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).

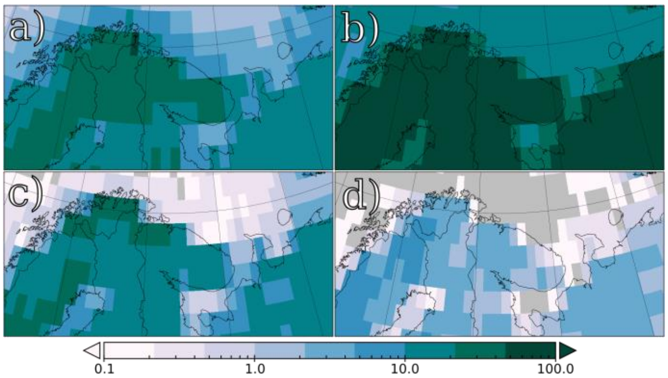

Figure 1. *Fraction of winter days meeting selected meteorological criteria: a) daily precipitation < 0.1mm; b) daily average wind-speed < 5 m/s; c) both conditions are met; d) precipitation <0.1mm and wind-speed < 3 m/s.*

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.

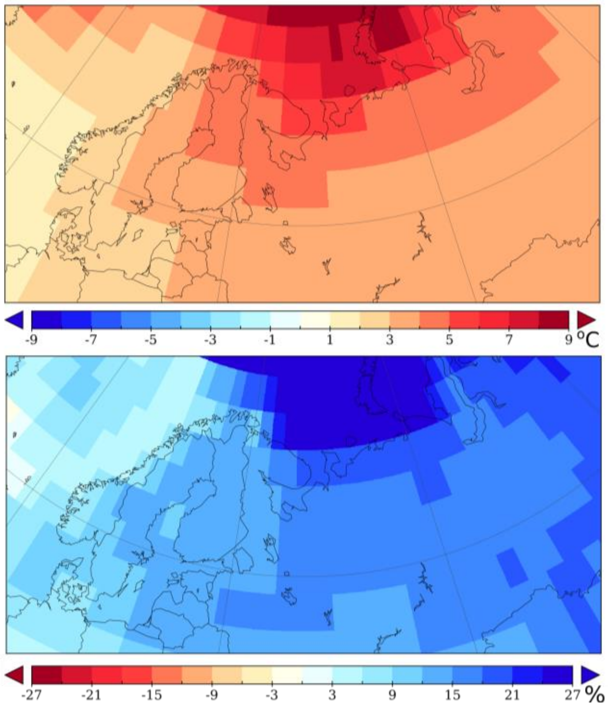

Figure 2. *Changes in winter-time 2-meter temperature (ºC, upper panels) and precipitation (%, lower panels) during the 21st century. Present-day climatology is averaged over years 1981-2010 and end-of-century climatology over 2070-2099.*

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.

References:

Hazeleger, W. et al. (2010), EC-Earth: A Seamless Earth-System Prediction Approach in Action, Bull. Amer. Meteor. Soc., 91, 1357–1363.
Gnatiuk, N. et al. (2018), Historical data analysis for the for Apatity-Kirovsk region in Russia: Climatology of days with synoptic conditions contributing to increased atmospheric pollution, TRAKT project special report, 2018.

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.

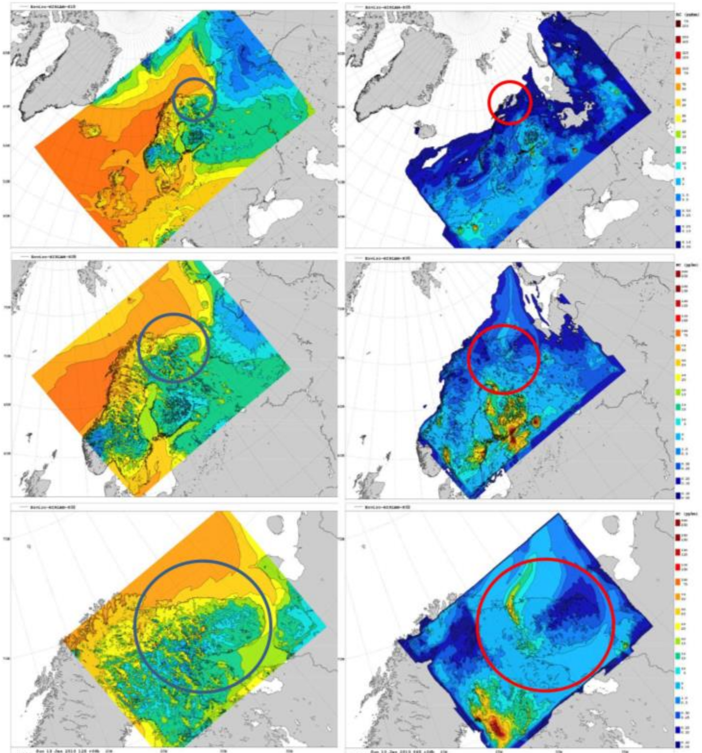

Figure 1. *An example of the Enviro-HIRLAM model output (runs in a downscaling chain over domain of K15, K05, and K02 with horizontal resolutions of 15, 5, and 2 km, respectively: top-middle-bottom plate) for the air temperature at 2 m (left) and organic carbon (OC) (right). The circles shows the Kola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

*Mahura A. (**TP2018**): Enviro-HIRLAM Downscaling Setup towards Fine Scale Modelling. TRAKT Project Special Report.*

*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.

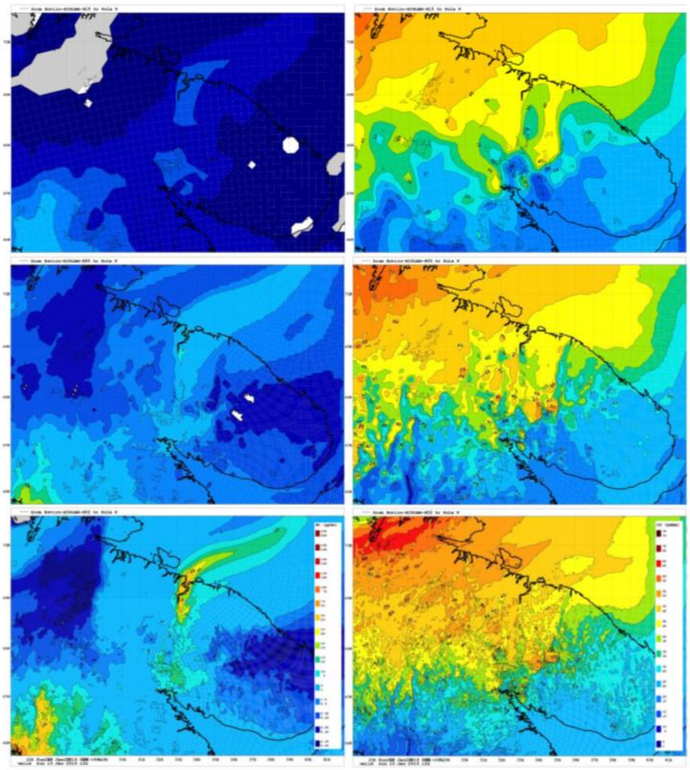

Figure 2. *An example of the Enviro-HIRLAM model output (runs in a downscaling chain with horizontal resolutions of 15, 5, and 2 km: top-middle-bottom plate) for the black carbon (BC) and ozone (O_3) concentration (right) zoomed over the Kola Peninsula area.*

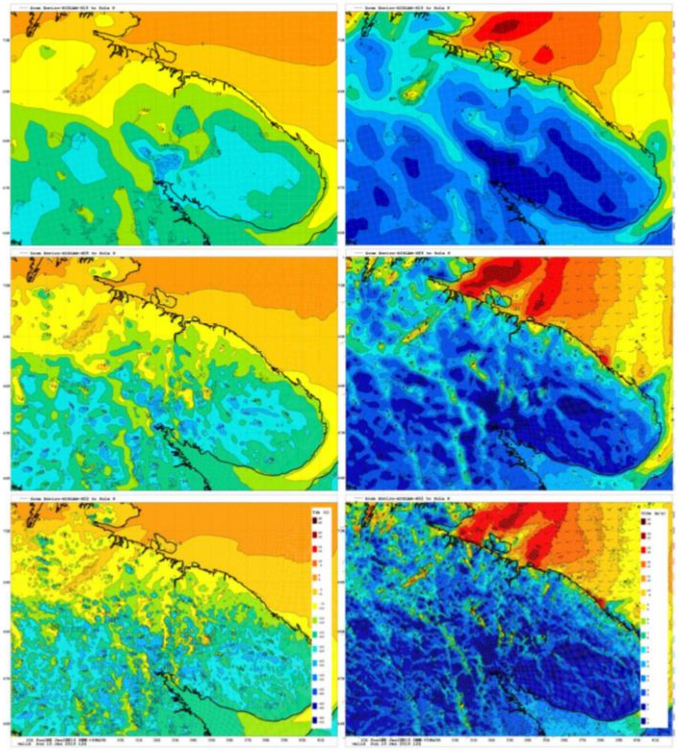

Figure 1. *An example of the Enviro-HIRLAM model output (runs in a downscaling chain with horizontal resolutions of 15, 5, and 2 km: top-middle-bottom plate) for the air temperature at 2 m (left) and wind speed at 10 m (right) zoomed over the Kola Peninsula area.*

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.

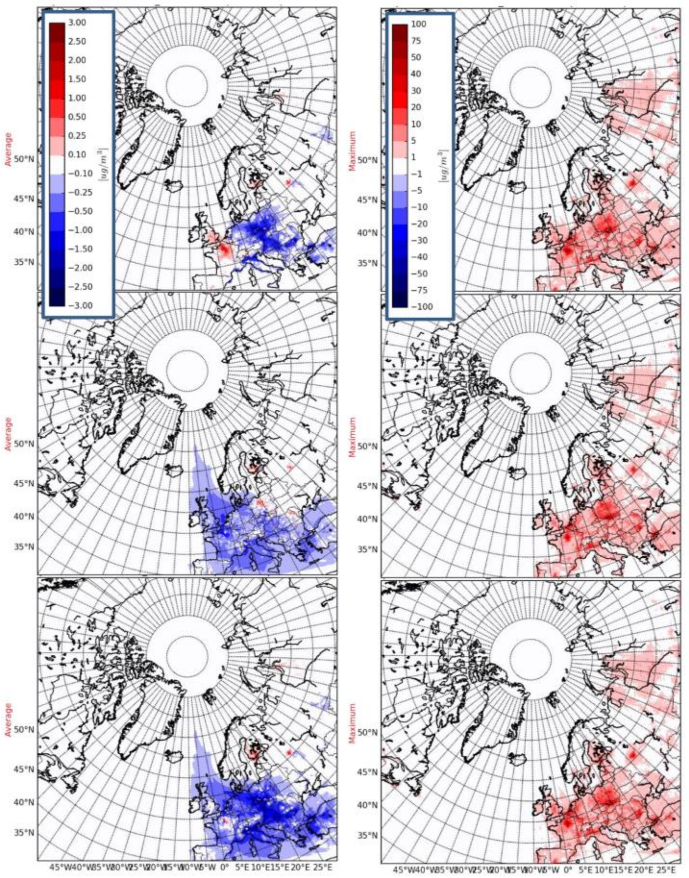

Figure 1. *Difference fields between CTRL&DAE (top), CTRL&IDAE (middle), CTRL&DAE+IDEA (bottom) runs with the Enviro-HIRLAM model for monthly (January) averaged (left) and maximum (right) concentration of black carbon (in µg/m^3).*

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.

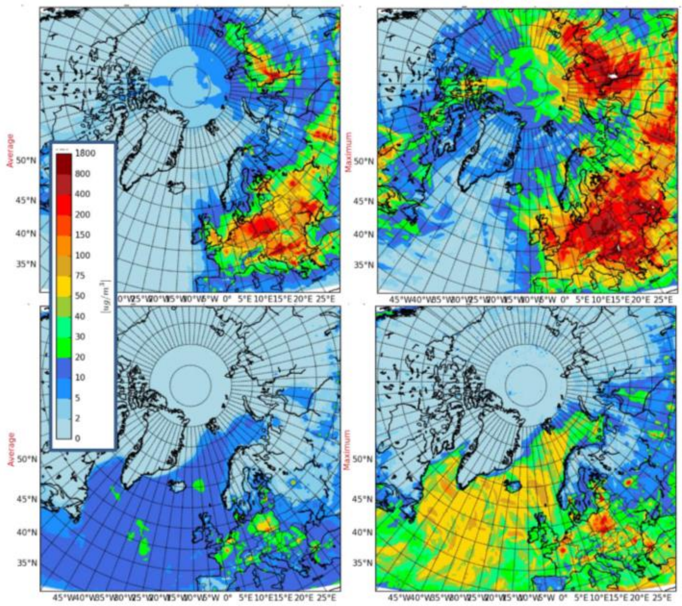

Figure 2. *January (12 UTC) monthly averaged (left) and maximum (right) simulated concentration (in µg/m^3) of SO_2 (top) and PM2.5 (bottom) based on the Enviro-HIRLAM control run simulations.*

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.

References:

*Mahura A., R. Nuterman, A. Baklanov (**2017**): High Resolution Modelling of Aerosols-Meteorology Interactions over Northern Europe and Arctic regions. Abstracts of European Geosciences Union (EGU) General Assembly, 17-22 Apr 2017, Vienna, Austria; Geophysical Research Abstracts, Vol.19, EGU2017-9607.*

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.

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*

*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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https://www.nersc.no/page/trakt-publications-outreach-and-special-reports

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