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

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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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