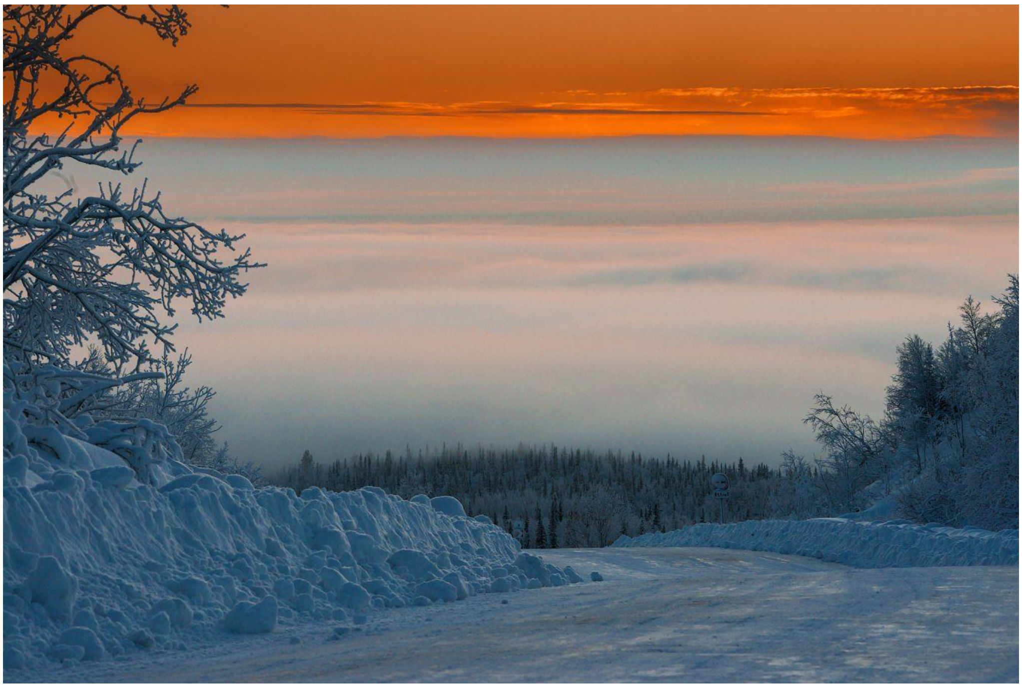
Pan-Eurasian Experiment
PEEX

TRAnsferable Knowledge and Technologies for high-resolution environmental impact assessment and management

2018



Project Special Reports

TRAKT

Winter road on the Kola Peninsula, Russia (photo by Sergey Rzhevsky)

Content: TRAKT Project Special Reports by INAR-UHEL team

PEEX – Pan-Eurasian EXperiment Programme Science Plan

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& PEEX Research Community [1]
[1] see pp 244-250 of the PEEX Science Plan

The **Pan-Eurasian EXperiment** (PEEX; https://www.atm.helsinki.fi/peex) is a multidisciplinary climate change, air quality, environment and research infrastructure program focused on the Northern Eurasian domain, and in particular, on the Arctic and boreal regions. It is a bottom-up initiative by several European, Russian and Chinese research organizations and institutes in co-operation with United States and Canadian organizations and institutes.
At current moment, the PEEX network includes more than 4000 researchers worldwide. There are several PEEX Thematic Working Groups (WGs) such as the Research Infrastructure, Modelling-Platform, Satellite, and foreseen other WGs. As of now, more than 30 PEEX Memorandum of Understanding (MoU) were signed with universities and research institutes in Russia and China (https://www.atm.helsinki.fi/peex/index.php/mou).

According to the developed PEEX Science Plan (*PEEX, 2015*), the **PEEX approach** emphasizes that solving challenges related to climate change, air quality and cryospheric change requires large-scale coordinated co-operation of the international research communities. Strong involvement and international collaboration between European, Russian and Chinese partners is needed to answer the climate policy challenge: how will northern societies cope with environmental changes?

The **PEEX vision** is to solve interlinked global grand challenges influencing human well-being and societies in northern Eurasia and China in an integrative way, recognizing the significant role of boreal and Arctic regions in the context of global change. The list of grand challenges cover subjects such as climate change, air quality, biodiversity loss, chemicalization, food supply, energy production and fresh water supply. The identified large scale research topics to be studied from a system perspective towards better system understanding of the Arctic-boreal regions are shown in Figure 1.
The vision also includes the establishment and maintenance of long-term, coherent and coordinated research and education activities and continuous, comprehensive research infrastructures in the PEEX domain. PEEX aims to contribute to the Earth system science agenda and climate policy in topics important to the Pan-Eurasian environment, and to provide adaptation and mitigation strategies for the Northern Pan-Eurasian and Chinese societies related to Grand Challenges particularly climate change and air quality.
The **PEEX mission** aim to be a next-generation natural sciences and socio-economic research initiative using excellent multi-disciplinary science with clear impacts on future environmental, socio-economic and demographic development of Arctic-boreal regions as well as of China.

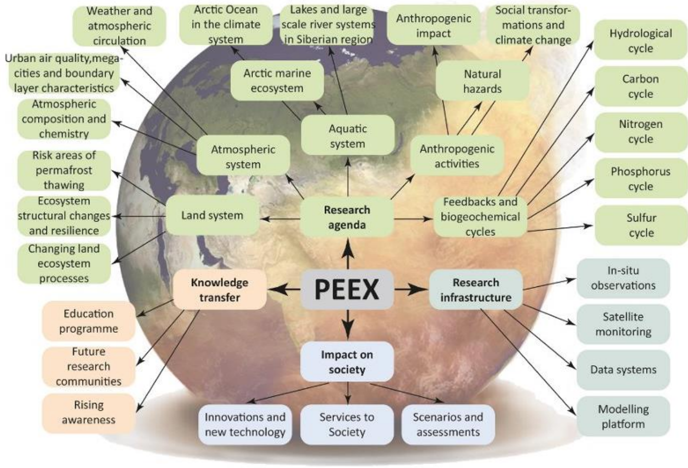

***Figure 1.** Detailzation of the PEEX agenda represented by 4 main focus areas: Research agenda, Research infrastructures, Impact on society, Knowledge transfer (Fig. from PEEX, 2015).*

The **PEEX *research agenda*** defines the large-scale key topics and research questions of the land-atmosphere-aquatic-anthropogenic systems in the Arctic-boreal context as well as megacity-climate interactions and air quality issues. The ***research infrastructure*** introduces the current state of the art observation systems in the Pan-Eurasian regions and presents the future baselines for the coherent and coordinated research infrastructures in the PEEX domain. The ***impact on society*** addresses key aspects related to mitigation and adaptation strategies. It also involves planning for preparing northern societies to cope with environmental changes, developing reliable early-warning systems, and addressing the role of new technology in the implementation of these strategies and plans. The ***knowledge transfer*** is focused on educational programs at multiple levels, strengthening future research communities, and raising awareness of global changes and environmental issues.

The **PEEX scientific results** will fill the current gaps in our knowledge of the processes, feedbacks and links within and between the major components of the Earth system, and the biogeochemical cycles, in the Arctic-boreal context.
The PEEX domain covers a wide range of interactions and feedback processes between humans and natural systems, with humans acting both as the source of climate and environmental change, and the recipient of the impacts. Reliable climate information and scenarios for the coming decades are crucial for supporting the adaptation of northern societies to the impacts of climate change and cryospheric changes. Human decision-making concerning, for example, land use and fossil fuel burning are represented by agent-based and integrated assessment models, and climate scenarios, which will be utilized and further developed for the Northern Pan-Eurasian region. In urban and industrialized regions, the process understanding of biogeochemical cycles includes anthropogenic sources, such as industry and fertilizers. PEEX climate scenarios, especially estimates of the type and frequency of natural hazards in the future, will be used to improve climate prediction capacities in Europe, Russia and China.

References:

PEEX (2015): Pan-Eurasian EXperiment Science Plan. Eds. Lappalainen H.K., Kulmala M., Zilitinkevich S., ISBN 978-951-51-0587-5, 307 p, http://www.atm.helsinki.fi/peex/images/PEEX_Science_Plan.pdf

Linking TRAKT project to the PEEX networking

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At current moment the Pan-Eurasian EXperiment programme (PEEX) network includes more than 4000 researchers worldwide. The existing PEEX dissemination platform and communication tools will be used for presenting and promoting the TRAKT-2018 project (*TRAnsferable Knowledge and Technologies for high-resolution environmental impact assessment and management*) for the PEEX community.

The information is distributed through the PEEX official website (https://www.atm.helsinki.fi/peex - in English, Russian and Chinese), e-news, instagram, twitter (https://twitter.com/PEEX_News), e-mailing list (https://www.atm.helsinki.fi/peex/index.php/peex-e-mailing-list), newsletters (https://www.atm.helsinki.fi/peex/index.php/newsletter). So far the PEEX programme signed more than 30 PEEX Memorandum of Understanding (MoU) with universities and research institutes in Russia and China (https://www.atm.helsinki.fi/peex/index.php/mou).

As part of the TRAKT project, during the official kick-off-meeting (22-24 Jan 2018, St. Petersburg, Russia; Fig. 1) such MoUs were signed also with 3 Russian partners involved into the project – the Nansen International Environmental and Remote Sensing Center (NIERSC; http://www.niersc.spb.ru; St. Petersburg), the Scientific Research Center for Ecological Safety (SRCES; http://ecosafety-spb.ru; St. Petersburg) and the Kola Science Center of the Russian Academy of Sciences (KSC RAS; http://www.kolasc.net.ru/english/index.html; Apatity, Murmansk region).

***Figure 1.** TRAKT-2018 project kick-off-meeting (Jan 2018) – participants working moments, and brainstorming on steps of the project realisation (led by the project coordinator Dr. Igor Ezau).*

Moreover, basic information about the TRAKT project is linked to the PEEX official website and available at: https://www.atm.helsinki.fi/peex/index.php/trakt-2018. The TRAKT activities are well linked with two PEEX focus areas (Fig. 2) such as the "*Knowledge Transfer*" and "*Impact on Society*".

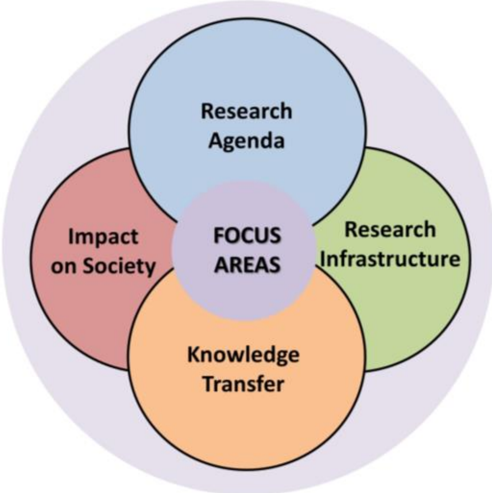

***Figure 2.** PEEX is represented by 4 main focus areas: Research Agenda, Research Infrastructures, Impact on Society, Knowledge Transfer.*

The "Knowledge Transfer" focus area directs towards educational programs at multiple levels, strengthening future research communities, and raising awareness of global changes and environmental issues. And in particular: (i) to educate the next generation of multidisciplinary experts and scientists capable of finding tools for solving grand challenges; (ii) to increase public awareness of climate change impacts in the Pan-Eurasian region; (iii) to distribute the new knowledge and data products to scientific communities and the public sector; and (iv) to deliver tools, scenarios and assessments for climate policy makers and authorities.

The "Impact on Society" focus area addresses key aspects related to mitigation and adaptation strategies. It also involves planning for preparing northern societies to cope with environmental changes, developing reliable early-warning systems, and addressing the role of new technology in the implementation of these strategies and plans.

As part of the PEEX Working Groups meeting (scheduled for 1-2 November 2018, Helsinki, Finland), the TRAKT partners were invited to present the achieved results to a wider PEEX community. TRAKT is also invited to contribute to the 4th PEEX Science Conference (2019, Helsinki). Materials and results of the project are expected to be included into lecture courses at Universities. In addition, the INAR-UHEL team is also agreeing to provide the Enviro-HIRLAM model through signing agreement on the model code transfer and use for research, development and educational purposes for the project partners. A closer involvement and project contribution are also expected as part of the PEEX climate policy making and to international forums, decision-makers and national authorities (see more information in the PEEX Science Plan, sections 5.2 & 6.1).

References:

PEEX (2015). Pan-Eurasian EXperiment Science Plan. Eds. Lappalainen H.K., Kulmala M., Zilitinkevich S., ISBN 978-951-51-0587-5, 307 p, http://www.atm.helsinki.fi/peex/images/PEEX_Science_Plan.pdf

SMEAR – Station for Measuring Ecosystem-Atmosphere Relations

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1 https://www.atm.helsinki.fi/SMEAR/index.php/people

The SMEAR research stations are developed and used to perform comprehensive and continuous observations (https://www.atm.helsinki.fi/SMEAR/index.php[2]) for the relationship of atmosphere – Earth's surface/ biosphere in boreal climate zone (Fig. 1). The main aims of research are: (i) biosphere - aerosol - cloud - climate interactions; (ii) biogeochemical cycles of carbon, nitrogen, sulphur and water; (iii) analysis of gaseous and particle pollutants and their role in cloud formation; (iv) analysis of water, carbon and nutrient budgets of soil; (v) analysis of environment and tree structure on gas exchange, water transport and growth of trees.

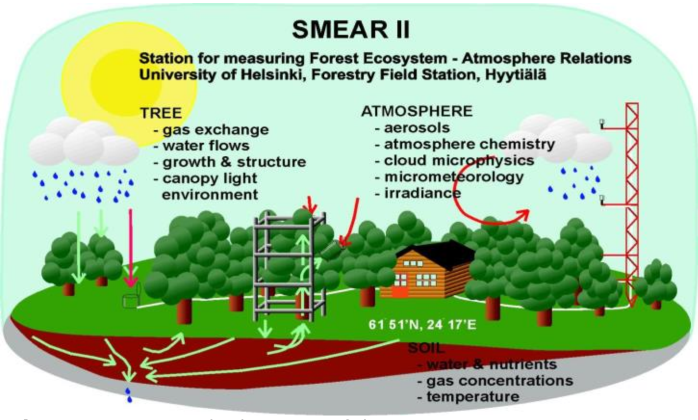

***Figure 1.** Conceptual schematics of the SMEAR stations measurements.*

At SMEAR stations, in total more than 1200 different variables can be measured in urban, forest, lake, peatland, and other areas. The SMEAR concept allows to study feedbacks with different surfaces such as land, water, urban, biosphere, cryosphere, etc. It relies on open data, open access, and open data flow. There are several SMEAR stations in Finland (Fig. 3; with the most advanced SMEAR-II station in Hyytiälä, where frequently the training and educational courses are carried out, Fig. 2), also in Estonia, China as well as planned in Russia.

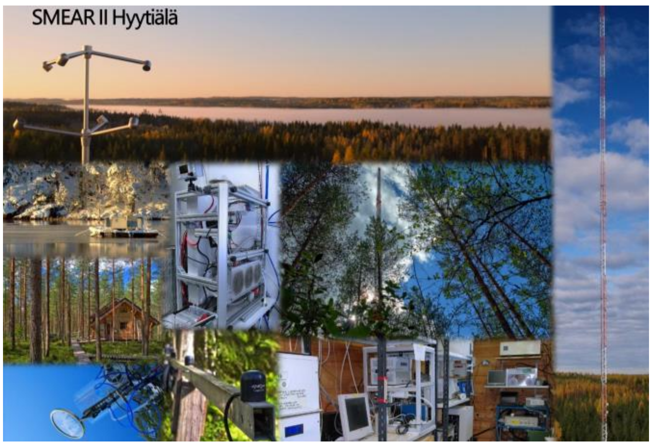

***Figure 2.** SMEAR-II station in Hyytiälä, Finland.*

The closest SMEAR station to the Russian North is called the SMEAR-I station (Fig. 3-left & 4-left). It was placed into operation in 1991 in order to measure pollution levels (at first, with focus on SO_2 and then later on other chemical species) in the Eastern Lapland of Finland from various industrial sources of the Kola Peninsula (Murmansk region, Russia). It is hosted by the Värriö Subarctic Research Station, which is placed in the Värriö Strict Nature Reserve (www.helsinki.fi/forestsciences/varrio/index.html).

***Figure 3.** Geographical locations of the SMEAR stations in Finland & 4 seasons at SMEAR-II station (see more illustrations at [2]).*

At SMEAR-I, during 1990s the measuring activity has increased to cover photosynthesis, weather, gas and particle measurements in addition to the measurements of air pollutants. In particular, the weather station measures wind speed and direction, air temperature and relative humidity on 5 levels (up to 15 m), and radiation (PAR, global, reflected and net radiation) is measured at the top level. Gas and particle measurements includes sampling on 4 levels (from 1 to 8 m). Concentrations of CO_2, SO_2, O_3 and NO, NOx are recorded as well as submicron particle number concentrations.The online available SMEAR-I measurements include: aerosol particle count and size distribution, atmospheric pressure, air temperature, relative humidity, precipitation, wind speed and direction, radiation components, soil temperature, carbon dioxide exchange of 4 pine shoots, and selected trace gas concentrations. Selected observations in a graphical format are web-online available (https://www.atm.helsinki.fi/SMEAR/index.php/online-observations) as well as data can be downloaded (https://avaa.tdata.fi/web/smart/smear/download).
In addition to the state-of-the-art SMEAR stations, the PEEX has also very close collaboration with many Russian partners on measurements (at different level of complexity) in the Arctic region. In particular, work is in progress on building the catalogue (Fig. 4-right) of the collaborating atmospheric-ecosystem in-situ stations in Russia. Information on these stations and their metadata is available from the developed database at https://peexdata.atm.helsinki.fi (*under request*).

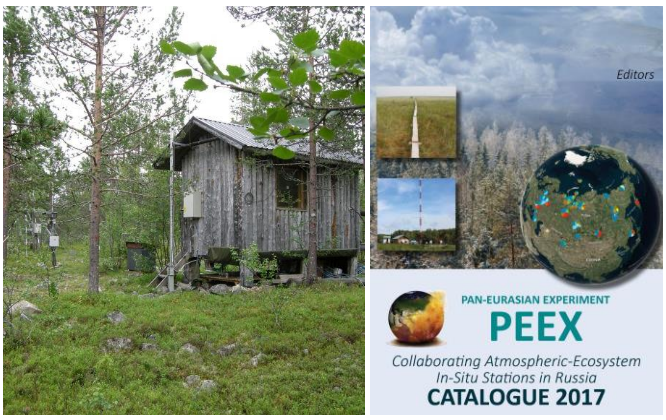

***Figure 4.** SMEAR-I station in Värriö, Finland & Catalogue.*

Multi-Scales and Multi–Processes Modelling at INAR

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According to the Pan-Eurasian EXperiment Science Plan (*PEEX, 2015*), the PEEX Modelling Platform (PEEX-MP) presents a strategy for best use of current generation modeling tools to improve process understanding and predictability on different scales in the PEEX domain (see https://www.atm.helsinki.fi/peex/index.php/modelling-platform). More than 100 members from European, Russian, and Chinese institutions have joined the PEEX-MP. The key issues considered by the MP include the following topics: anthropogenic emissions, permafrost effects, methane and carbon dioxide, ecosystem carbon cycle, short lived pollutants and climate forcers, biogenic VOC emissions, forest fires and their effects, aerosol formation in Arctic and Siberia, aerosol radiative forcing, air pollution – ecosystem feedbacks, dynamics of ocean and sea-ice, high impact events.

At INAR, a number of application areas of new integrated modelling developments is expected as a part of the research project "Enviro-PEEX on ECMWF" (2018-2020; https://www.atm.helsinki.fi/peex/index.php/enviro). The focus is to analyse importance of the meteorology-chemistry-aerosols interactions and feedbacks and to provide a way for development of efficient techniques for on-line coupling of numerical weather prediction (NWP) and atmospheric chemical transport via process-oriented parameterizations and feedback algorithms, and hence, to improve NWP, climate and atmospheric composition forecasting.

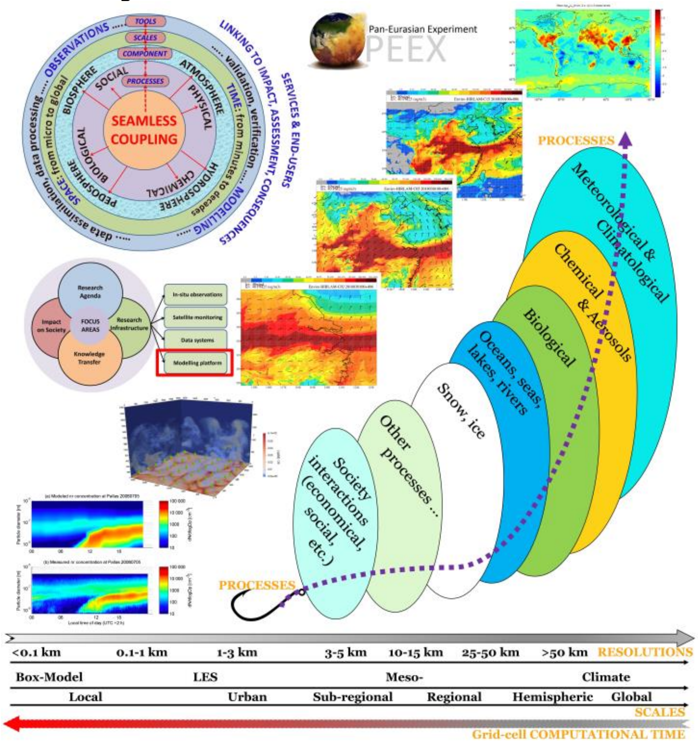

Figure 1. *Multi-scales & -processes modelling at INAR (NOSA-FAAR Conference, Mar 2018; poster by Mahura et al.).*

The seamless/ on-line integrated coupling includes different processes, components, scales and tools (see Fig. 1). At INAR, several research tools are used: the EC-Earth (*Hazeleger et al., 2010*), Enviro-HIRLAM (*Baklanov et al., 2017*), ASAM (*Jähn et al., 2015*), SOSAA (*Boy et al., 2011*), MALTE-box (*Huang et al., 2016*), and others.

The scales to be considered cover scales from micro- to local, urban, sub-regional, regional, hemispheric, global; and from box-model to large eddy simulations, meso- and climate scales. The horizontal resolutions for models runs are ranging from a few meters to more than a degree in the latitudinal-longitudinal domain. The processes, at the current moment studied at different degree of understanding and to be considered include meteorological and climatological, chemical and aerosols, biological, hydrological, and others as well as taking into account society interactions (see Fig. 1).

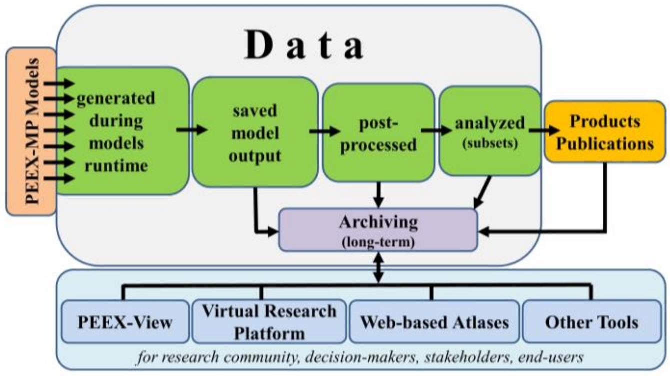

Figure 2. *PEEX Modelling Platform data flow from model runs to products and publications with long-term archiving and delivering for potential customers.*

Available observations for atmosphere and ecosystems (in particular, from the SMEAR stations and PEEX metadatabase stations) will be used for data assimilation and data processing as well as for the models validation and verification studies.

The IT Center for Science (CSC, Finland; https://www.csc.fi) and European Center for Medium-range Weather Forecasting (ECMWF, UK; https://www.ecmwf.int) are in active collaboration with INAR, where CRAY's supercomputing facilities, mass storage systems, meteorological and atmospheric composition data archives are used extensively.

The large dataset during PEEX-MP models runtimes will be generated, post-processed, analysed, and also saved for long-term storage (see Fig. 2). These data can be visualised and analysed using different tools such as the PEEX View, Web-based Atlases, Virtual Research Platform by the members of the research community, decision-makers, stakeholder, end-users.

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Earth System Modelling with EC-Earth

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TRAKT project assesses the performance of global Earth System Model EC-Earth in the study domain. EC-Earth is developed and applied jointly by over 30 European research institutes (*Hazeleger et al., 2010, 2012*). The Coupled Model Intercomparison Project 5 (CMIP5) was the first CMIP for EC-Earth, and now the model is participating CMIP phase 6 (CMIP6).

The EC-Earth comprises of atmosphere model IFS (Integrated Forecasting System), ocean model NEMO (Nucleus for European Modelling of the Ocean; *Madec et al., 2008*) and vegetation model LPJ-GUESS (Lund-Potsdam-Jena General Ecosystem Simulator), coupled with OASIS (Ocean Atmosphere Sea Ice Soil; *Redler et al., 2010*) coupler (Figure 1). Aerosols and chemistry are included through the global chemistry-transport model TM5 (Transport Model 5). The atmospheric model IFS might be changing to OpenIFS, which would also increase the potential user groups of EC-Earth model and link more to meteorological training. The full ESM version of EC-Earth is currently being implemented in computing infrastructures around Europe.

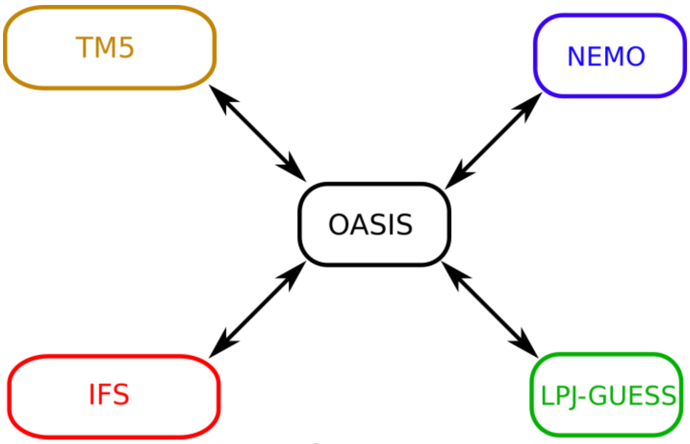

Figure 1.
EC-Earth model components: TM5 (aerosols and chemistry), NEMO (ocean), IFS (atmosphere), LPJ-GUESS (vegetation).

The IFS is the atmospheric model developed at European Centre for Medium-Range Weather Forecast (ECMWF, UK). The proposed assessment in TRAKT is using IFS with 62 vertical levels and a horizontal spectral resolution of T255 corresponding to roughly 0.54º×0.54º, which is rather high resolution for ESM applications. The IFS is coupled to the ocean model NEMO, which is run with 1º horizontal resolution and 42 vertical levels. The ice model LIM (The Louvain-la-Neuve Sea Ice Model; *Vancoppenolle et al., 2009; Rousset et al., 2015*) is coupled directly to the ocean model.

The TM5 (*van Noije et al., 2014*) describes aerosols using a 7-mode size distribution (*Vignati et al., 2004*), with 4 soluble and 3 insoluble modes. TM5 includes most abundant aerosol species: sulfate, black carbon, organic carbon, sea salt and mineral dust. TM5 uses a grid of 3º×2º for aerosols and chemistry.

For the current CMIP6 version of EC-Earth ESM, several relevant modifications are included: 1) TM5 aerosol fields are communicated via OASIS to IFS for aerosol indirect (cloud) effect, 2) interactive dust emissions and 3) secondary organic aerosol (SOA) scheme are implemented. The University of Helsinki has actively participated in the CMIP6-development of TM5, namely aerosol nucleation, aerosol growth and SOA module development.

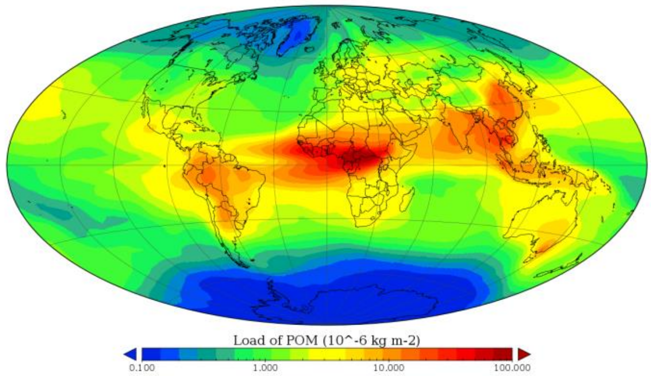

Figure 2.
Monthly average load of particulate organic matter for January (kg m-2), as simulated by TM5 aerosol-chemistry model in EC-Earth. Primary visible sources of POM in the model include wildfires, anthropogenic sources, and biogenic precursors.

The LPJ-GUESS (*Smith et al., 2001*) is the terrestrial vegetation components of EC-Earth. It is a dynamic process-based ecosystem model which can predict structural and compositional ecosystem properties. In EC-Earth, the atmospheric model IFS communicates temperature, radiation, precipitation and soil state to LPJ-GUESS. Concurrently, LPJ-GUESS updates simulated low and high vegetation fraction as well as leaf area index to IFS land surface module. In addition to land surface processes, gas-phase transport of CO2, aerosols and precursors is communicated between TM5 and LPJ-GUESS. The CMIP6-version of EC-Earth includes version 4 of LPJ-GUESS, together with e.g. a new land albedo parameterization and fire module. For the benefit of the proposed project, LPJ-GUESS is now being updated with speciated monoterpene emissions for detailed SOA formation in the atmosphere.

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Seamless Integrated Meteorology-Chemistry-Aerosols Enviro-HIRLAM Modelling

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The development seamless/ on-line integrated meteorology-chemistry-aerosols modelling system such as the **Enviro-HIRLAM** (***Environment – HIgh Resolution Limited Area Model***) is expected to be able to handle and study some of major existing processes and interactions, which is difficult to investigate using the off-line modelling approach. Following *Jacobson et al. (2007) and Zhang (2008),* among these processes and interactions there are the following. At first, the direct effect - radiative effect of chemical species in the atmosphere via absorption and scattering. At second, the semi-direct effect - effect of aerosols and clouds on photolysis rates via modifying actinic fluxes and temperature. At third, the semi-direct effect - effect of aerosols on boundary layer meteorology via changing meteorological variables and atmospheric stability. At fourth, the 1st and 2nd indirect effects - effect of aerosols on cloud formation and reflectance via aerosol activation, droplet and ice core nucleation, autoconversion, and collection. And, at firth, the indirect effects - effect of aerosols on precipitation by affecting clouds and water vapour. These processes and interactions are important in studies for weather, climate, air quality, ecosystems, etc. Aerosols, being an integral part of the atmosphere, play important role in the environmental conditions behaviour. Depending on origin, chemical composition, lifetime, size, shape, optical properties, etc. aerosols can cause multiple complex effects in the atmosphere at various temporal and spatial scales *(Kulmala et al., 2009; Calvoa et al., 2012).*

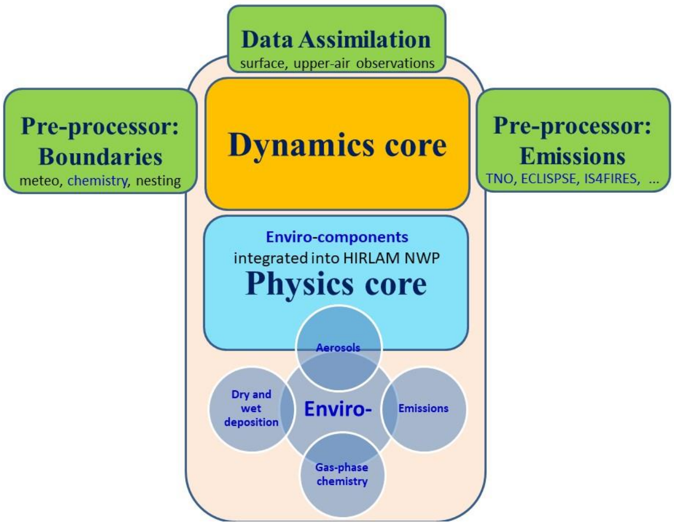

Figure 1. *General schematics of the Enviro-HIRLAM modelling system.*

The Enviro-HIRLAM model is developed as a fully online integrated numerical weather prediction (NWP) and atmospheric chemical transport (ACT) model for research and forecasting of joint meteorological, chemical and biological weather at multi-scales (*Baklanov et al., 2017*).

The NWP part developed by HIRLAM consortium is used for operational weather forecasting. The Enviro-components were developed in collaboration with the Universities from different countries. The Enviro-consists (*see all references in Baklanov et al., 2017*) modules for gas-phase chemistry CBMZ and aerosol microphysics M7 (includes sulphate, mineral dust, sea-salt, black and organic carbon). There are also modules of urbanization (anthropogenic heat flux and roughness, building effect parameterisation, others) for land surface scheme, natural and anthropogenic emissions, nucleation, coagulation, condensation, dry and wet deposition, sedimentation of aerosols. The improved Savijarvi radiation scheme takes into account explicitly for aerosol radiation interactions for 10 aerosol subtypes. The aerosol activation scheme was implemented in STRACO condensation-convection scheme. The nucleation is dependent on aerosol properties, ice-phase processes are reformulated in terms of classical nucleation theory. The schematics is shown in Fig 1.

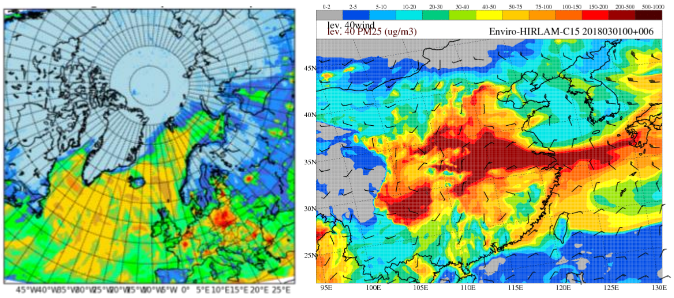

Figure 2. *Enviro-HIRLAM model simulation examples: (left) averaged spatial distribution of the maximum PM2.5 concentration field at 12 UTC for the month of Jan 2010; & (right) operational forecast for the China on 1 Mar 2018 (00+06 h forecast length).*

Enviro-HIRLAM runs in a downscaling chain, for the outer model domain (run at low resolution) the initial and boundary conditions for meteorology and atmospheric conditions are taken from ECMWF. The vertical levels vary between 40-60. The finest horizontal resolution is about 1.5 km. The model can be run in both research and operational modes. Emissions include anthropogenic, biogenic, and natural; and these are pre-processed. Different parts of the model were evaluated vs. ETEX-1 experiment, Chernobyl accident, Paris summer/winter campaigns, etc. The model was tested in FPs FUMAPEX, MEGAPOLI, TRANSPHORM, PEGASOS, MACC, MarcoPolo projects as well currently is used within frameworks of the Pan-Eurasian EXperiment programme (PEEX; https://www.atm.helsinki.fi/peex) tasks. Examples of the model simulations are shown in Fig 2.

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Process-Based Modelling for the Meteorology-Chemistry-Aerosol System

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The main focus of the process-based modelling in the PEEX-MP is to increase our understanding of hydrological, physical, meteorological and chemical mechanisms in the lower part of the troposphere. This includes the emissions of biogenic volatile organic compounds (BVOC) from different ecosystems with a special focus on boreal region, their vertical and horizontal distribution and their chemical reaction paths. Further to investigate the formation and growth of secondary organic aerosols (SOA) inside the planetary boundary layer (PBL) and to improve our understanding of in- and below cloud formation and activation mechanisms, which is still far away from complete. We aim at finding process parameterizations that can be subsequently applied in climate predictions and reduce significant uncertainties therein (see Figure 1).

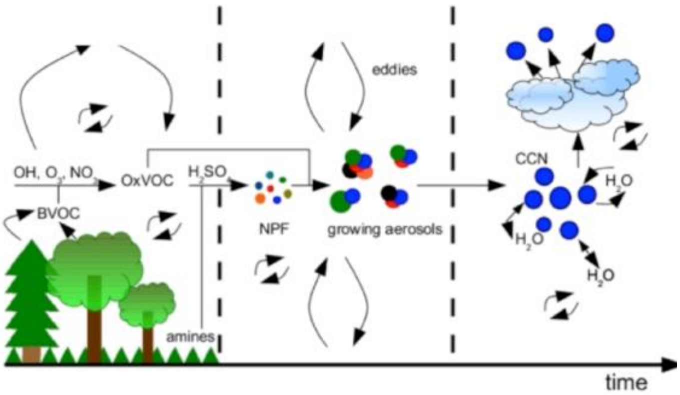

Figure 1: *General schematics on the scientific objectives.*

To achieve these goals we apply a seamless process-based modelling system including a set of different models: starting from the zero-dimensional models MALTE-BOX and ADCHAM, the one-dimensional model SOSAA, the two-dimensional model ADCHEM and the three-dimensional high-resolution regional model SILAM. In addition to understand the impact of turbulence on the different processes we operate the large-eddy-simulation model (LES) ASAM and the direct numerical simulation model (DNS) PENCIL-CLOUD. The advantage by applying this seamless-process-based model system is in the use of several modules like the ecosystem emission module MEGAN (Model of Emissions of Gases and Aerosols from Nature) or the aerosol module UHMA (University of Helsinki Multicomponent Aerosol Model) in several models, which provides improvements in one process to other models at the same time. A schematic spatial-temporal distribution for all models applied is provided in Figure 2.

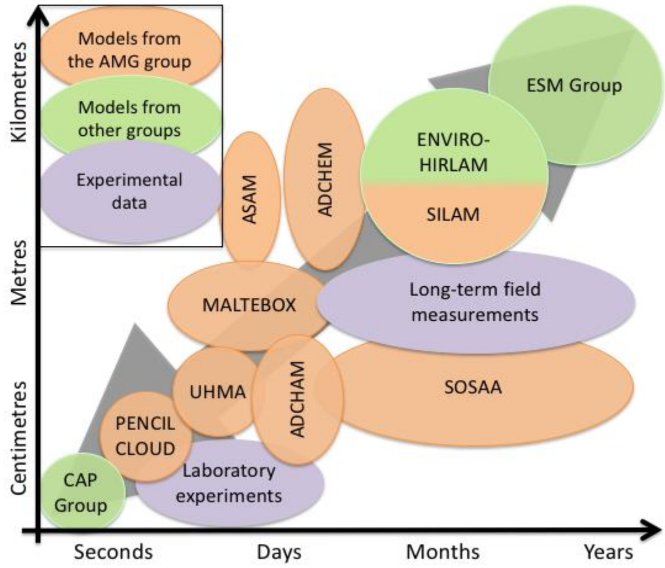

Figure 2: *Schematic time-space picture of the models applied in the Atmospheric Modelling Group, the connection to other groups (models) and the used experimental data (size of circles and ovals represent approximately the spatial and temporal area covered by the model or experimental data; CAP = Computational Aerosol Physics Group, ESM = Earth System Modelling Group).*

Detailed information for the individual models are available at the AMG website: https://wiki.helsinki.fi/display/AMG/Atmospheric+Models
One of the main objectives of the group is to gain a comprehensive understanding of the precursors, formation, growth, and transformation of SOA and to quantify the associated climate impacts with a focus on anthropogenic versus biogenic effects. Recently we have developed the most comprehensive Peroxy Radical Autoxidation Mechanism (PRAM), which explicitly simulates the formation of HOM from monoterpenes (*Roldin et al., 2018*). We use PRAM together with detailed molecular cluster dynamics and aerosol dynamics models to constrain the contribution of highly oxygenated organic molecules (HOM) to the formation and growth of new particles to the climatically important cloud condensation nuclei (CCN) size range. Based on our process-based model results we will evaluate and suggest how to improve the new particle formation (NPF) and SOA formation parameterization used by regional and earth system models (see figure 3).

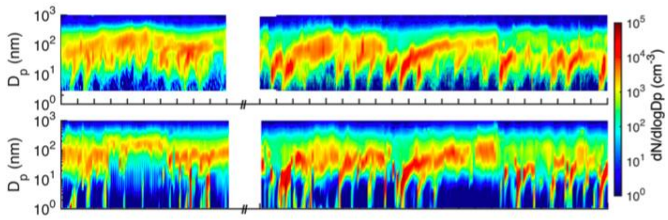

Figure 3: *Measured (upper plot) and modelled (lower plot) particle size distributions for the periods 15^t -25th of May 2013 and 15th of April to 4th of May 2014 at SMEAR II, Hyytiälä, Finland. ADCHEM was used for these model runs and the NPF was simulated with ACDC assuming that the clusters were formed from* NH_3 *and* H_2SO_4*.*

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Monthly Concentration & Deposition Patterns from Smelters of the Russian North: Atlas

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There are several locations in the northern Russian Arctic associated with large amounts of sulphur dioxide (SO_2) emission into the atmosphere. They are known as smelters, and they could have the largest environmental and health impacts. These are the Russian enterprises located in the cities of Norilsk (Krasnoyarsk Krai), Mochegorsk and Nikel-Zapolyarny (Murmansk region). Information about environmental and pollution situation in these regions of Russia is provided through annual state reports. A series of studies was performed as a part of the Russian state scientific-research programmes, Kola Science Center and Siberian Branch of the Russian Academy of Sciences projects, Arctic Monitoring and Assessment Programme activities, and others.

The modeling of atmospheric transport, dispersion and deposition of different pollutants is essential input for estimation of possible consequences on different scales ranging from hemispheric to urban/ local scales. Estimates of transboundary transport between selected countries is especially important for a decision making process. Generated model output is crucial for multi-level assessment of risk, vulnerability, impact, short- and long-term consequences for environment and population, which is living near-by or remotely from the sources of possible accidental releases and continuous emissions.

The long-term modeling of the atmospheric transport, dispersion and deposition of pollution resulted from continuous emissions from the Russian smelters was performed employing the Lagrangian-type Danish Emergency Response Model of the Atmosphere (DERMA; *Sørensen, 1998; Baklanov et al., 2008*).

The probabilistic approach, sensitivity of the model to meteorology and diffusion parameters, deposition processes, and other parameterizations are also described in more details by *Baklanov and Mahura (2004), Sørensen (1998)*, and others. The European Centre for Medium-Range Weather Forecast (ECMWF) data archives were used as input 3D meteorological fields for the year 2000. These meteorological data are given at 1°x1° resolution with 6 hour time intervals and covering the Northern Hemisphere, north of 10°N.

For each run, the pollution plume originated near the source was dispersed through the atmosphere (as well as deposited due to dry and wet deposition processes) during following 10 days. It should be noted that in general, levels of pollution can vary significantly depending on dominating meteorological conditions both within the boundary layer as well as the free troposphere, and the highest levels of pollution are generally observed in vicinity of the sources.

The generated model output included: the air concentration, the time integrated air concentration (TIAC), dry (DD) and wet deposition (WD) (see Fig. 1).

Note that such output - if it is summed over a long period of time (for example: month, season, year) or if it is averaged over a short period of time (for example: day, period of accidental release) - can represent possible short- and long-term effects and probabilistic characteristics of industrial pollution. In general, based on such available output, the geographical boundaries of potential influence due to continuous (or accidental) atmospheric releases of pollutants from different sources can be identified and possible impacts can be evaluated. An example of simulated summary and average TIAC, DD and WD patterns during 10 days of the atmospheric transport, dispersion and deposition for the month of November are shown in Fig. 1.

The Web-based Atlas, which is displaying a month-to-month (shown both as separate figures for each month as well as animation on a yearly basis) variability of these patterns is available and can be analysed at: http://www.atm.helsinki.fi/peex/webatlas/WEBATLAS.html

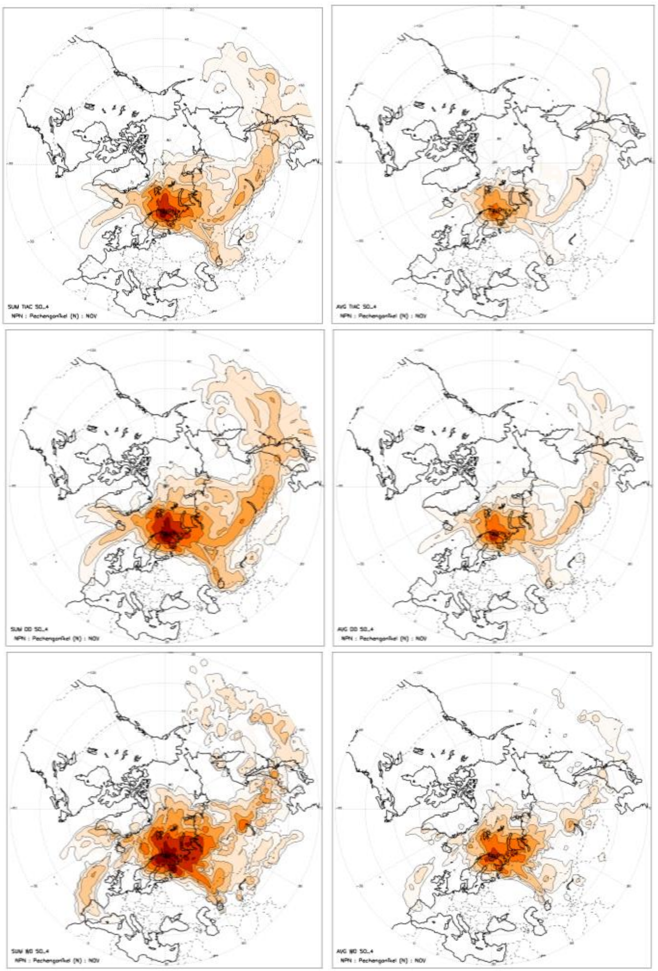

Figure 1. *Spatial patterns of the (left) summary and (right) average - (top) time integrated air concentration (TIAC), (middle) dry (DD) and (bottom) wet (WD) deposition - patterns during November due to continuous emissions of sulphates from the Nikel smelters (deposition and concentration isolines are shown starting from the lowest 1e-2 µg/m^2 and 1e-2 µg/m^3, respectively; ΔNPN – location of the plant on the Kola Peninsula)*

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Enviro-HIRLAM Downscaling Setup towards Fine Scale Modelling

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To demonstrate the seamless/ on-line integrated meteorology-chemistry-aerosols modelling system Enviro-HIRLAM (*Environment – HIgh Resolution Limited Area Model*), the downscaling chain (with 3 enclosed domains) was setup to perform fine-resolution simulations over territories of the Kola Peninsula and northern Finland and Norway in focus. The selected domains (with geographical boundaries) are shown in Figure 1. The basic parameters (horizontal resolution, number of grid-points along the latitude and longitude, number of passive boundary points, S-W-N-E boundaries of the domain in the rotated system of coordinates with positioning of the pole, time step, and number of vertical levels) for these model domains are given in Table 1. The ECWMF boundary conditions (BCs) are used to drive the Enviro-HIRLAM-K15 model runs. Then, meteorological and atmospheric composition output generated by the outer models (i.e. –K15 and –K05) is used as BCs for the inner models (i.e. –K05 and –K02, respectively) simulations.

Figure 1. *Geographical boundaries of model domains for the Enviro-HIRLAM subsequent downscaling at regional (K15) – subregional (K05) – urban (K02) scales.*

Note that the Enviro-HIRLAM model is developed as a fully online integrated numerical weather prediction (NWP) and atmospheric chemical transport (ACT) model for research and forecasting of joint meteorological, chemical (and biological weather in case of pollen) at multi-scales (*Baklanov et al., 2017*). And the selected online/ seamless and downscaling approaches are jointly able to handle and study major existing processes and interactions at multi-scales (i.e. regional-subregional-urban) which are difficult to investigate using the off-line modelling approach.

At initialisation, the physiographic data are pre-processed. In each grid cell of the modeling domains the elevation is calculated as mean, and land cover classes are transformed in accordance to the ISBA land surface scheme requirements. The climate generation procedure for the model uses a set of different data sources, including GTOPO30, GLCC, ECOCLIMAP, and CORINE (where it is available for European countries).

DOMAIN-NAME	K15	K05	K02
RESOLUTION (deg)	0.15	0.05	0.02
RESOLUTION (km)	15	5	2
# boundary points	10	10	10
NLON (grid-points)	310	442	460
NLAT (grid-points)	188	340	340
SOUTH	-27.527	-21.527	-15.357
WEST	-31.325	-16.025	-7.025
NORTH	0.523	-4.577	-8.577
EAST	15.025	6.025	2.155
POLAT	-10.0	-10.0	-10.0
POLON	40.0	40.0	40.0
Time step (sec)	240	120	60
# vertical levels	40	40	40

Table 1. *Summary of the basic parameters for the selected model domains.*

The NWP-components include the digital filtering initialization, semi-Lagrangian advection scheme, and a set of physical parameterizations such as the Savijaervi radiation, STRACO condensation, CBR turbulence and ISBA schemes, etc (see more in *Baklanov et al., 2017*). The Enviro-components include modules for aerosol microphysics M7, gas-phase chemistry CBMZ, urbanization, emissions, nucleation, coagulation, condensation, deposition, etc. (see more in *Uden et al., 2012*). The emissions are also pre-processed and include anthropogenic, biogenic, and natural.

Although the Enviro-HIRLAM model can be setup (*signing of the code transfer and use agreement is required*) and run at personal LUNIX/UNIX-oriented environment computer, for this study, the model runs are realised at the Sisu supercomputer (for each model setup 256 procs, with 16 nodes and 16 tasks per node are allocated). Sisu is the part of the CSC (IT Center for Science Computing; https://research.csc.fi/home) infrastructure, and it is the most powerful supercomputer in Finland. Sisu's Cray XC40 system architecture is designed for massively parallel applications (& include Xeon E5-2690v3 12C 2.6GHz, with 40608 cores and peak performance 1.7 PFlop/s; according to https://www.top500.org).

References:

Baklanov, A., Smith Korsholm, U., Nuterman, R., Mahura, A., Nielsen, K. P., Sass, B. H., Rasmussen, A., Zakey, A., Kaas, E., Kurganskiy, A., Sørensen, B., and González-Aparicio, I. (2017): Enviro-HIRLAM online integrated meteorology–chemistry modelling system: strategy, methodology, developments and applications (v7.2), Geosci. Model Dev., 10, 2971-2999.

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Analysis of Atmospheric composition at SMEAR I station in December 2017

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Air masses are often categorized by using temperature and humidity as the key characteristics. However, when measurements of aerosol particles and atmospheric trace gases are available, atmospheric composition can act as even better identifier of air mass. Lifetime of aerosols and gases in the atmosphere vary from hours to months. Sulfur dioxode (SO_2) and nitrogen oxides (NOx) both have a lifetime of a few days, so the pollution source must be relatively close, usually within some hundreds of kilometers, to detect traces of these gases. Carbon monoxide (CO) has a lifetime of several weeks, so it is harder to determine source of it. One important anthropogenic source of CO is biomass burning. In Finland, especially in winter, wood is an important source of energy in households so if an air mass is coming from a populated area, CO concentration is likely to increase. Concentration of ozone (O_3) near surface is typically low, but it is a product in photochemical smog, where NOx acts as a precursor of O_3.

SMEAR I station in Värriö, Finnish Lapland was constructed in 1991-1992 and SO_2, NOx and O_3 concentrations have been measured since then (Hari et al. 1994). More variables were included during the following years and currently continuous observations include measurements of tens of meteorological variables and atmospheric gases. Differential Mobility Particle Sizer (DMPS) has been measuring aerosol particle number size distribution since 1997 and in August 2017 Airmodus A20 PSM was installed to allow detection of particles down to diameter of 1.1 nm.

SMEAR I station is located in very scarcely populated area. Air quality at the station is very good, especially in wintertime natural sources of aerosol particles and trace gases are weak. Land is covered in snow and incoming solar radiation greatly decreases which means that photo-chemistry is very limited. In Värriö, polar night starts on December 13th and ends on December 31st. However, several significant local pollution sources in Kola peninsula are within 200 kilometers from the station (Paatero et al. 2008). When wind direction is favourable, SO_2 and NOx concentrations can peak very high (fig. 1).

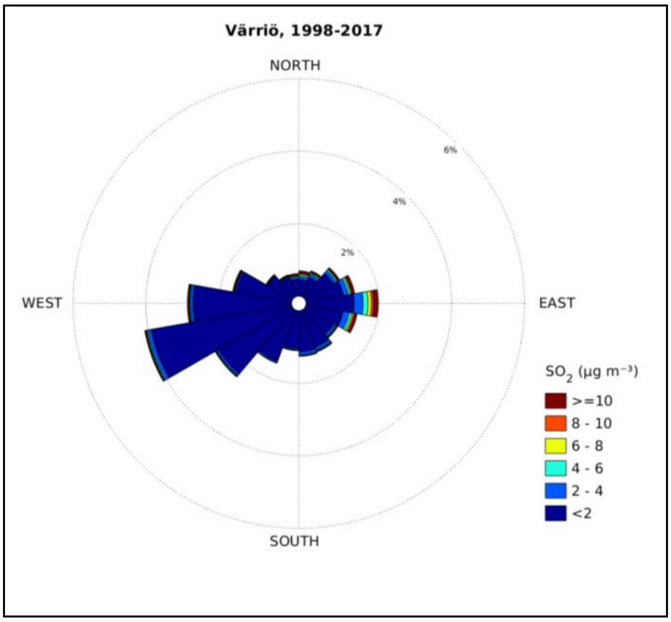

Figure 1. *Hourly averaged wind direction and SO_2 concentration at SMEAR I station in 1998-2017.*

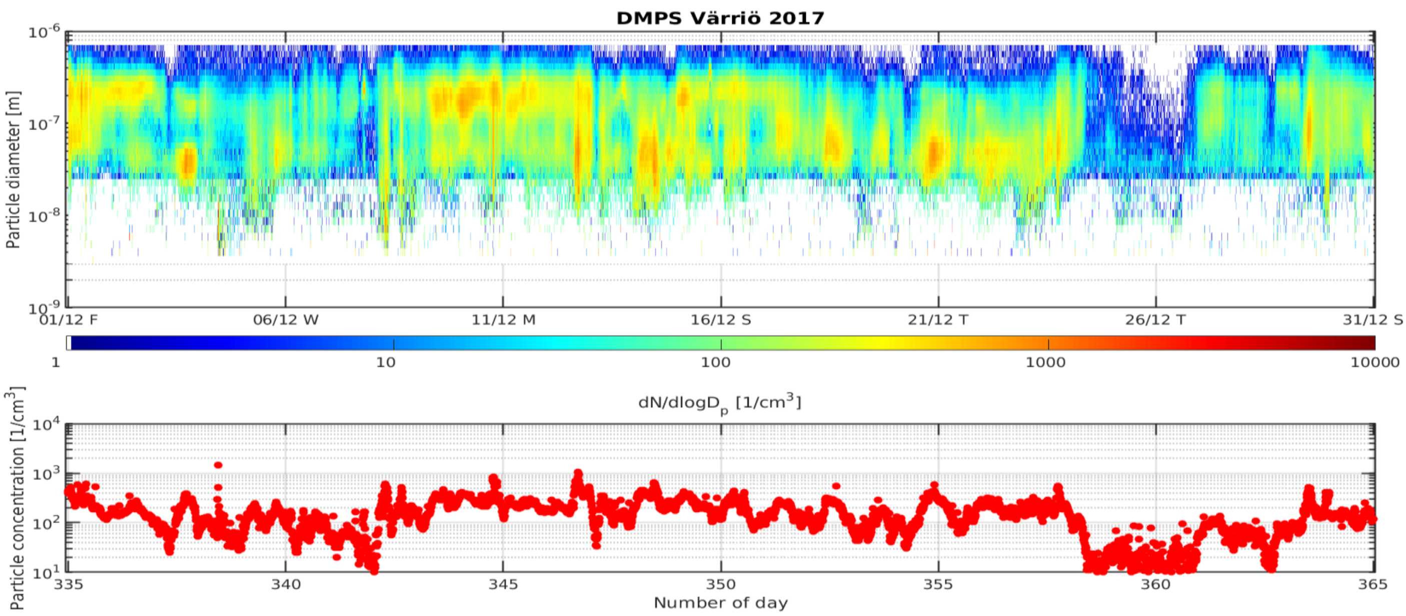

Figure 2. *Number size distribution at SMEAR I station in December 2017.*

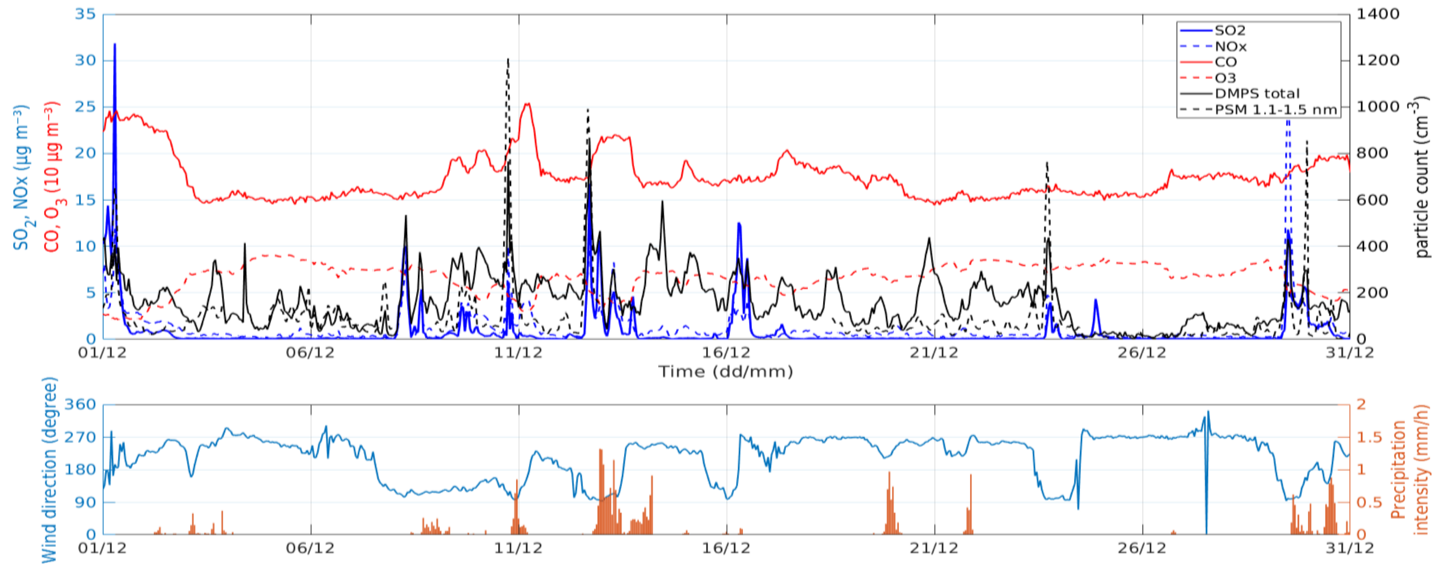

Figure 3. *Air quality (top), and wind direction and precipitation intensity (bottom) at SMEAR I station in December 2017.*

Analysis of DMPS data (fig. 2) shows that number concentration of aerosol particles in Värriö during December 2017 was very low with a mean of 163 cm^{-3}. Clear cases of new particle formation events were not observed. High SO_2, NOx and CO concentrations coincide well with easterly wind direction (fig. 3).

Two cleaner periods took place: first one from 3rd to 8th and the second one, much more pronounced case from 24th to 29th. During the latter time period aerosol particle number concentration as low as 10-100 cm^{-3} was frequently measured. A closer look at the clean time period suggests that the period can further be divided to an extremely clean period (25th-26th) with mean aerosol particle number concentration of 20 cm^{-3} and a more typical clean period (27th-28th) with mean aerosol particle number concentration of 63 cm^{-3}.

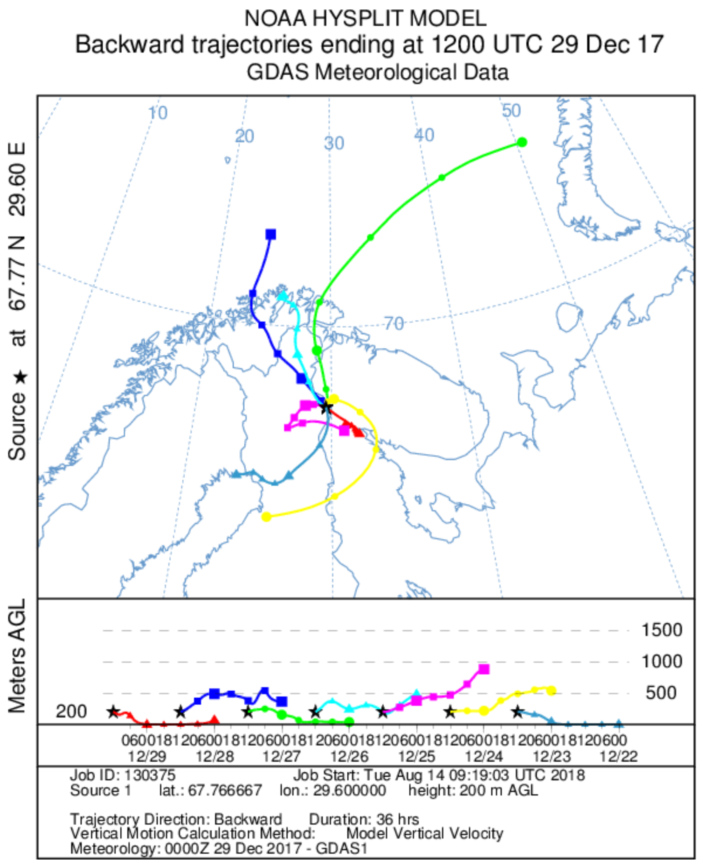

Figure 4. *Backward atmospheric trajectories for seven arrival times from 23th to 29th of December 2017.*

Local wind direction observation at the station is often not sufficient to determine origin of an air mass. Wind can be strongly influenced by terrain, which is also the case in Lapland where several fjeld ranges exist. Thus, for this study, HYSPLIT backward atmospheric trajectories were also used to explain atmospheric composition (fig. 4).

Trajectory model reveals that origin of air mass during these days indeed changed even though wind direction was nearly constant. Just before the clean period air masses formed south and were transported to Värriö via Kola peninsula. On the evening of 24th wind direction suddenly changed from easterly to westerly. For the next two days wind speed was low and air that arrived to Värriö had circulated over the scarcely populated boreal forest of northern Scandinavia. No significant aerosol particle or trace gas sources contributed to the composition of the air mass. Then, on 27th of December wind speed increased again and arctic air mass arrived from the arctic sea. It is likely that the particles observed at size range of 50-300 nm originated from the sea. On the 29th wind direction changed again in a way that arriving air mass was transported via Kola peninsula industrial sites, which can be observed as an increase of SO_2, NOx and aerosol particle concentrations.

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Analysis of meteorological conditions at SMEAR I station in December 2017

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SMEAR I station in Värriö, Finland (67°46′N, 29°36′E) is situated 390 meters above sea level in close proximity to Värriö fjeld range, pine forest and swamps (Hari et al. 1994). Several meteorological variables are measured at the station. Measured variables include air temperature, humidity, air pressure, wind speed and direction, visibility, precipitation, radiation and more. Most of these variables have been continuously measured for over 20 years, in this study December 2017 was studied. In addition to station data (available for download at: https://avaa.tdata.fi/web/smart/smear/download), UK Met Office synoptic weather charts (http://www1.wetter3.de/archiv_ukmet_dt.html) and HYSPLIT model backward atmospheric trajectories (http://ready.arl.noaa.gov/hypub-bin/trajtype.pl?) were used to study the synoptic meteorology during the study period.

Weather in Scandinavia in December is typically characterized by cyclonic activity. Cyclogenesis often occurs in Northeast Atlantic during early winter months, and from there cyclones propagate northeast. By the time they approach Värriö, they have often reached a mature, occluded stage. Air masses are usually maritime polar or arctic. Nearly all precipitation comes as snowfall, though most of the time water content of air is low due to low temperature, even when relative humidity is high. Still, snow depth can reach over 1 meter during winter months. Due to the northern location of SMEAR I station, the amount of incoming radiation is very low during winter months. Polar night lasts almost three weeks, from December 13th to December 31st.

In 2017, December begun with an almost occluded front passing Värriö on the 3rd, with only narrow zone of warmer, polar air between the warm and cold fronts. Rapidly intensifying cyclone formed just south of Iceland on the 6th and begun moving east, reaching its highest intensity on the coast of Norway. There it remained stationary for several days, gradually weakening and associated occluded fronts reached Värriö on the 9th and 11th, causing moderate precipitation. Meanwhile, over Bay of Biscay, north of Spain, a cyclone formed and begun to move northeast. The cyclone swept over the length of Finland from south to north and it reached Lapland on the 13th, bringing precipitation to Värriö from two rain bands following each other. On the 20th, an occluded front associated with a cyclone over the Arctic Sea briefly brought warm air and precipitation to Värriö, before a

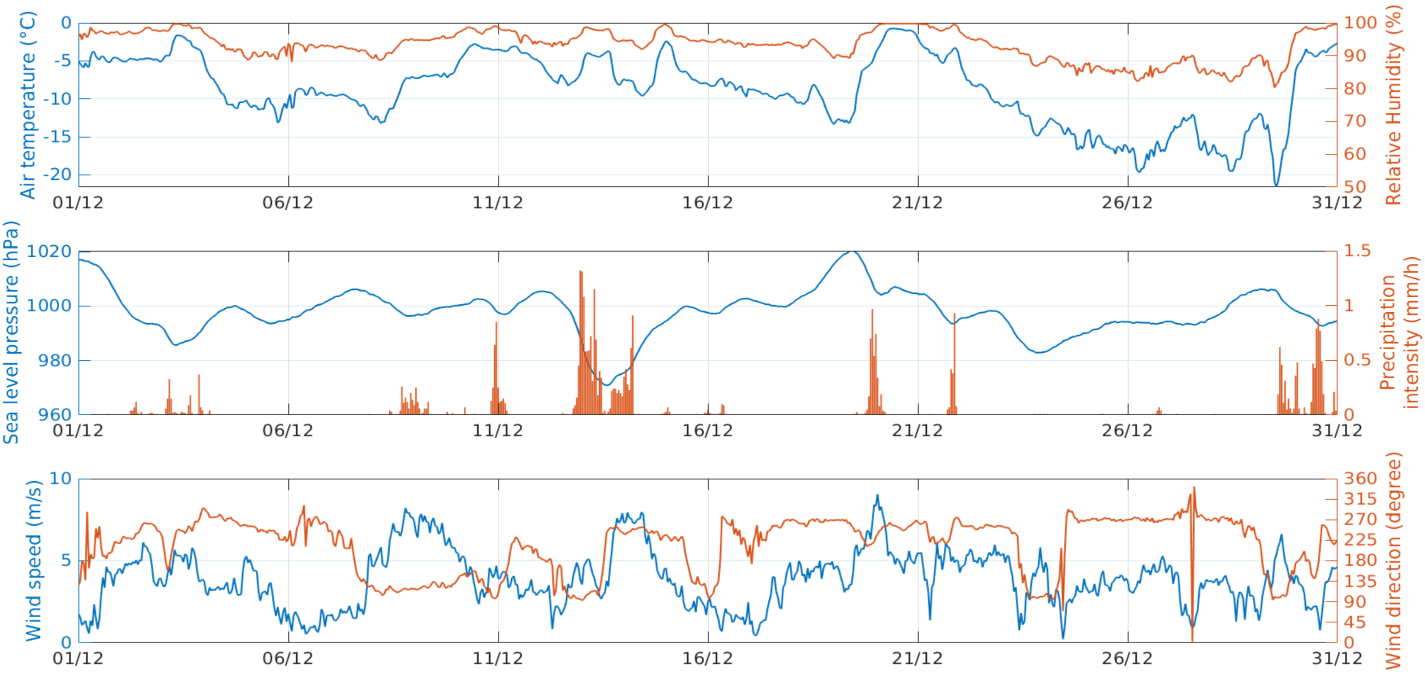

Figure 1. *Hourly averages of air temperature and relative humidity (top), Sea level pressure and precipitation intensity (middle), and wind speed and direction (bottom) measured at SMEAR I station in December 2017.*

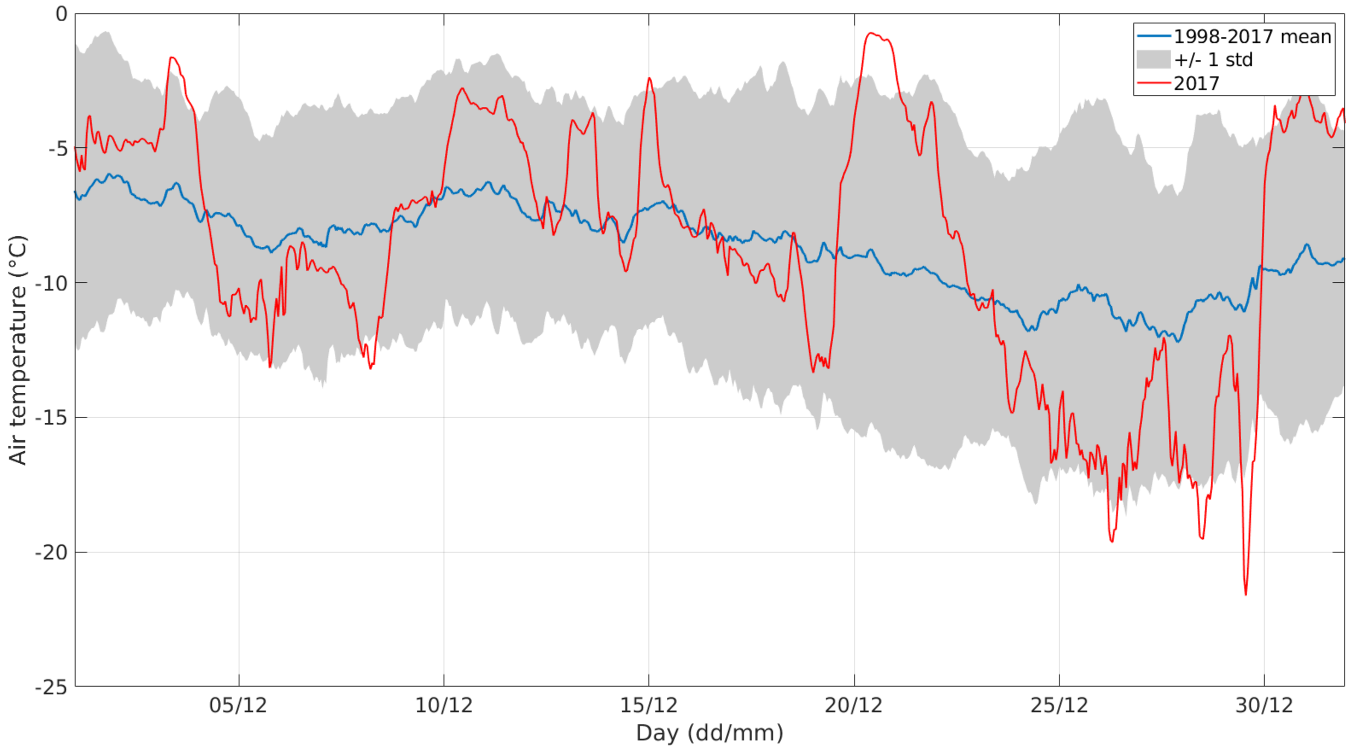

Figure 2. *Hourly average air temperature at SMEAR I station. Blue curve represents 1998-2017 mean and shading +/- 1 standard deviation from it. Red curve is 2017 observations.*

cold arctic air mass arrived on the evening of 21st. For the next few days, cyclone tracks were south of Lapland so that conditions remained stationary and temperature gradually decreased. The cold period ended with the arrival of warm front on the 29th, which brought snowfall and caused rapid increase of temperature (16.0 °C in 12 hours).

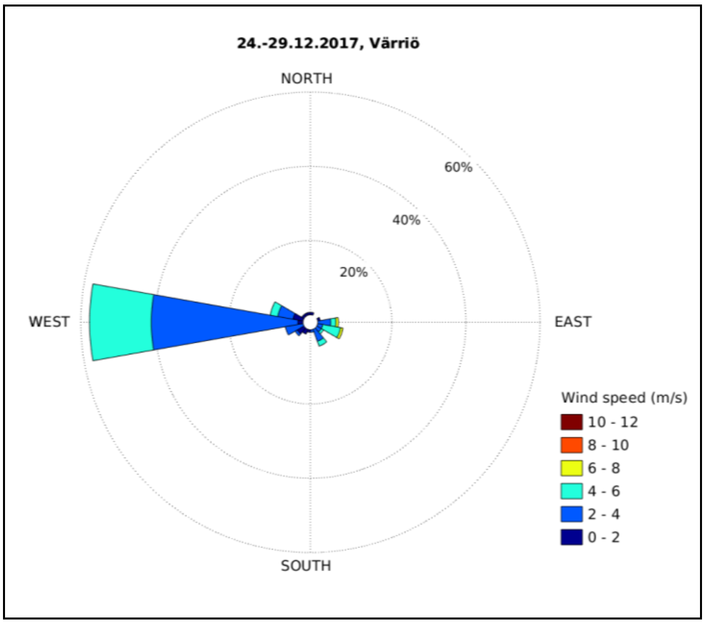

Figure 3. *Wind rose with colour resembling wind speed of hourly averages from 24th to 29th of December 2017 measured at SMEAR I station.*

The coldest period in Värriö, from 24th to 29th of December, was characterized by low temperature (fig. 2), westerly wind direction, low wind speed (fig. 3) and unusually low level of air pollution. Temperature was below 1998-2017 mean during that time and at times even below one standard deviation from past temperature measurements. December monthly mean temperature was -8.7 °C which is also the 1998-2017 December mean. Maximum temperature was -0.7 °C (Dec 20th) and minimum was -21.6 °C (Dec 29th). The cold period mean temperature was -15.6 °C and the maximum -10.3 °C.

At the station low wind speeds were measured and wind was mostly westerly. However, further analysis of wind trajectories showed that the air masses did not come from west, but from southeast until 25th and after that from the north. Thus, air masses were not being affected by Kola peninsula industrial sites (Paatero et al. 2008), which partially explains good air quality. Air pressure was quite stable during the time period. An increase in air pressure towards the end of the period increased visibility, however due to polar night, that only increased outgoing longwave radiation causing further cooling of the air mass.

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Seasonal impact due to sulphur emissions from Severonikel smelters

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During the last decades the enterprises of various risks (nuclear, chemical, biological, etc.) are under permanent and critical view from the society. Large Russian industrial major enterprises such as the Norilsk Nickel, Pechenganikel and Severonikel are sources of continuous emissions (www.nornickel.com, www.kolagmk.ru). The investigation of impact on population of different regions (Figs 1-2) due to continuous emissions of sulphates from the Severonickel Cu-Ni smelters (city of Monchegorsk, Murmansk region, Russia) was performed employing the Lagrangian long-range transport model DERMA (*Sorensen, 1998; Baklanov et al., 2008*) in a long-term simulation mode and applying GIS tools for integrating and analysis of modeling results (*Mahura et al., 2018*).

It was found that over the model domain (covering Northern Hemisphere starting at 10°N) on annual scale, daily dry deposition is about 6 t with the highest (10 t) - in September. The wet deposition is 23 t (maximum 50 t - in February), and it is dominating in the total deposition. On average, about 33% of the emissions could be deposited on the surface during 10 days of the atmospheric transport from the smelters with the highest (65%) and lowest (14%) deposited amounts observed in February and July, respectively.

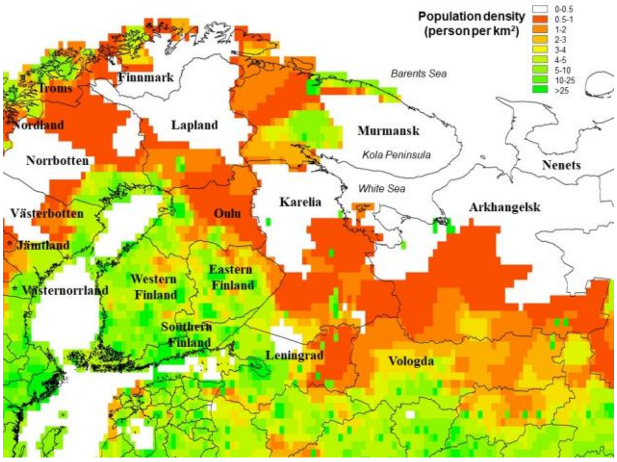

Figure 1. *Geographical boundaries of administrative units (regions, provinces, counties, etc.) and population density (in persons per km²).*

The Murmansk region, where the smelters are located, is the most impacted, followed by the Karelia Republic and Arkhangelsk region (with the total deposition more than order of magnitude lower compared with the Murmansk region). Among administrative units of the Scandinavian countries, Lapland (Finland), Norrbotten (Sweden) and Finnmark (Norway) have the highest depositions. On average, it is higher in autumn for all three Scandinavian countries; and lower in summer (for Finland) and winter (for Norway).

For the Russian regions, on average, deposition is higher in spring (except, the Arkhangelsk and Nenets regions), and it is lower in summer and winter.

The maximum total deposition is observed for the northern, central, and southern territories of Finland in spring, autumn and winter, respectively. For Sweden, it occurs in autumn. For the northernmost part of Norway it takes place in spring, and for other territories – in autumn. For Russia, the largest maxima are linked with spring and autumn for the territories southerly and easterly of the Severonikel smelters, respectively.

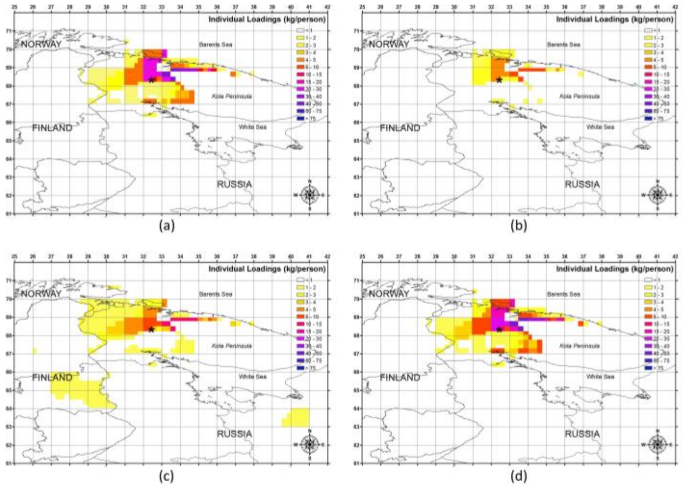

Figure 2. *Seasonal individual loadings for population (in kg/person) from deposited sulphates resulted from the Severonikel smelters continuous emissions (mild scenario; * - location of the Severonikel plant): (a) spring, (b) summer, (c) autumn, and (d) winter.*

The yearly individual loading can be up to 120 kg/person for the most populated urban areas of the Murmansk region. For bordering territories with this region such loadings are less than 5 kg/person for territories of the eastern Finland, Karelia Republic, and Arkhangelsk region; and not greater than 15 kg/person – for the Finnmark county of Norway. There exists seasonal variability (with lowest loadings in summer), which is less pronounced for the Scandinavian countries. The percentage contribution into such loading is higher in winter-spring for Russia (in sum 85%), in spring for Norway (34%), in autumn for Finland and Sweden (32 and 41%, respectively). The yearly collective loading is the highest (2403 tonnes) for the Murmansk region. Both the Karelia Republic and Arkhangelsk region have the second largest loadings (83 and 77 t). For populated territories of the bordering countries with the Murmansk region such loadings are 140.4, 13, and 10.7 t for Finland, Norway and Sweden, correspondingly.

The results of this study are applicable for (i) evaluation of risks, vulnerability, and short- and long-term consequences due to airborne pollution on population, environment, and ecosystems; (ii) complex human health impact assessments taking into account social, economical, and other factors; (iii) support of decision-makers, adjustment of legislation at regional levels, control pollution exceedances; planning preventive measures, mitigation scenarios, etc.

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Climate Model Data for TRAKT Domain: 21st Century Climate Change and Connection to Air Quality

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INAR has assessed the applicability of climate model data in TRAKT assessments. Two distinct assessments have been performed: analysis of IPCC AR5 future climate scenarios in TRAKT domain, and applying Earth System model EC-Earth results in assessing meteorological conditions relevant for air pollution episodes.
First, we applied simulated EC-Earth (*Hazeleger et al., 2010*) data of selected variables in TRAKT assessment by *Gnatiuk et al. (2018)* as potential indicators for local/regional air quality. Here, we show results based on simulated precipitation amounts and surface wind speeds. Since CMIP6 results of EC-Earth are not yet available, we obtained earlier CMIP5 data simulated with EC-Earth 2.3. The open-access global daily precipitation and wind data was downloaded from Swedish Earth System Grid Federation (ESGF) node in Sweden. The data applied here contains simulation of 2005–2015 with natural and anthropogenic forcings. IFS (cycle31r1) was simulated at T159 resolution (~80 km) with 62 vertical levels. In future CMIP6 simulations, IFS is integrated with improved spatial resolution of T255, corresponding to about 60 km.
Most of climate model output delivered at ESGF is at daily mean or monthly temporal resolution. Here we show two criteria (thresholds) selected for both climate variables: 0.01 mm and 0.1 mm for daily mean precipitation, and 2 m/s and 3 m/s for daily mean surface wind speed. We calculate the number of days when the simulated data is below these thresholds, and only focus on winter-time (DJF).

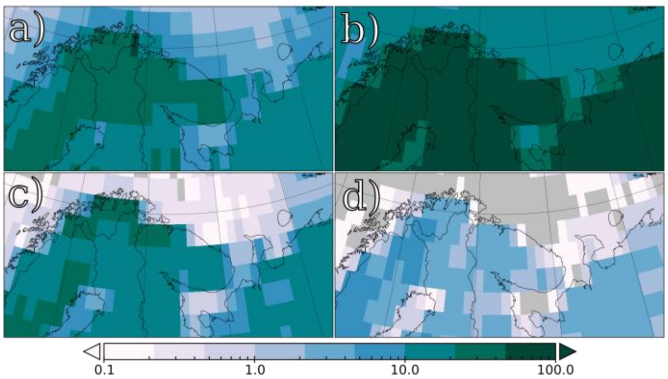

Figure 1. *Fraction of winter days meeting selected meteorological criteria: a) daily precipitation < 0.1mm; b) daily average wind-speed < 5 m/s; c) both conditions are met; d) precipitation <0.1mm and wind-speed < 3 m/s.*

Fig. 1a shows the fraction of winter days when daily precipitation is below 0.1 mm. For TRAKT case study region, the precipitation is below this limit for 22% of days. Similarly, Fig. 1b shows the fraction of winter days, when (daily average) surface wind speed is below 5 m/s. This condition results in 88% of days for TRAKT region.
Furthermore, we analysed days when both conditions are met. Fig. 1c shows fraction of winter days when precipitation is low (<0.1 mm daily sum) and when daily average surface wind speed is below 5 m/s.

For the current CMIP6 version of EC-Earth ESM, several This reduces the probability of such days in TRAKT region to only 15% in winter conditions. Since the threshold of 5 m/s for simulated daily average wind speeds is met during most winter days, we tested a more stringent threshold of 3 m/s. Together with the precipitation-threshold of 0.1 mm, this further reduces the amount of days to 2% in TRAKT domain, and the regional results are shown in Fig. 1d. Similar analysis, here shown for EC-Earth data and historical period of 2005-2015, can in future be extended to cover multimodel results (CMIP6) and ensemble of future projections. *Gnatiuk et al. (2018)* provides more detail on how such analysis can help in connecting the assessment to air quality projections.

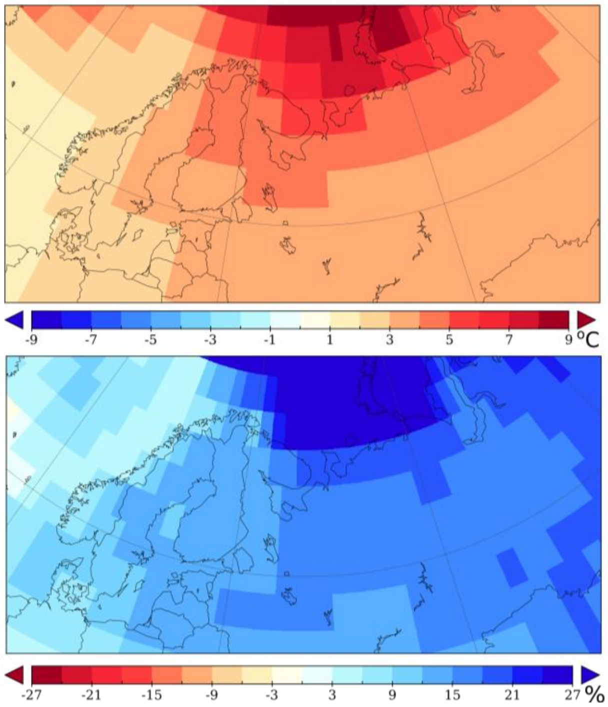

Figure 2. *Changes in winter-time 2-meter temperature (ºC, upper panels) and precipitation (%, lower panels) during the 21st century. Present-day climatology is averaged over years 1981-2010 and end-of-century climatology over 2070-2099.*

In the second part of analysis, we provide an assessment of future climate projection for broader TRAKT region. We have compiled multi-model ensemble (42 in total) results from CMIP5 (IPCC AR5) climate model results. Fig. 2 shows the changes in TRAKT region during 21st century, calculated as differences of end-of-century averages (years 2070–2099) to present-day averages (years 1981–2010). Ensemble-mean temperature show substantial warming over the Arctic Ocean and adjacent regions (Fig 2, top). For the TRAKT case study region, the average warming during 21st century is 4.5ºC, with somewhat stronger warming in eastern Kola Peninsula. In addition, the region exhibits a generally increasing trend in precipitation (Fig 2, bottom). Model average indicates 15% increase in winter precipitation for TRAKT region, with even stronger increases towards north and east of the peninsula. These results are in line with recent climate projections in IPCC 1.5ºC Special Report. It is expected that the projected increase in precipitation will have an effect in air quality episodes in TRAKT domain during the following decades.

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Online Integrated Multi-Scale Modelling: Downscaling Meteorology and Atmospheric Composition

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Following the Enviro-HIRLAM model setup (*Mahura, TP2008*), initial and boundary conditions (ICs and BCs) for both meteorological and atmospheric composition were extracted. Meteorological IC/BCs were retrieved from ECMWF-IFS (*European Centre for Medium- Range Weather Forecasts - Integrated Forecasting System*) model with a horizontal resolution 0.15 deg. These included fields (at model levels) for the air temperature, wind speed components, specific humidity, surface pressure. The MACC (*Monitoring Atmospheric Composition and Climate*) reanalysis data as chemical ICs/BCs were retrieved as well. These included fields (at the model levels) for mixing ratios of dust aerosols (0.03-0.55, 0.55-0.9, 0.9-20 µm), both hydrophilic and hydrophobic black carbon and organic matter, sulphate aerosols, as well as ozone, nitrogen oxides and sulphur dioxide. For gaseous components (such as H_2O, O_3, NO, NO_2, HNO_3, H_2O_5, H_2O_2, CH_4, CO, CH_2O, CH_3OH, C_2H_5OH, C_2H_6, CH_3CHO, C_3H_6, C_3H_8, CH_3COCH_3, C_5H_8, C_2H_4, C_4H_8, C_5H_{12}, C_7H_8, peroxyacyl nitrates (PAN), SO_2, dimethyl sulfide (DMS), SO_4) the IFS-MOZART (*Model for OZone And Related chemical Tracers*) model reanalysis data were used.

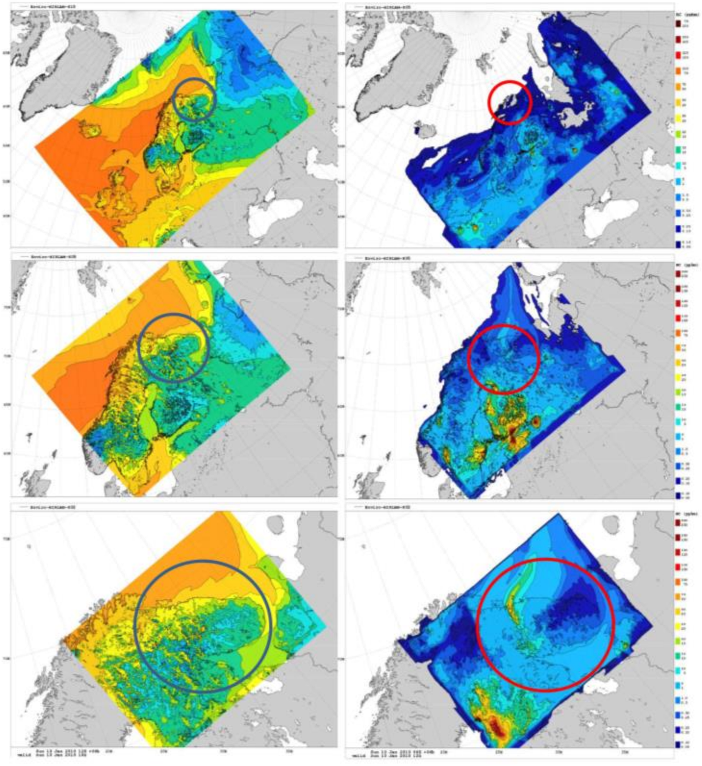

Figure 1. *An example of the Enviro-HIRLAM model output (runs in a downscaling chain over domain of K15, K05, and K02 with horizontal resolutions of 15, 5, and 2 km, respectively: top-middle-bottom plate) for the air temperature at 2 m (left) and organic carbon (OC) (right). The circles shows the Kola Peninsula location.*

The anthropogenic emissions are represented by emission inventory ECLIPSE (*Evaluating the Climate and Air Quality Impacts of Short-Lived Pollutants*) providing emissions for both long-lived greenhouse gases and short-lived aerosol species with horizontal resolution of 0.5 deg. For each pollutant, the emission data correspond to 10 codes SNAP (Standard Nomenclature for Air Pollution). These are linked to such sectors as industry, transportation, agriculture, residential, commercial, etc. The ship emissions are represented by a combination of AU-RCP6.0 (Aurhus University & Representative Concentration Pathways v6.0) and STEAM (Ship Traffic Emission Assessment Model) datasets, having 0.5 deg and 0.09x0.05 deg resolutions, respectively. The wildfires emissions are represented by IS4FIRES (*An Integrated Monitoring and Modeling System for Wild land Fires*) and GFAS (*Global Fire Assimilation System*) datasets with 0.5 deg resolution.

For the Enviro-HIRLAM simulation, the meteorological ICs/BCs are provided in GRIB-format (*GRIdded Binary*) which is commonly used in meteorology to store forecasting and historical weather data. The chemical ICs/BCs and emission inventories are provided in the netCDF-format (*Network Common Data Form*) files.

The M7 aerosol module (*Vignati et al., 2004*) takes into aerosol microphysics and includes the following components: black carbon (BC), organic carbon (OC), mineral dust, sulphate, and sea salt. The mass concentration (for Aitken, coarse and accumulation modes) of sulphur, black carbon and organic carbon for soluble, BC and OC – also in Aitken mode for insoluble; sea salt (both in coarse and accumulation modes for soluble); and dust (both in coarse and accumulation modes, and both soluble and insoluble) are modelled at each model level, with the lowest one at about 32 m asl. The number concentration of both soluble and insoluble aerosols for 3 modes are calculated as well as cloud droplet umber concentration. Concentration of particular matter - PM10 and PM2.5 - are then, calculated based on a proportional ratio of aerosols.

For aerosols, the dry deposition includes gravitational settling and deposition due to aerosol interactions with the underlying surface. Wet deposition or scavenging takes place in-cloud (i.e. rainout) and below-cloud (i.e. washout).

The Enviro-HIRLAM generated model output includes surface and model vertical levels (in total 40) fields for almost 200 meteorological parameters used in numerical weather prediction (all saved in GRIB-format). More details about these can be found at ECMWF (apps.ecmwf.int/codes/grib/param-db) or HIRLAM (hirlam.org) websites (registration is needed). The concentrations of chemical species/ aerosols (listed above) are saved in the same files of the GRIB-format.

As a demo-illustration, an example of the Enviro-HIRLAM model output in a downscaling chain over 3 different geographical domains having 3 different (15, 5 and 2 km) resolutions is shown in Fig. 1 for meteorological (air temperature) and chemical (organic carbon) parameters.

References:

*Mahura A., R. Makkonen, T. Petäjä, S. Zilitinkevich (in continuing collaboration with members of the Enviro-HIRLAM research and development team: R. Nuterman, A. Baklanov, B. Amstrup) (**2018**): Seamless Modelling: Downscaling to Northern Fennoscandia and Kola Peninsula. Presentation at the PEEX Working Group & iCUPE – ERA-PLANET Meeting in collaboration with Global-SMEAR-Climate-KIC and TRAKT projects, 1-2 Nov 2018, Helsinki, Finland.*

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*Vignati, E., J. Wilson, and P. Stier (**2004**): M7: An efficient size-resolved aerosol microphysics module for large-scale aerosol transport models. JGR: Atmospheres, 109 (D22202), doi:10.1029/2003JD004485*

Online Integrated Multi-Scale Modelling: Zooming to the Northern Fennoscandia and Kola Peninsula

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The Enviro-HIRLAM downscaling of meteorological and atmospheric composition patterns over several geographical areas in focus was performed in *Mahura et al. (TP2018)*. As winter period is in focus, the local meteorological situation is mostly dominated by a low wind conditions, and especially in central areas of the Kola Peninsula, compared to northern seashore and the Barents Sea (as seen in Fig. 1-right for wind speed). At high resolution, a more detailed complex structure of both temperature and wind fields became well pronounced, as small-scale features are better resolved at finer modelling scales (Fig. 1-bottom). Moreover, the populated urban territories (depending on a size/ area, or a number of grid-cells) are more visible at finer scales as well. An example of the model output for the air temperature at 2 m and wind speed at 10 m zoomed over the Northern Fennoscandia and Kola Peninsula is shown in Fig. 1.

Although winter period is limited in solar radiation due to polar night period, for clarity of simulation experiment, the model runs was performed taking into account both the direct (DAE) and indirect (IDEA) aerosol effects. The DAE is impact of aerosols on radiation due to existing absorbing and scattering properties of aerosols.

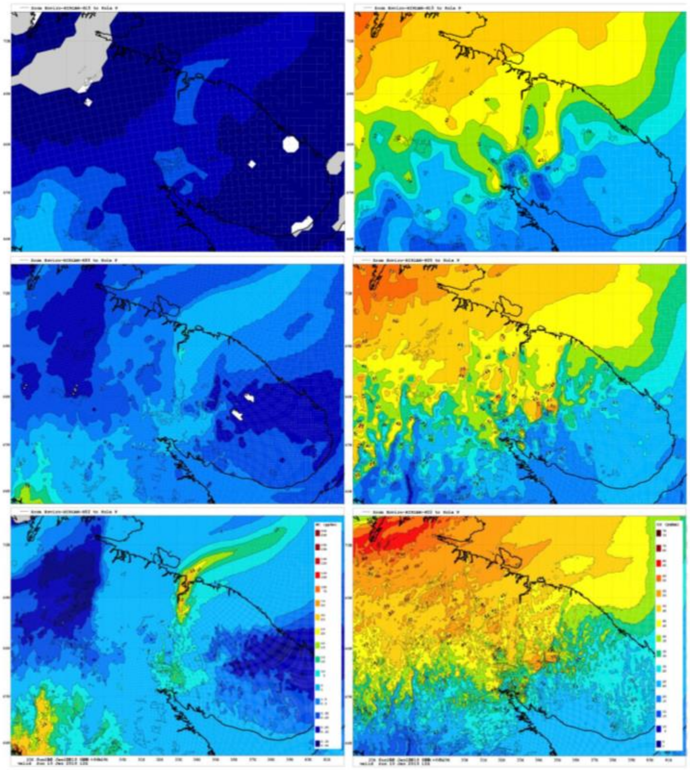

Figure 2. *An example of the Enviro-HIRLAM model output (runs in a downscaling chain with horizontal resolutions of 15, 5, and 2 km: top-middle-bottom plate) for the black carbon (BC) and ozone (O_3) concentration (right) zoomed over the Kola Peninsula area.*

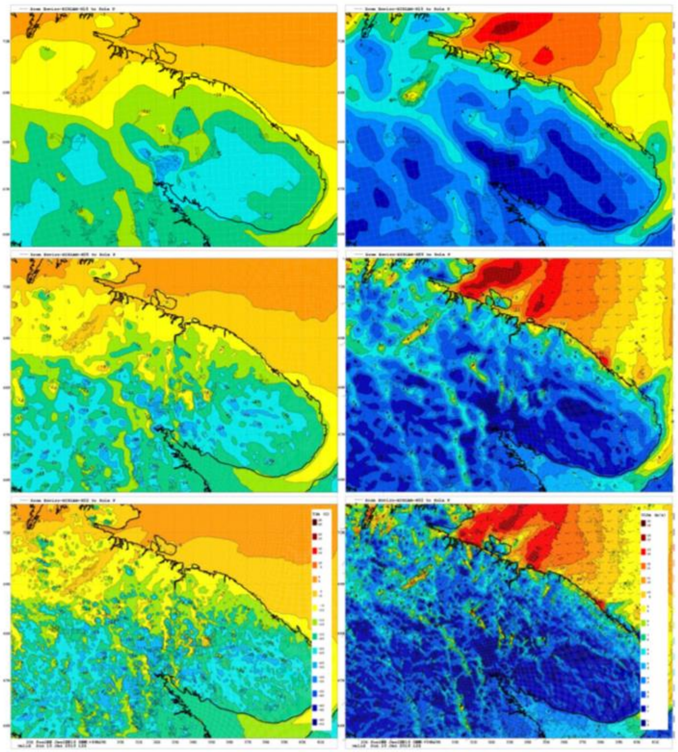

Figure 1. *An example of the Enviro-HIRLAM model output (runs in a downscaling chain with horizontal resolutions of 15, 5, and 2 km: top-middle-bottom plate) for the air temperature at 2 m (left) and wind speed at 10 m (right) zoomed over the Kola Peninsula area.*

For example, sulfates, nitrates, organic carbon will scatter solar radiation that will lead to cooling of the atmosphere. Black carbon will absorb heat that will lead to warming of the atmosphere. The IDAE is impact of aerosols on cloud formation and microphysics. Firstly, due to aerosols, it is increase of cloud droplet concentration and decrease in droplet size. Droplet size change will lead to increase in cloud albedo. Secondly, due to aerosols, it is decrease in cloud droplet size will influence precipitation formation/ removal.

The observed meteorological conditions in winter period also favour unfavourable pollution/ air quality situation as more pollution can be accumulated near the sources of emissions. The simulated concentrations of pollutants include contributions from background levels on the Northern hemispheric scale, long-range transport from remote regions, and local sources of pollution. Similar to meteorological patterns, the atmospheric composition patterns at higher resolution have more detailed structure (following more detailed meteorology with a better resolved small-scale features). An example of the Enviro-HIRLAM model output for black carbon and ozone concentrations at the 1st model level (32 m) zoomed over the Northern Fennoscandia and Kola Peninsula is shown in Fig. 2.

In the TRAKT project, capabilities of the multi-scale (from regional-subregional- to urban) modelling approach employing Enviro-HIRLAM seamless/ online integrated meteorology-chemistry-aerosols modelling system was demonstrated. This model is used as integral part of the PEEX-Modelling-Platform, and multi-scale and -processes modelling approach at INAR.

References:

*Mahura A., R. Makkonen, T. Petäjä, S. Zilitinkevich (in continuing collaboration with members of the Enviro-HIRLAM research and development team: R. Nuterman, A. Baklanov, B. Amstrup) (**2018**): Seamless Modelling: Downscaling to Northern Fennoscandia and Kola Peninsula. Presentation at the PEEX Working Group & iCUPE – ERA-PLANET Meeting in collaboration with Global-SMEAR-Climate-KIC and TRAKT projects, 1-2 Nov 2018, Helsinki, Finland.*

*Mahura A., R. Makkonen, S. Zilitinkevich, M. Kulmala (**TP2018**): Online Integrated Multi-Scale Modelling: Downscaling Meteorology and Atmospheric Composition. TRAKT Project Special Report.*

Black Carbon and Other Species in the Arctic

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Black carbon (BC) is a short-lived climate forcer. It influences air quality, meteorlogy and climate, and especially, in the northern latitudes and Arctic regions. After carbon dioxide, BC is the second main climate stressor. The BC atmospheric transport, dispersion, and deposition are especially difficult to simulate in the Arctic. It is, first of all, because complexity and multi-scale nature of meteorological/ climatological (numerical weather prediction/ climate modelling) processes simulations in these geographical regions. It is also due to complexity and variability of chemical processes, and especially during polar night periods in absence of solar radiation vs. photochemical reactions as well as atmospheric inflow of pollution transported from remote regions. Moreover, it is because uncertainties of emission inventories, and especially of higher both temporal and spatial resolutions (note, this problem exists for other countries and regions).
As additional part to the CarboNord project, the Enviro-HIRLAM simulations were performed (*Mahura et al., 2017*) over a large domain (including Arctic territories) at 0.15 deg horizontal resolution.

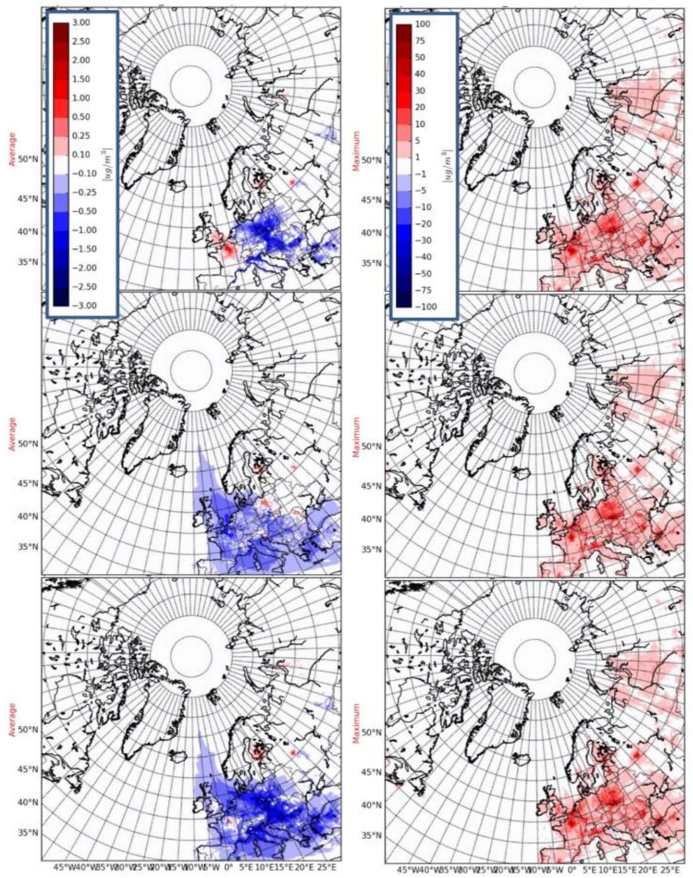

Figure 1. *Difference fields between CTRL&DAE (top), CTRL&IDAE (middle), CTRL&DAE+IDEA (bottom) runs with the Enviro-HIRLAM model for monthly (January) averaged (left) and maximum (right) concentration of black carbon (in µg/m^3).*

The model setup: 510 x 568 grid points along longitude x latitude; 360 sec time step; 40 vertical levels. The model runs included: control run (CTRL – none of aerosols effects included), and runs with direct (DAE), indirect (IDAE), and both combined (DAE+IDAE) effects included.
In winter time, BC is produced due to incomplete combustion of fossil fuels, etc. Once emitted, in the atmosphere BC is mixed with other aerosols species such as sulfates and organics. BC deposited on the snow surface, will change albedo and increase melting. At the same time, both sulphur dioxide and organic carbon are very important to take into account for estimating impact of BC on meteorology and climate.
Analysis of variability for basic statistical parameters such as average, median, maximum, minimum and standard deviation was performed for all model runs and differences between the model runs. As seen in Fig. 1, in winter time, the differences between the control vs. direct, indirect, and combined aerosol effects included are less pronounced for average concentration of BC in the Arctic regions, compared with other geographical regions. But these differences are observed for maximum concentration, and especially for the Siberia and Ural regions of Russia, where industrial complexes of metallurgy, etc. are located.

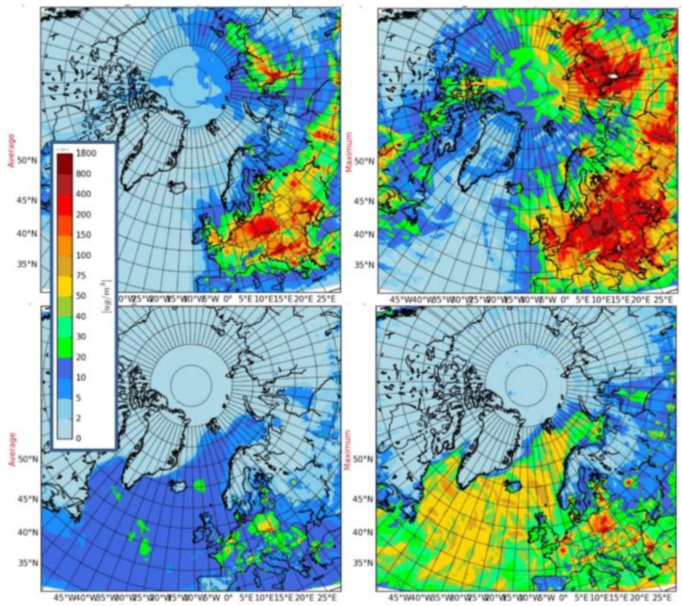

Figure 2. *January (12 UTC) monthly averaged (left) and maximum (right) simulated concentration (in µg/m^3) of SO_2 (top) and PM2.5 (bottom) based on the Enviro-HIRLAM control run simulations.*

For BC impact estimation, for example, consideration of SO_2 (gas-phase component) is also important. As seen in Fig 2-top-left, the average monthly concentration is larger over middle latitudes compared with Arctic region due to larger presence of anthropogenic sources in these regions. But maximum concentration despite absence of local sources is also observed due to long-range atmospheric transport.
The particular matter (PM) is also important for estimation of population exposure and health effects. In particular, PM2.5 concentration is simulated by the Enviro-HIRLAM model as shown in Fig. 2-bottom. Although averaged concentrations are lower in the Arctic regions, compared with mid-latitudes, but their composition is dominated by sea salt aerosols.

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TRAKT – PEEX Knowledge Transfer – continue networking and collaboration

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The Pan-Eurasian EXperiment (PEEX; www.atm.helsinki.fi/peex) "Knowledge Transfer" focus area directs towards educational programs at multiple levels, strengthening future research communities, and raising awareness of global changes and environmental issues; and it is well linked with the TRAKT-2018 project activities.

The *"TRAnsferable Knowledge and Technologies for high-resolution environmental impact assessment and management"* (www.nersc.no/project/trakt-2018) project is a part of the Programme for Environment and Climate Co-operation (PECC) – Nordic pilot programme for co-operation projects in the North-West Russia funded by the NMC (Nordic Council of Ministers) and administered by the NEFCO (Nordic Environment Finance Corporation).

During project realization, information about the project was distributed through the PEEX official website (www.atm.helsinki.fi/peex/index.php/trakt-2018), PEEX-e-news, instagram, twitter, PEEX-e-mailing list, PEEX newsletters.

From the University of Helsinki side (*TP2018*), at first, the SMEAR concept was promoted and demonstrated on example of the station measuring ecosystem-atmosphere relations (SMEAR-I - located in Lapland of Finland) by analysis of meteorological and atmospheric composition observations for a selected winter period of December 2017. The multi-scale (from global-regional-subregional-to urban) modelling approach employing the EC-Earth climate and Enviro-HIRLAM (Environment – HIgh Resolution Limited Area Model) online integrated models was also demonstrated. Note that the mentioned models are integral part of the PEEX-Modelling-Platform and multi-scale and multi-processes modelling at INAR. It should be noted that at INAR for the finest scales, a process-based modelling for the meteorology-chemistry-aerosol system is focused on understanding of hydrological, physical, meteorological and chemical mechanisms in the lower part of the troposphere.

Moreover, the transboundary atmospheric pollution (with focus on sulphates), based on atmospheric transport, dispersion and deposition patterns, was estimated on population over the Northern Scandinavia and Kola Peninsula; and demonstrated through web-based atlas (www.atm.helsinki.fi/peex/webatlas/WEBATLAS.html).

It is important to note that results of such studies are applicable for evaluation of risks, vulnerability, and consequences due to atmospheric; impact assessments on population and environment; supporting decision-makers, adjustment of legislation at regional and city levels; planning measures, mitigation scenarios, etc.

From the PEEX side, the TRAKT project outcomes and results will be promoted for a wider PEEX community:

• TRAKT project webpage at the PEEX website (at UHEL) will continue to be maintained with direct link to the official project website.

• TRAKT project final results were presented at the PEEX Workshop (1-2 Nov 2018, Helsinki, Finland); and will be presented on 4th PEEX Sci. Conference (2019) with involvement of Russian and Chinese researchers; Centre of Excellent ATM seminar (27-29 Nov 2018, Kuopio, Finland; *Mahura et al., 2018*).

• TRAKT project final results will be also presented in upcoming issues of the PEEX NewsLetters and e-News.

• Signed PEEX Memorandum of Understanding with TRAKT Russian partners (Scientific Research Center for Ecological Safety - SRCES; Nansen International Environmental and Remote Sensing Center, Kola Science Center) will be actively implemented.

• Web-based atlas on temporal and spatial variability of the atmospheric transport, dispersion and deposition of sulphates from Cu-Ni smelters of the Kola Peninsula and Krasnoyarsk Krai of Russia will be publicly available and freely accessible at the PEEX-web-site.

• Presented SMEAR, EC-Earth and Enviro-HIRLAM methodological approaches and obtained results will be actively used in educational process for the Universities' lectures and practical exercises.

• TRAKT project Enviro-HIRLAM downscaling results for the Northern Fennoscandia and Kola Peninsula to be included into student's workbooks on small-scale research projects and lectures (on atmospheric chemical transport, aerosol physics-chemistry, model evaluation and applications) for research training week on seamless modelling (June 2019, Tyumen, Russia); supported by AoF ClimEco project and PEEX.

• SRCES partner proposal on *"Integration of remote sensing and modelling for the risk assessment of the Russian Arctic atmosphere pollution"* (2019-2022) submitted to the Russian Science Foundation; the Enviro-HIRLAM model installation (with signing Code Transfer and Use) & setup at computing cluster; UHEL will assist with sci. co-supervising of 2 PhD students on Enviro-HIRLAM modelling and SMEAR measurements.

• A closer involvement is also expected as part of the PEEX climate policy making and to international forums, decision-makers and national authorities.

• The TRAKT project was well linked with the PEEX programme and tasks of the PEEX Science Plan (*PEEX, 2015*) as well as it was promoted to larger research, decision-making, stakeholders and end-users communities.

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*PEEX (**2015**): Pan-Eurasian EXperiment Science Plan. Eds. Lappalainen H.K., Kulmala M., Zilitinkevich S., ISBN 978-951-51-0587-5, 307 p, http://www.atm.helsinki.fi/peex/images/PEEX_Science_Plan.pdf*

*Mahura A., Makkonen R., Poutanen P., Lappalainen H.K., Petäjä T., Boy M., Kulmala M., Zilitinkevich S. (**2018**): TRAnsferable Knowledge and Technologies: Measuring Ecosystem-Atmosphere Relations, Climate and Seamless Multi-Scale Modelling for Environmental Impact Assessment and Management. Abstract for the Centre of Excellent ATM seminar. 27-29 Nov 2018, Kuopio, Finland; 4pp.*

*TRAKT Project (**TP2018**) Special Reports by the University of Helsinki are all linked at: https://www.nersc.no/page/trakt-publications-outreach-and-special-reports*

TRAnsferable Knowledge and Technologies: MEASURING ECOSYSTEM-ATMOSPHERE RELATIONS, CLIMATE AND SEAMLESS MULTI-SCALE MODELLING FOR ENVIRONMENTAL IMPACT ASSESSMENT AND MANAGEMENT

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Keywords: TRAKT, PEEX, SMEAR, EC-Earth, Enviro-HIRLAM, Climate and Seamless / Online Integrated Multi-Scale Modelling

INTRODUCTION

The TRAKT (*TRAnsferable Knowledge and Technologies for high-resolution environmental impact assessment and management*; www.nersc.no/project/trakt-2018) project is focused on implementation of a novel advanced technology for high-resolution environmental impact assessments. The technology consists of modern observations and satellite remote sensing, data fusion, and downscaling towards high resolution modelling. The main demonstration case is the Apatity-Kirovsk urban area (Kola Peninsula, Murmansk region, Russia). In this area, since 2014 a high-resolution observational and environmental monitoring network was established. The purpose of such technology is to support sustainable city development and planning with quantitative analysis, environmental assessment and scenario modelling. The University of Helsinki (UHEL) team's focus and contribution in this project was placed on demonstration of capabilities of the measuring ecosystem-atmosphere relations (SMEAR stations) concept, climate (EC-Earth) and seamless/ online integrated (Enviro-HIRLAM) modelling approaches. Moreover, the TRAKT project tasks are well inter-linked with activities of the Pan-Eurasian EXperiment (PEEX; www.atm.helsinki.fi/peex) (*PEEX, 2015*). PEEX is a multidisciplinary climate change, air quality, environment and research infrastructure programme focused on the Northern Eurasian domain, and in particular, on the Arctic and boreal regions.

METHODS

SMEAR research stations:
are developed and used to perform comprehensive and continuous observations (www.atm.helsinki.fi/SMEAR/index.php) for the relationship of atmosphere – Earth's surface/ biosphere in boreal climate zone. The main aims of research are: (i) biosphere - aerosol - cloud - climate interactions; (ii) biogeochemical cycles of carbon, nitrogen, sulphur and water; (iii) analysis of gaseous and particle pollutants and their role in cloud formation; (iv) analysis of water, carbon and nutrient budgets of soil; (v) analysis of environment and tree structure on gas exchange, water transport and growth of trees. At these stations, in total more than 1200 different variables can be measured in urban, forest, lake, peatland, and other areas. The SMEAR concept allows to study feedbacks with different surfaces such as land, water, urban, biosphere, cryosphere, etc. It relies on open data, open access, and open data flow. There are several such stations in Finland, Estonia, China as well as planned in Russia. The closest SMEAR station to the Russian North is called the SMEAR-I station (67°46'N, 29°36'E). It was placed into operation in 1991 in order to measure pollution levels in the Eastern Lapland of Finland from various industrial sources of the Kola Peninsula (Murmansk region, Russia). It is hosted by the Värriö Subarctic Research Station, which is placed in the Värriö Strict Nature Reserve (www.helsinki.fi/forestsciences/varrio/index.html). At SMEAR-I, during 1990s the measuring activity has increased to cover photosynthesis, weather, gas and particle measurements in addition to the measurements of air pollutants. The online available measurements include: aerosol particle count and size distribution, atmospheric pressure, air temperature, relative humidity, precipitation, wind speed and direction, radiation components, soil temperature, selected trace gas

concentrations, etc. Selected observations in a graphical format are web-online available (www.atm.helsinki.fi/SMEAR/index.php/online-observations) as well as data can be downloaded (avaa.tdata.fi/web/smart/smear/download). See more details in on the SMEAR concept and observations in *Petäjä et al. (TP2018)* and *Poutanen (TP2018a,b).*

Climate modelling:
is valuable approach to study changes in the Arctic regions. Project assessed the performance of global Earth System Model EC-Earth (*Hazeleger et al., 2010, 2012*) with zooming down to the Northern Fennoscandia and Kola Peninsula regions. The EC-Earth comprises of atmosphere model IFS (Integrated Forecasting System), ocean model NEMO (Nucleus for European Modelling of the Ocean) and vegetation model LPJ-GUESS (Lund-Potsdam-Jena General Ecosystem Simulator), coupled with OASIS (Ocean Atmosphere Sea Ice Soil) coupler. Aerosols and chemistry are included through the global chemistry-transport model TM5 (Transport Model 5). In this study, IFS is applied with 62 vertical levels and a horizontal spectral resolution of T255 corresponding to roughly 0.54ºx0.54º. It is coupled to NEMO (run at 1º horizontal resolution, 42 vertical levels). The ice model LIM (The Louvain-la-Neuve Sea Ice Model) is coupled with the ocean model. The TM5 describes aerosols using a 7-mode size distribution with 4 soluble and 3 insoluble modes, includes most abundant aerosol species (sulfate, black carbon, organic carbon, sea salt, mineral dust) and uses 3ºx2º resolution for aerosols and chemistry. LPJ-GUESS has been also updated with speciated monoterpene emissions for detailed SOA formation in the atmosphere. See mode details on EC-Earth modelling in *Makkonen (TP2018*).

Seamless modelling:
is advanced approach where online integration of numerical weather prediction (NWP) and atmospheric chemical transport (ACT) processes into one modelling system is realised. In this study, the Enviro-HIRLAM (Environment – HIgh Resolution Limited Area Model; *Baklanov et al., 2017*) was applied in a research mode. To demonstrate the online integrated meteorology-chemistry-aerosols modelling approach, the downscaling chain (with 3 enclosed domains with horizontal resolutions of 15, 5, 2 km; time steps of 240, 120, 60 sec; and 40 vertical levels) was setup to perform fine-resolution simulations over territories of the Kola Peninsula and Northern Fennoscandia in focus. The NWP-components include the digital filtering initialization, semi-Lagrangian advection scheme, and a set of physical parameterizations such as the Savijaervi radiation, STRACO condensation, CBR turbulence and ISBA schemes, etc. (*Uden et al.,2002*). The Enviro-components include modules for aerosol microphysics M7, gas-phase chemistry CBMZ, urbanization, emissions, nucleation, coagulation, condensation, deposition, etc. (*Baklanov et al., 2017*). The emissions are also pre-processed and include anthropogenic, biogenic, and natural. The Enviro-HIRLAM simulations are performed on Sisu's Cray XC40 system architecture which is designed for massively parallel applications. The UHEL team agreed to provide the model through signing agreement on the model code transfer and use for only research, development and educational purposes by other project partners. See mode details on Enviro-HIRLAM modelling in *Mahura et al. (TP2018a,b*).

Linking to PEEX:
at current moment the PEEX network includes more than 4000 researchers worldwide. The PEEX "Knowledge Transfer" focus area directs towards educational programs at multiple levels, strengthening future research communities, and raising awareness of global changes and environmental issues. The existing PEEX dissemination platform and communication tools were used for presenting and promoting the TRAKT project. The project information was distributed through the PEEX official website (www.atm.helsinki.fi/peex/index.php/trakt-2018), e-news, instagram, twitter, e-mailing list, newsletters. So far, the PEEX programme signed more than 30 PEEX Memorandum of Understanding (MoU) with universities and research institutes in Russia and China. In this project, MoUs were signed with 3 Russian institutions/ partners of the project. The TRAKT partners will present the achieved results during the PEEX Working Groups meeting (1-2 Nov 2018, Helsinki, Finland). The project is also invited to contribute to the 4th PEEX Science Conference (2019, Helsinki). Materials and results of the project are expected to be included into lecture courses at Universities. A closer involvement and project contribution are also expected as part of the PEEX climate policy making and to international forums, decision-makers and national

authorities. See mode details on the project linking to PEEX in *Kulmala et al. (TP2018), Lappalainen et al. (TP2018).*

CONCLUDING REMARKS

In this project, the SMEAR concept was promoted and demonstrated on example of the station measuring ecosystem-atmosphere relations (SMEAR-I) by analysis of observations for meteorology and atmospheric composition for a selected winter period (*Petäjä et al., TP2018; Poutanen TP2018a; Poutanen TP2018b*). The multi-scale (from global-regional-subregional- to urban) modelling approach employing the EC-Earth climate and Enviro-HIRLAM online integrated models was also demonstrated (*Makkonen, TP2018; Mahura, TP2018b*). Note that the mentioned models are integral part of the PEEX-Modelling-Platform (*Mahura et al., 2018a*) and multi-scale and multi-processes modelling at INAR (*Mahura et al., TP2018c*). It should be noted that at INAR for the finest scales, a process-based modelling for the meteorology-chemistry-aerosol system is focused on understanding of hydrological, physical, meteorological and chemical mechanisms in the lower part of the troposphere (*Boy et al., TP2018*).
In addition, transboundary atmospheric pollution (with focus on sulphates), based on atmospheric transport, dispersion and deposition patterns, was estimated on population over the Northern Scandinavia and Kola Peninsula (*Mahura et al., 2018b*); and demonstrated through web-based atlas (*Web-Atlas, 2018*). Note that results of such studies are applicable for evaluation of risks, vulnerability, and consequences due to atmospheric; impact assessments on population and environment; supporting decision-makers, adjustment of legislation at regional and city levels; planning measures, mitigation scenarios, etc.
The TRAKT project was well linked with the PEEX programme (*Lappalainen et al., TP2018*) and tasks of the PEEX Science Plan (*PEEX, 2015*) as well as it was promoted to larger research, decision-making, stakeholders and end-users communities. The intermediate report of the TRAKT project was published in summer 2018 (*Esau et al., 2018*).

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