparing to the control simulation the global CO_2 concentration is reduced by 7 ppm in the deployment scenario starting in 2030 and 4 ppm in the deployment scenario starting 2040 by end of the century (see Fig. 1). For real life deployment the efficacy and detectability of the alkalinity enhancement is a major concern. We will show that the temperature change in the earlier deployment scenario (higher removal potential)

cannot be distinguished from the annual variability illustrates the problem in detectability. In the current simulations there are still issues with too high alkalinity in low oceanic transport regions.

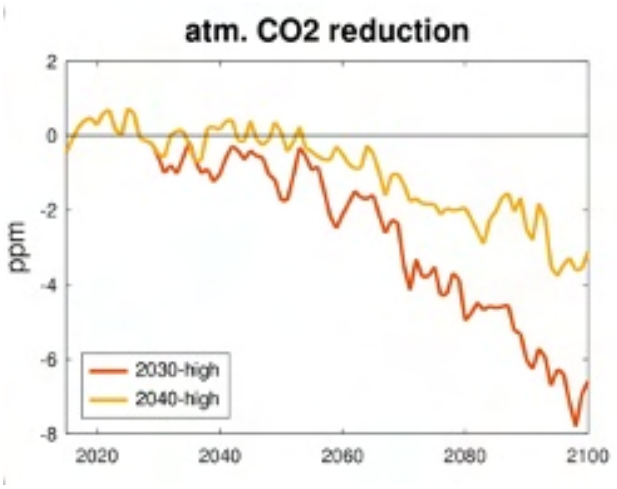

Figure 1: Change in atmospheric CO_2 concentration in two scenarios compared to the simulation without alkalinity enhancement. Yellow line depicts the change in deployment initiated at 2040 and red line shows the earlier initiation in 2030.

CONCLUSIONS

Using a more realistic scenario for ocean alkalinization we can give a more realistic assessment of its climate effects and explore new research questions such as detectability of local changes in pH or carbon fluxes with slowly increasing deployment rates. The realistic deployment scenario does not produce a large signal in the temperature but does decrease the CO_2 concentration. Therefore, this method can be seen only as a small component in reducing the carbon in the atmosphere. Furthermore, the effects on the natural system still require more analysis.

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AIR MASS TRANSFORMATION OVER BOREAL FOREST: EFFECT ON CLOUDS AND PHOTOSYNTHESIS

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Keywords: CLOUDS, BOREAL FOREST, PHOTOSYNTHESIS, AIR MASS.

INTRODUCTION

Clouds play a crucial role for the Earth radiation budget, with low clouds having a net cooling effect. Boundary-layer clouds are in contact with the underlying surface: an air mass moving over a rather homogeneous surface, e.g., forest or ocean, is transforming accordingly and acquiring properties specific of that surface. Importantly for clouds, a surface can be a source of atmospheric aerosol particles and water vapour. Surface albedo, thermal properties, moisture and roughness influence its energy budget with consequences on air mass transformation. It was shown earlier that forest can contribute to increasing low-level cloud cover as compared to grassland areas (e.g., Duveillier *et al.*, 2021). In future warmer climate, forest is a strong source of aerosol particles, making low-level clouds optically thicker (Yli-Juuti *et al.*, 2021). Moreover, transformation of air masses from polar marine to continental over boreal forest is characterised by an increase in cloud condensation nuclei and absolute humidity. There are also indications that clouds become optically thicker and precipitation frequency is somewhat enhanced after air mass has spent 50-55 h over boreal forest (Petäjä *et al.*, 2022, Räty *et al.*, 2023). Here we continue analysis to include effect of forest on clouds and photosynthesis employing satellite and ground observations data.

METHODS

The data set used in this study includes atmospheric observations and satellite data. Satellite data set is MODIS Level-2 cloud product, and cloud optical thickness and cloud fraction for liquid boundary layer clouds over the SMEAR II station were aggregated to a resolution of 0.25°. Atmospheric observations include the air temperature, relative humidity, global and diffuse radiation, cloud base height and CO_2 fluxes (specifically gross primary production, quantifying photosynthesis) measured at SMEAR II, Finland. The data sets used in this study cover the summer seasons during 2008-2018. Air temperature and relative humidity were used to calculate vapour pressure deficit; global radiation and cloud base height were used to classify clouds following Ylivinkka *et al.* (2020). One of the parameters used for cloud classification is transmittance: the ratio between measured and modelled clear-sky global radiation, averaged over 20-min intervals.

The study consists of several parts. First, we assess the link between radiation-based transmittance (TR) on the one hand, and satellite-based cloud parameters: cloud fraction (CF) and cloud optical thickness (COT), on the other hand. Second, we relate transmittance and vapour pressure deficit (VPD) to photosynthesis via gross primary production (GPP). Third, we assess the change in transmittance, vapour pressure deficit and gross primary production as a function of time over land (TOL). For part 1, we suggest a theoretical formula, and use observations to test it. Part 2 is based on a statistical data analysis. Part 3 employs time-over-land analysis based on back-trajectories as in Räty et al. (2023), also focusing on a clean north-west sector, but extracting from the data set clear sky conditions, cumulus (Cu) and stratus (St) clouds.

RESULTS

The theoretical formula connecting radiation-based TR with satellite COT and CF is in agreement with observations when multilayer clouds are excluded from the data set. Therefore, using transmittance we can assess the joint effect of CF and COT on radiation, and further connect it to photosynthesis. Employing transmittance instead of satellite-based parameters significantly increases the data set available for analysis and allows for a better statistics.

As a reference value of GPP, we choose the mean value for the clear sky conditions. GPP exceeding the reference value by more than a standard deviation corresponds to enhanced photosynthesis, and GPP under the reference value by more than a standard deviation is referred to as dampened photosynthesis. We identified three separate regimes of GPP based on TR, diffuse radiation and VPD. These regimes can be roughly characterized as 1) low or dampened GPP under low radiation conditions (TR < 0.4), 2) enhanced GPP under high global and diffuse radiation conditions, moderate VPD (TR > 0.5 and DiffRad > 250 W m^{-2}) and 3) reduced GPP under high global and low diffuse radiation, high VPD (VPD > 1.7 kPa, DiffRad < 200 W m^{-2}). In VPD- and especially radiation-limited regimes, photosynthesis is dampened, whereas diffuse radiation can enhance photosynthesis. We further assess how different cloud conditions affect the ecosystem and if a given regime can be changed in the process of air mass interaction with boreal forest.

We find that in general, stratus clouds dampen photosynthesis, putting a forest ecosystem into the radiation-limited regime. This effect is augmented with larger values of TOL, with the mean TR decreasing from about 0.3-0.4 down to 0.2. Oppositely, TR for cumulus clouds is high at the level of about 0.8, slightly decreasing at higher TOL above 55 h. Simultaneously, CF tends to decrease with an increasing TOL, indicating that the effect of decreasing transmittance is due to increasing COT. GPP values under cumulus clouds are always above the reference value, indicating enhanced photosynthesis. VPD values are mainly below the approximate threshold of 1.7 kPa, making cumulus clouds favourable for ecosystem photosynthesis. GPP under Cu clouds are also consistently higher than clear-sky GPP for all TOL values.

CONCLUSIONS

Using satellite and ground-based observations, we studied the effect of boreal forest interaction with air mass and its influence on low-level clouds. We show that St clouds dampen photosynthesis, and this effect is increased with the time that air masses have spent over forest. Oppositely, Cu clouds enhance photosynthesis. If an air mass is longer exposed to boreal forest, this effect persists, whereas transmittance is somewhat decreased indicating additional cooling.

ACKNOWLEDGEMENTS

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DIRECT MITIGATION OF ORGANIC AEROSOL PARTICULATE POLLUTANTS BY PHOTOCATALYSIS: AN INNOVATIVE CONCEPT FOR AIR POLLUTION CONTROL

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Keywords: SECONDARY ORGANIC AEROSOL, TITANIUM DIOXIDE, PHOTOCATALYSIS, AIR POLLUTION ABATEMENT

INTRODUCTION

Particulate matter represents one of the most severe air pollutants globally and together with nitrogen dioxide they are concerned as two key pollutants in Europe. Organic aerosol (OA) contributes 20–50% to the total mass of submicron particulate matter at continental mid-latitudes, and even up to 90% in tropical forested areas (Kanakidou *et al.*, 2005; Hallquist *et al.*, 2009). Developing effective strategies to mitigate organic aerosol is crucial for urban air pollution abatement. This work presents the results of α-pinene secondary organic aerosol (SOA) formation in the presence of titanium dioxide (TiO_2) seed aerosols.

METHODS

The SOA experiments were carried out in the 9 m^3 atmospheric simulation chamber at University of Eastern Finland. Three types of experiments were performed.

(1) Mitigation of SOA particles in an internally-mixed state: SOA was generated from dark ozonolysis of α-pinene in the presence of TiO_2 photocatalytic seeds. After SOA was formed in an internally mixed state with TiO_2, UV irradiation was used to examine whether TiO_2 can remove SOA matter.

(2) Mitigation of SOA particles in an externally-mixed SOA-TiO_2 state: SOA was generated from dark ozonolysis of α-pinene by nucleation. After the SOA mass reached maximum, TiO_2 was added to the chamber and UV lamps was turned on to examine the impact of TiO_2 on the SOA particles that have formed.

(3) Suppression of SOA formation experiments in the presence of TiO_2 nanoparticles: TiO_2 was injected to the chamber as seed aerosols, followed by α-pinene and ozone (O_3). The formation of SOA was then examined under UV irradiation.

The time evolution of α-pinene and other gas compounds was monitored by a proton-transfer-reaction time-of-flight mass spectrometer (PTR-ToF-MS). The mass concentration and size-resolved chemical composition of aerosol particles was measured with a high-resolution time-of-flight aerosol mass spectrometer (HR-ToF-AMS). Particle size distributions were measured using a scanning mobility particle sizer (SMPS).

RESULTS AND DISCUSSION

In the internally-mixed experiments (Fig. 1a), SOA was produced at a mass yield of 12.1%. After SOA formation reached its maximum, the UV irradiation was turned on. It is especially interesting to note after UV irradiation SOA matter coated on TiO_2 was completely removed over the next 3 hours. The observation is further evidenced by a notable shrinkage of the particle sizes.

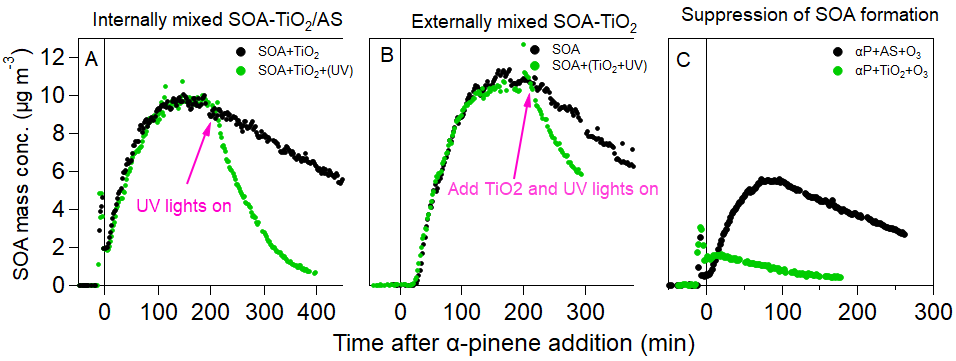

Figure 1. Mitigation of α-pinene SOA matter by TiO_2 photocatalysis in an internally-mixed state experiments (A), in an externally-mixed state experiments (B) and suppression of SOA formation (C).

In the externally-mixed experiments (Fig. 1b), addition TiO_2 caused 22% decrease in SOA mass. It was further estimated that the coagulation sink can interpret 29% of SOA mass loss, e.g. SOA particles collided with TiO_2 nanoparticles and were photocatalytically reacted away, resulting in the direct loss of SOA particles. The remaining decrease in SOA mass (73%) is attributed to the indirect SOA loss mechanism.

Fig. 1c shows the formation of SOA from ozonolysis of α-pinene in the presence of TiO_2 and AS seed aerosols. In the UV irradiation experiments, the formation SOA particles was not observed when the TiO_2 nanoparticles were present (green circles, Fig. 1c). However, in similar experiments using AS seed aerosols, SOA was formed in a large amount with a mass yield of 5.9%.

Our results highlight for the first time that photocatalysts such as TiO_2 can not only suppress SOA formation, but can also directly remove SOA matter condensed on its surface, and also decrease mass of SOA not in direct contact with TiO_2 surface. The results will have potential implications in studying SOA formation and curbing air pollution.

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INTERCONDUIT PITS OF TWO CONIFER SPECIES SCALE WITH CONDUIT DIMENSIONS

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Keywords: WOOD ANATOMY, CONIFERS, 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 (e.g., Domec et al., 2006; Zimmermann, 1983). Several studies found that to counterbalance the accumulating resistance to water transport, conduits widen 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), the coordination of conduit and pit dimensions is poorly known (e.g., Losso et al., 2018). On the other hand, air seeding (hydraulic failure) occurs through the pits, and wider pits and conduits (with more pits) have a lower hydraulic safety, i. e., they are more susceptible to air seeding under stressed conditions (Domec et al., 2006; Jacobsen et al., 2019; Zimmermann, 1983). Thus, trees exposed to stressful conditions may adjust their size or the conduit-widening pattern to increase their hydraulic safety. Our study aims to a) shed new light onto the coordination of conduit and pit dimensions at different distances from the treetop, and b) study if trees adjust the widening pattern of their conduits and particularly their pits to environmental conditions.

METHODS

In our study, we sampled Scots pines (*Pinus sylvestris* L.) and Norway spruce (*Picea abies* (L.) Karst) on two sites (labeled 'limited' and 'favorable') with different environmental conditions (soil types) and thus different tree growth rates (see Table 1). We took wood samples along the water transport pathway from the treetops to the roots. From the wood samples, we extracted the two outermost tree rings (2021, 2020) and prepared cross sections for light microscopy to analyze the mean conduit diameter, mean hydraulic diameter (Sperry and Hacke, 2004), and cell wall reinforcement (Hacke et al., 2001). Furthermore, we prepared tangential sections for scanning electron microscopy to measure the diameter of the margo (pit membrane), torus (central thickening of the pit membrane), and pit aperture.

Table 1. Basal area increment and tree height. Different letters indicate significant differences ($p < 0.05$) between sites. Mean ± SE.

Species	Limited site	Favorable site
	Basal area increment (cm^2)	
Scots pine	7.85 ± 0.39^a	13.1 ± 0.73^b
Norway spruce	6.67 ± 0.42^a	8.42 ± 0.24^b
	Tree height (m)	
Scots pine	18.69 ± 0.52^a	19.67 ± 0.53^a
Norway spruce	16.55 ± 0.27^a	21.39 ± 0.59^b

PRELIMINARY RESULTS

In both species, we found that the conduit and pit dimensions increase with distance from the treetop in aboveground xylem. However, the xylem in roots does not necessarily follow the scaling pattern. Pit dimensions increased with mean hydraulic diameter (Figure 1), whereas they tend to decrease with cell-wall reinforcement. The scaling of pit dimensions with mean hydraulic diameter agrees to what we found in a previous study, in which we analyzed breast-height conduit and pit dimensions from pith to bark (Held et al., 2021).

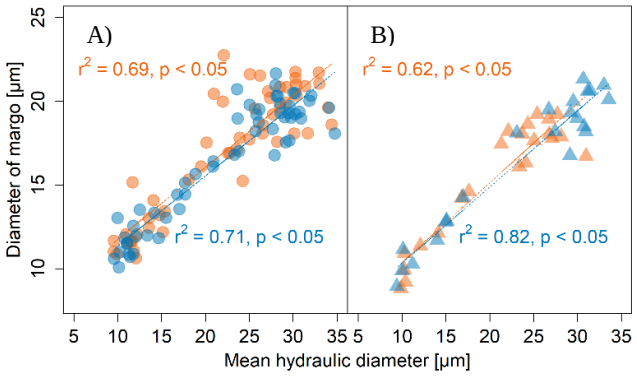

Figure 1. Change of margo diameter with mean hydraulic diameter of conduits in A) Scots pine and B) Norway spruce on the limited (orange) and favorable site (blue).

PRELIMINARY CONCLUSIONS

The analyzed trees widen their conduit and pit dimensions with distance from the treetop to maintain a sufficient water flow through their stems. Roots, however, have to meet different hydraulic and mechanic challenges. Overall, conifers seem coordinate their conduit and pit dimensions well (Figure 1). So far, we detected no site differences, but statistical analysis is still ongoing.

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BIOAEROSOL FLOW CYTOMETRY IN THE ATMOSPHERE

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Keywords: Bioaerosol monitoring, Cytometry, Machine learning.

INTRODUCTION

The present study focuses on bioaerosol flow cytometry in the atmosphere, utilizing recently acquired Swisens Poleno real-time air-flow cytometers. These automated systems, comprising both hardware and identification algorithms, mark their debut in Finland and have been installed at the Finnish Meteorological Institute's rooftop in Helsinki and on the top of Sammaltunturi in Pallas Atmosphere-Ecosystem Supersite. The device facilitates in-flight measurements of particle shape, size, and fluorescence, encompassing real-time bioaerosol identification. The study's findings are verified through comparisons with manually operated Hirst-type traps.

METHODS

The working principle of Swisens Poleno is as follows: laser light scattering triggers the measurement, providing an initial estimate of particle size, velocity, and alignment by combining information from two trigger lasers. Following the trigger, two focused images, 90∘ apart, are reconstructed using digital holography, and UV-induced fluorescence provides information about the particle composition. Finally, optical polarization characteristics of the particle are measured in a time-resolved manner before it exits the device.

The study began with the crucial task of defining the specific pollen species for recognition, focusing on those common in the Southern Finland region. A total of 14 samples, including pine, birch, alder, various grasses, and others, were selected. To facilitate image recognition, the neural network had to be trained using labelled data. Pollen samples were aerosolized using the Swisens Atomizer, resulting in an inhomogeneous mixture of particles, including out-of-focus images, partially captured particles, conglomerates, debris, and pollen grains of other species. Cleaning this dataset was essential to ensure the quality of the training data, as machine learning algorithms may generate false positives when trained on noisy data. After data preparation, the study proceeded to the neural network training phase, utilizing a Convolutional Neural Network (CNN) model similar to the one proposed by Sauvageat *et al.* (2020).

RESULTS

The classification algorithm demonstrated remarkable performance, achieving an overall accuracy of nearly 90%. Most misclassified events belonged to the same family, which is understandable given the close resemblance between certain pollen grains, such as Betula and Corylus.

However, it is important to note that this algorithm was exclusively trained on laboratory data. Therefore, it was not surprising that the transition to real atmospheric conditions revealed new challenges. The primary challenge was the occurrence of false negatives, which was partially mitigated by incorporating fluorescence and polarization signals. The study's results were compared to Hirst-type pollen trap data, considered the gold standard in this field (see Figure 1). Furthermore, the recognition algorithm was assessed in the EUMETNET AutoPollen Intercomparison Campaign, where its performance was found to be on par with two other top-performing algorithms (Maya-Manzano *et al.*, 2023).

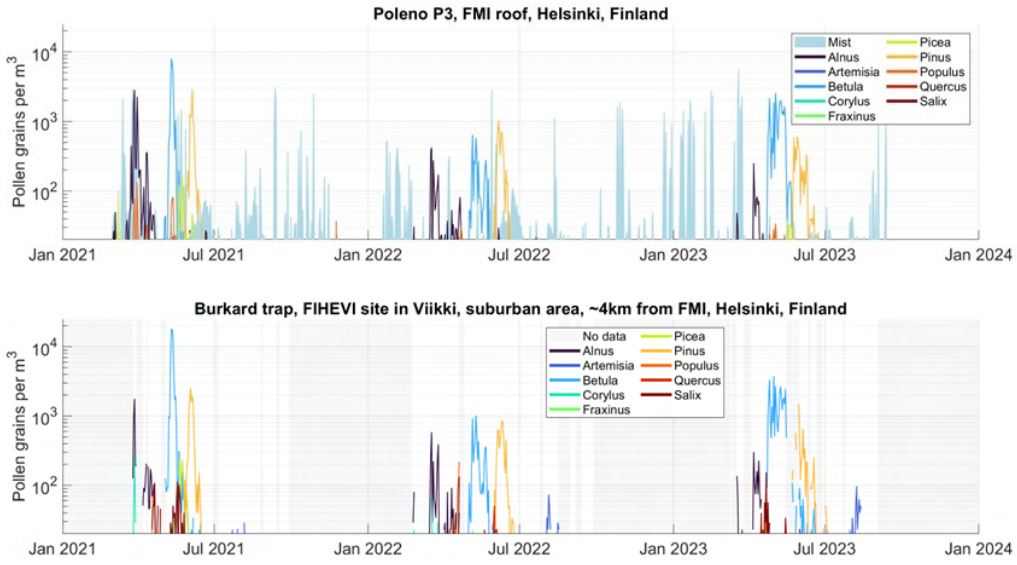

Figure 1. Time series of observed pollen concentrations by Swisens Poleno (top panel) and by Hirst-type pollen trap (bottom panel).

The next phase of our research aims to extend recognition to spores. While we have obtained some preliminary results, spore recognition presents a more formidable challenge, necessitating further investigation.

CONCLUSIONS

The study successfully trained a neural network on a training dataset consisting of typical Southern Finland pollen, resulting in an algorithm with excellent accuracy under laboratory conditions. However, when applied to real atmospheric data, it revealed new challenges. The inclusion of spore recognition is expected to be even more challenging. Additionally, it's worth noting that only a fraction of the available measurement data has been utilized to date. Therefore, the development of a new machine learning algorithm that encompasses all available data, including comprehensive utilization of fluorescence, scattering, lifetime, and polarization signals, is an important future development. This research lays a promising foundation for advancing bioaerosol flow cytometry in atmospheric studies.

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REACTIVE NITROGENOUS GAS (NITROUS ACID) EMISSIONS ALONG THE FEN-BOG GRADIENT FROM SOUTHERN BOREAL IN FINLAND TO SUBARCTIC PEATLAND IN THE CONTEXT OF CHANGING CLIMATIC CONDITIONS.

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Keywords: Biogeochemical, changing climate, edaphic factors, HONO, Northern peatlands, Reactive nitrogen gas.

Peatlands are integral ecosystems within the global nitrogen cycle, and understanding their role in reactive nitrogen gas emissions, particularly nitrous acid (HONO) gas, is crucial for assessing their impact on atmospheric chemistry and climate change (Bhattarai *et al*., 2022 and Wang *et al*.,2023). Exploring the impact of changing environmental conditions on HONO emissions can reduce existing uncertainties in regional and global nitrogen budgets. This study investigates potential HONO emissions across the fen-bog gradient in peatlands, ranging from southern boreal in Finland to the arctic and permafrost zone in northern Sweden.

The study combines *in-situ* sampling of pristine soil cores with controlled laboratory analyses. HONO emissions were quantified using a dynamic chamber system integrated with a long path absorption photometer (LOPAP) analyzer. In addition, the physical and chemical properties of the soil were analyzed to elucidate the factors influencing HONO emissions in peatlands along the climatic gradient.

Preliminary findings suggest HONO emissions from peatlands are subject to an intricate interplay of biogeochemical factors leading to significant variations in emission rates. Notably, the research result highlights the importance of moisture content and temperature variation, and vegetation composition in controlling HONO production and release. This ongoing research effort underscores the need for region-specific approaches in addressing the impact of peatlands on atmospheric chemistry.

Acknowledgement:

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IMPACT OF LONG-TERM WATER LEVEL DRAWDOWN AND CONTRASTING WEATHER CONDITIONS ON GROUND LEVEL VEGETATION IN BOREAL PEATLANDS.

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Keywords: Peatland drying, leaf area phenology, biomass growth, *Sphagnum* mosses, vascular plants, water level changes, plant functional types

INTRODUCTION

Peatlands are the largest natural terrestrial carbon (C) storage with 500–1000 Gt of stored C (Nichols & Peteet, 2019). Despite their low primary production, these ecosystems are a C sink due to low decomposition rates (Loisel et al., 2021), and therefore they are critical to prevent and mitigate climate change (Helbig et al., 2020). Climate warming with more frequent summer droughts puts northern peatlands under pressure by subjecting them to a combination of gradual drying and extreme weather events. Evapotranspiration from vegetation is expected to increase and water table levels are going to lower in boreal peatlands (Helbig et al., 2020). As peatland properties (vegetation composition and biomass production) are primarily defined by the hydrology, those changes will lead to drastic shifts in peatland structure and functionality (Tahvanainen, 2011). This study aims to fill the knowledge cap on how sensitive the boreal peatland vegetation to the climate change induced long-term drying and interannual growing season weather conditions is.

METHODS

This study aimed to assess effects of long-term (>15 years) experimental water level drawdown (WLD) and contrasting interannual weather conditions on the leaf area phenology of vascular plants and the seasonal photosynthetic biomass production of ground layer vascular plants and *Sphagnum* mosses of boreal peatlands. Our study site was located at Lakkasuo in southern Finland (61°47'N, 24°18'E) that is characterised by a highly diverse ecohydrology and vegetation (Laine et al., 2004). Lakkasuo can be divided into a mesotrophic fen, an oligotrophic fen and an ombrotrophic bog, hereafter called rich fen, poor fen, and bog, respectively. Thus, our experiment covered three peatland sites of different nutrient status, representing the inherent variation found in boreal peatlands. Responses of vegetation were quantified over two growing seasons with contrasting weather conditions (a wet and cold summer in 2017 versus a warm and dry summer in 2021). The seasonal development was estimated for each vascular plant species based on the seasonal LAI maximum (LAIMAX), the timing of LAIMAX (DMAX) and a unitless parameter that described the length of the growing season (Shape). Biomass growth over the growing season for each *Sphagnum* species and leaf biomass production of vascular plants was defined using cranked wire method and conversion from LAI, respectively (Köster et al., 2023).

RESULTS

Lower water table had a strong effect on both leaf area development and biomass production of ground layer vegetation of boreal peatlands. However, these responses varied between peatland types. We found that the fen sites were highly responsive, while only modest responses could be seen in the bog. Likewise, the direction of the responses differed between peatland types. In the poor fen and the bog, WLD increased the growth of ground vegetation, while it decreased the plant growth in the rich fen. In addition, our results suggested that peatlands that differ in their relative contributions of plant functional types responded to WLD at different speeds and the differences originate from the nutrient status. Graminoid dominated rich fens respond to WLD faster and stronger. WLD reduced the growth of graminoids, while shrubs and tree seedlings benefited from it. The direction of change in all peatland types was towards an arboreal vegetation type. Furthermore, lower water table made the vegetation more responsive to short-term climatic variations. We observed, that WLD resulted in a greater maximum and earlier peaking of leaf area index, as well as in greater biomass production by vascular plants and *Sphagnum* mosses in the warmer summer. Similarly, the response to short-term weather variability was affected by the nutrient status of the site and enhanced by long-term gradual drying.

CONCLUSIONS

We can conclude that lower water tables make all types of boreal peatlands more responsive to weather conditions. Furthermore, our results indicate that in the long-term, lower water table increase the net primary production of vascular plants on boreal peatlands, and warmer air temperatures and longer growing seasons enhance this impact even more. This outcome indicates that global climate change will increase the production of boreal peatland vegetation. However, this increase in production comes at the expense of changed composition of ground layer and, therefore, results in changed functioning of the current ecosystem.

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CARBON SEQUESTRATION IN DIFFERENT URBAN VEGETATION TYPES

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

INTRODUCTION

Cities all around the world are actively working towards combating climate change by implementing strategies to decrease their human-caused emissions and striving for carbon neutrality. As a result, there is a growing demand for urban vegetation, as it is seen as a cost-effective and manageable way to offset some of these emissions. As a result, there is a growing interest and necessity to quantify the carbon storage and fluxes within various types of vegetation to accurately assess their potential. Such information can also be utilized to guide sustainable urban planning and management, including the overall design and selection of planted species, to better mitigate and also adapt to the effects of climate change.

The heterogeneity of urban vegetation types and variation in weather events challenges the estimation of carbon sequestration by empirical means, and therefore models are needed to quantify the current magnitude and to estimate the potential of carbon sequestration, especially for the future. Based on extensive empirical data in native and managed ecosystems, many comprehensive models have been published during recent years but those are rarely tested in urban circumstances. In urban green spaces, the response of vegetation to environmental factors can be altered as there are, for example, limitations in soil water availability, differences in soil properties, higher evaporative demand caused by increased temperatures, altered biological competition and interaction, heavy management and exotic species. Therefore, applying those models in urban green spaces includes uncertainty. This study aimed to estimate the applicability of different ecosystem models with varying features and complexity to describe the carbon cycle in diverse urban areas and quantify the carbon sequestration potential of different urban vegetation types.

METHODS

In CarboCity (2019–2023) and CO-CARBON (2020–2026) projects, we collected observations in various vegetation types consisting of lawns, meadows, parks, an apple orchard, a street side/road verge, and an urban birch forest in Helsinki, Southern Finland. Most of them were in the footprint area of the eddy covariance tower FI-Kmp (Vesala et al., 2008). Some sites were more intensively studied than others but overall, the dataset includes manual and automatic measurements of net CO_2 exchange of tree shoots, manual light response curve measurements of net CO_2 exchange over 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. In addition to the ground-truth measurements, we

utilized solar induced fluorescence (SIF) measurements from TROPOMI and OCO-2, and leaf area index (LAI) derived from Sentinel-2.

The data collected served as an important testing material for ecological and micrometeorological research questions, but these measurements were also used to evaluate and develop, if needed, process-based models simulating carbon cycle. We run urban SUEWS model (Havu et al. 2022), in addition to LPJ-GUESS (Smith et al., 2001), and JSBACH (Kaminski et al., 2013), which are land-surface modules in earth system models EC-EARTH and MPI-ESM, respectively. In addition, we tested soil carbon model Yasso (Viskari et al. 2022). The validated models will be used to simulate carbon sequestration over large spatial scale and to support planning and maintaining sustainable and climate-smart urban nature.

RESULTS

The successfully tested models replicated observed component fluxes, such as seasonal changes in soil respiration and shoot photosynthesis, as well as the influencing factors for these fluxes, such as LAI, soil moisture, and soil temperature. This suggests that the response of urban vegetation to changes in environmental factors is fairly similar to that of non-urban environments. However, the amount of annual carbon sequestration varied significantly among the different models. Additionally, simulations showed that irrigated plots generally had a higher annual carbon sequestration rate compared to non-irrigated plots. Since a significant portion of urban nature is irrigated, this should be considered in model applications.

Urban areas have been found to have a significantly high soil carbon pool. In our study of various aged plots, the soil carbon pool was over 10 kg C m^{-2} in a densely tree-covered urban park, while other studies have reported that the average pool size in forests is only 6.3 kg C m^{-2}. We were able to demonstrate that the soil carbon pool experienced a notable increase within the first 100 years after establishment. Despite the surface layer having the highest carbon content, the significant increase in soil carbon was mainly observed in the lower layers.

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ON THE NEW PARADIGM TO INVESTIGATE NPF

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Keywords: ATMOSPHERIC CLUSTERING, NEW PARTICLE FORMATION, FORMATION AND GROWTH RATES

INTRODUCTION

Besides directly emitted primary aerosol particles, large fractions of atmospheric aerosols relevant to both air quality and climate are produced via new particle formation (NPF; Kerminen et al., 2018; Chu et al., 2019; Kulmala et al., 2021). Atmospheric NPF, together with secondary formation of particulate matter (secondary aerosol formation), modify the number concentration, size distribution, chemical composition and mass loading of atmospheric aerosol populations. Kulmala et al. (2021) showed that NPF and secondary aerosol formation contribute to over 2/3 of the haze particle number load and over 80% of the corresponding mass load in Beijing. Physically, the influences of atmospheric NPF and secondary aerosol formation depend on particle formation rates and on rates at which newly formed particles grow to larger sizes (Kulmala et al., 2017).

METHODS

We are combining the following tools to be able to find out physical and chemical mechanisms of atmospheric NPF: i) targeted laboratory experiments, ii) comprehensive *in situ* observations including supersites in the Chinese gigacity (see Kulmala et al., 2021a), iii) comprehensive vertical observations using aircrafts, tall towers, tethered-airships and ground-based remote sensing, iv) satellite remote sensing and v) multi-scale modelling and model development. Understanding chemistry and physics at the 2–25 nm size range for atmospheric aerosol particles and sub 2 nm atmospheric clusters are grand challenges for both fundamental and applied sciences.

SOME RECENT RESULTS

Here, we summarize our latest findings on atmospheric new particle formation (NPF) based on atmospheric observations and model simulations. Our first investigation was a closure study on sub-6 nm atmospheric aerosol particles and clusters, which showed that present observations are able to detect a major fraction of existing atmospheric clusters (Kulmala et al. 2022a). Our second finding, based on long-term measurements in four very different environments, was that atmospheric NPF tends to occur also on days characterized

traditionally as non-event days (days with no observed NPF), with typical particle formation rates ranging between about 2 and 20 % of those on traditional NPF event days (Kulmala et al. 2022b). We termed this phenomenon "quiet NPF" and showed that it may have a significant contribution to the production of secondary particles in the atmosphere. Thirdly, we investigated the growth of newly-formed particles into sizes relevant to climate and air quality using box model simulations that were constrained with atmospheric observations in two very different environments: 1) Beijing, a polluted megacity in China, and 2) SMEAR II station, a boreal forest site in Finland. Our simulations for Beijing showed that NPF is capable of giving large contributions of haze particle mass and number concentrations (Kulmala et al. 2022c). The results indicate that reducing primary particle emissions may not decrease PM pollution effectively in heavily polluted environments without simultaneous emission reductions for precursor gases responsible for NPF and subsequent particle growth. At SMEAR II, we used simulations to investigate the role of NPF in the Continental Biosphere-Atmosphere-Cloud-Climate (COBACC) feedback mechanism (Kulmala et al. 2023). We found that outside the late autumn and winter periods when NPF events tend to be rare at SMEAR II, NPF gives a dominant contribution to both condensation sink and cloud condensation nuclei concentration – the two most relevant quantities in the COBACC feedback mechanism. We estimated that the same conclusion is likely to hold over large regions in the boreal forest zone, as it has been demonstrated that the oxidized products of biological volatile organics (VOCs) sustain the strong particle formation and condensational growth that contributes about 90% of the cloud condensational nucleus (CCN) at high altitude over Amazon basin (Liu et al., 2023).. As a side product of our observations, we found surprisingly low variability in growth rates of newly formed particles in both Beijing and SMEAR II. This points toward a potentially important role of multiphase reactions causing the bulk growth of newly formed atmospheric particles – a phenomenon that needs to be investigated in more detail in the future.

PARADIGM CHANGE

Based on the above mentioned recent results and reasoning given in the previous section, we suggest the following paradigm change when investigating the general characteristics of atmospheric NPF using field measurements:

1) Instead of making binary (event, non-event) classification of NPF, we will use a more continuous approach, such as the ranking method, to obtain regionally representative distribution of particle formation and growth rates
2) We use particle and ion number concentrations in the smallest possible size regimes in the ranking method:
    a. In case of regional NPF, total particles (2.5-5 nm) or intermediate ions (2-7 nm)
    b. In case of sub-regional (local) NPF, ions at diameters as close to 2 nm as possible
3) We use the regionally representative particle growth rate, derived from the largest possibly subset of data, to calculated both regional and local particle formation rates in this region
4) The particle formation rates can be determined for all the days, and its distribution can be given as a continuous function of different parameters

The main difference between the new paradigm and the traditional method is that the new paradigm gives estimates on particle formation rates for all the measurement days. This, together with regionally representative particle growth rates, provides us with a tool to quantify the contributions of both local and regional NPF to total particle number concentrations in a regional atmosphere.

ACKNOWLEDGEMENTS

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CLIMATE UNIVERSY FOR VIRTUAL EXCHANGE (CLUVEX)

H.K. LAPPALAINEN[1], A. MAHURA[1], L. RIUTTANEN[1] AND THE CLUVEX TEAMS

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Keywords: climate action, climate messengers, soft skills, on-line learning, MOOCs

INTRODUCTION

Climate University for Virtual Exchanges (CLUVEX; https://www.atm.helsinki.fi/cluvex; 1 Jul 2023 – 30 Jun 2026) is a 3-year project conducted by two European Erasmus+ program countries: Finland (INAR University of Helsinki) as the coordinator and Denmark (University of Copenhagen). It also involves the Neighbourhood East countries such as Ukraine (with two Partners – Odessa State Environmental University and Taras Shevchenko National University of Kyiv) as well as Armenia (Yerevan State University). Additionally, an art and science non-profit association, the BioArt Society, based in Finland, collaborates in this initiative.

This project aims to connect students from European and Neighbourhood East universities and involve them in climate-related topics, including ideas for adapting to and mitigating the effects of climate change and advancing the green agenda. Moreover, the project emphasizes the development of interdisciplinary, green, and soft skills among the participants. In practice, the project is responsible for designing and organizing a series of interactive online workshops or trainings known as "virtual exchanges" (VE). These exchanges are structured to include educational materials and engage students, professors, teachers, and researchers collaboratively in small groups. During the project, a total of 5 VE Calls will be initiated, spanning both the Spring and Autumn semesters and starting from Autumn 2024. Each VE Call will extend invitations to 500 students from the CLUVEX Universities and other institutions in European and Neighbourhood East countries to participate in VE training weeks.

During a VE week, various activities will take place, including plenary sessions, discussions, and exercises focused on specific climate change topics within smaller groups. CLUVEX is rooted in atmospheric sciences research and builds from the "Climate University" (https://climateuniversity.fi). The goal is that, after participating in a VE, participants will gain a deeper understanding of climate-related issues and foster meaningful connections with their peers.

CLUVEX is implemented with a 50%x50% basis, meaning that half of the participants is from universities in Denmark and Finland, representing European universities, while the other half is from universities in Ukraine and Armenia, designated as Neighbourhood East countries. All partner institutions contribute their technical tools and pedagogical expertise to collaboratively design innovative VE interactions for students. The project also leverages its networks, such as Una Europa, an alliance of 11 European universities, and the World Meteorological Organization's Global Campus initiative in Europe and Neighbourhood East, to attract a diverse array of participants. The main motivation is to cultivate a new generation of young Climate Messengers who possess the skills and knowledge to foster climate awareness and sustainability strategies within their home organizations and future professional endeavours.

METHODS

In 2023, the project partners will be focused on designing the VE concept and exercises. Simultaneously, they will be conducting a study to understand the challenges and opportunities associated with online

learning and communication. Teaching a class with virtual students presents unique challenges. During the first year, the project will concentrate on training VE moderators/ facilitators.

The CLUVEX team leaders and team members are already well-versed in various pedagogical approaches, services for society, and have a track record of publishing several peer-reviewed papers. It's worth noting that the content of the VE weeks will be delivered in English. The project places special emphasis on ensuring an adequate number of well-educated staff members with strong language skills who can effectively act as moderators.

Throughout the entirety of the CLUVEX process, feedback questionnaires will be employed. These questionnaires will be utilized for analyzing and improving the VE concept, from the education of moderators to piloting and implementing the VE weeks for students.
As an exciting innovation, the art and science partner, the BioArt Society (https://bioartsociety.fi), will bring artistic perspectives into the project. They will offer VE lectures and creative exercises that explore how contemporary art contributes to public discourse on climate change.

CONCLUSIONS

CLUVEX is gaining momentum in the post-COVID-19 era and even the war time conditions in Ukraine, given the uncertainty surrounding when face-to-face communication will return to normal and the growing emphasis on sustainability in a world working toward carbon neutrality. In this context, the VE cooperation serves as a valuable complement to traditional physical mobility opportunities in the field of climate change research.

The project plays a vital role in addressing the complex web of political decisions and issues related to climate change, where the Neighbourhood East region holds also a significant position on a global scale. The emergence of new Climate Messengers, equipped with expertise in climate awareness and sustainability strategies, is highly relevant in today's labour markets. These individuals are well-positioned to contribute to the critical work of advancing climate-related initiatives in a world undergoing transformative changes.

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EXPLORING CLIMATE CHANGE RELEVANT ART-SCIENCE METHODOLOGIES

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Keywords: *art-science, sense and knowledge-making, climate change, sustainability*

INTRODUCTION

Like all themes of sustainability (Miller et al. 2014), climate change too, is perpetually looking for new forms of collaboration on finding innovative and more effective solutions to resolve its issues (Ravetz 2006). In academia, multidisciplinary sustainability science (Lang et al. 2012) and transdisciplinary projects of co-creation thereof (Mauser et al. 2013) have become commonplace. However, involving *other-than-scientific* methodologies into processes of knowledge- and sense-making (Clark et al. 2016) and redefining the issues as well as find solutions for them seems not only viable but necessary (Lozano 2007). In this presentation, we explore such co-creative methodologies and the potential of art-science collaboration, in asking what emerges between and from the combination of these domains of human process. We use two experimental examples from ACCC-related work, a Nordic art-science workshop (ABS network) and Finland's first Climate Security Festival (Safer Climate).

METHODS

During an experimental ABS network workshop, organised the summer of 2023 in Norway (see more: www.atm.helsinki.fi/abs/), preliminary ideas for such testable methodologies emerged. The workshop of near 20 participants, with experience and expertise in either science or art–or some with both–led into several realisations, such as that; art and science both, at their basic level, were seen as explorative and inventive by nature rather than necessarily strictly methodologically defined (as also addressed in; Ellison et al. 2018); and that there are historical roots to art and science in general and especially respective branches of them once being considered inseparable (from past polymaths to renaissance); and ultimately that the collaboration was seen not only as an opportunity but a logical necessity in thinking of the issues various dimensions (Coombs 2010); from posing existential dilemmas to requiring epistemic plurality, and creating new narratives of the problems to formulating critical understandings of the potential solutions.

Finland's first Climate Security festival was organized in the fall of 2023 (see more: https://www.saferclimate.org/climatesecurityfestival). The festival brought together almost 100 people from different sectors to discuss how can we find a joint understanding of climate security and move beyond its traditional – yet important – security policy-oriented definitions (for an overview on climate security see e.g. Hakala 2023). Central questions included: 1) what subthemes emerges from joint discussion 2) what is the role of civil society and arts in climate security 3) what kind of collaboration and solutions we can create together for a safer future climate and a safer space for climate discussion. The involvement or artists and art institutions as well as the use of artistic and participatory methods (such as Silent Walk [see e.g. Foster 2019] and eco-emotions poetry) gained positive feedback and sparked many ongoing discussions on how to foster new methodological, critical and solution-oriented collaboration between arts and science.

RESULTS

From the exploration thus far, two methodological framings (of which one is presented in fig. 1 and another as a verbiage for *'artentic'* research in fig. 2) are utilised further for conceptualising potential collaborations. A funding application for a project is in the making between the University of Helsinki and two Nordic partners. The application is for a 3-4-year project with aims to run annual events, workshops and courses for developing and testing different art-science methodologies and running collaboration pilots based on the findings, resulting in establishing an international network of art-science for climate co-creation hubs.

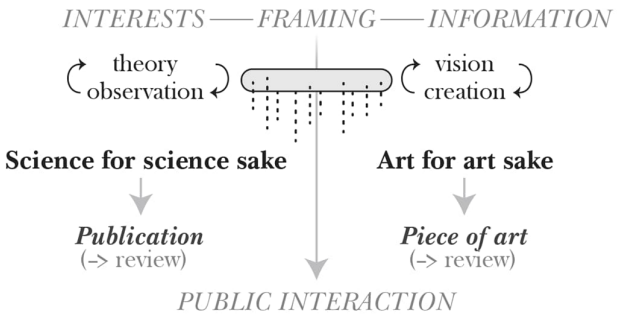

Figure 1. *Schematics of the parallel processes of science and art* (Adapted from a workshop poster by a group with A. Lauri, V. Sandqvist, Ivar Veermäe, and Pavla Dagsson Waldhauserová, as members. 2023)

ARTENTIC SEARCH

From art and science, something old and familiar we construct artence and from their amalgamated practice; the artentic search—pre and post re-search, when we, the human— ancestral or child, used to invent the reality we lived in.

It's not defined alone by the questions it seeks to answer nor can you point to it by distinguishing its outcomes, but you can find it in children exploring the nearby forest as much as it is in the attempt of human development where we acknowledge the multiple crisis but cannot seem to invent ourselves out of.

Thus, be a scientist—when it suits your exploration, or be an artist—if that fits your urge, but foremost be an inventor of new, and defy the boxed paths that limit you and instead define the search by being an artentist.

Figure 2. *Manifesto for art-science (*'artentic'*) collaboration* ('search') (Adapted from a workshop memo by a group with Z. Lycka, L. Riuttanen, M. Saladrigues, and J. Salovaara as members. 2023)

CONCLUSION

By recognising the historical roots, the procedural similarities, the commonplace yet unacted-on interest in the collaboration, and foremost the necessity for democratic and emancipatory approaches in redefining and solving climate change and sustainability related issues, we set forth to explore and develop such art-science collaboration methodologies.

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LUNG DEPOSITED SURFACE AREA OF PARTICLES NEAR VARYING POLLUTION SOURCES AND IN DIFFERENT COUNTRIES: RELATIONSHIP WITH $PM_{2.5}$

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Keywords: Urban air quality, Ultrafine particles, Particulate matter, Human respiratory tract

INTRODUCTION

Ambient fine particles are known to be harmful for human health, and the health effects are especially associated with $PM_{2.5}$, i.e., the mass concentration of particles smaller than 2.5 µm. $PM_{2.5}$ is also the most widely monitored and regulated metric for particles. However, recent studies have indicated that monitoring only $PM_{2.5}$ is not enough to comprehensively understand the total health burden caused by particulate pollution. For example, the dose-response curve of $PM_{2.5}$ is not linear and the health effects per unit $PM_{2.5}$ seem to be higher in regions with low $PM_{2.5}$ compared to highly polluted ones (e.g., Vodonos et al. 2018). Also, health effects per unit of $PM_{2.5}$ seem to increase near local pollutions sources like traffic (e.g., Segersson et al. 2021). Thus, there is a need for additional metrics and point-of-views for monitoring and regulating particulate pollution to better tackle the health burden caused by outdoor air pollution.

There are many potential explanations for the inadequacy of $PM_{2.5}$. Aerosol-wise, for example, ultrafine particles (< 100 nm) are too small to contribute on mass, but they are still considered to have important effects on health and e.g., human brain. Furthermore, particle composition affects aerosol oxidative potential (OP) which is considered to be especially important for the toxicity of inhaled aerosol. In addition, particle size affects their deposition efficiency in the human respiratory tract. Lung deposited surface area ($LDSA^{al}$) is a measure of the surface area of particles deposited in the lung alveoli. Biologically, surface area has been suggested to be the most effective dose metric for acute nanoparticle toxicity in the human lung (Schmid and Stoeger, 2016). Particle deposition in the alveoli is considered to be especially relevant as the interaction between respiration and pulmonary circulation occurs there. Thus, differences with $LDSA^{al}$ characteristics and concentrations near different pollution sources and geographical regions could give a potential additional point-of-view for the varying toxicity of $PM_{2.5}$ in different environments.

METHODS

In our study, we measured $LDSA^{al}$ concentrations and size distributions in different urban environments and countries. The study includes data from 8 ambient measurement campaigns conducted in Finland (4 campaigns), Germany, Czechia, Chile, and India, covering urban traffic sites, highways, airports, detached-housing residential areas, shipping, and industrial sites. In addition, we investigated the relationship between $LDSA^{al}_{2.5}$ and $PM_{2.5}$ concentrations in the different environments to better understand the reasons behind $PM_{2.5}$ health effects. $LDSA^{al}$ and $PM_{2.5}$ were measured with an Electrical low pressure impactor (ELPI+). The duration of the campaigns was 1.5 weeks – 1 month, and they were done during the years 2013 – 2021.

RESULTS

We found that $LDSA^{al}$ size distributions depend significantly on the urban environment and the country (see Lepistö et al. 2023b). In Finland ($PM_{2.5}$: 3.2 – 11.8 µg/m^3), $LDSA^{al}$ was mainly composed of ultrafine and soot particles but in each studied environment the dominating particle size was different. For example, 50 –

200 nm particles dominated in the traffic sites whereas < 50 nm particles dominated in the airport and 100 – 400 nm particles in the detached housing areas (Fig 1). In Central Europe ($PM_{2.5}$: 17.8 – 28.6 µg/m^3), similar effects from the local pollution sources were observed but in addition regional aerosol constantly contributed to $LDSA^{al}$ of 200 – 800 nm particles. In Chile and India ($PM_{2.5}$: 329 – 330 µg/m^3), $LDSA^{al}$ was almost completely composed of the regional aerosol even though the measurements were done next to busy traffic sites. The results show that the sizes of lung-depositing particles vary significantly near different pollution sources and in different geographical regions, suggesting also varying composition of inhaled particles. Also, the observed differences affect the ratio between $LDSA^{al}$ and $PM_{2.5}$ which increases strongly in low $PM_{2.5}$ -areas: 2.0 – 5.8 mm^2/µg in Finland, 1.4 – 2.8 mm^2/µg in Central Europe, and 0.9 – 1.2 mm^2/µg in Chile and India. The high $LDSA^{al}_{2.5}/PM_{2.5}$ -ratio was especially related to ultrafine particles: 25 – 73 % of $LDSA^{al}_{2.5}$ in Finland, 22 – 52 % in Central Europe and 9 – 13 % in Chile and India.

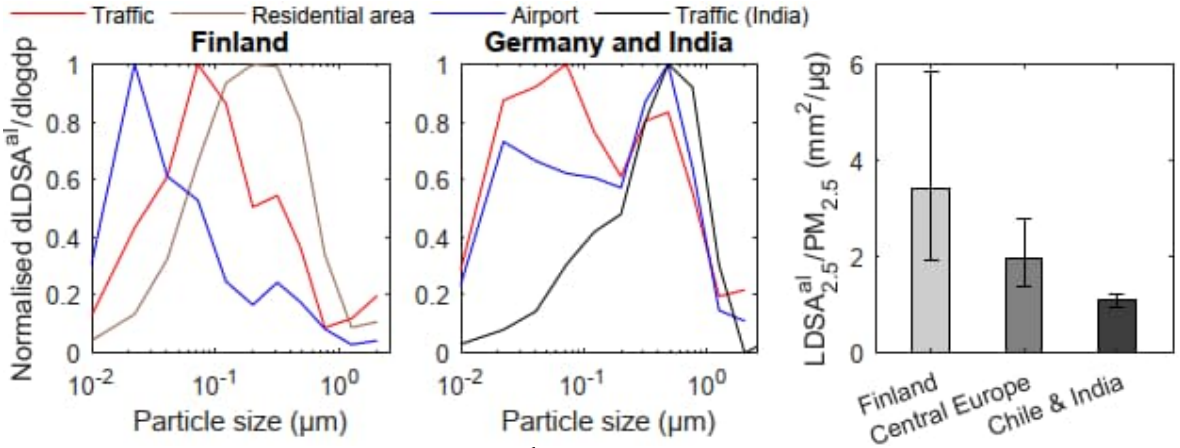

Figure 1. Normalized (by maximum) $LDSA^{al}$ size distributions in Finland, Germany and India. Also, average $LDSA^{al}_{2.5}/PM_{2.5}$ -ratios in the studied regions are shown. Results based on Lepistö et al. (2023b).

CONCLUSIONS

Our findings show major differences in particle lung deposition which cannot be detected by monitoring only $PM_{2.5}$ in different urban environments and geographical regions. Ultrafine particles have a major influence on $LDSA^{al}$ especially in regions with low $PM_{2.5}$. The findings provide potential additional explanations for the varying health effects of $PM_{2.5}$ as the measured $LDSA^{al}_{2.5}/PM_{2.5}$ -ratios behave similarly as the $PM_{2.5}$ dose-response curve suggested by various studies, i.e., sharply increasing in low $PM_{2.5}$ -areas.

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TURNING COMPLEX SCIENCE INTO COHERENT POLICY: WHY DO SCIENTIFIC FINDINGS ON THE LINKS BETWEEN CLIMATE CHANGE AND AIR POLLUTION NOT HAVE A BIGGER IMPACT ON GOVERNANCE?

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Keywords: science-policy interface, policy integration, short-lived climate pollutants, environmental law.

INTRODUCTION

Air pollution and climate change have overlapping sources and many air pollutants are also climate forcers. In particular, short-lived climate pollutants (SLCPs) like black carbon and methane can be powerful warming agents while also negatively affecting public health. Indeed, in its *Special Report on Global Warming of 1.5°C,* the IPCC (2018) found no realistic scenarios to reach global climate targets without "deep reductions in the emissions of methane and black carbon (35% or more of both by 2050 relative to 2010)". However, despite these findings, regulatory responses to climate change and air pollution have proceeded largely separately, leaving potential synergies and trade-offs between these policy fields unexplored. For example, the EU's responses to these issues rest on entirely separate laws which target *either* greenhouse gases *or* air pollutants – and some important SLCPs like methane and black carbon are not subject to any specific rules in this framework.

My presentation asks why this is the case by discussing insights from political science literature on the interactions between scientists and policymakers and on policy integration, the process of increasing coherence and synergy between different policy fields in order to address cross-cutting problems. It will be introductory and tailored to an audience consisting mostly of natural scientists that may not be familiar with these concepts yet. I will discuss the difficulties involved in translating scientific knowledge into political action and the political hurdles preventing increased integration between climate change and air pollution policy. Furthermore, I will offer preliminary conclusions on potential ways towards more integrated, scientifically informed policies, and introduce a new project at the University of Eastern Finland, ClimAirPathways, as one step in this direction.

ClimAirPathways is a joint project between the UEF Law School and the Finnish Meteorological Institute, funded by the Research Council of Finland (2023-27), and launched this autumn. Its unique structure brings together legal and policy experts with natural scientists to jointly develop and model the impacts of integrated policy pathways that tackle both climate change and air pollution. Beyond this, its longer-term contribution will be to put natural and social science in dialogue and thereby advance the problem-oriented, interdisciplinary research necessary for tackling complex environmental problems and overcoming the prevailing fragmentation in their governance. By introducing social scientific concepts and questions to an audience of mostly natural scientists, my presentation is designed to contribute to exactly this dialogue.

ACKNOWLEDGEMENTS

This work is supported by the Research Council of Finland (grant no. 355184).

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RELIABILITY ANALYSIS FOR ESTIMATED GLOBAL N100 CONCENTRATIONS PRODUCED WITH MACHINE LEARNING METHODS

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Keywords: N100, machine learning, reliability analysis

INTRODUCTION

We have trained machine learning (ML) models to estimate the global concentrations of aerosol particles with diameters larger than 100 nm (N100) with daily temporal resolution and 0.75x0.75 spatial resolution. The models were trained with N100 measurements from 35 measurement stations as target data and ECMWF reanalysis data as predictor data.

It is relatively simple to evaluate model performance at the existing stations, where we can compare the estimate against measurements. However, since our method produces estimates outside the existing measurement stations, we need to develop a method for evaluating the performance in areas without ground truth values. The main challenge for the ML model is producing N100 estimates for a type of environment not represented in the training data. Even though the model does produce a result for these areas, it is not likely to be reliable. We need a reliability estimate method that identifies these areas.

METHODS

Our reliability estimation method is based on Oikarinen *et al*., (2021), which describes a generalisation error method for regression functions. Their method estimates if the test data variable distributions have evolved outside the scope of the original training data variable distributions, which increases the risk of unreliable results. Their method was applied to time-series data. Our modified version attempts to do this spatially.

First, we train 35 mini-LR models, which are linear regression models trained with each station's own data. These are relatively simple models that represent a type of data in the training set (i.e., a type of environment). Using the 35 mini-LR models and the test data, we produce 35 estimated daily concentration time series in each grid cell. The mini-LR estimates are the same length as the ML estimate (e.g., one year). Second, we calculate the difference between the ML estimate and each mini-LR estimate in every grid cell. The idea is that if at least some of the mini-LR estimates are close to the ML estimate, then the original training dataset had at least some data that resembles the test data in that grid cell. If the differences between the ML estimate and all the mini-LR estimates are large, it indicates that the original training data does not represent the test data, and it is therefore likely that the model result is unreliable in this grid cell.

CONCLUSIONS

Our result is a global map that shows a high difference between the ML model estimate and mini-LR estimates in the areas where our ML model is likely to be unreliable. The error analysis can be done annually or for a longer time period. The method can be useful when producing estimates with machine learning

methods in cases where it is uncertain if all target spatial areas have representation in the training data. With the method, we can estimate whether the target variable, in our case N100, can be estimated in selected grid cells using the original model training. The method also helps us to determine environments currently unrepresented in the training data. One possible application is identifying areas the existing long-term measurements do not cover.

ACKNOWLEDGEMENTS

The training and test sets contain modified Copernicus Atmosphere Monitoring Service and Copernicus Climate Change information 2021, downloaded from ADS and C3S.

This project has received funding from the European Union's Horizon 2020 programme (821205) and Horizon Europe programme (101056783), the European Regional Development Fund (UIA03-240), Academy of Finland (337549 and 311932).

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WINTER NITROGEN CYCLING IN SEDIMENTS OF LARGE BOREAL LAKES AFFECTED BY BROWNING AND MINING

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Keywords: Nitrogen cycle, N2O, winter limnology, sediment microbiome

There is limited knowledge on the N (nitrogen) cycling in winter, on the role of organic matter quality on N cycling, and on the microbes involved on. We studied Lake Viinijärvi and Lake Höytiäinen, oligotrophic large boreal lakes in Finland, each lake with clear-water (CW) and brown-water (BW) sides. Viinijärvi has an additional side affected by mining activities in the catchment showing higher nitrate and sulphate levels. During winter of 2021 we sampled 5 sites at the beginning and at the end of the ice-covered period. Using the Isotope Pairing Technique we incubated sediment cores with $^{15}NO_3^-$ and quantified the products of 1) complete denitrification (N_2), 2) truncated denitrification (N_2O), and 3) dissimilatory nitrate reduction to ammonium (DNRA, NH_4^+) to infer the process rates. We characterized the DOM using FT-ICR MS. We explore the genetic potential (DNA) of the top sediment microbiome by using several sequencing techniques. During winter the sediment-water interface is an active compartment. The sediment microbiome has heterotrophic bacteria with flexible metabolism, breaking-down OM during winter despite most of the DOM is recalcitrant. Impacts of browning and mining with major differences between sites in the chemistry of the hypolimnion, of the water overlying the sediment, and of the top sediment; also, in the top sediment with differences in the prokaryotic community. The genetic potential of the sediment microbiome indicates more recycling of reactive-N and GHG consumption in CW, while in the mining-impacted site and BW sites the dominant pathway depends on the sediment layer with truncated denitrification in top layer, and methanogenesis and N-fixation in sub-top layer. The N_2O production, that fits the genetic potential, is highest in the mining-impacted site, followed by the BW sediments, with the lowest rates in the CW sediments.

THE EFFECT OF BURNING CONDITION ON THE CCN ACTIVITY OF BIOMASS BURNING PARTICLES

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Keywords: CCN activity, biomass burning, savannah, boreal forest.

INTRODUCTION

Biomass burning (BB), such as wildfires, is one of the major sources of primary organic aerosol and black carbon (BC) globally (Andreae, 2019). The intensity and rate of wildfires has been observed to increase during recent decades (Tyukavina et. al., 2022) and is expected to further increase in the future. Biomass burning particles can act as cloud condensation nuclei (CCN) and thus have an indirect cooling effect on the climate. The properties of the aerosol particles such as chemical composition, size distribution and CCN activity depend on the burned fuel as well as the burning condition. In this study, we characterised the CCN activity of BB particles from different fuels in varying burning condition and the impact of chemical aging of the primary aerosol.

METHODS

The measurements presented here were part of the BASFAA (Boreal And Savannah Fire Aerosol Aging) campaign carried out in May-June 2022 in Kuopio, Finland. The ILMARI atmospheric chamber was utilised to measure the primary and aged combustion emissions of three biomass types (woody and grassy savannah material as well as boreal forest floor material) in burning conditions varying from pure smoldering to flaming dominated. The burning condition was characterized with the modified combustion efficiency (MCE). To induce photochemical aging, H_2O_2 and O_3 were fed into the chamber and UV lights were turned on. Dark aging was initiated by adding only O_3 into the chamber. After an hour of primary measurements, the emissions were aged and measured for about 4.5 hours.

Size-resolved CCN activity measurements were conducted using a CCN counter, a differential mobility analyser (DMA) and a condensation particle counter (CPC). Among the wide range of instruments included in the campaign, the composition of the particles was analysed with a high-resolution time-of-flight aerosol mass spectrometer (HR-ToF-AMS), the concentration of BC with an aethalometer (AE-42) and a single particle soot photometer (SP2) and the size distribution of the particles with a scanning mobility particle sizer (SMPS).

RESULTS

The particles were highly dominated by organic material as measured with HR-ToF-AMS. The organic fraction in the primary particles was 84-98 % of the total non-refractory mass while the fraction of BC was 0.5-6 %.

The CCN activity of the particles was characterized with the hygroscopicity parameter κ. Figure 1 shows the CCN activity of the primary particles for supersaturation of 0.43 %. For this supersaturation, the primary κ values ranged from 0.07 to 0.186. For MCE < 0.85 the CCN activity of the primary particles was observed to be constant with mean κ of 0.082 $\pm$ 0.012. For MCE values above that, κ increased with MCE. Aging decreased the CCN activity of savannah wood and grass burning particles from experiments with high MCE but did not have any effect in experiments with low MCE. Photochemical aging of particles from BB of boreal forest floor material increased their CCN activity, but there was no change with dark aging. The range for aged κ values was from 0.07 to 0.15. Overall, aging of the particles decreased the variability in CCN activity. The changes in the CCN activity of the particles were influenced by the changes in the organic fraction.

The results presented here emphasize the importance of investigating a wide range of burning conditions to gain more knowledge on the indirect effect of BB particles on the climate.

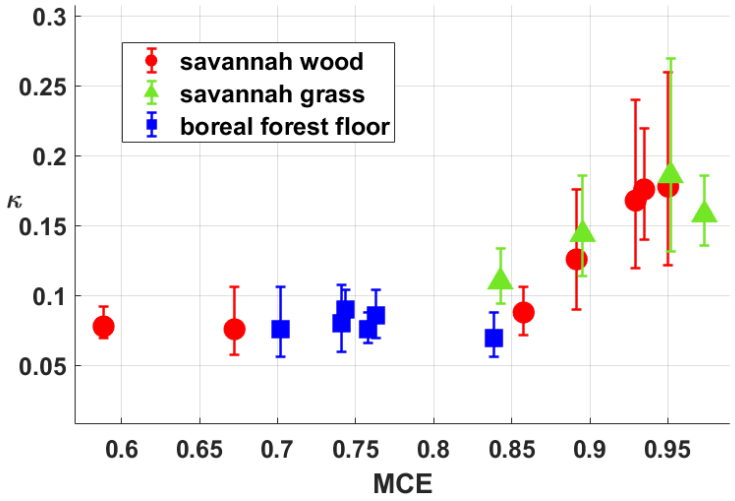

Figure 1. Hygroscopicity of primary particles for supersaturation of 0.43 %.

ACKNOWLEDGEMENTS

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LOCAL CLIMATE EFFECTS OF PEATLAND REWETTING – A SITE PAIR ANALYSIS TO SIMULATE FOREST-TO-WETLAND TRANSITION IN BOREAL ECOSYSTEMS

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Keywords: surface energy balance, boreal ecosystems, peatlands, surface biophysical properties.

INTRODUCTION

Managed or drained peatlands in the boreal zone, especially in Finland, constitute a large portion of the total peatland area. Restoration of peatlands by rewetting may offer considerable climate change mitigation potential as peat decomposition and resulting carbon dioxide emissions are reduced. In addition to greenhouse gas fluxes, rewetting changes the biophysical surface properties, which leads to changes in local microclimate, e.g. surface temperature. To fully understand the climate change mitigation potential of peatland rewetting, also these local effects need to be estimated properly (Lee et al., 2021).

Surface energy balance (SEB) describes the division of incoming radiation energy to the turbulent fluxes of sensible and latent heat in the atmosphere and heat conducted into the soil. Land surface temperature (LST) is an important environmental variable within the SEB and thus responds to land use or land cover changes including peatland management.

The components of the SEB are related to surface biophysical properties such as albedo and aerodynamic roughness, and changes in LST due to land cover change can be attributed to these properties. The two-resistance mechanism (TRM) attribution framework (Rigden & Li, 2017) parameterizes the turbulent heat fluxes using aerodynamic resistance and bulk surface resistance independently. While TRM has been widely used for investigating the changes in LST related to e.g. deforestation (Liao et al., 2018), bare land conversions (Wang et al., 2020) and crop greening (Yu et al., 2022), LST changes due to peatland rewetting have not been studied previously.

We study the change in LST due to a land cover transition from forest to wetland using space-for-time substitution. The results establish a better understanding of SEB in boreal peatlands and indicate what kind of microclimatic changes are expected from changes in their land cover. The sites differ in their trophic status and vegetation, which provides additional information about the connection of environmental and ecological variables to this response.

METHODS

Our long-term measurement data are from three northern boreal measurement sites located in northern Finland (Halssiaapa, Kaamanen and Lompolojänkkä). All sites consist of a subsite pair: a pristine peatland and a mineral soil forest. Sensible and latent heat fluxes were measured using the eddy covariance method, and other measurements include radiation components or net radiation, soil heat flux, air temperature, atmospheric pressure and relative humidity. Heat storages within the canopy and in the soil layer above the ground heat flux sensors were ignored. The measurement data were filtered for quality control and gap-filled using state-of-the-art methods.

We first determined the components of SEB and their diel and seasonal variations at the studied sites. Then, we assessed how boreal peatlands respond to changes in surface properties and meteorological conditions by varying the parameters of the TRM attribution model and its meteorological driver variables. By using the TRM, we attributed the differences in LST to biophysical differences between the subsite pairs.

RESULTS AND CONCLUSIONS

Our LST attribution analysis indicates that the transition from forest to open wetland in the northern boreal latitudes leads to lower LSTs during spring and summer. Surface albedo and aerodynamic resistance (surface roughness) are the main drivers during late spring. In summer, the LST difference results from the bulk surface resistance, which differs between forest and wetland vegetation.

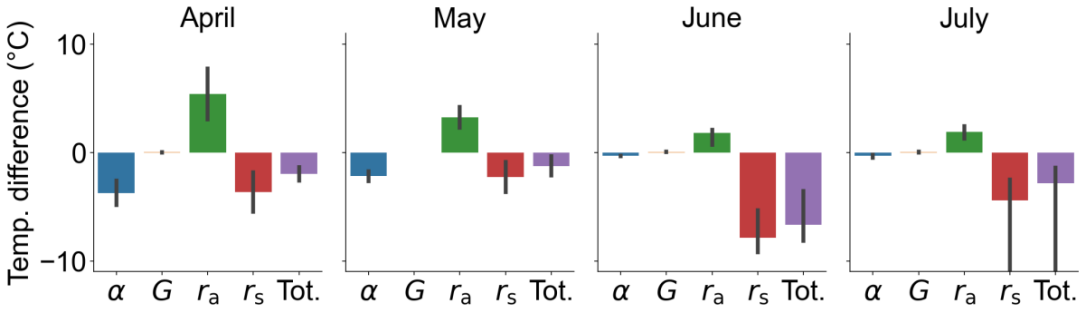

Figure 1. Difference between the Sodankylä wetland and forest LST attributed to the surface biophysical properties albedo (α), soil heat flux (G), aerodynamic resistance (r_a) and bulk surface resistance (r_s). Bars show monthly medians of daily average values during daylight hours (incoming solar radiation > 25 W/m²), and error bars cover 95% of values.

This research is continued at a ditched peatland site with data collected before and after rewetting. Changes in LST will be measured and explained by changes in surface biophysical properties. Understanding the local effects of peatland restoration helps to understand its potential for climate change mitigation and thus to prioritize restoration efforts and methods.

ACKNOWLEDGEMENTS

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ACTRIS - SHAPING THE FUTURE OF ATMOSPHERIC RESEARCH

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Keywords: Aerosol, Clouds, Trace Gases, Research Infrastructure, Atmospheric composition

INTRODUCTION

The Aerosol, Cloud and Trace Gases Research Infrastructure (ACTRIS) is a pan-European legal organization that coordinates the provision of data and services on short-lived atmospheric constituents. As the European organization to facilitate research in the field of atmospheric sciences, its goal is to document variability, to understand processes and to quantify the impacts of short-lived atmospheric constituents on the Earth's climate, air quality, health, and ecosystems. ACTRIS facilitates atmospheric research and technological developments by providing access to large and comprehensive atmospheric research facilities, distributed across Europe and beyond, and a unique portfolio of services available to users to conduct cutting-edge research on aerosols, clouds and reactive trace gases.

The recent report of the Intergovernmental Panel on Climate Change (IPCC), released in August 2021, confirms that the impacts of climate change are already visible in natural systems all around the world. Atmospheric environmental observations are the foundation upon which society builds effective environmental policies and strategies to reduce emission of pollutants, which mitigate climate change and improve air quality.

ACTRIS provides harmonised, intercomparable, QA/QC-ed and innovative observations on short-lived atmospheric constituents and services to advance knowledge and expertise on methodologies and instrumentations. The enhancement of data production, data quality assurance and access to data by ACTRIS enables advances in a fundamental understanding of physical and chemical processes, leading to advances in theory, modelling, and observations, that are vital in narrowing gaps in the predictive capability of simulation models from the local to the global scale (Laj et al,submitted).

METHODS

ACTRIS will increase the understanding of the complex feedback in the atmospheric system and its links to other components of the Earth system. IPCC dedicates a full chapter to the role of short-lived climate forcers (SLCFs), on how they affect climate and are, in most cases, also air pollutants. The complex role of SLCFs as climate forcer agents, impacting, e.g., human and ecosystem health, has been recognised and will be an important focal point of research in next years. In this context, ACTRIS will be a tool to support the establishment of the European Green Deal towards Carbon neutrality in Europe in 2030.

ACTRIS contributes to the knowledge on climate change impacts and adaptation through:

- Observation and Monitoring - ACTRIS operates a network of exploratory and observatory platforms across Europe and beyond, which continuously monitor various atmospheric components such as aerosols, clouds, and trace gases. These observations provide essential data for climate scientists to better understand the current state of the atmosphere and track changes over time. These changes can be indicative of climate change and its impacts.

- Air Quality and Health: ACTRIS also collects data on air quality, which can have direct impacts on climate and human health. Understanding air quality dynamics is essential for devising strategies to mitigate and adapt to climate change-related health risks.

- Data Sharing and Collaboration: ACTRIS actively promotes data sharing and collaboration among scientists and research organizations. This facilitates the integration of atmospheric data into climate models, enabling more accurate predictions of future climate change impacts and the development of adaptation strategies. ACTRIS facilities are open for science via dedicated access call.

CONCLUSIONS

ACTRIS contributes to the knowledge of climate change impacts and adaptation by providing valuable data and insights into the atmospheric processes that are intricately linked to climate dynamics. Its observations and research findings support climate scientists and policymakers in making informed decisions regarding climate change mitigation and adaptation efforts.

ACKNOWLEDGEMENTS

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MASS AND MOBILITY OF IONS PRODUCED BY RADIOACTIVE SOURCES AND CORONA DISCHARGES

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Keywords: ion mass; ion mobility; aerosol charging; charger ion; charging efficiency

INTRODUCTION

Aerosol charging is an important process for aerosol detection and characterization by electrostatic classification. Aerosol particles are charged by combination with ions, with their combination coefficient determining the charging efficiency (Fuchs, 1963). The commonly used bipolar charging method has the advantage that is only weakly dependent on variations in ion properties (Steiner & Reischl, 2012). However, a major drawback is that bipolar chargers have extremely low charging efficiencies for particles having diameters below 10 nm. Particles in this size range are rapidly gaining importance in the understanding of atmospheric processes. This creates a need for an efficient ion attachment charging method, where unipolar charging is the more adequate tool than bipolar charging. In unipolar charging, the ion attachment rate is proportional to the efficiency of the charger. For this size range, the ion attachment rate can be expressed by

$$\frac{di}{dt} = n_i \pi {d_p}^2 \left[\frac{kT}{2\pi m_i}\right]^{\frac{1}{2}} exp\left[\frac{-2e^2 i}{d_p kT}\right] \quad [1]$$

where i is the number of charges, n_i is the ion concentration, m_i is the ionic mass, e is the elementary charge, k is the Boltzmann constant, T is the temperature and d_p is the particle diameter (Friedlander, 2000). The ion attachment rate for unipolar chargers is thus proportional to $(1/m_i)^{1/2}$.

In this work we tested the effect that the following factors have on ion mobility (Z_i) and mass (m_i), for both the positive and negative polarity: 1) the purity of the carrier gas; 2) the bulk composition of the carrier gas; 3) the type of ion source; 4) the use of silicone-based conductive tubing in sampling lines.

METHODS

Two aerosol neutralizers were employed in our experiments: an ^{241}Am radioactive neutralizer (Model 5622, GRIMM Aerosol Technik GmbH, Germany) and a bipolar corona neutralizer (Model 1090, MSP Corp., Minnesota, USA). The mobility of the ions produced by the two neutralizers was measured using a high resolution, high transmission parallel-plate DMA (SEADM P5 DMA) coupled to a Faraday cage electrometer (SEADM). The mass of the ions produced by the two neutralizers was measured with a custom-made Atmospheric Pressure interface Time-of-Flight Mass Spectrometer.

The bulk composition of the carrier gas was varied using nitrogen or synthetic air (purity > 99.999%). Impurities contained in the carrier gas were either removed by using a gas purifier (Aglient, Model CP17973), or they were added by including a small piece of silicone-based conductive tubing of 1-cm long and 0.6 cm in internal diameter in the sampling line (TSI, ID 3001788, USA).

RESULTS

Figure 1 provides measurements of the ion mobility and mass distribution produced by the neutralizer, with and without a 1-cm piece of conductive silicone tubing installed upstream the charger, using purified nitrogen as carrier gas. Upon the introduction of silicone tubing in the sampling line, $\overline{Z_i}$ decreased by 39.0 % (positive) and 15.0 % (negative), whereas $\overline{m_i}$ increased with 385 % (positive) and 76 % (negative). This shows that conductive tubing has a strong influence on the mean ion properties and that the positive ions are more strongly affected by changes in purity of the carrier gas compared to the negative ones.

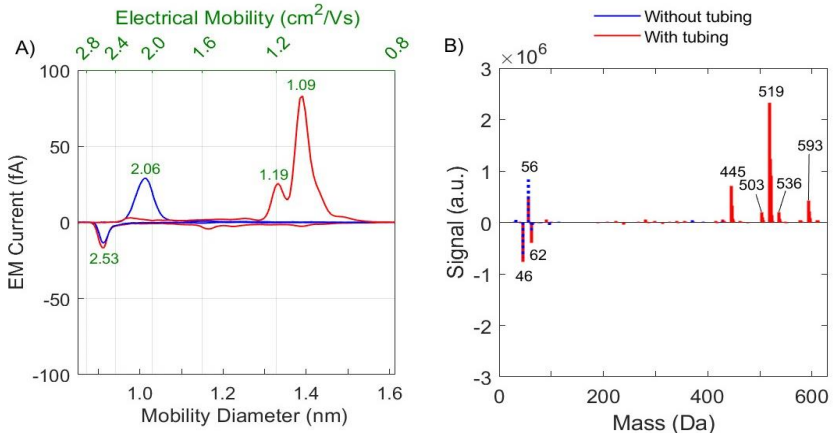

Figure 1: Mobility (A) and mass (B) distributions of positive and negative ions produced by the radioactive source, with and without a 1-cm piece of silicone tubing upstream the charger, using purified nitrogen as carrier gas. The positive and negative ions are represented on the respective x-axis.

Furthermore, additional results showed that upon gas purification, $\overline{Z_i}$ increased with up to 65 % and $\overline{m_i}$ decreased with up to 61 %. Using 5.0 synthetic air as carrier gas instead of 5.0 nitrogen increased $\overline{Z_i}$ up to 52 % and decreased $\overline{m_i}$ with 39 %. Our results also show that the ionization methods (bipolar corona charger or radioactive Am-241 decay) were comparable in their yielded ion properties.

CONCLUSIONS

By using a variety of experimental setups that are relevant to aerosol charging, we showed that the mobility and mass of ions produced by radioactive and corona chargers are highly sensitive to the specific configuration that is used. In particular, the use of silicone conductive tubing in sampling lines or the purification level of the nitrogen gas strongly affects the ion properties, where trace amounts of impurities can already have a significant effect. The present study therefore demonstrates that the ionic species produced in aerosol chargers are mainly based on impurities. This finding underscores that one must be critical concerning the general assumptions for ion properties utilized in aerosol charging theories, especially when employing unipolar chargers.

ACKNOWLEDGEMENTS

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Identifying controls of the intensity of extra-tropical cyclones using a massive ensemble of baroclinic life cycle simulations.

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Keywords: extra-tropical cyclones, winds, precipitation, climate change.

INTRODUCTION

Extra-tropical cyclones - often also called mid-latitude cyclones or low pressure systems - are weather systems which regularly occur in the mid-latitudes. These weather systems are responsible for the majority of the precipitation in the mid-latitudes and often have strong winds associated with them. The most extreme extra-tropical cyclones can lead to major societal and economic impacts. For example, intense or sustained rain can lead to surface flooding,particularly in urban areas, whereas strong winds can down electricity lines and trees. Furthermore, these strong extra-tropical cyclone can lead to storm surges and extensive coastal flooding. Therefore, it is very important to consider how both the meteorological aspects and impacts of extra-tropical cyclones will change in the future as the climate warms. Furthermore, to enhance our understanding of the dynamics and physics governing the intensity of extra-tropical cyclones, it is also fundamentally important to be able to explain why these weather systems will respond in the way they do to climate change.

METHODS

Fully coupled climate models are extremely complex and often it is exceptionally difficult, if not impossible, to identify clear chains of causality when looking at how extra-tropical cyclones respond to climate change. Furthermore, given the large amount of variability in extra-tropical cyclone structure and intensity, it can be hard to extract statistically significant signals from climate model simulations. For this reason, we have adopted an idealised modelling framework for this study in which the background state of the atmosphere can be heavily controlled. More specifically we perform baroclinic life cycle simulations which have been used extensively since the 1970s onwards to understand the dynamics of extra-tropical cyclones and more recently to investigate how extra-tropical cyclones respond to increasing temperatures.

However, these baroclinic life cycles simulations are often difficult to set up and previous studies that have used baroclinic life cycle simulations to understand cyclone dynamics often include only a handful of different initial background states. Here we introduce a flexible set up for both dry and moist baroclinic life cycles that can be run with and without physics. We have successfully implemented this initial state into OpenIFS, which is a state-of-the-art global numerical weather prediction model developed by ECMWF and is also the atmospheric component of the climate model, EC-Earth. A key strength of this set-up is that via the namelist a user can control many aspects of the background state: the height, width and strength of the upper level jet stream, the average surface temperature, the environmental lapse rate, the surface relative humidity and the surface roughness. Using this set-up we have performed a huge ensemble (more than 5000

members) of baroclinic life cycle simulations with the aid of climateprediction.net, a volunteer computing, climate modelling project coordinated by the University of Oxford.

RESULTS

The results from the control simulation indicate that the baroclinic state has been correctly implemented into OpenIFS and that realistic weather systems develop. Furthermore, unlike many previous baroclinic life cycle simulations that were run in limited area models, the global simulation performed here allows for the realistic development of both upstream and downstream cyclones. The initial results from the large ensemble show that the intensity of the extra-tropical cyclones, quantified by the maximum vorticity at 850-hPa, is strongly controlled by the strength and width of the jet stream and thus the large-scale temperature gradient. Analysis is on-going to determine the full relation between the specified background states and the meteorological intensity, and impact relevant diagnostics, of the simulated extra-tropical cyclones.

CONCLUSIONS

A large ensemble of idealised simulations of extra-tropical cyclone has been successfully performed and an extensive data set produced. This will enable unprecedented analysis of how the back ground state of the atmosphere controls the evolution, intensity and impacts of extra-tropical cyclones now and in future climates.

ACKNOWLEDGEMENTS

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PHYSICOCHEMICAL PROCESSES BEHIND NEW PARTICLE FORMATION IN THE PO VALLEY, ITALY

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Keywords: FORMATION RATE, NEW PARTICLE FORMATION, PARTICLE SIZE DISTRIBUTION

INTRODUCTION

The Po Valley in Italy is considered one of the most polluted areas in Europe as the area has many sources of anthropogenic pollutants, from local industrial sites and power plants to agricultural activities and ship emissions from the Adriatic Sea. The surrounding mountains also modulate the air flows in the area and often trap pollution. In this study, we investigate the formation of new particles in the Po Valley during spring 2022 by measuring the size distribution of aerosol particles and the concentrations of aerosol precursor vapors with a set of instrumentation specifically designed to study new particle formation (NPF).

METHODS

We measured the size distribution of atmospheric aerosols between 1 and 800 nm by using a combination of instruments: A half-mini differential mobility particle sizer (DMPS) to measure aerosols between 2-15 nm, a Hauke-type DMPS for measurements from 10 to 800 nm in size and a Particle Size Magnifier (PSM) to measure the smallest clusters between 1 and 3 nm in size. Precursor vapor measurements were conducted with a Chemical Ionization – Atmospheric Pressure interface – Time of Flight mass spectrometer (CI-APi-ToF) and an APi-ToF. The measurements took place at the San Pietro Capiofume meteorological station, about 25 km north-east of Bologna in the Po Valley and lasted from February 17th to May 7th, 2022.

CONCLUSIONS

Our comparison of the particle formation rates (Figure 1) in the Po Valley to chamber studies performed at the CLOUD chamber (Cosmics Leaving Outdoor Droplets) chamber shows that the nucleation mechanism in Po Valley is likely driven by a combination of sulfuric acid, amines and ammonia. Further growth of the particles is not well explained by sulfuric acid (H_2SO_4, SA) and its stabilizing molecules, instead requiring the presence of other vapors such as oxidized organic molecules, likely of both anthropogenic and biogenic

in origin. We further explore the relevance of NPF in Po Valley and its significance to the atmospheric system in one of the most polluted areas of Europe by analyzing the particle number size distributions and chemical precursor vapor concentration data collected in the field.

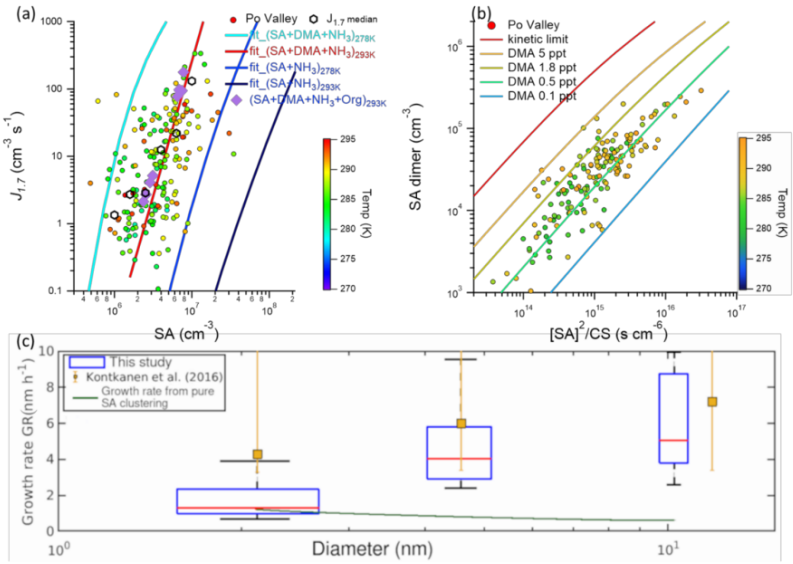

Figure 1. (a) The formation rate of 1.7 nm particles ($J_{1.7}$) versus SA concentrations in the spring in Po Valley (circles) and experimental results from CLOUD chamber experiments (diamonds). The lines are from the fitted results of chamber experiments, (b) the relationship between sulfuric acid (SA) dimer and monomer concentration and the condensation sink (CS). The $J_{1.7}$ and corresponding SA concentrations of CLOUD chamber results are from previous literature (Xiao et al., 2021). (c) Calculated growth rates from this study and values reported by Kontkanen et al 2016. (yellow squares). The red lines are the median values, the blue boxes contain values between 25th and 75th percentiles and the black whiskers mark the 5th and 95th percentiles. The green line represents predicted growth rates from pure sulfuric acid condensation (Stolzenburg et al., 2020). Figure from Cai et al., (2023).

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MODELLING CARBON EXCHANGE IN A DECIDUOUS FOREST USING LEAF CHLOROPHYLL DATA

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Keywords: The QUINCY model, carbon cycle, nitrogen cycle, leaf area index

INTRODUCTION

Climate change will potentially alter the terrestrial carbon cycle and the carbon sequestration potential of the vegetation might change. Understanding the processes governing the interactions between the atmosphere and the vegetation will help us to predict the carbon sequestration capacity of the vegetation in future. The terrestrial biosphere models (TBMs) are crucial tools in combining all the process understanding of the ecosystem processes and in making predictions of the carbon cycle.

Parts of these models have been developed on a theoretical basis, while some parts rely on semi-empirical relationships. It is important to challenge these models with data, so that the most important development needs can be understood. Novel observations, also from spaceborne observations, have become available and provide a rich source of data for model testing and development. In this work we have used several data sources together with a TBM at a deciduous forest site. First, we tuned the model using observations of leaf area index and leaf chlorophyll. Next we evaluated the model performance against other data.

METHODS

We used observations from the Borden Forest Research Station, a mixed deciduous forest located in southern Ontario, Canada. The carbon flux observations by eddy covariance method were available for 1996-2018 (Froelich et al., 2015) and continuous leaf area index (LAI) observations for 1998-2018 (Rogers et al., 2021). Additionally leaf level observations of leaf chlorophyll, biochemical parameters and leaf nitrogen content were used (Croft et al., 2017). Meteorological data from the site was needed to run the model and soil moisture and temperature were used in model evaluation.

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. QUINCY explicitly simulates the leaf chlorophyll content of the leaves.

RESULTS

The original model predicted too late autumn drawdown of the gross primary production (GPP). This was improved by using the LAI observations and tuning the model parameter controlling autumn senescence. Next we used the leaf chlorophyll observations to improve modelling of this variable. Tuning its magnitude did not have a pronounced effect on the simulation results. During spring the development of leaf chlorophyll and LAI were decoupled in the observations (Croft et al., 2017). When we included this behaviour also to the model, we obtained a better seasonal fit of the model results to the observed GPP and biochemical parameters.

Despite these improvements and generally successful modelling results, the simulated summertime magnitude of GPP remained underestimated by 20%. The QUINCY model was successful in estimation of the growing season length, but the observed increase in the annual GPP values during the whole time period was not replicated by the model. This might imply other reasons than climatic variability to influence this trend, e.g. changes in the forest structure, that are not included in the model. A drought that took place in 2007 influenced the observed carbon fluxes in the following year in a way that the model was not able to simulate, suggesting that the mechanism causing this legacy effect is not included in the QUINCY model.

CONCLUSIONS

Using leaf chlorophyll observations to tune the QUINCY model improved the seasonal cycle of the simulated GPP. Overall, using the different observations helped to pinpoint which processes in the QUINCY model require improvements. The demonstration of how leaf chlorophyll improved the modelling of GPP paves way for making use of remote sensing observations of leaf chlorophyll in our modelling framework and towards evaluation of nitrogen cycle at global scale using optical observations.

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SMART INDICATORS FOR THE RESTORATION OF ECOSYSTEM SERVICES IN EUROPEAN WETLANDS

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Keywords: Ecosystem services, SMART indicators, Restoration, Wetlands.

INTRODUCTION

Wetland restoration is an emerging management practice that aims to reduce ecosystem degradation, improve the recovery of ecosystem functions, increase resilience against future changes in the environment and climate and offer recreational and economic benefits. WaterLANDS, an EU Green Deal Project (H2020-LC-GD-2020-3), aims to restore European wetland sites damaged by human activity and create best practice models that can be applied to wetland restoration at other sites and on a large scale.

Our task within the project focuses on measurable indicators that can be used when evaluating the restoration success defined as the provision of targeted ecosystem services. A specific task (WP1,task 1.1.) is to identify and evaluate the most suitable tools and SMART indicators (Specific, Measurable, Achievable, Realistic and Time-bound (Doran 1981)) to monitor the success of restoration actions in inland and coastal European wetlands based on existing scientific and practical knowledge.

METHODS

First, we performed a systematic literature survey on the ecosystem services produced by the main types of palustrine wetlands that occur in Europe: fens, bogs, inland marshes, coastal marshes and swamps, and on the main indicator variables of each ecosystem service in each wetland type.

The second step of the study was to interview restoration managers of already restored wetland sites on their views of the most suitable indicators and measurement methods for the ecosystem services at their sites. The semi-structured interviews were addressed to the WaterLANDS partners working on restoration in so called Knowledge Sites (n = 14) in different countries across Europe. Prior to the interviews, the respondents were asked to fill in a short pre-questionnaire. The battery of questions was pre-tested, and the final battery of questions edited according to this advance preparation. A key aspect of this approach was to create a conversational and neutral platform between the interviewer and each respondent to openly share views and opinions.

RESULTS

Bogs, fens and inland marshes were similar in their ecosystem services: biodiversity, habitat provision and nature conservation, water quality and nutrient regulation, global climate regulation and water flow regulation were the most recognized services with fairly equal shares. In coastal marshes, sediment retention was the most recognized service.

Indicator variables for the same services differed between the wetland types. Nevertheless, plant community composition, water table level and dynamics, water chemistry and plant aboveground biomass were common indicator variables across ecosystem services and wetland types.

CONCLUSIONS

The combination of the literature-based and practice-based approach will produce knowledge base for the growing field of wetland restoration in Europe. By providing achievable measures to monitor restoration success it will clarify the target state aimed in restoration practises. Restoration practitioners can follow the offered guidelines to implement their restoration actions in a way that supports their needs and consider the different aspects of the overall sustainability. Conclusively, the knowledge created by this study will help restoration practitioners for better design and planning of restoration actions.

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INCREASING TREND OF GLOBAL IN-AIR DESERT DUST CONCENTRATION BASED ON THE SILAM DISPERSION MODEL AND ERA5 METEOROLOGICAL DATA

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Keywords: dust, atmospheric transport, climatology.

INTRODUCTION

Wind-blown desert dust impacts the Earth radiation budget both through in-air plumes and deposition onto snow and ice covered surfaces. Dust also presents risks to human health, and is involved in providing nutrients for oceanic ecosystems. Understanding the factors that impact dust emission and transport, and how these change with time, is thus essential for multiple fields of research.

METHODS

A climatological study of global dust concentration, emission, and deposition has been performed with the SILAM atmospheric dispersion model for the time period 1980 - 2022. The model for the emission and transport of dust was driven by ECMWF ERA5 meteorological reanalysis data. The SILAM dust emission model is driven by the 10 m wind speed, surface soil moisture, leaf area index (LAI) and snow cover provided by ERA5, as well as the global surface roughness retrieved from satellite measurements. Of these, the surface roughness and the LAI do not vary by year, which means that the modeled trend of dust emission mainly depends on changes of the surface wind speed and soil moisture.

RESULTS

The study suggests a clear increase of the global dust burden, highlighted by the trend of the surface PM10 dust concentration shown if Fig. 1. Overall, the average global surface PM10 dust concentration has increased by roughly 10 %, i.e. from roughly 9 $\mu g/m^3$ to 10 $\mu g/m^3$, during the 43 year long simulation period, mostly driven by increasing dust concentrations in the Saharan desert. Statistically significant increases are also found in more populated areas, such as Eastern Africa and Central Asia, and even in South-Eastern Europe and some southern parts of North America.

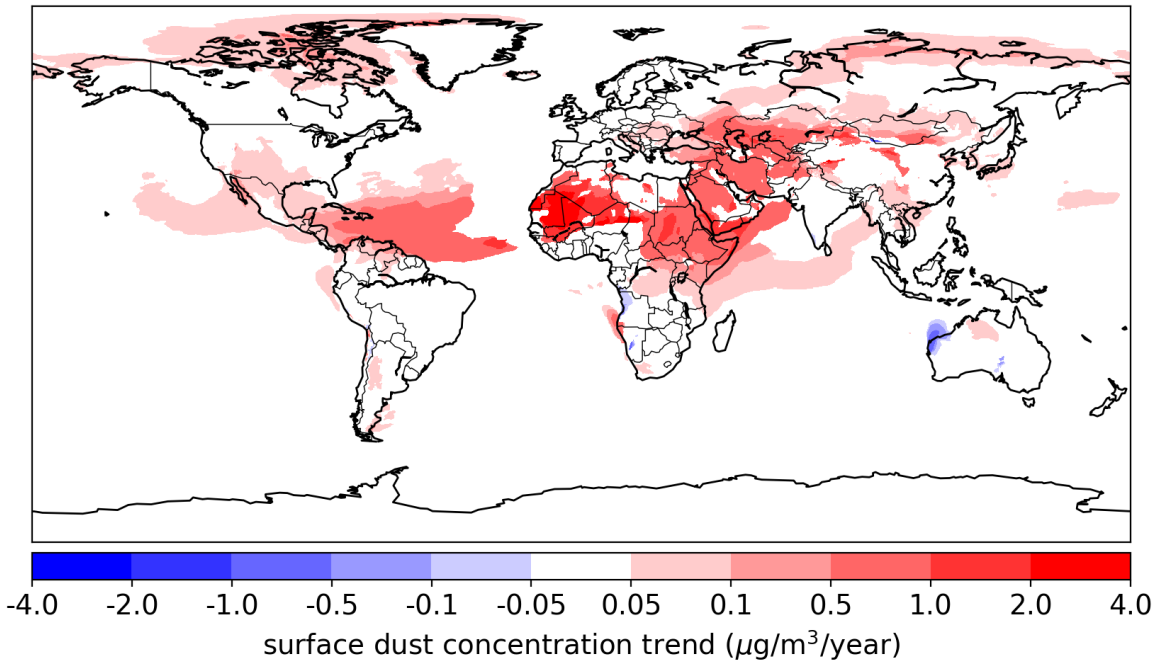

Figure 1: Global trend of surface dust PM10 concentration based on the SILAM model and ERA5 meteorological data. A nonzero trend has been plotted only when the corresponding p-value is less than 0.05.

CONCLUSIONS

The study suggests an increasing trend of in-air dust concentrations during the past 43 years. Although the total aerosol optical depth modeled by the SILAM model has been validated against recent AERONET sun photometer data, further studies are required to fully validate the existence of the simulated trend.

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PROJECTED CHANGES IN PRECIPITATION AND WIND SPEED OVER FINLAND FROM A CONVECTION-PERMITTING REGIONAL CLIMATE MODEL

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Keywords: Regional climate modeling, Convection-permitting, HARMONIE-Climate, Climate change.

INTRODUCTION

The future's climate can be simulated using global circulation models (GCMs), which apply relatively coarse spatial resolutions and hence, they cannot resolve all the features on the regional scale. High-resolution regional climate modeling is a dynamical downscaling method, which uses GCM data as its boundary conditions, and allows to explore very fine grid resolutions down to 1−5 km. At this convective scale, it is possible to explicitly resolve deep convection. In addition to the more precise modeling of topography, this convection-permitting feature enhances modeling of moisture transport and, consequently, this adds value in model's short-duration extreme precipitation events at local scales (Me dus *et al.*, 2021).

In Finland, the climate change studies have projected an increase in precipitation in the future (Ruosteenoja and Jylhä, 2022). This trend is expected to continue towards the end of the century, with potentially severe consequences on ecosystems and economy. This thesis studied precipitation in Finland's land area and determined if there was any change in its intensity under the given climate scenario.

METHODS

The model output data were analyzed to understand the implications and trends of near-future climate change in Finland, with a specific emphasis on future precipitation and wind speed patterns on hourly scale. The comparison was made for the historical time period 1985−2005 and the scenario data RCP4.5 for the near future 2040−2060. The examined months for this study were May, June, July, August, and September. The climate model data is from a climate model called HARMONIE-Climate AROME (cycle38) (Belusic *et al.*, 2020), which used data from the global circulation model (EC-Earth2) as boundary conditions.

RESULTS AND CONCLUSIONS

The frequency analysis of the precipitation intensities showed an increasing trend of higher precipitation intensities, and the trend was stronger as the intensity increased. Light precipitation appeared to decrease while heavy and extreme precipitation became more common. This is shown in Fig. 1, where for the intensity category 0.1−5 mm/h the change between the examined time intervals showed a decrease of (-5.2 ± 6.7) %. For the heavier intensities beyond, there were a strong positive relative changes: 5−10 mm/h had a corresponded change of (+14.6

± 9.0) %; 10−20 mm/h had a change of (+23.2 ± 13.0) %; 20−30 mm/h had a change of (+41.1 ± 25.0) %; and 30−45 mm/h had a change of (+68.7 ± 45.0) %. The highest examined intensity was 45 mm/h or more, and it had an outstanding change of (+106.0 ± 72.0) %. The lowest and highest intensity categories failed to reject the null hypothesis. The regional average precipitation analysis showed that the biggest change occurs in Lapland by +4.1 %; Southwest and western Finland has relative change of +2.2 %; and the least change occurs in Southeast and eastern Finland by +1.3 %.

The projected wind speed did not show any strong signals or statistically significant results with the one-model set-up, as was expected based on the previous studies. The frequency analysis showed a slight indication of a decrease in the future's wind speed, but the projection processes a high uncertainty. HCLIM38 showed topographically distinct regions within the domain for the wind speed and, for example, the in-land water regions were clearly visible and realistically modeled.

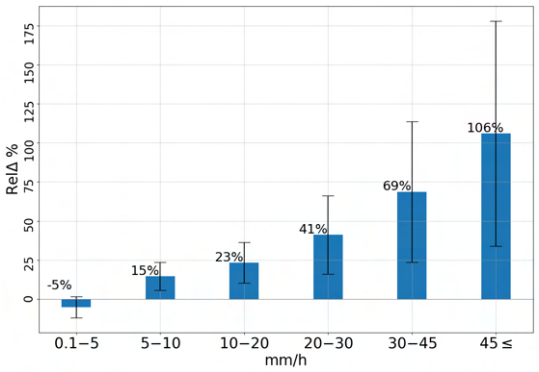

Figure 1: Relative change of precipitation intensities between periods 1985−2005 and 2040−2060 RCP4.5.

The statistical significance analysis of the average precipitation changes showed that most of the results failed to reject the null hypothesis. Such a result could suggest that the studied climatic periods, 21 years, were not long enough as suggested also in the study by (Lind *et al.*, 2023). While the analyzed model data can be considered state of-art, the use of single model results and the stochastic nature of climate data prompts further investigations of these findings using, for example, multi-model ensembles and investigations of extended time series in the analysis.

ACKNOWLEDGEMENTS

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AMMONIA FLUX MEASUREMENTS AT THE SMEAR-AGRI STATION USING BENZENE-CIMS

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Keywords: AMMONIA, EDDY COVARIANCE, MASS SPECTROMETRY, AGRICULTURE.

INTRODUCTION

Agriculture accounts for 90% of ammonia (NH_3) emissions in Finland and in Europe (Monteny & Hartung, 2007). NH_3 directly contributes to aerosol particle formation by associating with acids to form inorganic salts, which can dominate the inorganic aerosol loading. NH_3 can also participate in the first steps of new particle formation (NPF) by cluster formation and in the subsequent growth of these clusters to climatically relevant sizes (50-100 nm) (Kulmala et al., 2013). However, relatively few studies have measured the ecosystem-scale exchange of NH_3 originating from agricultural fields. While the deposition of NH_3 can compete with its uptake into aerosol particles, it is also associated with numerous adverse biological and environmental effects. A broader understanding of the exchange of NH_3 is required to fully describe the couplings between emissions, transport and deposition, and health- and climate-relevant aerosol formation. Eddy covariance (EC) is a micrometeorological technique that directly measures the vertical exchange of trace gases such as NH_3. It can overcome the undesirable side effects of chamber measurements and is more representative of ecosystem-scale NH_3 exchange by minimizing potential sampling error when upscaling from a small number of enclosures to ecosystem fluxes. The accurate determination of NH_3 exchange rates is challenging due to its interaction with instrument surfaces leading to high detection limits and slow response times. Also, EC measurements require a rapid data acquisition (typically 10 Hz) to capture the full range of turbulence fluctuations. Recent advances in this field taking advantage of benzene cation ionization scheme have allowed us to investigate inherently sticky NH_3, with low detection limits (down to < 10 part per trillion) and fast time response (better than 1 sec) at high acquisition rates (10 Hz) (Schobesberger et al., 2023). Here, we report ecosystem-scale NH_3 fluxes measured by benzene chemical ionization mass spectrometry (B-CIMS) combined with the EC technique. We use flux footprint calculations to pinpoint the source of the NH_3 and show land use (application of fertilizers) impact on NH_3 emissions.

METHODS

EC flux measurements were carried out at Station for Measuring Ecosystem-Atmosphere Relations - Agriculture (SMEAR-Agri) in Viikki, near Helsinki (60º13' N, 25º01' E, 1.6 m a.s.l.). The EC measurements took place during the transition from winter to spring (March 16 to May 22, 2023). NH_3 was measured using a B-CIMS, sampling co-located with a sonic anemometer (METEK USA-1) at 10 Hz, from a height of 2.5 m above ground. A high-flow main inlet with >5000 lpm suction flow with a horizontal core sub-sampling of 22 lpm was used to sample air into the B-CIMS to minimize sample-wall interactions (Vettikkat et al., 2023). The large high-frequency dataset was analyzed using tofTools, and parallel computing was utilized for peak fitting. We followed standard procedures for EC analysis, including spectral corrections using the InnFLUX toolbox. The B-CIMS data was corrected for water-dependent sensitivity. Meteorological parameters such as air temperature and relative humidity were measured at SMEAR-Agri using a Rotronic HC2 sensor (Junninen et al., 2009).

RESULTS

We measured NH_3 fluxes using B-CIMS and observed that there was a clear diurnal pattern for the fluxes (Figure 1a), peaking at noon with a median of 0.006 ppbv m s^{-1}. We measured the highest ammonia flux of 1.8 ppbv m s^{-1} on 27th April 2023. The flux footprint analysis show that the source area during the highest flux was from Alaniitty 1 field (Figure 1b) which was being fertilized with organic manure. This footprint-based analysis enables us to relate the source area with the measured NH_3 and calculate the N balance. Figure 1b shows that 90% of the flux footprint for the whole campaign was within the agricultural fields. Detailed analysis relating the fertilizer application and meteorological parameters will enable modelling the ammonia emissions from agricultural fields.

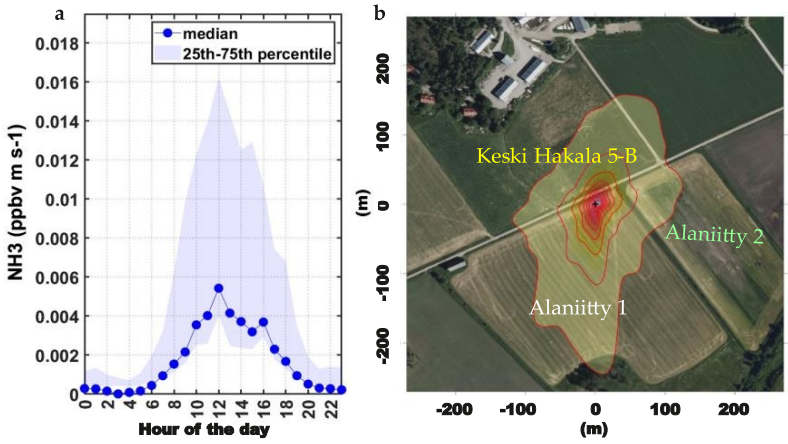

Figure 1. a. Diurnal plot of NH3 fluxes (in ppbv m s^{-1}) measured using B-CIMS throughout the campaign. b. Flux footprint for the whole campaign. The contour lines show the average source areas from 10% to 90% flux contributions.

ACKNOWLEDGEMENTS

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INVESTIGATING NITROUS OXIDE DYNAMICS IN CRYPTOGAMIC LICHEN, PLATISMATIA GLAUCA, WITHIN NORWAY SPRUCE FOREST ECOSYSTEMS

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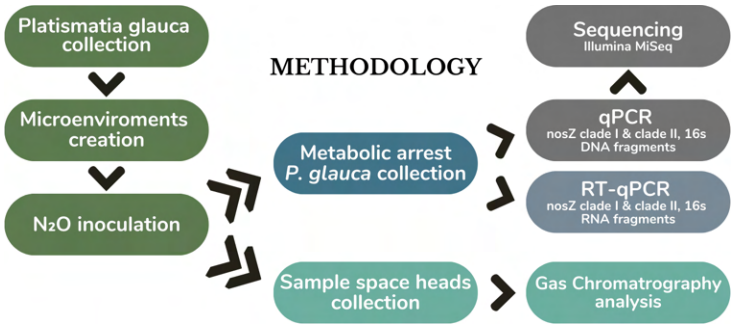
Keywords: Nitrogen, Nitrous Oxide, Nitrous Oxide Consumption, nosZ gene, Lichen, Boreal Forest, Greenhouse Gases (GHG).

INTRODUCTION

The boreal spruce forest ecosystems exhibit the intriguing capacity to assimilate atmospheric nitrous oxide (N_2O) through various biological mechanisms, including symbiotic relationships with mycorrhizae and bacteria. This phenomenon is particularly prominent during the spring and autumn seasons when aerobic microsites within the soil become prevalent. In cold soils characterised by a large field capacity (FCD), high humidity, and a lack of fertilisation, a delicate balance is observed between N_2O absorption and emission. In many instances, this balance appears to approach zero and, in some cases, even assumes negative values, indicating that these forest soils have the potential to absorb more N_2O than they emit. Moreover, the presence of cryptogamic coverings, such as mosses and lichens, in these ecosystems seems to enhance the capacity for N_2O absorption. While the primary role in nitrogen dynamics is attributed to soil and root systems, the specific contribution of epiphytic organisms, such as lichens, to this process has remained elusive. In this study, we focused on investigating the dynamics of N_2O within the lichen species *Platismatia glauca*. Our findings indicate that N_2O consumption is particularly pronounced at lower incubation temperatures. Quantitative analysis, involving real-time PCR of the nitrous oxide reductase gene fragment nosZ, revealed the presence of the enzyme in the lichen, with gene transcription being more active at lower incubation temperatures. These results shed light on the role of cryptogamic coverings in N_2O consumption within boreal spruce forest ecosystems, with consumption rates ranging from 0.1 to 0.4 ng N_2O-C/g (ww)/h. This consumption occurs at atmospheric N_2O concentrations through complete dissimilatory denitrification, particularly when nitrogen is limited, highlighting the intricate interplay between lichens and the nitrogen cycle in these unique forest environments.



CONCLUSIONS

Cryptogamic covers have a role in the dynamics of nitrous oxide, as all four lichen species studied show the capability of consuming N_2O. The epiphytic lichens present in the boreal horizons present complete dissimilatory denitrification pathways. The abundance of gene and transcript copies of the nosZ fragment at basal levels was found in all *Platismatia glauca* samples; an enrichment in gene copies and expression was observed in the samples at 5°C in oxic and dark conditions.

AIR QUALITY AND CHARACTERISTICS RESEARCH IN FOOTBALL HALLS

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Keywords: air quality, football hall, inflatable arena, climate change impacts.

INTRODUCTION

Physical activity has been found to be good for human health, and a diversity of sport infrastructures have been built for that purpose. However, a poor state of the indoor air (including air quality, temperature, relative humidity, O_2 and CO_2 contents) may have a counterproductive effect on human health. Indoor environments with poor ventilation commonly contain high concentrations of particulate matter, CO_2, and microorganisms, which can be several times higher than outdoors (e.g., Tran et al., 2020). Therefore, exercising in indoor sport facilities with poor air quality poses a severe risk for human health and may significantly affect athlete performance. A continuous monitoring of important air quality parameters would greatly benefit the development of indoor air quality metrics and help in enforcing new governmental regulations, which are currently either missing entirely or insufficient to ensure the safety of indoor sport infrastructures. Climate change impacts on sports facilities and athletes is a topic which has not been investigated in Finland. We will conduct new measurement campaigns regarding the impacting issues on sports facilities and sports athletes to know the current risks in their sport.

The aims of this campaign are to evaluate the air quality in inflatable arenas and the potential risks for the athletes' health. More precisely, the aims are as follows:
1) To determine the gaseous and particulate chemical composition inside inflatable arenas and in outdoor sport centers, and evaluate how external anthropogenic activities (traffic/biomass burning) influence those properties.
2) To obtain air quality indexes for different inflatable arenas, compare those with the ones for outdoor environments, and find additional metrics to evaluate air quality during sport activities.
3) To determine the meteorological factors affecting state of the air and air quality indoors and outdoors. For instance, by monitoring the effect of artificial turf vs. grass on the near air temperature sports fields.
4) To propose new metrics to evaluate indoor air quality which can be used for the implementation of new policies concerning the regulation of indoor centers.

METHODS

The measurement of air pollutants inside inflatable arenas and outdoor sport centers will be performed using an array of state-of-the-art sensors for the measurement of several relevant air quality parameters. The focus will be on particulate mass concentration, particle number size distributions, gases concentration, VOCs mass concentration, and VOCs chemical composition. The sensors will be most of the time permanently installed at the sites in a protective box located 2m height from the ground. However, short-term field campaigns where the mentioned box will be installed in a drone for the measurement of studied parameters at different locations of the arenas will be also performed.

The measurement of meteorological parameters will be performed using two Vaisala WXT weather stations. They are placed in two sites permanently for the whole duration of the campaign.

The study will be performed in 3 different sport centers containing inflatable structures that are removed during spring and summertime and rebuilt again in late autumn (Fig. 1). Site 1 is located next to a busy road and is therefore exposed to significant traffic emissions. Site 2 is located in a residential area and its air quality is potentially influenced by residential biomass burning emissions, especially during the coldest months. Site 3 is located next to greener areas such as city parks.

The total campaign duration will be 2 years. The air quality instruments will be installed at each location for four months at a time; two "sets" of instruments rotate in three sites. The weather stations will be permanently installed during the whole campaign.

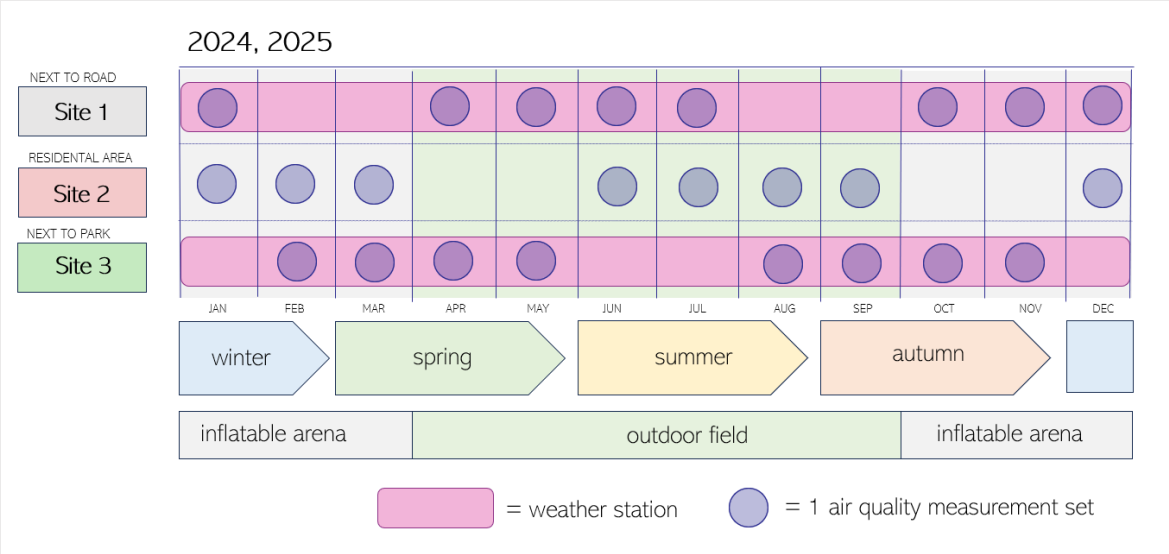

Figure 1. Work plan for the campaign, including measurement sites and seasons of the year.

We have carried out preliminary measurements of indoor air quality with low-cost sensors in an inflatable football arena located in Järvenpää, southern Finland during 2021-2022 (Gregow et al., 2022).

CONCLUSIONS

The campaign is in its starting phase, and we are currently ordering measuring devices and planning the campaign.

ACKNOWLEDGEMENTS

This work is supported by the ACCC and more funding will be applied for it.

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GENERATION OF MOLECULAR BIG DATA FOR ATMOSPHERIC SCIENCE PURPOSES

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Keywords: machine learning, particle formation, molecular data, oxygenated organic molecules.

INTRODUCTION

It is estimated that more than 70% of all cloud condensation nuclei origin from so-called New Particle Formation, which is the process of gaseous precursors clustering together in the atmosphere and subsequent growth into aerosol particles. After initial clustering, growth is strongly driven by condensation of a extremely low volatile organic compounds (ELVOC), that is molecules with saturation vapor pressures (p_{Sat}) below approx. 10^{-9} mbar (Donahue *et al.*, 2012). ELVOC are a volatility-subclass of *Oxygenated Organic Molecules* (OOM), which stem from rapid oxidation of organic molecules emitted by vegetation or anthropogenic sources in the atmosphere. Statistical tools can accelerate studies into these phenomena, but extensive and versatile OOM datasets are lacking in the atmospheric research community. The objective of this study is to create large data sets of OOM, including molecular properties computed on a high-level of theory. We further show that these properties can be learnt by a machine learning model.

METHODS

The raw data available to us was 180k atmospherically relevant molecules generated from simulated atmospheric oxidation of α-pinene, toluene and decane through the chemical mechanism GECKO-A (Isaacman-VanWertz and Aumont, 2021). For a randomly chosen subset of these molecules we

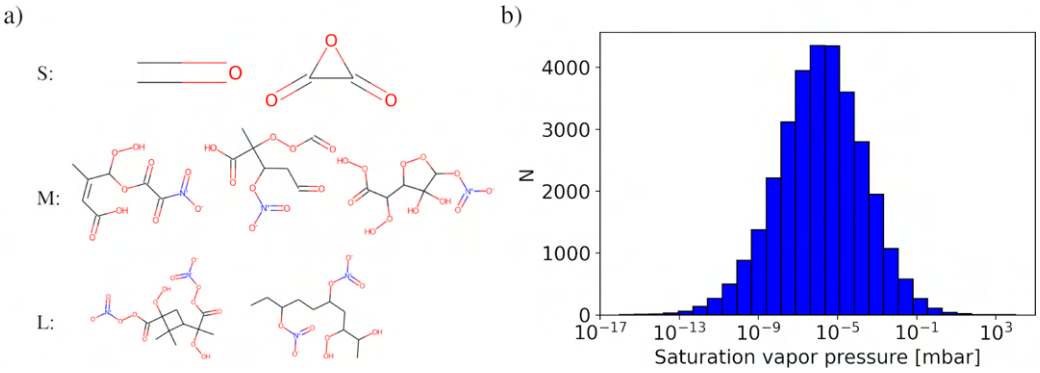

Figure 1: (a) Sample molecules of small (S), medium (M) and large (L) size included in the GeckoQ data set. (b) p_{Sat} distribution of all GeckoQ molecules.

utilized the COSMO*conf* program to find and optimize structures of possible conformers on a DFT level of theory (BP86). Then, we calculated thermodynamic properties, such as the p_{Sat}, with the COSMOtherm program and the included the Conductor-like Screening Model for Real Solvents (COSMO-RS) model, a sophisticated continuum solvation model (Klamt and Schüürmann, 1993). We bundled all these computations in a highly parallelised high-throughput workflow with the Merlin workflow program. We apply Gaussian Process Regression, a kernel-based probabilistic tool for supervised machine learning, to learn and predict the p_{Sat} of OOM.

RESULTS

We have created the GeckoQ data set containing 31,637 OOM structures and respective p_{Sat}, chemical potentials, and free energies (Besel *et al.*, 2023). See a histogram of the calculated p_{Sat} in Figure 1b. The data set further contains over 7.25 Mio. conformers. We are able to predict p_{Sat} of OOM down to an uncertainty of 0.8 order of magnitude.

CONCLUSIONS

The GeckoQ data has been published under the FAIR data principles. Thus it is freely and easily accessible and can facilitate research into molecular processes involving OOM, such as particle formation. Yet, as Fig. 1b shows the data is also limited regarding its ELVOC content, which are particularly interesting for particle formation processes in the atmosphere. In future work, we will employ Machine Learning models in a targeted search for ELVOC in available OOM data.

ACKNOWLEDGEMENTS

This work was supported by the CSC - IT Center for Science as well as EuroHPC. This study received financial support from the Academy of Finland through its flagship program, the Atmosphere and Climate Competence Center (Grant No. 337549), and the Centers of Excellence Program (CoE VILMA, Grant No. 346368).

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BUILDING A MACHINE LEARNING MODEL TO PREDICT SAMPLE PESTICIDE CONTENT UTILISING THERMAL DESORPTION MION-CIMS ANALYSIS

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Keywords: machine learning, chemical ionization mass spectrometry, pesticides, targeted screening.

INTRODUCTION

Pests are the main cause of crop yield losses, which lead to food insecurity. Pesticides are substances, or a mixture of substances, made to eliminate or control pests, or to regulate the growth of crops. Currently, more than 1000 pesticides are available in the market. Their use must follow regulations as they can cause risks to human health and the environment, as they can persist for decades and pose a global threat to the entire ecological system. Therefore, there must be a rigid control of pesticide content in the food that reaches the market (FAO, 2022). One way to analyze the content is through mass spectrometry.

This project applies machine learning (ML) tools to chemical ionization mass spectra to ultimately develop a technique capable of predicting spectra's peak intensities and moreover the chemical ionization mass spectrometry (CIMS) sensitivity to pesticides. The research will improve the effectiveness and accuracy of the analysis of mass spectra, to help the detection of pesticides in the substances analyzed. The challenge of this study consists in creating a ML model able to explain the complex ion-molecule interaction by avoiding the extremely high-cost computations that would otherwise be necessary.

METHODS

Our data set comprises different standard mixtures containing, in total, 716 pesticides measured with an orbitrap atmospheric pressure CIMS, with a multi-scheme chemical ionization inlet (MION) and five different concentrations (Rissanen et al, 2019; Partovi et al, 2023). The reagents of the ionization methods are CH_2Br_2, H_2O, O_2 and $(CH_3)_2CO$, generating respectively Br^-, H_3O^+, O^{2-} and $[(CH_3)_2CO + H]^+$ ions.

The project follows a general ML workflow: after an exploratory analysis, the data are preprocessed and fed to the ML algorithm, which classifies the ionization method able to detect the molecule, and predicts the peak intensity of each pesticide; the accuracy of the prediction can be retrieved after measuring the performance of the model. The random forest classifier algorithm was chosen to perform the classification of the ionization methods, to predict which one was able to detect each pesticide. The regression was performed with a kernel ridge regressor. Each algorithm was run with different types of molecular descriptors (topological fingerprint, MACCS keys and many-body

tensor representation), to test which one was able to represent the molecular structure in the most accurate way.

RESULTS AND CONCLUSIONS

The results of the exploratory analysis highlight different trends between the positive and negative ionization methods, suggesting that different ion-molecule mechanisms are involved (Figure 1). The performance of the classification reaches the 80% or higher for each individual ionization method. The regression is able to predict the log of the intensities for one ionization method at a time, with a correlation coefficient of 0.48 with MACCS keys as molecular descriptor (in the case of $(CH_3)_2CO$ reagent, see Figure 2).

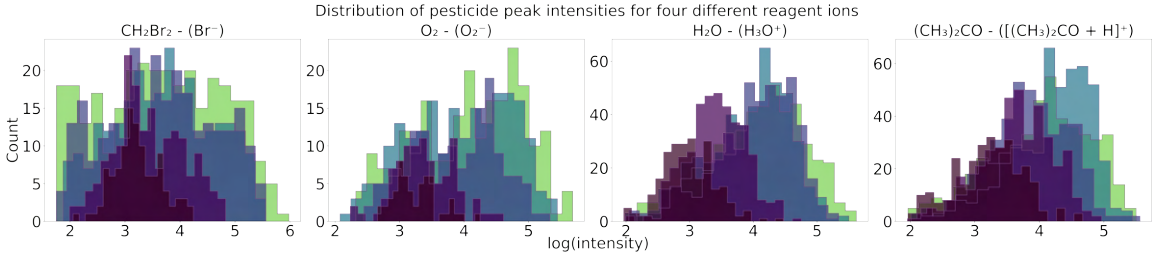

Figure 1: Distribution of pesticide peak intensities for each reagent ion at five different concentrations.

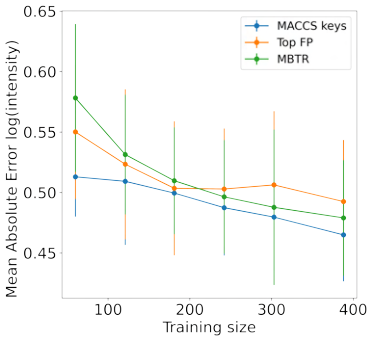

Figure 2: Comparison of the KRR performance on $(CH_3)_2CO$ reagent data with three different descriptors.

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TOWARDS UNDERSTANDING THE EFFECT OF PARAMETRIC AEROSOL UNCERTAINTY ON CLIMATE USING A CHEMICAL TRANSPORT MODEL PERTURBED PARAMETER ENSEMBLE.

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Keywords: Aerosols, Chemical transport model (CTM), PPEs, Emulator

INTRODUCTION

Aerosols in the climate system have a direct link to the Earth's energy balance. Aerosols interact directly with the solar radiation through scattering and absorption; and indirectly by changing cloud properties. The effect aerosols have on climate is one of the major causes of radiative forcing (RF) uncertainty in global climate model simulations. Thus, reducing aerosol RF uncertainty is key to improving climate prediction. The objective of this work is to understand the magnitude and causes of aerosol uncertainty in the chemical transport model TM5. Aerosol parameters are inputs to TM5 that describe the aerosol sources, sinks, transformations, physical, chemical and optical properties. Perturbed Parameter Ensembles (PPEs) are a set of model runs created by perturbing an ensemble of parameters. Parameters are model inputs, for this study we focus on parameters describing aerosol emissions, properties and processes, such as dry deposition, aging rate, emissions to aerosols microphysics. PPEs vary theses parameters over their uncertainty range all at once to study their combine effect on TM5.

This is computationally very expensive, so emulators are used to replace the full model (in our case TM5) with a statistical surrogate model that is quick and efficient. Emulation is a Gaussian based machine learning tool that simulates model outputs, based on outputs from a small number of training runs (Lee et al., 2011, 2013). It provides model outputs over the full parameter uncertainty space. The use of emulator in PPE's studies of climate models has been shown to be robust, (Lee et al., 2011; Johnson et al., 2020; Lee et al., 2013; Watson-Parris et al., 2021; Yoshioka et al., 2019).

METHODS

With the collated set of aerosol parameters and their uncertainties from literature (table 1), each one is currently tested individually in TM5. Each parameter's value is scaled to the highest and lowest values from literature to understand TM5's response to each variation.

The TM5 PPE will be composed of a set of most influential parameters that will be then varied all at once within their uncertainty range. Outputs from running TM5 a manageable number of runs spanning this parameter space, will be collected to train and validate our emulator based on one developed by Kenneth Carslaw (Leeds University) and Jill Johnson (Sheffield University) with their permission.

Table 1. Example aerosol parameters with their uncertainty ranges to be used in TM5 PPE.

Parameter	Range (R) or scaling factor (F)	Source
Sea spray	(F) 0.2-5	(Lee et al., 2013)
SO2 anthropogenic	(F) 0.5-2	Yoshioka et al., 2019
DMS	(F) 0.5-2	(Lee et al., 2013)
Black Carbon	(F) 0.5-2	(Yoshioka et al., 2019)
Nucleation rate	(F) 0.1-10	(Yoshioka et al., 2019)
SO4	(R) 3-100 nm	Yoshioka 2019
Biomass burning	(R) 90-300 nm	Yoshioka 2019
Dust accumulation mode mass mean radius	(R) 0.16-0.47 um	Huneeus 2001
Dust coarse mode mass mean radius	(R) 0.59-2.5 um	Huneeus 2001

CONCLUSIONS

The emulator outputs will show which aerosol parameters or combination of them strongly influences CCN concentrations and aerosol absorption. I will then compare with previous CTMs studies (Lee et al., 2013; Yoshioka et al., 2019) and see if the influential combination of parameters are similar from model to model or not.

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MASS SPECTROMETER DATA PMF EVALUATION TOOLKIT

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Keywords: POSITIVE MATRIX FACTORISATION, MASS SPECTROMETRY, FIGAERO-CIMS.

MOTIVATION

Mass spectrometry techniques have become an essential research tool in atmospheric science. They enable the analysis of the chemical composition of gaseous, aerosol particle, and soil samples. As examples, the gas phase concentrations of volatile organic compounds and the products of their atmospheric oxidation can be detected with Chemical Ionisation Mass Spectrometers (CIMS) with high time resolution revealing, e.g., the pathways and kinetics of chemical processes in the atmosphere (e.g., Yan et al., 2016). The Aerosol Chemical Speciation Monitor (ACSM), a simplified version of the Aerosol Mass Spectrometer (AMS), is the standard instrument for the chemical speciation of the sub-micron aerosol composition within the ACTRIS monitoring network. A special case is the Filter Inlet for Gases and AEROsols (FIGAERO). This inlet collects particles on a filter and desorbs them with a heated nitrogen flow for detection in a mass spectrometer. Since the thermal desorption is gradual, the volatility of the detected compounds can be derived in addition to the molecular composition.

Most mass spectrometer applications produce large and complex datasets which pose a challenge for the analysis and interpretation. Statistic dimension reduction techniques – especially Positive Matrix Factorisation (PMF, Paatero and Tapper (1994)) – have been found to be useful to reduce the complexity of mass spectrometry data and identify underlying trends. PMF analyses the data for underlying correlations and groups correlating signals into a few so-called factors. Instead of inspecting the trends of hundreds of individual ions, the behaviour of these few factors can be investigated and interpreted. PMF analysis of AMS data has revealed underlying trends in the data which indicate different sources of organic aerosol (Lanz et al., 2007). More recently the application of PMF has been extended to all kind of ambient mass spectrometer datasets (Yan et al., 2016; Buchholz et al., 2020).

For ease-of use, multiple user interfaces have been created to run the underlying algorithm (pmf2 or me2) – some freeware (e.g., EPA PMF software or the PMF Evaluation Toolkit, PET (Ulbrich et al., 2009)) others commercial (e.g., SoFI, Canonaco et al. (2013)). Although all of these have their strength for specific applications, none of them was equipped for the special requirements of the thermal desorption data of FIGAERO measurements. Thus, the Mass Spectrometer data PMF Evaluation Toolkit (MaS-PET) was created based around the core functionality of the PET software.

SOFTWARE DESCRIPTION

MaS-PET is designed to guide the user through the whole PMF analysis from loading their pre-processed data to providing publication-quality figures of the results. The user chooses their data type and is then presented only with the steps/functions relevant for this specific task. All analysis steps can be conducted via the graphic user interface. These features make the software versatile while keeping it simple to use even for beginners or users without programming experience. A handy export functions enables the easy export of PMF results into simple text files to be used in other applications.

A data loader is included which while optimised for the most commonly used data processing software in this field (i.e., PIKA or Tofware) also handles data from all kinds of sources using simple text files. Special focus was put on providing advanced visualisation options to easily inspect the data at any stage of the preparation as well as the PMF results. Additional functions are included to compare individual PMF

solutions with each other. For FIGAERO thermal desorption data, multiple useful visualisations are available to help with the scientific interpretation of the PMF results.

MaS-PET runs in the Igor (Wavemetrics, Versions ≥7) software environment. While licenses are required for Igor and the pmf2 algorithm, MaS-PET and PET are open-source software and freely available. Future improvements by the community are thus possible and highly desired, e.g., incorporating the AMS database comparison tool (MARMOT, Jeon et al. (2023)) or adding functionality to support new data types like binned PMF (Zhang et al., 2019).

MaS-PET was created to make the process of running a PMF analysis easier to allow the user to focus on the scientific interpretation of the results.

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INTERCOMPARISON STUDY OF PARAMETERIZATIONS FOR SECONDARY ICE PRODUCTION USING UCLALES-SALSA AND OBSERVATIONS OF ARTIC MIXED-PHASE CLOUDS

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Keywords: mixed-phase-clouds, aerosol-cloud-interactions, large-eddy-simulations

INTRODUCTION

Secondary ice production (SIP) refers to a series of in-cloud physical mechanisms that generate ice particles from pre-existing ones without intervention of ice nucleating particles (INP). SIP can increase ice number concentrations up to 10^4 above INP concentrations. This can significantly affect water-phase partitioning and in-cloud stratification in mixed-phase clouds affecting their cloud radiative feedback and their role on precipitation formation. Changes in MPC dynamics driven by stronger turbulent mixing in warmer climate scenarios may strengthen atmosphere-cryosphere interactions at high latitudes where MPC occur frequently.

SIP mechanisms go beyond the well-known rime splintering mechanism, also called Hallet-Mossop mechanism. There are parameterizations based on laboratory experiments describing SIP rates during drop freezing and ice-ice collisions. Despite being implemented in weather and climate models, it is unknown if they can be scaled up to mixing lengths observed in real clouds. Results from different parameterizations even for conceptually identical processes may differ by orders of magnitude, and it is difficult to distinguish individual SIP pathways because variable dependencies overlap among parameterizations. The most challenging issue is the lack of information about the size distribution of secondary ice particles generated per event.

Parametrizations for SIP rates are expressed as the product of an ice multiplication factor that describes the fragments generated by a single SIP event times the number of possible SIP events per unit of time given by gravitational collisional kernels. Both factors are strongly influenced by the relative size of interacting hydrometeors that defines not only the efficiency and frequency of hydrometeor-hydrometeor interactions, but also the energy available for ice fragmentation. Unlike other large-eddy-simulation models, UCLALES-SALSA allow us to monitor closely these dependencies because it incorporates a detailed microphysics scheme for aerosol-hydrometeor interactions into the cloud formation process (Tonttila et al., 2023). We present here a model version including SIP through rime splintering, fragmentation of freezing droplets and ice-ice collisional breakup using the most commonly used parameterizations of ice multiplication reported in literature.

In this study we have used two-well characterized cloud cases of the 2019 Ny-Ålesund Aerosol Cloud Experiment (NASCENT) (Pasquier et al., 2022) to investigate which variable constraints are needed to make a clear distinction of individual SIP mechanisms and what kind of feedbacks can occur among them. We have also tested which assumptions about the size distribution of secondary ice particles allow to capture observed ice number concentrations.

METHODS

We performed large-eddy-simulations for cloud events in November, 11, 2019 at the Ny-Älesund station in Svalbard. The model domain was 5600 m by 5600 m by 3000 m with horizontal and vertical resolution of 50 m and 15 m, respectively. Aerosol particles were assumed to be internally mixed composed by 95% v/v/5%v/v organic carbon/dust. The model was initialized with aerosol size distributions derived from DMPS and APS measurements and vertical profiles of observed meteorological variables combined with ECMWF-ERA5 reanalyzed data (Pasquier et al., 2022). Primary ice formation was modelled as immersion freezing, while secondary ice production was simulated in single or multi-mechanism scenarios including rime splintering, fragmentation of freezing droplets and ice-ice collisional breakup. Ground-based observations from cloud radar and halo doppler lidar, as well as in-cloud observations from the HOLographic cloud Imager for Microscopic Objects (HOLIMO) were used to mimic cloud boundaries, vertical wind distributions and size number concentrations of ice nucleating particles, ice particles and droplets.

RESULTS

Despite the close agreement between modeled and observed droplet microphysics and INP concentrations, none of the simulation scenarios with individual SIP mechanisms or combination among them produced SIP that were high enough to reproduce observed ice number concentrations. In all cases, SIP rates were limited by very low collision kernel values indicating a very reduced number of possible SIP events. Number concentrations along cloud events were below 10 cm^{-3} for droplets and below 10 $^{-3}$ cm^{-3} for ice particles. Parameterizations of ice multiplication factors with droplet diameter dependence (RS, FFD) predicted very low ice multiplication factors per SIP event at the count-mean droplet size of 50 μm. Low ice multiplication factors were also calculated for ice-ice collisional breakup as the count-mean ice particle maximum size remained around 300 μm with the largest particles around 1000 μm.

CONCLUSIONS

Current SIP parameterizations do not reproduce observed ice number concentration in Artic mixed-phase clouds influenced by SIP events. There is an urgent need for laboratory studies that settle variable dependencies of SIP rates in all the studied mechanisms. In-cloud observational studies are also needed to gain insights on the size distribution of secondary ice particles and also on the expected range of variation for collision kernels.

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MODELLING CO_2 AND CH_4 FLUXES FROM PEATLAND FORESTS WITH JSBACH-HIMMELI MODEL

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Keywords: CLIMATE CHANGE, METHANE, MODELLING, PEATLAND

INTRODUCTION

Peatlands are important carbon sinks and simultaneously, sources of methane (CH_4). Water table level (WTL) is an important driver for CO_2 and CH_4 fluxes between the peat and the atmosphere (Minkkinen & Laine 2006). In Finland, around half of the peatland area is drained for forestry. Drainage leads to WTL drop, which increases soil CO_2 emissions, especially in nutrient-rich sites (Ojanen & Minkkinen 2019). In addition, harvesting has an impact on CO_2 emissions from the soil, because WTL can differ considerably between different harvesting intensities (Korkiakoski *et al.* 2019). Rewetting, by rising the WTL by blocking the drainage ditches, can reduce CO_2 emissions and eventually return the soil back as carbon sink (Wilson *et al.* 2016).

Our aim is to first simulate the impacts of management (with different harvest intensities) and later, simulate the effects of rewetting, on the soil CH_4, and CO_2 exchange of peatland forests with JSBACH-HIMMELI model (Raivonen *et al.* 2017, Reick *et al.* 2013). The production and oxidation of CH_4 and the production of CO_2 from aerobic respiration vary in different peat layers (Peltoniemi *et al.* 2023, Putkinen *et al.* 2018, Urbanová *et al.* 2013, Glatzel *et al.* 2004), depending on e.g. WTL. In the model, we want to realize this by adjusting the parameter values responsible for these processes, depending on the peat depth. As a result of the first study, we will present a new HIMMELI model version and show simulated CH_4 and CO_2 fluxes from six forestry-drained peatlands.

METHODS

HIMMELI was originally developed to predict methane emissions from pristine peatlands. The model is driven by the rate of anaerobic respiration, WTL, soil temperature and LAI of the aerenchymatous gas-transporting vegetation (Raivonen *et al.* 2017). A process-based ecosystem model JSBACH (Reick *et al.* 2013), driven by weather data, is here used to produce site-specific anaerobic soil respiration rate, WTL and soil temperature as inputs for HIMMELI. WTL data and manual chamber flux data have been earlier collected from each of the six peatland forest sites, including 1-3 different management types (control = no management, selection harvesting, clear-cut), and differing by the level of nutrient-richness. We use the measured WTL data to adjust the modelled WTL.

Starting point to our work was HIMMELI version, which was earlier developed (Li *et al.*) for drained peatland forests. The main difference to the original version is in how the dissolved gas concentrations are treated when WTL drops. We will further develop this version by adjusting the model parameters controlling the production and oxidation of CH_4 and aerobic respiration individually in different peat depths. To assess suitable parameter values, we are using results from the peat incubation experiment conducted in 2022 in a nutrient-rich peatland forest Rottasniitunsuo, which will be rewetted in 2024.

CONCLUSIONS

Based on the preliminary results we can conclude that the new HIMMELI version, with the implemented changes to the CH_4 production and oxidation and CO_2 production in different peat layers, can improve the prediction for CH_4 and CO_2 fluxes from different drained peatland forests. Controlling the WTL in JSBACH-HIMMELI seems to be a sufficient way to simulate the fluxes in differently managed peatland forests.

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THE FLEXPART-SOSAA MODELLING SYSTEM FOR ANALYSIS OF AIR QUALITY AND ATMOSPHERIC CHEMICAL AND PHYSICAL PROCESSES AROUND THE WORLD

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Keywords: Air quality, Atmospheric modelling, Atmospheric chemistry, Trajectory analysis.

INTRODUCTION

At the Multiscale Modelling (MSM) Group at the Institute for Atmospheric and Earth System Research (INAR) at the University of Helsinki, together with the Atmospheric Modelling Centre (AMC) – Lahti, also part of INAR, we have been developing the model to Simulate the concentration of Organic vapors, Sulfuric Acid, and Aerosols (SOSAA), an atmospheric column model for simulating atmospheric chemistry and physical processes. SOSAA has already been tested and proven as a geographically static model at the Hyytiälä field station (Zhou et al., 2014; Boy et al., 2011). One major advantage of SOSAA compared to other models, such as regional chemical transport models, is that SOSAA includes size distribution of aerosols in addition to total particulate mass concentration (Zhou et al., 2014).

We are now running SOSAA along trajectories arriving at Hyytiälä, which are calculated with the Flexible Particle Dispersion Model (FLEXPART). The purpose of running SOSAA along trajectories instead of a static location is to trace back emission sources and airmass history prior to observation at the station. In addition to Hyytiälä, we are also running the FLEXPART-SOSAA system in Beijing for air quality analysis. Additionally, we are planning to run the FLEXPART-SOSAA modelling system over Istanbul, Athens, and Lagos for air quality studies, and we further plan to run it for a site near Manaus, Brazil with the aim to better understand atmospheric chemical processes and aerosol formation over a tropical rainforest. Furthermore, our plans include a long-term SOSAA study in Lahti, Finland, with the aim to look at changes in the city's air quality over time as the city implements green policies, for example transition to electric buses and vehicles.

METHODS

As input, FLEXPART requires the output of a numerical weather prediction model, and for this project, we have chosen the European Centre for Medium-Range Weather Forecasts (ECMWF) Reanalysis version 5 (ERA5) datasets, which is based on ECMWF's Integrated Forecast System. For the Beijing air quality study, we also ran the Environment-High Resolution Limited Area Model (Enviro-HIRLAM) to use as meterological input for FLEXPART. The reason to use Enviro-HIRLAM is because it includes the effects of aerosols (both direct and indirect) in its numeric weather forecasting, which is done online and is integrated into the forecast. The primary motivation for this in our case study is because we hypothesize that the effects of aerosols in heavily polluted regions will impact the meteorology, which will in turn impact the trajectories and thus the results from the FLEXPART-SOSAA model system. We believe that during the haze event with heavy aerosol loading, the impact of aerosols on meteorology should be included for best results. Details of the Enviro-HIRLAM-FLEXPART integration are in Foreback et al. (currently under review in *Big Earth Data*). A map of our current and planned FLEXPART-SOSAA model runs and analyses is shown Figure 1.

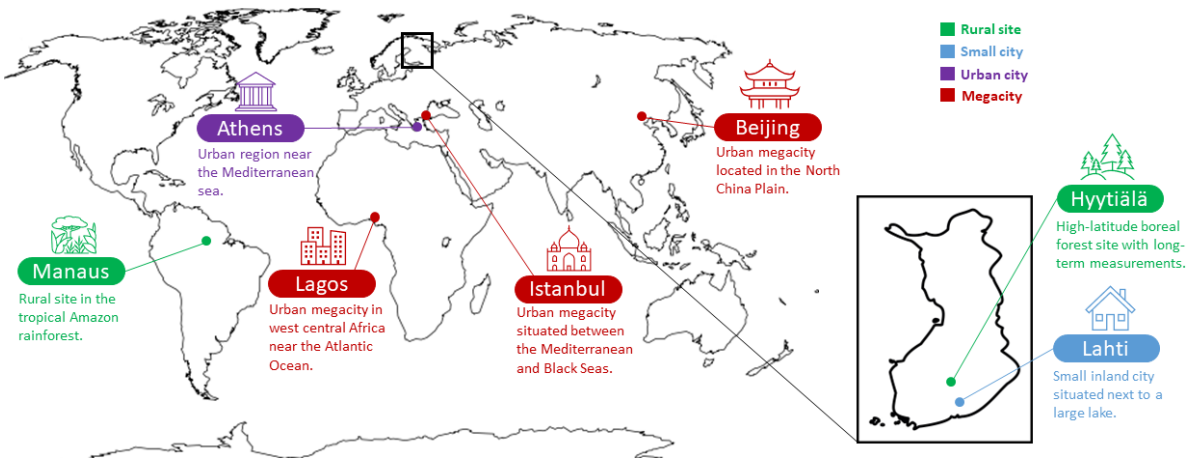

Figure 1: Map showing sites where we are running the FLEXPART-SOSAA modelling system.

RESULTS AND FUTURE WORK

Figure 2 shows an example trajectory and modelled vs. observed results in Beijing during the November 2018 haze episode. This is still a work in progress, but preliminary results are very promising. We anticipate that the results will continue to improve as more chemical reactions and new research and development is added to the model runs.

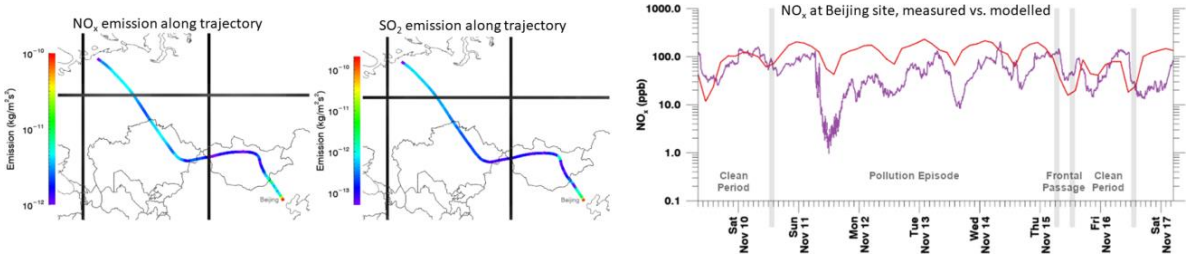

Figure 2: Left: Example of a trajectory arriving in Beijing during a severe haze episode, including emissions along the trajectory. Right: an example of modelled vs. observed results in Beijing during the haze episode.

In addition to running the FLEXPART-SOSAA system for the cases and locations described above, we are also developing a surrogate model for SOSAA using Machine Learning techniques, and the SOSAA surrogate model will be incorporated into Earth System models for larger-scale use, such as climate simulations.

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NOVEL ADSORBENT FOR SELECTIVE IN-TUBE EXTRACTION OF NITROGEN CONTAINING COMPOUNDS IN AIR

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Keywords: Nitrogen containing compounds, Zinc oxide, In-tube extraction, Air samples.

INTRODUCTION

Nitrogen-containing compounds in air originate from both biogenic and anthropogenic sources (Cape et al. (2011), Ge et al. (2011)). Analysis of those compounds is quite challenging due to their low concentrations, volatility, polarity and similar structures. This call upon selective sampling techniques for their successful analysis to access their contribution to the atmospheric processes and air quality. In our recent study, mesoporous silica materials demonstrated good selectivity for nitrogen-containing compounds using in-tube extraction (ITEX) for sampling (Pusfitasari et al. (2022)). The adsorption and desorption behaviour of volatile nitrogen-containing compounds between vapour phase and ITEX has also been recently clarified, in addition to their saturated vapour pressures that were experimentally and theoretically determined (Pusfitasari, Ruiz-Jimenez et al. (2023)). Porous ZnO fibers also have strong affinity and selectivity for amines (Pusfitasari et al. (2022), Lan, Holopainen et al. (2019)). However, poor stability of these nanofibers limited their ITEX applicability since they are easily blocked (Pusfitasari et al. (2022)).

In this study (Pusfitasari, Youngren et al. (2023)), mesoporous silica spheres were infiltrated with ZnO to overcome the problem faced with ZnO fibers. The new sorbent material in ITEX sampling was tested and applied for the analysis of nitrogen-containing compounds in cigarette smoke, indoor air and outdoor air.

METHODS

The pseudomorphic transformation of spherical silica was done according to Martin et al. (2002). The pseudomorphic silica (PM-SiO_2) obtained was infiltrated with ZnO using approach of Leitner et al. (2017). Resulting composite materials after one to three infiltration cycles are called PM-SiO_2/ZnO-1, PM-SiO_2/ZnO-2 and PM-SiO_2/ZnO-3, respectively. The materials were characterized by scanning electron microscopy, transmission electron microscopy, nitrogen physisorption and x-ray diffraction. Gas chromatography-mass spectrometry (GC-MS) was used for the analysis of air samples as described by Pusfitasari et al. (2022) and Lan, Zhang et al. (2019).

Indoor air samples were collected from the laboratory that had storage cabinet for nitrogen-containing compounds. Cigarette smoke samples were collected in a fume hood. Consecutive outdoor air samples were collected near the highway close to Kumpula Campus in Helsinki (60º12′14″N; 24º57′56″E), Finland. The samples were collected on autumn 2022. In all cases, ITEX tubes packed with 50 mg PM- SiO_2/ZnO-2 were used for sampling. Samples (triplicate) were collected at 50.0 mL min^{-1} with sampling time of 5 min for cigarette smoke and 15 min for indoor/outdoor air. All samples were analysed by the GC–MS system.

RESULTS

Modification of silica beads by the pseudomorphic transformation resulted a material with narrow (2.7 nm) mesopores. The ZnO infiltration process had no effect on the morphology of the particles. However, the surface area decreased with number of infiltration cycles. Sampling selectivity and efficiency were improved with the number of infiltration cycles, but the mechanical stability of the packing was decreased and the ITEX backpressure increased with more than 2 cycles. The large particle size of the produced material (~5.0 μm) lowered the backpressure on the ITEX and had no effect on the sampling selectivity and efficiency. For the nitrogen-containing compounds studied, the repeatability varied between 2.4 (triethylamine) and 16.8% (isobutylamine). Reproducibility of the ITEX packing was from 4.8 (pyridine) to 19.4% (isobutylamine).

Linear regression was used for the quantification in targeted analysis ($r^2 > 0.995$), where the lowest LOD and LOQ values 6.6 and 21.8 ng L^{-1} were obtained for pyridine. Dipropylamine had the largest linear range (23.6-3194.7 ng L^{-1}). Partial least squared regression was used to semi-quantify the compounds identified in untargeted analysis. ITEX sampling with the PM- SiO_2/ZnO-2 material performed well for the nitrogen-containing compounds in indoor air, cigarette smoke and outdoor air. The lowest concentration was 0.7 ng L^{-1} for 1-nitropentane in outdoor air and the highest 1580.4 ng L^{-1} for acetonitrile in cigarette smoke.

CONCLUSIONS

ZnO incorporated into mesoporous silica (PM-SiO^2/ZnO-2) was successfully used as ITEX sorbent for collection of nitrogen-containing compounds in indoor air, cigarette smoke and outdoor air. The selectivity and affinity for these compounds were clearly improved by ZnO in comparison with the silica alone. Furthermore, the ITEX with developed sorbent is well applicable sampling tool for aerial drone.

ACKNOWLEDGEMENTS

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Boreal Rivers, a neglected source of Biogenic Volatile Organic compound emissions.

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Abstract

Boreal ecosystems, characterized by wetlands, peatlands, and rivers act as a fundamental reservoir for global carbon (C) stocks. However, their potential as sources of biogenic volatile organic compounds (BVOCs) remains largely unexplored. BVOCs, including aromatic hydrocarbons, can significantly influence the radiative forcing of the atmosphere because they play an important role in the formation of secondary organic aerosols. This study focuses on characterizing and quantifying BVOC emissions from peatland-based river compared to mineral based river and how the seasonal variation as well as biotic and abiotic factors influence on the emissions. Monthly BVOC flux measurements and subsequent analyses were performed from spring till late autumn during two growing seasons (2022-2023). The Study sites are located in Värriö Strict Nature Reserve (67° 44’ 16’’ N, 29° 38’ 58’’ E) in Finnish Lapland close to Värriö Subarctic Research Station (SMEAR I). Preliminary results show BVOC emissions from the peat river being the dominant source of emissions in spring when snow melts and emission patterns shift as we progress from summer to late autumn in the river originating from the mineral soil. These findings emphasize the significant role played by catchment diversity and seasonality and highlight boreal aquatic ecosystems as emerging sources of BVOC emissions.

ALGAE AS A POSSIBLE SOURCE OF HIGH ATMOSPHERIC MIXING RATIOS OF METHANETHIOL ON UTÖ ISLAND IN BALTIC SEA

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Keywords: VOCs, marine air, sulphur compounds, phytoplankton

INTRODUCTION

Phytoplankton is known to emit organic sulfur compounds into the marine air. While there are lots of studies on the marine dimethyl sulfide (DMS), less is known on the other sulfuric compounds (e.g. methanethiol). In the atmosphere these compounds are oxidized forming sulfur dioxide (SO_2), which is further oxidized producing sulfuric acid and participating in new particle and cloud formation. In earlier studies methanethiol has been detected, for example in phytoplankton and oceanic emissions (Kilgour *et al.* 2022; Novak *et al.* 2022). It is formed in the seawater from the same precursor metabolite, dimethyl sulfoniopropionate (DMSP), as DMS (Kiene and Linn, 2000). In the atmosphere methanethiol oxidizes with hydroxyl (OH) radicals seven times faster than DMS (Kilgour *et al.* 2022). OH oxidation of methanethiol produces SO_2 with almost unity yield (Novak et al. 2022).

METHODS

Mixing ratios of methanethiol were studied at the Utö Atmospheric and Marine Research Station of Finnish Meteorological Institute (59º 46'50N, 21º 22'23E, Laakso et al. 2018). It is located at the outermost edge of the Archipelago Sea, facing the Baltic proper. Measurements were conducted using an in situ thermal desorption – gas chromatograph – flame ionization detector/mass spectrometer (TD-GC-FID/MS) from March 2018 until March 2019. Ambient air samples were collected from a 9 m long mast (inlet 12 m above sea level). Samples were taken every or every other hour for 30 minutes.

RESULTS

At Utö methanethiol mixing ratios started to increase in the end of April when daily mean ambient air and seawater temperatures were above 5 and 4 ºC, respectively (Fig. 1). Mixing ratios increased following the changes in seawater temperature. The maximum mixing ratios (up to ~2000 pptv) were measured at the end of May. After mid-July mixing ratios started to decrease even though seawater temperature still increased. Diurnal variation of the mixing ratios still followed the variation of the temperatures. During that time also abundance of phytoplankton in the seawater declined (Kraft et al. 2022). Total phytoplankton biomass in seawater were measured concurrent with the atmospheric VOCs only during July-August. Mixing ratios had also negative correlation with sea level height especially in May and August (R^2=0.69). Macroalgae exposed to the ambient air during low sea levels may start decaying faster and induce methanethiol emissions. This together with seawater and ambient air temperature dependence and high summertime mixing ratios indicated biogenic origin of the methanethiol.

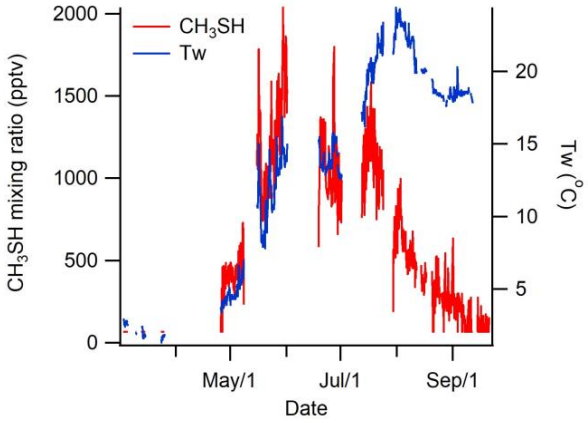

Figure 1. Methanethiol (CH_3SH) mixing ratios together with seawater temperature (Tw) in March – September 2018 on Utö island.

CONCLUSIONS

Results indicated biogenic origin of methanethiol possible from phytoplankton or macroalgae. Detected mixing ratios were high enough to be the source of malodour detected at the island during strong phytoplankton blooms. Methanethiol may have strong impacts on the local SO_2 production and new particle formation. More studies on the methanethiol emissions and atmospheric impacts would be needed.

ACKNOWLEDGEMENTS

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CHEMICAL COMPOSITION OF AMBIENT CLUSTERS CONTRIBUTING TO CLUSTERING EVENTS AT THE PRISTINE HIGH-ALTITUDE IZAÑA ATMOSPHERIC OBSERVATORY (2367 M A.S.L.)

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Keywords: chemical composition, pristine new particle formation, high altitude

INTRODUCTION

Aerosol particles cool down the atmosphere by scattering incoming radiation and acting as cloud condensation nuclei (CCN; Anderson et al., 2005). A significant fraction (>50%) of current CCN is estimated to stem from the formation of new particles (Merikanto et al., 2009). But the mechanisms governing new particle formation (NPF) process are still poorly understood, especially when trying to understand preindustrial NPF.

METHODS

In order to investigate preindustrial NPF process and its contribution to CCN budget, intensive ambient observations were carried out between March 28 and June 27, 2022 at the pristine high-altitude Izaña Atmospheric Observatory (IZO; 2367 m a.s.l., 28°18'32.3"N 16°29'58.1"W), which is located on the island of Tenerife, Canary Islands. This site is characterized by clean air and pristine skies with minimum local anthropogenic influences. Among with other instrumentations, a Multi-scheme chemical IONization (MION) inlet (Rissanen et al., 2019) coupled to an atmospheric pressure interface time-of-flight mass spectrometer (APi-ToF-MS) was used to measure the molecular composition of neutral vapours including the less oxygenated organic compounds, sulphuric acid (SA), methane sulfonic acid (MSA), and highly oxygenated organic molecules (HOM) via the fast switching of two reagent ion schemes (Br^- and NO_3^-). A Vocus proton-transfer-reaction time-of-flight mass spectrometer (PTR-ToF; Krechmer et al., 2018) was deployed to measure the potential precursor volatile organic compounds (VOC), dimethylsulphide (DMS) and their oxidation products. Filter samples were collected and analyzed in the laboratory with a filter inlet for gases and aerosols coupled to a high-resolution time-of-flight chemical ionization mass spectrometer (FIGAERO-HR-TOF-CIMS), yielding the molecular composition of particulate organics (Lopez-Hilfiker et al., 2014).

CONCLUSIONS

During the measurement period, clustering events were frequently observed, particularly in May and June. NPF precursors, e.g., MSA, SA, and HOM, were also substantially higher in May and June (see Fig. 1),

indicating their potential role in the NPF process. This is also consistent with the time series of their precursors such as DMS, SO_2, and terpenes. NPF events in the presence of Sahara dust events were also observed, exhibiting lower levels of organics in both gas and particle phase compared to clear NPF events. In addition, higher levels of marine MSA were observed on some nights, potentially resulting from the updraft and transport from the Atlantic Ocean to the marine free troposphere (Scholz et al., 2023).

The measurements at IZO provide us with a valuable dataset regarding NPF at this pristine high-altitude location. Chemical characterization of the freshly formed clusters will increase our understanding of the nucleation mechanism responsible for preindustrial NPF, as well as free tropospheric chemistry. Our study will also provide new insights on a molecular basis to better understand present and future aerosols, and their effects on air quality and climate.

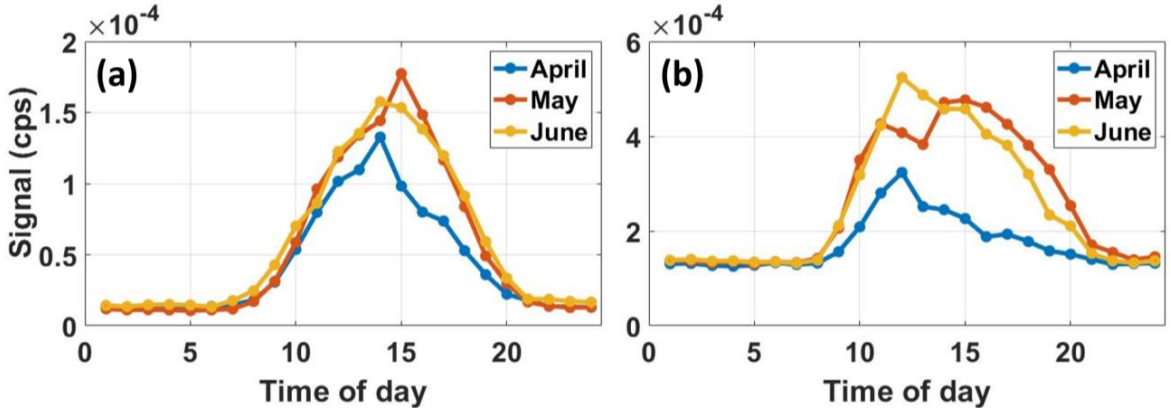

Figure 1. Monthly median levels of SA (a) and HOM (b) measured with NO_3-MION-APi-TOF. Time is in UTC.

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INDOOR EXPOSURE AND REGIONAL INHALED DEPOSITED DOSE RATE DURING SMOKING AND INCENSE STICK BURNING—THE JORDANIAN CASE AS AN EXAMPLE FOR EASTERN MEDITERRANEAN CONDITIONS

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Keywords: fine particles, particle losses, particle number size distribution.

INTRODUCTION

Incense-burning and aroma products are not widely prohibited worldwide, as some countries still use them extensively; for example in the Middle East and North Africa (MENA) region. Smoking is not only considered harmful for the smoker themselves, but also for second-hand and third-hand smokers. Although the Jordanian Ministry of Health has stated that smoking is forbidden in microenvironments, people are still violating this law. In fact, Jordan acquires the highest rate of smoking; 8 out of 10 men consume nicotine products such as cigarettes, shisha (waterpipe, hookah, narghile), and e-cigarettes. Contrary to smoking, incense burning does not have any regulations in Jordan. These two types of indoor activities impose serious health issues indoors. It is, therefore, very important to quantify the exposure to air pollution during these activities for Jordanian conditions, which can be a good representative of several nations in the Eastern Mediterranean region. Here (Hussein 2023), we aim to present the exposure levels and regional inhaled deposited rate in respiratory tracts during the most common combustion activities in Jordanian microenvironments. The investigation included measurements of particle number size distributions (diameter 0.01–25 µm) during typical smoking and incense stick-burning scenarios inside a closed room. The exposure and dose rates were presented in terms of two metrics (number and mass) of submicron and fine particles. In order to put an insight into the exposure scenarios, the regional inhaled deposited dose rates were calculated for an adult male or female during two of the main human activities (walking and standing).

METHODS

The measurement setup was according to the description provided by Hussein et al. (2022), which included: (1) condensation particle counters (CPC, 3007-2, TSI, Minnesota, US), (2) handheld optical counter (P-Trak 8525, TSI, Minnesota, US), and (3) and a handheld optical particle counter (AeroTrak 9306-V2, TSI, Minnesota, US). These instruments allowed us to obtain the particle number size distribution (diameter 0.01–25 µm; 8 channels; 30 seconds time-resolution).

The exposure scenarios included smoking (two cigarettes smoking, a shisha smoking session, or two incense stick burning) and incense stick burning inside a fully furnished naturally ventilated office room (5×2.7×2.7 m^3). Each scenario was repeated four times. The room was kept closed and unoccupied during the scenario.

The size-specific emission rate and losses of aerosol particles were calculated by utilizing a simple indoor aerosol model (Hussein 2017). The basic principle is based on the change rate of particle number concentrations calculated for each particle size. At first, the particle loss rate was calculated. Then, the emission rate was calculated and corrected for the particle losses.

The inhaled deposited fraction of aerosols in the respiratory tracts was calculated according to a previous approach described elsewhere (Hussein et al. 2013). Here, the respiratory tracts were divided into three main

regions: head/throat (H), tracheobronchial (TB), and pulmonary/alveolar (P/Alv), according to the ICRP and MPPD models.

RESULTS

During cigarette smoking and incense stick-burning scenarios, the particle number concentrations exceeded 3×10^5 cm^{-3}. During shisha smoking, they exceeded 5×10^5 cm^{-3}. The average emission rates were estimated at 1.9×10^{10}, 6.8×10^{10} and 1.7×10^{10} particles/s, respectively, for incense, cigarettes, and shisha. That corresponded to about 7, 80, and 120 µg/s, respectively. Interestingly, the exposure levels were almost similar for incense and cigarette-smoking aerosols, but the emission rate from cigarette smoking was about three times that during incense burning. This was expected, because the smoking occurred for a shorter time than the burning of the incense sticks.

In general, and regardless to the type of combustion scenario and concentration metric, males received higher dose rates than females, with average percentiles in the different regions of the respiratory tracts of 7%, 18%, and 75%, respectively, for the head and throat airways (H), tracheobronchial (TB), and pulmonary/alveolar (Alv) regions during walking. During standing, the corresponding dose rates were 25%, 20%, and 55%, respectively. The total inhaled dose rates during standing for submicron particle number concentration and $PM_{2.5}$ were in the order of 10^{12} #/h and 10^3 µg/h, respectively. During walking (4 km/h), they were in the order of 10^{13} #/h and 10^4 µg/h, respectively.

CONCLUSIONS

The exposure levels, emissions rates, and inhaled deposited dose rates during the studied scenarios of smoking and incense burning are considered seriously high, re-calling the fact that aerosols emitted during such scenarios consist of a vast range of polycyclic aromatic hydrocarbons (PAHs), volatile organic compounds (VOCs), and heavy metals, in addition to harmful gases such CO, CO_2, NO_x, and SO_2. By all means, the Jordanian authorities have to take immediate actions to enforce the prohibition of cigarette smoking indoors and develop regulations for incense stick burning.

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CONCEPTUAL MODELS FOR SEASONAL FORECASTING

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Keywords: SEASONAL FORECASTING, CLIMATE INDICES, CONCEPTUAL MODELS, MACHINE LEARNING

INTRODUCTION

Seasonal forecasts (forecasts of monthly average conditions) help to make decisions in many areas of society, thanks to physics-based dynamic models that have improved considerably in recent years. However, in addition to dynamic models, simpler conceptual models could be used to support decision making.

These conceptual models are based on physically based indices of large-scale climatic and oceanographic phenomena. The best known index is probably the El Niño Southern Oscillation (ENSO). Recent high values of El Niño have attracted media interest, and scientifically justified information on its effects on Finland would be useful.

METHODS

ENSO alone probably cannot explain the climatic variability in Northern Europe but should be studied in combination with other major ocean variability modes, the Atlantic Multidecadal Oscillation (AMO), the Pacific Decadal Oscillation (PDO), the North Pacific Gyre Oscillation (NPGO), the El Niño Modoki Index (EMI) and the Atlantic El Niño Index (ATL3).

On the one hand, conceptual models help to interpret the predictions of numerical models. On the other hand, the indices themselves can be used as input for machine learning models. Our attempt is to continue the work started earlier (Kämäräinen *et al.*, 2019) and combine use of indices, conceptual models and machine learning in new ways.

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NEW ACCC COLLABORATION: PIRKANMAA CLIMATE ACTION LAB

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Keywords: Carbon neutrality, Biodiversity, Climate change mitigation, Climate change adaptation.

INTRODUCTION

The Pirkanmaa region of Finland has set goals to achieve carbon neutrality by 2030 and, in addition, has an ongoing programme for retaining biodiversity (LUMO). Achieving such goals requires multidisciplinary expertise and continuous learning (Riuttanen *et al*., 2021, Siponen *et al*., subm.). The Pirkanmaa Climate Action Lab (in Finnish *Pirkanmaan Ilmastotoimintakeskus*, PIK) aims to help communities and businesses to find solutions for developing their practices towards increased environmental sustainability. On a regional level, this framework is the first of its kind in Finland.

The PIK is a joint operation between University of Helsinki and Tampere University, funded by The Council of Tampere Region and co-funded by the European Union. The PCAL is based on previous regional collaboration (Riuttanen *et al*., 2022). The purpose of the PIK is to deliver scientific knowledge to practical activities and to maintain discussion on climate-related topics among the stakeholders in the region. Practical activities of the PIK are centred in the SMEAR II station in Hyytiälä Forest Station in Juupajoki, Finland. These practical activities include co-creation workshops on different topics related to carbon neutrality and biodiversity. In addition, the PIK enables learning about new co-creation methods achieved from this practical work. We invite ACCC researchers to join as scientific experts to the workshops.

METHODS

The PIK comprises 10-12 co-creation workshops, each on different subtopic. During the pre-survey phase, the participants have an opportunity to influence the selection of subtopics; in the implementation phase, they can participate those workshops that are relevant for their community or company. These subtopics include, for instance, carbon sinks, climate-related regulation, wood construction, and fragility of global supply chains. The workshops include brief lectures by experts, group work, and concluding discussion. The outcome of these workshops will be compiled and published online, and it will be basis of an information bank which is accessible to everybody.

The information bank, which will be established on the basis of results from the workshops, is planned to contain general-level information on the most popular topics discussed in the workshops. This information bank will be published online and therefore, it is expected to be beneficial also generally. In addition to the content online, the co-operation between the stakeholders and the universities is expected to be continuous.

ANTICIPATED RESULTS

We expect a large variety of participants to take part in the workshops, including small and medium-sized enterprises, municipalities, parishes, and associations. The PIK establishes co-operation between the regional stakeholders and the scientists and provides science-based knowledge to improve climate and environmental work in Pirkanmaa. These actions strengthen the activities of all stakeholders and benefits the green transition in the region. In addition, the recognition of Hyytiälä Forest Station increases on a regional level.

SUMMARY

The PCAL develops longstanding solutions to the Pirkanmaa region and enables improved climate resilience in the region. The infrastructures for the PIK already exist. The PIK will expand the local relevance of the state-of-the-art climate observations performed in Hyytiälä and capitalizes on the climate expertise provided by the scientists on a regional scale.

ACKNOWLEDGEMENTS

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VOLATILITY OF SECONDARY ORGANIC AEROSOL EMISSIONS FROM SHIP ENGINE IN REAL-WORLD CONDITIONS

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Keywords: Air Quality, Marine Emissions, Volatility, Secondary Organic Aerosols.

INTRODUCTION

Marine traffic is an important source of particles in the atmosphere. In addition to primary organic aerosol (POA) emissions, ship emissions contain large amounts of semi- and intermediate volatility organic compounds (SVOCs and IVOCs) (Huang, 2018). These have a high potential of forming secondary organic aerosols (SOA). How these compounds are divided between the particle and the gas phase depends on their volatilities and the total mass of the individual species present. Therefore, to fully understand how the shipping emission evolves in the atmosphere, information on the volatility of these emissions is needed.

Representing the aerosol volatility as a volatility distribution is an effective modelling approach (Donahue, 2006). The species are placed in bins based on their effective saturation concentrations. Determining a volatility distribution is not without complications. It is difficult to identify all the species in an aerosol and there is lack of information on the volatilities of individual species. One approach is to look for a distribution with a modelled evaporation matching measured evaporation. This is also challenging, since several combinations of effective saturation concentrations, vaporization enthalpies and mass accommodation coefficients can results in similar evaporation.

METHODS

To study the volatility distribution of a ship emission, particle mass concentrations were measured aboard a ship in real-life conditions using an Aerosol Mass Spectrometer (AMS). Thermodenuder was used to compare the evaporation of the aerosols in different temperatures. This was used as target data for later modelling studies. Prior to the thermodenuder treatment, some samples were also aged in Potential Aerosol Mass (PAM) chamber to study SOA formation.

Simulating the evaporation of an aerosol with a known volatility distribution is done by solving the saturation concentration driven mass transfer between phases (Riipinen, 2010). To find a volatility distribution matching the measurement data, genetic optimization algorithm similar to e.g. Tikkanen *et al.* (2019) is used. A set of volatility distributions is created and compared to the measured data to give a fitness value to each individual. The population then produces children by combining the properties of two parents. This repeats over the whole population and children with good enough fitness values enter the population. This proceeds several generations to improve the population and find the best possible individual. Possible mutation keeps the process from converging to a local rather than global minimum.

RESULTS

In an example case of marine gas oil (MGO) used as fuel with 50% engine load and after-treatment with urea, aging the aerosol in PAM-chamber increases the particulate mass concentration from 1.15 mg/m^3 to 12.65 mg/m^3 when compared to fresh emission. The evaporation simulation shows that a significant amount of the organic mass is in the IVOC range with effective saturation concentrations of 10^3 and 10^4 μg/m^3 dominating the volatility of aged particle phase emission. This agrees well with our understanding of significant gas phase IVOC emissions from ship engines and their capability to form SOA during atmospheric processing.

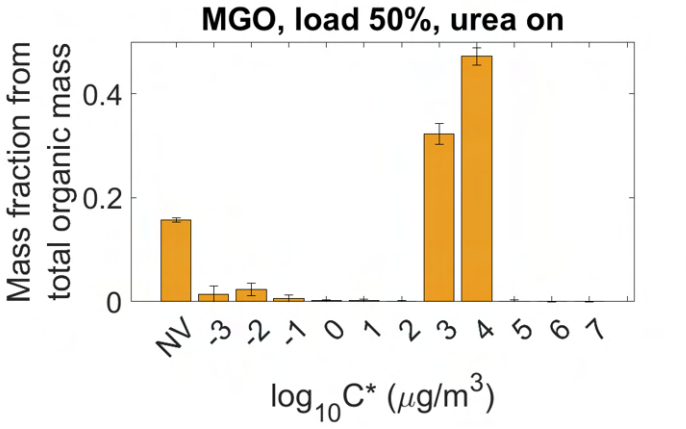

Figure 1: Volatility distribution of an aged aerosol based on thermodenuder measurements using maringe gas oil as fuel, 50% engine load and urea after-treatment.

ACKNOWLEDGEMENTS

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CARBONSINK+ POTENTIAL IN HEMI-BOREAL AND BOREAL ECOSYSTEMS: SITE-SCALE ANALYSIS OF NEGATIVE ION FORMATION AND NET ECOSYSTEM CO2 EXCHANGE

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Keywords: CarbonSink+ potential; Hemi-boreal and boreal ecosystems; CO_2 uptake; Negative intermediate ions

INTRODUCTION

Global climate warming is a concerning issue for human and Earth system. Carbon dioxide (CO_2) is one of the most important greenhouse gases in the atmosphere (Jia et al., 2022). Terrestrial ecosystems, e.g., forests, take an important role in the global CO_2 budget through photosynthesis and respiration process. Apart from acting as a CO_2 sink, terrestrial ecosystems can also influence climate by actively interreacting with atmosphere and potentially enhancing formation of organic aerosols. The CarbonSink+ concept makes it possible to compare the relative roles of carbon uptake, atmospheric NPF and surface albedo changes in mitigating the climate chance in a boreal forest using a single metric (Kulmala et al., 2020).

Recently, the concept of CarbonSink+ potential has been established (Kumala et al., 2023), which enables direct comparison of site-scale CO_2 uptake and aerosol production. In this study, the long-term online monitoring of intermediate ions and CO_2 fluxes were collected in various hemi-boreal and boreal ecosystems across Finland and Estonia. In summary, four forests, one peatland, three agricultural lands, one urban background, and one costal environment were investigated. The negative intermediate ions and CO_2 fluxes for these ecosystems were compared. Based on the CarbonSink+ potential concept, the potential of mitigating climate warming regarding CO_2 uptake and aerosol production were summarized for these ecosystems. The most important ecosystems for climate warming mitigation were also summarized.

RESULTS

The NEE (net ecosystem exchange) and negative ion cluster formation at each site were compared. The negative ion cluster concentration at 2.0-2.3 nm (with geometric mean of 2.16 nm) is chosen as it is strongly correlated with the number concentrations of total particles at 3-6 nm (Tuovinen et al., 2023, under review) and good indicators of new particle formation. Table 1 list the result in the midday (10:00-14:00) in the summer. In both spring and summer, clear diurnal variation of NEE and negative ion cluster can be seen, with the highest absolute values appearing in the midday.

Table 1. Comparison of NEE and negative intermediate ions in the midday of summer.

Site	Ecosystem	Area for the ecosystem type in Finland (ha)	Midday negative intermediate ions ($1/cm^3$, 50%)	Comparing with Hyytiälä (50%)	Midday NEE (mol m^{-2} s^{-1}, 50%)	Comparing with Hyytiälä (50%)
Värriö	Forest	26.3 million[a]	2.53	0.70	-4.87	0.46
Hyytiälä			3.60	1.00	-10.6	1.00
Ränskälänkorpi			1.87	0.52	-6.13	0.58
Järvselja			1.93	0.54	-11.2	1.05
Haltiala	Agricultural land	2.27 million[a]	2.78	0.77	-16.9	1.59
Qvidja			3.28	0.91	-8.91	0.84
Viikki			4.14	1.15	-9.62	0.91
Siikaneva		8.31 million[a]	2.94	0.82	-3.23	0.30
Kumpula	Urban garden		6.23	1.73	-7.14	0.67
Tvärminne	Costal		1.45	0.40	0.00	0.00

[a] Natural Resources Institute Finland 2022

CONCLUSIONS

The results show that the agricultural lands have similar to or even higher CO_2 uptake potential comparing with the boreal forests during summers. In the studied urban vegetation area, the CO_2 uptake potential is in the same magnitude with the boreal forest sites in the summer. The tundra site has the smallest CO_2 uptake potential among all the studied terrestrial ecosystems discussed above. The difference in the concentrations of negative intermediate ions between the studied sites was less significant than those in the CO_2 fluxes. The negative intermediate ion concentrations followed the sequence: urban gardens > agricultural lands ≈ forest sites > peatland and tundra > costal area. Generally, the agricultural lands and the biggest CarbonSink+ potential.

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NATURAL TEMPERATURE GRADIENT OF GEOTHERMAL AREA IN ICELAND ON MICROBIALLY DRIVEN CO2 AND CH4 DYNAMICS

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Keywords: terrestrial greenhouse gas dynamics, geothermal gradient, stable isotopes, targeted metagenomics.

INTRODUCTION

Natural temperature gradients within geothermal areas provide a platform for studying the effects of warming on microbially driven greenhouse gas (GHG) dynamics in natural environment. Sitka spruce forest (FN) in Iceland is a study site as a part of "ForHot" research network that was established in 2011 to study soil temperature effects on ecosystem processes. The FN site has a natural geothermal soil temperature gradient that, at the depth of 10 cm, ranges from ambient temperature to +65 °C. Soils in Northern latitudes, especially boreal forests and permafrost, store most of the global soil organic carbon. Soil organic carbon is at high risk to be released to the atmosphere as carbon dioxide (CO2) and methane (CH4), due to temperature induced microbial activity.

Objective of the study is to quantify the temperature effects on biotically produced CO2 and CH4 in natural environment.

METHODS

We measured CH4 and CO2 dynamics along the natural temperature gradient at sitka spruce forest in Iceland during peak growing season in June 2022, and connected the GHG fluxes to simultaneous RNA expression and the presence of functional genes of methanogenesis with novel targeted metagenomics -tool. We measured both soil surface flux with static chambers and soil depth profile with soil gas probes at 5, 10, 15, and 20 cm. Stable isotopes (13C-CO2 and 13-C CH4) were measured to source partition and to exclude geothermal bias. Parallel to GHG measurement soil RNA and DNA were sampled at ambient, +5 and + 40 °C soil temperatures. Results will be discussed.

WATER TABLE, NITROGEN AND LABILE CARBON AFFECT THE BIODEGRADABILITY OF DISSOLVED ORGANIC CARBON IN BOREAL PEATLAND FORESTS

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Keywords: Dissolved organic carbon, Nitrogen, Peatland, Water table.

INTRODUCTION

Boreal peatlands are an important carbon sink, that can be disturbed by human activities. In the Nordic countries, a substantial proportion of peatlands have been converted to forests by drainage which has caused several harmful effects on the environment such as increased CO_2 emissions and brownification of the inland waters. Dissolved organic carbon (DOC) is a key component of the carbon cycle, transporting carbon between terrestrial and aquatic systems and affecting the water quality and greenhouse gas emissions from the aquatic ecosystems. Still, the processes underlying its production and degradation in peatland forests are poorly known. In this study, we investigated how changes in water table level, forest clear-cutting, as well as inputs of labile carbon and nitrogen affect the production and biodegradation of DOC.

METHODS

We conducted a pulse labelling study with ^{13}C-labelled glucose and ^{15}N-labelled glycine in a common garden experiment using peat cores from a boreal peatland. Half of the cores were from an unharvested forest, and half from a clearcut one. The water table in the columns was set to either high (10 cm below the peat surface) or low (30 cm below the peat surface), and the labelled glucose was added to half of the columns. Column groundwater was extracted monthly for DOC concentrations, water quality analyses and a laboratory incubation to study the biodegradability of the DOC. Replicate incubation series with added nitrogen were added at the two last months.

RESULTS

DOC concentrations in the column groundwater decreased in the samples from columns with low water table and glucose addition. Water table, forestry type or glucose did not change the biodegradation of DOC, but the degradation of more recalcitrant DOC increased with time as well as with nitrogen addition.

CONCLUSIONS

Our results indicate the importance of available N and labile C, as well as the water table on the biodegradation rate of DOC. Our results suggest that DOC formation and biodegradation is a complex process affected by various site characteristics and environmental factors working together. Further field studies are needed to reveal the possible effects of labile carbon on the biodegradation of recalcitrant DOC.

ACKNOWLEDGEMENTS

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A DEEPENED WATER TABLE INCREASES THE VULNERABILITY OF PEAT MOSSES TO PERIODIC DROUGHT

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Keywords: Drought stress, Global change ecology, Photosynthesis, Plant-climate interactions.

INTRODUCTION

Climate change is anticipated to both gradually lower water tables (WTs) in boreal peatland due to increased evapotranspiration in a warming climate (Helbig *et al*., 2020), but also increase the frequency of growing season droughts (Donat *et al*., 2016). This has already been witnessed in Europe, but the consequences of these two combined stressors for peatlands vegetation – particularly hydrologically-sensitive *Sphagnum* mosses – is yet unknown.

One of the most important plant groups in boreal peatlands are *Sphagnum* mosses, which, owing to their extensive cover, account for up to 300 Gt of biomass (Rydin and Jeglum, 2013). Despite lacking roots and stomata, Sphagna, can adapt to a range of moisture conditions through trait variation (Hájek and Vicherová, 2014; Laine *et al*., 2021). Here, we address the combined impact of long-term drying and periodic drought on *Sphagnum* mosses. We aim to determine if long-term deepened WTs 1) increase the base-level physiological stress of Sphagna resulting in decreased photosynthesis, 2) decrease the impact of periodic drought due to acclimation to dryness, or 3) exacerbate the impact of periodic drought due to higher base levels of physiological stress.

METHODS

We conducted a greenhouse experiment using peat surface cores ("mesocosms") of selected lawn *Sphagnum* species with three different WT histories: naturally wet, 17-year water level drawdown (WLD), and naturally dry. Mesocosms were removed from Lakkasuo and placed in a greenhouse where the climate, precipitation and WT were controlled following the design outlined in Nijp *et al*. (2014). Half of the mesocosms were subject to a 43-day ecohydrological drought. Mesocosm photosynthesis was measured three times using a sealed chamber: at the end of a 7-week adjustment period, at the end of the drought, and after 3 weeks of recovery.

To quantify the resistance and resilience of Sphagna to periodic drought, we estimated maximum photosynthesis and respiration using the hyperbolic light response curve (Smolander and Lappi, 1985). To analyse the impact of and recovery from periodic drought, we used non-liner mixed-effects models. We built two models for drought impact and recovery: the first to test the impact of experimental factors, namely WT history and peatland type, the second to test the impact of mesocosm moss carpet traits.

RESULTS

We found that long-term deepened water tables increased the base stress level, as indicated by low photosynthesis, of bog lawn Sphagna but not fen lawn Sphagna (1). We found no evidence to support that *Sphagnum* mosses acclimate to deepened WTs giving them better drought resistance (2). Instead, a history of deep and deepened WTs exacerbated the vulnerability of Sphagna to periodic drought, indicating that these stressors had an additive effect on mosses (3). This implies that the impact of climate change on peatland lawn surfaces, which are dominated by Sphagna, may be more sudden than originally anticipated due to this additive effect. However, we found that lawn mosses with large capitula -a feature found in fen species in our study – were more resistant to periodic drought. Bog species from lawns lack both the dense hummock structure that protects hummock species from moisture loss and large capitula making them vulnerable to drought.

Our results suggest that bog lawn Sphagna are closer to their tipping point than lawn Sphagna in fens. However, other studies have found that fen vegetation often undergoes rapid succession following hydrological changes compared to stable bogs (e.g. Kokkonen *et al*., 2019). The relatively uniform lawn surface commonly found in boreal fens (Rydin and Jeglum, 2013) combined with high nutrient availability makes them more sensitive to critical transitions (Scheffer *et al*., 2012) than bogs with a diverse microform surface. The distribution of microforms in bogs will shift towards hummocks as lawns suffer in drought, but the overall system changes little due to limited species able to survive such restrictive habitats.

CONCLUSIONS

Water level drawdown associated with climate change increases the sensitivity of peatlands to periods of drought and moves them toward their tipping point as species on the edge of their ecological envelope shut down photosynthesis and recover poorly. Water-retaining traits may increase *Sphagnum* resilience to periodic drought, but the structural diversity of communities is key to long-term ecosystem stability.

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SECONDARY ORGANIC AEROSOL FORMATION FROM LABORATORY- BIOMASS BURNING EMISSIONS

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Keywords: BIOMASS-BURNING AEROSOLS, 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. The primary BB aerosol particles undergo atmospheric aging. Additionally, secondary organic aerosols (SOA) are formed from the oxidation of the gaseous BB emission contributing to particle mass and potentially altering their physical properties (Hodshire et al., 2019). Due to climate change, BB/forest fires are becoming more frequent which enhances the impact of their emissions on the atmosphere. Understanding the effect of BB emissions and their oxidation is, therefore, crucial. In this study, we characterized fresh and aged aerosols stemming from burning three different biomasses at different burning conditions followed by photochemical or dark oxidation in the chamber.

METHODS

We studied the burning emissions from three different biomass samples (woody and grassy material from the African Savannah, and boreal forest floor material) at the ILMARI chamber facility at the University of Eastern Finland in Kuopio, Finland in May – June 2022. For each fuel and burning condition, the primary emissions were fed into the ILMARI chamber where oxidation was initiated by OH radicals (from photolysis of H_2O_2) and/or O_3 addition. To represent the burning condition of each experiment the modified combustion efficiency (MCE) was determined from the CO and CO_2 concentrations. The aerosol particles and gas phase 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 high-resolution organic mass spectra data to separate the primary organic aerosol (POA) and SOA formation during aging.

RESULTS

The initial total mass of NR-PM_1 in the chamber varied widely (~20-80 µg/m^3) for different experiments depending on the biomass type, burning conditions, and oxidation process. For all experiments, organic

compounds dominated the primary aerosol mass by contributing on average ~ 94 % of the total NR-PM_1 mass.

PMF analysis for all experiments suggested a three-factor solution with two primary factors (POA and biomass-burning organic aerosol (BBOA)) and one secondary factor (SOA). The factor mass spectra and time series for one of the experiments are shown in Figure 1 as a case study. POA factor is characterized by the presence of signals at m/z 55 ($C_4H_7^+$), and 57($C_4H_9^+$) representing combustion emissions. BBOA factor is differentiated by the peak signal at m/z 60 ($C_2H_4O_2^+$), a marker ion for biomass burning emissions. The mass spectra of the SOA factor show a substantially higher contribution to the signal at m/z 44 (CO_2^+) representing higher oxidized compounds formed during the aging of the primary organic emissions. The mass concentration of both primary factors decreased with time during the experiment. The mass concentration of SOA factor increased after oxidation was started in the chamber indicating the secondary nature of this factor. The average mass fraction of SOA increased from ~9 % at the start of aging to ~ 50 % of the detected organic mass, after ~5 hours of photochemical aging in this case.

SOA formation was observed in all experiments, however, the mass fraction of SOA formed in O_3/dark aging experiments was less compared to that in photochemical aging experiments. Next, the effect of different burning conditions (MCE) on SOA formation will be investigated.

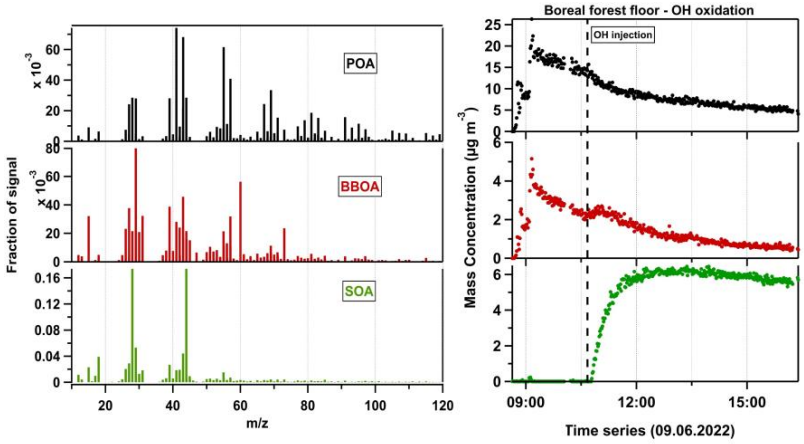

Figure 1. Factor mass spectra (left) from PMF analysis of AMS high-resolution organic mass spectra for all experiments in the campaign. Factor time series (right) for the experiment on 09.06.2022 (boreal forest floor BB emissions with OH oxidation) during the campaign.

ACKNOWLEDGEMENTS

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EFFECT OF A DEFLECTOR ON DEPOSITION OF PARTICLES WITH DIFFERENT DIAMETERS IN A RIB-ROUGHENED CHANNEL

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Keywords: Particle deposition, Particulate gas flow, Rib-roughened channel, CFD.

INTRODUCTION

Particulate matter (PM) is one of the main components of air pollution, which negatively affects air quality especially in urban areas both outdoors and indoors. To improve indoor air quality while at the same time ensuring sufficient ventilation and ensuring low energy consumption, a range of methods are necessary. One of these methods is the use of rough elements in ducts. Rough elements can improve collection efficiency without significantly increasing energy consumption, making them a cost-effective way to enhance air-cleaning processes. On the other hand, by using rib-roughened elements to capture some particles before they reach the filter, you can extend the lifespan of the filter. Filters can become clogged over time, reducing their effectiveness. Therefore, ribbed ducts help reduce the load on the filter. Regarding to previous studies, windward surfaces of ribs are the main area for particle deposition. Changing the trajectory of particles by using a deflector, so as to increase the interaction between particles and rough elements, would be a good idea in the scope of designing suitable geometries in the expectation of increasing the deposition ratio in a ventilation duct.

METHODS

In this study a RANS model known as LRR model is chosen due to its capability of reproducing anisotropic features of turbulence. A turbulent dispersion model was implemented in order to estimate the turbulent diffusion of particles. An Eulerian approach for simulating the airflow, and a Lagrangian approach for simulating particles were utilized. By comparing the behavior of particle deposition on the ribbed walls, in the cases with and without a deflector, the effect of this type of geometry on the particle deposition is assessed (Fig. 1).

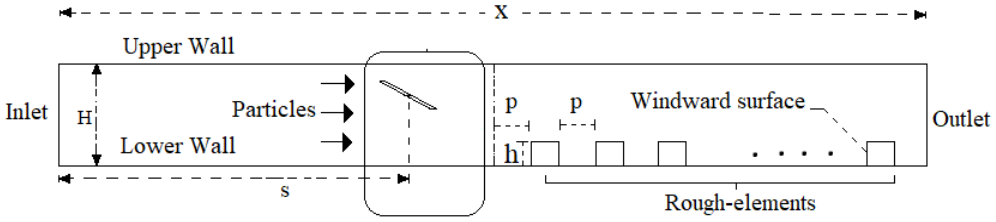

Figure 1: Schematic of two-dimensional rib-roughened channel with a deflector

RESULTS

Fig. 2 compares the deposition efficiency as a function of dimensionless relaxation time, for both cases: with and without the deflector. The deposition efficiency is calculated as:

$$\eta = \frac{N_{dep}}{N_{tot}} \tag{1}$$

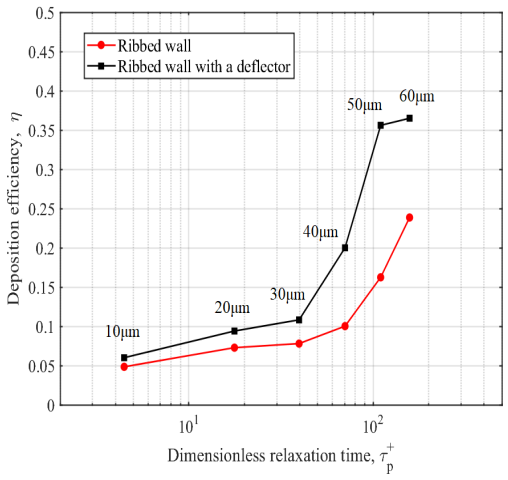

Figure 2: deposition efficiency in cases with and without a deflector[%]

where N_{dep} and N_{tot} are deposited particle number and released particle number in the domain, respectively. By increasing the size of particles, the deposition efficiency demonstrates a corresponding increase, which shows the significant role of gravitational force in the deposition process. The presence of a deflector changes the trajectory of particles, causing those with higher relaxation times to deviate from their previous direction and continue moving towards the lower region of the channel until they exit. This effect exposes them to increased interaction with rough elements within the channel, leading to enhanced particle interaction and deposition.

CONCLUSIONS

The presence of a deflector significantly enhances the deposition ratio of particles. This improvement is due to the increased interaction between the particles and the lower wall of the channel. Smaller particles, such as those with a diameter of 10 µm, experienced a 24.71% increase in their deposition velocity and larger particles, such as those with a diameter of 50 µm, exhibited a more significant increase, reaching a value of 148.36% in their non-dimensional deposition velocity. Although a deflector can increase the deposition ratio, it is important to keep in mind that it can also produce a higher pressure drop compared to a scenario without any deflector as a result of the flow blockage. In conclusion, a deflector has a high potential to be used for removing particles with different sizes.

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ON-BOARD PARTICLE AND SOOT MONITORING USING SENSORS ON A CRUISE FERRY

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Keywords: Marine traffic, Particulate emissions, Sensors

INTRODUCTION

Global trade is heavily dependent on maritime transport: in 2019, approximately 11 billion tons of cargo were shipped overseas and thus, it comprised 80 % of total world trade that year (UNCTAD, 2020). Due to these massive annual amounts of cargo shipped, shipping produced 2.89 % of the total greenhouse gas emissions in 2018 (IMO, 2020). Along with the greenhouse gas emissions, cargo and passenger vessels produce significant amounts of particulate emissions, by both number and mass. These particulate emissions not only impair air quality near seaports and coasts and cause potential health effects to humans, but they also affect the climate in the long term. Yet, these emissions largely remain unregulated with only few exceptions.

Before any regulation could be implemented, its enforcement would require technology to monitor particulate emissions from the ships. One possible solution to this would be to retrofit ships with periodic testing and inspection (PTI) equipment because the operation of such PTI devices is nearly fully automatic.

In this study, we used commercially available PTI sensors on-board a cruise ferry during its routine operation, to measure particle number (PN) and black carbon (BC) concentration. The purpose of these measurements was to study their performance and maintenance requirements. The results from the sensors were compared to ones from scientific aerosol measurement instruments, which were used as a reference.

METHODS

All measurements were performed on board Stena Germanica cruise ferry, on its normal route between Gothenburg, Sweden, and Kiel, Germany. The measurement period was between 1st October – 10th October 2021, during which the ferry performed five round trips between these two destinations. The sensor set-up and the reference instruments sampled flue gas from the smokestack of main engine number 2, a Wärtsilä four-stroke 8ZAL40S marine engine retrofitted for flex-fuel use: this retrofitting enables use of methanol fuel as an alternative to traditional marine gas oil. Figure 1 shows the experiment setup.

Upstream all the sensors in this study, an electronically controlled diluter was applied to dilute and cool down the sample aerosol prior to sampling. The electronic diluter allowed testing the sensors with two dilution ratios (DRs), namely 75 and 150; between the experiment runs, the diluter provided particle-free air to the sensors and reference instruments. The PN sensors included two commercially available models from two manufacturers, which both detect particles using diffusion charging and detection by electrometers. Both sensors are of a robust design with stainless steel housing and no moving parts.

The BC sensors comprised of two units of a commercially available model designed for BC monitoring. In these units, BC detection is based on light absorption (wavelength 880 nm) of BC collected on a filter located within the unit. In this study, the two BC sensor units were operated on different sample flow rates, 30 ccm and 90 ccm: the purpose of this was to investigate how increased flow rate affects the sensor performance and maintenance interval.

The reference instruments, to which the results from the sensors were compared to, comprised an engine exhaust particle sizer (EEPS, TSI 3090) and a condensation particle counter (CPC, TSI 3775) for particle size distributions and total PN, respectively. The reference instrument for the BC sensors was an aethalometer (Magee Scientific AE33), which was connected to another sampling line parallel to the one used for sensors and the other reference instruments.

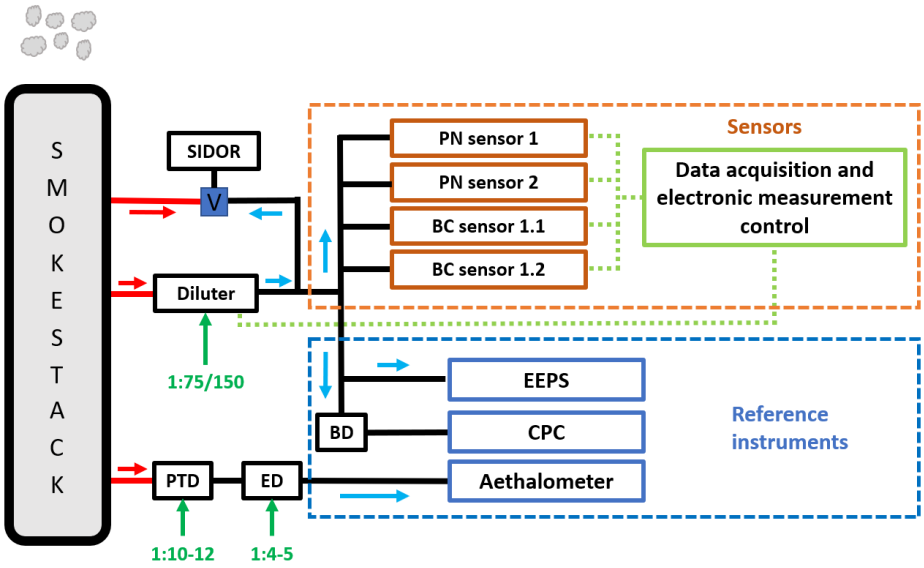

Figure 1. Experiment setup used in this study.

RESULTS

The intercomparison of the PN sensors showed good agreement with 400 data points, only 3.7% total bias towards Sensor #1. Comparison to the total PN measured from the CPC showed larger bias up to 63.5% towards the CPC, which is likely due to differences in smallest particle size detectable by each instrument. The BC sensors showed good overall agreement to one another: with 916 data points, the bias was 8% towards the unit with lower flow rate. In addition, we found that filter dirtiness had no or little effect on sensor performance within the recommended replacement interval. All instruments within the sensor section of Fig.1, including the diluter, showed no malfunctions during the measurement period.

CONCLUSIONS

The sensor package used in this study is capable of fully automatic measurement, including starting and stopping the measurement event and change of DR when necessary. The results from the sensors agreed well to one another. Comparison to reference instruments showed relatively good agreement when differences in detection limits were considered. The PN sensors were reliable and needed no maintenance during the measurements; the BC sensors, however, needed daily maintenance (filter replacement).

ACKNOWLEDGEMENTS

This work was a part of project SCIPPER, Shipping Contributions to Inland Pollution Push for the Enforcement of Regulations, funded by European Union's Horizon 2020 research and innovation programme under grant agreement Nr. 814893. Ship owner and engine crew are gratefully acknowledged for their great support of the measurement campaign.

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PROMOTING CLIMATE CHANGE EDUCATION AT METROPOLIA UNIVERSITY OF APPLIED SCIENCES IN THE CARBON BUSTERS PROJECT

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Keywords: Climate change education, sustainable development, emission reduction

INTRODUCTION

Metropolia University of Applied Sciences' Myyrmäki campus has a new learning and co-development environment for climate change mitigation and sustainable development, *Carbon garage* (in Finnish: *Hiilitalli)*, where solutions for climate change mitigation, in the short and long term, will be concretely promoted. The Carbon Busters project is a joint project of Metropolia University of Applied Sciences, VTT Technical Research Centre of Finland and the Finnish Meteorological Institute, where a new innovation ecosystem will be created to respond to the development of skills, new operating models and solutions related to sustainable development, carbon sequestration and emission reduction.

The Carbon Busters project will start using the Carbon garage space in November 2023, by piloting a series of lectures and discussions - *Studia Carbon garage events*- focusing on the root causes of climate change.

STUDIA CARBON GARAGE CLIMATE LECTURES

Each Studia Carbon Garage event consists of three 20-minutes lectures followed by a 10-minutes discussion. The Studia Carbon Garage events are hybrid, meaning that participants can participate remotely or on-site. The Studia Carbon Garage events are open to everyone and free of charge.

The storyline of the first three events (Table 1) is to start by guiding through the scientific basis of climate change, by introducing the global and local changes already observed, the basics of the greenhouse effect and the climate system together with the carbon cycle. Discussions will be encouraged on the climate changes that the participants themselves have noticed and the magnitudes of the time scales of the carbon cycle. The second session will introduce the way to study the future of the climate through climate models, emission scenarios and climate scenarios. The Climate Law will be introduced as a way to meet international agreements on emission targets, followed by discussion on how we could utilize the Climate Law in our actions. In the third session, climate change mitigation and adaptation actions will be presented as well as climate change services and applications that allow users to access and work with climate data and information. We will discuss what kind of climate change mitigation and adaptation actions are we aware of, for an individual, in society. Some openly available climate services and applications will also be presented and tested during a hands on session.

Table 1. The topics at the first three Studia Hiilitalli events

Title of the event	Topics
1) The scientific basis of climate change	• The observed climate change • The greenhouse effect • The climate system and the carbon cycle
2) The future of the climate I	• Climate models • Emission scenarios and climate scenarios • Climate law
3) The future of the climate II	• Climate change mitigation • Climate change adaptation • Climate services and applications

In the production of the Studia Carbon Garage lecture material, course materials of the Climate University (www.climateuniversity.fi) online courses *Climate.now* (https://digicampus.fi/course/view.php?id=3548) and *Living with changing climate* (https://digicampus.fi/course/view.php?id=4738) are utilized. The Studia Carbon Garage lecture series will be developed into its final form in spring 2024 based on feedback from pilot lectures held in November 2023.

ACKNOWLEDGEMENTS

This work is supported by the Carbon Busters project funded by the European Regional Development Fund, Helsinki-Uusimaa Regional Council (project number R-00246). We acknowledge the production team of the Living with changing climate course (ATM389), in the ClimComp project funded by the Research Council of Finland (Decision number 340791).

METHANE AND CARBON DIOXIDE DYNAMICS IN A CHANGING CLIMATE: A 13-YEAR TIME SERIES OF A FEN IN PALLAS, NORTHERN FINLAND

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Keywords: boreal, peatland, greenhouse gases, global warming

INTRODUCTION

Northern peatlands store vast amounts of carbon. With ongoing climate change, these carbon stocks could decline in future, further enhancing climate change. Yet, long-term studies evaluating the impact of climate change on the methane and carbon dioxide exchange of boreal peatland ecosystems are rare.

METHODS

We measured methane (CH_4) and carbon dioxide (CO_2) exchange at a subarctic/boreal fen in Lompolojänkkä, Northern Finland (ICOS ecosystem class II site) during 2007-201) using the eddy covariance technique, with parallel measurements of abiotic and biotic variables such as soil temperature, water table, and vegetation parameters. CH_4 and CO_2 data were gap-filled using a machine-learning approach based on gradient boosting [1].

CONCLUSIONS

Annual CH_4 emissions ranged from +17.3 to +26.9 g CH_4 m^{-2}, annual net CO_2 exchange from –0.36 to +0.17 kg CO_2 m^{-2}. Summer fluxes determined the annual budgets, with contributions of 45-57% for CH_4, 67-84% for gross primary production and 46-54% for ecosystem respiration. Soil temperatures strongly drove daily CH_4 emissions ($R^2 = 0.69$), i.e., CH_4 emissions were rising significantly with soil temperatures. Year-to-year variation in CH_4 emissions was correlated to year-to-year variation in soil temperatures ($R^2 = 0.52$). Annual variation in water levels had no significant impact on CH_4 emissions. Our results confirm that soil temperature primarily drive CH_4 variation, as found in several studies [2-4].

ACKNOWLEDGEMENTS

This work was financed by the Ministry of Transport and Communications through ICOS Finland.

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MODELLING AIR QUALITY AND CLIMATE IMPACTS OF POLLUTANTS USING MACHINE LEARNING AND A CLIMATE MODEL

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Keywords: Climate modelling, Air quality, Machine learning.

INTRODUCTION

Climate change and air pollution are two of the most important challenges to public health and sustainability, closely linked both in terms of emission sources and impacts (Melamed et al 2016). Currently these two problems are addressed in a fragmented, siloed manner, and there is no sufficient understanding of what explains such policy disintegration and how to develop and diffuse effective legal rules to achieve co-benefits for climate and air quality. One example is reducing emissions of short-lived climate pollutants (SLCPs), including black carbon (BC), which contributes to both climate change and air pollution. An integrated policy development on the two topics is further hindered by the fact that different models are used to study impacts of pollutants on either climate or air quality: Global climate models work at to coarse resolutions to properly capture air quality, which varies strongly over short distances and times. Air quality models, on the other hand, are usually limited to smaller geographical domains and to the lower part of the atmosphere. Air quality models are thus not feasible for studying climate effects. Furthermore, models which do not simulate the entire atmosphere have to be driven by external meteorological fields (for instance from global climate models or reanalysis). Therefore, to capture the effects of pollutant mitigation on both air quality and climate, the results of several different types of models have to be synthesised. This makes assessment of the efficacy of new legislation slow.

METHODS

The Academy of Finland project "Science-based legal pathways to reduce black carbon emissions in the EU and China: Towards integrated climate – air quality approaches" (ClimAirPathways) aims to study how legislation on climate and air quality aspects is and can be combined in order to maximise co-benefits and minimise possible trade-offs. To support the legal part of the projects we aim to develop new methods to better integrate air quality and climate impact assessment of pollutant mitigation.

If the shortcomings due to the coarse resolution of global climate models can be rectified, the models can be viable candidates for studying both climate and air quality effects of future emission changes. To this end, we develop a tool which employs machine learning to downscale and bias-correct global climate model data to local scales relevant to air quality assessment. The main machine learning algorithm to be used is random forest (RF) (Breiman, 2001) regression, but other methods (e.g., Gradient Boosting (Friedman, 2001), Support-vector machine (Boser, 1992)) will also be tested. The working principle of the downscaling tool is based on a two-stage process. In the first stage, the tool is trained using present-day climate model simulation and observational data, deducing rules on how to correct the modelled air quality data (e.g., PM) towards observations. In the second stage, the tool applies these rules to estimate future air quality based on model data from climate projections. A first version of the method has already been developed using the aerosol climate model ECHAM in combination with the ECLIPSE v6 emission scenarios and has been

tested for the city of New Delhi, India to very good success (Miinalainen et al., 2023). Here we will extend the method to cover more cities and, eventually, entire regions at once.

CONCLUSIONS

The project is still in its starting phase, and we are currently collecting measurement data to support the development of the downscaling tool. We are open to collaborations concerning both observational data provision and modelling work.

ACKNOWLEDGEMENTS

This work is supported by the Research Council of Finland (Grant nr. 355531) and the ACCC.

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EFFECTS OF STRATOSPHERIC AEROSOL INJECTIONS ON CLIMATE: THE ROLE OF INJECTION RATES AND AEROSOL MODULE

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Keywords: Solar radiation management, Aerosol microphysics, Climate modelling.

INTRODUCTION

One of the most extensively researched solar radiation modification techniques is the Stratospheric Aerosol Intervention (SAI), which has the intent to create an aerosol layer that reflects solar radiation back into space (Caldeira et al., (2013)). The majority of these studies employ injections of SO_2. This mimics the effects of large volcanic eruptions. Once injected, the SO_2 oxidizes into sulfuric acid establishing a reflective aerosol field in the stratosphere. The estimated climate effects of SAI depend heavily on model used for simulations and specific model components for individual processes e.g for aerosol microphysics and the climate feedbacks that dictate how the radiative effects of aerosols translate into climate impacts. In this two-phase study, the aerosol and radiative impacts are first simulated using a global climate model with both modal and sectional aerosol models. These simulated aerosol optical properties are then incorporated into three different Earth System Models (ESM). Consequently, we obtain six distinct projections of the resulting climate impacts. Additionally, this study examines the role of the injection rate (i.e., the amount of sulfur introduced into the stratosphere annually) in conjunction with the aerosol-climate model combination.

METHODS

Aerosol optical properties and radiative impacts were simulated for six different injection rates ranging from 2 to 100 Tg(S)/yr. Sulfur was injected continously as SO2 over equator and to 20 km altitude. These simulations were done with modal (M7) and sectional (SALSA) aerosol modules within the ECHAM-HAMMOZ aerosol-climate model. To simulate climate impacts of aerosol injections, EC-Earth, MPI-ESM and CESM Earth System Models were used. To produce consistent perturbation on radiation, simulated aerosol optical properties were implemented to each ESMs. So-called regression method were used to quantify fast (temperature independent) and slow (feedback, temperature dependent) responses.

RESULTS

The shortwave radiative forcing was 45 %-85% larger (cooling) in SALSA than in M7 with the corresponding injection rate while the longwave radiative forcing was 33%-67% larger (warming) in M7. These large differences are identified to be caused by two main factors(Laakso et al., (2022)): 1) In SALSA, the injected sulfur was more inclined to form new particles rather than condensing

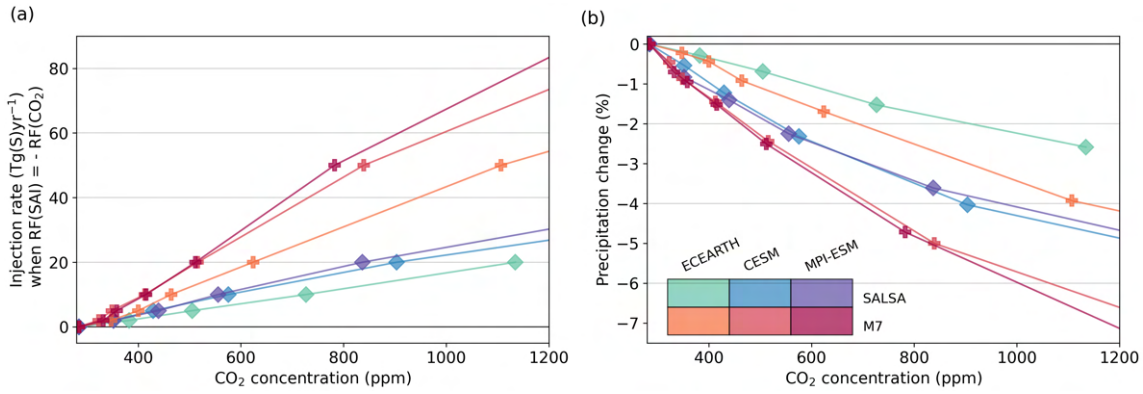

Figure 1: a) The injection rate of stratospheric sulfur injections and b) estimated precipitation change in different model combinations if radiative forcing (RF) of CO_2 concentration is compensated by SAI.

on existing ones, whereas M7 exhibited the reverse tendency and 2) The modal size distribution treatment in M7 prevented aerosols from reaching the optimal size for scattering during continuous injections. These variations led to significant discrepancies in the projected changes to surface temperature and precipitation within ESM simulations: with an injection rate of 20 Tg(S)/yr, the CESM model using M7-simulated aerosols resulted in a global mean cooling of just 2.2 K, whereas the EC-Earth-SALSA combination produced a change of 5.2 K. In the simulations, where SAI was deployed to offset the radiative forcing of a 500 ppm atmospheric CO_2 concentration, the models showed a variation in global mean precipitation reduction, ranging from -0.7% to -2.4%. The observed changes in precipitation was attributed to the fast precipitation response to radiation alterations induced by both SAI and CO_2. This is because the fast precipitation response tends to have a negative correlation with the absorbed radiation.

CONCLUSIONS

Our study indicates that estimating the climate impacts of SAI is complex. The sulfate layer's ability to reflect solar radiation and absorb long-wave radiation is influenced both by the injection rate and the aerosol model chosen for simulation. These factors significantly determine the cooling potential of SAI and the subsequent side effects, such as those observed in precipitation. These insights underscore the importance of accurately simulating aerosol microphysics to reliably assess the climatic consequences of SAI. Additionally, our study highlights existing knowledge gaps and uncertainties surrounding these controversial techniques.

ACKNOWLEDGEMENTS

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LIQUID CLOUD MICROPHYSICAL PROPERTIES WITH POLARIZATION CEILOMETERS

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Keywords: liquid cloud, remote sensing, depolarization ratio, lidar.

INTRODUCTION

Ceilometers have always played an important role in observing clouds continuously in national networks and at airports all over the world. However, the signal is heavily attenuated inside the cloud, limiting the capability of ceilometers to only obtaining useful data up to the cloud base. With the recent development of depolarization in ceilometer and wind lidar, signal from a bit further inside the cloud might finally be utilized to potentially unveil the microphysical properties of liquid clouds.

METHODS

The measured depolarization signal inside liquid clouds is influenced by multiple scattering and results in a constant increasing trend in depolarization upwards from the cloud base. The degree of this increase (denoted as d_δ/d_{height}) depends on the lidar characteristics, and the cloud macrophysical and microphysical properties. Following the method from Donovan *et al.* (2015), we aim to retrieve microphysical properties of liquid clouds in Kenttärova and Hyytiälä using Vaisala CL61 ceilometers and Halo Doppler lidars. Afterwards, we will investigate the interaction of cloud and aerosol through the vertical wind mixing below the cloud base and the airmass origin of the cloud.

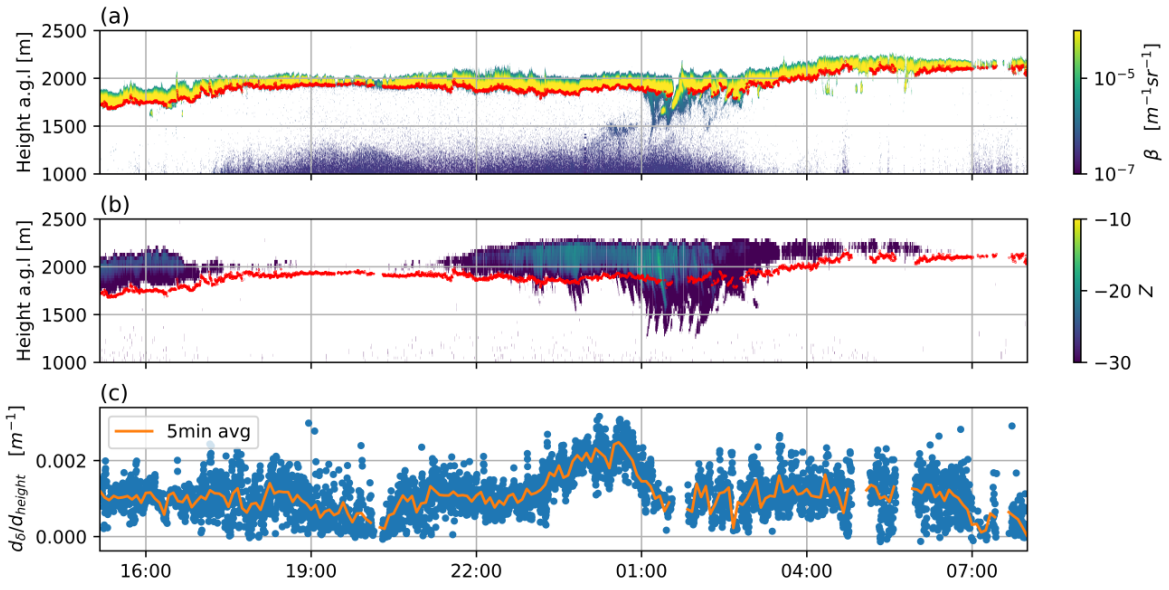

Figure 1. Measurement at Kenttärova from 2023-08-21 to 2023-08-22 a) Attenuated backscatter (β) from a ceilometer, b) Reflectivity (Z) from cloud radar. Cloud base is indicated in red in panels a and b. c) The degree of increase in depolarization ratio from the cloud base (d_δ/d_{height}).

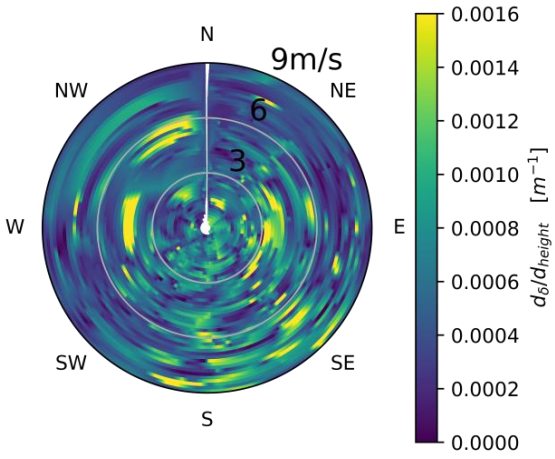

Figure 2. The degree of increase in depolarization ratio from the cloud base (d_δ/d_{height}) with respect to wind speed and wind direction in Kenttärova from 2023-01-01 to 2023-10-01. Only cloud base below 2.5 km is included. The model wind data is obtained from Cloudnet (O'Connor et al., 2023)

Figure 1 displays a study case of a liquid cloud. The dissipation of the cloud as seen by the ceilometer (Fig. 1a) and the radar (Fig. 1b) can also be observed by the decrease of d_δ/d_{height} (Fig. 1c) from 18:00 to 20:00. Then from 23:00 to 24:00, as the sizes of the cloud liquid particles grow, Z and d_δ/d_{height} also increase. Finally, from 0:00 to 01:30, these big hydrometeors fall out of the cloud, resulting in the decrease in d_δ/d_{height}.

Figure 2 represents the results from a longer statistic in Kenttärova in 2023. The values of d_δ/d_{height} are generally higher in the East to South direction. This suggests that air mass originated from this direction resulted in cloud with higher degree of multiple scattering. In other words, air masses from continental Europe resulted in clouds with smaller particles consistent with a higher cloud droplet number concentration, as is expected for more polluted clouds.

CONCLUSIONS

To sum up, the degree of multiscattering, repsented by d_δ/d_{height} observed from a ceilometer, is capable of qualitatively describing the characteristics of a liquid cloud. The statistics from Kenttärova show a promising result. The next step is to calculate the cloud microphysical properties (cloud droplet effective radius, liquid water content and number concentration of cloud droplets) from this degree of multiple scattering, together with airmass backward trajectories.

ACKNOWLEDGEMENTS

This work was supported by the Magnus Ehrnrooth foundation.

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HOW PARTICLE NUMBER MEASUREMENT IN PERIODICAL TECHNICAL INSPECTION OF PASSENGER VEHICLES REFLECT REAL DRIVE EMISSIONS?

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Keywords: exhaust emission, passenger vehicles, particle number emission, periodical technical inspection.

INTRODUCTION

Aerosol particle emissions are a major factor in poor urban air quality worldwide, with road traffic being one of the main sources. New protocols to control particle number (PN) emissions of under 200 nm from vehicles are being implemented in Europe. Starting with Belgium, Germany, the Netherlands, and Switzerland, PN concentration limits for periodical technical inspection (PTI) have been set. This study aims to assess the effectiveness of these protocols in comparing PTI emissions to real driving emission factors (EFs) from passenger vehicles. In addition to the effectiveness evaluation, we compare the distributions of PN concentration and EF from Finnish vehicle fleet based on large datasets from PTI and chase measurements.

METHODS

PN measurements were conducted on 234 Finnish passenger vehicles undergoing regular PTI checks. The measurements were conducted only for vehicles whose owners were approved the measurement. The background information of vehicles included vehicle age, mileage, and emission classification. The measurement protocol consists of a 15-second engine stabilization followed by a 60-second idle measurement. The number concentration (PN) for solid particles larger than 23 nm ($PN_{>23}$) was determined using the Dekati® ePNC™ PN measurement system with a heated probe.

The PTI measurement data was compared to on-road chase measurements performed on over 300 randomly selected passenger vehicles under various driving conditions. PTI measurements were conducted in May 2021 in Tampere, and extensive chase measurements were carried out during the summer of 2020, mostly on highway road between Tampere and Helsinki using the Tampere University mobile laboratory, ATMo-Lab (Olin et al., 2023). This study focuses on comparing factors affecting $PN_{>23}$ from the PTI measurements and the corresponding EFs of particles larger than 23 nm from the chase measurements ($EF_{>23}$, [1/km]).

Figure 1 shows the distribution of vehicles in the chase and PTI datasets, compared to the real Finnish light-duty vehicle fleet. The distribution shown in Figure 1 and other analysis (not shown here) indicate that both the chase and the PTI dataset are relatively close to the real Finnish vehicle fleet.

The datasets were analysed with Generalized Additive Models (GAM: Wood, 2011) to find common factors affecting the $PN_{>23}$ and $EF_{>23}$. The main predictors in models for both $PN_{>23}$ and $EF_{>23}$ were vehicle age, mileage (total or annual mean), and by which emission standard (Euro 1-6) the vehicle was built. Gasoline and diesel vehicles were analysed separately. In addition to these, for $PN_{>23}$, temperature of the heated sampling line was accounted for as one aim for the measurements was to see how it affects the measurement. For $EF_{>23}$, in turn, driving speed, meteorological parameters, and measured CO_2 emission were also considered.

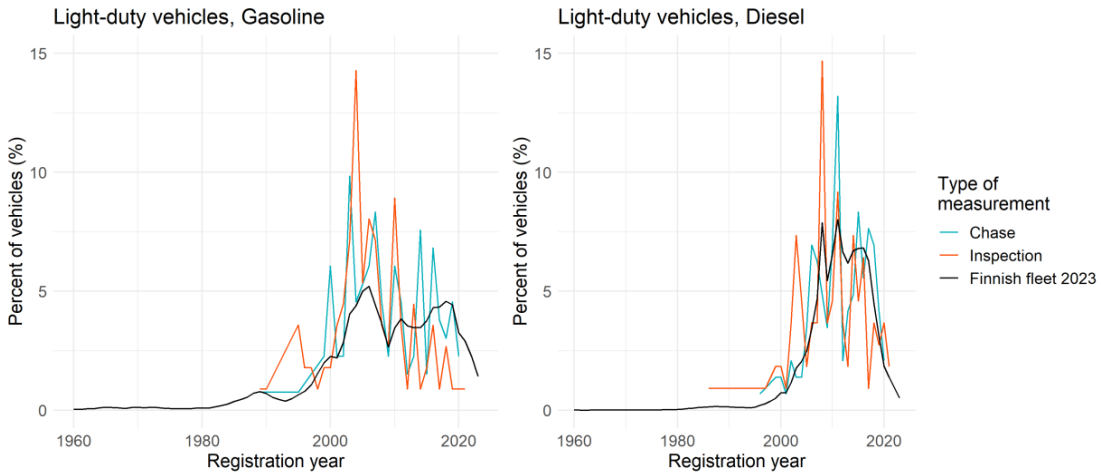

Figure 1. Density plot of light-duty (passenger) vehicles as a function of registration year of a vehicle in the chase and PTI datasets, compared to the Finnish light-duty vehicle fleet from Traficom database.

RESULTS

The results indicate that the factors tested affect the emissions differently between the fuels. Diesel $PN_{>23}$ emissions have been decreasing with stricter Euro classes, whereas $PN_{>23}$ from gasoline engines has been steady or even increasing. The GAM models for $EF_{>23}$ and $PN_{>23}$ indicate that the annual mileage is also connected to varying emissions, especially with gasoline engines (Fig. 2). For gasoline vehicles the effect is not linear, but it varies as function of mileage/year as shown in Fig. 2. For diesel vehicles, this kind of pattern was not seen (not shown here).

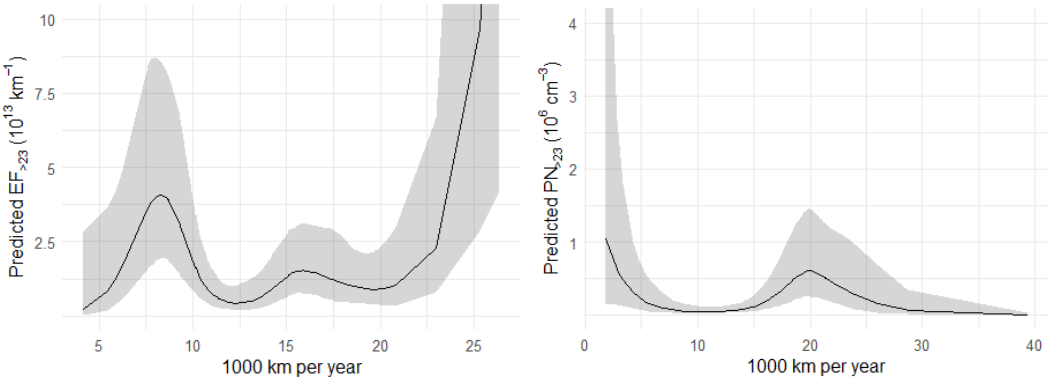

Figure 2. Effect of mileage/year on $EF_{>23}$ (chase, gasoline) and $PN_{>23}$ (PTI, gasoline) from GAM model.

ACKNOWLEDGEMENTS

This research was funded by the Jane and Aatos Erkko's Foundation, and the Research Council of Finland (Grant no. 322120, 325022, 337550, 337551, and 352968).

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CLOUDNET – DATA PORTAL FOR CLOUD REMOTE SENSING OBSERVATIONS

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Keywords: Cloud properties, Data processing.

INTRODUCTION

Clouds strongly regulate the Earth's water cycle and the planetary radiation balance. Currently, they remain the largest contributor to the overall uncertainty in climate feedbacks. These uncertainties propagate into global temperature projections (Arias *et al.*, 2021).

Cloudnet aims to provide high-resolution cloud property datasets derived from ground-based observations. These datasets will be used to validate satellite cloud imaging products and can be used to improve the accuracy of climate and weather forecast models.

Cloudnet is part of the Aerosol, Clouds and Trace Gases Research Infrastructure (ACTRIS). ACTRIS is now in the implementation phase and plans to be fully operational in 2025 (Häme *et al.*, 2018).

METHODS

Cloudnet receives data regularly from around 20 stationary observation platforms (Figure 1). Each platform is equipped with instruments that meet the requirements of the ACTRIS Centre for Cloud Remote Sensing (CCRES). These instruments include Doppler cloud radars, Doppler lidars, ceilometers, microwave radiometers, disdrometers, and weather stations. We also host and process data from mobile and campaign platforms.

Cloudnet processes raw instrument data to derive cloud property products such as target classification of the scatterers, liquid and ice water content, and drizzle drop size distribution (Illingworth *et al.*, 2007) using the open-source Python package CloudnetPy (Tukiainen *et al.*, 2020). In the future, Cloudnet also provides wind and boundary layer height products derived from Doppler lidar data.

All the raw and processed data are freely available adhering to the FAIR principles (Wilkinson *et al.*, 2016) via the data portal at cloudnet.fmi.fi.

ACKNOWLEDGEMENTS

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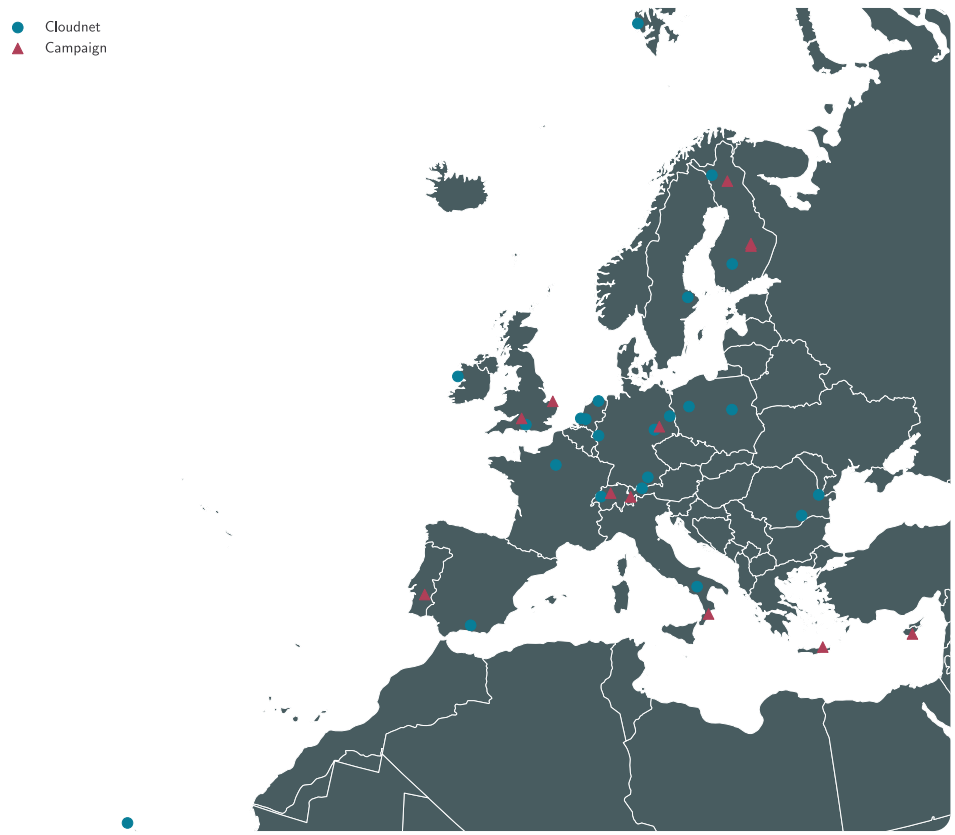

Figure 1: Locations of the Cloudnet sites.

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OVER 20 YEARS OF OBSERVATIONS IN THE BOREAL FOREST REVEAL A DECREASING TREND OF ATMOSPHERIC NEW PARTICLE FORMATION

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[α]the second and third authors contributed equally to this work

Keywords: new particle formation, sulfuric acid, HOMs, long-term trends.

INTRODUCTION

We investigated over 20 years of measurement data in Hyytiälä to reveal the long-term trends and entanglement among precursor vapor concentrations, particle formation and growth, and the potentially shifting new particle formation (NPF) mechanisms. We derived a new highly oxygenated organic molecules (HOM) proxy for conducting the long-term trend analysis (due to the lack of direct measurement) for its significant contribution in the initial and subsequent particle formation and growth. Our trend analyses provide insights to the variations on the NPF characteristics in corresponds to the changing climate, as well as a clear direction to further improve the performance of climate models.

METHODS

Data used in this study were collected from SMEAR-II STATION in Hyytiälä, during 1996–2019. NPF event classification, particle formation rate (J_3), particle number concentrations ($N_{3\text{-}25}$), particle growth rate ($GR_{3\text{-}25}$) and condensation sink (CS) are determined from Differential Mobility Particle Sizer (DMPS) measurements. The long-term sulrufic acid (H_2SO_4), monoterpene (MT) and HOM concentrations are calculated from proxies to match the over 20-year time span. HOM proxy is newly developed based on the pathways through MT-ozone (O_3) and MT- hydroxyl radicals (OH) oxidation (EQ.1):

$$[HOM]_{proxy} = \frac{(k_a[O_3]+k_b[OH])[MT]}{CS} \qquad \text{Eq. 1}$$

RESULTS

The newly developed HOM proxy shows satisfactory predictions shown by the correlation coefficients (Fig. 1), while it can predict HOM concentrations without seasonal discrepancies. During the past 20 years, the intensity (i.e., J_3) and frequency of NPF events have both been declining, implying that H_2SO_4 as the precursor vapor is still more important compared to HOM in the initial steps of NPF (Fig. 2). At this rate of persistent increase of HOM and decrease of H_2SO_4, a speculated change in particle formation pathway from

H_2SO_4-dominated to HOM-dominated is expected in the future, starting already from sub-3 nm particle size range (Eichkorn et al., 2002; Lee et al., 2003).

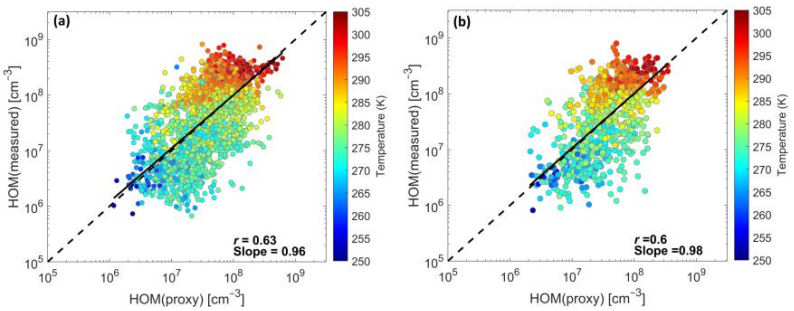

Figure 1. Parameterization results of the measured HOM concentration vs. HOM proxy during 2016-2019 using (a) training dataset and (b) testing dataset. The data is from all seasons and considers both daytime and night-time measurements in hourly averages. The solid straight lines represent robust linear fits, and the dashed lines are 1:1 line.

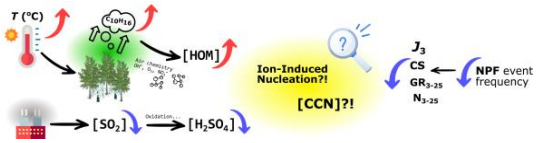

Figure 2. The rationale of this study on the series effects of the change of NPF characteristics and climate leading to a potentially more prevailing ion-induced nucleation (IIN) pathway in NPF, as well as a speculated decrease in the cloud condensation nuclei (CCN) concentration in Hyytiälä.

CONCLUSIONS

Based on the long-term trends, if the organic vapor concentrations continue to rise as predicted, the volatility distribution of HOMs would alter due to the increasing vapor amount and potentially vapor species, which could lead to changes in the contribution of HOMs in the early stage of NPF (Dada et al., 2023). Hence, the synergy between the increasing temperature and the rising HOM concentrations, chemical compositions, and volatility on NPF needs further detailed investigations, as well as the IIN contributions in the early stage of NPF when organic vapor level is high. Parallelly, the decreasing J_3 and $N_{3\text{-}25}$ suggest an overall decrease in CCN concentrations, which requires long-term inspection in a regional context.

ACKNOWLEDGEMENTS

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SIMULATING SPATIAL DISTRIBUTION OF AEROSOL IN A REAL URBAN NEIGHBOURHOOD: SENSITIVITY TO VEHICLE EMISSION AND POLLUTION BACKGROUND

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Keywords: Large-eddy simulation, aerosols, vehicle emission, aerosol size distribution.

INTRODUCTION

With the coincidence of high population densities, large air pollution emissions, and poor air ventilation, an increasing number of urban dwellers are exposed to high concentrations of gas pollutants and aerosol particles. Vehicle emission is a major source of urban air pollutants, which greatly affects the air quality, particularly in pedestrian and neighbourhood level. Recently, a parallelized large-eddy simulation (LES) model PALM (Maronga et al., 2020) was developed and incorporated a Sectional Aerosol module for Large Scale Systems (SALSA, Kokkola et al., 2018; Kurppa et al., 2019) to resolve the turbulent wind field and pollutant dispersion in a realistic complex urban environment. Emissions and pollutant background are crucial inputs for SALSA and may represent a major source of uncertainty.

METHODS

In this study, the PALM model system 6.0 with SALSA module was applied to simulate aerosol concentration, aerosol size distribution and its spatial distribution in a real urban neighborhood in Beijing. Different emission size distributions, emission inventories, and pollutant background were adopted in the simulations with the aim to investigate the modelling sensitivities of PALM to vehicle emissions and pollutant background.

The simulation was conducted during the winter morning rush hours near the campus of Beijing University of Chemical Technology (BUCT). The self-nesting setup was implemented comprising a root, parent, and child modelling domain. The turbulence flow was solved in each domain whereas SALSA was only applied in the child domain with a resolution of 1 m. Dynamic boundary conditions from ERA5 reanalysis data provided changing synoptic conditions and forcing for the flow initialization. A comprehensive air pollutant monitoring station in BUCT provided us with air pollutant background concentrations. Traffic volumes were retrieved from EMBEV-Link (Link-level Emission factor Model for the BEijing Vehicle fleet, Yang et al., 2019). Two different emission size distribution treatments from the Gains model and source appointment analysis (Jing et al., 2020) were applied, which reveal a large difference in Aiken and accumulated mode emissions. Meanwhile, time-dependent pollutant background from simulation period and fixed pollutant background from low emission period were also involved in different model runs.

RESULTS

The spatial distribution of aerosol (Fig.1) showed a strong effect of turbulent structures and the formation of aerosol concentration hotspots within the road areas. The differences in the total particle number concentration between the two emission size distribution cases were lower than 1%, while the effects of the background were obvious. The effect of emission size distribution and pollutant background on the modelled

number size distribution has also been analysed. The shape of the number size distribution seemed to be similar in both the main road area and the child domain with two dominant modes. When applying a lower fixed pollutant background, the changes in number concentration were obvious in almost all size bins.

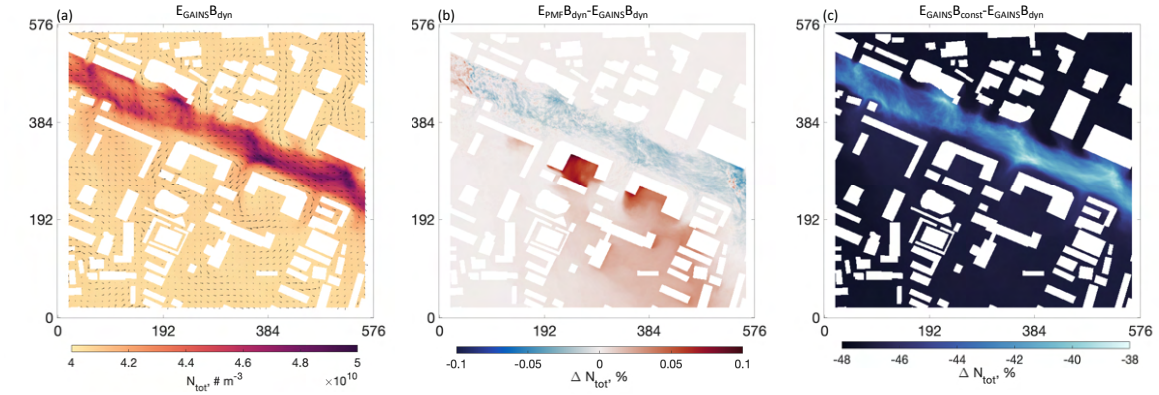

Figure 1. a) Modelled total particle number concentration (N_{tot}) at 2 m with GAINS emission size distribution and dynamic background, the change of N_{tot} in percentages with b) source appointment size distribution and dynamic background and c) GAINS emission size distribution and fixed background.

CONCLUSIONS

The impacts of traffic emission size distribution on the total particle number concentration are quite small and the size distribution can be explained more by the pollutant background. Work is in progress to test the effect of the dynamic aerosol processes especially the condensation on the size distribution output.

ACKNOWLEDGEMENTS

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Concentration and flux measurements of VOCs at an agricultural site in southern Finland during growing season

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Keywords: Volatile Organic Compounds, Flux measurements, Mass spectrometry.

INTRODUCTION

Volatile Organic Compounds (VOCs) consitute a significant fraction of atmospheric trace gases, globally totalling more than 1000 Tg in annual emissions (Guenther *et al.*, 2012). VOCs and several other gaseous compounds are emitted from agricultural land (Gentner *et al.*, 2014). Oxidation products of these compounds have been shown to contribute to aerosol mass by condencation and participate in new particle formation (Laaksonen *et al.*, 2008), which makes VOCs relevant both from the perspective of climate, and health (Rosenfeld D. *et al.*, 2014; Shiraiwa *et al.*, 2017).

The aim of this experiment was to capture emissions from the growing season as well as the agricultural start-up season, with a focus on the concentrations and fluxes of biogenic volatile organic compounds (BVOCs), including isoprene (IP), monoterpenes (MTs) and sesquiterpenes, as well as nitrogen-containing compounds derived from some of the agricultural activities, such as amines and urea. The mechanism of secondary organic aerosol production and its influence on the subsequent production of new particles will also be investigated.

By stuying the flux of VOCs above agricultural land during the growing season, we hope to better understand and quantify the impact of farmland on VOC profile and atmospheric trace gas composition.

METHODS

The measurements were conducted from April to May 2023 at the SMEAR-AGRI measurement station, which is the first comprehensive agricultural measurement station studying the impacts of agricultural land use on climate and waterways. The station also contains several other measurments that may assist in data interpretation, like CO_2 balance.

The VOCUS proton transfer reaction mass spectrometer was used for quantitative detection of VOCs (Li *et al.*, 2020). Together with wind data from an anemometer situated close to the inlet line of the mass spectrometer, the spectrometer allows for estimating fluxes using eddy covariance (Fischer *et al.*, 2021).

In addition, a nitrate chemical ionization time of flight mass spectrometer was used for detecting highly oxygenated species as well as sulphuric acid at a location nearby (Jokinen *et al.*, 2012).

RESULTS

During the whole campaign, the BVOCs and their oxidation products increase gradually, although a steep decline in temperature on May 16th breaks this trend. Most compounds follow the same

trend. Exceptions are two high concentration amine peaks, DMA and TMA, appearing after one fertiliazation activity. We also find some sulfur containing species, like dimethyl sulfoxide, being another evidence that agricultural emission is a source of sulfur in the atmosphere.

Based on 10Hz VOCUS PTR sampling, we also try to use the eddy covariance method to calculate fluxes from several interesting species. So far, we have some reasonable flux data, including BVOCs, benzene, toluene, xylene, oxgenated VOCs, amine, and others. IP flux is higher than MT, they both show a daytime peak pattern. One interesting compund is DMS, for which we see a daytime peak and a high concetration at May 16th. We guess this considerable flux and high peak on the day with bad weather with a high variation in temperature and humidity indicate a special air-soil interaction or soil emission process.

CONCLUSIONS

Credible VOCs concentration and some small positive fluxes were detected from the agricultural land during the growing season, high amine and different VOCs responses from varying weather or meterology emphasize the interaction between agricultural activities and atmospheric processes. Work is still in progress to analyze the whole measurement period, and conduct further analysis.

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ENVIRO-HIRLAM IN ENVIRONMENTAL STUDIES: RESEARCH, DEVELOPMENT, APPLICATION, AND SCIENCE EDUCATION

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Keywords: PEEX, Enviro-HIRLAM, multi-scales and -processes modelling

INTRODUCTION

The development and application of **seamless/ on-line** (compared with off-line) **approach** in modelling is expected to be able to handle and study many existing processes and interactions. The modelling platform is important component of the **PEEX** (Pan-Eurasian EXperiment programme; www.atm.helsinki.fi/peex) research infrastructure. In particular, online-integrated models can be applied for studies on interactions and feedbacks of meteorology vs. aerosols/chemistry; aerosols vs. cloud formation and radiative forcing; boundary layer parameterizations; urbanization processes impact on changes in weather/climate; environmental assessments; improving prediction of extreme weather/ pollution events; etc.

METHODS AND RESULTS

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. The **Enviro-components** are described in details by *Baklanov et al. (2017)*.
The **research, development and science education of the modelling system and its applications** will be demonstrated on examples of ongoing projects, where the Enviro-HIRLAM is used as a research tool for studies in the PEEX domain. These studies include: (i) Development of PEEX Modelling Platform towards seamless environmental prediction (*Mahura et al. 2023a*); (ii) Implementation of Enviro-HIRLAM meteorological output for FLEXPART trajectory calculations with focus on a heavy air pollution event in Nov 2018 in Beijing, China (*Foreback et al. 2023*); (iii) Seamless downscaling modeling of direct and indirect aerosol effects during Apr 2020 wildfire episode in Ukraine (*Savenets et al. 2023a*); (iv) Seamless modelling of meteorology and air pollution to estimate impacts of covid-19 in urban Finland (*Heibati et al. 2023+*); (v) Quantifying aerosol effects on meteorology in various weather conditions using seamless integrated modeling system for case studies (*Savenets et al. 2023b*); (vi) Testing results of Enviro-HIRLAM parameterizations for sea-spray emissions in Arctic domain (*Mahura et al. 2023c+*); (vii) Further integration between regional-subregional-urban and turbulence resolving (large-eddy simulation) meteorological models creating a seamless modeling chain for very high-resolution environmental assessment and prediction (*Esau et al. 2023+*); and other studies (*Mahura et al. 2023b; Savenets et al. 2022*).
The **science education component** (as part of the PEEX Educational Platform) for the Enviro-HIRLAM model is also realised, and though the organization and carrying out of short-term research trainings. The recent training took place during 23 Oct – 21 Nov 2023 (https://arcg.is/1Wbq4u0) as hybrid (onsite/online) Young Scientist School (YSS) URSA MAJOR on "*Socio-Environmental Interactions in Sustainable Smart Cities*" in Tromso, Norway. It is the 2nd School organized in the Memory of Professor Sergej Zilitinkevich

(1936-2021). This YSS introduced young generation of researchers to special topics in urban, societal, environmental, and computational sciences. The focus is on digital communications, massive environmental monitoring, and integrated urban system modelling to support sustainable development pathways in smart cities. School included a series of lectures and 2+ weeks of remote work on practical exercises (so-called small-scale research project, SSRP) realised by groups of students. In particular, the Enviro-HIRLAM SSRP focused on studying effects of model urbanization on meteorology over metropolitan areas.

The **model application areas** are the following: aerosols-chemistry feedbacks studies on various meteorological variables; effects of various interactions of aerosols and cloud formation processes and radiative forcing on urban-regional scales; boundary layer and sublayer parameterizations; urbanization processes impact on changes in urban weather and climate on urban-subregional-regional scales; studies on atmospheric pollution and its local impacts; improving prediction of extreme weather events; providing meteorology-chemistry input to assessment studies for population and environment; integration modelling results into GIS environment for further risk/vulnerability/consequences/etc. estimation, and others.

CONCLUDING REMARKS

The Enviro-HIRLAM model is continuously developed and applied for the PEEX domain studies as a part of the PEEX-Modelling-Platform research and development at the CSC & ECMWF HPCs, ongoing/planned Horizon-Europe, Nordic, AoF, etc. research projects and applied for different research tasks according to the PEEX Science Plan (*PEEX, 2015*). The emphasis is 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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IMPACT OF EXPERIMENTAL DROUGHT ON BIOGENIC VOLATILE ORGANIC COMPOUNDS EMISSIONS FROM *SPHAGNUM* MOSSES OF BOREAL PEATLANDS

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Keywords: Climate change impacts, Drought, Experiment, Isoprene.

INTRODUCTION

Boreal peatlands have a globally significant role in climate regulation as they are an important carbon sink and storage, while also emitting methane and other biogenic volatile organic compounds (BVOC). Because BVOCs contribute to the secondary organic aerosol (SOA) formation in the atmosphere, they are regarded to have a net cooling effect on climate (Kulmala *et al.*, 2014). *Sphagnum* mosses that are a fundamental part of boreal peatland ecosystems are also known to emit different BVOCs (Faubert *et al*., 2010; Männistö *et al*., 2023), but it is not well known how their emissions respond to environmental stressors such as drought.

The ongoing climate warming is predicted to lower the water table of boreal peatlands due to increased evapotranspiration and to increase the frequency of extreme climatic events, such as heatwaves and seasonal droughts (IPCC, 2023). This can have both direct and indirect impacts on functioning of *Sphagnum* mosses, which can further affect carbon dynamics and climate feedback of the peatlands. However, there are no studies directly quantifying the impact of drought on BVOC emissions of *Sphagnum* mosses. In this study, we experimentally quantified the effect of severe seasonal drought on BVOC emissions from *Sphagnum* mosses from pristine wet open and naturally drier treed boreal fen and bog. We expected drought to decrease total BVOC emissions from *Sphagnum* and alter their emission cocktail.

METHODS

Altogether 32 *Sphagnum* moss mesocosms were collected from Lakkasuo peatland complex located in Southern Finland. Eight mesocosms of *Sphagnum recurvum* coll. were collected from two minerotrophic fen sites, an open wet fen and a naturally drier treed fen. Similarly, eight *Sphagnum balticum* mesocosms were taken from two ombrotrophic bog sites –from an open wet bog and naturally drier treed bog. After seven weeks of acclimatization period half of the mesocosms were kept as controls with natural water table (-10 cm), while the other half was exposed to an experimental drought with lowered water table (-30 cm) in a controlled greenhouse set-up. The drought treatment lasted six weeks after which the water table was raised back to normal and the mesocosms were let to recover for another six weeks. BVOC (C_5-C_{16}) emissions from the mesocosms were measured three times: 1. before drought, 2. in the end of the drought treatment, and 3. after the recovery period. Measurements were conducted with dynamic chamber method

sampling BVOCs using Tenax TA-Carboback B adsorbent tubes and analysing samples using thermal desorption-gas chromatography.

RESULTS

Altogether 30 compounds were identified, ten of which were detected only once or twice. Isoprene was the most emitted compound comprising on average 42% (up to 80% before the drought treatment) of the total BVOC emission and having flux rates ranging 0–31.9 μg m^{-2} h^{-1} with mean 5.6 μg m^{-2} h^{-1}.

Drought reduced total BVOC, isoprene and sesquiterpene emissions. Additionally, drought induced green leaf volatile emissions from *S. balticum*, as 1-hexanol and 1-octen-3-ol were detected from dry bog mesocosms during the 2. campaign but not otherwise. An alkane compound, n-decane, was detected from both bog and fen mesocosms before and after the drought but not during the drought. The drought treatment did not affect the emission of other alkanes, or emissions of oxygenated alkanes, monoterpenoids, organic halides and benzenoids.

Sesquiterpene emissions were higher from the bog mesocosms than from the fen mesocosms. Otherwise, there were no differences in BVOC emissions between bogs and fens, and none of the BVOC groups had different emission rates between the open wet and naturally drier treed sites.

CONCLUSIONS

Due to the ongoing global warming, seasonal droughts are predicted to occur more frequently in the future (IPCC, 2023), and they have already been shown to disrupt the carbon cycling of boreal peatlands and their feedback to climate (Rinne *et al*., 2020). Our results show that seasonal drought can change both quality and quantity of BVOC emissions from *Sphagnum* mosses, which can have further impact on the climate feedback of boreal peatlands, and therefore they should be included in global climate models to predict future changes more precisely.

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BEYOND AESTHETICS: ECOLOGICAL QUALITY OF URBAN GREEN SPACES AS A CATALYST FOR HAPPINESS

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Keywords: well-being, green space, social value, pollution

ABSTRACT

Currently, more than half of the world's human population (55%) resides in cities (UN-Habitat, 2022) but this proportion is expected to increase to 68% by 2050 (UN, 2019). In this scenario, the well-being of urban dwellers is crucial to realise their maximum potential in dealing with the everyday stressors of busy city life (Houlden *et al.*, 2018). Urban green space (UGS) is believed to contribute to residents' happiness. However, forming a holistic overview of this relationship based on regional studies is challenging. This literature review aims to synthesise the current evidence on the UGS-happiness relationship based on the ecological quality of urban green space.

In this study, we specifically looked at the ecological quality measures of UGS to understand the urban greenery and happiness nexus. We followed the reporting standards for systematic evidence syntheses (ROSES) developed by Haddaway *et al.* (2018). We used the search terms "urban forest*", "urban green*", "green infrastructure*", "happy OR happi*life", "satisf*", "subjective well*", and "quality of life" to create standard search strings using Boolean operators. We selected the Web of Science and Scopus databases for the literature search as they are the most credible and repeatable pools of published scientific sources from 2013-2023.

We identified around 19 studies after the full-text screening which associated the ecological quality measures of UGS with happiness. The ecological quality was measured using vegetation indices, biodiversity richness, diversity of habitats, green space elements and pollution measures. All 19 studies demonstrated a positive correlation between perceived happiness and the ecological quality of UGS, of which 14 were statistically significant We found that people in greener, more biodiverse with natural vegetation elements, and exposed to lower air pollutants were found to be happier. Liu *et al.* (2021) found that while there was no substantial short-term impact of any particular air pollution on subjective well-being, locals' subjective well-being was considerably reduced over the medium and long term by exposure to air pollution. The common mediating factors observed in the association between quality and happiness are the individuals' response to natural beauty and socio-economic and demographic variables.

In this review, it is evident that urban dwellers' happiness is influenced by high-quality UGS. However, along with the demographic variables such as age and gender, it is important to take the socio-economic variables, especially in the global south.

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TEACHER'S CLIMATE CHANGE ACADEMY - CLIMADEMY

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Keywords: teacher education, climate change training, Hyytiälä

INTRODUCTION

Climate change is already affecting Europe, heat waves, extreme drought and flood events affect human health. The European Parliament supports education development, Teacher's CLIMate change AcaDEMY (CLIMADEMY) is an Erasmus+ Teachers' Academies project is one example of concrete actions to foster it. Its aim is to build a teacher network, support teacher education and to give hands on training on how to teach climate change in school. However, the national variation is huge, while some countries have climate change as a theme that is included in all teaching from physics to philosophy and arts, it some countries is not yeat included in the curricula.

CLIMADEMY is led by University of Crete, where University of Helsinki INAR (Institute for Atmospheric and earth system Research) in collaboration with Universities of Bremen, Bologna and Crete create teachers' education on climate change. The aim is to build up a European network that offers a program for teachers for communication and sharing tools for teaching climate change related issues. In Finland the teacher network are built around activities in SMEAR II and Hyytiälä.

Hyytiälä forest station has been a hub of atmospheric and forestry scientist to educate on most recent science topics and practices (Ruuskanen et al., 2018, Lauri et al., 2020). The SMEAR II station, has particularly good opportunity to combine school subjects such as biology, physics, mathematics and chemistry and tie them to current research work. Carbon tree (www.carbontree.fi) is one example such and it opens connections of carbon exchange between plants and atmosphere.

Alongside learning the phenomena that are dealt with, our aim is to enhance scientific curiosity and teach the main requirements for scientific thinking. The target is to give the students tools for understanding causal relationships and evaluating the knowledge they get from their own analyses, school, media etc. Logical thinking and acknowledging the sources of errors are the basis of any inference and these skills are needed to an increasing extent in current overflow of information.

METHODS

In CLIMADEMY project, four education hubs have been created, one in each participating country. A common virtual platform Climate Auditorium (CLAUDI) has been launched and it will be used for networking, communication, training and sharing tools and practices among teachers and scientists within and among the four hubs. Creation of openly available educational material is on its' way and it will based on climate change teaching framework that is designed bases on European sustainability competence framework GreenComp (Bianchi et al. 2020) and climate change competence framework (Taurinen et. al. In review). The education material will cover basics on the drivers and impacts of climate change and measures for sustainability and provide examples of how a teacher can implement it in school teaching.

CLIMADEMY teachers from Greece, Germany, Italy as well as Finland were invited to participate in this years Teachers' Climate Change Forum (TCCF). Teachers participated also in planning of the programme and held workshops on their own teaching experiences. The conference has been organized since 2017 and deals with climate science, climate education and the connection between these two domains. Participants were given the opportunity to self-study Climate.now - course material before the conference. This year TCCF was held 2.-3. October as a hybrid event where mornings with keynote lectures and discussions were available also for remote participants and afternoons concentrated on onsite workshops.

CONCLUSIONS

CLIMADEMY strengthens the science education activities in Hyytiälä. The newly launched science education hub gives hands-on training and provides an excellent possibility for teachers to see research work in action and how scientific measurements are done at a field station. Its location within forests allows for many kinds of field exercises and tours. Location in central Finland makes it reachable from many directions.

ACKNOWLEDGEMENTS

This work was supported by the Erasmus+ Teachers' Academies project CLIMADEMY (grant agreement no. 101056066) and Metsämiesten Säätiö.

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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 (Peräkylä et al., 2020). The results provided by the algorithm were compared against the results of the previously conducted thorough manual analysis.

CONCLUSIONS

Comparison between algorithm and manual results for the real data 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 may not be good enough to

completely replace manual analysis, but are certainly good enough to provide an excellent starting point for manual correction of algorithm results. 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.

ACKNOWLEDGEMENTS

This work was supported by funding from Academy of Finland, grants 317380 and 320094, and Svenska kulturfonden, grant 190437.

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IMAGING SPECTROSCOPY OF PHOTOSYNTHETIC SPRING RECOVERY

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Keywords: hyperspectral imaging, spring recovery, photochemical reflectance index, red edge position

INTRODUCTION

Finland's forested regions, covering approximately 75% of its land area, store a vast quantity of carbon. The future effectiveness of boreal forests' ability to absorb and store carbon is uncertain due to the impacts of climate change, such as warmer winters and droughts. These impacts modulate photosynthetic phenology, or the seasonal pattern of carbon uptake, which is measurable remotely using optical techniques such as sun-induced fluorescence (SIF) (Nichol et al., 2019) or carotenoid-induced reflectance changes picked up by the photochemical reflectance index (PRI). Until recently such data was obtained using satellite observations, sometimes validated with non-imaging devices mounted on tower infrastructure (Nichol et al., 2019) and occasionally measured with high-cost airborne platforms. These measurements typically obscured the contribution of individual trees due to the low spatial or temporal resolutions (Kellner et al., 2019). Hence disentangling the biological signal from background noise (e.g., angular effects, non-tree signal, instrumental errors) was a challenge. Recent technologies like drones, affordable compact hyperspectral imaging (HSI) systems, and machine learning have significantly improved our ability to combine information across different spatial and spectral scales and retrieve the signal from the object of interest, individual trees. That's why the primary goal of this work is to use these new technologies to track the photosynthetic phenology of individual trees. We first demonstrate that imaging spectroscopy can be used to follow carotenoid induced changes in reflectance over winter in a greenhouse experiment, and that these results have an individualistic component and are comparable to a reference (non-imaging) spectrometer. Next, we will upscale our measurements using a drone platform targeted at the flux footprint of SMEARII. These measurements are currently ongoing and will extend into 2024.

METHODS

Greenhouse experiment: Five *Pinus sylvestris* saplings were stored above freezing temperatures in greenhouse conditions over winter, while five were stored outside. The photosynthetic recovery of these saplings was monitored during spring and summer 2023 using HSI. Imaging results were validated by collecting non-imaging spectral data with an ASD FieldSpec instrument, and by collecting pigment samples, which will be used to determine chlorophyll and total carotenoid content using a spectrophotometric approach. Individual shoots and new buds will be segmented from hyperspectral images so that development of segments and their contribution to plant-wide signal can be monitored. Analysis will mostly be concerned with PRI to track carotenoids and red edge position (REP) to track chlorophyll content.

Drone measurements: The photosynthetic phenology of in situ trees located in the flux footprint of SMEAR II are monitored using a hyperspectral and a multispectral drone. Imaging will be accompanied by drone-based

point SIF measurements. Two imaging datasets have been collected as of October 2023. Measurements will continue for the full 2024 season.

RESULTS AND CONCLUSIONS

From the greenhouse experiment we found that the HSI technology can adequately capture the spring photosynthetic phenology of individuals relative to reference instrumentation (Fig. 1A). Although the temporal pattern between sensors is similar, the dashed line shows smaller dispersion in HSI values due to out-masking of non-vegetative pixels. The potential of image segmentation is further illustrated in Fig. 1B. From the drone data we conclude that we can successfully capture hyperspectral and multispectral data in the flux footprint area of SMEARII (Fig. 1C).

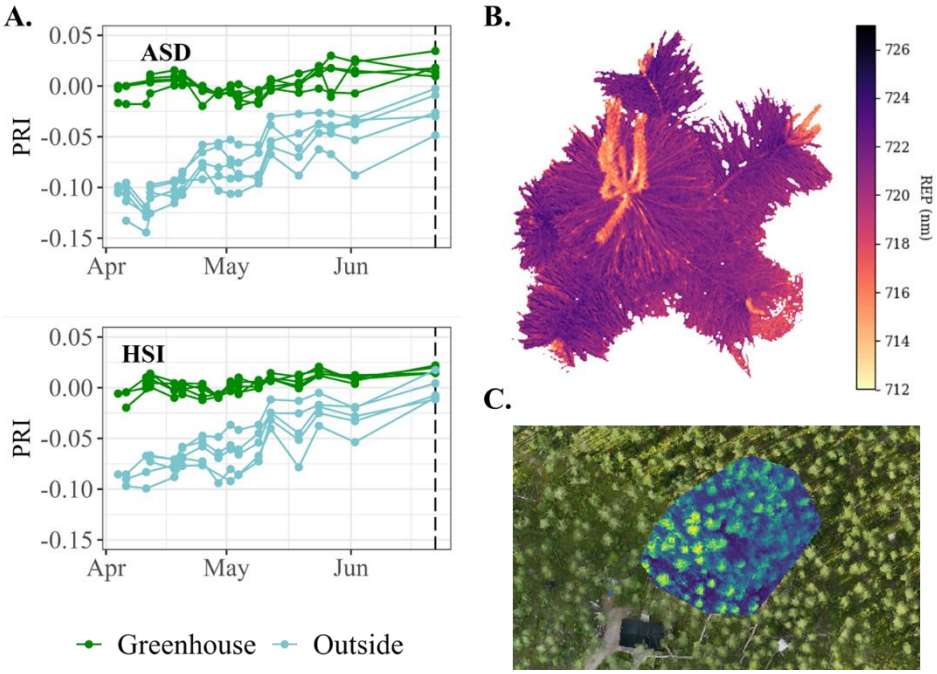

Figure 1. (A) Spring recovery of PRI signal as detected by the ASD reference spectrometer (above) and HSI camera (below). (B) REP value image of a greenhouse treatment sapling during bud break. (C) An RGB orthophoto with overlayed subset reflectance at 740 nm in the SMEAR II flux footprint measured using HSI camera.

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Feasibility study of CO2 satellite retrievals over snow for supporting the upcoming Copernicus anthropogenic CO2 monitoring mission

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Keywords: carbon dioxide, satellite remote sensing, snow, surface reflectance.

Space-based observations of greenhouse gases (GHG) are currently revolutionizing carbon cycle science and our ability to globally monitor anthropogenic GHG emissions. With the European fleet of upcoming high-priority Copernicus satellites named Anthropogenic CO2 Monitoring Mission (CO2M), satellite observations will soon contribute to the Monitoring and Verification Support system that supports the goals of the Paris Agreement by verifying national emission reductions. This means that GHG satellite observations will directly contribute to carbon policymaking already in this decade – a significant and demanding responsibility for the entire scientific field.

High latitudes pose significant challenges to reliable space-based observations of greenhouse gases. In addition to large solar zenith angles and frequent cloud coverage in the high latitude regions, snow-covered surfaces absorb strongly in the near-infrared wavelengths. Because of the resulting low radiances of the reflection measured by the satellite in nadir geometry, the retrievals over snow may be less reliable and are typically filtered or flagged for potentially poor quality.

This feasibility study demonstrates that more sophisticated modeling of snow surface reflectivity and non-traditional observation modality boosts satellite-based observability of CO2 over snow surfaces especially in the Spring months. These results aid in the developing the retrieval algorithms and mission operational planning of CO2M, but existing CO2 observing satellite missions, such as NASA's Orbiting Carbon Observatory-2, can also benefit from these results in reprocessing their observational history.

SENSITIVITY STUDY OF VOLATILITY BASIS SET IN ECHAM-SALSA

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Keywords: SECONDARY ORGANIC AEROSOL, VOLATILITY BASIS SET, GLOBAL MODELLING, SEMI-VOLATILE ORGANICS, AEROSOL-CLOUD INTERACTIONS.

INTRODUCTION

Secondary organic aerosol (SOA) is formed in the atmosphere by the oxidation of volatile organic compounds (VOCs) and the subsequent condensation of the oxidation products. SOA plays a critical role in the Earth's system, mainly by influencing the radiative balance. Despite considerable progress in understanding the SOA formation mechanisms and properties, their representation in current climate models remain inadequately defined. This arises primarily from the complex nature of SOA formation, which involves diverse VOCs with varied oxidation processes (Donahue et al., 2012). While oxidation of VOCs form compounds with a broad range of volatilities, the exact volatilities of these compounds remain uncertain. This uncertainty hinders our efforts to better understand the mechanisms and properties of SOA formation and their climatic impacts.
In this study, we investigated the sensitivity of simulated cloud condensation nuclei (CCN) and SOA mass concentrations in the boreal region to the volatility distribution of SOA precursor species. We employed the volatility basis set (VBS) approach within the global aerosol-climate model ECHAM-SALSA. We also compared different level of detail for describing the volatility distribution to model monoterpene oxidation products by comparing a finely resolved 9-bin VBS setup with a simplified 3-bin VBS setup. The 9-bin VBS setup groups the organic compounds into 9 volatility bins while the 3-bin VBS setup groups them into 3 volatility bins. Furthermore, we analyzed how the simulated CCN, SOA mass and radiative properties are sensitive to volatility assumptions.

METHODS

To improve our understanding on atmospheric SOA and its climatic effects, a finely resolved 9-bin VBS setup was implemented to the global aerosol-climate model ECHAM-SALSA (Kokkola et al., 2018). Through a series of sensitivity simulations, we investigated how the SOA mass and CCN concentrations are affected if the volatilities of monoterpene oxidation products are shifted by one order of magnitude. For the simulations of VBSx10 and VBSx0.1, the volatilities were increased and decreased by one order of magnitude, respectively, compared to the base case VBS (VBSx1). Note that this shifting of VBS volatilities was applied only to monoterpene oxidation products while the volatilities of all other SOA constituents were kept unchanged. The study was also expanded to compare the 9-bin VBS setup with a simplified and computationally less expensive 3-bin VBS setup. The sensitivity of the simulated SOA mass and CCN concentrations

to the volatility of individual volatility bins were studied using the 3-bin VSB setup by shifting the volatility of one bin at a time while the volatilities of other bins remain unchanged. To understand the impact of different assumed volatility distributions on the simulated Earth's radiation balance, we calculated the shortwave Effective Radiative Forcing (ERF) and Instantaneous Radiative Forcing due to aerosol-radiation interactions (IRF_{ari}).

CONCLUSIONS

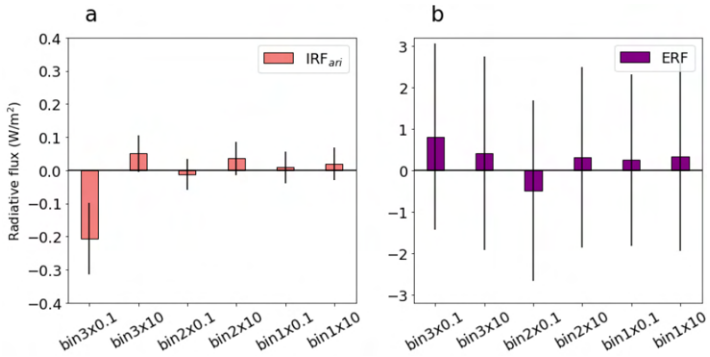

Figure 1: Summer Mean **(a)** IRF_{ari}, **(b)** ERF for the shift in volatility of individual volatility bins with respect to the base volatility using the 3-bin VBS setup analysed over the boreal region.

As expected, the increase in SOA volatility leads to a smaller SOA mass burden while the decrease in the volatility leads to larger SOA burden. Interestingly, the change in particle number concentrations seem to be very small for both the volatility shifting cases as compared to the base case. Therefore, shifting volatilities lead to a smaller relative change in CCN concentrations. Average change for tropospheric N100 (concentration of particles with diameter $>$ 100nm) is found to be -3% for VBSx10 and +2% for VBSx0.1 simulations with respect to the base case. The comparison between 9-bin VBS setup and 3-bin VBS setup revealed that the 3-bin VBS setup led to approximately 25% higher N100 than the 9-bin VBS setup. The analysis also indicated that N100, SOA mass burden, and the radiative effects of SOA (see Figure 1) were more sensitive to the uncertainties associated with the volatility of semi-volatile bins than the low-volatile bins. The simulated IRF_{ari} is sensitive to uncertainties in volatility in the 9-bin VBS setup while, the ERF is sensitive only when the 3-bin VBS setup is used. This underscores the importance of better defining the volatility of semi-volatile compounds in global models in order to accurately capture the aerosol properties and their impacts on climate.

ACKNOWLEDGEMENTS

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CORRECTING MEASUREMENTS OF EXHAUST PARTICLE SIZE DISTRIBUTIONS DISTORTED BY COAGULATION IN SAMPLING LINES

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Keywords: coagulation, particle size distribution, uncertainty quantification, exhaust emissions.

INTRODUCTION

Particulate matter (PM), i.e., particle pollution, poses great health risks to humans and causes environmental damage. Significant PM sources, such as vehicle tailpipe emissions, are therefore in most cases subject to particle mass regulations but nowadays also usually to particle number regulations. There are, however, aspects of measuring such emissions that are rarely accounted for, but that may affect the result considerably. In a direct raw exhaust particle size distribution (PSD) measurement, the measurement devices are attached to the exhaust pipe via a sampling system and the PSD of the sample that has travelled through the system is then measured. However, usually diffusional losses and in some cases also coagulation inside the sampling system can significantly alter the measured PSD. Whereas diffusional losses are commonly corrected, the effect of coagulation is typically not due to its complexity.

METHODS

In this work, we model coagulation and wall diffusion for a laminar tube flow and, based on a PSD measurement at the end of the tube, estimate the emitted PSD (i.e., in the beginning of the tube) using Bayesian inversion. We therefore acknowledge that due to uncertainties related to the measurement (e.g., noise) and to the coagulation model, the resulting estimate is also uncertain to some degree, quantified by the posterior probability (Kaipio and Somersalo, 2006). Using Bayesian inversion allows us to not only compute the most probable values of the emitted PSD, but also to explicitly quantify the uncertainty related to it.

We model coagulation with the discrete coagulation equation (Seinfeld and Pandis, 2016). In the coagulation kernel, we include effects of van der Waals and viscous forces (Alam, 1987), as well as model the fractal nature of soot particles (Rogak and Flagan, 1992). This increases the coagulation rate significantly compared to just Brownian motion of spherical particles. We carry out inversion with both synthetic data and real emission measurements of a fuel-operated auxiliary heater (Oikarinen et al., 2022). Measurements are done with the Engine Exhaust Particle Sizer™(EEPS), which measures currents induced by charged particles impacting on electrodes. We use these currents as measurement data for the inversion.

RESULTS

Figure 1 shows an example inversion result for a measurement from Oikarinen et al. (2022). The sampling line was 3 meters long with a residence time of 0.9 seconds. The figure shows the MAP, or *maximum a posteriori*, estimate which is the most probable value for the PSD, and an uncertainty

estimate for the PSD as a shaded region around the MAP estimate. The uncertainty estimate shown here corresponds to ±1 posterior standard deviation. To see the effect of the sampling line, we have plotted both the result where the sampling line is modelled and where it is omitted. As can be seen, processes in the sampling line shift the PSD towards larger particles, and omitting coagulation and diffusion effects in this case underestimates the number of particles below 50 nm, by up to more than an order of magnitude. Results like these can be expected for cases where the initial number concentration is high, but for measurements with a lower initial number concentration coagulation effects in the same residence time will naturally be less pronounced.

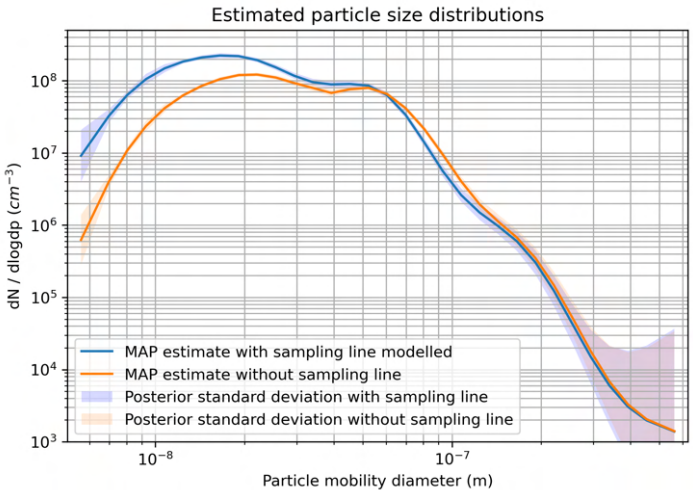

Figure 1: Inversion results for the PSD without modelling the sampling line (orange), and with the sampling line modelled (blue).

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THE EFFECT OF PHOTO-OXIDATION ON THE VOLATILITY OF LEVOGLUCOSAN IN BIOMASS BURNING AEROSOL

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Keywords: AEROSOLS, ATMOSPHERE, MASS SPECTROMETRY

INTRODUCTION

Due to climate change, both the length of fire seasons and the frequency of wildfires have been increasing lately (Jolly et al. 2015), which makes wildfires an important emission source. It has also been suggested that smoke from wildfires is more harmful to respiratory system compared to other particulate matter (Aguilera et al. 2021). The biomass burning emissions are often identified by using tracers (compounds that are known to be emitted from burning). One biomass burning tracer is levoglucosan ($C_6H_{10}O_6$), which is a sugar, that is formed in the combustion of cellulose, and is therefore practically always produced in biomass burning. In addition, atmospheric levoglucosan is not typically created by other processes, and very few isomers of $C_6H_{10}O_5$ are typically present. These circumstances make it a well-suited tracer for biomass burning.

METHODS

Our research group participated in the boreal and savannah fire aerosol ageing (BASFAA) campaign in the ILMARI environmental chamber at the University of Eastern Finland (UEF) during summer 2022. Three actual biomass types (savannah, grass and boreal) were burned during the campaign, and fed into the chamber, where the sample was going through OH ageing (exposure to UV lights, OH radicals and ozone), and dark ageing (exposure only to ozone) to study the difference between these two ageing types. The volatility of the burning emissions was investigated with chemical-ionization mass spectrometer (CIMS), coupled to a filter inlet for gases and aerosols (FIGAERO) (Lopez-Hilfiker et al. 2014). In FIGAERO, aerosol sample is collected on a PTFE filter, and evaporated by heated nitrogen flow. The aerosol constituents are then detected by the CIMS, using iodide adduct ionization, allowing for quantification (via detected ion signal intensity) and molecular identification (via measured ion masses). The signal plotted against the filter temperature is called a thermogram. Temperature where the signal reaches its maximum is called T_{max}, and that is often used to define the volatility of a compound as saturation vapor pressure (Ylisirniö et al. 2021).

RESULTS

During the BASFAA campaign levoglucosan was found to be a major constituent of the organic aerosol. The intensity of the levoglucosan signal was decreasing during the aging, regardless of the aging and biomass type, which was expected due to wall losses (and exposure to OH). However, also the volatility of levoglucosan was decreasing when it was exposed to OH (see Fi 1). Similar behavior was also observed for some other compounds during OH aging. During dark aging, the volatility of all studied compounds remained the same. After the campaign, laboratory experiments were performed to investigate, if the observed change in volatility was due to mixing with some other

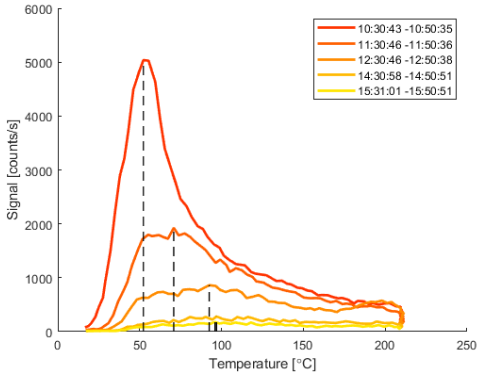

Figure 1: Evolution of the $C_6H_{10}O_5$ thermograms during one experiment day, savannah biomass and OH aging.

compounds, or reaction with OH or UV light, or combination of these two. In the experiments, pure levoglucosan was introduced to oxidation flow reactor (OFR) and conditions inside were varied. Based on these experiments, even pure levoglucosan goes through similar changes when exposed to OH and UV light, suggesting that the volatility change can not be explained at least entirely by mixing effects. Further experiments are planned to investigate the underlying mechanisms, exploring a wider range of conditions in the OFR, as well as aerosol mixtures. We will also use inverse desorption modeling to constrain the involved thermodynamics (Schobesberger et al. 2018).

ACKNOWLEDGEMENTS

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PARTICLE EMISSIONS FROM ENGINES AND AUXILIARY HEATERS OF PASSENGER CARS

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Keywords: Exhaust emissions, Auxiliary heaters, Passenger cars, Emission factors.

INTRODUCTION

Vehicle emissions are a major source of particulate matter exposure especially in urban areas. Particulate emissions pose significant health risk due respiratory and cardiovascular stress and have environmentally adverse effects. Direct tailpipe emissions are well researched and regulated, but less attention has been paid to auxiliary heater emissions. Fuel-operated auxiliary heaters (AHs) are frequent solutions to heat the vehicle engines and cabins in cold areas. Particulate exhaust emissions of AHs are unregulated and unevaluated; therefore, their contribution to local air quality and thus human health and even the global emissions budget is unknown. Prior research on AH emission has been rare (Karjalainen 2021, Oikarinen 2022).

METHODS

In this work we have determined primary and secondary particulate emissions from 6 passenger cars and 3 auxiliary heaters in indoor laboratory conditions. Measured passenger vehicles included both diesel- and petrol-powered cars. Furthermore, single PHEV petrol hybrid car and CNG petrol hybrid car were also measured. Engine emissions were determined with dynamometer for 50 km/h and 100 km/h driving and AH emissions were determined for 20 min preheating cycle. Measurement setup also included smog chamber for aging collected aerosol sample for period of 4 hours to determine SOA formation potential.

RESULTS

We present quantitative results of particle number emissions down to 1.3 nm, particulate mass, black carbon. AH emissions were compared against measurements from outdoor winter conditions for vehicles present in both measurement campaigns to compare effect of operation temperature to emission factors (table 1).

Table 1. Comparison between PN, PM and eBC emission factors from outdoor winter measurements and laboratory measurements.

	Petrol vehicle		**Diesel vehicle**	
Conditions	Winter	Laboratory	Winter	Laboratory
PN (10^{12}/30 min)	89	210	15	7.5
PM (mg/30 min)	1.9	0.12	0.28	0.13
eBC (mg/30 min)	1.5	3	0.087	0

Secondary organic aerosol (SOA) formation during Aging process of collected exhaust sample in smog chamber was measured with two SMPS size ranges between 3-400 nm. Particle size distributions are presented (figure 1). When effect of SOA formation to particle mass is accounted for over 90 % total mass is secondary for gasoline AHs and over 66 % for diesel vehicles.

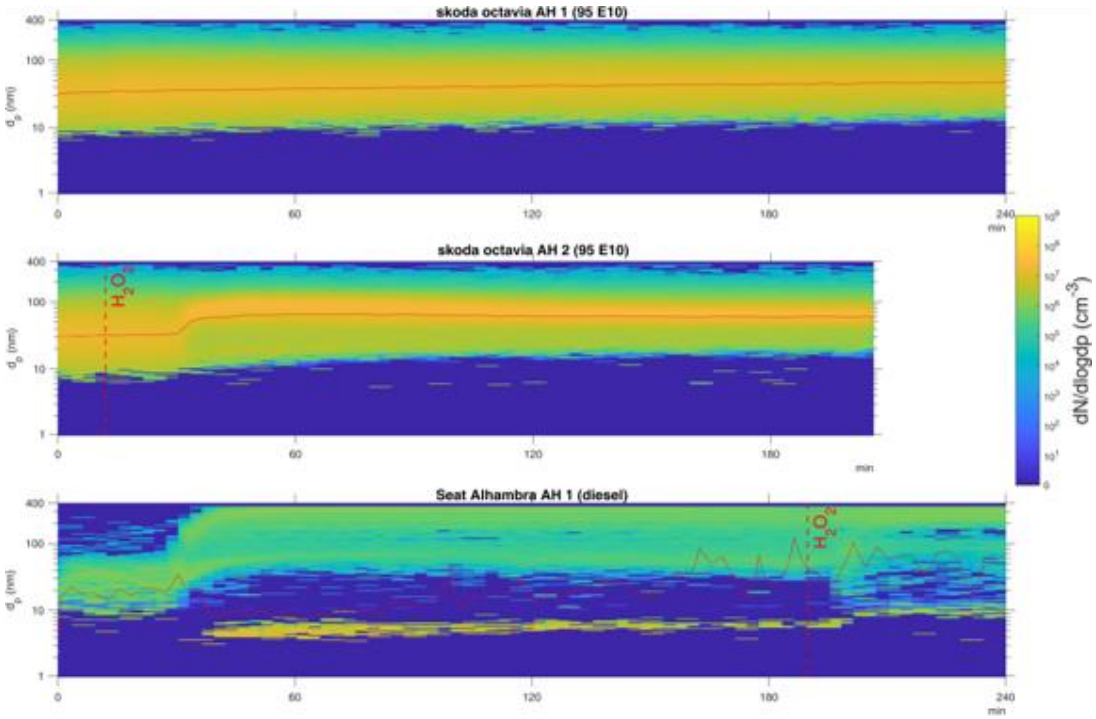

Figure 1. Size distributions of AH emissions collected to ILMARI chamber during ageing process. H_2O_2 injection time is marked. Geometric mean diameter of the size distribution is presented by red line

CONCLUSIONS

Based on comparison between outdoor winter measurements and laboratory measurements, AH emissions are more accurately measured in cold outdoor temperatures, due to effects of operating temperature. Secondary particle formation should be accounted for when determining AH emissions to more accurately reflect effects of AH emissions to air quality and environment.

ACKNOWLEDGEMENTS

This research was funded by the Jane and Aatos Erkko's Foundation, the Academy of Finland (Grant no. 322120, 325022, 337550 and 337551) and Kone foundation.

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NEW PARTICLE FORMATION IN COASTAL SOUTHERN FINLAND: A COMPARISON STUDY BETWEEN AN URBAN AND A RURAL ENVIRONMENT

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Keywords: new particle formation, urban environment, rural environment, air masses.

INTRODUCTION

New particle formation (NPF) contributes around 40 to 80 % of the total particle number concentration in the atmosphere (Dunne et al., 2016; Kulmala et al., 2016). Due to this, NPF affects climate via aerosol–cloud interactions and air quality. When atmospheric NPF is followed by the subsequent growth of particles, we call this phenomenon an NPF event (NPFE). NPFEs can simultaneously take place over areas of minimum tens of kilometers in radius (regional events), or have a more local footprint (Dada et al., 2023). The aim of this work is to analyze and compare NPFEs in Qvidja and Helsinki, representing rural and urban environments, respectively. Both stations are in a coastal area of Finland within 140 km from each other. Through comparison of NPFEs in Qvidja and Helsinki, we try to identify, separate, and investigate regional events, the coastal influence, and the impact of local emissions.

METHODS

We measured particle number size distribution with a neutral cluster and air ion spectrometer (NAIS) (Mirme & Mirme, 2013) and a differential mobility particle sizer (DMPS) (e.g., Wiedensohler et al., 2012) from 2019-2021 at two locations in southern Finland: Qvidja and Helsinki. Qvidja (60°17'42.6"N 22°23'32.2"E) represents a rural and coastal environment and is located in southwestern Finland, 25 km southeast of the closest city, Turku. The surrounding of the station contains cultivated grassland, horse pastures, small-scale crop production, and a forest (Heimsch et al., 2021; Lan et al., 2021). The Station for Measuring Ecosystem-Atmosphere Relations (SMEAR III, 60°12'10.4" N, 24°57'40.2" E) (Järvi et al., 2009) is located in the coastal city of Helsinki, approximately 140 km west of Qvidja. SMEAR III is classified as an urban background station. The surrounding of the station contains buildings, parking lots, low vegetation, and a deciduous forest (Järvi et al., 2009). The forest separates the measurement site from the closest busy road (Hämeentie).

To study NPFEs in these locations, we introduced a custom-made classification of NPFEs containing three main classes of events: *NPFE complete*, *NPFE no fresh particles*, and *NPFE no growth*. *NPFE complete* contains events in which a new mode appears in sub-5 nm range and continuous growth of this mode is observed for at least 2 hours. During *NPFE no fresh particles*, a new mode appears in particles larger than 5 nm and a continuous growth of this mode is observed for at least 2 hours. During *NPFE no growth* a new mode appears in the sub-3 nm range, and it is observed for at least half an hour in Qvidja or an hour in Helsinki, but it does not grow, or the growth is unclear. The appearance of a new mode simultaneously in particles smaller than 5 nm and larger than 25 nm is classified as *uncertain*, because this particle range corresponds to traffic emissions from an exhaust line (Rönkkö & Timonen, 2019). Additionally, situations in which the appearance of a new mode is ambiguous or events which do not persist for the times defined above, are added to class *uncertain*. It is worth noting that in contrast to traditional event classifications (e.g. Dal Maso et al., 2005), we do not classify event days but times during which a NPFE is taking place, thus more than one event can be observed during a day. Furthermore, we analysed the air mass history of classified events with Lagrangian particle dispersion model FLEXPART version 10.04 (Pisso et al., 2019).

PRELIMINARY RESULTS

We found 352 NPF events in Qvida and 469 in Helsinki (Table 1) from 2019-2021. The largest difference was observed in the *NPFE no growth* event - the class containing the most localized NPF events. In Helsinki, a significantly higher number of these events were counted compared to Qvidja, which may suggest that our classification method may not fully separate the traffic emissions from locally formed particles.

Table 1. Number of events classified in Qvidja and Helsinki during 2019-2021

	NPFE complete	NPFE no fresh particles	NPFE no growth	Total
Qvidja	104	83	165	352
Helsinki	90	100	279	469

In order to understand what drives the growth of locally formed particles during NPFE in Qvidja, we analysed the mean air mass residence time during clustering time (elevated concentrations of sub-5 nm particles) of *NPFE complete* and *NPFE no growth* occuring in Qvidja at noon (Fig. 1). Our result suggests that the growth of particles is observed when the air masses come from north to east -sector thus travelling over the land. In contrast, when the air masses come from the northwest and interact only briefly with the land before arriving at the measurement station, the formation of new particles takes place but their subsequent growth is not observed. This suggests that the NPFE event area is limited by the coastline, i.e. the NPFE occurs widely over the land area, but not over the Gulf of Bothnia. Next, we will further analyse events in Qvidja and Helsinki as well as compare them.

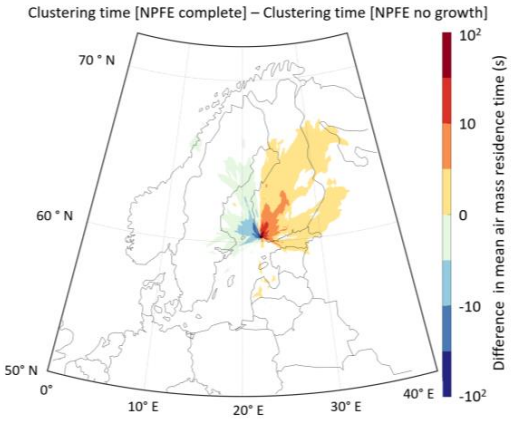

Figure 1. Difference in the mean air mass residence time between clustering time of *NPFE class 1* and *NPFE no growth* occuring at noon (9:00-12:00 local time) in Qvidja.

ACKNOWLEDGEMENTS

This research was supported by the Academy of Finland (ACCC flagship grant no. 337549, 337552, 337551), European Commission via Horizon Europe project "Non-CO2 Forcers and their Climate, Weather, Air Quality and Health Impacts, FOCI" (101056783), and European Union Horizon 2020 research and innovation programme (grant no. 821205, FORCeS). We thank Pasi Aalto for carrying out the DMPS measurement at SMEAR III.

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ASSESSING THE ROLE OF INDIRECT ANTHROPOGENIC LAND SINK AND NON-CO_2 GREENHOUSE GASES IN THE CARBON NEUTRALITY PATHWAY OF FINLAND

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Keywords: LULUCF, Carbon neutrality, non-CO_2 greenhouse gases, indirect effects.

INTRODUCTION

Finland has set a legally binding goal of achieving "carbon neutrality" by 2035 and net-negative greenhouse gas emissions thereafter. The scientific background for this goal is based on an interpretation of what a nationally fair share of global carbon budget compatible with 1.5 °C warming is (Ollikainen et al., 2019). This national carbon budget includes also non-CO_2 greenhouse gas (GHG) emissions. On one hand it, is thus stricter than the original, global CO_2-only, carbon budget. On the other hand, non-CO_2 GHGs were made CO_2-equivalent using Global Warming Potentials with a time horizon of 100 years (GWP100), which underestimates especially methane's warming effect in the next decades. Finland's pathway to carbon neutrality relies not only on emission reductions but also on carbon sinks in the land use, land-use change and forestry (LULUCF) sector. The net sink in the LULUCF sector, as estimated in the national greenhouse gas inventory, is interpreted as negative emissions. This assumption is problematic, as part of the LULUCF sink is considered natural sink in the conceptual framework behind the global carbon budget estimates and assuming it entirely anthropogenic leads to underestimation of the net CO_2 emissions (Grassi et al., 2021). These so-called indirect effects that are caused by climate change and elevated CO_2 concentration, and not directly caused by direct forest management actions in each country.

Here we present an analysis and revision of the Finnish net greenhouse gas emission pathway with two major improvements. First, we extend the carbon budget framework to nationally allowed warming to be able to account explicitly also for national non-CO_2 GHG emissions. Second, we consider the recent advancements in disentangling natural and anthropogenic carbon fluxes in the LULUCF sector (Grassi et al., 2021, 2023).

METHODS

To evaluate the effect of non-CO_2 GHGs and indirect effects, we designed three methods to calculate emission (all GHGs) and carbon (CO_2-only) budgets, and schematic emission pathways resulting from them. The reference method was designed to follow the principles of earlier reports by the Finnish Climate Change Panel regarding using only GWP100-based CO_2-equivalent emissions and assuming all LULUCF sink as anthropogenic. Then, we designed two methods that calculate the warming effects of non-CO_2 GHGs

explicitly using a simple climate model FaIR 2.1 (Leach et al., 2021) and considering the indirect effects in the LULUCF sector either by 1) adjusting the global carbon budget or 2) adjusting the national LULUCF sink. We calculate emission and carbon budgets by evaluating 1,000,000 realizations based on random draws on probability distributions covering non-CO_2 GHG warming impacts, transient response to cumulative CO_2 emissions, global aerosol effects, and national and global indirect effects.

RESULTS

The emission and carbon budgets with the reference method was 118 Mt CO_2-eq and -200 Mt CO_2, respectively. Explicit calculation of the warming effect of non-CO_2 GHGs yielded 603 Mt CO_2-eq while the reference method had only 318 Mt CO_2-eq using GWP100. Indirect effects in Finland for the years 2020–2050 were -438 Mt CO_2, which consists of about 60% of the assumed -23.7 Mt CO_2 yr^{-1} annual LULUCF sink for the same years. If the global carbon budget was adjusted for the indirect effects, the reduction in Finland's carbon budget was only 31 Mt CO_2.

CONCLUSIONS

The results indicate that Finland's currently planned pathway is not compatible with its national fair share of allowed warming compatible with the 1.5-degree target, and more stringent emission reductions coupled with strengthening of the land sink and other forms of negative emissions are very likely needed. Also, more focus should be placed on mitigation of individual GHGs instead of monitoring only the CO_2-equivalent emissions. Further work is needed to develop new self-consistent mitigation pathways, but these results can offer a starting point and framework for such analysis.

ACKNOWLEDGEMENTS

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Exploring Nitrogen Cycling in the Forest: Insights from the Boreal Spruce Phyllosphere

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Nitrous oxide (N_2O) is a strong greenhouse gas (GHG). The sink strength of N2O consuming activity can important for the for climate change mitigation in the warming climate. Currently, in the climate change assessment and GHG flux models, are lacking information on microbiological mechanisms consuming atmospheric N_2O within above-ground vegetation. Therefore in the present study we investigated the activity of the N_2O consumption in above-ground processes. We have collected phyllospheric samples from spruce upland forest in Finland from Viikki, Kuopio and Pallas. Activity of N2O dynamics in small microcosm experiment will be discussed. However, there was variation in the samples collected closely to the city environments or from the pristine environment. Optimization of microbial DNA extraction protocol for plant samples were evaluated with captured metagenomics on nitrogen cycling genes. Bioinformatics analysis was done to identify the abundance of functional genes involved in the process in phyllospheric samples. Functional gene diversity analysis indicated abundance of nitrogen cycling genes in all the samples. There was variation in the clade distribution among nitrous oxide reductase gene *nosZ*. Bacterial genera *Bradyrhizobium, Acidovorax, Thauera*, *Azoarcus*, *Rubrivivax, Leptothrix* were observed. Abundance of genes on nitrogen fixation and denitrification activities by microbes in the phyllospheric samples. Therefore, our finding indicates the importance of microbial interactions in above-ground systems on nitrogen metabolism.

NEW EDUCATION FOR WORKING LIFE: SPECIALISATION PROGRAMME IN CLIMATE EXPERTISE

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Keywords: Climate expertise, climate education, Climate University, continuous education.

INTRODUCTION

New competencies for climate expertise are needed to address climate change mitigation and adaptation needs across all domains of society (Bianchi et al. 2022). Role of atmospheric and Earth system sciences has traditionally been the education of natural sciences (Riuttanen et al., 2021) and no single education programme has responded to the multidisciplinary need of climate expert education in Finland.

In a recent study, a group of professionals working as climate experts in Finland were surveyed (Siponen et al., subm.) regarding their views on the essential competencies (knowledge, skills, and attitudes) that are needed for effective climate action. In response to these needs and the increasing demand for climate expertise across different sectors, a Specialisation programme in climate expertise has been established by the University of Helsinki. The primary objective of the programme is to empower professionals and leaders with the tools and insights necessary to drive systemic change towards a sustainable and climate-resilient future.

METHODS

The planning and preparation of the Specialisation programme in climate expertise has been coordinated by the Institute for Atmospheric and Earth System Research, University of Helsinki, and Finnish Meteorological Institute, together with the Climate University network and Climate Leadership Coalition. The developed course programme offers a comprehensive education encompassing the scientific foundations of climate change, its impacts on both ecosystems and human societies, relevant legislation, and strategies for adaptation and mitigation while the elective course palette offers complementary theoretical and applied studies and it is taught together with Universities and Applied Universities. Overall, the curriculum is divided into three content groups including knowledge base, legislation, and policies, as well as applications for mitigation and adaptation (Fig. 1).

The programme lasts for two years and integrates remote teaching, active learning methodologies, and collaborative peer-to-peer engagement, facilitating the development of critical skills such as analytical thinking, innovation, and effective problem-solving. Overall, the programme combines the scientific understanding of climate change with practical approaches to combat climate change, providing students with the knowledge and tools needed to address one of the most pressing global challenges of our time.

Figure 1. Contents of the Specialisation programme in climate expertise are divided into three categories: knowledge base (taught in Finnish by University of Helsinki), legislation and policies (taught in Finnish by University of Eastern Finland), and applications (courses offered by University of Helsinki, University of Oulu, LAB University of Applied Sciences, Haaga-Helia, Tampere University of Applied Sciences, Karelia University of Applied Sciences, and Vaasa University of Applied Sciences) with examples of each content matter provided in the text box below the main title.

RESULTS

Aside from education, the programme is designed to provide a platform for the students to form a climate network that will benefit them and their work in the future. Each student also prepares a final project that corresponds to the needs of climate expertise in their own field. Furthermore, the success of the program is studied through student surveys and questionaries, which serve as the groundwork for future pedagogical work on climate education. Eventually we hope that the program will serve the needs of all stakeholders involved with climate action.

CONCLUSIONS

The program is developed by a team of leading climate science experts in Finland, and it is purpose-built to address the needs of different stakeholders, spanning from non-governmental organizations to corporations. Its collective aim is to enhance climate expertise, and it promises to increase the understanding of climate-related issues among different stakeholders as well as serving as a platform for collaboration that will hopefully cultivate genuine opportunities for transformative action and sustainable change.

ACKNOWLEDGEMENTS

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LOCAL NEW PARTICLE FORMATION AT THE BALTIC SEA COAST

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Keywords: Aerosol formation, marine aerosols, coastal.

INTRODUCTION

Despite their importance for understanding global climate, marine aerosol measurements are scarce. Coastal regions are of special interest since they are often heavily impacted by human activities and highly productive. The Baltic Sea is a great example of these phenomena, as it has a long history of eutrophication and a coast with diverse habitat and species. Coastal measurements in the Baltic Sea Coast have already shown a high variability of greenhouse gas (GHG) emissions both seasonally and between habitat types (Roth et al 2022). In addition to emitting GHGs, coastal zones can influence climate by acting as a hotspot for new particle formation (NPF, McFiggans et al. 2004). Despite evidence of cyanobacterial blooms influencing NPF over the open Baltic Sea (Thakur et al. 2022), we still lack a holistic understanding of NPF and its potential climate impacts at the Baltic Sea coast. This is why the recently founded Centre for Coastal Ecosystem and Climate Change Research (CoastClim) has gathered expertise spanning from atmospheric sciences to marine biogeochemistry and ecology. As a part of this effort, we have established a new long-term atmospheric measurement site at Tvärminne Zoological Station. Here, we use the data from these measurements to explore local NPF at the site to explore whether the Baltic Sea coast can act as a hotspot for new particle formation and thus have climate impacts beyond GHG emissions.

METHODS

A new atmospheric measurement station was established at Tvärminne Zoological Station in 2022. The measurements consist of aerosol measurements spanning from 1 nm to 20 µm, meteorological data, gas measurements (CO, NO, NO_2, O_3, CO_2, CH_4, volatile organic compounds) as well as chemical composition of condensable species. In this work we focus on the Neutral Air cluster and Ion Spectrometer (NAIS) data which gives us the size distribution of 0.8-42 nm ions and 2-42 nm particles. This instrument has been widely used to detect new particle formation and recently Tuovinen et al. (2023) showed that limiting the used size range to negative 2.0-2.3 nm ions is a good indicator of NPF happening locally, meaning that this size range can be used to understand how local sources influence NPF. This is why we also focus on this size range to understand if the Baltic Sea coast is producing new aerosols.

RESULTS & CONCLUSIONS

Traditional NPF event analysis showed that the event frequency at Tvärminne is similar to that at the boreal forest site of Hyytiälä, located 235 km northeast of the station. Looking into air mass back trajectories showed that regional events are likely occurring over land since they require homogeneous conditions over several hundreds of kilometres to happen.

To better understand local cluster and aerosol formation, we then focused on ~2-2.5 nm ions to see if the coast can act as a cluster source. Comparing the median diurnal cycles of negative ions in different size

bins in coastal and continental air masses shows that the ion concentrations are higher in coastal air in all the size bins (Figure 1). This indicates that the Baltic Sea coast is a hotspot for cluster formation. The preliminary results also indicate that the formation of these ions is favoured by sunny and dry conditions, which is in line with many previous studies. Future research will use chemical composition of volatile organic compounds and condensable species to investigate which precursors are responsible for this cluster formation and how this connects to biological processes and the climate.

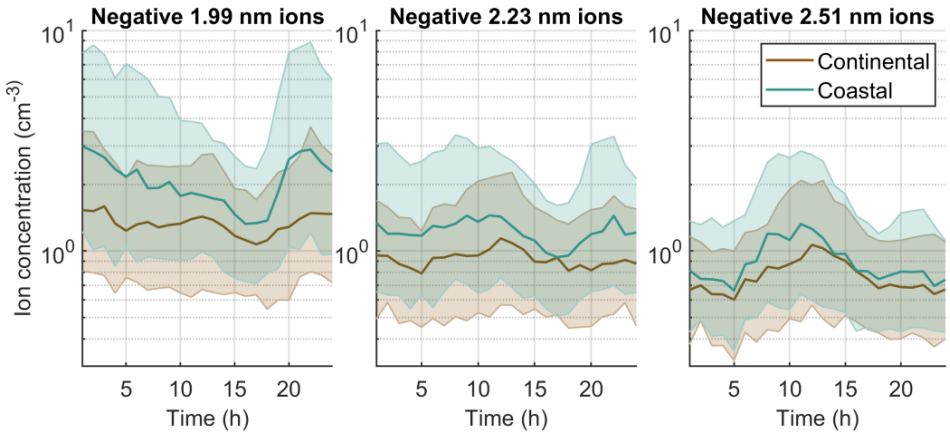

Figure 1. Diurnal cycles of negative ions in different size bins for coastal (100-240°) and continental wind sectors. The lines represent the medians and the shaded areas span the 25th-75th percentiles.

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LOW-TEMPERATURE ICE NUCLEATION ENHANCEMENT OF SAHARAN DUST TRANSPORTED TO FINLAND

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Keywords: AEROSOL-CLOUD INTERACTION, ICE NUCLEATION, SAHARAN DUST, IMMERSION FREEZING, AMMONIUM SULFATE.

INTRODUCTION

Mineral dust is one of the most abundant ice-nucleating particle types playing a major role in the glaciation of supercooled clouds. However, the ice nucleation (IN) ability of dust might change with long-range transport as atmospheric processing including coatings and mixing with organic and inorganic materials are likely to take place along the transport route. Coatings from organic VOC (e.g., α-pinene) can inhibit the IN ability of dust while biogenic material, containing IN-active proteins, has the potential to enhance the IN ability of dust, especially at temperatures warmer than -15°C. Inorganic salts can either deactivate (NaCl) or enhance ($(NH_4)_2SO_4$) the IN ability of dust (Whale *et al.*, 2018). Here, we evaluate the IN ability of long-range transported Saharan dust collected in Finland (Meinander *et al.*, 2022) in the temperature range relevant for mixed-phase cloud formation, and we compare it to dust transported over a shorter distance to Spain. We investigate the presence of organic material and explore the hypothesis that atmospheric processing with inorganic salt can explain the characteristic IN-spectrum of the long-range transported dust.

METHODS

We evaluate the immersion freezing efficiency of six Saharan dust samples collected in Southern Finland (F41, F80, F91, F101, F106, F115) and two collected in Spain (S1, S2), by performing drop-freezing assays with an Mk-1 droplet-freezing cold stage (Sikora Scientific Instrumentation). In the drop-freezing experiments, the temperature of the cold stage is lowered from 0°C to -30°C at a 1°C/min rate, and freezing events are detected with a high-resolution camera. To investigate the contribution of heat-sensitive, biological components to the IN ability, heat treatments at 100°C are applied to the samples. The effect of inorganic salts on the IN ability of the dust samples is tested through ammonium sulfate (AS) assays, adding the salt to obtain 0.015M concentration in the suspension. The sample-specific surface area A_{BET} was obtained from N_2 adsorption measurements for selected samples. Here, we present preliminary results showing the effect of the heat and AS treatments (experiment overview can be found in Table 1).

RESULTS AND CONCLUSIONS

All the Finnish samples exhibit similar freezing behavior (untreated and heat-treated). Exemplary results from samples F106 and F115 are shown in Figure 1 together with four parametrizations of the IN ability of dusts from the literature. None of the parametrizations describes the IN ability

of the untreated Finnish samples in the whole temperature range. After the heat treatment, the freezing spectra agree better with the temperature dependence of the K-feldspar parametrization.

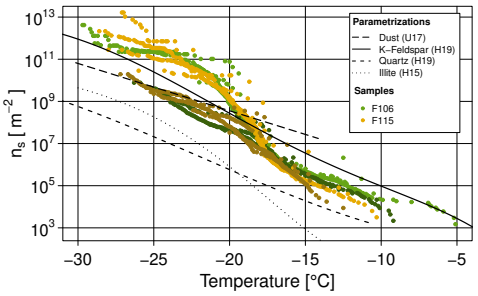
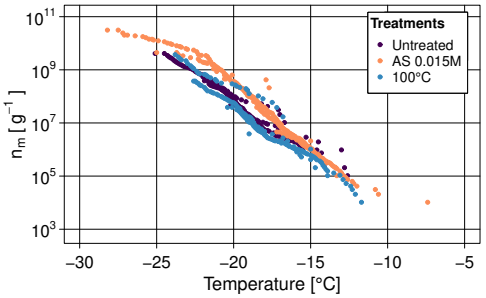


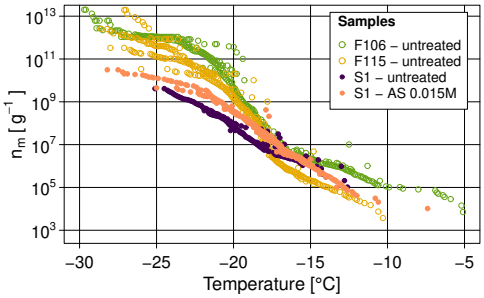
Figure 1: Active site density (n_s) for two Finnish samples. Untreated (light color) and heat-treated (darker color). Literature parametrizations for mineral dusts are shown as lines for comparison.

Sample label	Sampling location	IN pre-treatment	A_{BET} $[m^2 g^{-1}]$
F106	Vantaa (Finland)	UT, WH	4.79
F115	Klaukkala (Finland)	UT, WH	1.18
S1	Sevilla (Spain)	UT, WH AS, AS-WH	-

Table 1: Experiment and sample overview. UT: un-treated, WH: wet heat-treated, AS: 0.015M AS assay, AS-WH: heat-treatment after AS assay.



(a) Effect of AS and heat on sample S1.



(b) Sample comparison.

Figure 2: Effect of ammonium sulfate (AS) treatment on active site density (n_m).

No deactivation is observed for the Spanish sample S1 (Fig. 2a), inferring that the heat treatment does not alter the un-aged mineral. We suggest that the increase in IN activity below -18°C must be caused by atmospheric processing with AS during the long-range transport. The preliminary results from the AS assays indicate a slight increase in the IN activity of S1 after treatment (Fig. 2b), making its IN-spectrum resemble the one of the Finnish samples. Additional tests are to be performed to assess what AS concentration should be added to reproduce the low-temperature enhancement. DNA and proteinaceous content analysis will be carried out on the same subset of samples to identify components of biological origin.

ACKNOWLEDGEMENTS - Work supported by Academy of Finland Flagship ACCC (grant no. 337552) and MEDICEN project (grant no. 345125).

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SOIL REACTIVE EMISSIONS FROM BOREAL FORESTS

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Keywords: soil, boreal forest, emissions, volatile organic compounds (VOCs)

INTRODUCTION

Boreal forests represent about a third of the Earth's forested surface and form an almost continuous belt around the Northern hemisphere at high latitudes. Biogenic emissions of volatile organic compounds (VOCs) from tree species present in the boreal forest have been studied at the leaf and ecosystem levels. Monoterpenes, the most important class of biogenic VOCs in the boreal forest, emitted by the soil can contribute up to 10% of the total monoterpene emissions (Smolander *et al.*, 2014). However, other VOCs are known to be emitted by forest soils and sesquiterpenes, for instance, are emerging as an important class of reactive BVOCs emitted by forest soils (e.g., Bourtsoukidis *et al.*, 2018). In this study, we aim at linking biogenic VOC emissions from boreal forest soil to both site characteristics (e.g. tree species, nitrogen availability) as well as environmental conditions (soil temperature and water content, ambient air temperature and relative humidity, as well as photosynthetically active radiation).

METHODS

Sample collection was done at two forest sites from Luke's long-term and well documented experiments in Finland. The first site is in Karkkila (60.577°N, 24.261°E), a spruce dominated stand, where we collected soil emissions from a control plot and from a nitrogen-fertilization plot (180 kg N ha^{-1} every fifth year since 1988), each ca. 30 x 30 m in size. The second site is located in Taivalkoski (65.316°N, 28.161°E), where we have measured from three plots (ca. 40 x 40 m) with differing tree stands (silver birch, Scots pine, and Norway spruce, respectively). At both sites, three metallic frames (aluminium or stainless steel, ca. 60 x 60 x 20cm) were placed in the soil of each plot, about one month before the first sampling. Then, using Die Kohlenwasserstoff Probe I (DPKI; Aalto et al., 2019), we have sampled about once a month from each frame using an enclosure that fits onto the frame (ca. 20cm height; fluorinated ethylene propylene, FEP, spanned on a metal canvas). DKPI filters ambient air with an ozone scrubber and activated charcoal to remove oxidants and VOCs and direct the cleaned air in the enclosure at about 4.5 l min^{-1}. The enclosure is flushed for about 30 min first, after which DKPI allows for the simultaneous sampling with multi-bed adsorbent tubes (Tenax® TA and Carbopack™ B) of the ingoing cleaned air and the outgoing air containing the soil emissions for 30 min at ca. 200 ml min^{-1}. The collected samples were analysed in the laboratory with a thermal desorption gas chromatograph coupled to mass spectrometry (TD-GC-MS; e.g. Hellén *et al.* 2020).

RESULTS

Preliminary results indicate that soil emissions vary in quantity and in their composition. While for a given plot, emissions collected on the same day are relatively similar in their composition with varying quantities, the composition of the emissions changed with the season, reflecting a myriad of processes taking place. Besides monoterpenes, compounds such as methyl salicylate and trichloromethane were found to be emitted in comparable amounts.

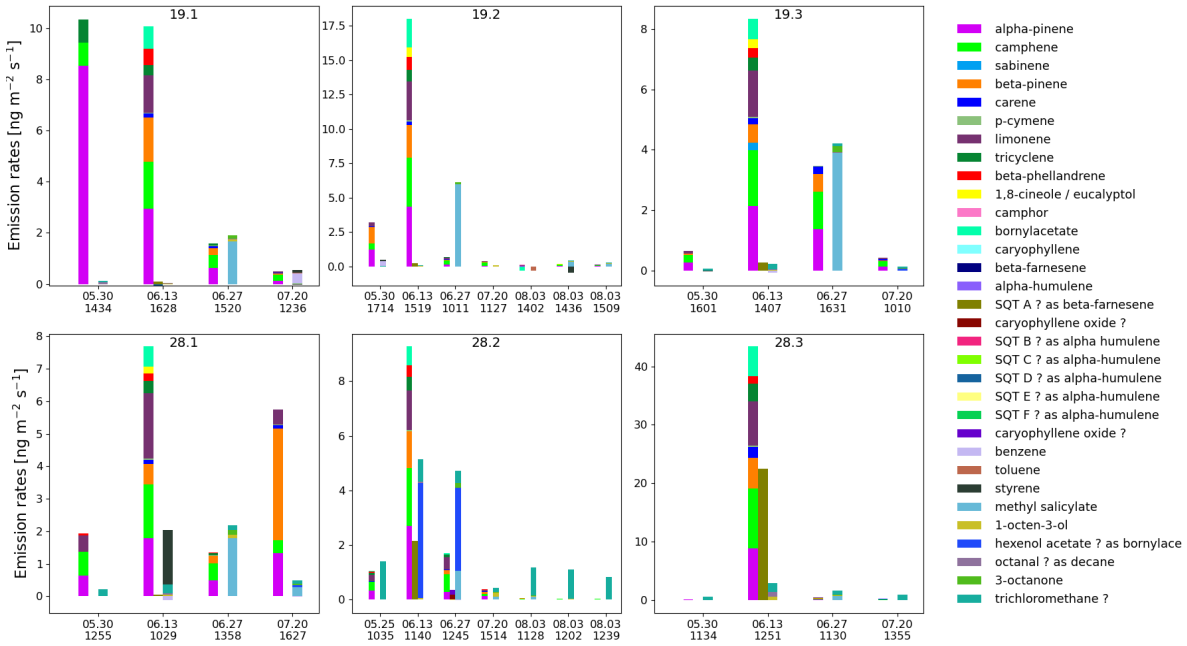

Figure 1. Emissions rates measured at the Karkkila site. The upper row are the frames for the control plot (19) and the lower row are the frames for the N-fertilized plot (28). For each measurement, three stacked bar plots are drawn: for monoterpenes, sesquiterpenes, and other VOCs. Note that the y-scale vary between each panel and that the high values in panel 28.3 are due to an extremely high temperature inside the enclosure. Some negative values results from zero air values higher than in the emissions. Labels on the x-axis indicate the date and time of sampling.

CONCLUSIONS AND OUTLOOK

While difference in soil emissions could be observed between the control and the N-fertilized plots in Karkkila and between the different plots in Taivalkoski, our results show also large differences for all frames according to the time of the year. Emission rates measured were generally higher in Karkkila, which is located in the Southern part of the country. Further analysis will establish links between emissions, site characteristics, and environmental conditions.

ACKNOWLEDGEMENTS

This work was supported by the Academy of Finland (grants no. 348013 and 348014).

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CHANGING PEATLAND ECOSYSTEMS: FIRST LOOK INTO AEROSOL FORMING POTENTIAL

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Keywords: Peatlands, SOA, Aerosol Yield, Ecosystem change.

INTRODUCTION

Atmospheric aerosols affect human health and climate (IPCC, 2013). Climate effects originate from how aerosols scatter and absorb solar radiation, act as cloud condensation nuclei (CCN), and regulate cloud properties (Rosenfeld et al., 2008; Clement et al., 2009). A large fraction (up to 90%) of atmospheric sub-micrometre particle mass consists of organic compounds (Jimenez et al., 2009). Currently, peatland emissions are not being included in global climate simulations despite peatlands covering 18-28 % of boreal regions (Kauppi et al., 1997). Research has shown that different peatland types have very different greenhouse gas budgets due to differences in production and decomposition processes (Bubier et al., 1998; Leppälä et al., 2008; Turetsky et al., 2014). Previously, it has been shown that increased temperatures lead to increased BVOC emissions (Lindwall et al., 2016), while lowered water table decreases the total peatland BVOC emissions (Faubert et al., 2010). With changing climate and human land use, peatlands are experiencing a drying trend, and the lower water table is expected to result in changing peatland vegetation. With drying, minerotrophic fen ecosystems may go through ombrotrophication and the vegetation could develop towards the species composition of ombrotrophic bogs or forests. This change will be reflected in the overall BVOC emissions, which in turn may lead to changes in biogenic secondary organic aerosol (SOA) formation and properties. The aim of this study was to investigate the SOA formation and properties as induced by the magnitude and compound composition of the BVOC emissions from the two main boreal peatland site types.

METHODS

We used previously published data about the BVOC emissions from the main boreal peatland site types (Männistö et al. 2023). These emissions were quantified with chamber method over two growing seasons at two boreal peatland sites within the same Siikaneva peatland complex; an ombrotrophic bog and an oligotrophic fen. This information was used to create synthetic BVOC mixtures representing the two peatland types. An Oxidative Flow Reactor (PAM, Aerodyne Researach Inc.) was used to probe the SOA formation. To avoid nucleation, ammonium sulphate seed was used. VOC concentrations (PTR-MS, Ionicon Analytik GmbH, Austria), aerosol bulk mass and properties (AMS, Aerodyne Research Inc., USA), particle size distribution (SMPS, TSI Incorporated, USA), and ozone were monitored (TE49i, Thermo Fischer Scientific) to determine yield curves for each mixture. For part of the experiments, a VOCUS-PTR (Aerodyne Researach Inc.) was used to analyse the formed gas phase oxidation products. The effect of isoprene was probed by getting yield curves with and without isoprene.

RESULTS

Table 1 shows the highest emitting compounds in the BVOC emissions measured from the two peatland types calculated from Männistö et al. (2023). The most obvious difference is the total emission rate (166.6 vs 44.5 ug m^{-2} h^{-1}). In both ecosystems isoprene is the main VOC emitted, however the proportions are very different. In fen ecosystems, isoprene accounts for almost 90% of all measured VOCs, while in bogs it is "only" 55%. In the fen ecosystem case, the next largest contributors all make up less than 2% each of the total VOC emissions, highlighting the dominance of isoprene. In the bog case, the next highest emission is a sesquiterpene, β-caryophyllene, at nearly a quarter of all emissions. In absolute emission rates, the sesquiterpene emissions from the bog are several times higher than those of the fen, despite having overall lower emissions.

Table 1. Main compounds in the BVOC emissions from two different types of peatland. The values represent averages over two growing seasons.

FEN			BOG		
compound	emissions rate / ug m^{-2} h^{-1}	fraction / %	compound	emissions rate / ug m^{-2} h^{-1}	fraction / %
isoprene	149.0	89.6	isoprene	24.5	55.1
nonanal	3.0	1.7	β-caryophyllene	10.6	23.9
β-caryaphyllene	2.3	1.4	nonanal	2.9	6.6
α-pinene	1.2	0.7	decanal	1.2	2.7
decanal	1.2	0.6	α-pinene	0.9	2.0
sabinene	0.9	0.5	limonene	0.6	1.3
trans-2-hexenal	0.7	0.4	β-myrcene	0.5	1.1
others	8.1		*others*	3.3	
sum (all)	166.3		sum (all)	44.5	

The total emissions from the fen ecosystem are several times higher than those of the bog ecosystem. However, as nearly 90 % comprises of isoprene, and only few percent are coming from monoterpenes sesquiterpenes, or other compounds with high aerosol yields, the SOA forming potential is limited. In comparison, bog emissions are lower in total, but the high contribution from the sesquiterpene β-caryophyllene can increase the SOA forming potential, despite isoprene still contributing more than all the other compounds combined.

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MODELLING THE IMPACT OF SECONDARY ORGANIC AEROSOL ON SHALLOW CLOUDS

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Keywords: Large-eddy simulation, aerosol-cloud interactions.

INTRODUCTION

Large fraction of atmospheric aerosol is composed of organic species, and especially the submicron aerosol is dominated by secondary organic aerosol (SOA). SOA is formed when vapor-phase organics condense to existing aerosol. Volatile organic compounds (VOCs) are too volatile to condense, but their oxidation produces a range of species including semi-volatile organic compounds (SVOCs) which partition between aerosol and vapor phases. Instead of describing individual organic species and their reactions, Donahue *et al.* (2006) described those for volatility bins containing species with similar saturation vapor pressures. This Volatility Basis Set (VBS) approach simplifies the description of SOA formation.

When environmental relative humidity increases, water vapor condenses to aerosol particles depending on their size and hygroscopicity. When RH exceeds 100%, some of the largest and most hydrophilic aerosol particles (cloud condensation nuclei, CCN) become cloud droplets. On one hand SOA formation increases particle size, but on the other hand SOA is not as hygroscopic as typical inorganic species, so the effect of SOA on cloud droplet number concentration (CDNC) is not always clearly positive. Large-eddy simulators (LESs) are computationally efficient tools for modelling turbulent atmospheric boundary layers including boundary layer clouds. However, few LES account for aerosol-cloud interactions and even fewer account for SOA formation. Here, we use such a LES to model the impacts of SOA formation on aerosols and clouds.

METHODS

UCLALES-SALSA (Tonttila *et al.*, 2017) contains a large-eddy simulator UCLA-LES and the sectional aerosol and cloud microphysics module SALSA, which accounts for details like aerosol-cloud interactions. Recently, Prank *et al.* (2022) added a SOA module based on the VBS approach. Here, this SOA module is updated and extended by increasing the number of SVOCs. The LES setup is obtained from Caldéron *et al.* (2022) who used observations from the 2020 cloud sampling campaign at Puijo SMEAR IV (Station for Measuring Ecosystem-Atmosphere Relations) in Kuopio, Finland. The focus is on the nocturnal stratocumulus cloud case with low aerosol concentrations and high organic aerosol fraction (88%).

RESULTS

First, we quantified the impact of SOA on cloud properties. A simulation without aerosol and simulations with and without SOA showed similar results, which means that aerosol-cloud interactions have small impact. This could be expected as the cloud is neither precipitating nor CCN-limited. Nevertheless, there are clouds where SOA formation can have an impact, so we examined which processes are important for SOA formation. Figure 1 shows the development of the organic aerosol (OA) mass concentration from three simulations with different processes included. The first simulation without SVOCs (and SOA production) has the lowest and almost constant OA mass. OA mass increases when SVOCs are included. This is caused by the radiative cooling of the boundary layer, which favours partitioning to the condensed phase. The highest OA concentrations are seen with vapor-phase SVOC oxidation (aging), which reduces volatility.

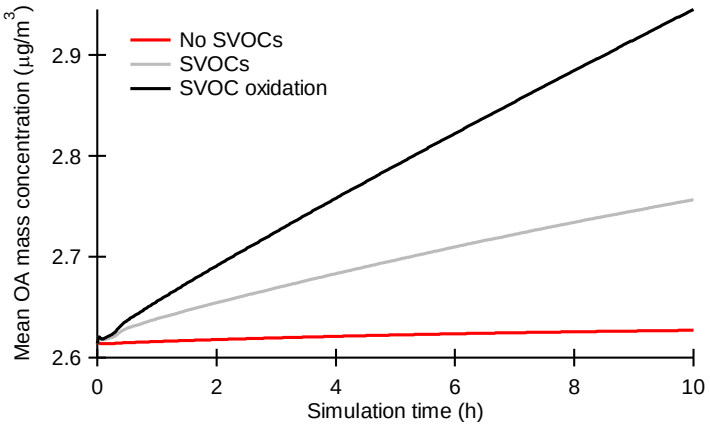

Figure 1. Domain mean organic aerosol (OA) mass concentration as a function of simulation time.

Finally, we conducted sensitivity tests to see which processes could have an impact on cloud state. For example, we examined the impacts of VOC surface emissions and using different stoichiometric coefficients (the amounts of different SVOCs from VOC oxidation). These had small impact on clouds. Finally, we examined the effect of solubility on SVOC partitioning. SVOCs in the default partitioning are immiscible with water. When miscibility is assumed, co-condensation of SVOCs and water vapor during droplet growth makes cloud activation easier and thereby increases CDNC. Indeed, co-condensation seem to have the largest impact on cloud properties and SOA formation.

CONCLUSIONS

The impact of secondary organic aerosol (SOA) formation on a cloud case was examined by using the UCLALES-SALSA large-eddy simulator. The simulations showed that the cloud is not sensitive on aerosol properties including SOA formation. In general, simply allowing vapor-aerosol partitioning has a clear impact on aerosol. Another important factor is the vapor-phase aging. The third important factor for SVOC partitioning is water solubility. The default is immiscible organics, but if miscibility is expected, co-condensation of SVOCs into growing droplets increases cloud activation. The real solubility, which is not well known, is somewhere between these limits.

ACKNOWLEDGEMENTS

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THE LONG-TERM EFFECT OF RESTORATION ON NUTRIENT POOR PEATLANDS' FUNCTIONAL DIVERSITY

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Keywords: Restoration, Peatland, Functional diversity, Testate amoeba

INTRODUCTION

Functional diversity (FD) refers to the components of biodiversity that influence how an ecosystem operates or functions (Tilman, 2001). In this study we address FD in peatlands as the variability of functional traits which are defined as "any attribute that has potentially significant influence on establishment, survival, and fitness" (Reich et al., 2003).

For our purpose, we selected the functional traits approach using vegetation and testate amoeba, single-celled protists found on the surface of peatlands that show fast response to changes in the hydrological conditions (Fisk et al., 2003, Rydin & Jeglum, 2006), as proxies to assess the recovery of disturbed peatlands. As functional traits are known to mediate ecosystem services through ecosystem processes (Díaz et al., 2007, Lavorel, 2013, Lamarque et al., 2014), making them useful in determining and better understanding the ecological consequences of environmental changes.

In this study, we are asking how large is FD in restored nutrient-poor peatlands in relation to FD in pristine and forestry-drained nutrient-poor peatlands?

To answer our research question, we are comparing the vegetation and testate amoeba functional traits in restored, forestry-drained, and pristine nutrient-poor peatlands within southern and mid boreal Finland (from Helsinki to Ranua). The study includes 25 peatland sites: eight clusters with drained, restored, and pristine sites, and one additional drained site.

In addition to the FD, in all the study sites greenhouse gas fluxes have been measured and peat samples have been collected for properties analysis. This will allow us to comprehensibly describe the factors that predict the recovery of the peatland ecosystems.

METHODS AND FUTURE WORK

The vegetation and testate amoeba data was gathered by doing inventories during the summer 2023. We set up three 10-meter transect lines which all had ten sampling plots, each located one meter apart. At drained and restored sites, the transect lines started from the ditch and continued through the strip between the ditches, while in pristine sites, transect lines were set according to the moisture gradient, from wetter areas towards drier. This way the transect lines included most of the microform variation at the sites.

For the vegetation inventory, we visually estimated the coverage for plant species and for mosses (0-100 percent). We also measured functional traits for most common vascular plants (height, specific leaf area, leaf dry matter content) and *Sphagnum* species (fascicle density, capitulum density, capitulum dry matter content, capitulum size). Trait samples were collected from each microform present in transect lines (hollows, lawns, and/or hummocks).

For the testate amoeba, trait samples were collected from the topmost peatland surface (0-3cm and 3-5cm) of each of the sampling plots aiming to represent all microforms present in the lines. In each plot, at least 10 *Sphagnum* moss shoots or, in the lack of *Sphagnum*, forest mosses shoots were selected and collected. The community assemblage (species identification and abundance) and functional traits (test length, test width, and

aperture width) will be measured under a light microscope. In addition, functional traits like mixotrophy, aperture position, and biovolume will be calculated.

To find out whether functional diversity is different between sites we will calculate community weighted mean for all functional traits. Then we will compare them first using the Principal Component Analysis (PCA) to examine the overall interrelations and later with the one-way Analysis of Variance (ANOVA). If significant differences are present, we will use a post hoc test to find out which sites are different from each other.

ACKNOWLEDGEMENTS

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THE ROLE OF LAND COVER AND HYDROLOGY IN REGULATING METHANE (CH_4) AND CARBON DIOXIDE (CO_2) EMISSIONS FROM SUBARCTIC STREAMS

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Keywords: Carbon, Methane, Carbon dioxide, Greenhouse gas, Freshwater, Subarctic.

INTRODUCTION

Freshwater rivers and streams transport carbon (C) compounds and nutrients from terrestrial to aquatic ecosystems, being significant sources of powerful greenhouse gases methane (CH_4) and carbon dioxide (CO_2) to the atmosphere. Across northern landscapes, climate-induced changes in vegetation cover and hydrology have been found to increase the export of dissolved organic carbon (DOC) from terrestrial to aquatic ecosystems. The increased delivery of terrestrial organic carbon might further accelerate the degradation of DOC and consequent greenhouse gas (GHG) emissions from freshwaters. To provide more accurate estimates of landscape-scale C balances in a changing climate, it is crucial to understand the factors regulating the sources, processing, and fate of C along the terrestrial-aquatic continuum. In this study, we aimed to investigate the influence of land cover and seasonality on the emissions of CH_4 and CO_2 from subarctic streams.

METHODS

We conducted floating chamber flux measurements and stable isotope analyses of CH_4 and CO_2 and analyzed CH_4-related microbial communities in two pristine subarctic catchments differing in vegetation, soil type and water quality. Monthly flux measurements and analyses were performed from spring to fall during two growing seasons (2022–2023). The study area is situated in a subarctic coniferous forest located in Värriö Strict Nature Reserve (67° 44’ 16’’ N, 29° 38’ 58’’ E) in Finnish Lapland close to Värriö Subarctic Research Station (SMEAR I). Meteorology, water level and DOC concentrations are continuously monitored at the research station.

RESULTS

Preliminary results show the highest fluxes of both CH_4 and CO_2 in the peatland-associated stream throughout the year. In both streams, the fluxes of CH_4 and CO_2 peaked during spring freshet.

CONCLUSIONS

The results indicate a strong influence of catchment vegetation and hydrological conditions on the dynamics of CH_4 and CO_2. This highlights the close connection between terrestrial landscapes and small headwater streams.

ACKNOWLEDGEMENTS

This work was supported by the Academy of Finland projects CASCAS (Cascading carbon flow in managed forested catchments, 2019-2023) and RIVERVOC (Biogenic Volatile Organic Compound Emissions from

Northern Rivers, 2023-2027) (PI Professor Jukka Pumpanen, UEF), and The ACCC Flagship funded by the Academy of Finland.

OUTDOOR AIR QUALITY IMPACTS INDOOR AIR QUALITY IN OFFICE SPACES

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Keywords: indoor air quality; ultrafine particles; submicron particles; LDSA; I/O ratio; infiltration factor

INTRODUCTION

Good indoor air quality, i.e., low amounts of particulate matter and toxic gases, is important for human health as the time spent indoors often outweighs the time spent outdoors. The parameters influencing indoor air quality include ventilation, filtration, outdoor air quality, cracks in the building envelope and indoor sources of particulate matter or gases. Many of these parameters depend on the individual building properties or even the specific room studied. In this work, we investigated the particle size distributions and concentration in four office rooms in four different cities: Tampere, Helsinki, Düsseldorf, and Prague, alongside the outside air quality (Silvonen et al. 2023). Our aim was to establish the parameters which had the most influence on the indoor air particle concentration. Our chosen metric was the lung-deposited surface area (LDSA) of particles due to its relevancy to health.

METHODS

The particle concentration in each of the four offices was measured with ELPI+ (Electrical low-pressure impactor, Dekati Ltd.) for roughly two to three weeks. Measurements were simultaneously conducted from outdoor air (also with ELPI+). Information about the offices is in Table 1.

Table 1: Information on the four office spaces studied.

	Tampere	Helsinki	Düsseldorf	Prague
Building year	1971	1972	1969	1861
Ventilation type	Mechanical	Mechanical, partially recirculated	Exhaust-only	Natural
Filter grade	G5	F7	-	-
Supply air flow (m^3/h)	313	331	-	-
Room volume (m^3)	124	66	52	100
Room floor area (m^2)	43	25	17	20
Estimated room usage (%)	50	10	90	10

RESULTS & CONCLUSION

Scatter plots of indoor LDSA versus outdoor LDSA reveal a high correlation between the two (Figure 1). Comparing the plots to one another shows that ventilation and filtration of supply air greatly affect the infiltration factor (gradient of the best fit lines). Differences between working hours (black line) and all hours (grey line) were small, and the y-intercepts were close to zero. This means that indoor sources had at most a minor influence on the indoor air LDSA concentration.

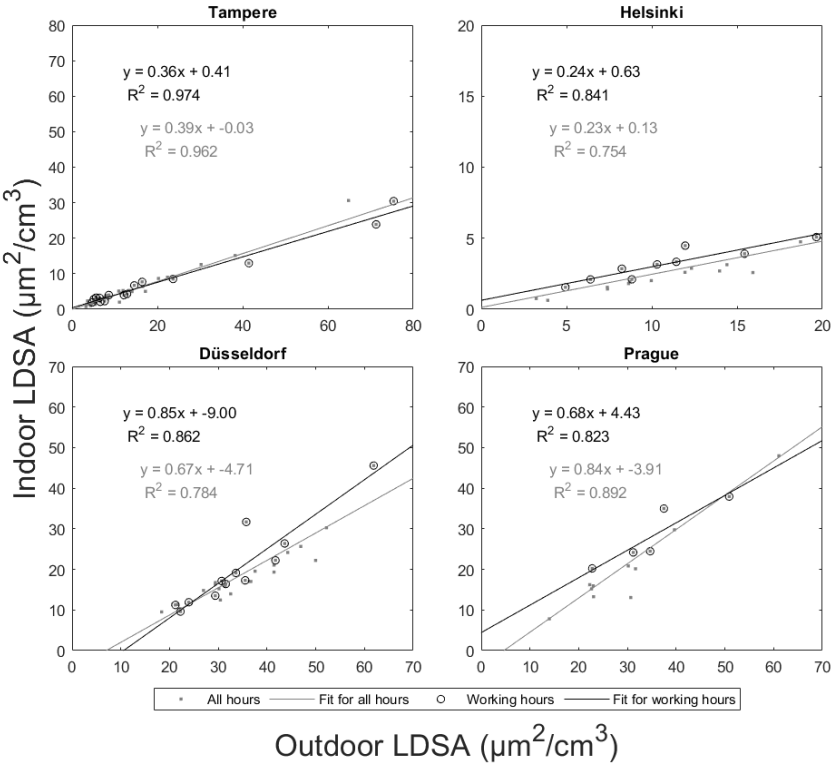

Figure 1: Indoor versus outdoor LDSA scatter plots with fitted lines (regular least-squares fit). Data is presented as 12-hour averages. Data from all hours is shown in grey and working hours in black. Working hours data is from weekday daytime hours (6:00 to 18:00). Figure published in Silvonen et al. 2023 (preprint).

Outdoor air was found to be the main source of indoor particulate matter in all studied offices. This observation is supported by previous research (Morawska et al. 2017). In the offices employing supply air filtration, the negative impact of outdoor air on indoor air was diminished. This implies that the best way to control air quality in offices is to control infiltration.

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STUDENTS' SENSE OF BELONGING IN A JOINT DEGREE ENVIRONMENTAL SCIENCE MASTER'S PROGRAM

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Keywords: Sense of belonging, higher education

INTRODUCTION

The sense of belonging among students is widely recognized for its significant impact on academic achievement and overall university success (e.g Thomas 2012, Pittman and Richmond 2007). Sense of belonging can be defined as the emotional attachment individuals feel toward specific groups, systems, or environments (Maestas et al., 2007) and their perception that their personal attributes fit to these entities (Hagerty & Patusky, 1995). In the context of higher education, students' sense of belonging has been found to be influenced by various factors, including social relationships, attachment to the academic sphere, personal well-being, and connection to the place and surroundings (Ahn & Davis, 2020). This study examines the factors that foster and cultivate a sense of belonging within a distinctive Master's program that operates across multiple universities and involves students attending courses in different countries and institutions. Consequently, the student group is dispersed across various institutes and countries, lacking some elements commonly associated with traditional graduate student experiences, such as on-site attendance in a physically shared space with a relatively stable group of peers and instructors. This study highlights the significance of exploring how to foster a sense of belonging in non-traditional educational settings, particularly as higher education is moving more towards online teaching.

METHODS

We conducted 15 semi-structured interviews with current or graduated students enrolled in the Joint Master's Program in Environmental Changes in Higher Latitudes. The interviews explored the student's perception of their own sense of belonging during their studies and how different aspects had affected it. The interview transcriptions were coded in ATLAS.ti (version 23.2.2.27458) and the codes were further grouped into larger themes.

The program is jointly offered by the University of Helsinki, Lund University, and the Agricultural University of Iceland. Students in this program spend at least two semesters at two different degree-awarding institutions, along with participating in an intensive course in Greenland, which varies from 2 to 4 weeks depending on the year of enrollment. Additionally, students engage in various modes of education, ranging from fully online semesters to intensive residential courses, while studying at different institutions and locations.

RESULTS

Peer relationships were identified as significant factors influencing the sense of belonging. The opportunity to connect with both fellow students and instructors on an informal level was seen as a key means of supporting belonging. In addition to peer relationships, many interviewees highlighted how opportunities to strengthen their professional identity and academic connections fostered a sense of belonging. While the majority of interviewees reported experiencing both social and professional dimensions of belonging to varying degrees, some participants exclusively attributed their sense of belonging to social relationships, while others linked it solely to their professional identity.

Notably, a sense of familiarity with different places, cultures, and study content had a positive effect on the sense of belonging. Many interviewees believed that a sense of belonging to a new country or location could be promoted by studying the local culture or environment, thus creating a sense of familiarity.

The factors that contributed to a sense of belonging varied significantly among different students. Similar situations led to different emotional responses and perceptions of belonging. One significant contrast emerged in relation to the small group size and living in a small, rural area. Some students found that the small group and isolated environment helped them form strong connections with their peers and surroundings. In contrast, others saw these conditions as restricting their opportunities.

CONCLUSIONS

In conclusion, this study highlights the role of peer relationships, informal interactions, and the importance of both social and professional dimensions in shaping the sense of belonging among students. Moreover, a sense of familiarity with different places, cultures, and study content was found to positively impact belonging. However, it is crucial to recognize the individualized nature of belonging, as factors contributing to it varied widely among students.

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QUANTIFYING AEROSOL EFFECTS ON METEOROLOGY IN VARIOUS WEATHER CONDITIONS USING THE ENVIRO-HIRLAM MODELING SYSTEM: CASE STUDIES OF UKRAINE

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Keywords: seamless modeling, Enviro-HIRLAM, direct and indirect aerosol effects

INTRODUCTION

Severe meteorological and hazardous air pollution events are important to be accurately assessed for improving their predictability and optimizing the decision-making processes during their occurrence. Under current climate changes, Ukraine is facing more frequent extreme weather events and wildfire episodes. Previously used monitoring data and numerical weather prediction models provided valuable information; however, the absence of a seamless modeling approach was the reason for uncertainties in estimates. Consideration of direct and indirect aerosol effects can significantly improve the accuracy of meteorological modeling and our understanding of aerosol-meteorology interactions during typical extreme weather and pollution conditions in the midlatitudes, where Ukraine is located. These, consequently, can be further implemented in national hydrometeorological services. Based on the Environment - HIgh Resolution Limited Area Model (Enviro-HIRLAM) seamless modeling system (Baklanov *et al*., 2017), we performed a series of simulations covering three various hazardous weather episodes in Ukraine to quantify direct and indirect aerosol effects on meteorology, paying attention to synoptic patterns that typically enhance the severity of dangerous natural phenomena. Selected episodes include (1) summer 2010 heat-wave event followed by elevated aerosol content caused by wildfire emissions and heavy rainfall in the Carpathians mountain areas; (2) a heavy snowfall event in March 2013; and (3) an April 2020 wildfire pollution episode in the Chornobyl Exclusion Zone (CEZ) and adjacent northern parts of Ukraine.

METHODS

For all case studies, the Enviro-HIRLAM model simulations were performed with a downscaling for 15-5-2 km spatial resolution and a model time step of 240-120-60 s respectively. A domain consisted of 190x240 grids for 15-km resolution, 310x310 for 5- and 2-km resolutions, and included 40 vertical model levels. Four model modes were used: reference (REF) run with no aerosol effects, including direct (DAE), indirect (IDAE) and combined (COMB) aerosol effects.

RESULTS

The observed aerosol effects modify meteorological fields in different ways, depending on the synoptic patterns. Especially sharp aerosol effects are typical for areas covered by atmospheric fronts. DAE model runs showed more intense changes in air temperature, specific humidity, and relative humidity in comparison to IDAE effects, being mostly responsible for modifications of meteorological fields in COMB runs. Elevated black and organic carbon content emitted from wildfires enhanced the severity of the observed weather conditions. The impact of aerosol effects on meteorological fields mostly resulted in changes at a local scale having a spot-like appearance that was better represented by a finer 2-km spatial resolution. Aerosol effects can enhance the spatial gradients of meteorological parameters without dependence on atmospheric front types (cold, warm, or occluded). Overall, aerosol effects caused changes in the 2-m air temperature maximum by ±4^{o}C, relative humidity by ±40%, and accumulated total precipitation by ±10 mm/ 6 hours. Variability in total cloud cover and precipitation patterns often results

from their spatial shifts due to differences in wind field, not due to in-cloud processes. The obtained results showed a crucial role in accurate natural hazard event assessments. For example, the lack of attention to the role of aerosol effects not included in numerical weather prediction models can cause an underestimation of extreme heat-wave conditions, as DAE effects showed an increase in near-surface air temperature during blocking anticyclones. Aerosol effects that tend to dry conditions during wildfires might enlarge the wildfire coverage and worsen the ability of emergency services to put them out.

CONCLUSIONS

Seamless modeling performed for extreme weather and pollution events showed the significant role of aerosol effects in modifying meteorological fields. The changes were observed for temperature, moisture, and wind regimes, which were dependent on synoptic patterns. DAE and IDAE aerosol effects were especially strong during atmospheric front movement. The reasons for variability in cloud and precipitation patterns can be complex due to not only in-cloud processes but also because of their location changes driven by wind field variations. Consideration of aerosol effects is critical for hydrometeorological phenomena prediction and decision-making activities during extreme weather and pollution events. In some cases, aerosols can enhance the severity of the observed conditions.

ACKNOWLEDGEMENTS

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COMPARISON OF PARTICLES PRODUCED BY DOFR AND PAM AGING CHAMBERS FROM PURIFIED BACKGROUND AIR

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Keywords: Aging chamber, Oxidation flow reactor, Secondary aerosol

INTRODUCTION

Aging chambers, also known as oxidation flow reactors, simulate the natural aging process of emitted exhaust gas in the atmosphere. Feeding ozone, humidity, and UV light to the gas sample in the chamber causes similar photochemical reactions as in the natural environment, but in much shorter time, allowing for almost real-time measurement of secondary aerosols. Utilizing aging chambers gives essential understanding of the impact of secondary aerosol on health and climate. (see e.g. Simonen et al., 2017; Kang et al., 2007)

Two commercially available aging chambers are DOFR™ (Dekati® Oxidation Flow Reactor DOFR™) by Dekati Ltd. (Kangasala, Finland) and PAM (Potential Aerosol Mass Oxidation Flow Reactor) by Aerodyne Research Inc. (Boston, Massachusetts, USA). In this study, we compared the production of particles from purified background air between the two chambers. It is important to understand the effect the aging chamber may have on the secondary aerosol formation, and to quantify the background aerosol formation before adding exhaust emissions. This work is setting up for further studies with the two chambers as part of the HERPA summer campaign 2023 project at Tampere University.

METHODS

The pressurized air sample was purified using two units. First, Parker Balston® FT-IR Gas Generator 75-62 removed humidity and CO_2. Then a four-filter unit removed particles (coarse particles, fine particles, activated carbon, coarse particles (generated by activated carbon)).

The purified air was led alternately to both aging chambers. Particle concentrations after DOFR and PAM were measured using a CPC battery (condensation particle counter battery) and ELPI+ electrical cascade impactor (electrical low-pressure impactor, Dekati Ltd). The CPC battery contained four CPCs: CPC-PSM (Airmodus, cut-off size 1 nm), CPC3776 (TSI, 2.5 nm), CPC10 (Airmodus, 10 nm) and CPC23 (Airmodus, 23 nm).

Measurements were repeated for both chambers without and with UV-lamps on. DOFR and PAM have different kinds of UV light controls: With DOFR it is possible to choose how many of the twelve bulbs are on whereas with PAM it is possible to choose voltage of the lamps. In this experiment we chose four DOFR lamps and 3 V for PAM lamps. The relative humidity of both chambers was adjusted to about 30 % and ozone was fed in excess. The photochemical ages of DOFR and PAM were measured to be 4,3 and 5,4 days, respectively.

In addition to the CPC battery and ELPI+, the volatile organic compounds (VOCs) in the purified air samples after DOFR and PAM were analysed using Vocus PTR-ToF-MS time of flight mass spectrometer (Tofwerk AG, Thun, Switzerland).

RESULTS

When the lamps were switched off the particle number concentrations were negligible with both chambers. When the lamps were switched on, both chambers produced a distribution of particles with an emphasis on sub-23 nm particles. With the lamp combinations used (DOFR: four lamps, PAM: 3 V) the number concentrations of DOFR were approximately 6- to 7-fold compared to PAM. Comparison of the chambers with lamps on is illustrated in Figure 1.

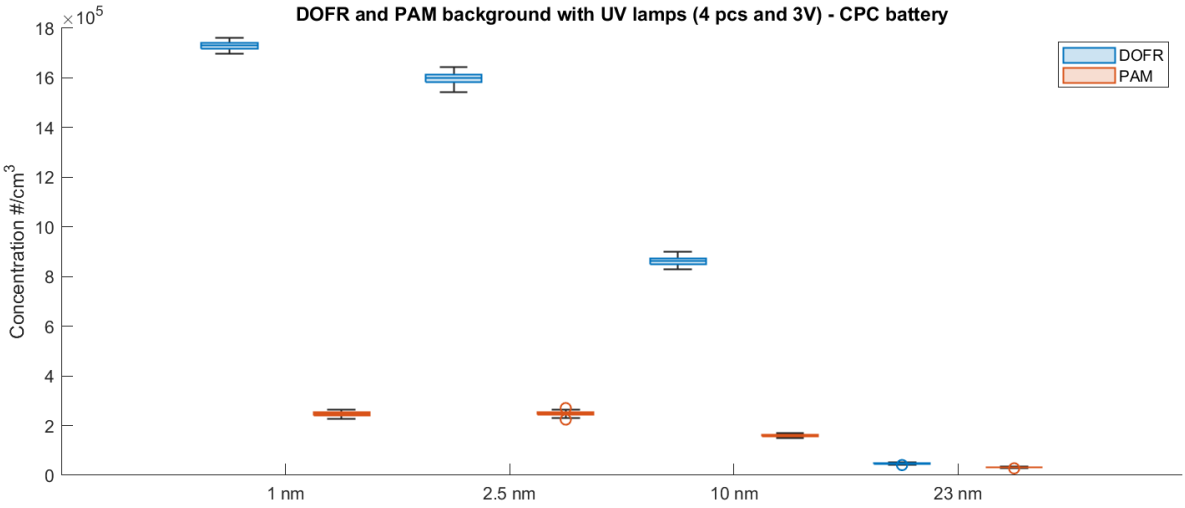

Figure 1. Particle number concentrations after DOFR (blue) and PAM (red) according to the CPC battery when UV lamps are on.

CONCLUSIONS

The PAM and the DOFR aging chambers were tested with the same purified air to measure background particle formation. Without the UV lamps the chambers did not increase particle concentrations as was expected. When the UV lights were on, the chambers generated mostly sub-23 nm particles from the purified pressurized air. The particle number concentrations were of the same order of magnitude; however, the DOFR produced more particles with the chosen UV intensities.

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SEASONAL CHANGES OF NO3 REACTIVITY IN A BOREAL FOREST

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Keywords: NO_3, Volatile organic compounds, CRDS

INTRODUCTION

Nitrogen Oxides (NO_x = NO + NO_2) are one of the major anthropogenic greenhouse gases. The nitrate radical (NO_3) is formed as a product of NO_2 and Ozone (O3). It is mostly relevant to night time chemistry, since during the day the presence of sunlight results in its photolysis almost immediately after its formation. As a strong oxidant, NO3 reacts with volatile organic compounds (VOC) and biogenic VOC (BVOC) forming organic nitrates, which can serve as an NO_x reservoir or sink. While the interactions between NO_3 and BVOC are a phenomenon known for several decades, the picture is far from complete. Some of the obstacles are the heterogenous nocturnal atmosphere and an incomplete understanding of mechanisms involved. (Nga Lee Ng and Steven S. Brown et al., 2017)

In boreal forests, the BVOC production is heavily influenced by the season, which is little to none during the winter, due to the low temperature and the resting period of the trees.

This work aims to contribute to the completion of the picture, by extending on the work of Liebmann et al. (2018) which measured the reactivity of the atmosphere towards NO_3 at the SMEAR II station in Hyytiälä, Finland, for 16 days during the IBAIRN campaign.

METHODS

A custom build cavity ringdown spectrometer (CRDS) is used for the measurement. Synthetically produced NO_3 is mixed with zero air or ambient air and the respective NO_3 concentrations are measured. From this comparison, the overall reactivity of the ambient air towards NO_3 is calculated. The details of the instrument are described by Liebman et al. (2017).

The measurement site is the SMEAR II station in Hyytiälä. The ambient air is sampled in 1-minute intervals from different hights ranging from 4 – 120 m. The sampling is synchronised across multiple other measurements at the site, including NO_2, VOC and meteorological data.

The reactivity measurement will remain at the site for a period of 1-2 years to capture several season changes. In autumn 2024 an intensive campaign is in planning to compliment the existing measurements and give different groups the opportunity to collaborate on the topic.

CONCLUSIONS

With the extended measurement we will capture several season changes, which improves the picture on how the NO_3-BVOC interaction changes when the trees go into their resting period and back to growing period. Due to the hight dependant measurements we can separate between different layers (e.g. above/below canopy) and hopefully get a better insight into the heterogenous night-time atmosphere.

With the intensive campaign we intend to create a more complete snapshot of the season change.

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DETECTION AND CHARACTERIZATION OF AIRBORNE POLLEN USING LIDARS AT SEVERAL EUROPEAN SITES

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Keywords: Pollen, Lidar, Aerosols, Remote sensing.

INTRODUCTION

Airborne pollen is recognized as one of the major agents of allergy-related diseases. As one important type of biogenic particles, pollen has various climatic and environmental impacts. Studies show that lidar (light detection and ranging) can detect the presence of pollen in the atmosphere, with a strong diurnal cycle on the pollen backscattering, and that the non-spherical pollen can generate strong depolarization of laser light. Therefore, it is possible to track airborne pollen in the atmosphere using the depolarization ratio in the absence of other depolarizing non-spherical particles (e.g. dust). Lidar-derived optical profiles can provide information about the vertical distribution of pollen, which could result in an improvement in the model input parameters and serve as validation for model results.

METHODS

Pollen campaigns were performed at several European sites since 2016 (Table 1). The main campaign site is Vehmasmäki in Kuopio, located ~18 km from the cite centre, mainly surrounded by forest. The clean air in Finland favours the pollen study. Finokalia and Antikythera sites locate in the Eastern Mediterranean Sea, often affected by marine and dust aerosols. Other sites are urban/sub-urban areas, with frequent presence of anthropogenic pollution and sometimes dust. To avoid the dust effects on pollen properties retrieval, only dust-free periods were considered, which were determined using models and back-trajectories.

Table 1. Information of the pollen campaigns.

Sites	Pollen campaign periods	Dominant pollen types
Kuopio, Finland	Mar-Aug 2016, 2019-2023	Birch, Pine, Spruce
Finokalia, Greece	Feb-May 2018	Olive, Cypress
Antikythera, Greece	Jun-Jul 2018	Nettle
Melpitz, Germany	Mar-June 2019	Birch, Grass
Leipzig, Germany	Jul-Sep 2019, May 2020	Birch, Grass, Pine
Hohenpeißenberg, Germany	May 2020	Birch, Grass
Warsaw, Poland	May 2020	Birch

All sites were equipped with a multi-wavelength Raman polarization lidar Polly^{XT}. Hirst-type Burkard pollen samplers were deployed to measure the pollen type and concentration at most sites, except Hohenpeißenberg and Warsaw. Furthermore, Kuopio site is permanently equipped with a Polly^{XT}, a Halo Photonics StreamLine Pro Doppler lidar (Vakkari *et al*., 2019), a Vaisala CL61 ceilometer, and multiple in situ instruments. All three lidars are equipped with polarization channels and enable the investigation of the

optical properties at the wavelengths of 355, 532, 910 and 1565 nm. Vertical distribution and optical properties of airborne pollen were characterized using lidar-derived parameters: backscatter coefficients (~amount), linear particle depolarization ratio (PDR, ~shape), Ångström exponent (ÅE, ~size), and lidar ratio (LR, ~chemical composition).

RESULTS

At Kuopio site in 2016, during an intense pollination event of birch pollen occasionally mixed with spruce pollen, enhanced PDRs were detected by Polly^{XT}, suggesting the presence of non-spherical particles (Bohlmann *et al.*, 2019). With additional presence of larger and more un-spherical spruce pollen, even stronger PDRs were observed. At Finokalia site in 2018, enhanced but relatively smaller PDRs were detected in the pollen layers, indicating the almost spherical shape of pollen types in Mediterranean region (e.g. olive). From pollen observations, clear tendencies towards higher pollen contribution with increasing PDRs and decreasing ÅEs were found, indicating the increasing impact of pollen in the aerosol mixture. Based on measurements during pollen seasons of 2021 and 2022 at Kuopio site, a positive (negative) correlation was found between the pollen concentration (contribution of other aerosols) and PDRs (Filioglou *et al.*, 2023). Depolarization ratios of pollen layers were also measured at four wavelengths at Kuopio site, allowing investigating its wavelength dependence (Bohlmann *et al.*, 2021, Filioglou *et al.*, 2023). This could enable the distinction of pollen from other depolarizing aerosols. Results also highlight the suitability of the PDR at longer wavelengths for pollen detection. We have developed two pollen algorithms for characterizing the optical properties of pure pollen particles, based on Polly^{XT} measurements (Shang *et al.*, 2020, 2022). They were applied to evaluate the pollen depolarization ratio which is an essential parameter needed to separate pollen backscatter from the background aerosol backscatter. The algorithm was also applied for the aerosol classification, and identified different pollen types.

ACKNOWLEDGEMENTS

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THE IMPORTANCE OF INTEROPERABILITY IN EUROPEAN RESEARCH INFRASTRUCTURES

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Keywords: standards, open science, data, governance, communication.

CONTEXTUALIZATION

Research Infrastructures (RI) are facilities that offer resources and services for research communities to conduct research and promote innovation. RI can be a single site or distributed and include major scientific equipment, collections, archives or scientific data, computing systems and communication networks.

Interoperability is an important aspect of Open Science (OS). It refers to the ability of different systems and organizations to work together and exchange information seamlessly. Interoperability involves establishing common standards, formats, and protocols that enable different systems or components to communicate with each other and exchange the data without loss or distortion of information. Data interoperability addresses challenges related to data compatibility, structure, semantics, and technical integration. It involves defining and adhering to shared data models, schema, and metadata standards, as well as utilizing common communication protocols and interfaces. In the context of OS, interoperability allows for the integration and interconnection of research infrastructures, reducing the fragmentation of the research and innovation ecosystem and avoiding the duplication of effort. Achieving interoperability across resources and services within RIs can present several challenges. Most of the interoperability challenges can be divided into two blocks, namely technical and social challenges (Figure 1).

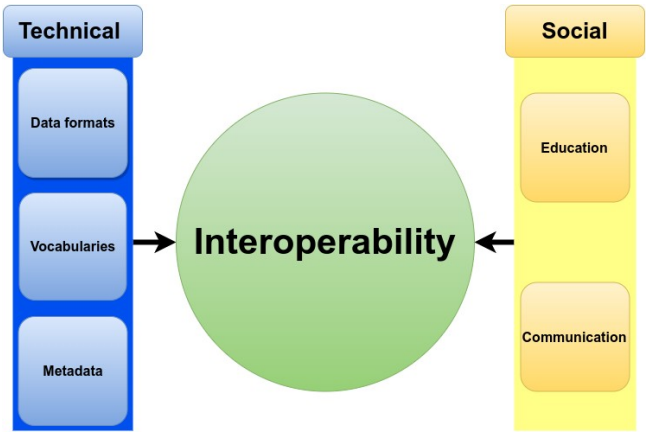

Figure 1. Challenges achieving data interoperability among research infrastructures can be divided in two groups: technical and social.

The technical challenges in data interoperability are various, but probably the most relevant ones in the context of RIs are the data formats, the vocabulary standards and the metadata quality. The use of common vocabulary and data format standards is probably the most basic, yet difficult challenges to overcome in order to achieve interoperability among RIs. In many research fields, researchers are not familiarized with the best practices and standards, therefore it is imperative that this type of information is effectively communicated to data producers. While the change to proper data format standards is likely an easier problem to be solved, the adherence to proper vocabularies is more challenging, as in many fields of research, the vocabulary standards are non-existent or are incomplete. Additionally, there are difficulties related to interdisciplinary in semantics, as terms might have a different meaning and understanding

among different disciplines (e.g. environmental and social scientists), yet scientists need to have a common view of the used terminology in order to address the common societal challenges like climate change or biodiversity loss. Another technical challenge in achieving interoperability in RIs is the quality and completeness of metadata. Metadata is essential for data discovery and reuse. However, metadata is often incomplete or inconsistent, making it difficult to find and use data. RIs should promote, facilitate and ensure that metadata is complete, accurate, and up-to-date by using standard metadata schema and ontologies.

The social challenges in interoperability can also be split into two groups, namely education (of the scientific community) and communication (among RIs). Even though researchers are well-educated people in their fields, many times they lack training or access to information related to the best practices in research data management (RDM). This is important because it can make them more aware of the importance of adhering to proper data formats, standard vocabularies and generating complete metadata entries to their data. Researchers are crucial in the process of data collection and sharing, and thus effectively training and informing them about good practices in RDM can be an invaluable step towards interoperability. Communication, or lack of communication among RIs is another challenge, as it can prevent the fragmentation of the RI landscape. When different RIs operate in isolation, they can create problems such as the adoption of incompatible standards; misalignment on governance policies on data access, intellectual property and or licensing. To enhance the interoperability of RIs, it is vital to foster open lines of communication and collaboration among them. This can be achieved through regular meetings, workshops, and forums where infrastructure managers, data providers, and researchers can exchange knowledge, share best practices, and align their efforts. Encouraging the adoption of common standards, establishing interoperability frameworks, and promoting data sharing initiatives can also facilitate effective communication and enhance interoperability across RIs.

CONCLUSIONS

In conclusion, RIs are crucial for promoting scientific research and driving innovation in various fields. To maximize their impact, achieving interoperability is a key challenge that needs to be addressed. Centralized hubs of standards, such as common vocabularies and data formats, can facilitate communication and collaboration among research infrastructures. Improved communication and coordination among research infrastructures can also help prevent the duplication of effort and increase efficiency. These initiatives are essential for accelerating scientific progress, bridging gaps, and improving the usability of RIs.

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IMPACT OF ATMOSPHERIC AEROSOLS ON LOW-LEVEL WARM CLOUDS

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Keywords: Aerosol-cloud interactions, CDNC, N100, MODIS

INTRODUCTION

One of the largest uncertainties in estimating the anthropogenic radiative forcing is related to the impact of atmospheric aerosols on cloud properties. This uncertainty originates mainly from the complicated nature of aerosol-cloud interaction as it is much stronger and more difficult to observe than the aerosol-radiation interaction (Bellouin et al., 2020). In addition, the indirect effect of anthropogenic aerosols cannot be estimated without the knowledge of what is the baseline indirect effect of natural aerosol (Carslaw et al., 2013). Currently, one of the least well-understood aerosol components is secondary organic aerosol (SOA), most of which is likely of natural origin, i.e. biogenic SOA (BSOA) (Yli-Juuti et al., 2021). Kulmala et al. (2004) hypothesized, that the increasing BSOA in the warmer future could enhance the direct and indirect aerosol radiative effects. However, it is very challenging to quantify the BSOA-cloud interactions as meteorology affects both BSOA formation and the properties of clouds.

The estimates of radiative forcing due to changes in cloud properties vary significantly between different global climate models, highlighting the need for constraining this forcing by using observations. Thus, in this study, we aim to quantify the radiative effects of BSOA by combining field observations of aerosol properties and satellite observations of cloud properties together with large eddy simulations, and meteorological reanalysis data.

METHODS

The level-2 collection-6 MODIS cloud property dataset with 1 km resolution is used in this analysis. From the MODIS data, cloud droplet number concentration (CDNC) values are calculated for liquid, single-layer clouds. Following the work of Gryspeerdt et al. (2019), we used the sampling strategy that includes only liquid, single-layer warm clouds, considering the adiabatic assumption. The in-situ data on particle number concentration were measured with Scanning-Mobility Particle Sizer (SMPS), and only particles with diameter larger than 100 nm (N100) are considered in this study as they are large enough to act as cloud condensation nuclei (CCN). These two datasets are collocated with each other, and the relationship between CDNC and N100 is assessed over two different regions, the Southern Great Plains (U.S.) and Hyytiälä (Finland). Different linear regression methods are used in the analysis, taking into account the measurement uncertainties. The large scale eddy simulations (LES) are performed for Hyytiälä, using the UCLALES SALSA model (Tonttila et al., 2017). The model is initialized with observed vertical profiles of atmospheric properties and aerosol size distributions from the Hyttiälä SMEAR II station.

RESULTS

Figure 1 illustrates the relationship between CDNC and N100 with different linear regression fitting methods, with measurement uncertainties taken into consideration. Here, we observe that the ordinary least squares (OLS) regression method results in strongly biased slope values compared with other error-in-variables (EIV) regression methods that are known to take errors in the variables into account. The bivariate slope (0.742) for Hyytiälä is steeper than that over SGP (0.588), although the uncertainties reflected by the 95 % confidence interval of the regression slope are more in case of SGP than over

Hyytiälä. The satellite retrieval uncertainties are observed to be larger than the variability due spatial aggregation of the satellite dataset, indicating that larger uncertainties may lead to smaller slopes. A good agreement is observed between the observed and modeled relationship between CDNC and N100 over Hyytiälä.

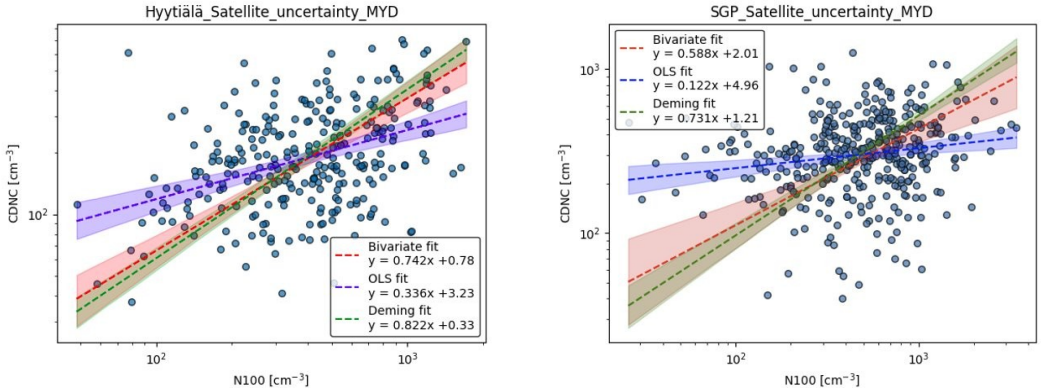

Figure 1: Scatterplots showing different linear regression fits between satellite derived CDNC and in-situ N100 measurements for Hyytiälä and Southern Great Plains (SGP).

CONCLUSIONS

In this study, we show how defined relationship between aerosols and cloud properties depends on the consideration of measurement errors and linear regression methods. Based on the results, it is evident that the satellite retrieval errors are larger than spatial aggregation errors, and these measurement errors can significantly affect the susceptibility we get for the clouds. Therefore, uncertainties in the measurements play an important role in the analysis of aerosol-cloud interactions. We also compare the results obtained from the observations with the theoretical relationships obtained from the LES simulations.

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CLIMATE CHANGE COMPETENCIES FROM THE PERSPECTIVE OF FINNISH YOUNG PEOPLE

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Key Words: CLIMATE CHANGE, YOUNG PEOPLE'S PERSPECTIVE, CLIMATE CHANGE COMPETENCIES

INTRODUCTION

The climate-changing future causes an increasing amount of climate related anxiety and worry in today's young people (Ojala 2015). Young people have strong feelings of uncertainty about their future, betrayal and even abandonment by governments and adults (Marks et al., 2019; Myllyniemi et al., 2019). In this research the aim is to hear and discuss with the young people themselves and see their point-of-view. The goal is to build a framework of climate change competencies from the perspective of Finnish young people. By competency we mean a set of knowledge, skills, values, and attitudes (Wiek, Withycombe, and Redman, 2011). The climate change competence framework can be further utilized as an opening for discussion about coherent, meaningful, and comprehensive climate change education path (Riuttanen et al., 2021; Bianchi et al., 2022).

METHODS

A qualitative survey was addressed for young Finnish people participating in a climate change related event *(Climate and Nature Summit for Young People)* organized in Helsinki, Finland, in October. The participants were asked to name knowledge, skills, values, and attitudes they perceived needed by society to mitigate climate change and adapt to it. We used the purposeful sampling technique to ensure information rich cases. We wanted to affect as little as possible the subjects' answers but at the same time reach as in-depth, multi-perspectival and comprehensive view from the young people as possible (Harsh et al., 2011; Patton et al., 2002). The survey consisted of 10 open-ended questions in addition to background questions and it was distributed to 15 to 29 years old participants. The analyzing was done with Atlas.ti (Atlas.ti, 2022). We used code-based analysis for reducing text data into summary categories.

RESULTS

Every feature listed by the participants was coded using, where possible, the exact words of the answers. The analysis resulted into six climate change (CC) competencies (figure 1).

1. **CC Systems Thinking** - *i.e., Understanding the climate system, the society, effects of actions, ability to discuss the climate system*
2. **Science Literacy** - *i.e., Orientation to seek scientific information, critical information literacy, curiosity as a learner*
3. **CC Leadership** - *i.e., Understanding the realistic solution possibilities, ability to make quick and rational decisions, skills of performing, ambition*
4. **CC Justice and Collaboration** - *i.e., Understanding and aiming for equality, equity, and justice, ability to cooperate and work in collaboration*

5. **Implementation** - *i.e., Understands society's ability to change, able to put action into practice, willingness to end unsustainable practices*
6. **Well-Being** - *i.e., Ability and knowledge on how to take care of one's well-being (mentally and physically) in a changing climate and uncertainty, values one's and other's limits*

Figure 1. Flower illustration of climate change competencies.

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Nitrogen Cycling Microbial Communities in Vegetated Landscapes: Insights from Temperate to Sub-Arctic Zones

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Nitrous oxide (N_2O) is a strong greenhouse gas and it plays key role in the nitrogen cycling. Understanding the microbial communities responsible for N_2O metabolism within the above-ground vegetation in the terrestrial ecosystems is crucial for comprehending the regional and global potential of microbes on the N_2O dynamics. This study investigates the distribution and diversity of nitrogen metabolizing microbes within above-ground vegetation along transect-spanning from temperate to sub-arctic regions. We also conducted tree stem N_2O concentration and flux measurements on the tree stem to understand how N_2O is either emitted or consumed by plants samples. Using probe targeted metagenomic analysis, we studied the composition of microbial communities and abundance of functional genes involved in nitrogen metabolism. To gain further insights into the microbial community structure, we studied the diversity of genes which are sequenced with targeted metagenomic analysis. Our findings reveal shifts in the abundance, diversity, and composition of nitrogen metabolizing microbes as we move from temperate to sub-arctic ecosystems. Through this research, we aim to elucidate the ecological drivers and mechanisms influencing on N_2O emissions and consumption in above-ground vegetation. This is shedding light on the potential impacts of climate change on these vital processes in terrestrial ecosystems across different climatic zones. This knowledge contributes to our broader understanding about greenhouse gas dynamics and can inform strategies for mitigating nitrogen metabolism in the plant tissues.

Climate effects of boreal forests

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Keywords: Boreal forest, Climate change.

INTRODUCTION

Forests cover about a quarter of the ice-free land surface, serve as crucial carbon reservoirs. Changes in forest extent affect the land characteristics, which, in turn, significantly influence the climate through the exchange of energy, water and carbon between the earth and the atmosphere. The replacement of forests with crops and pastures (deforestation), has a strong impact on land surface albedo and transpiration, and leads to carbon losses to the atmosphere, which is a major driver of climate change effects.

Previous model simulation studies on deforestation indicate more global cooling while in observation-based studies tend to show a global warming. For instance Boysen et al, (2020) found a temperature increase over deforested land in the tropics and a cooling over deforested boreal land. Globally the ney effect on annual temperature is less than 0.55°C cooling.

Boreal forests are an important carbon storage, and a warmer climate, along with growing forests, will increase carbon storage in the future. In this study we investigate the impacts of boreal forests on future climate using vegetation and carbon cycle versions of EC-Earth (Döscher et al, 2022).

METHODS

We did simulations for years 2015-2100 with both EC-Earth-Veg and EC-Earth-CC. CTRL-simulations are SSP2-45 simulations starting from historical simulation. In pasture simulations forests between 50°N-90°N were changed to pasture grass. Forests in other regions stay forests. Four ensemble member pairs have done with EC-Earth-Veg, and three with EC-Earth-CC. All results are from ensemble means.

RESULTS

The albodo in the world without boreal forests is larger than with the forests. Boreal forests decrease cloudiness and increase snow amount which affect to the albedo decreasing it. The effect is seen mainly on the boreal region. In EC-Earth-CC the decrease is similar but smaller.

Boreal forests warm the climate according to EC-Earth-Veg (about 0.25°C globally and 0.5–1°C in boreal region). According to EC-Earth-CC the mean changes are smaller (globally about 0.1°C and 0.25–0.75°C in boreal). In Veg simulations boreal forests warm the sea areas more than in CC simulation. The temperature increase is mainly due to albedo changes.

In the Veg simulations the precipitation amount increases globally 5-10 mm/year and in boreal region about 20 mm/year due to boreal forests. In CC simulations the change is smaller.

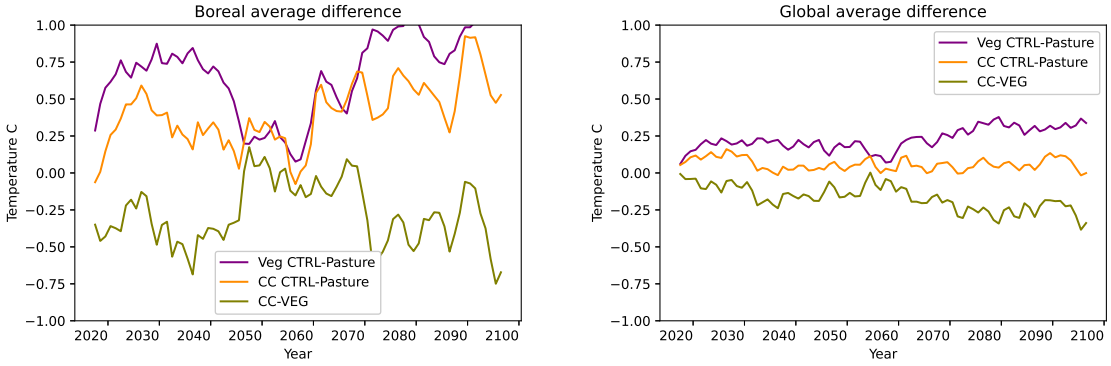

Figure 1: Mean temperature change a) in boreal region, b) globally.

CONCLUSIONS

The world without boreal forests would be about 0.1°C colder than now. Boreal forests warm the climate and increase the precipitation amount in average globally. The change is the largest in the boreal region, but elsewhere there could be also cooling and drying due to boreal forests.

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MEASUREMENTS OF CLOUD MICROPHYSICAL PROPERTIES AT PUIJO STATION

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Keywords: cloud droplets, aerosol-cloud interactions, LWC, MVD

INTRODUCTION

Observations of the spatial and temporal variability of cloud microphysics in varied cloud types are required for estimates of cloud-related climate forcing. Upon a new measurement technique, it is possible to sharpen the determination of microphysical properties of cloud droplets e.g., using high resolving power imaging.

METHODS

Cloud droplet properties and aerosol-cloud interactions have been studied since 2005 at the Puijo measurement site in Kuopio, Finland (e.g., Leskinen *et al.*, 2009, Tiitta *et al.*, 2022). For measuring the cloud droplet properties *in situ* we have used a suite of instruments that measure the cloud droplet number concentration (N_d) and size distribution (DSD), such as a cloud droplet spectrometer (FM-120, Droplet Measurement Technologies) and a holographic imaging instrument (ICEMET, University of Oulu) (e.g. Tiitta *et al*., 2022), as well as a Cloud Droplet Analyzer (CDA, Palas GmbH). Continuous measurements of total and cloud interstitial particle size distributions have been carried out with a Twin-inlet differential mobility particle sizer system (Twin-DMPS, e.g., Portin *et al*., 2012). With the Twin-Inlet system, we have been able to estimate activated particles concentration (N_{act}) as the difference of the number concentrations of the total and cloud interstitial particles during a cloud event.

RESULTS

In this campaign in Puijo, we measured the cloud droplet properties using ICEMET and CDA instruments and compared these results to estimated activated particle concentrations in March-April 2022. During the campaign, several short periods with visibility below 0.2 km at the site were classified as cloud events. During these cloud events, the measured cloud droplet number concentration (CDNC) increased up to about 250 cm^{-3}. The estimated N_{act} concentration, from the Twin-inlet system analysis, was observed to follow closely the variation in the measured CDNC. The median volume diameter (MVD) of the cloud droplets, calculated from the size distributions measured by the ICEMET and the CDA, varied from 5 to 13 µm during the cloud events. CDA observed lower cloud droplet number concentrations than ICEMET but the median volume diameters (MVDs) measured with the different instruments matched quite well with each other during the most intense cloud events.

CONCLUSIONS

The differences in the observed cloud microphysical properties arise from the different detection ranges of the droplets and operating principles including sample losses. The wind wing was used in ICEMET to align the sensor according to the wind direction which minimized sampling losses. Ice crystals cause uncertain measurements by cloud spectrometers such as CDA because they make assumptions about refractive index and droplet shape to predict droplet size from measured optical scattering cross-section.

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WETLAND SITE SIMULATIONS USING JSBACH-HIMMELI

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Keywords: wetland restoration, greenhouse gas fluxes, ecosystem modelling.

INTRODUCTION

Peatlands store large amounts of carbon. Its release and intake through natural and human-influenced processes is measured using various methods on different peatland ecosystems across the globe. Computer simulations of wetlands are needed to complement in-situ measurements of different greenhouse gas (GHG) fluxes from the soil to complete measured timeseries, to help to understand the underlying soil processes, and to spatially upscale and estimate the future climate impact of wetland ecosystems under land use and climate change scenarios. JSBACH-HIMMELI ecosystem model has been previously used to model GHG fluxes of uplands in Finland (Gao et al., 2017; Mäkelä et al., 2020) and peatlands in Europe (Petrescu et al., 2021). Here we simulate a variety of peatland sites across Europe to study their GHG fluxes in pristine, forestry-use and restoration states using two different forcing data. Measured flux values are used to validate model results and to adjust the model parameters.

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 only a 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.

Two types of reanalysis weather data are used to force the model: site-adjusted CRU-JRA data (Harris, 2019) and CERRA data (Schimanke et al., 2021). Precipitation values for CERRA are from CERRA-Land dataset, which uses CERRA forcing and daily measured precipitation for SURFEX V8.1 land surface model (Soci et al., 2016). The measurements include chamber and eddy covariance measurements of GHG fluxes and WT level, but the availability and the length of measurements varies between the sites.

RESULTS

The simulation has been run for 24 pristine, 1 managed forest and 7 restored peatland sites across Europe. The results show that the simulated Net Ecosystem Exchange (NEE), Gross Primary Productivity (GPP) and methane (CH4) perform well compared to the measured GHG fluxes. To achieve sufficient fluxes, site-specific Leaf Area Index (LAI) needs to be set, and for certain sites the WT needs to be adjusted according to the measurements as it drives the CH4 production. The CERRA and the site-adjusted CRU-JRA forcing data give similar simulation output, although some sites have larger difference.

CONCLUSIONS

The general performance of the JSBACH-HIMMELI model is promising. More adjustments of site-specific parameters are required to further improve the annual balance and seasonal cycle of GHG fluxes. The most important parameter for CO2 balance is the site-specific maximum LAI, which can be obtained from satellite observations to complement the in-situ measured LAI.

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TREES IN HUMAN SURROUNDINGS – FORMATION OF HUMAN-TREE RELATIONSHIPS

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Keywords: BIOPHILIA, HUMAN-NATURE RELATIONSHIP, NATURECULTURE, NATURE RELATENESS,

INTRODUCTION

Trees are natural objects that carry practical, cultural and spiritual meanings to humans. Trees are an elemental part of human daily life, both in urban and rural environments, and even in locations where forests are distant. Conflicts related to the removal of trees in close environments of humans indicate that individual trees may be of special significance. Despite that, we have little knowledge of the ways these relationships are formed and the meanings they carry.

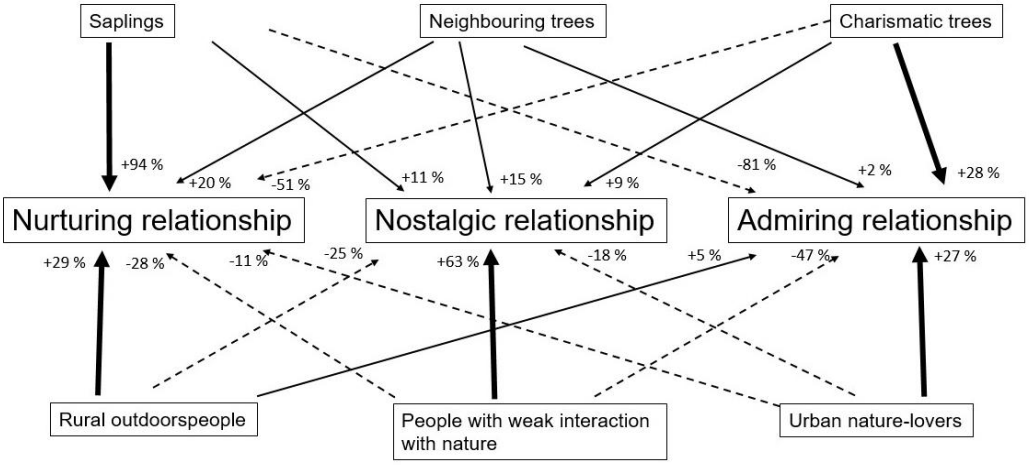
METHODS

To examine how the properties of trees and humans influence the type of relationships that are formed between them, we conducted a large-scale survey in Finland (n = 1758). We used cluster analysis to identify typical groups of trees and human-tree relationships and conducted cross-tabulation to correlate human- and tree-types in the relationships. In studying the human-tree relationship, we applied the framework of natureculture to address how the lives of humans and trees are bound together in interspecies-relationships.

RESULTS

Our results show that the strongest influence on tree-human relationships originates from human lifestyles and nature connections. Consequently, we identified three main types of human-tree relationships: 1) *Admiring relationships* with large, old, and charismatic trees, primarily grounded in sensory and emotional experiences, are common among *urban nature-loving people*. 2) *Nurturing relationships* that occur with young trees in people's own gardens, which is most typical for *rural outdoorspeople* owning houses. 3) *Nostalgic relationships* are linked to trees with symbolic value in the memories of those who no longer have a material connection to their once significant environment. (Figure 1)

Figure 1. Connections between tree, human, and relationship types based on cross-tabulation. Arrows represent connections that were > 24.9 % more common than expected (in bold), > 24.9 % rarer than expected (dashed) and near average values in between (ordinal). These limits do not denote any specific significance level but are sufficiently conservative to be treated as significant differences. Percentages refer to differences from expected frequencies.



CONCLUSIONS

Our study revealed that the affection of humans for trees in their close environment varied strongly in emotional intensity and practical actions related to trees. We provide new knowledge of the correlations between human and tree characteristics in forming their interspecies relationship and how this relationship affects human emotional well-being. Based on our findings, we suggest that understanding human-nature interdependence helps to sustain and create emotionally supportive multispecies environments through green design and management.

In the context of our related further studies, we have found that not only physical and measurable attributes of human and trees influence on human-tree relationships. Qualitative analysis of our data has revealed a variety of ideas, memories, and knowledge, which also have an impact of emotions and actions towards selected special trees. Major environmental issues such as climate change are directly reflected in tree-related preferences and values. Environmental knowledge seems to have an impact on tree appreciation and adds another level to diverse tree relationships. It may also affect the demands and wishes of citizens for the management of green areas and forests. Cutting down a single tree is therefore a multidimensional crisis, equally personal, but also a symbol of the environmental and climate crisis.

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SUBMICRON AEROSOL SIZE DISTRIBUTION IN FRESH EMISSIONS FROM BOREAL AND SAVANNA FIRES

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Keywords: size distribution, biomass burning, savanna, boreal forest.

INTRODUCTION

Landscape fires are among the largest sources of submicron aerosol particles globally, including ca. 40 % of the annual black carbon (BC) emissions (e.g. Andreae 2019). Globally, both savanna and boreal forest fires form a significant fraction of open biomass burning aerosol emissions (Andreae 2019). These emissions impact the climate both directly by scattering and absorbing solar radiation, as well as indirectly by acting as cloud condensation nuclei (CCN). In climate simulations, biomass burning emissions are typically described with one log-normal size distribution (e.g. Carslaw *et al.*, 2013). Here, we investigate the effects of biomass type and combustion process on biomass burning submicron aerosol size distribution using an extensive set of laboratory experiments.

METHODS

Woody and grass biomass from a savanna region in South Africa, as well as boreal forest floor samples (including ground vegetation, litter and soil organic horizon) sourced in Finland were burned at the ILMARI combustion facility in Kuopio, Finland under an open stack mimicking natural burning and dilution. For each fuel type, several experiments were conducted under variable ratio of flaming to smouldering combustion from May to June 2022 totalling 27 burns. Combustion was characterized through modified combustion efficiency (MCE), i.e. $CO_2/(CO_2+CO)$.

The burning emissions were injected into a 29 m^3 environmental chamber and diluted to typical atmospheric concentrations of ca. 5 to 50 µg m^3. Primary emission was characterised by measurements from the chamber before oxidation was initiated either by photooxidation with mainly OH radicals or through dark chemistry with only O_3 added to the chamber. However, here we focus on characterising only the fresh emission before the oxidation. Number size distribution was measured with a TSI scanning mobility particle sizer (SMPS), which was operated with a TSI model 3776 CPC and flow ratio of 0.3 to 3 litres per minute. Size range covered by the SMPS was 14.6 - 685 nm at a time resolution of 3 min. For each experiment, the fresh size distribution was determined as a 30-min average of the SMPS measurements during the period when the sample had fully mixed in the chamber, but oxidation has not yet been initiated.

RESULTS

In Fig. 1, we present size distributions from different experiments with varying combustion characteristics. For flaming combustion (Fig. 1a), size distribution peaks in the Aitken mode size range between 40-70 nm. With decreasing MCE, the peak in size distribution shifts towards larger particles and, for the most smouldering experiments that we carried out (MCE<0.75), the peak of the size distribution exceeds 100 nm (Fig. 1c). At similar MCE, only minor differences appear between the three biomass types (Fig. 1). Notably, one log-normal mode is not enough to describe the size distribution in any of the cases.

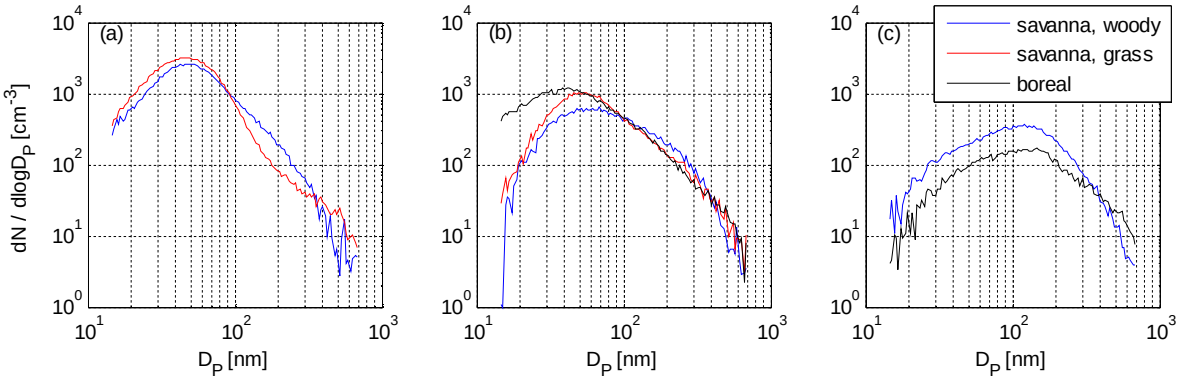

Figure 1. Fresh emission size distributions for three different biomasses and MCE ranges. All size distributions have been normalized to 1 µg m^3 concentration. (a) Flaming-dominated combustion, MCE is 0.950±0.017 and 0.952±0.010 for woody and grass biomass from savanna, respectively. (b) Mostly smouldering combustion with MCE ranging from 0.83 to 0.86. In (b), savanna grass is the median of two experiments. (c) Smouldering combustion with MCE ranging from 0.59 to 0.75. In (c) woody savanna is the median of two and boreal forest floor the median of three experiments.

CONCLUSIONS

Our experiments suggest that combustion characteristics described by MCE have a larger effect on the size distribution of primary particles than the type of biomass in the fire. Furthermore, one log-normal mode cannot capture both the number and the mass of the size distribution, which needs to be considered when mass emissions are converted into number size distribution in simulations (e.g. Carslaw *et al.*, 2013).

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THE IMPACT OF SERIAL CYCLONE CLUSTERING ON EXTREMELY HIGH SEA LEVELS IN THE BALTIC SEA

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Keywords: Serial Cyclone Clustering, Extratropical Cyclones, High Sea Levels, Baltic Sea.

INTRODUCTION

Extremely high sea levels in the Baltic Sea and the resulting coastal flooding events are typically caused by the passage of extratropical cyclones (ETCs). ETCs raise the sea level by their strong winds and low atmospheric pressure.

Individual ETCs have been studied in the context of extreme sea levels in the Baltic Sea (e.g. Soomere et al., 2008), but less attention has been paid to the serial clustering of ETCs (SCC, the passage of multiple cyclones within a short period of time (Dacre & Pinto, 2020)). In particular, little research has been done on whether extremely high sea level events in the Baltic Sea are typically caused by just one extreme ETC or by the combined effect of several consecutive ETCs. Nevertheless, previous research suggests that extreme sea levels are not solely the result of a single, powerful ETC, but may require a series of ETCs to reach peak levels (Post & Kõuts, 2014; Soomere & Pindsoo, 2016; Suursaar et al., 2018).

In this study, the role of SCC for the extreme sea levels in the Baltic Sea is investigated. Specifically, the question we seek to address is whether extreme sea level events are generally induced by isolated, singular ETCs or are the outcome of the cumulative effects of several successive ETCs. Additionally, we also aim to assess how the intensity of cyclones within a cluster affects the magnitude of sea level anomalies.

METHODS

We use objectively determined cyclone tracks from ERA5 reanalysis and sea level observations from four tide gauges: Kemi (Finland), Helsinki (Finland), Pärnu (Estonia) and Riga (Latvia). All ETCs from the October-March period in 1980-2019 that pass within 700 km of the tide gauge are included in the analysis. Clustering and non-clustering days are defined as days when the 7-day running sum of ETCs is ≥ 3 and 1, respectively. Then, SCC and single cyclone periods are defined by adding ± 1 day to the dates of the first and last ETC around the clustering and non-clustering days.

Hourly sea level data from tide gauges in Finland, Sweden, and Estonia from 1980–2022 were detrended to account for post-glacial uplifting and analyzed to study the effects of ETCs on short-term and weekly-scale sea level components. Extreme sea level events were defined by local 98th percentiles and analyzed alongside composite sea level anomalies around each SCC onset date.

RESULTS

We find that SCC periods tend to produce on average 30 cm higher sea level than the climatology at the tide gauges, and about six days after the SCC onset dates. In addition, the daily maximum sea level peaks about 40 cm higher during SCC periods than during single cyclone periods. Thus, this result implies that the SCC periods are typically associated with higher sea level than the periods when only one intense ETC passes the tide gauge. However, when we look at the extreme sea level events at the tide gauges, we find that in Helsinki, Pärnu and Riga about 40 % of the events can be attributed to the SCC periods and about 15 % to the periods when only single ETC passes the tide gauge.

Additionally, we find that stronger ETCs, measured by lower mean sea level pressure (MSLP), strongly correlate with higher sea levels. This relationship is especially notable in clustered cyclone events (SCCs).

CONCLUSIONS

Our results demonstrate that serial cyclone clustering is an important phenomenon for the occurrence of extreme sea levels in the Baltic Sea, and in fact relatively few extreme sea levels and the associated coastal flooding events in the Baltic Sea are caused by only one single ETC. More intense ETCs tend to enhance the risk of high sea levels, specifically if stronger ETCs occur in a cluster.

ACKNOWLEDGEMENTS

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DOWNSCALING THE AEROSOL SIZE DISTRIBUTIONS OF A GLOBAL CLIMATE MODEL USING MACHINE LEARNING

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Keywords: machine learning, climate model, air quality, aerosol size distribution.

INTRODUCTION

The accuracy of coarse resolution models can be improved by determining and utilizing the statistical dependency between the models' outputs and in-situ measurements. This procedure, typically performed using methods such as linear regression, is known as statistical downscaling. In recent years, machine learning (ML) methods have surpassed traditional regression methods in numerous applications, and they have also been succesfully applied to downscaling. In this study, aerosol size distributions simulated by a global climate model were downscaled towards measurements from two locations by various ML methods. ECHAM6.3–HAM2.3–MOZ1.0, a global aerosol-climate model, was selected for this purpose (Schultz *et al.*, 2018; Tegen *et al.*, 2019). Size distribution was chosen as the target to be downscaled, as this enables us to analyze the capability of the methods separately in different particle size ranges. Ultimately, downscaling the global scale simulations of aerosol size distribution could offer a computationally efficient way to expand past air quality records for use in epidemiologic studies. Additionally, this would enable local air quality to be studied simultaneously with larger scale atmospheric processes.

MATERIALS AND METHODS

In this study, the aerosol size distribution was represented by three modes: nucleation mode ($<$ 7.7 nm), Aitken mode (7.7 - 50 nm) and accumulation mode (50 - 700 nm). Measurements of particle number concentration (PNC) from two locations, urban Leipzig and rural Melpitz in Germany, were categorized into these modes (see Leinonen *et. al* (2022)) which then served as target variables for ML. The downscaling was applied to all available modes from both locations, resulting in five datasets in total, as Leipzig's nucleation mode was not available. The datasets were each comprised of three years (2016–2018) of daily-averaged values. ECHAM-HAMMOZ, combined with the SALSA2.0 aerosol module (Kokkola *et al.*, 2018), was utilized to produce three years of simulation data. Over 100 output variables from ECHAM-HAMMOZ were considered as potential inputs to the ML models. Through a data-driven feature selection procedure, this number was reduced to about 20, depending on the dataset. Each complete dataset, containing both the inputs and targets of ML, was split into three one-year subsets: ML models were fitted on the training data (2016), their hyperparameters optimized using validation data (2017) and their performance evaluated on test data (2018). Six statistical methods were selected for the comparison, of which five were ML methods: Random Forest (RF), XGBoost, neural network, support vector machine (SVM) and Gaussian process regression. The sixth method was a generalized linear model (GLM), which is a relatively simple regression method.

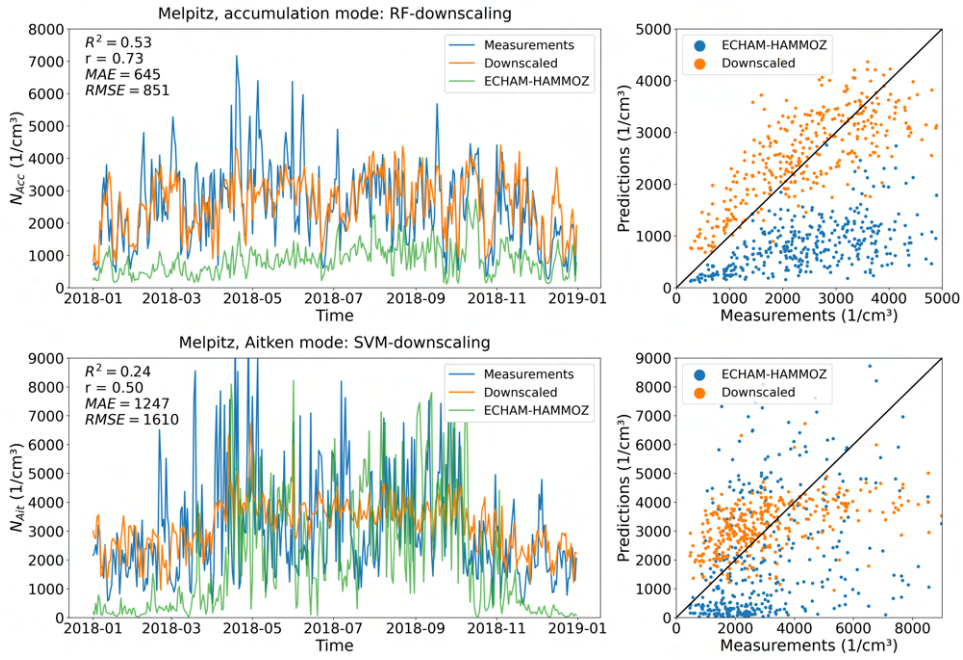

Figure 1: Results of the downscaling for accumulation and Aitken modes from Melpitz. The performance metrics between measurements and downscaled data are indicated in the upper left corner. The 1:1 line is shown in black. Only the results of the best performing ML methods are shown for each dataset.

Figure 1 shows that ECHAM-HAMMOZ consistently underestimates the accumulation mode PNC in Melpitz, while Aitken mode PNC is underestimated especially in wintertime. A clear improvement due to downscaling can be seen in both examples. Results for Leipzig are similar, although less successful overall. All six statistical methods were capable of improving the PNC estimates, although their performance varied considerably across the five datasets. The ML methods were mostly, though not always, more accurate than the simpler GLM method. Overall, we found that ML methods can be successfully utilized for reducing the local error of global-scale models.

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BLACK AND BROWN CARBON IN THE ATMOSPHERE AND THE CRYOSPHERE (BBRCAC)

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Keywords: Black Carbon, Brown Carbon, Absorption, Radiative Forcing, Emissions

INTRODUCTION

Incomplete combustion of organic fuels results in emission of light-absorbing carbon (LAC) particles that contain both black carbon (BC), which has the strongest visible light absorption per unit mass and brown carbon (BrC). Globally, BC has been estimated to be the second most important climate warming pollutant after carbon dioxide. The climate effects of BC depend significantly on the mixing state and atmospheric aging by coating with secondary components induces BC absorption enhancement. BrC, on the other hand, is light-absorbing organic matter in atmospheric aerosols of various origins. BrC comprises a wide range of poorly characterized compounds that exhibit highly variable absorptivities, with reported values spanning two orders of magnitude. Due to its significance the research on BrC has been very active during the previous two decades as is shown by review articles (e.g., Laskin et al., 2015; Yan etal., 2018). However, emission data for e.g global scale models are currently missing BrC as a compound.

The main objective of the BBrCAC project is to estimate the contributions of both BC and BrC to the radiative forcing of climate especially in Finland but also in a wider boreal context. The goals of the measurements are to estimate the contributions of both BC and BrC to light absorption in the uv-vis wavelength range 1) for urban and background aerosols in Finland in the past and at present, 2) in snow and precipitation, and 3) in aerosol emissions from different biomass fuels (e.g. wood, oil, peat). The second goal is to update present emission inventories to also include BrC by using the measured BC and BrC emission factors. The inventories will be used for updating emission scenarios. These will be used for reaching the third goal: estimating the radiative forcing of BC and BrC in selected scenarios. An important specific goal is to obtain detailed information of the optical properties of BC and BrC from peat fires.

BBrCAC is a 4-year project (1.9.2021 – 31.8.2025) funded by the Academy of Finland. The project is carried out by a consortium of four research institutes: Finnish Meteorological Institute, Department of Environmental and Biological Sciences of University of Eastern Finland, Finnish Environment Institute, and Department of Chemistry of University of Helsinki

METHODS

The project consists of seven work packages depicted schematically in Fig. 1. WP1. Long-term atmospheric aerosol filter samples (FMI). WP2. Present-day light-absorbing aerosols (FMI). WP3. Absorption measurements in the aerosol phase (UH-C). WP4. Emission and aging experiments (UEF). WP5. BC & BrC in the cryosphere: snow and ice (FMI). WP6. Emission inventories and scenarios (SYKE). WP7. Radiative forcing of BrC and BC (FMI).

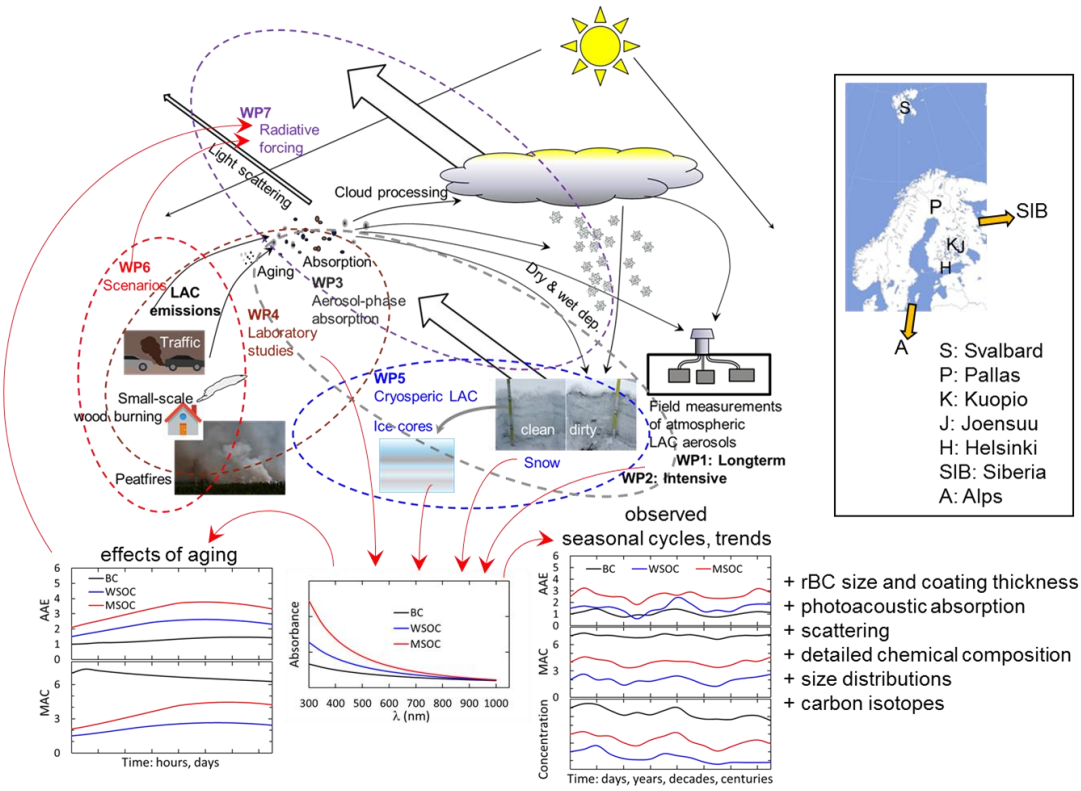

Figure 1. Overview of the contents of the BBrCAC project, its work packages, and the geographical scope.

RESULTS

The BBrCAC project is progressing as planned. WP1. A 50-year long time series of absorption spectra from high-volume filter sample have been measured. Papers will be published. WP2. Measurement campaigns have been conducted, manuscripts submitted. WP3. The photoacoustic absorption spectrometer is ready and published. It will be taken to the aging experiments of WP4. WP4. Chamber experiments have been conducted and BC and BrC emission factors published. New campaign will take place in November 2023. WP5. A large Soot-on-Snow field experiment was conducted in Sodankylä in March-April 2023. Papers have been published. WP6. Emission inventories are being updated using WP4 results as planned. The results of the new WP4 experiments will also be used by WP6. WP7. The EC-EARTH model has been modified as planned. New emission factors from WP6 have not yet been used.

ACKNOWLEDGEMENTS

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A CASE STUDY OF THREE DAMAGING THUNDERSTORMS IN FINLAND IN JUNE 2021

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Keywords: Thunderstorms, wind gusts, reanalysis

INTRODUCTION

Thunderstorms can cause severe impacts to, e.g., forestry, agriculture, infrastructure and aviation safety due to strong wind gusts, severe hail, heavy rain and lightning. Identifying the environments in which damaging thunderstorms occur helps forecast future events. In Finland, the environments of intense mesoscale convective systems and severe-wind producing convective storms have been investigated in a study by Punkka and Bister (2015). They identified the convective parameters that best distinguished intense organized cases from weaker ones, however, the range of values of the parameters was large. Case studies of past high-impact events help understand in more detail the extreme environments and where in the parameter range specific cases reside. In this study, we investigated the environment and convective parameters associated with damaging thunderstorms Ahti, Paula and Aatu that occurred in Finland in 21-23 June 2021. We briefly compare their environments with past cases in Finland.

METHODS

We used ERA5 reanalysis data (Hersbach et al. 2020), surface observations and analyses and radar reflectivity data. Sounding-derived convective parameters were investigated at grid points close to where strong wind gusts were observed roughly one-to-three hours before the arrival of each thunderstorm. The parameters were calculated using the ThundeR rawinsonde package at http://rawinsonde.com/.

RESULTS

The synoptic environment was characterized by an upper-level trough over western Fennoscandia and an upper-level ridge with warm and moist air over eastern Fennoscandia. The preconvective environments showed 1) strong CAPE (most unstable CAPE was over 1800 J kg^{-1}), 2) moist air near the surface (mixing ratio in the lowest 0.5 km layer was over 12.2 g kg^{-1}) and 3) lapse rate over 6.2 K km^{-1} in the 850-500 hPa layer. The 0-6 km bulk wind shear and mean wind speed were moderate-to-strong (over 13.4 m s^{-1} and 10.5 m s^{-1}, respectively). Additionally, surface observations showed wind gusts exceeding 27 m s^{-1}. However, the observed maximum wind gusts most likely underestimate the true maximum wind gusts. This is because the thunderstorms, especially Paula, impacted regions of North Ostrobothnia and Kainuu where the observation network is coarse and, therefore, the strongest gusts may not have been detected. Subsequently, a total of 4 million m^3 of forest fell in those areas (Finnish Forest Centre, 2022).

CONCLUSIONS

The large-scale weather pattern resembled the mean weather pattern associated with intense lightning days in Finland (Virman et al., 2022). Convective parameters calculated from ERA5 soundings before the arrival of Ahti, Paula and Aatu where somewhat different from each other. Nevertheless, CAPE, wind shear and low-level mixing ratios were within the strongest 50% or 25% of severe-wind producing convective storms observed previously in Finland in the study of Punkka and Bister (2015). Further analyses of numerous past events are needed to identify in more detail the environments in which different damaging thunderstorms occur. Besides the better understanding of convective wind climate of Finland, this would help forecasting

future events and assessing their past and future climate trends. However, lack of observational datasets makes detecting and learning from past events difficult, which was also the case in this study.

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). While electrification of transportation is progressing, it is not happening fast enough to meet emission reduction targets. To mitigate emissions, various technological solutions are being implemented, such as the use of hybrid engines to reduce fuel consumption and the use of renewable fuels to avoid burning fossil fuels in combustion engines. The aim of using renewable fuels is to burn fast-carbon-storing materials like plants or waste to emit only CO_2 that was recently removed from the atmosphere, compared to fossil materials that cannot be replaced on a reasonable timescale.

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, meaning 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 is used. The engine was run in various operating conditions, including stable operation points, the RMC-C1 cycle, cold starts and hot starts.

Various instruments were used to measure emissions, including an FTIR for trace gases (CO_2, H_2O, CO, CH_4, N_2O, NO, NO_2, SO_2), a microsoot sensor for particle mass concentration, a condensation particle counter for particle number concentration, an engine exhaust particle sizer for particle size distribution, a trace gas analyzer for CO_2 and H_2O, as well as a Vocus PTR mass spectrometer for volatile organic compounds (VOCs).

RESULTS

Emissions from both fuels differ significantly. During stable engine operation, the renewable fuel yielded approximately a 30% reduction in particle emissions. Furthermore, the renewable fuel showed 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 increased rapidly during engine transition states to a higher 10^7 cm^{-3} range. During stable operation points, mostly a single mode of 45 nm was observed, but concentration did not settle to constant values. Trace gases levelled 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.

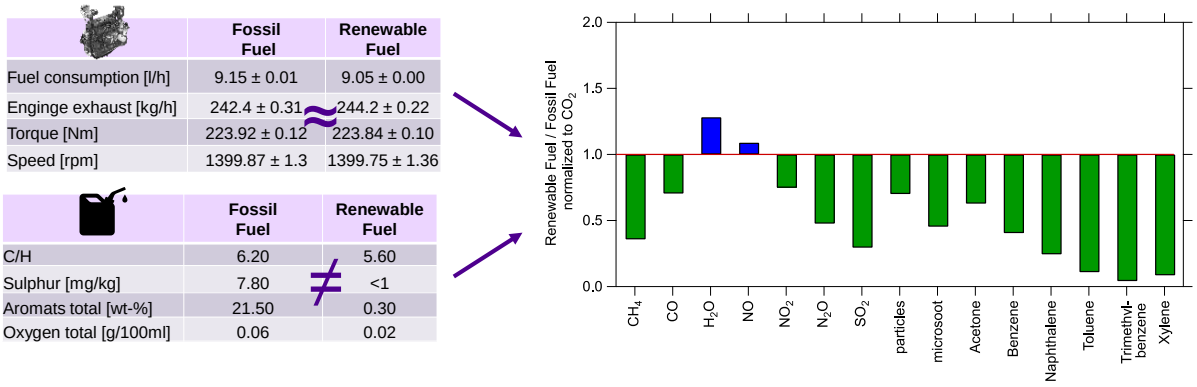

Figure 1. Emission factor comparison for steady state motor operation: Values <1 indicate lower emissions from renewable fuel compared to fossil fuel.

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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Deliquescence at very low temperatures determined from homogeneous freezing experiments

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Keywords: Deliquescence, homogeneous ice nucleation, cirrus clouds.

INTRODUCTION

We present experimental evidence for a novel approach to determine the deliquescence relative humidity (DRH) at low temperatures. Deliquescence is the process by which crystalline salts absorb water to form a saturated solution. Due to decreasing solubility towards low temperatures, DRH increases. At temperatures below 233 K, solution droplets can freeze homogeneously. When comparing measured conditions of homogeneous freezing to calculated ones (Koop, 2000) using the equilibrium solution droplet size, the conditions might differ. A deviation towards higher relative humidity indicates that the salt particles have not reached their DRH below the homogeneous freezing line and the new freezing condition marks the deliquescence point.
Low temperature deliquescence of salts has an impact on, for example, cirrus cloud formation and on rock weathering in the polar region and in the martian environment.

METHODS

Homogeneous freezing data from salts without any heterogeneous ice nucleation ability are used for the analysis. Ice nucleation experiments are conducted using a modified version of the SPectrometer for Ice Nucleation (SPIN) chamber (Welti, 2020) capable of exposing test particles to temperatures down to 208 K and variable humidity. Particles are prepared using a combination of atomizer, dryer, and size selection with a differential mobility analyzer. Salt particles introduced into the SPIN chamber absorb water and equilibrate to the thermodynamic conditions inside the chamber. Freezing is detected optically after a residence time of 10 s from the growth of ice crystals. 20 and 200 nm sized dry particles of several salts are used. The two sizes allow to extend the detectable DRH due to the Kelvin effect, shifting the deliquescence point of small particles (< 100 nm) to higher relative humidity than of larger ones. Exemplary results of experiments on homogeneous ice nucleation with 200 nm $(NH_4)_2SO_4$ particles are shown in Fig. 1(a) in terms of 1% ice activated fraction (AF) points. The measurements where homogeneous freezing conditions indicate the DRH of $(NH_4)_2SO_4$ together with DRH data from literature are shown in Fig. 1(b).

CONCLUSIONS

The deliquescence points of various salts has been detected at very low temperatures with a new approach. The measurements extend the available data-set of temperature dependent DRH by several tens of Kelvin for the tested salts, for most of which measurements are only available down to 273 K. The gained knowledge on the temperature dependence of the DRH helps the interpretation of homogeneous ice nucleation experiments, to evaluate the conditions at which different salts can

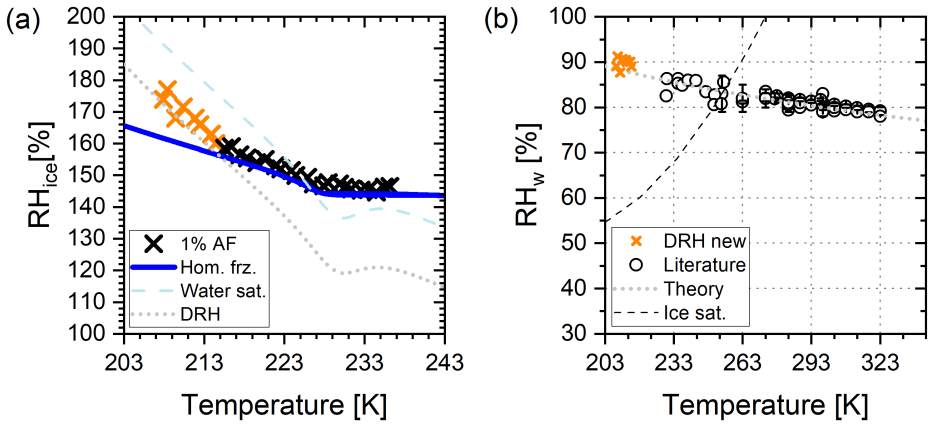

Figure 1: (a) Crosses indicate measured conditions (RH_{ice}, temperature) at which 1% of 200 nm $(NH_4)_2SO_4$ particles form solution droplets that freeze homogeneously. For comparison, the homogeneous freezing conditions of solution droplets in equilibrium, predicted using the Koop *et al.* (2000) framework with the water saturation line from Holten *et al.* (2012) are shown. Orange crosses highlight measurements diverging from the prediction. Calculated DRH conditions (Seinfeld and Pandis, 2006) are shown as dotted line. (b) Comparison of diverging freezing conditions (orange crosses) to DRH from literature and theory.

cause homogeneous ice nucleation in high-altitude cirrus clouds, and to analyse the extend of microscopic brine formation via deliquescence under extreme conditions.

ACKNOWLEDGEMENTS

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UPDATE OF SMEAR IV PUIJO TOWER MEASUREMENT FACILITIES FOR ACTRIS MEASUREMENT NETWORK

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Keywords: ACTRIS, Measurement station, monitoring

INTRODUCTION

Puijo SMEAR IV is semi-urban aerosol and air quality measurement station situated at top of Puijo Observatory Tower, Kuopio, Finland, operated co-jointly by University of Eastern Finland and Finnish Meteorological Institute (see website). 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). 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 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 needs to be updated.

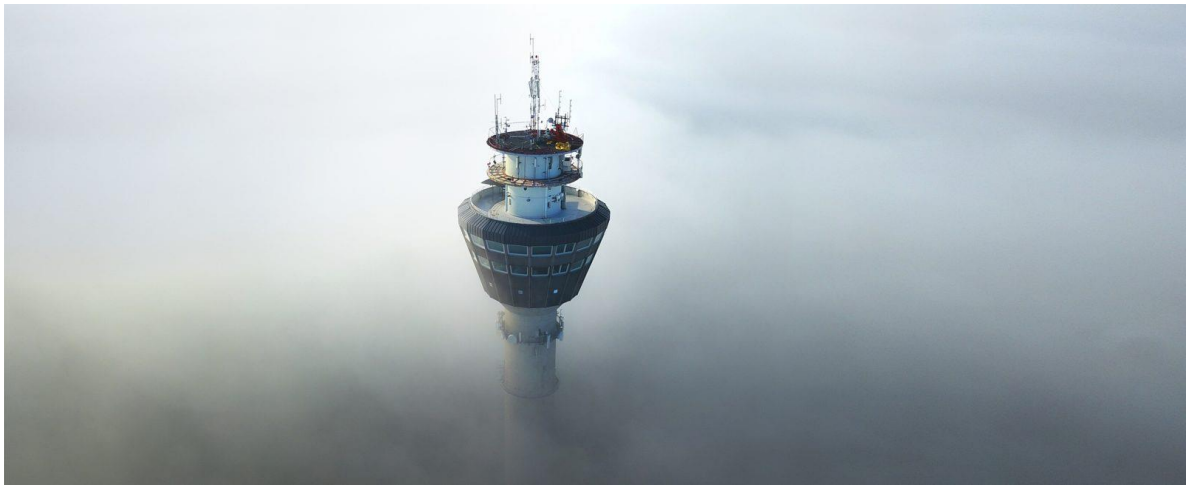

Figure 1. Puijo tower inside low-level clouds.

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).

As the station accompanies two separate inlet lines, aerosol parameters mentioned above are measured from total air inlet. Instrumentation connected to 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 not planned to be uploaded to ACTRIS database but is available upon request.

Additional modifications to the current measurement station infrastructure is renovation of the aerosol sampling lines. New sampling lines will be constructed which will be more vertical and shorter than previous ones. Aerosol sample flows will be dried with nafion dryers and additional RH and temperature monitoring will be added to sample lines. The cut-off size of interstitial line will be increased to PM 2 µm (currently PM 1 µm).

The instruments delivering data to ACTRIS database will be located in single cabinet, which will be closed and temperature controlled.

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.

ACKNOWLEDGEMENTS

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LONG-TERM AEROSOL MASS CONCENTRATIONS IN SOUTHERN FINLAND

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Keywords: Particulate mass, Long-term trends, Aerosol, Emission.

INTRODUCTION

Particulate mass (PM) has been widely measured due to the impacts of aerosol particles on air quality and human health. Yearly, millions of deaths are caused by poor air quality. Legislation on emissions of particles and different trace gases leading to secondary formation of aerosol particles have been tightened to improve air quality (WHO, 2021). In this work, we show the long-term trends of different PM classes from SMEAR II (Station for Measuring Ecosystem–Atmosphere Relations) using three different methods and give insights into the sources of observed pollution episodes.

METHODS

PM concentrations has been measured at SMEAR II with two direct methods: cascade impactor measuring PM10, PM2.5 and PM1 concentrations and Synchronized Hybrid Ambient Real-time Particulate Monitor (SHARP) measuring real-time PM10 concentration. Indirectly the PM mass concentrations can be retrieved from aerosol number size distribution when assuming that particles have spherical shape and constant density of 1.5 g cm^{-3} (Saarikoski *et al.*, 2005). We combine DMPS (Differential Mobility Particle Sizer) and APS (Aerosol Particle Sizer) measurements to cover size ranges needed for PM1, PM2.5 and PM10 (Aalto *et al.*, 2001).

RESULTS

Our results show that the three methods correlate well, the correlation coefficients exceeding 0.8 for all other methods except between SHARP and impactor (0.74). The impactor method seems to give more often higher concentrations compared to the other two methods, leading to scatter in data points. Impactor measurements are sensitive to any disturbances in the weighing procedure, which might explain the scatter. Impactor is, however, the only method measuring directly the mass of particles at SMEAR II.

The PM mass concentrations are decreasing in all size classes and in all seasons. However, the decrease is fastest in spring and winter, and slowest in summer and autumn. In summertime in boreal region the organic compounds from the forest make up a large fraction of the aerosol mass (Heikkinen *et al.*, 2020). Hence, in summer the PM concentrations are less depended on anthropogenic pollution and therefore only slight decrease is detected.

Because the overall PM levels in Hyytiälä are low, certain pollution episodes are more easy to detect. For example, in 2006 and 2010 pollution from forest fires in eastern Europe reached Hyytiälä increasing the PM concentrations (Heikkinen *et al.*, 2020). Winters 2010 and 2012 were colder than

average, and the PM concentrations peaked during those years. Simultaneously, SO_2 concentration also peaked, implying that anthropogenic pollution due to heating is likely affecting the observed PM concentrations.

CONCLUSIONS

Long-term measurements show that even in remote areas the air quality is improving. Long-term measurement ensure detection of trends but also different kind of pollution episodes. Utilizing air mass back-trajectory techniques, we can further analyze the source areas of observed pollution episodes.

ACKNOWLEDGEMENTS

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THE COMPARISON STUDY ON AIR IONS IN BOREAL FOREST OF FINLAND AND MEGACITY OF EAST 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). 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.

METHODS

In this work, all the measurements used for the comparison in SMEAR II and SORPES sites were conducted during a year period between 7 June 2019 to 31 August 2020. The SMEAR II station (61°51′N, 24°70′E, 181 m ASL) is located in Hyytiälä, southern Finland. This station is a boreal forest site in a pristine rural environment. SMEAR II site has carried out the world's longest, continuous measurements of aerosol particle-number concentration and size distribution since 1996. More details about the site are described by Hari et al. (2013). The SORPES station (32°70 ′N, 118°57′E, 40 m ASL) is located about 20 km east of downtown Nanjing in eastern China. With few local emission sources within 2−3 km surrounding, the station is located in a suburban environment. 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. Detailed site description is presented by Ding et al. (2016). Ambient air ion size distribution data employed in this study were all measured by Neutral Cluster and Air Ion Spectrometer (Mirme and Mirme, 2013) in SMEAR II and SORPES at the ground level. The mobility range of NAIS is 2.4−0.001 $cm^2\ V^{-1}s^{-1}$, equivalent to 0.8-47 nm of mobility diameter range.

CONCLUSIONS

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}). The NPF events occurred more frequently at SORPES site, and the highest values of NPF frequency at both

sites were in spring. During the noon time on NPF event day, the concentration of intermediate ions were 8-14 times higher than same hours on non-event days, indicating that can be used as an indicator for NPF. At 2 nm, the formation rate of charged particles was only 16% and 3% of the total rate at SMEAR II and SORPES respectively, which supports the current view that neutral ways dominate the new particle process in continental boundary. However, higher ratio between charged and total formation rate of 2 nm particle at SMEAR II indicates ion-induced nucleation can have a bigger contribution to NPF in clear area in comparison to polluted area.

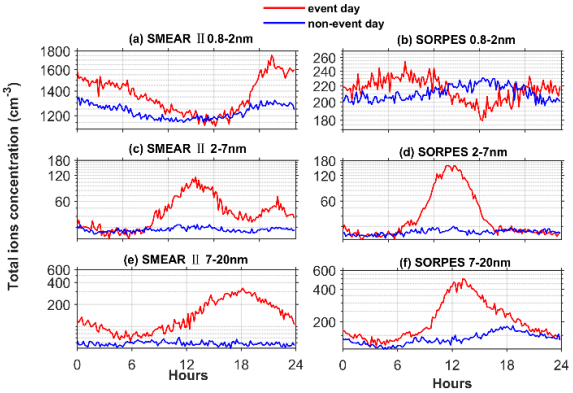

Figure 1. Median diurnal cycles for total ion concentrations at SMEAR II and SORPES in three size ranges from June 2019 to August 2020, separated by days with and without new particle formation (event/non-event dyas). (a-b) Cluster ions: 0.8-2 nm. (c-d) Intermediate ions: 2-7 nm (e-f) Large ions: 7-20 nm.

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RELATIONSHIP BETWEEN H_2SO_4-NH_3 CLUSTERS AND LOCAL NPF EVENTS AT AN AGRICULTURAL SITE IN VIIKKI, FINLAND

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Keywords: Agricultural site, H_2SO_4-NH_3 clusters, Local new particle formation.

INTRODUCTION

The Northern agricultural ecosystem and agricultural activities play a crucial role in atmospheric chemistry and climate regulation. Agricultural activities release volatile organic compounds (VOCs) and ammonia (NH_3), among other species, which can react in the atmosphere to form new molecules and/or clusters that can grow to new particles. This new particle formation (NPF) can subsequently exert significant impact on the production of cloud condensation nuclei (CCN) and, thus, the regulation of atmospheric temperature.

This interplay operates not only on a local scale but also holds implications for global climate. As global temperatures continue to rise, the influence of agricultural ecosystems and activities will undergo shifts. Therefore, gaining a comprehensive understanding of the impact of northern agricultural ecosystems and agricultural activities on atmospheric chemistry and climate is of paramount importance for a holistic comprehension of the mechanisms driving climate change and for implementing corresponding regulatory measures.

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 negative ions in the range 0.8–42 nm were measured using a neutral cluster and air ion spectrometer (NAIS; Airel Ltd) (Mirme and Mirme, 2013; Manninen *et al*., 2016).

RESULTS

In the period of April to May 2023, we observed H_2SO_4 and NH_3 clusters at our research site. The clusters (such as $(H_2SO_4)_3(NH_3)HSO_4^-$, $(H_2SO_4)_4(NH_3)HSO_4^-$, $(H_2SO_4)_4(NH_3)_2HSO_4^-$) exhibited distinct diurnal variations, with higher concentrations during the day and lower concentrations at night. Tuovinen *et al*. (2023) 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 and NH_3 clusters and 2.16 size bin negative ions and found a linear correlation ($r = 0.68$), indicating that H_2SO_4-NH_3 clusters very likely contributes to the local NPF events at the Viikki station.

The application of fertilizers leads to increased NH_3 emissions, resulting in stronger local NPF events after fertilization. In the northern agricultural environment, such as the Viikki site, temperature variations are likely to exert a greater influence. Changes in temperature affect the release of biogenic VOCs and the formation of HOMs. We observed no clear relationship between HOMs variations and NPF events.

CONCLUSIONS

In the months of April to May 2023, we observed a significant relationship between H_2SO_4-NH_3 clusters and local NPF events. The correlation between H_2SO_4-NH_3 clusters and local NPF events emphasizes the need for further investigation into the interactions between agricultural activities and atmospheric processes. Particularly noting the impact of fertilizer application. There is an important role of the fertilization process on NPF at the Viikki agricultural site. Additionally, situated in a northern agricultural region, our findings highlight the sensitivity of this area to temperature variations, providing insights for future research.

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PHOTOCHEMICAL REFLECTANCE INDEX TO INVESTIGATE SHOOT BIOGENIC VOLATILE ORGANIC COMPOUND EMISSIONS FROM SCOTS PINE AND ENGLISH OAK SAPLINGS IN RESPONSE TO WARMING

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Keywords: Carotenoids, Isoprene, Monoterpenes, Photosynthesis, PRI, Xanthophyll pigments

INTRODUCTION

Accurate quantification of long-term emissions of biogenic volatile organic compounds (BVOCs) is essential for understanding biosphere-atmosphere feedbacks due to their key roles in atmospheric chemistry. However, proper tools for observing BVOC emissions at large scales are still missing. Remote sensing of optical signals such as photochemical reflectance index (PRI) are promising solutions to fill the spatial knowledge gap (Peñuelas et al., 2015). We hypothesize that the carotenoid-related vegetation index such as PRI is a promising way to investigate plant emitted BVOCs.

The PRI measures short-term changes of xanthophyll pigments, long-term changes of carotenoid/chlorophyll ratios and photosynthetic light use efficiency (Porcar-Castell et al. 2012; Zhang et al., 2016). These carotenoids and most (isoprene) and second (monoterpenes) abundant plant BVOCs are produced from the same precursor via the same pathway (Peñuelas et al., 2015). Biosynthesizing BVOCs has also been hypothesized to co-vary with xanthophyll cycle for releasing excess energy absorbed by the photosystem when plants suffer from stresses (Peñuelas et al., 2015). Thus, PRI and BVOC emissions have a close functional link. However, it is still not clear what leaf-level factors (e.g., carotenoids, xanthophyll pigments, etc.) control the relationships between optical signals and BVOC emissions under warming stress conditions.

We conducted a leaf-level experiment in greenhouse in the summer of 2022 to investigate how the relationships between PRI and BVOC emissions in response to mild or extreme heat stresses in Scots pine and English oak saplings during the peak of growing season. We would like to answer the questions (1) what factors control the relationships between PRI and BVOC emissions in response to warming stresses; (2) whether these controlling factors will be different between vegetation species or BVOC emission types; and (3) whether PRI can capture the changes of BVOC emissions in response to warming stress.

METHODS

The experiment was conducted in the greenhouse of Viikki campus in the University of Helsinki from July 20 to Sep 9th. 12 three-years old *Pinus sylvestris* (Scots pine) and 12 four-years old *Quercus robur* (English oak) with a height of 50 to 70 cm were started to grow in greenhouse from middle of May 2022 so that they could acclimate to the greenhouse environment before the experiment in August. During the experiment, 4 saplings of each species were grown in climate chamber under room temperature (25 °C), mild (35 °C) or extreme heat (40 °C) treatment for around 4 hours in the morning respectively. Before the experiment, saplings in each treatment were grown in growth chamber around 24 hours under room temperature to adapt growing environment in growth chamber. All the measurements were conducted from 13:00 to 17:00. All the leaf level measurements for pine were focused on the one-year-old needles

and for oak were focused on the fully developed mature and healthy leaves. To avoid the effects of young leaves / needles on BVOC emissions, we removed all the new buds from the BVOC measurement shoots one month ago before the start of the measurement to ensure that the wound can be healed completely.

RESULTS

For Scots pine, PRI and LUE (light use efficiency) decreased as the increase in temperature (Fig. 1A and B). In the contrary, de-epoxidation state of xanthophyll cycle pigments (DEPS) and isoprene and monoterpene emission rates increased along with the increase in temperature (Fig. 1 C-E). For English oak, PRI, LUE and DEPS only respond to extreme heat: either decreased (PRI and LUE) or increased (DEPS). Whereas, both isoprene and monoterpene emission rates increased in response to mild heat stress. These results suggest that PRI has a potential to detect isoprene and monoterpene emissions in response to warming stress for Scots pine and probably DEPS was one important factor to control their correlations. However, for English oak, the temperature threshold of changes in PRI and BVOC emissions seems different, but PRI still has a potential to track changes in isoprene and monoterpene emissions in response to heat stress.

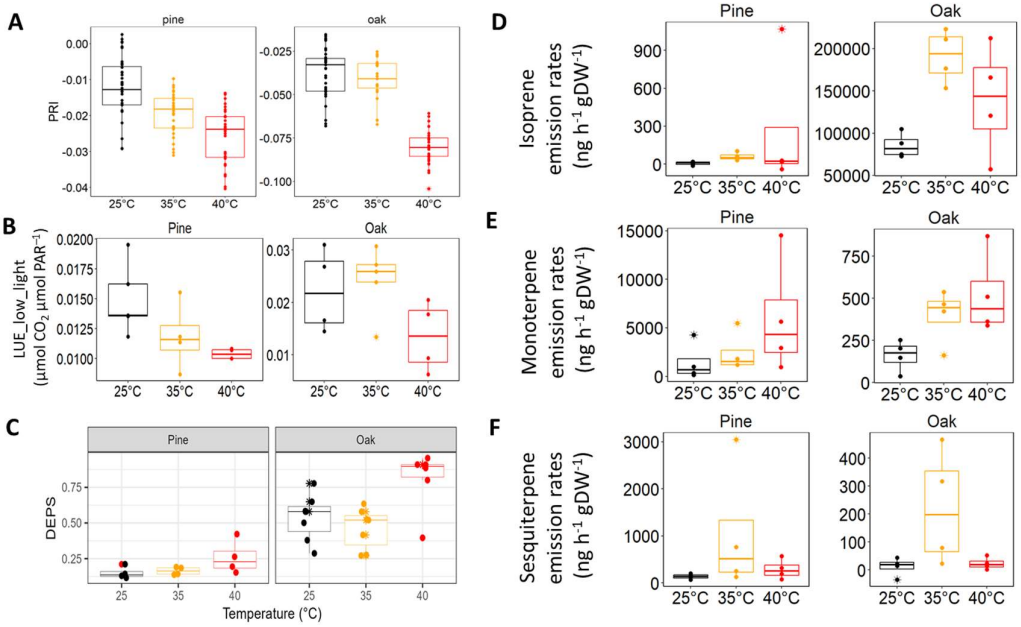

Figure 1. Photochemical reflectance index (PRI; A) and light use efficiency under low light (LUE_low light; B), de-eposition state of xanthophyll cycle pigments (DEPS; C), and isoprene (D), total monoterpene (E) and total sequesterpene emission rates (F) in response to warming stress

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SIMULATING THE DUST EMISSIONS AND SOA FORMATION OVER NORTHERN AFRICA DURING THE MID-HOLOCENE GREEN SAHARA PERIOD

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Keywords: TM5-MP, BVOC, SOA, Mid-Holocene, Green Sahara

INTRODUCTION

A Green Sahara, instead of present desert Sahara, existed in North Africa (NA) during the early- to Mid-Holocene (MH) from 11000 to 5000 years before present as suggested by comprehensive paleoproxy data and studies (e.g., Hély *et al.* (2014)). The higher summer insolation in the Northern Hemisphere intensified the West African Monsoon (WAM), leading to increased rainfall across NA. More vegetation grew and more lakes appeared, which reduced dust emissions, and enhanced WAM and precipitation (Pausata *et al.* (2016)). Vegetation also emits biogenic volatile organic compounds (BVOCs) (Guenther *et al.* (2012)), which can be oxidized to form secondary organic aerosol (SOA), impacting radiative forcing. In this study, based on the vegetation simulation result from Lu *et al.* (2018), we applied the chemical transport model to provide the comprehensive datasets of BVOC emissions, dust emissions and SOA formation in NA (Zhou *et al.* (2023)).

METHODS

The global chemical transport model TM5-MP (Tracer Model 5, Massively Parallel version) was applied with prescribed vegetation cover data from LPJ-GUESS simulations of pre-industrial (PI) and MH periods in Lu *et al.* (2018).

CONCLUSIONS

Our result shows that dust emissions reduced from 280.6 Tg a^{-1} in the PI to 26.8 Tg a^{-1} in the MH. The northward vegetation expansion in NA resulted in an increase in annual emissions of isoprene and monoterpenes during the MH, around 4.3 and 3.5 times higher than that in the PI period, respectively, causing 1.9 times increase in the SOA surface concentration (Fig. 1). Enhanced BVOC emissions and reduced dust emissions altogether lead to a 17% increase in the cloud condensation

nuclei at 0.2% super saturation over NA. Our simulations provide consistent datasets of BVOC emissions, dust emissions, and SOA formation aligned with the northward vegetation shift during the "Green Sahara" period, which could serve as a benchmark for MH aerosol input in future simulation experiments.

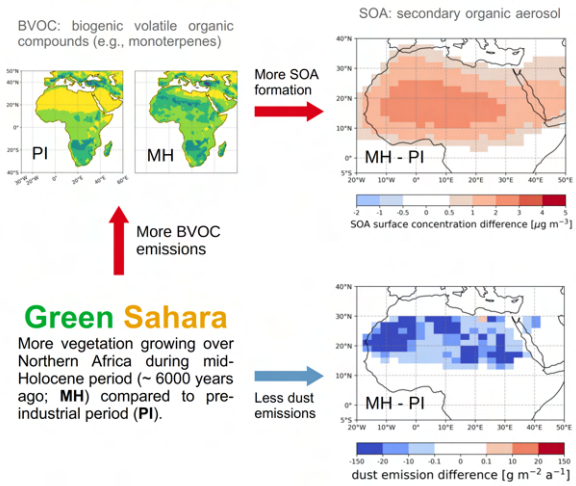

Figure 1: Simulated monoterpene emissions during PI and MH, the differences of dust emissions and SOA surface concentration between MH and PI cases.

ACKNOWLEDGEMENTS

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Local dispersion with an offline Eulerian chemistry-transport model driven with LES

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Keywords: Large-Eddy Simulations, Chemistry Transport model

INTRODUCTION

Large-Eddy Simulation (LES) is a powerful and computationally expensive tool to get a turbulence-resolving hydrodynamic fields and calculate transport within them. LES techniques has been extensively used in atmospheric sciences to calculate local pollution dispersion up to a meter scale. In many problems of atmospheric dispersion the dynamic part of the LES takes a vast majority of computational resources. Therefore using and offline transport model with pre-calculated wind ant turbulence fields id rather tempting. Moreover, with such an approach adjoint calculations become feasible at LES resolution.

METHODS

An interface has been developed to drive SILAM chemistry-transport model (`https://silam.fmi.fi`) with wind fields produced by a Large-Eddy Simulation (LES) model. Several tests indicating the feasibility of the approach have been performed with output fields of the PALM model of the university of Hannover. Two SILAM/LES setups were tested: passive plume dispersion from a moving ship in Turku harbor, and a full-chemistry simulation over the city of Turku.

RESULTS

The air flow over the Turku harbor was simulated with PALM model within a 3x4-km domain with a spacial resolution of 16m with the PALM model. The LES wind fields were used to drive a simulation of a plume from a ship departing from the Turku harbor (Fig. 1). The terrain relief in the simulations has been handled by masking-out cells at the bottom of the domain. In the experiments we tested several coupling intervals to update the velocity fields for SILAM. It was shown that a realistic plume can be obtained with few hundreds of pre-calculated wind-field sets with very moderate computing resources.

In the second setup PALM LES was used to simulate the air flow in a 12x12-km domain above the city of Turku with same 16-m resolution. A regular air-quality SILAM simulation driven with the LES fields was

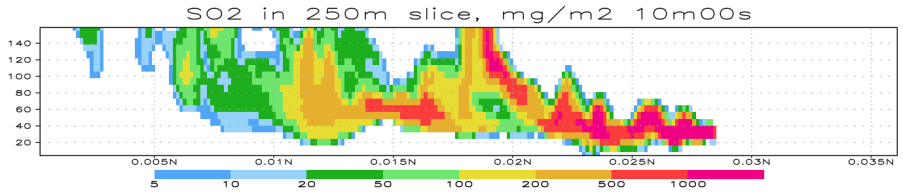

Figure 1: The vertical cross-section of an SO_2 concentration in a plume from a ship in Turku harbor, simulated with SILAM driven with PALM LES. The extent of the figure is 4 km in horizontal, and 160 m in vertical. The wind is from right to left at a speed of 5 m/s

nested into a regional air-quality model. Preliminary results of the simulations show promisingly looking pollutant distributions.

CONCLUSIONS

The SILAM model driven with pre-calculated LES fields can be used to simulate atmospheric dispersion of pollutants at urban scale with a several-meter resolution. Pre-calculated velocity and turbulence fields allow for substantial reduction of compute resources. The Turku full-chemistry setup can be used as a prototype for high-resolution urban air-quality forecasting system. The approach can be utilized for studies of chemistry-transport interactions e.g. within street canyons.

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ECOSYSTEM SCALE CARBON UPTAKE OF URBAN GREEN AREAS

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Keywords: eddy covariance, climate mitigation, urban green area, carbon sequestration.

INTRODUCTION

In the fight against climate change, cities seek solutions to reduce their CO_2 emissions and maximize carbon sinks to urban vegetation and soil. For this it is critical to have understanding on the strength and variability of the different CO_2 components present in cities. There are different methods how carbon exchange in urban areas can be quantified with the most direct observational method being the eddy covariance (EC) technique (Nicolini *et al.*, 2021). This technique measures the turbulent transport of momentum, heat or mass (in this case CO_2) between certain source area and the atmosphere giving the net exchange including all sources and sinks within the source area. In urban areas, this means that the EC measurements contain both anthropogenic and biogenic components. Thus, to measure the anthropogenic CO_2 emissions, the biogenic components need to be separated or if interest lies in biogenic components, alternative approaches need to be used. To separate the different components from each other, additional observations or modelling approaches are needed. One option is to measure CO_2 exchange only of biogenic origin using e.g. EC measurements or chamber measurements but an emerging method is to use eddy covariance measurements of carbonyl sulphide (COS) to separate photosynthesis from the net exchange (Asaf *et al.*, 2013). The aim of this study is to examine the biogenic CO_2 exchange over different urban green areas using the EC technique and examine the usability of COS exchange to estimate photosynthesis.

METHODS

This study uses EC observations from two sites located in Helsinki metropolitan region: around the ICOS Associated Ecosystem Station FI-Kmp (Järvi *et al.*, 2009), where the continuous observations of net CO_2 exchange were complemented with COS exchange in 2022-2023, and managed lawn in Espoo, where measurements were conducted between 2021-2022. In the first, the observations were carried out on top of a measurement tower at the height of 31 m and, in the latter, at the height of 1.2 m. At FI-Kmp site, the surrounding area can be divided into three distinct surface cover areas (urban, built and vegetation) dominated by the different surface covers. Both measurement setups consisted of an ultrasonic anemometer (Metek USA-1, Metek GmbH) to measure wind components and sonic temperature, and an enclosed path infrared gas analyzer (LI-7200, Licor) to measure the mixing ratios of water and CO_2. The COS mole fractions were measured using a quantum cascade laser gas analyser (AD-QCL, Aerodyne Research Inc). Data were recorded at 10 Hz. All data were post-processed using commonly accepted procedures (see details Nordbo *et al.*, 2012 and Soininen, 2023).

CONCLUSIONS

The diurnal variability of CO_2 exchange shows how carbon sink to urban lawn can be in the same order of magnitude as sink to the mixed vegetation type present in the vegetation area of FI-Kmp. On an annual level the urban lawn was taking up 81 g C m^{-2} which is about almost half of the uptake that has been measured in boreal forests. This indicated the importance of urban lawns in carbon uptake calculations in cities. The

results show how COS exchange over the vegetation area follows a similar behavior as over natural ecosystems with comparable leaf relative uptake (LRU) values. We also demonstrate how it proves to be a useful means to separate photosynthesis from the different components of net CO_2 exchange in urban areas.

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A TOOL FOR NEAR REAL-TIME OPERATIONAL ATTRIBUTION OF THE EFFECT OF CLIMATE CHANGE ON MONTHLY TEMPERATURES: SEPTEMBER 2023 IN HELSINKI

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Keywords: Climate change attribution, operational weather services, science-to-service.

INTRODUCTION

Meteorologists at FMI and climate scientists are often asked - by the public, the media, and decision-makers - whether a particular weather event is related to climate change. At present, only rough information based on past climatological observations can be provided. Due to high societal interest, we are developing new climate change attribution tools of climate change weather impacts that can be used in operational services near real-time.

Here, we present a new tool for attributing the impact of climate change on monthly mean temperatures for weather stations with long (over ~50 years) records of observational data. As a case study, we estimate the impact of climate change on the record-high 2023 September mean temperature in Kaisaniemi, Helsinki.

METHODS

The attribution method is based on that presented by Räisänen and Ruokolainen (2008) with a few modifications. Importantly, the current version uses data from the latest generation CMIP6 models, and a more robust method for estimating the continuous probability distributions has been adopted, now using stochastically generated skewed (SGS) distributions (Sardeshmukh et al. 2015). The four parameters of the SGS-distribution are derived from the mean, standard deviation, skewness and kurtosis of the sample. Further, a more comprehensive bootstrap approach for evaluating the uncertainty in the results has been developed.

The presented attribution tool uses in-situ observations from the Finnish Meteorological Institute (FMI) weather observation network, CMIP6 climate model data historical and SSP2-4.5 scenario data from 29 models (other SSP scenarios could also be used), and annual HadCRUT5 global mean surface temperature data.

Shortly, the method is as follows. First, observed surface temperatures are converted to *pseudo-observations* that represent stationary past, present or future climates at the station. This is done assuming that the mean temperature and temperature variability at the station change linearly with low-pass-filtered (11-years running mean) global mean temperature. CMIP6 model data are used for calculating the regression coefficient for both the mean value and the amplitude of variability. Pseudo-observations representing stationary climate states can then be derived from the regression according to the method in Räisänen and Ruokolainen (2008), using the difference in the 11-year running mean global mean temperature between the target time and the time of the observation. Lastly, the pseudo-observations are converted to continuous SGS probability distributions. Uncertainty in the internal climate variability is derived by generating 29 different time series of pseudo-observations based on 29 CMIP6 models with historical and SSP2-4.5 scenario data, and by using bootstrap sampling. By repeating these calculations both for the present (year 2023) and near-pre-industrial (year 1900) climates, the effect of global warming on the observed

temperature can be evaluated. Using future time series of global mean temperature in the CMIP6 simulations, the local temperature distribution in the future (e.g., year 2050) can also be estimated.

RESULTS

The method is here applied to attribute the impact of climate change on September 2023 mean temperature in Helsinki, Kaisaniemi, which was the highest recorded (15.8 °C) in the observational series dating back to 1844. Figure 1 shows the actual monthly mean temperatures (continuous line) and pseudo-observations representing today's (2023) climate from year 1900 onwards. By using the new tool, we estimate that September 2023 in Helsinki was about 1.5°C warmer (0.9–1.9°C; 5th and 95h percentiles) in today's climate than it would have been without human-induced climate change. Without climate change, such a warm mean temperature would be observed once in 460 years due to natural variability, but once every 49 years on average in today's climate. In 2050 and assuming SSP2-4.5 "middle of the road" scenario, such an event will take place once in 16 years.

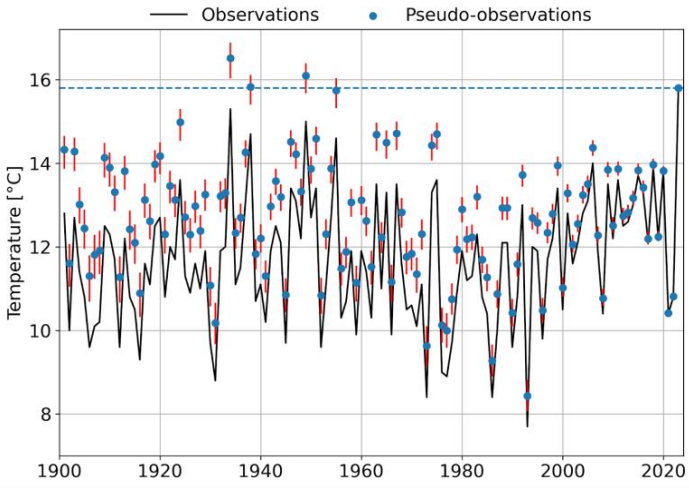

Figure 1: Time series of observed September mean temperature in Helsinki Kaisaniemi in 1901-2023 showing actual (continuous line) and pseudo-observations (blue dots) representing today's (2023) climate.

CONCLUSIONS

We have generated a new tool for attributing the impact of climate change on monthly mean temperatures at FMI's weather stations with long enough (over ~50 years) observational record. The tool is now planned to be used in FMI's monthly climate bulleting to estimate the impact of climate change on the recorded temperatures at selected stations. Within ACCC project, we will further develop attribution tools that can analyze also daily extremes, including extreme precipitation events. Such tools will greatly benefit from planned new kilometer-scale climate modeling runs for the Nordics using HARMONIE-Clim regional climate model.

ACKNOWLEDGEMENTS

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THE FIRST ACTRIS INTERCOMPARISON WORKSHOP OF CHEMICAL IONIZATION MASS SPECTROMETRY TO MEASURE CONDENSABLE VAPOURS

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Keywords: condensable vapours, mass spectrometry, intercomparison, calibration, trace gases

INTRODUCTION

ACTRIS is the pan-European research infrastructure with the aim to produce high-quality openly available data and information on short-lived atmospheric constituents and on the processes leading to the variability of these constituents in natural and controlled atmospheres. It is divided to several National Facilities producing the data and eight Central Facilities supporting the National Facility users by providing training, guidelines and standard operation procedures to them. The Central Facility of reactive trace gases in situ measurement has CiGas-UHEL unit hosted by University of Helsinki. The key-mission of CiGas-UHEL is to offer operational support for continuous long-term measurements of condensable vapours and aerosol precursors such as sulphuric acid and oxidized organic compounds in the atmosphere. The core activity of CiGas-UHEL is to ensure sustainable and traceable high-quality data and data products of in-situ measured atmospheric reactive trace gases with known uncertainty. To supper the core objective the unit arranges intercomparison workshops of instruments measuring condensable vapours. Intercomparison workshops provide crucial information about the functionality of individual instruments and understanding of the sensitivity and selectivity of the instruments, thus, the intercomparison workshops are a great tool towards the general goal of CiGas-UHEL to standardize and harmonize the measurement methods.

THE FIRST INTERCOMPARISON WORKSHOP

CiGas-UHEL arranged the pilot intercomparison workshop of chemical ionization mass spectrometers (CIMS, Jokinen *et al.* 2012) at the twin chamber facility ACDC (Atmospheric Chemistry Department Chamber) at TROPOS in March 2023 in collaboration with the ACTRIS OrGanic Tracers and Aerosol Constituents - Calibration Centre (OGTAC-CC). The intercomparison workshop gathered ten instruments measuring condensable vapours with different setups (Table 1.) that include an inlet where the chemical ionization happens with certain reagent ions and ionization method and a time-of-flight mass spectrometer that detects the ions with a certain resolution.

Table 1. The different inlets, ionization methods and mass spectrometers of the instruments participating the intercomparison workshop. The instruments were divided to measure from two chambers A and B.

chamber	inlet	reagent ions	ionization	mass spectrometer
A	EISELE	NO_3^-	corona	L-TOF
A	aircraft CI	NO_3^-	corona	H-TOF
A	AIM	NO_3^-	VUV	L-TOF
A	EISELE	NO_3^-	X-ray	H-TOF
A	EISELE	NO_3^-	X-ray	H-TOF
B	MION	NO_3^-/Br^-	X-ray	L-TOF
B	MION	NO_3^-/Br^-	X-ray	L-TOF
B	EISELE	NO_3^-	X-ray	L-TOF
B	EISELE	NO_3^-	Am241	C-TOF
B	FIGAERO	I^-	Po210	H-TOF

In the experiments (Table 2.) we focused on the detection of sulfuric acid and different oxidized organic compounds that are the target compounds of CiGas-UHEL unit. We also had special interest on the effect of high relative humidity (RH) on the detection of target compounds. We used two calibration compounds in the chamber: 4-nitrophenol (4-NP) and 1,2-ISOPOOH (1,2-IP) that we measured with different concentration steps and dry and high RH conditions. We measured oxidation of α-pinene with OH and ozone also with high RH and NO in the chamber. Lastly, we measured different concentrations of sulfuric acid with dry and high RH conditions and with and without α-pinene in the chamber.

Table 2. The experiment list in the intercomparison workshop

	Experiment	**compounds**	**Oxidant/condition**	**Experimental steps**
1	Calibration	4-Nitrophenol 1,2-ISOPOOH		Compound conc. increased -> 4-NP: 5 pptv; 15pptv, 40 pptv -> 1,2-IP: 4 concentration steps RH increased in the end
2	Calibration/tuning	4-Nitrophenol 1,2-ISOPOOH		
3	VOC oxidation	α-pinene	OH (H_2O_2 photolysis)	α-pinene conc. increased -> 5 ppbv; 10 ppbv, 20 ppbv RH increased after the last step + 20 ppbv NO as last step
4	VOC oxidation	α-pinene	~ 18 ppbv O_3	
5	VOC oxidation + NO	α-pinene	~ 18 ppbv O_3	
6	Sulfuric acid	20 ppbv SO_2	5 ppbv O_3 + TME 10% RH	TME (2,3-Dimethyl-2-butene) conc. Increased -> 10 pptv; 20 pptv, 40 pptv
7	VOC oxidation/ With sulfuric acid	200 pptv α-pinene 20 ppbv SO_2	5 ppbv O_3 + TME 10% RH	Constant concentrations

The intercomparison workshop provided critical information about the detection of CIMS instruments. The data analysis on the results is still work in progress. The response of the instruments to the changes in chamber conditions was not uniform which underlines the importance of intercomparison workshops.

ACKNOWLEDGEMENTS

This work is a result of great collaboration with intercomparison participants from Leibniz Institute for Tropospheric Research (TROPOS), Forschungszentrum Jülich, Centre d'Estudis Ambientals del Mediterrani (CEAM), Cyprus Institute, Goethe University Frankfurt, Tampere University and instrument manufacturers Karsa, Aerodyne and Tofwerk. The intercomparison workshop was organized at the twin chamber facility ACDC (Atmospheric Chemistry Department Chamber) in collaboration with the OrGanic Tracers and Aerosol Constituents - Calibration Centre (OGTAC-CC) and the Centre is acknowledged for all the arrangements and hosting. This work is supported by University of Helsinki hosting the ACTRIS Topical Centre Units and Research Council of Finland supporting the implementation and operation of the Units (FIRI funding, ACTRIS Central Facilities 2020-2024, grant no. 329274). The ACCC (Atmosphere and Climate Competence Center) Flagship funding by the Research Council of Finland (grant no. 337549) and Jane and Aatos Erkko Foundation funding are also acknowledged.

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SATELLITE PROXIES FOR ESTIMATING SPATIAL VARIATON OF NEW PARTICLE FORMATION

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Keywords: Satellite remote sensing, new particle formation, proxies, UV radiation, aerosol optical depth.

INTRODUCTION

In situ measurements are the only observational method to obtain information on new particle formation (NPF) events and particle growth. However, they are bound to a certain location and often lack the information on regional scale variability. Satellites have the advantage of providing global observations on multiple atmospheric components but freshly formed, nano-sized aerosol particles are far too small to be observed with optical remote sensing measurements. Satellite instruments can observe aerosols only after they have grown to optically active sizes.

Even though direct observation of nanoparticles is not possible with satellites, they provide relevant information on nanoparticle precursors, UV- radiation and optically active aerosols. In this work we investigate the capabilities of current operational satellites to provide information on NPF by developing satellite-based proxies that are formulated by source and sink terms for atmospheric nanoparticles. The overall goal is to use the satellite-based proxies to obtain information on regional, and even global scale variability of NPF.

METHODS AND RESULTS

The approach presented in this work is based on a hypothesis that the formation of atmospheric nanoparticles is governed by sink and source terms. The main sink for the nanoparticles and precursor vapors is condensation sink to the pre-existing aerosol particles, that can be estimated using aerosol optical depth (AOD), or modified AOD observations. The source term on the other hand is related to UV-radiation and different precursor gases. In this work we use current operational satellite products (e.g. from Moderate Resolution Imaging Spectroradiometer MODIS, and Ozone Monitoring Instrument, OMI) to derive the source and sink terms. In addition, we have developed a new satellite algorithm to derive surface photolysis rate for ozone, that would better describe the hydroxyl radical (OH) concentration than the operational UV products. With the help of detailed in situ measurements in Hyytiälä and Beijing, we are able to derive and test satellite-based proxies for NPF. Results indicate that the ratio of surface level ozone photolysis rate to AOD squared is sensitive to NPF events, and a clear difference of the proxy value distributions is seen between event and non-event days both in Hyytiälä and in Beijing. Distributions of proxy values are further used to determine local thresholds for NPF event and non- event days, that can be used to estimate the frequency of NPF events and their spatial variation. The results are verified using in situ measurements.

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KILPISJÄRVI SCIENCE TRAILS APP – A MODEL FOR NEW DIGITAL SCIENCE TRAILS WITHIN ACCC-FASN?

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Keywords: DIGITAL SCIENCE TRAILS, SCIENTIFIC OUTREACH, RESEARCH STATIONS.

INTRODUCTION

Science outreach can increase public awareness of science and the importance of science and spark excitement and interest in science. It can also be used to help increase public understanding of certain issues, which can lead to more informed choices, and make the public take ownership of addressed problems and affect the political agenda. Science outreach can take many exciting forms and science trails are one such. During 2022-2023 digital science trails were developed for popular hiking routes in Kilpisjärvi in the format of an app (Fig. 1). This app can be extended to also include science trails located in the areas surrounding the research stations and/or institutes which are covered under ACCC and FASN, or new similar apps can be developed based on the Kilpisjärvi Science Trails app model.

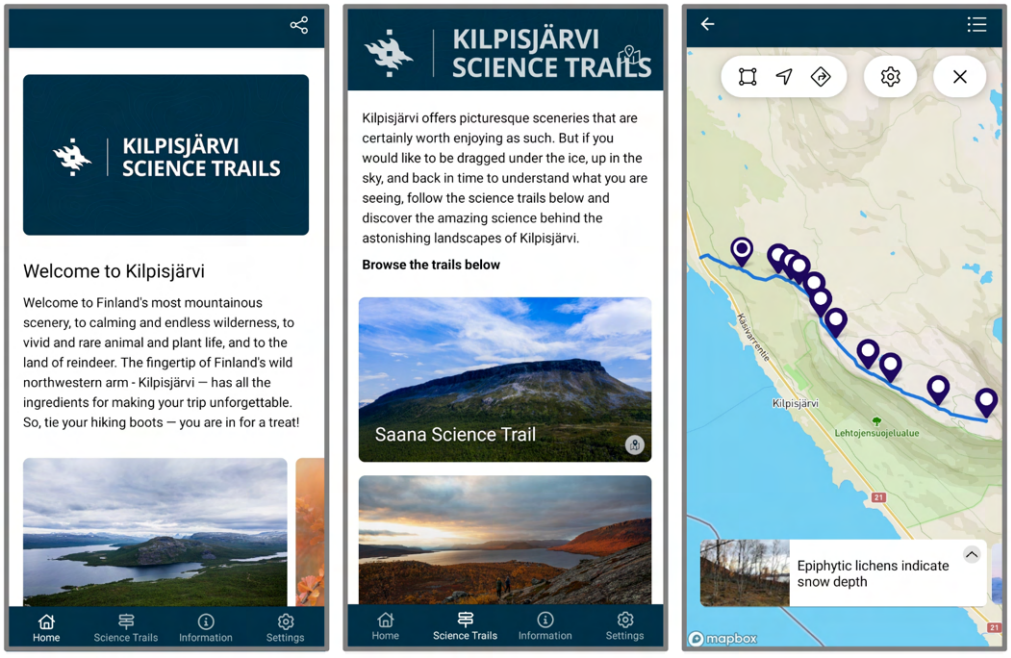

Figure 1. The Kilpisjärvi Science Trails app. The front page of the app (left), the four science trails (middle), Saana Science Trail route and stops (right).

THE APP

Digital science trails were chosen over trails with physical structures (such as for example information boards) to reduce environmental impacts, increase accessibility and because digital trails are easier to

update. We settled on an app as the digital solution, since most people nowadays carry a smartphone and are familiar with apps. Instead of creating a custom made app from scratch, we subscribed to a white-label visitor experience app provider (STQRY) as this was a much more cost-effective solution both in a short and long term. Four science trails were developed with a total of 35 stops covering sciences ranging from biology, physics, and geology to archeology, history and bioart. Examples of these are provided in Fig. 2. When walking along the trails, users are notified of the stops using GPS and the app also shows your current location. The app works offline and the content can be accessed whenever. The app is currently available in English, Finnish and Swedish, and as an audio version (also available in three languages). Changes to the app can easily be implemented and users can check and pull updates. The app does not collect any data from users and it is for free. The app is published under its own name (Kilpisjärvi Science Trails) in Google Play Store. It is also available in web version (https://kilpisjarvisciencetrails.stqry.app/). Due to internal University of Helsinki regulations, the app is currently only available in Apple Store via STQRY Guide. More digital science outreach products which are linked to the app are found here: https://www.helsinki.fi/en/research-stations/science-trails/locations/kilpisjarvi-science-trails.

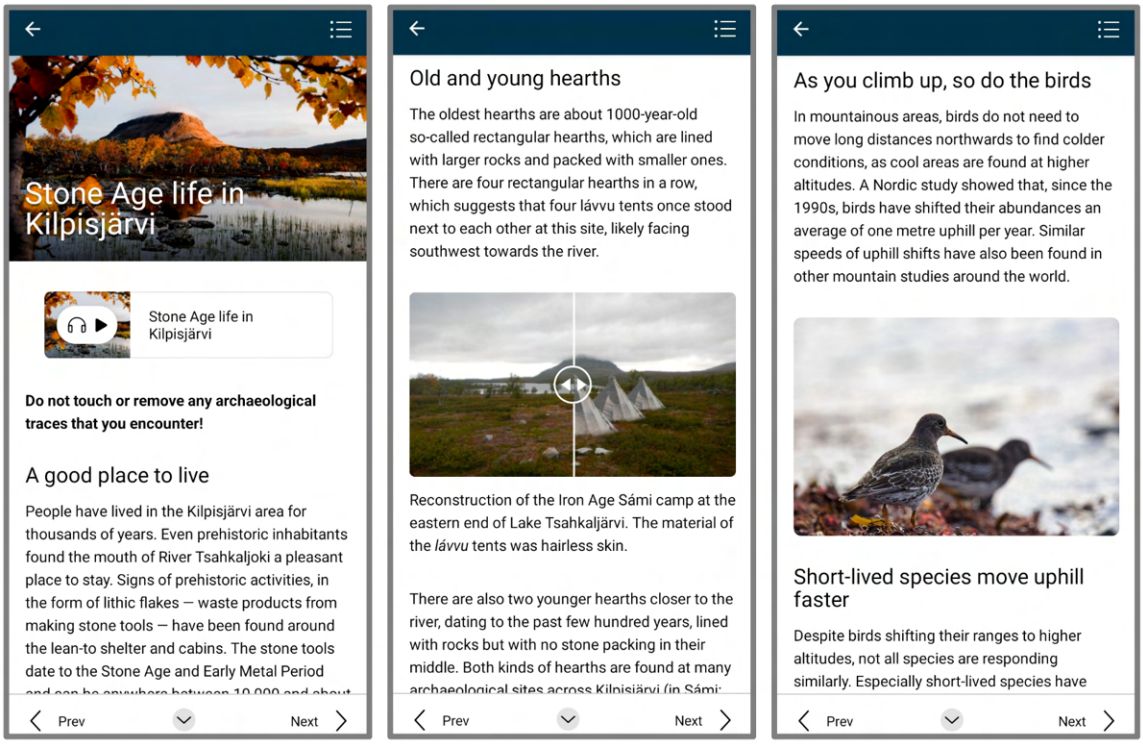

Figure 2. Examples of stops and stop content in the Kilpisjärvi Science Trails app.

CONCLUSIONS

Digital science trails were successfully developed for popular hiking routes in Kilpisjärvi in the format of a smart, user-friendly, cost-effective and long-lived app. This app can be extended to also include science trails located in the areas surrounding the research stations and/or institutes which are covered under ACCC and FASN, or new similar apps can be developed based on the Kilpisjärvi Science Trails app model.

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GLORIOUS CROP MODELLING

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Keywords: Crop model, Data assimilation, Parameter estimation, STICS.

INTRODUCTION

Biodiverse agriculture is becoming increasingly important as a potential method of improving agricultural soil health, with benefits extending to increasing soil carbon content and improved ecosystem health. However, models do not yet directly model all interactions within multi-crop plots. To promote a swift, broad transition there is a need to accurately model and predict the effects of different climate smart agricultural approaches. Calibrating current crop models potentially allows us to simulate some of these approaches by capturing unmodelled interactions in the calibrated model parameters. Furthermore, the utility of different data streams in providing useful agricultural estimates remains understudied. We aimed to capture the interactions between barley and a variety of cover crop species that were not directly modelled in STICS by calibrating parameters of barley using the 4DEnVar technique. Additionally, we assessed the effect of varied data streams on calibration with a focus on yield estimates.

METHODS

This study simulated a number of plots containing both barley grown alone and with one of eight other species in replication of the TWINWIN field experiment in Viikki in 2020 and 2021, which provided green area index, net ecosystem production, and yield observations. Eight cover crop species were chosen that varied across two main functional traits: rooting depth and nitrogen fixing ability. Within the crop model STICS (Brisson et al., 2003) we calibrated the barley parameters using the 4DEnVar technique of Pinnington et al. (2020), firstly in a twin experiment approach using synthetic observations, and subsequently using real observations from TWINWIN. The twin experiment approach was used to assess the performance of our data assimilation process by using known parameter values to generate observations used in the data assimilation then seeing whether the method was able to find the correct parameters during calibration. This allowed us to refine our parameter selection and ensemble size thereby improving the confidence in our calibrations involving real observations. During both stages the data streams used in calibration were varied to assess the effect on yield estimates. We calibrated using the more plentiful observations from 2020, and reserved 2021 for validation purposes.

RESULTS

The twin experiments showed a productive coupling of STICS and 4DEnVar, as the posterior estimates reproduced the synthetic observations when 8 parameters were varied. However, we were

only able to reproduce the synthetic values of up to 4 parameters before encountering problems of equifinality. This reduced 4 parameter set was used in calibration with the observations from TWINWIN. The yield predictions improved in most configurations during 2020, while the 2021 yield estimates showed little change and remained well predicted. The observed yields were much lower in 2021, implying the limiting factors and key parameters were different. Yield estimation accuracy decreased when including green area index measurements in calibration, with inclusion of yield and net ecosystem production together producing the best results. The net ecosystem production over the barley growing season was compared, with notable increases relative to sole barley seen when barley was grown with clover varieties (*Trifolium* spp.), and to a lesser extent when grown with *Lolium multiflorum*, *Festuca arundinacea* and *Cichorium intybus*.

CONCLUSIONS

Our results show that accounting for unmodelled interactions through plasticity in plant parameters can improve predictions of agriculturally important variables when exploring climate smart agricultural practices. Additionally, the coupling of the relatively lightweight 4DEnVar calibration method with the widely used crop model STICS has immense potential in providing specific guidance to farmers looking to implement these practices. The low computational and implementation costs of 4DEnVar allow for simple and quick calibrations across a large variety of circumstances that may be modelled with STICS. Furthermore, the choice of companion crop has a significant effect on net CO_2 emissions during the barley growing period with much smaller relative effect on yields. Unfortunately the exclusion of soil parameters to aid transferability of results in this study reduced our ability to estimate longer term effects on the ecosystem fluxes. Finally, there is a need for further research into the effects of including varying data streams in data assimilation processes, as relatively easily available leaf area index measurements may not provide useful improvements in model estimates in agricultural contexts. This study demonstrates the feasibility of using existing crop models to simulate novel cropping systems by lightweight calibration, allowing for more informed guidance and predictions in the vital and ongoing transition to climate smarter agriculture, as well as an early stepping stone to better understanding of the impact of different data streams on agricultural modelling systems.

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TWO CONTRASTING YEARS OF CONTINUOUS N_2O AND CO_2 FLUXES ON A SHALLOW-PEATED DRAINED AGRICULTURAL PEATLAND GROWING SILAGE GRASS

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Keywords: Nitrous oxide, Eddy covariance, Drained peatland, Glyphosate.

INTRODUCTION

Cultivated organic soils represent ca. 13% of agricultural fields in Finland but they contribute to 43% and 82% of total N_2O and CO_2 emissions from agricultural fields. N_2O emissions do not follow a strong seasonal pattern. Instead, they have high spatial and temporal variability throughout all seasons. Short-term N_2O peak emissions can be observed after various meteorological or soil management events, for example after soil freezing and thawing or fertilization. To reduce the uncertainty of annual budgets and increase our understanding of N_2O emissions, more continuous measurements are needed. The general aim of this study (Gerin et al., 2023) was to address the following research questions: 1) Does a warmer winter induce more N_2O emissions than a colder winter? 2) How do N_2O fluxes respond to short-term meteorological variation and management events? 3) What is the contribution of N_2O and CO_2 emissions to the relative radiative impact?

METHODS

Since November 2019, N_2O and CO_2 fluxes have been measured continuously on the NorPeat platform, a shallow-peated drained agricultural peatland in Northern Finland (N64°41.039' E25°6.379'). The field follows a grass-intensive crop rotation, where forage grasses are cultivated for 3-4 years and then sown again with cereal crops as a cover. From 2019 to 2021, grass was cultivated at the site. N_2O and CO_2 fluxes were measured with the eddy covariance technique alongside multiple auxiliary measurements such as weather and vegetation parameters and soil properties.

RESULTS

We observed several N_2O emission peaks related to soil thawing/freezing periods during the winter and after fertilization and precipitation during the summer (Fig. 1). High emissions were also observed during fall 2021, likely due to glyphosate application. The annual N_2O budget was 4.74 ± 0.47 and 6.08 ± 0.49 kg N_2O-N ha^{-1} y^{-1} in 2020 and 2021, respectively. The annual CO_2 budget, comprising the sum of net ecosystem exchange and biomass export, was 3.70 ± 0.22 and

5.54±0.33 t CO_2-C ha^{-1} y^{-1} in 2020 and 2021, respectively. The N_2O budget during the first, warmer winter was 106% higher than during the second, meteorologically more typical winter, due to the higher frequency of soil freezing-thawing cycles.

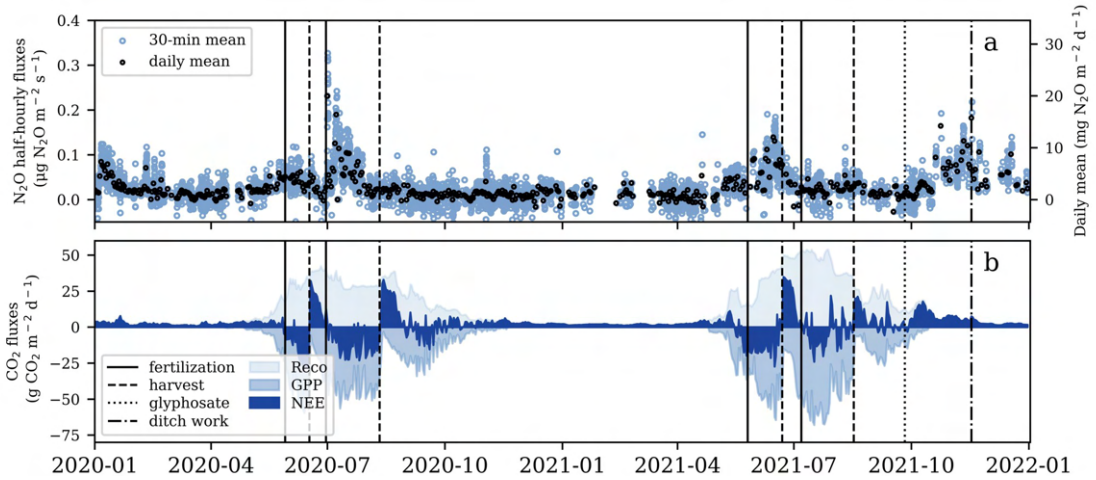

Figure 1: Filtered N_2O fluxes (a) and gap-filled daily net ecosystem exchange (NEE), total respiration (Reco) and gross primary production (GPP) (b).

CONCLUSIONS

N_2O contributed to 12% of the total GHG emissions in CO_2-equivalents. The warm winter had significantly higher N_2O fluxes, while CO_2 emissions were also higher although not significantly. The N_2O annual budget of the study site was lower than the IPCC emission factor for drained boreal grassland. However, more continuous measurements over the full rotation are needed to know whether this factor should be reassessed and adjusted to different management practices or meteorological condition. Finally, the application of glyphosate seems to have a notable impact on CO_2 and N_2O fluxes. More in-depth experiments are needed to assert the impact of glyphosate application on N_2O emissions.

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ACTRIS (AEROSOL, CLOUDS AND TRACE GASES RESEARCH INFRASTRUCTURE) – ACTIVITIES OF 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. April 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 / chambers 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 UH Topical Centre Units, related to measurements of sub-10 nm particles and aerosol precursors, are to 1) provide training and consultancy, 2) produce and provide measurement and data procedures and tools (e.g. measurement protocols and recommendations, see *SOPs for NAIS and PSM/nCNC and ACTRIS recommendations*), 3) improve the methods to calibrate the relevant instrumentation and provide instrument calibrations for ACTRIS National Facilities, 4) organize calibration and intercomparison workshops and 5) carry out measurement and calibration method and instrument development.

ACTRIS TOPICAL CENTRE IMPLEMENTATION AND RECENT ACTIVITIES

The CCC and CiGas-UHEL are currently mid-way in their implementation. 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. Pilot ACTRIS workshops for sub-10 nm particle instruments and chemical ionization mass spectrometers have been/ will be organized in 2023: 1st Chemical Ionization Mass Spectrometer intercomparison workshop March 2023 (Leipzig) by CiGas-UHEL, and 1st Neutral cluster and Air Ion Spectrometer (NAIS) intercomparison workshop May 2023 (Helsinki) and 1st Nanoparticle instrument intercomparison workshop November 2023 (Helsinki) by CCC.

ACKNOWLEDGEMENTS

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MODELLING NANOPARTICLE GROWTH ON CHACALTAYA MOUNTAIN

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Keywords: nanoparticle growth, modelling, volatility, VBS, sulfuric acid.

INTRODUCTION

New particle formation events (NPF) were studied on Chacaltaya mountain station (5240 m a.s.l.) in Bolivia. NPF events are an important source of atmospheric particles worldwide: it is estimated that up to 50% of atmospheric particles acting as cloud condensation nuclei are secondary particles formed in the atmosphere (Merikanto *et al.*, 2009). These freshly formed particles need to grow substantially in order to partake in cloud formation and hence their early growth to cloud condensation nuclei sizes is an important subject of study. Our aim was to study how freshly formed particles grow on this high-altitude site and what are the important factors and compounds contributing to the growth.

METHODS

Based on measured gas phase concentrations of organic compounds and sulfuric acid, companied with observed ambient conditions, the particle growth was calculated using condensational single-particle growth model; Model for Oligomerization and Decomposition in Nanoparticle Growth (MODNAG, Heitto *et al.*, 2022). The organics were grouped by their volatility based on Volatility Basis set (VBS, Donahue *et al*., 2006) and the volatilities of individual organic compounds were estimated using parametrization by Li *et al*. (2016), based on their molecular composition measured by chemical ionization mass spectrometer with a filter inlet for gas and aerosols (FIGAERO-CIMS), that uses iodide as a reagent ion Simulated growth rates were then compared to the measured growth rates (GR) that were determined from particle size distribution measurements conducted with a Neutral cluster and Air Ion Spectrometer (NAIS).

RESULTS AND CONCLUSIONS

Despite the difficult surroundings, the model simulations were able to capture the observed particle growth relatively well, modelled GRs being mostly within factor of two compared to the measured GRs. The event-by-event comparison is presented in the Figure 1a. The most important contributor to the particle growth was found to be low volatile organic compounds (LVOC), that on average covered around 67 % of the simulated particle mass in particle of 35 nm in diameter. The simulated mass fractions for each event are presented in Figure 1b. In addition to LVOCs, during days when volcanic activity was observed in the area, sulfuric acid had a major role in particle growth, covering up to 39 % of the simulated particle mass. Our study gives valuable new information on compounds contributing to the particle growth on high altitudes and highlights the potential of volcanic activity to affect the particle growth in the atmosphere.

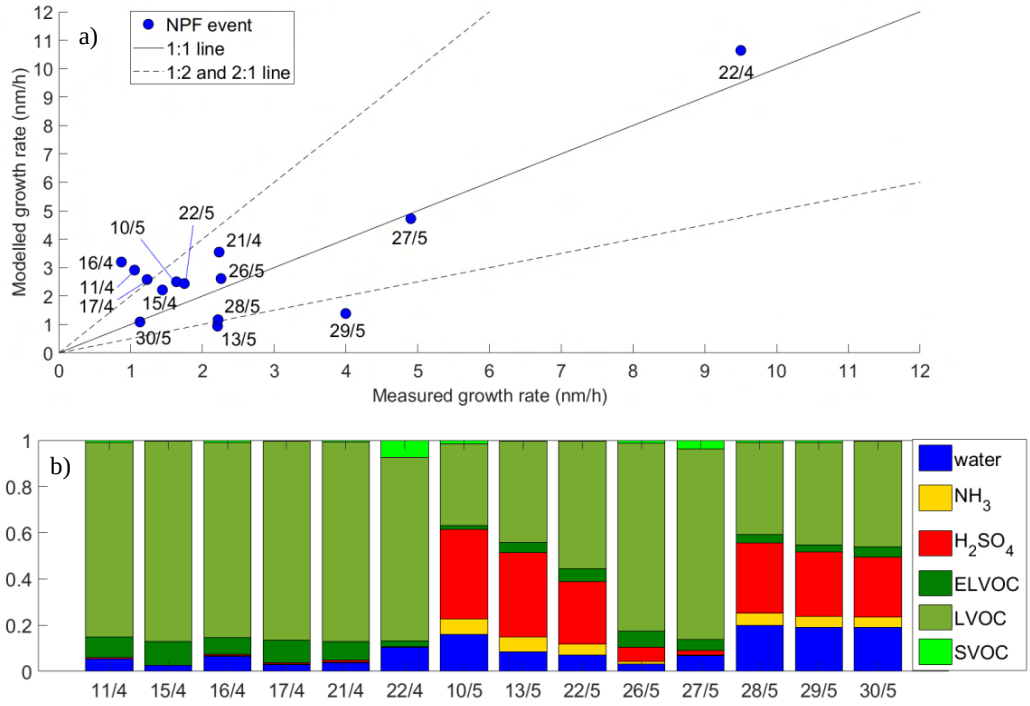

Figure 1. a) Modelled vs. measured growth rates of particles, b) modelled mass fractions of different compounds in 35 nm diameter particle.

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IMPACT OF FOREST FIRE AND WIND-THROW TO CARBON BALANCE IN BOREAL FOREST

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Keywords: Ecosystem modeling, forest fire, wind-throw, soil carbon pools, climate change.

INTRODUCTION

Forest fires and wind-throw are natural disturbances in boreal forests. They are beneficial to the biodiversity by renowning forests and creating habitats for various species. Climate change and human actions change natural disturbance dynamics. A rise in temperature increases the risk of fires even though an increase in precipitation reduces it. The wind-throw risk may change due to the changes in precipitation and season of frozen ground. We study the impacts of forest fires and wind-throws on the mineral soil of boreal forests in the changing climate by means of an ecosystem model. Our aim is to demonstrate variations in carbon balances between disturbances, climate scenarios and locations.

METHODS

We simulated changes in soil carbon storage (Goll *et al.*, 2015) with the JSBACH ecosystem model (Thonicke *et al.*, 2010; Lasslop *et al.*, 2014) by four disturbance scenarios. Our alterations are 1) basic: no disturbances 2) wind: with wind-throw 3) fire: with forest fires and 4) firewind: with wind-throw and forest fires. The modelled point locations in Finland are Uusimaa, South Savo, North Karelia and Lapland. The simulation is from 1900 to 2100 with climate scenarios CanESM2, MIROC5 and CNRM-CM5 under RCP 4.5.

Above and below ground soil carbon pools are modelled using Yasso07 (Goll *et al.*, 2015) in the JSBACH. The litter flux increases, whereas respiration reduces the soil carbon pools. During the spin-up process, the initial carbon pools are in equilibrium. The amount of fuel is estimated from the above ground soil carbon pools, which may change due to forest fires and wind-throw.

In the JSBACH-SPITFIRE model, the probability of forest fires depends on weather conditions (temperature and precipitation) and fuel properties. If there is enough dry fuel available and human or lightning caused ignition hapens, the fire will begin to spread. The carbon is either emitted into the atmosphere as CO_2 or is stored in the soil carbon pools. Wind-throw is modelled in a very simple manner in JSBACH. It depends only on wind speed. Carbon from damaged woody type vegetation is all stored in soil carbon pools.

RESULTS AND CONCLUSIONS

The amount of soil carbon pools has seasonal fluctuations. The level of the carbon pools depends on the location and the climate scenario (Fig. 1). The largest soil carbon pool is in Lapland, which is located in northern Finland. The above ground soil carbon pool is significantly increased by wind-throw and reduced by forest fires. Our next steps are to do a baseline analysis of the amount of wind and a further analysis to demonstrate the interaction between wind-throw and forest fires. We are going to do regional simulations for the Fennosandia with these disturbance scenarios.

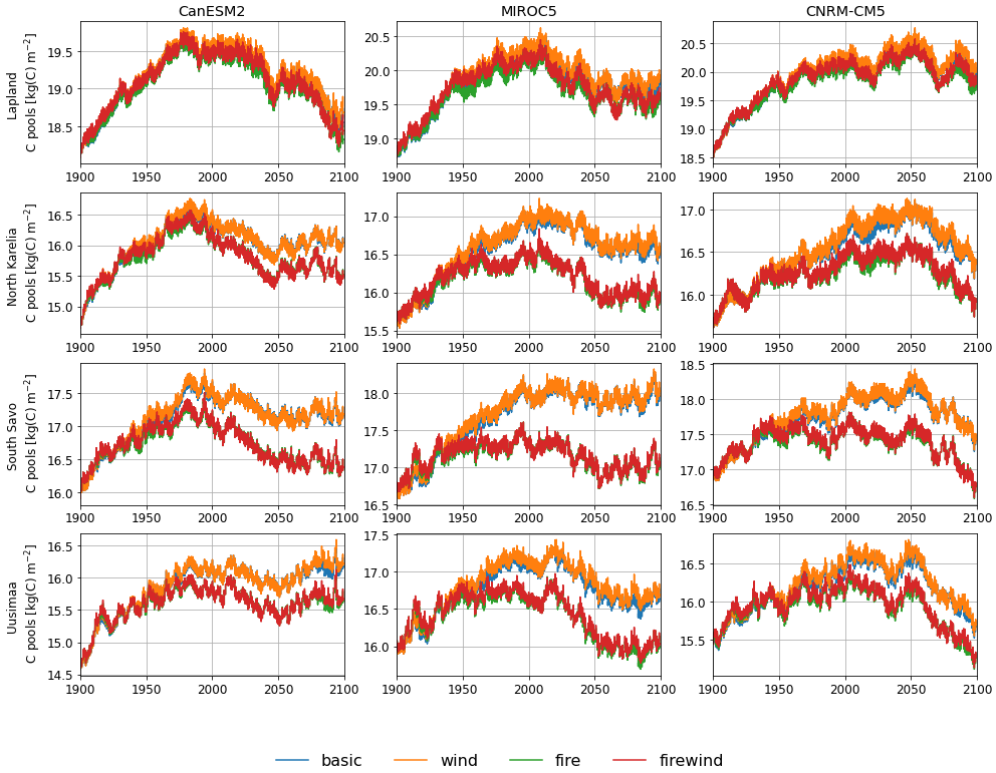

Figure 1: The total amount of soil carbon [kg (C) m^{-2}] from four disturbance scenarios at Uusimaa, North Karelia, South Savo and Lapland under three climate scenarios.

ACKNOWLEDGEMENTS

The work is a part of the ACCC Flagship programme (grant No 337552) and funded by the project "Evaluating integrated spatially explicit carbon-neutrality for boreal landscapes and regions" of the Academy of Finland (grant no. 347860).

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CLIMATE CHANGE IMPACT ON CARBON SEQUESTRATION OF URBAN VEGETATION TYPES IN FINNISH CITIES

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Keywords: NET ECOSYSTEM PRODUCTION, CLIMATE CHANGE, ECOSYSTEM MODELLING, CARBON SMART CITIES.

INTRODUCTION

Urbanization is one of the global mega-trends and the percentage of the global population living in cities is expected to increase rapidly in the future. Cities are sources of carbon emissions but also important actors in climate change mitigation and adaptation (Frantzeskaki *et al.*, 2019). Urban green areas have large potential for carbon sequestration and are one of the main ways cities can reduce their carbon emissions. They also provide important co-benefits in water runoff management and in reducing the urban heat island (UHI) effect. Cities need more information on carbon sequestration of different urban ecosystems and their resilience against extreme weather stress in future to build more resilient urban ecosystems to efficiently mitigate and adapt to climate change.

Carbon cycling in urban green spaces is controlled by vegetation type and size, meteorological conditions and soil properties. Urban green area carbon sequestration is also affected by management like irrigation, soil modification and removal of above-ground litter. Here we use the JSBACH ecosystem model to understand how carbon sequestration in different urban vegetation types responds to future climate scenarios. We are especially interested in the differences between urban ecosystem types and the way the increasing drought periods in future will affect these ecosystems.

METHODS

Seven different urban vegetation types were simulated in nine Finnish cities. Urban vegetation types used were urban lawn, park site with *Tilia cordata*, urban birch-dominated forest, mesic meadow and dry meadow. In addition, we included irrigation in a set of simulations of urban lawn and park with *Tilia cordata*. The parameterization of these vegetation types is based on measurements collected in the Kumpula area in Helsinki (Ahongshangbam et al. 2023). Cities included in the simulation setup were Helsinki, Turku, Lahti, Jyväskylä, Joensuu, Kuopio, Vaasa, Oulu and Rovaniemi.

The JSBACH model was driven by daily EURO-CORDEX data (Jacob et al., 2014). We used data from 2006 to 2100 for RCP8.5 climate change projection. The EURO-CORDEX data used in this study had been downscaled from the global CanESM2 model to the EUR-44 domain. Bias correction had been applied for both temperature and precipitation.

RESULTS AND CONCLUSIONS

Rising temperatures will increase primary production in all ecosystems and cities. Net Ecosystem Production (NEP) changes will be smaller and NEP will increase or decrease depending on city and

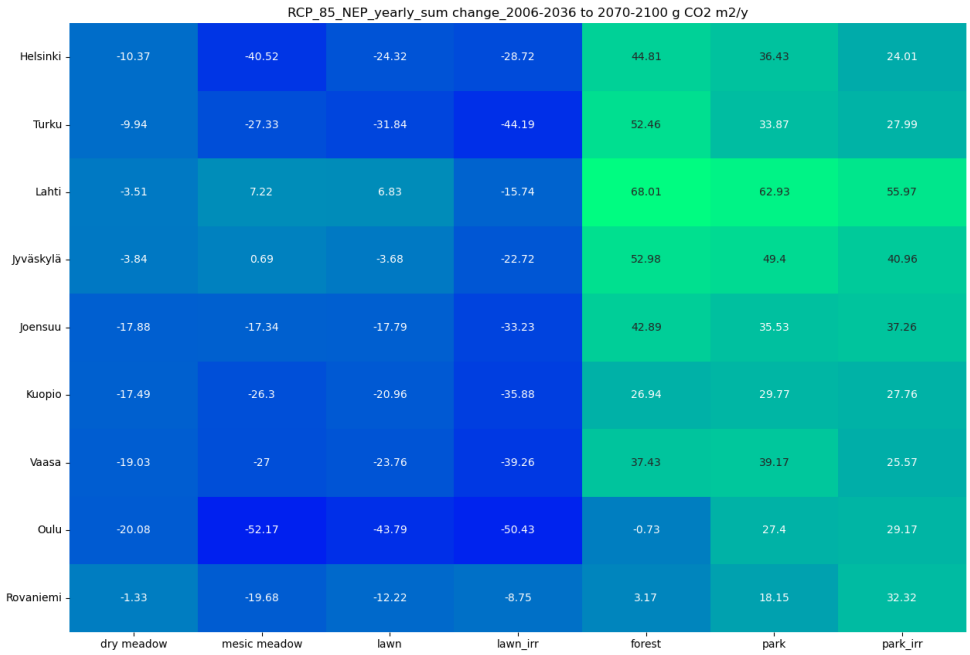

Figure 1: Change in Net Ecosystem Production (NEP) between 2006-2036 and 2070-2100 period (CO_2 g m^{-2} y^{-1}). Positive values (green) indicates increasing NEP and negative values (blue) indicates decreasing NEP

vegetation type (Fig. 1). Drought is going to affect ecosystem NEP in dry summer months but the losses are partly compensated by longer growing seasons in the future. NEP in urban ecosystems with trees is less sensitive to drought than NEP in urban grass based ecosystems (Fig 1.).

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FIRST INSIGHTS INTO THE COMPARISION OF FIELD AND LABORATORY BURNING EXPERIMENTS – BIOMASS AND CARBON LOST THROUGH COMBUSTION

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Keywords: Prescribed fires Laboratory burning, Carbon loss.

INTRODUCTION

Fire is a result of the physio-chemical process known as combustion. Through combustion, fires release carbon stored in the vegetation and organic matter, and this can create a positive feedback loop for climate warming (Li et al., 2017). Complete combustion occurs when there is an abundant supply of oxygen, which allows the fuel to burn completely. This type of combustion produces carbon dioxide and water as its products. Incomplete combustion occurs when there is a limited supply of oxygen, which prevents the fuel from burning completely. This type of combustion produces carbon monoxide, water, and carbon as its products. Understanding how changes in fire dynamics (fire intensity, severity, frequency, occurrence time) and combustion conditions influence the carbon dynamics of boreal forests is crucial not only for predicting future climate impacts but also for developing mitigation strategies that support forest resilience. In this study, we aimed to: (1) analyse the quantity of biomass and carbon lost during the surface fires taking place in boreal forests of Fennoscandia, (2) determine how burning conditions are affecting the carbon losses and created pyrogenic matter, and (3) provide a comparison between field (experimental fire in field) and associated laboratory burning experiments, to assess the loss of biomass and carbon from them.

METHODS

The study contains the measurements from two different experiments: the experimental burning in the field (Evo state forest, where the experimental fire was conducted in the summer of 2020) and the laboratory burning experiment (Boreal And Savannah Fire Aerosol Aging (BASFAA) campaign carried out in May-June 2022 in Kuopio), and our aim was to investigate the biomass loss and carbon loss on both burning campaigns.

In Evo, the experimental fire area was established in a mature Scots pine forest, where the study area covered 2700 m^2, containing areas burned at high- and low-severity fires in addition to unburned control plots that were placed next to the experimental burning quadrats (Oranen 2022). We had four sample plots (15 x 15 m) in each treatment. The experimental burn occurred on June 16th, 2020. An assessment of the ground vegetation within all sample plots was undertaken before the fires, including species presence, coverage (%) and biomass (kg m^{-2}). Ground vegetation biomass (kg m^{-2}) was determined from three randomly located spots (0.033 m^2 circle) from each sample plot. The ground vegetation biomass samples were separated into different vegetation groups (mosses and lichens, grasses, shrubs), and dried at 60ºC for 24 hours or until a constant mass was achieved. Immediately after the experimental fire in the field, the burn depth was measured, and ash and charred material samples were collected (all the burned material within the 0.033 m^2 circle was removed with the vacuum cleaner).

Before the experimental fire in Evo, 15 samples were collected from every sample plot. Collected samples contained ground vegetation (lichen, mosses, shrubs, grasses), litter, and a portion of the organic and mineral soil horizons (O- and A-horizons). Samples were taken with the cylindrical metal collar (diameter 21cm). The cylindrical collar was inserted into the ground and assisted by a knife or shovel to cut through the roots. The sample was then extracted from the ground, and as much of the soil mineral horizon was removed as

possible. All the samples were dried in an oven at 60ºC for 24 hours before being sent to the ILMARI research facility in UEF (https://sites.uef.fi/ilmari/) for a burning experiment. The boreal forest floor samples (including ground vegetation, litter and soil organic horizon) were burned under an open stack mimicking natural burning at the ILMARI combustion facility in Kuopio, Finland in May-June 2022.

RESULTS

During the experimental fire in the field and during the laboratory combustion, the sample biomasses decreased significantly. However, it was observed that the burning conditions in the laboratory experiment were more severe compared to the experimental burning in the field, as we lost more biomass in laboratory burning compared to the field burn. The total biomass loss in laboratory burning was on average 68.5%, while the total biomass loss in experimental burning in the field was on average 35.1%. At the same time, the carbon lost through combustion in laboratory burn was approximately three times higher than that from the experimental field burn. On average more than 90% of the carbon was lost in laboratory burning while around 20 % of carbon was lost during the experimental field burning.

CONCLUSIONS

In our comparison, laboratory combustion showed a more significant impact on ground vegetation biomass and on different soil horizons compared to experimental field burning. Low-severity surface fires (that are common in boreal Scots pine forests), damaged mostly ground vegetation, as almost all the vegetation was burned away. At the same time, these fires had a much smaller effect on the litter layer and soil humus horizons, as these parts of the soil were not damaged. In laboratory burning, most of the material available was combusted, therefore much bigger biomass and carbon losses were observed.

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NITROUS OXIDE BUDGETS IN THE PAN-ARCTIC REGION

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Keywords: Nitrous oxide, Pan-Arctic, Statistical upscaling.

INTRODUCTION

Arctic soils store large amounts of nitrogen (N). Evidence is accumulating that part of the large soil N stocks can be emitted in the form of a strong greenhouse gas, nitrous oxide (N_2O). Over the last decades, there have been a number of breakthroughs in this field, such as identification of N_2O hotpots in permafrost peatlands (Repo et al., 2009) and observation of substantial N_2O emissions at landscape scale , high enough to be detectable with air-borne measurements (Wilkerson et al., 2019). However, our understanding of the total N_2O budgets in the pan-Arctic region is still limited.

METHODS

Based on the permafrost N_2O database and statistical models, we upscales the N_2O emissions to the pan-Arctic region.

RESULTS

The total N_2O emissions across the pan-Arctic region was about 0.492 Tg N_2O yr^{-1}. The N_2O emissions from the tree land cover, peatland, grass land cover, and bare soils of the pan-Arctic region were 0.175, 0.05, 0.138, and 0.129 Tg N_2O yr^{-1}, respectively.

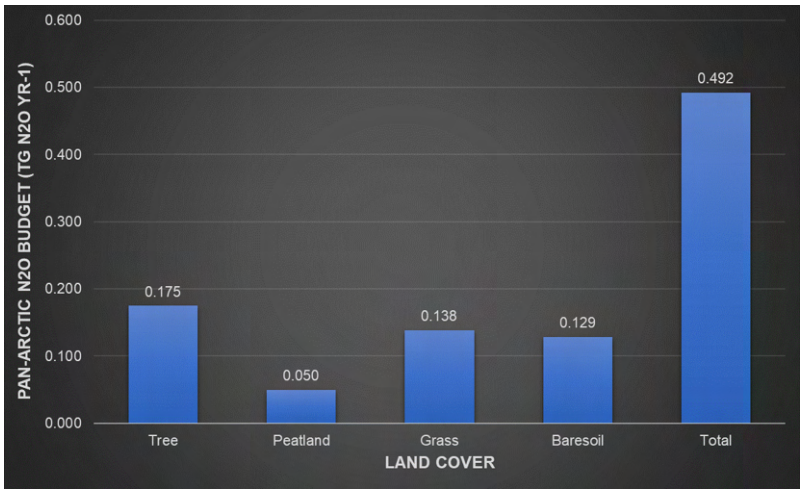

Figure 1. Nitrous oxide budgets in the pan-Arctic region.

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FORMATION AND TEMPERATURE DEPENDENCE OF HIGHLY OXYGENATED ORGANIC MOLECULES FROM Δ^3-CARENE OZONOLYSIS

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Keywords: HOM, Δ^3-carene oxidation, temperature dependence, RH effect

INTRODUCTION

Monoterpenes ($C_{10}H_{16}$) constitute approximately 15% of the total annual global emissions of biogenic volatile organic compounds (Guenther et al., 2012). Δ^3-carene is the second most prevalent monoterpene in the atmosphere, which has been found to yield as much or even more secondary organic aerosol (SOA) upon oxidation compared to the most abundantly emitted monoterpene α-pinene ozonolysis under similar conditions (Thomsen et al., 2021; Thomsen et al., 2022). However, up to now, most research has primarily centered around α-pinene (Bianchi et al., 2019), while knowledge about Δ^3-carene oxidation pathways, particularly regarding its ability to form highly oxygenated organic molecules (HOM), is still limited.

METHODS

We explored the HOM formation during the ozonolysis of Δ^3-carene in atmospheric simulation chambers. A chemical ionization atmospheric pressure interface time-of-flight mass spectrometer with nitrate as the reagent ion (NO_3-CIMS) was used to measure HOM formed from Δ_3-carene ozonolysis. Furthermore, the impact of temperature and relative humidity on the composition and distribution of HOM was investigated under different temperature conditions (0, 10, and 20 ºC) and humidity levels (below 15% and around 80%).

CONCLUSIONS

We detected various HOM monomers and dimers from Δ^3-carene ozonolysis as shown in Figure 1(a). We detected $C_{10}H_{14,16}O_9$ and $C_9H_{12,14}O_9$ as the predominant HOM monomers, and $C_{19}H_{30}O_{6,10,11}$ and $C_{20}H_{32}O_{7,9,11}$ as the largest dimers. HOM monomers with 9 or more O-atoms and all dimers condensed onto particles irreversibly while HOM monomers with 6-8 O-atoms behaved more like semi-volatile organic species, maintaining a noticeable gas phase concentration. Δ^3-carene ozonolysis yielded higher HOM concentrations than α-pinene, with a distinct distribution, indicating differences in formation pathways.

We observed that HOM concentrations decreased considerably at lower temperatures, which is consistent with previous studies on α-pinene ozonolysis(Quéléver et al., 2019; Simon et al., 2020). The main HOM species were similar at three different temperatures (20, 10 and 0 °C). However, HOM dimers-to-monomers ratio increased from 0.78 to 1.51 when the temperatures decreased from 20 °C to 0 °C.

ACKNOWLEDGEMENTS

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AURA chamber is funded by the Danish Agency for Higher Education and Science. We also acknowledge funding from The Independent Research Fund Denmark.

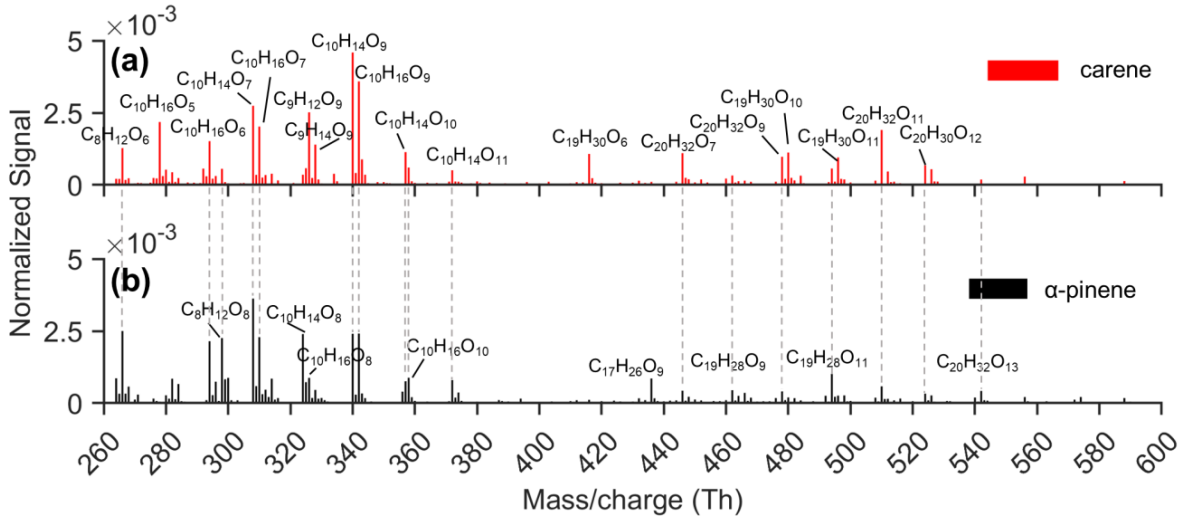

Figure 1. UMR (unit-mass resolution) mass spectra from Δ^3-carene (a) and α-pinene (b) ozonolysis under the same conditions (VOC = 20 ppb, O_3 = 30 ppb). All peaks labelled were detected as a cluster with NO_3^-, and the gray dashed lines mark some of the products with the same formulas detected both in Δ^3-carene and α-pinene ozonolysis experiments.

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STOMATAL OPTIMIZATION MODELLING IN THE LAND SURFACE MODEL JSBACH: AN IN-DEPTH CASE STUDY ON SMEAR II

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Keywords: stomatal control, land surface modelling, ecosystem gas exchange, ecophysiology

INTRODUCTION

The stomata on the leaves of terrestrial plants are a crucial pathway in global and local cycles of carbon and water. Stomatal optimization approaches have proven to be relevant in better understanding the trade-off between carbon assimilation and water stress avoidance. In this in-depth case study, we use new optimization-based stomatal models in modelling vegetation gas exchange with the land surface model JSBACH, with a particular focus on drought stress.

The theoretical framework we use (Dewar et al. 2018) combines different optimization hypotheses and photosynthesis models to provide analytical solutions for various leaf-level state variables such as stomatal conductance and photosynthesis rate. The most successful combinations assume that plants regulate stomata as if to maximize photosynthesis at all times, while photosynthesis is restricted by non-stomatal limitations related to water stress. We further develop the framework and use it to create new stomatal conductance models.

We then implement these stomatal models in the land surface model JSBACH, which we run for a single boreal forest site, the SMEAR II measurement station in southern Finland. The model is constrained with meteorological and soil moisture data from the site, and model parameters are mostly based on onsite measurements. Gross primary production and transpiration rates predicted by JSBACH using different stomatal and photosynthesis models are compared to eddy covariance measurements from SMEAR II, covering the years 2006 through 2012. The model results are also compared to each other and to those obtained using the well-established Unified Stomatal Optimization model.

Results indicate that the new models perform well enough to be worth considering in other land surface modelling applications, which adds to the credibility of the chosen optimization approach.

ACKNOWLEDGEMENTS

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STUDYING FORMATION PATHWAYS OF HIGHLY OXYGENATED ORGANIC MOLECULES (HOM) FROM A-PINENE OZONOLYSIS USING SELECTIVE DEUTERATION

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Keywords: autoxidation, HOM, 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.

THEORY

In the autoxidation process, peroxy radical (RO2) intermediates can undergo intramolecular hydrogen abstractions (H-shifts) followed by oxygen (O2) additions. The process can repeat until the radical terminates, for example, via the loss of a hydroxyl radical from the molecule. (Ehn *et al.*, 2014, Kurtén *et al.*, 2015) This process can be monitored using selective deuteration, where the precursor molecule has had the hydrogen atoms (1H) of a specific carbon replaced with deuterium atoms (2H, hereupon referred to as D). If the deuterated carbon undergoes a hydrogen abstraction, a deuterium atom can be shifted to a hydroxy or hydroperoxy group, where it is readily exchanged with a hydrogen atom if the molecule comes into contact with water vapour. Alternatively, a deuterium atom can be lost if the C-atom it is attached to is lost during the oxidation process. In both cases, the loss of the deuterium atom from the molecule can be determined using mass spectrometry.

METHODS

In this work, we studied the initial formation pathways of HOMs in reactions of the monoterpene α-pinene with ozone. Our goal was to elucidate the autoxidation process experimentally by monitoring which carbons in α-pinene lose hydrogens and at what point using the method described by Meder et al. (2023). We used eight selectively deuterated α-pinene samples with hydrogens connected to carbons at positions 1, 3, 4, 5, 7, 8, 9, and 10 exchanged with deuterium atoms (see fig. 1). We reacted the precursors with ozone to produce HOMs in a flow tube. To monitor the oxidation products, we employed the CI-Orbitrap (Riva *et al.*, 2020), a very high mass resolution Orbitrap mass spectrometer coupled to an Eisele-type chemical ionisation (CI) inlet (Jokinen *et at.*, 2012), using both nitrate (negative mode, selective towards HOMs) and butylammonium (positive mode, broader selectivity range) as reagent ions. Using this instrumentation, we

can determine which of the deuterated precursors are prone to losing deuterium atoms during the (aut)oxidation process.

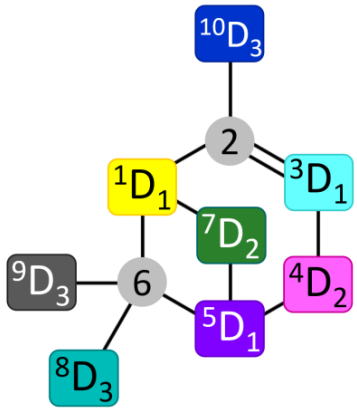

Figure 1. Structure of a-pinene showing the naming convention of deuterated precursors. The number before "D" shows the corresponding positional number of the carbon atom following IUPAC numbering, and the latter number tells the number of deuterium atoms in the precursor.

RESULTS AND CONCLUSIONS

Preliminarily, we found that for the primary RO2 radicals $C_{10}H_{15}O_4$, a deuterium atom was lost when the deuterated carbon was 10 (see fig. 1, $^{10}D_3$), as would be expected from the initial ozonolysis. Contrastingly, no deuterium atoms were lost from carbon 4 (fig. 1, $^{4}D_2$), however, $^{4}D_2$ had always lost a deuterium atom in the next step of the autoxidation, i.e. the $C_{10}H_{15}O_6$ radicals formed from $^{4}D_2$ precursor always lost a deuterium atom. This indicates that $C_{10}H_{15}O_4$ radicals that have lost a deuterium atom from carbon 4 do form, but the following reactions are so fast that the molecules are consumed and thus not seen in the mass spectra. For the more oxidised HOM radicals $C_{10}H_{15}O_8$ and $C_{10}H_{15}O_{10}$, D loss was most prominent from carbons 4 and 10. This indicates that HOM formation is most likely when the primary RO2 forms with the peroxy group on carbon 4 or carbon 10. Comparing the HOM from the other deuterated precursors gives additional insights and will help to finally determine the steps leading to HOM formation in this system.

ACKNOWLEDGEMENTS

This work was supported by the Magnus Ehrnrooth foundation and The Academy of Finland.

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THREE STATION NETWORK FOR ICE NUCLEATING PARTICLE MEASUREMENTS ACROSS FINLAND

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Keywords: AEROSOL-CLOUD INTERACTION, ICE NUCLEATION, IMMERSION FREEZING.

INTRODUCTION

Ice crystal formation plays an important role in cloud microphysics by affecting clouds' lifetime, the formation of precipitation, and radiative properties. The most relevant process of ice crystal formation in mixed-phase clouds (MPC) is by immersion freezing (Ansmann et al. 2009). Immersion freezing takes place when an ice nucleating particle (INP) is immersed in a water droplet and freezing is triggered on the particle surface. The temperature at which immersion freezing occurs is determined by the nature of the INP.

Among all aerosol particles, only a small fraction are active INP. Therefore, large volumes of air have to be analyzed to get statistically robust information on the concentration of INP. Existing data sets show that INP concentrations spans from $< 0.1\,m^{-3}$ up to $> 1\,cm^{-3}$ in the temperature range (0 to -38°C) where MFC exist, which complicates their parametrization for modeling. Furthermore, the relative contributions of local sources and long-range transport to the INP concentration remain uncertain.

In this research we report a new effort to quantify INP concentrations across Finland. An offline method will be used to monitor INPs at three different locations in Finland during 3 years. Automatic filter samplers were installed during the summer 2022 at the ACTRIS station in Pallas, at the Pujio tower in Kuopio and in Utö. Collected daily filter samples are sent to the laboratory at FMI Helsinki for INP analysis. The large number of samples will be used to identify INP sources, and analyze their spatial distribution and temporal variation across Finland.

METHODS

Atmospheric particles are collected onto membrane filters with an automatic sample changer that pumps $24\,m^3$ of ambient air per day though a filter. Collected filters are stored at a temperature of -20 °C to preserve, for example, biological aerosol. Each filter is analyzed independently to obtain the INP concentration as a function of activation temperature, location and date. Collected atmospheric aerosols are washed off the filter with ultra pure water. The resulting aqueous solution is divided into $50\,\mu L$ aliquots in a 96-well PCR-plate. The filled plate is partially submerged into a temperature controlled ethanol bath to observe the ice formation temperature in each well. To detect at which temperature each aliquot freezes, the PCR-plate is illuminated from below and monitored with a camera from above. When ice nucleation and freezing occurs, a change in transparency is detected, allowing to determine the frozen fraction of the aliquots as a function of temperature. Finally, using the frozen fraction of aliquots at a given temperature, the volume of each aliquot and the sample's air volume, the cumulative number of INPs in the given sample at

each temperature is calculated following Vali (2019). This analysis enables the quantification of the INP concentration in the sampled atmospheric aerosols in the immersion freezing mode.

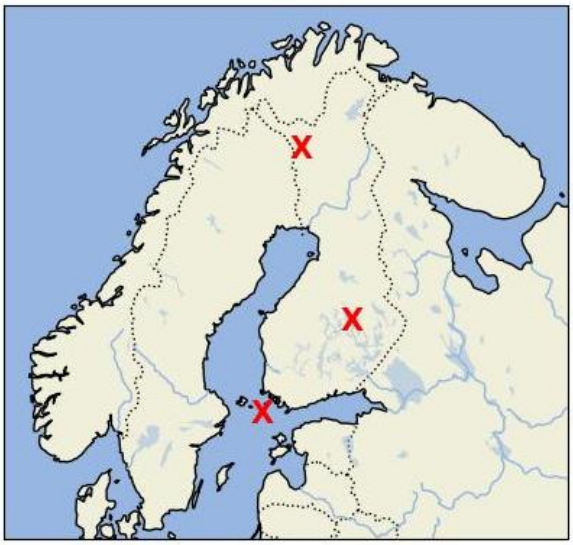

Figure 1: Map showing the location of sampling sites. From North to South: Pallas, Kuopio (Pujio tower) and Utö.

Fig. 1 shows the location of the selected sampling sites. Pallas station is located in western Lapland and is representative for INP sources related to the boreal forest. Pujio tower is located in an elevated location in a semi-urban area in central Finland. INP sources for this station are expected to be the surrounding wetland, forests and urban areas. Utö station is located on an island in southern Finland, with potential INP sources for this station being sea spray and particles released during algae bloom in summer. Auxiliary data is also collected at ACTRIS stations to augment the data set.

ACKNOWLEDGEMENTS

This research is part of the project *Distribution And Sources of Ice nucleating particles across Finland* (DASI) supported by the Academy of Finland (grant no. 342227), and by Academy of Finland Flagship funding (grant no. 337552).

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MODELLING THE IMPACTS OF CLIMATE CHANGE ON WHEAT DISEASES CAUSED BY RUST FUNGI

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Keywords: Climate change impacts, fungal crop pathogens, primary biogenic aerosol particles, atmospheric long-range transport.

INTRODUCTION

The distributions of agricultural pests and diseases are already responding to climate change, and the exposures seem to be increasing. Thus, robust strategies are required for pest and disease mitigation for securing the food for the growing global population. However, global crop models that inform the future agricultural management and decision-making are missing the impacts of pests and pathogens.

Wheat rusts - leaf rust (*Puccinia triticina*), stripe rust (*Puccinia striiformis f. sp. tritici*) and stem rust (*Puccinia graminis f. sp. tritici*) - have been listed among the most devastating crop diseases, stem rust capable of causing 100% yield losses under suitable conditions. The emergence of several new hypervirulent races has increased the related risk to global food security. The complex life cycles of rusts with different temperature and humidity requirements in various phases and their reliance on airborne spores for annual recolonization of areas not climatically suitable for year-round survival make them especially sensitive to climate change. For many rust fungi the main vector of spread is atmospheric transport of urediniospores.

By developing a mechanistic model capable of simulating the life cycle of the rust fungi, taking into account the environmental requirements during different growth phases and long-range airborne transmission by uredinoispores, we can identify when and where changing climate will increase the risks of crop yield losses from the wheat rusts, and characterize the role that changes in land and crop management (distribution of crops, irrigation, fertilization, sowing time, cultivar resistance, presence of alternate host etc.) play in modulating these losses

METHODS

A mechanistic model has been developed to simulate the spatiotemporal development of the prevalence and severity of the wheat rusts based on Prank et al. (2019). It includes parameterizations to account for spore production on infected wheat fields and escape from the crop canopy, spore mortality during long range transport due to UV radiation, spread of the infection from the deposited viable spores taking into account the influence of local meteorological conditions on spore germination and overwintering.

RESULTS

Evaluating the infection model is challenging due to limited availability of observational data of rust prevalence. However, the model does show some skill in reproducing the annual recolonization of United States wheat growing areas by stem rust compared to observations reported by farmers to USDA (Figure 1) and the extent of dispersion of the hypervirulent Ug99 lineage from Uganda.

Comparing present day simulations with the end of the century following climate scenario RCP8.5 showed that warmer and dryer climate leads to poleward expansion of overwintering areas and more wheat stem rust spores being produced and larger fraction escaping to the free atmosphere, while reducing substantially the germination probability due to reduction of liquid water availability. However, as these simulations were

made with simplified version of the model that did not include the whole life cycle of the fungus, the combined effect of these competing factors requires further investigation.

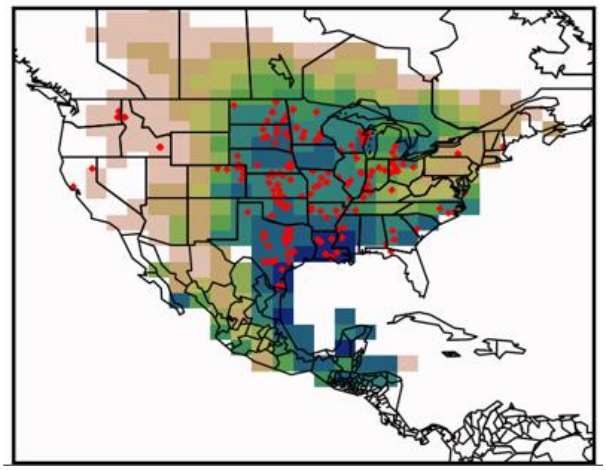

Figure 1. Maximal infection levels on susceptible crops. Red dots – rust reports from USDA

It is often claimed that a very small fraction of large primary biogenic particles escape the crop or forest canopy (up to a few percent). However, Aylor & Ferrandino (1988) evaluated the escape fraction 2 m downwind a line source of 32 µm sized spores to be 22-57% and 56-64% for spores released at 0.4 m and 0.7 m height in wheat canopy. Preliminary results with a simplified model show that due to correlation between preferred conditions for spore removal from leaf surface and escape from crop canopy, on average ~20% of all produced spores escape. Further studies using a using a large eddy simulator are on the way, also regarding rainy conditions where the splash of the raindrops is considered a release mechanism for the spores from the leaf surface.

CONCLUSIONS

A detailed mechanistic model has been developed to study the impacts of climate change on the prevalence of wheat diseases caused by rust fungi. Model evaluation is challenging due to limited availability of quantitative observational data. The model will be used to investigate when and where changing climate will increase the risks of crop yield losses from the three wheat rusts, as well as the role that changes in land and crop management could play in modulating these losses.

ACKNOWLEDGEMENTS

This work was supported by the Academy of Finland under grant 356444.

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OBSERVATION OF SECONDARY AEROSOLS PRECURSORS AT THE ANTARCTIC PENINSULA

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Keywords: New particle formation, Mass Spectrometry, Antarctica

INTRODUCTION

The Antarctic environment, characterized by snow, ice, permafrost-covered land, a lack of vegetation, and a strong marine influence along its coast, stands as the Earth's most pristine region due to its remoteness and minimal human activity. The Antarctic atmosphere represents particularly well conditions of the pre-industrial era, and its characterisation could help in assessing the grounds to model and predict the Anthropocene. Atmospheric aerosol particles can impact the climate in many ways, either by scattering or absorbing the solar radiation or by impacting cloud properties, cloud processes, and precipitation when they reach the state of cloud condensation nuclei (CCN). In Antarctica, a significant fraction of CCN can originate from secondary particles which formation frequency is peaking during summertime. Recent studies (Brean et *al.* 2021; Quéléver *et al.* 2022) have identified condensing vapours responsible for new particle formation (NPF) in the Antarctic peninsula to be primarily sulfuric acid, ammonia, and possibly different type of amines. However, these observations lack consistency in time and space to properly address the complete picture of Antarctic NPF. With this work, we are presenting measurements of aerosol precursors performed in the North of the Antarctic Peninsula with field observations from two sites, on land and from a research vessel, during the austral summer.

METHODS

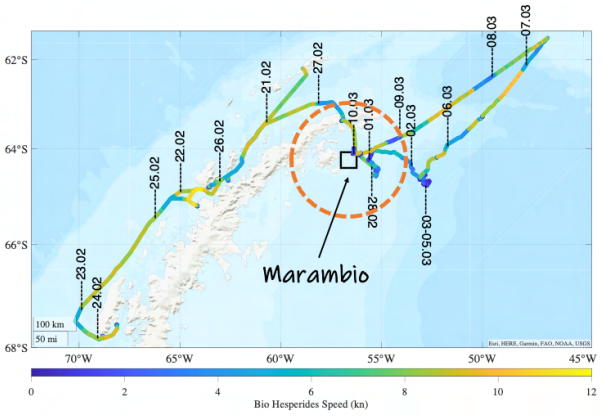

Figure 1. Position of the B.I.O Hesperides around the Antarctic Peninsula.

Field campaigns were performed (1) at the Argentine research station Marambio (64°14'S, 56°37'W) during Jan. - Apr. 2023, and (2) in the research vessel *B.I.O. Hesperides* owned by the Spanish armada during the polar change expedition from mid-Feb to mid-Mar (See path in Figure 1).

As a whole, these quasi-simultaneous deployments target multiscale processes from (1) NPF-precursor identification, (2) chemical characterisation of the aerosol phase, (3) cloud droplets and the CCN evaluation as well as (4) ice nucleation particles quantification and (5) characterization of the aerosol biological activity.

RESULTS

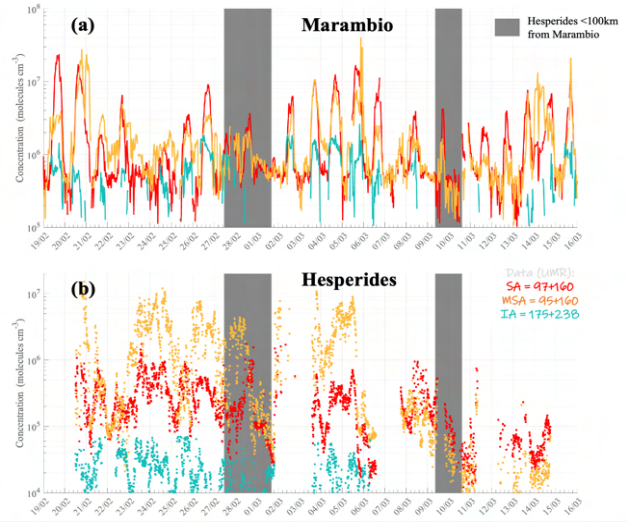

Figure 2. Time series for SA, MSA and IA at Marambio (a) and during Polar Change (b) - UMR resolution, preliminary data.

Precursor vapours (Sulfuric Acid- SA, Iodic Acid-IA, and Methane Sulfonic Acid-MSA) where measured similarly at Marambio and on B.I.O. Hesperides (Figure 2). Preliminary results suggest that SA concentration is typically higher on land but reversely MSA would be more abundant at sea, especially on the western side of the peninsula. Surprisingly, IA was higher in land but, when measured at sea, its concentration would rise when close to the ice edge.

Many NPF (nucleation and growth) were observed in Marambio when only a couple of (transported) events were seen during PolarChange. The ion composition during NPF in Marambio hints on a nucleation process involving SA, Ammonia and Ammines, confirming the observations of Quéléver *et al.* (2022). These stabilizing bases were however not seen from the ship-based measurements which might explain why NPF did not occur at sea.

CONCLUSIONS

The on-going analysis of the ion composition during the multiple events observed in Marambio will help in defining the Antarctic NPF regionally. With consistent observations of the atmospheric composition including particle size distribution and trace gases qualitative and quantitative analysis, we highlight the importance of natural mechanisms involved in Antarctic NPF where compound such as ammonia seem to play a critical role. Furthermore, direct quantification of in-situ ammonia will be revealed in a separate study, enabling, for the first time, a characterization of NPF parameters entirely based in-situ measurements.

ACKNOWLEDGEMENTS

This work was supported by the Academy of Finland (project no 335844 - Antarctic Climate Forcing Aerosol- ACFA, Flagship funding no 337552, VILMA project no 1346372), and the European Research Council (ERC-GASPACON, CRiceS - 101003826). We are grateful for the collaboration of the Servicio Meteorológico Nacional – SMN, Fuerza Aerea Argentina – FAA and the FINNish Antarctic Research Program – FINNARP.

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CONTINUOUS COVER FORESTRY IN NUTRIENT-RICH PEATLAND FOREST: CO_2 BUDGET BEFORE AND AFTER SELECTION HARVEST

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Keywords: peatland, 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 highest 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 was gapfilled (data coverage 34 % and 10 % 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 410±55 g C m^{-2} y^{-1} before harvesting in 2020 (Fig. 1). Net emissions were 445±60 g C m^{-2} y^{-1} in the harvesting year 2021 but decreased to 275±30 g C m^{-2} y^{-1} in the second year after harvesting in 2022. The control site was a net source of CO_2 with CO_2 budget varying between 440 and 475 g C m^{-2} y^{-1} during the three full measurement years 2020-2022. GPP decreased from 1340 to 855 g C m^{-2} y^{-1} in 2021 and increased by 10 g C m^{-2} y^{-1} in 2022. TER of CCF decreased in the harvesting year 2021 from 1750 to 1300 g C m^{-2} y^{-1} and further decreased in 2022 by 130 g C m^{-2} y^{-1}.

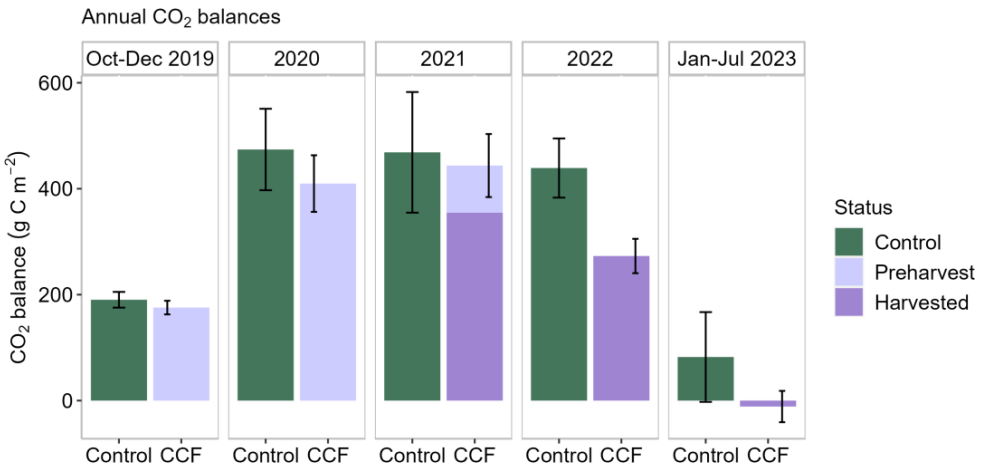

Figure 1. Annual net CO_2 balances of control site and the continuous cover forestry (CCF) treatment. Harvesting in CCF was done in March 2021 and the bar for 2021 in CCF shows contribution of preharvest months to the annual budget in lighter color. Bars for 2019 and 2023 show net CO_2 balances only for part of the year.

CONCLUSIONS

Peatland forest site was a large source of CO_2 before harvesting and continues to be a net source of CO_2, although the source decreased in the second year after harvesting. The decrease in the net annual CO_2 emissions in the second year after harvest can be explained by decreasing TER and slightly increasing GPP compared to the harvesting year. Year-to-year variation in environmental conditions may affect the annual CO_2 budget and, therefore, the interpretation of the effect of harvesting on it, although CO_2 budget in the control site remained similar throughout the years.

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 Maj and Tor Nessling foundation (grant no. 202000391) and the ACCC Flagship funded by the Academy of Finland (Grant no. 337552).

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Assessing drivers in the Arctic vegetation productivity and chlorophyll fluorescence in the last two decades

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Keywords: Vegetation Chlorophyll Fluorescence, Gross Primary Productivity, Arctic

INTRODUCTION

During the last four decades, the Arctic has been warming faster than the globe, a phenomenon known as *Arctic amplification*. Climate warming and increasing atmospheric carbon dioxide (CO_2) have raised vegetation productivity in the extratropical Northern Hemisphere since the 80s. Quantifying the drivers that trigger changes in vegetation activity is essential to understanding how vegetation responds to climate change in the Arctic region. In this study, we performed a sensitivity analysis through the SHapley Additive exPlanations (SHAP) technique (Lundberg and Lee, 2017) on different satellite-derived and data-driven datasets combining information about Solar-Induced vegetation Chlorophyll fluorescence (SIF) and Gross Primary Productivity (GPP). The SHAP method is used here to break down individual predictions from the machine learning XGboost models (Chen and Guestrin, 2016) built for SIF and GPP.

METHODS

Two XGBoost models were trained for GPP and SIF datasets separately. The FLuxSAT dataset of GPP estimations combine satellite-derived retrievals, tower measurements, and neuronal networks for data upscaling (https://daac.ornl.gov). For the SIF dataset, we selected the GOSIF product (http://globalecology.unh.edu), which is a data-driven approach generated using SIF satellite estimations from the OCO-2 instrument together with other remote sensing and meteorological auxiliary data. The input parameter space was divided into two categories: one collecting atmospheric and climate-related variables (surface latent heat flux, surface net solar radiation, surface pressure, surface sensible heat flux, surface solar radiation downwards, total precipitation, vapor pressure deficit, and 2-meter air temperature), and a second group also including information regarding surface and vegetation cover (albedo and leaf area index). The reasoning behind this classification was to ensure that relationships found in the climate-related variables are not altered or overcompensated for the lack of surface-related information. Input drivers evaluated in the model were obtained from the ERA-5 model at hourly resolution (www.ECMWF.com). All the datasets were aggregated to 0.05 degrees spatial resolution and the ERA-5 datasets were daily resampled to match the 8-day interval time series of SIF and GPP. The total number of random samples used from the input data was 10^7, covering the months of June-July from 2000 to 2020 between 60-90N.

RESULTS

Both XGBoost models were evaluated (with a fraction of 10/90 for training/testing). The R^2 for the XGBoost GPP(SIF) models were 0.83(0.91) and 0.73(0.86) using climate&surface-related and

just climate-related variables, respectively.

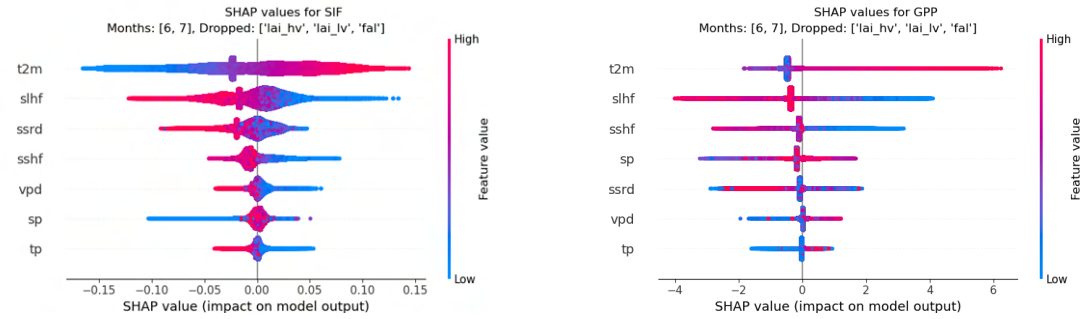

Figure 1: SHAP SIF (left) and GPP (right) Beeswarm diagrams.

For both SIF and GPP, air temperature is the main driver, and the higher the temperature value, the higher the positive impact on the GPP and SIF predictions (see Fig. 1). The second most driving variable is the surface latent heat flux *(slhf)*. Since no other variables regarding transpiration or evaporation were included, the latent heat flux should include all these phenomena. The higher the *slhf* values (more evaporation upwards), the lower the GPP and SIF values. The third driver in GPP is the surface sensible heat flux (*sshf*), which accounts for the transfer of heat through turbulent fluxes between surface and atmosphere, being the higher the flux, the lower the GPP. On the other hand, the third driver for SIF is surface solar radiation downwards *(ssrd)*. While most of the samples produce SIF values close to the mean expected value (SHAP=0), higher *ssrd* ranges produce a decline on SIF. This pattern is also consistent in the GPP analysis where *ssrd* is the 5th in the ranking. The impact produced by the 3rd-4th-5th drivers is quite similar (similar bar length). Interestingly, for the total precipitation (*tp*) and Vapor Pressure Deficit (*vpd*), the higher their values, the higher GPP but the lower SIF predictions. Changes in surface pressure (*sp*) do not produce too much change in SIF with the exception of low *sp*, which is also associated with lower SIF and GPP predictions.

CONCLUSIONS

In the Arctic region during summer, air temperature is the primary driving factor for gross vegetation productivity (GPP) and fluorescence emission (SIF), with vapor pressure and solar radiation not being a limiting factor, highlighting the direct influence of the Arctic amplification effect on projected GPP and SIF values.

ACKNOWLEDGEMENTS

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ACTIVITY AND ABUNDNACE OF METHANOTROPHIC BACTERIA IN A NORTHERN MOUNTAINOUS GRADIENT OF WETLANDS

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Keywords: Methane, Methanotrophy, Peatlands.

INTRODUCTION

Methane uptake and diversity of methanotrophic bacteria was investigated across six hydrologically connected wetlands in a mountainous forest land-scape upstream of lake Langtjern, southern Norway. From flood plain through shrubs, forest and sedges to a Sphagnum covered site, growing season CH4production was insufficiently consumed to balance release into the atmosphere.

RESULTS

Emission increased by soil moisture ranging 0.6–6.8 mg CH_4 m^{-2} h^{-1}. Top soils of all sites consumed CH_4 including at the lowest 78 ppmv CH_4 supplied, thus potentially oxidizing 17–51 nmol CH_4 g^{-1}dw h^{-1}, with highest Vmax 440 nmol g^{-1} dw h^{-1} under Sphagnum and lowest Km 559 nM under hummocked *Carex*. Nine genera and several less understood type I and type II methanotrophs were detected by the key functional gene *pmoA* involved in methane oxidation. Microarray signal intensities from all sites revealed *Methylococcus*, the affiliated Lake Washington cluster, *Methylocaldum*, a Japanese rice cluster, *Methylosinus*, *Methylocystis* and the affiliated Peat264 cluster. Notably enriched by site was a flood-plain *Methylomonas* and a *Methylocapsa*-affiliated watershed cluster in the Sphagnum site.

CONCLUSIONS

The climate sensitive water table was shown to be a strong controlling factor highlighting its link with the CH_4 cycle in elevated wetlands.

ACKNOWLEDGEMENTS

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EMISSIONS OF MARINE MONOTERPENES AT THE COAST OF THE BALTIC SEA

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Keywords: Monoterpenes, marine, Baltic Sea, volatile organic compounds.

INTRODUCTION

Coastal new particle formation (NPF) may contribute to the formation of clouds, which affect many ecosystem processes and the radiation budget globally. Previous studies in coastal settings have identified biogenic emissions as the main driving factor for the NPF at some locations (O'Dowd *et al*., 2002). Every year extensive cyanobacterial blooms occur in the Baltic Sea region and Finnish water bodies, and these blooms could be a significant source of condensable vapors including biogenic volatile organic compounds (BVOCs) (Thakur *et al*., 2022). Most of the studies of monoterpene fluxes have extensively covered the terrestrial fluxes and much less attention has been given to the marine emissions of monoterpenes. To understand the impact of biogenic emissions on secondary aerosol formation, we have set up a permanent atmospheric laboratory at the Tvärminne Zoological Station on the Finnish coast of the Baltic Sea in 2022, in the "CoastClim" centre (*https://coastclim.org*).

METHODS

The laboratory houses state of art instrumentation mass spectrometers and particle size analyzers to measure many other gaseous organic and inorganic compounds along with continuous measurements of aerosol size distributions. 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 (Mäki *et al*., 2017) made from glass, floating on the seawater surface above high and low macroalgae (bladder wrack, *Fucus vesiculosus*) abundance. Emissions were sampled through Tenax TA Carbopack B adsorbent tubes and analysed via Gas Chromatography technique. The compounds were desorbed from the tenax tubes and analysed through the gas chromatography technique. Each spot was sampled in the morning, afternoon, and evening over the sampling days to study diurnal variations.

RESULTS

Our results showed that overall emissions of α-pinene fluxes from both the less and more abundant macrolagae sites were very similar. Median flux values in the mornings were higher than afternoon and evening at Spot 1, the location with abundant macro-algae as compared to the location with less macroalgae (spot 2) (fig. 1). For Limonene fluxes morning and evening fluxes were slightly higher at spot1. The analysis is still ongoing and the results need to be carefully evaluated taking into account the effect of chamber temperatures, water temperature and data of photosynthetically active radiation which play a major role in driving emissions from the water into the overlying atmosphere.

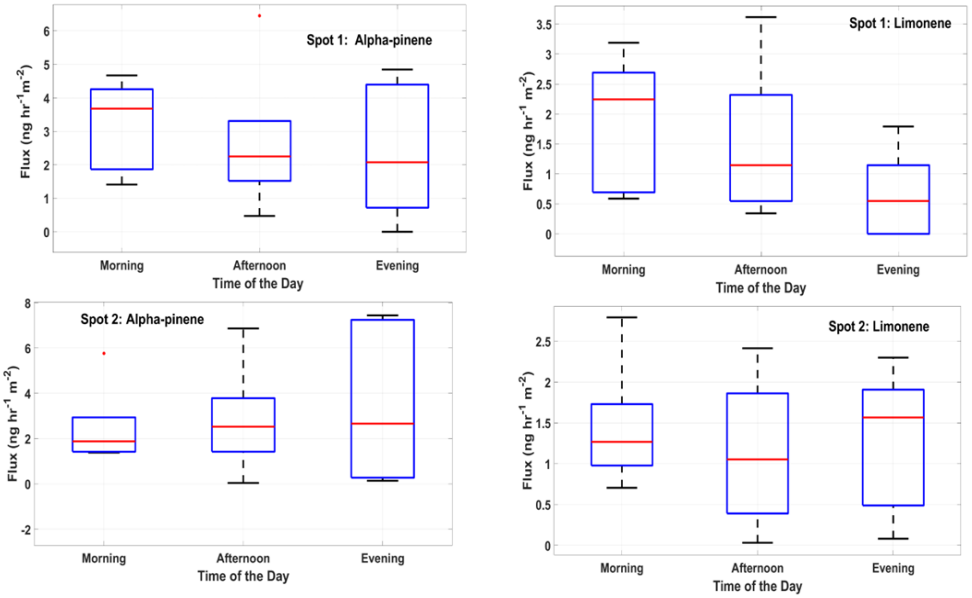

Figure 1. α-pinene flux at both the Spots. The red line shows the median flux value, the upper end and lower end of the box demonstrates the 75th and 25th percentile, respectively. The whiskers show the variability in the data.

CONCLUSIONS

The first results highlight the need for more laboratory/mesocosm experiments with different species of phytoplankton and macroalgae to 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

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ON THE POTENTIAL USE OF HIGHLY OXYGENATED ORGANIC MOLECULES (HOM) AS INDICATORS FOR OZONE FORMATION SENSITIVITY

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Keywords: Ozone sensitivity, Highly oxygenated organic molecules, NO_x, Volatile organic compounds.

INTRODUCTION

Ozone (O_3), an important and ubiquitous trace gas, protects lives from harm of solar ultraviolet (UV) radiation in the stratosphere but is toxic to living organisms in the troposphere. Additionally, tropospheric O_3 is a key oxidant, and source of other oxidants (e.g., OH and NO_3 radicals) for various volatile organic compounds (VOC). Recently, highly oxygenated organic molecules (HOM) were identified as a new compound group formed from oxidation of many VOC, making up a significant source of secondary organic aerosol (SOA) (Bianchi *et al.*, 2019). The pathways forming HOM from VOC involve autoxidation of peroxy radicals (RO_2), formed ubiquitously in many VOC oxidation reactions. The main sink for RO_2 is bimolecular reactions with other radicals, HO_2, NO or other RO_2, and this largely determines the structure of the end products. Organic nitrates form solely from RO_2 + NO reactions while accretion products ("dimers") solely from RO_2 + RO_2 reactions. The RO_2 + NO reaction also converts NO into NO_2, making it a net source for O_3 through NO_2 photolysis (Fig. 1).

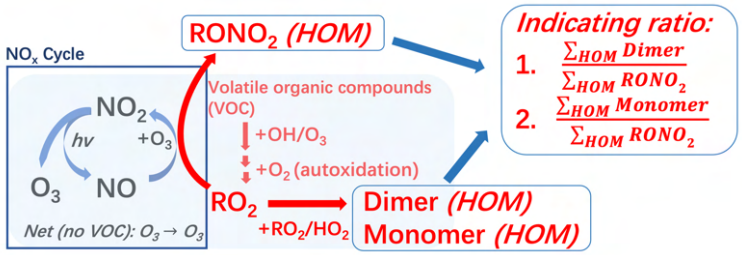

Figure 1. Sketch of the connection between HOM and O_3 formation. Based on the formation connection, two indicating ratios between HOM species are defined. "$RONO_2$ (HOM): nitrate-containing HOM monomers, "Dimer (HOM)": non-nitrate HOM dimers, "Monomer (HOM)": non-nitrate HOM monomers.

There is a highly nonlinear relationship between O_3, NO_x, and VOC. Understanding the O_3 formation sensitivity to changes in VOC and NO_x is crucial for making optimal mitigation policies to control O_3 concentrations (Wang *et al.*, 2017). However, determining the specific O_3 formation regimes (either VOC-limited or NO_x-limited) remains challenging in diverse environmental conditions. In this work we assessed whether HOM measurements can function as a real-time indicator for the O_3 formation sensitivity based on the hypothesis that HOM compositions can describe the relative importance of NO as a terminator for RO_2. Given the fast formation and short lifetimes of the low-volatile HOM (timescale of minutes), they describe the instantaneous chemical regime of the atmosphere. In this work, we conducted a series of monoterpene oxidation experiments in our chamber while varying the concentrations of NO_x and VOC under different NO_2 photolysis rates. We also measured the relative concentrations of HOM of different types (dimers, nitrate-containing monomers, and non-nitrate monomers) and used ratios between these (i.e., both indicating ratio 1 (IR1) and IR2 shown in Fig. 1) to estimate the O_3 formation sensitivity.

METHODS

The experiments were conducted in the COALA chamber (2 m^3), which was run in "steady-state mode". A nitrate-adduct Chemical Ionization Mass Spectrometer (NO_3-CIMS, Tofwerk AG/Aerodyne Research, Inc.) was used for online measurements of HOM with high selectivity. We constructed a simple 0-D box model (12 reactions, 9 species) to mimic the main reactions and to generate O_3 isopleth diagrams.

RESULTS

Based on model and experimental results (Fig. 2): Higher values of the indicating ratio suggest a higher likelihood of the system being in the NO_x-limited regime, while lower values suggest being VOC-limited. Overall, our study proves that indicating ratios can predict O_3 formation sensitivity, qualitatively and even quantitatively (e.g., IR1<0.2: VOC-limited; IR1>0.5: NO_x-limited).

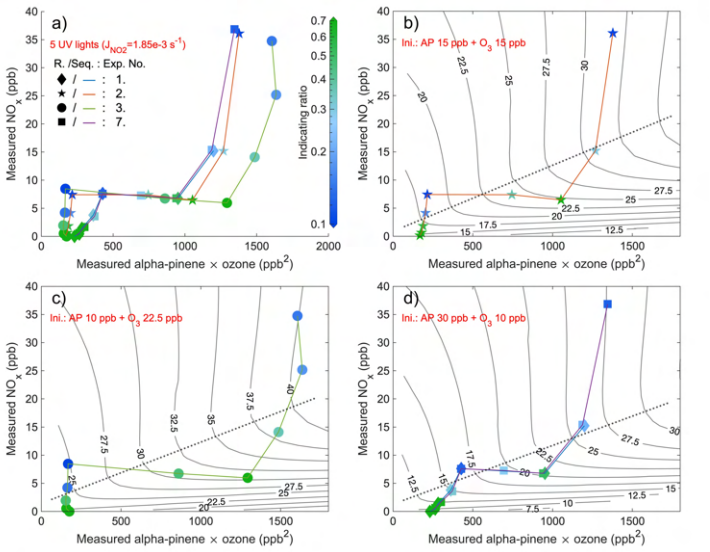

Figure 2. Steady state IR1 of experiments with 5 UV lights. Dotted ridge lines divide the two limited regimes.

CONCLUSIONS

Due to the intrinsic connection between the formation pathways of O_3 and HOM, the ratio of HOM dimers or non-nitrate monomers to HOM organic nitrates could be used to determine O_3 formation regimes. Owing to the fast formation and short lifetimes of HOM, the HOM-based indicating ratios can describe the O_3 formation in real time. Despite the success of our approach in this simple laboratory system, the applicability to the much more complex atmosphere remains to be determined.

ACKNOWLEDGEMENTS

This work was supported by funding from Academy of Finland (grant no. 345982) and the Jane and Aatos Erkko Foundation.

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COMPARISON OF GAS- AND PARTICLE-PHASE HIGHLY OXYGENATED ORGANIC MOLECULES FROM MONOTERPENE OZONOLYSIS

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Keywords: Highly oxygenated organic molecules, Monoterpene, Chemical ionization mass spectrometer, Vaporization inlet for aerosols.

INTRODUCTION

Highly oxygenated organic molecules (HOM) are important components of organic aerosol in the atmosphere. Although the mechanisms of gas-phase HOM formation have been extensively studied over the past decade, the speciation of particle-phase HOM and its relationship with gas-phase HOM has been limited by the lack of suitable analytical techniques. To quantify the concentration of particle-phase HOM, we coupled a novel Vaporization Inlet for Aerosols (VIA) with a nitrate Chemical Ionization Mass Spectrometer (NO_3-CIMS) in our lab. In this work, a sheath flow unit, which is crucial for the detection of these low-volatile "sticky" HOM species, is invented and is the main hardware update based on the first version of the VIA (Häkkinen et al., 2023). The entire system was characterized thoroughly and a simple one-dimensional model was developed to account for the evaporation of particles and the temperature-dependent wall losses of the evaporated molecules, and thereby the concentration of HOM in the particle phase could be estimated (Zhao et al., 2023). We investigated the gas- and particle-phase HOM distribution from ozonolysis of α-pinene, 3-carene, β-pinene, and limonene, which are the predominant monoterpenes in boreal forests, especially in southern Finland. We found dramatically different HOM distributions between the gas- and particle-phase measurements, which indicates the existence of particle-phase transformation of HOM species after their condensation.

METHODS

The VIA was designed to provide online measurements of compounds in the particle phase and was connected to the NO_3-CIMS in this work to identify particle-phase HOM. First, the honeycomb-activated carbon denuder allows particles to pass through while removing gaseous compounds. Then, the particle stream enters a heated desorption tube to be continuously evaporated into the gas phase. Finally, a sheath flow unit was used to cool down and minimize the wall loss of the hot vapors for subsequent ionization and analysis in the mass spectrometer.

The monoterpene experiments were conducted in the COALA chamber (2 m^3, Teflon) at the University of Helsinki. Four monoterpenes (α-pinene, 3-carene, β-pinene, and limonene) were used as the precursors for SOA formation. In one set of the experiment, α-pinene, 3-carene, β-pinene, limonene, and β-caryophyllene were mixed with a molar ratio of 60:25:10:4:1, roughly representing the averaged constituent of terpenes emitted by Scots pines dominated coniferous forests in Southern Finland. Neither OH scavengers nor seed particles were added during the experiments.

RESULTS

The comparison of gas- and particle-phase HOM mass spectra for the ozonolysis of each monoterpene is given in Figure 1. In general, quite different HOM distributions were observed for all monoterpenes between the two phases. In particular, α-pinene and β-pinene showed the largest enhancement of dimers in the particle phase, while limonene showed relatively comparable dimer to monomer ratios in the two phases. Nevertheless, all dimers measured in the particle phase shifted to lower mass ranges compared to the gas phase measurements, indicating quite different HOM species were identified between the two phases.

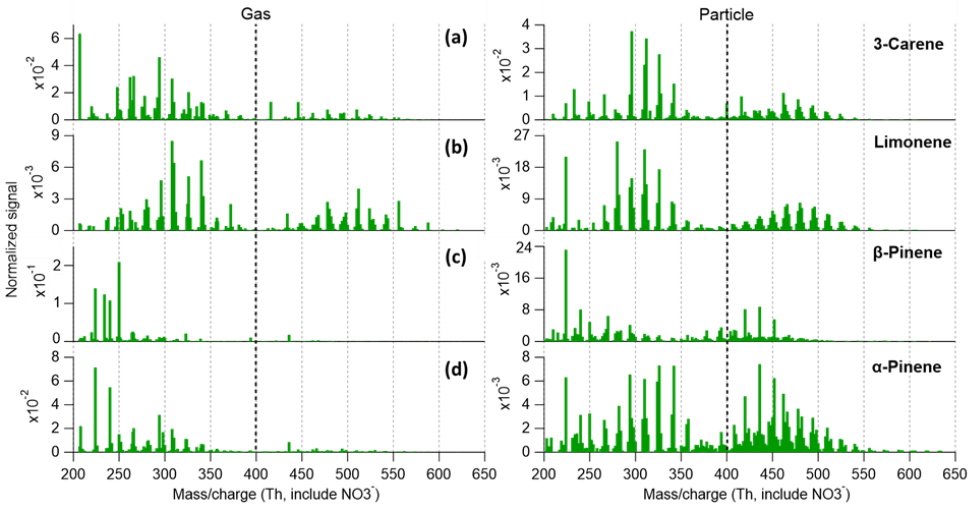

Figure 1. (left) Gas- and (right) particle-phase mass spectra of HOM from ozonolysis of (a) 3-carene (120 ppb), (b) limonene (30 ppb), (c) β-pinene (300 ppb), and (d) α-pinene (60 ppb) measured by a NO_3-CIMS. Comparable O_3 concentrations (58.8-62.0 ppb) were used, while different input concentrations of monoterpenes were adjusted based on their reaction rate constants with O_3 to form comparable amounts of RO_2. The dashed lines roughly separate the monomer and dimer ranges in the mass spectra.

CONCLUSIONS

In this work, we showed that the updated VIA-NO_3-CIMS combination could be a very promising technique for quantitative online measurements of particle-phase HOM. By comparing the gas- and particle-phase HOM mass spectra obtained from the ozonolysis of four different monoterpenes, we suggest that more work is needed to investigate the potential particle-phase transformation of HOM species after their condensation from the gas phase.

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THE VERTICLE TRANSPORT OF POLLUTANT THROUGH MOUNTAIN VALLEY BREEZE IN CITY ATMOSPHERE

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Keywords: Mountain-valley breezes, Mountain Chimney effect, Beijing, Air quality.

INTRODUCTION

The concentrations of atmospheric pollutants are highly influenced by several meteorological parameters, i.e., wind patterns, temperature, cloud cover, and relative humidity (among others). These parameters are, in turn, affected by both large-scale and small-scale weather systems. Large-scale weather systems exert control over the overarching meteorological conditions within a given region, while local meteorological phenomena, such as mountain-valley breezes, assume a pivotal role in shaping and regulating air quality at the local level.

Mountain-valley breezes significantly impact pollutant transportation and spatial distribution, particularly during high pollution episodes(Chen et al., 2009). Baumbach and Vogt (1999) observed that in Freiburg, air pollutants emitted during the day were transported to the Black Forest by valley winds, returning to Freiburg at night when mountain winds reverse directions. Similarly, Wang, Ding, Gao, and Wu (2006) suggested that the high ozone episode, peaking at 286 ppbv, could be attributed to mountain-valley breezes transporting urban pollutants to the mountainous regions north of Beijing. Furthermore, Seibert et al. (1998) demonstrated that pollutants emitted from the Po Valley can be transported to mountain summits and nearby valleys, Alps.

Beijing, situated at the base of the Yan Mountains and Taihang Mountains to the north of the North China Plain, experiences the influence of mountain-valley breezes in facilitating the transport of urban-sourced air pollutants. Mountains contribute to this process by expelling pollutants beyond the temperature inversion layer from the boundary layer, commonly known as the Mountain Chimney Effect (MCE) (Miao et al., 2015).

METHODS

Ceilometer (CL51, Vaisala) measurements can provide high resolution information on atmospheric conditions such as cloud base height (CBH) and vertical frequency of cloud occurrence (CVF). Planetary boundary layer (PBL) height is also be inferred from the backward scattering signals. The ceilometer was located in Beijing University of Chemical Technology (Liu et al., 2020). Other common meteorological variables are measured with an Automatic Weather Station (AWS310, Vaisala) at the same site as the ceilometer. The ceilometer data is provided in 16 s temporal resolution. The study period was from 2018-2022.

RESULTS

Data from ceilometer backscatter coefficient measurements reveal that before some air pollution events in Beijing, there are clear signs of an elevated pollution layer descending from 2500 to 3000 meters into the

planetary boundary layer, providing robust evidence of the existence of such elevated pollution layers in Beijing's atmosphere This descent of elevated pollutants acts as a contributor to subsequent pollution events. These layers have the potential to worsen pollution episodes in the city and may even initiate new events, complicating the dynamics of air quality. This study emphasizes the importance of monitoring and understanding elevated pollution layers in urban settings to improve air quality prediction and mitigation.

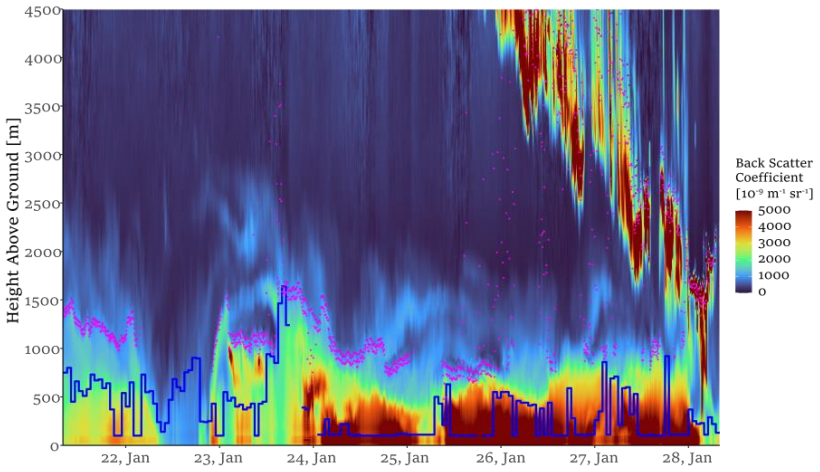

Figure 1. The Back scatter coefficient from 10th to 20th January 2020 of the atomosphere over certain above ground height of BUCT station. The colors indicate the strength of the back scatter, the pink dots indicated the cloud height detected by Cilometer, and the red line represents the boundary layer height in meters.

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