LATE REQUEST FOR A SPECIAL PROJECT 2018–2020

MEMBER STATE: ……………………FINLAND…………………….…………………..….

This form needs to be submitted via the relevant National Meteorological Service.

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[1] The Principal Investigator will act as contact person for this Special Project and, in particular, will be asked to register the project, provide an annual progress report of the project's activities, etc.

[2] If e.g. you archive x GB in year one and y GB in year two and don't delete anything you need to request x + y GB for the second project year.

Project Title: **Enviro-PEEX on ECMWF:** *Pan-Eurasian EXperiment (PEEX) Modelling Platform research and development for online coupled integrated meteorology-chemistry-aerosols feedbacks and interactions in weather, climate and atmospheric composition multi-scale modelling* ……………………………………………………..……

If this is a continuation of an existing project, please state the computer project account assigned previously.	**SP** _________________	
Starting year: (A project can have a duration of up to 3 years, agreed at the beginning of the project.)	2018	
Would you accept support for 1 year only, if necessary?	YES ☐	NO ☐

Computer resources required for the years: (To make changes to an existing project please submit an amended version of the original form.)		**2018**	**2019**	**2020**
High Performance Computing Facility	(SBU)	4000 kSBU	4000 kSBU	4000 kSBU
Accumulated data storage (total archive volume)[2]	(GB)	9000	9000	9000

***An electronic copy of this form must be sent via e-mail to**:* *special_projects@ecmwf.int*

Electronic copy of the form sent on (please specify date):

…………20 November 2017……..……

Continue overleaf

Principal Investigator: …………Alexander Mahura………………………………………

Project Title: **Enviro-PEEX on ECMWF:** *Pan-Eurasian EXperiment (PEEX) Modelling Platform research and development for online coupled integrated meteorology-chemistry-aerosols feedbacks and interactions in weather, climate and atmospheric composition multi-scale modelling* …..…………………………………….……

Extended abstract

All Special Project requests should provide an abstract/project description including a scientific plan, a justification of the computer resources requested and the technical characteristics of the code to be used.

Requests asking for 1,000,000 SBUs or more should be more detailed (3-5 pages).

Following submission by the relevant Member State the Special Project requests will be based on the following criteria: Relevance to ECMWF's objectives, scientific and technical quality, disciplinary relevance, and justification of the resources requested. Previous Special Project reports and the use of ECMWF software and data infrastructure will also be considered in the evaluation process.

All accepted project requests will be published on the ECMWF website.

Introduction

As the societal impacts of hazardous/ unfavorable weather and other environmental pressures grow, the need for integrated predictions which can represent the numerous feedbacks and linkages between sub-systems of our environment is greater than ever. This has led to development of a new generation of high resolution coupled prediction tools to represent the two-way interactions between different components of the environment. For example a new generation of online integrated Atmospheric Chemical Transport (ACT) and Meteorology (Numerical Weather Prediction, NWP and Climate) models represent the interactions between different atmospheric processes including chemistry (both gases and aerosols), clouds, radiation, boundary layer, emissions, meteorology and climate. In parallel, coupled environmental prediction at km-scale which includes feedbacks between the atmosphere, land surface, coastal areas and oceans aim to better represent the interactions in the water cycle, to provide tools for improved natural hazard response or water management, for example. Global Earth system models simulate the atmosphere, cryosphere, biosphere, and oceans, allowing investigation of interactions and feedbacks within and between these different spheres, including how these affect climate and biogeochemistry on timescales of hours to millennia.

The simulation of the coupled evolution of atmospheric transport and chemical composition remain one of the most challenging tasks in environmental modelling. Many of the current environmental challenges in weather, climate, and air quality modelling involve strongly coupled systems (*Zhang, 2008; Baklanov et al., 2008a, 2010; Alapaty et al., 2011*). It is well accepted that weather is element of key importance for air quality for daily life as well as accidental/emergency situations. It is also recognized that chemical species and aerosols can influence weather by changing the atmospheric radiation budget as well as through cloud and precipitation formation. However, until recently (because complexity and lack of computer power) air pollution and weather forecasts have developed as separate disciplines, leading to development of separate modelling systems which are only loosely coupled (off-line). In Numerical Weather Prediction (NWP), a substantial increase in computer power and capabilities enables to run NWP models at higher horizontal (down to 1+ km) as well as vertical (more model levels within the atmospheric boundary layer) resolutions to explicitly resolve small-scale circulation features, fronts, clouds, or to increase the complexity of the numerical models. Additionally, even though it is widely accepted that atmospheric processes have an impact on hydrological systems, these are not yet well integrated with NWP; and hence, modules for water runoff generation and water quality in hydrological pathways need to be coupled.

As of now, it is possible directly couple air quality forecast models with numerical weather prediction models to produce a unified modelling system – online – that allows two-way interactions. While climate modelling centres have directed towards an Earth System Modelling (ESM) approach that includes also atmospheric chemistry and ocean-sea-ice interactions, the NWP and Air Quality (AQ) forecasting centers/ organizations have started discussions whether an on-line approach is important enough to justify the extra-cost (*IFS, 2006; Grell, 2008; Baklanov et al, 2008a; Grell & Baklanov, 2011*). NWP and AQ forecasting centres may have to invest in additional computer power as well as additional man-power, because additional expertise may be required. Meteorological institutes are in favour of integrating weather and chemistry together, for improvement of weather prediction skills as well as for air quality and chemical composition forecasting. For NWP centres, an additional attractiveness of the on-line approach is its possible usefulness for meteorological data assimilation (*Hollingsworth et al., 2008*), where the retrieval of satellite data and direct assimilation of radiances will likely improve – assuming that the modelling system can beat climatology when forecasting concentrations of aerosols and radiatively active gases.

The focus on integrated systems is timely, since recent research has shown that meteorology/climate and chemistry feedbacks are important in the context of many research areas and applications, including NWP, climate, and air quality forecasting, and Earth system modelling. Potential impacts of aerosol feedbacks include (*Jacobson et al., 2007; Zhang, 2008; Baklanov et al., 2008a; Baklanov, 2010; Grell & Baklanov, 2011; Zhang et al., 2010ab*): reduction of downward solar radiation (direct effect); changes in surface temperature, wind speed, relative humidity, and atmospheric stability (semi-direct effect); decrease in cloud drop size and an increase in drop number by serving as cloud condensation nuclei (first indirect effect); increase in liquid water content, cloud cover, and lifetime of low level clouds, and suppression or enhancement of precipitation (second indirect effect).

Traditionally, aerosol feedbacks have been neglected in NWP and air quality modelling mostly due to an historical separation between the meteorological and air quality communities as well as a limited understanding of the underlying interaction mechanisms. Such mechanisms may, however, be important on a wide range of temporal and spatial scales, from days to decades and from global to local. Field experiments and satellite measurements have shown that chemistry-meteorology feedbacks exist among the Earth systems including the atmosphere (*e.g., Kaufman & Fraser, 1997; Rosenfeld, 1999; Rosenfeld & Woodley, 1999; Givati & Rosenfeld, 2004; Grell et al., 2005; Lau & Kim, 2006; Rosenfeld et al., 2007, 2008*).

PEEX-Modelling-Platform (PEEX-MP) Research, Development and Application

The PEEX-MP (https://www.atm.helsinki.fi/peex/index.php/modelling-platform) presents a strategy for best use of current generation modeling tools to improve process understanding and improve predictability on different timescales within the PEEX domain, and also presents potential future developments. A number of application areas of new integrated modelling developments are expected to be considered, including: (i) improved numerical weather prediction (NWP) and chemical weather forecasting (CWF) with short-term feedbacks of aerosols and chemistry on meteorological variables; (ii) two-way interactions between atmospheric pollution/ composition and climate variability/ change; (iii) better prediction of atmosphere and/or ocean state through closer coupling between the component models to represent the two-way feedbacks and exchange of the atmospheric and ocean boundary layer properties; (iv) more complete/ detailed simulation of the hydrological cycle, through linking atmospheric, land surface, ecosystems, hydrological and ocean circulation models.

The PEEX-MP focuses on new generation of integrated models and is based on the seamless Earth System Modelling (ESM) approach to evolve from separate model components to seamless meteorology-composition-environment models to address challenges in weather, climate and atmospheric composition fields whose interests, applications and challenges are now overlapping. Several models, being a part of the PEEX-MP, are to be further developed and tested in this HPC project.

The **Enviro-HIRLAM** (***Environment – HIgh Resolution Limited Area Model***) was developing as an on-line coupled Numerical Weather Prediction (NWP) and Atmospheric Chemical Transport (ACT) integrated modelling system for research purposes and for joint forecasting of meteorological, chemical, and biological (including pollen) weather. The integrated modeling system was started since 2000s to be developed by DMI (*Chenevez et al., 2004; Baklanov et al., 2004, 2008ab; Korsholm, 2009; Korsholm et al., 2008, 2009, 2010*) and further in a close collaboration with the Universities, and it was used by the HIRLAM consortium as a baseline system for the HIRLAM Chemical Branch (http://www.hirlam.org/chemical). The Enviro-HIRLAM model was the first meso-scale on-line coupled model in Europe, which considered two-way feedbacks between meteorology and chemistry/ aerosols.

As of now, the Enviro-HIRLAM is a fully online-coupled NWP-ACT modeling downscaling system for hemispheric-, regional-, subregional- and urban scale different environmental applications. The NWP part was originally developed by the HIRLAM consortium (*Unden et al, 2002*) and it is used for operational weather forecasting. Since beginning of 2000, the Enviro-components were mainly developed, tested and implemented in the model by Danish Meteorological Institute (DMI) with partners from European Universities. Since May 2017, the further research and development of the modelling system is realized by the University of Helsinki (UHEL) in collaboration with the University of Copenhagen (UCPH) and involvement of DMI.

It consists of gas-phase chemistry CBMZ (*Zaveri & Peters, 1999*) and aerosol microphysics M7 (*Vignati et al., 2004*), which includes sulfate, mineral dust, sea-salt, black and organic carbon (*Nuterman et al. 2013*).

There are modules of urbanization for land surface scheme, natural and anthropogenic emissions, nucleation, coagulation, condensation, dry and wet deposition, and sedimentation of aerosols. The Savijarvi radiation scheme (*Savijaervi, 1990; Wyser, 1999*) has been improved to account explicitly for aerosol radiation interactions for 10 aerosol subtypes. The aerosol activation scheme (*Abdul-Razzak & Ghan, 2000*) was also implemented in STRACO condensation-convection scheme. The nucleation is dependent on aerosol properties and the ice-phase processes are reformulated in terms of classical nucleation theory. Emission inventories include: anthropogenic - TNO-MEGAPOLI, MACC, ECLIPSE, and others; biomass burning - IS4FIRES; natural - interactive sea-salt (*Zakey et al., 2008*) and mineral dust (*Zakey et al., 2006)* emission modules. The latest description of the Enviro-HIRLAM modeling system is given by Baklanov et al. (2017; https://www.geosci-model-dev.net/10/2971/2017).

For NWP and climate modelling, the hydrological processes contribution at different scales is also important for the ISBA land-surface-scheme. Conceptual models of catchment erosion, sediment delivery and nutrient transport are to be coupled. Such approach aims to resolve knowledge gaps and develop watershed-scale sediment and nutrient modelling necessary to determining impacts of land-use/cover patterns in a changing climate on current nutrient loading and hydrological pathways as well as interactions and feedbacks between water surfaces – atmosphere. The approach to be tested on case study medium and large-size catchments.

Following the main development strategy of the HIRLAM community (HIRLAM-C project) the Enviro-HIRLAM further developments are moving step-by-step towards the new NWP **HARMONIE** (***HIRLAM-ALADIN Research for Meso-scale Operational NWP In Europe***) model platform by incorporating (of the Enviro-part of the Enviro-HIRLAM modelling system - chemistry and aerosol-radiation-cloud interactions modules), testing and further development of the **Enviro-HARMONIE** integrated modelling system. It is also possible to consider enhancement of the HARMONIE framework by coupling NWP and ACT models in order to provide on-line weather information needed for modelling atmospheric composition and air quality. Note that the NWP HARMONIE system combines elements from the global IFS/Arpege model (*Déqué et al., 1994*) with the ALADIN non-hydrostatic dynamics (*Bénard et al., 2010*). At high horizontal resolutions (<2.5 km), the forecast model and analysis system are basically linked with AROME model from Météo-France (*Seity et al., 2011; Brousseau et al., 2011*). Physical parametrizations from ALARO, HIRLAM (*Undén et al., 2002*) and ECMWF are applicable in this framework.

SOSAA is a 1D column model which was first developed by *Boy et al. (2011)* and applied in several subsequent studies (e.g., *Kurtén et al., 2011; Mogensen et al., 2011; Bäck et al., 2012; Boy et al., 2013; Smolander et al., 2014; Zhou et al., 2015; Mogensen et al., 2015; Zhou et al., 2017*). SOSAA is written in Fortran90 and able to run in parallel in superclusters. The current version has coupled 5 modules. The meteorology module is derived from SCADIS (SCAlar DIStribution; *Sogachev et al., 2002*) which is originally a 3D boundary layer meteorology model. The BVOC emissions from the forest ecosystem are computed by MEGAN (Model of Emissions of Gases and Aerosols from Nature; *Guenther et al., 2006*). The chemistry module codes are created by KPP (Kinetic PreProcessor; *Damian et al., 2002*) based on the chemical mechanisms generated by MCMv3.2 (Master Chemical Mechanism version 3.2; http: //mcm.leeds.ac.uk/MCM) (*Jenkin et al., 1997; Saunders et al., 2003; Jenkin et al., 2012*). The aerosol module is based on UHMA (UHEL Multicomponent Aerosol model; *Korhonen et al., 2004*), which describes the nucleation, condensation, coagulation and deposition of aerosol particles. The gaseous dry deposition module was introduced in *Zhou et al. (2017ab)* mostly focusing on dry deposition of organic compounds. A unique peroxy radical autoxidation mechanism (PRAM) for production of highly oxygenated organic molecules (HOM) from ozonolysis of monoterpenes with endocyclic double bonds was implemented recently.

The **EC-Earth** is developed jointly by 28 European research institutes (*Hazeleger et al., 2010*). EC-Earth comprises of atmosphere model IFS, ocean model NEMO and vegetation model LPJ-GUESS, coupled with OASIS coupler. Aerosols and chemistry are included through the global chemistry-transport model TM5 *(van Noije et al., 2014*). EC-Earth is participating in ongoing Coupled Model Intercomparison project phase 6 (CMIP6). EC-Earth has been implemented to ECMWF supercomputing infrastructure, and is being used there by e.g. KNMI.

Scientific developments

The overall objectives of the special project will be to analyse the 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 and atmospheric chemical transport via process-oriented parameterizations and feedback algorithms, which will improve the numerical weather prediction, climate and atmospheric composition forecasting.

The developing on-line integrated meteorology-chemistry-aerosols modelling system Enviro-HIRLAM/ HARMONIE is expected to be able to handle the following major processes and interactions (*Jacobson et al., 2007; Zhang, 2008*): (i) direct effect - radiative effect of chemical species such as ozone and aerosols in the atmosphere via absorption and scattering; (ii) semi-direct effect - effect of aerosols and clouds on photolysis rates via modifying actinic fluxes and temperature; (iii) semi-direct effect - effect of aerosols on boundary layer meteorology via changing meteorological variables and atmospheric stability; (iv) 1st and 2nd indirect effects - effect of aerosols on cloud formation and reflectance via aerosol activation, droplet and ice core nucleation, autoconversion, and collection; (v) indirect effects - effect of aerosols on precipitation by affecting clouds and water vapour. These processes and interactions are essential in studies for weather, climate and air quality. Aerosol particles, as an integral part of the atmosphere, play important role in the environment and have impact on human health. Depending on aerosols' origin, chemical composition, lifetime, size, shape and optical properties aerosols can cause multiple complex effects in the atmosphere at various spatio-temporal scales (*Kulmala et al., 2009; Sesartic et al., 2013; Lohmann & Feichter, 2005; Calvoa et al., 2012*). Additionally these processes will be coupled with hydrologically-driven catchment erosion and nutrient catchment-scale model with integrated meteorology-chemistry-hydrology conceptual framework.

According to evaluation of the COST Action EuMetChem (European framework for online integrated air quality and meteorology modelling; http://eumetchem.info), among main important couplings for numerical weather prediction there are the following when changes in aerosols affect: precipitation (initiation and intensity of precipitation); radiation (short-wave scattering/ absorption and long-wave absorption); cloud droplet or crystal number density (cloud optical depth); haze (hydroscopic growth of aerosols interrelated with relative humidity); cloud morphology (reflectance); and others. Among main important couplings for chemical weather forecasting there are the following when changes: in wind speed affect dust and sea-salt emissions; in precipitation affect atmospheric composition; in temperature and radiation affect chemical reaction rates and photolysis; in liquid water affect wet scavenging and atmospheric composition; and others. EuMetChem case studies showed that improvement due to aerosol feedbacks depends on geographical region and season; during extreme episodes such as dust-storms and forest-fires the improvement can be larger; and indirect effects can be larger (or similar) to direct effects of aerosols. Approach on implementation of the indirect effect have a large impact on model results, and hence this should be a focus for future studies as well as complete analysis will require simulations at high resolution and aerosol representations in the model. Model based forecasts are usually done with insufficient or approximate input data like initial and boundary conditions, approximate emission source estimates and model coefficients. These uncertainties can be potentially reduced with assimilation of available measurement data covering a relatively small number of model parameters. Numerical experiments should be performed to evaluate performance of data assimilation algorithms in the context of integrated models on realistic inverse modelling scenarios.

In the previous **Enviro-Aerosols on ECMWF HPC** project (2015-2017) the following case studies were realised: on-line meteorology-chemistry/aerosols modelling for risk assessment integration; sensitivity of precipitation simulations to soot aerosol presence; precipitation forecast sensitivity to data assimilation on a very high resolution domain; aerosol effects at high resolution convection modelling; effects of aerosols on clear-sky solar radiation; impacts of the direct radiative effect of aerosols in NWP; meteorological and chemical urban scale modelling for selected metropolitan areas; direct variational data assimilation algorithm for atmospheric chemistry data with transport and transformation model; aerosol influence on high resolution NWP operational forecasts; impact of regional afforestation on climatic conditions in metropolitan area; spatio-temporal variability of aerosols in the Arctic and boreal regions; aerosols regional influence on air temperature and total cloud cover; atmospheric transport and deposition patterns of sulphates for assessment on population and environment; downscaling to metropolitan areas; influence of aerosols on atmospheric variables in the NWP model.

Overview of projects that benefits from the special project

The two previous Special Projects "***EnviroChemistry on ECMWF****: Enviro-HIRLAM/HARMONIE development and test of an NWP model system accounting for aerosol-meteorology interactions*" (2012-2014) and "***EnviroAerosols on ECMWF****: Enviro-HIRLAM/ HARMONIE model research and development for online integrated meteorology-chemistry/aerosols feedbacks and interactions in weather and atmospheric composition forecasting*" (2015-2017) both substantially contributed to the following EU and national research projects:

- HIRLAM-B(&-C) (http://hirlam.org);
- COST Action EuMetChem ES1004 "*European framework for online integrated air quality and meteorology modelling*" (http://eumetchem.info);

- FP7 EU MEGAPOLI "*Megacities: Emissions, urban, regional and Global Atmospheric POLlution and climate effects, and Integrated tools for assessment and mitigation*" (http://megapoli.info);
- FP7 EU MACC "*Monitoring of Atmospheric Composition and Climate*" (https://www.gmes-atmosphere.eu);
- FP7 EU PEGASOS "*Pan-European Gas-AeroSOls-climate interaction Study*" (http://pegasos.iceht.forth.gr);
- FP7 EU TRANSPHORM "*Transport related Air Pollution and Health impacts - Integrated Methodologies for Assessing Particulate Matter*" (http://www.transphorm.eu);
- CEEH "*Danish strategic research Center for Energy, Environment and Health*" (http://ceeh.dk);
- AQMEII "*Air Quality Model International Initiative*" Phase 2 (http://aqmeii.jrc.ec.europa.eu);
- NordForsk CarboNord "*Impact of black carbon on air quality and climate in Northern Europe and Arctic*";
- NordForsk CRAICC-PEEX "*Cryosphere-atmosphere interactions in a changing Arctic climate - Pan-Eurasian Experiment";*
- NordForsk PEEX-CRUCIAL "*Pan-Eurasian Experiment - Critical steps in understanding land surface – atmosphere interactions: from improved knowledge to socio-economic solutions*";
- FP7 EU MarcoPolo "*Monitoring and Assessment of Regional air quality in China using space Observations, Project Of Long-term sino-european co-Operation*" (http://www.marcopolo-panda.eu).
- and others.

The suggested new Special Project "***Enviro-PEEX on ECMWF****: Pan-Eurasian EXperiment (PEEX) Modelling Platform research and development for online coupled integrated meteorology-chemistry-aerosols feedbacks and interactions in weather, climate and atmospheric composition multi-scale modelling* (2018-2020)" is to be realised in a close relation with several European and national research projects as well as in a close collaboration with Universities and research institutions:

UHEL – University of Helsinki, Finland;
UCPH – University of Copenhagen, Denmark;
FMI – Finnish Meteorological Institute, Finland;
OSENU – Odessa State Environmental University, Ukraine;
ITU – Istanbul Technical University, Turkey;
UoLA – University of L'Aquila, Italy;
RSHU – Russian State Hydrometeorological University, Russia;
UHMI – Ukrainian Hydrometeorological Institute, Ukraine;
ICMMG – Institute Computational Mathematics and Mathematical Geophysics, Russia;
KazNRTU – Kazakh National Research Technical University, Kazakhstan;
NIERSC – Nansen International Environmental and Remote Sensing Centre, Russia;
TShNUK – Taras Shevchenko National University of Kyiv, Ukraine;
MSU – Moscow State University, Russia;

involved into Enviro-HIRLAM/HARMONIE and PEEX-Modelling-Platform research and development tasks/ activities, including the following:

HIRLAM-C: HIRLAM-C Programme (2016-2020) plans include realisations of specific tasks on coupling with atmospheric chemistry and cloud microphysics, radiation and aerosols within the HIRLAM community for development of on-line integrated NWP and ACT modelling system (e.g. from Enviro-HIRLAM to further Enviro-HARMONIE) to be realised by members of the HIRLAM-ALADIN consortium in collaboration with mentioned Universities.

PEEX (Pan-Eurasian Experiment) Programme (https://www.atm.helsinki.fi/peex) is a multidisciplinary, multi-scale programme focused on solving grand challenges in Northern Eurasia and China focusing in Arctic and boreal regions. Among main building blocks are the PEEX Research Agenda; Infrastructure (including Modelling and Observational Platforms); Impact on Society; and Knowledge Transfer. Following PEEX Science Plan (http://www.atm.helsinki.fi/peex/images/PEEX_Science_Plan.pdf), programme will also help to develop service, adaptation and mitigation plans for societies to cope with global change. It is a bottom-up initiative by several European, Russian and Chinese research organizations and institutes with co-operation of US and Canadian organizations and Institutes. 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.

CRAICC (Cryosphere-atmosphere interactions in a changing Arctic climate; https://www.atm.helsinki.fi/craicc) is part of the Top-level Research Initiative, the largest joint Nordic research and innovation initiative to date, aiming to strengthen research and innovation regarding climate change issues in the Nordic region. Main objectives are: (i) to identify and quantify the major processes controlling Arctic warming and related feedback mechanisms; (ii) to outline strategies to mitigate Arctic warming; (iii) to develop Nordic Earth System modelling. The focus is on short-lived climate forcers, including natural and anthropogenic aerosols.

FCoE-ATM (The Centre of Excellence in Atmospheric Science - From Molecular and Biological processes to The Global Climate; https://www.atm.helsinki.fi/FCoE) main aim is to quantify the COBACC (COntinental Biosphere-Aerosol-Cloud-Climate) feedbacks in changing climate. The specific objectives are: (ii) to find out and quantify the main climatic feedbacks and forcing mechanisms related to aerosols, clouds, precipitation, biosphere-atmosphere and cryosphere-atmosphere interactions; (ii) to develop, refine and utilize the newest measurement techniques and modelling tools scaling from quantum chemistry to global Earth System Observations and Models; (iii) to create a deep and quantitative understanding on the role of atmospheric clusters and aerosol particles in local and global biogeochemical cycles of water, carbon, sulfur and nitrogen and their linkages to the atmospheric chemistry; and (iv) to integrate the results in the context of regional and global scale Earth system understanding.

TRAKT-2018: "*TRAnsferable Knowledge and Technologies for high-resolution environmental impact assessment and management*" project is aimed at implementing a novel advanced technology for the high-resolution environmental impact assessment. The technology consists of citizen observations and data fusion; satellite remote sensing; and high-resolution urban modeling. It is based on accumulated knowledge and understanding of specific environmental phenomena in the cold climate (stably stratified atmosphere, snow and ice processes, polar clouds, permafrost), which result in large errors and uncertainties, when more general approaches are being regionalized. It is supporting sustainable city and land-use planning with quantitative analysis, environmental assessment and scenario modeling, including the high-resolution (urban) downscaling of the climate change and local socio-economic scenarios.

URSA: "*Socio-environmental interactions and sustainable ecosystem services in the urban Arctic*" project is aiming at identifying strength and extent of the socio-environmental interactions in aspects of the ecosystem and climate changes following the urbanization of the Arctic and adjacent cross-boundary regions. The specific objectives are: (i) co-variability and changes in the essential socio-environmental indicators, using primarily the satellite information to reveal the geographical extent and variability; (ii) urbanization affects the active micro-climate in a selection of Arctic settlement using high-resolution process assessment and modeling; (iii) detailed study in selected county to test the envisioned holistic approach of the PEEX research community; (iv) biotic and urban biodiversity study exploring the fundamental connections with the urban bioclimatic system on the background of the amplified regional climate change and how this in turn affects the ecosystem services. The urbanization transforms arctic landscape (land use and land cover change cause habitat fragmentation, loss of habitat and species extinctions), changes bioclimatic conditions in urban areas (city climate is warmer and dryer then surround areas) and develops new habitats for plants and animals. These factors give an opportunity to make the arctic city greener and provide environmental needs (ecosystem services) for arctic populations.

H2020-MSCA-GC-PEEX-ETN: "*The Grand Challenges in the Pan-Eurasian Experiment (PEEX) domain*" project is focused on the following main research themes: climate feedbacks and comprehensive measurements, climate forcing and global modelling, climate-air quality interactions, anthropogenic emission inventories and scenarios, land-atmosphere interactions, air quality and regional modelling, biogeochemical cycles, ecosystem functioning and biogenic emissions, greenhouse gas exchange, carbon sink and source estimation. The focus will be on studies with modelling for urban areas in changing land cover and climate conditions as well as on regional integrated modelling of meteorology-chemistry/ aerosol feedbacks and interactions through further development and employing Enviro-HIRLAM/ HARMONIE/ EC-Earth modelling systems.

3CD: "*Changing Climate and Changing Diseases in the Russian and Finnish Arctic*" project is aimed at assessing impact of weather and climate in the etiology of diseases with a special reference to the Finnish and Russian Arctic regions and to help in mitigation of the climate change. The specific objectives are: (i) to develop integrated experimental and modelling methodologies for assessing and predicting the impact of climatic factors on the health of the populations in the Russian and Finnish Arctic territories; (ii) to use those methodologies for evaluating the dispersal and occurrence of climate-related diseases both presently and in the future; and (iii) to present policy-relevant results and recommendations for mitigating the health effects of such diseases. The focus is on utilization and further refinement of novel methodology for observations and modelling for the dispersion of diseases in order to understand their spatial distribution and resistance to the Arctic climate, now and in future. The project aims at quantifying the risk of climate-dependent diseases (e.g. anthrax) and assess the relationships between geographical and socio-economic conditions, and population health in a changing Arctic climate.

ClimEco: "*Mechanisms, pathways and patchiness of the Arctic ecosystem responses and adaptation to changing climate*" project is aimed at improving modern knowledge of mechanisms, feedbacks and pathways of the Arctic ecosystems response and their adaptation to the Arctic warming and, thus, to advance scientific background and tools for projecting current and future changes in Arctic ecosystems and microclimates. The specific objectives are: (i) to integrate historical and newly obtained in-situ and remote-sensing data for demonstrating and quantifying parallel ongoing changes in climate and ecosystems over Northern Finland and North-Western Siberia; (ii) to identify and specify by field observations and experiments in different ecosystems (mires, shrublands tundra and forest, permafrost and non-permafrost) concrete responses of Arctic ecosystems to climate warming and land-use disturbances at small scales; (iii) to advance conventional concept and methods of calculation of Arctic boundary layer and heat/moisture exchange between the atmosphere and selected Arctic ecosystems, towards better understanding and forecasting of local Arctic climate-biosphere systems.

PEEX Academic Challenge: FIRST+ networking project is aimed at (i) strengthening collaboration between Finnish and Russian Universities involved into the PEEX research and educational agenda; (ii) sharing knowledge, experience and promote the state-of-the-art research and educational tools such as the SMEAR observational platform and the seamless/online integrated and Earth system modelling and GIS technology by research-educational training (through short- and long-term visits and intensive courses); (iii) improving added value of science oriented education and research carried out in the University system of both countries and boost the PEEX international collaboration. The outcomes of the Enviro-PEEX will be used for lecturing and developing small-scale research projects for 1 week research training intensive course on "Earth system modelling and seamless/ online integrated meteorology-chemistry-aerosols multi-scale modelling for environmental applications" (with EC-Earth & Enviro-HIRLAM/ HARMONIE).

eSTICC: A Nordic Centre of Excellence (NCoE) funded by NordForsk. eSTICC stands for "eScience Tools for Investigating Climate Change at High Northern Latitudes" and aims for a more accurate description of the high-latitude feedback processes in the climate system by improving the eScience tools for the climate research community. eSTICC has pooled together researchers from 13 top institutes in the Nordic countries working in the fields of climate and/or eScience to improve eScience tools for climate research. Specifically, eSTICC will develop tools needed for more efficient use of experimental and model data, and improve the computational efficiency and coding standards of Earth System Models (ESMs) and tools for inverse modeling of emission fluxes.

Workplan

The main **application areas** of the on-line integrated modelling are expected to be considered:

(i) improved numerical weather prediction with short-term feedbacks of aerosols and chemistry on formation and development of meteorological variables;
(ii) improved atmospheric composition forecasting with on-line integrated meteorological forecast and two-way feedbacks between aerosols/chemistry and meteorology;
(iii) coupling of aerosols and chemistry in Earth System modelling, aiming towards more realistic description of aerosols and relevant microphysical processes, and their effect on radiative fluxes and clouds;
(iv) improved understanding and ability in prediction of chemical and physical processes related to the formation and growth of atmospheric particles.

Following the past practice, the models will be maintained on the ECMWF HPC platform. The **emphasis** in this Special Project at ECMWF is primarily on the evaluation and testing of the online integrated Enviro-HIRLAM/ HARMONIE/ EC-Earth modelling systems and sensitivity analyses the feedback mechanisms for weather, climate and atmospheric composition modelling.

The **simulations** are expected for:

(i) short-term case studies with physical and chemical weather forecasting (downscaling from hemispheric-regional-subregional to urban/ city scales) in order to evaluate sensitivity of aerosol feedback effects on meteorology, atmospheric composition and climate;
(ii) episodes simulations for weather, climate and air quality applications to evaluate possible effects;
(iii) testing of parameterisations, meteorological and chemical initial and boundary conditions, and chemical data assimilation.

The Special Project computational resources will be used mainly to experiment with newly developed components of the modelling systems and evaluate their performance and sensitivity to feedbacks. In-depth validation and intensive testing of all of these developments will be carried out at UHEL, mentioned Universities and research institutions as well as ECMWF environments.

The **evaluation methodology** will follow the recommendations/guidelines for the evaluation methodology and protocol for online integrated meteorology-chemistry-aerosols modelling systems, developed by the COST Action EuMetChem ES1004 (*EuMetChem, 2010*; *Galmarini et al., 2011;* http://eumetchem.info).
The **duration** of the requested Special Project is expected to be from 1 January 2018 until 31 December 2020. The computational costs of these simulations and validation activities might likely extend beyond the requested project resources (see the specification below).

New developments towards PEEX-Modelling-Platform

Based on recent scientific developments and working plan the following topics, which are important for operational numerical weather prediction, atmospheric composition forecasting, and climate modelling will be investigated during the Special Project (through collaboration of UHEL with the listed above in the "Overview …" partners):

- Aerosols impact on changes in atmospheric meso-scale circulation and life-time and physical parameters of convective cells with a focus on physical and dynamical mechanisms of feedbacks due to direct and indirect aerosol interactions on weather prediction (*OSENU, UHMI, ITU, FMI, UHEL*);
- Aerosol influence on high resolution meteorological Enviro-HIRLAM/HARMONIE forecasting (*RSHU, OSENU, NIERSC, UoLA, UHEL*);
- Enhance use of high density radar data observations, optimisation of flow-dependent assimilation method, and development of radar data assimilation suitable for nowcasting range for Enviro-HIRLAM/HARMONIE modelling (weak precipitation, active formation & intense release events) for Nordic domain (*UHMI, ITU, OSENU*);
- Energy- and flux-budget (EFB) turbulence closure testing for Arctic stable boundary layer conditions (winter period) for Enviro-HIRLAM/ HARMONIE (*FMI, UHEL*);
- Case studies on influence of selected metropolitan areas on formation and development of the urban heat island, microclimate features, and meteorology-chemistry-aerosols fields due to effects from urban structure/ surfaces and existing/ developing urban land-cover/ use in a changing climate (*ITU, RSHU, NIERSC, TSchNSU, KazNRTU, UoLA, FMI, MSU, UHEL*);
- Chemical data assimilation for Enviro-HIRLAM/HARMONIE for Nordic and Siberian domains (*ICMMG, UCPH, UHEL*);
- Approaches and integration of multi-scale modelling results for risk assessment on environment and population (*ICMMG, UCPH, RSHU, UHEL*);
- Sensitivity tests and assessment for different meteorological situations and episodes for short-term accidental releases (industrial explosions, oil, chemical and ammunition storage facilities, traffic-fire accidents) and relatively long-term (peat-fires, forest-fires,) and continuous emissions (industrial and transport sources, heat energy plants) on regional, subregional and urban/ megacity scales (*KazNRTU, UCPH, RSHU, UoLA, UHMI, UHEL*);
- Case studies on estimation impact of land-use/cover changes on air composition and regional climate parameters changes (*UHMI, UHEL*);
- Sensitivity tests for different meteorological situations in spring-summer seasons for analysing interhemispheric temperature linkages (*NIERSC*);
- Case studies on modelling of air contamination level pollution in urban and industrial areas in terms of traffic jams, urban infrastructure, solar radiation and terrain (*KazNRTU, UHEL*);
- Case studies for applications in management of energy systems (possessing renewable energy sources) using calculated generation of electricity as a function of meteorological parameters (*KazNRTU*);
- Development of conceptual framework to spatially lump a distributed rainfall-runoff-sediment-nutrient module at the catchment scale for water surfaces and atmosphere interactions and feedbacks (*MSU*);
- Sensitivity tests and case studies with models downscaling technology to obtain meteorological fields at different resolutions, including at climatological time scales, for better understanding of large- and fine-scale processes on regional-local scales in a changing climate (*MSU, UHEL*);
- Sensitivity tests with nucleation and growth of atmospheric aerosols as well as secondary organic aerosol (SOA) formation (*UHEL*);
- Sensitivity tests for the new developed peroxy radical autoxidation mechanism (PRAM) for different environments (*UHEL*).

Workplan tasks for the first year (2018)

Within the Special Project the following specific activities will be performed:

T01-2018: Adaptation of the Enviro-HIRLAM/ HARMONIE/ EC-Earth/ SOSAA on ECMWF HPC
T02-2018: Implementation and tests of modules for both aerosols and clouds interactions
T03-2018: Testing and evaluation of models for case studies/ episodes simulations
T04-2018: Sensitivity runs/studies of aerosol feedback mechanisms on meteorol. and air pollution events
T05-2018: Implementation of energy- and flux-budget turbulence closure for testing in winter Arctic PBL
T06-2018: Sensitivity runs/studies of accidental releases in selected metropolitan areas
T07-2018: Sensitivity runs/studies of urban heat island intensity and microclimate features
T08-2018: Sensitivity runs/studies of extreme events (severe storms, polar lows, heat waves, etc.)
T09-2018: Sensitivity tests, analysis for spring-summer seasons for interhemispheric temperature linkages
T10-2018: Sensitivity runs/studies for mesoscale analysis improvement using high-density radar observ.
T11-2018: Elaboration framework and module for water surfaces and atmosphere interactions
T12-2018: Elabor. user-oriented datasets (for episodes) for meteorology-atmospheric composition studies
T13-2018: Sensitivity runs/tests with nucleation, atmospheric aerosols growth, SOA formation
T14-2018: Implementation and testing of PRAM mechanism in SOSAA

List of deliverables for the first year (2018)

D1: 31-05-2018: Modelling systems setup on the ECMWF HPC
D2: 31-08-2018: Test runs for selected case studies/ episodes completed
D3: 31-10-2018: Analyses and preliminary results of evaluation for selected case studies/ episodes according to new developments towards the PEEX-Modelling-Platform
D4: 31-12-2018: Summary reporting on final results of 1st year sensitivity studies/runs for:

(*) influence of aerosol feedback mechanisms on selected meteorological and air pollution events;
(*) influence of selected metropolitan areas on meteorology and atmospheric composition;
(*) energy- and flux-budget turbulence closure in Arctic stable boundary layer conditions;
(*) integration multi-scale modelling results for risk assessments;
(*) evaluation of territorial, environmental, and population impact resulted from accidental releases;
(*) heat energy plants impact on levels of air pollution in metropolitan areas;
(*) interhemispheric temperature linkages during spring-summer seasons;
(*) interconnections between urban structure/ surfaces and UHI intensity and microclimatic features;
(*) enhanced use of high-density radar observations in assimilation systems;
(*) models applications for multi-scale simulations in different geographical regions;
(*) elaboration of user-oriented datasets (based on simulations) for various applications;
(*) better understanding of large- and fine-scale processes on regional-local scales in climate change;
(*) better understanding of nucleation, atmospheric aerosols growth, SOA formation processes;
(*) peroxy radical autoxidation mechanism (PRAM) for different environments in SOSAA.

Estimated resource requirements

The initial phase of the proposed Special Project will focus on performing various technical evaluations, sensitivity experiments and configuration studies, based on the Enviro-HIRLAM /HARMONIE/ EC-Earth/ SOSAA modelling systems implemented at the ECMWF platform.
For example, for a typical Enviro-HIRLAM (note, that Enviro-HARMONIE – more expensive due to non-hydrostatic approach and more expensive dynamical core) simulation with a gas-phase (simple) chemistry, the runtime costs is at the order of 10000 SBU per experiment day. For example, for a typical EC-Earth, a typical simulation time is about 2 simulated years per wall-clock day (when all model components (IFS, NEMO, TM5) coupled with OASIS and a CPU configuration of about 400 cores are considered); note that parallellization of EC-Earth is somewhat limited by 3D communication between IFS and TM5).
Note that significant variations depend on horizontal/vertical resolutions and overall size of models' domains, sophistication of chemistry and aerosol schemes, etc. A rough estimate of a half-year worth of simulation experiments would arrive at 4 million (for Enviro-HIRLAM/HARMONIE/EC-Earth/ SOSAA and other modules simulations) SBU.

Allocation of 1 token per research team of the - RSHU, NIERSC, ICMMG, UHMI, OSENU, TSchNSU, KazNRTU - might be sufficient for realisation of the research and development tasks towards the PEEX-Modelling-Platform by the mentioned teams.

ECMWF tokens (new) are required for the following researches involved:

- Alexander Mahura

- Michael Boy
- Eugeny Kadantsev
- Sergej Zilitinkevich
- Julia Palamarchuk
- Serguei Ivanov
- Roman Nuterman
- Kairat Bostanbekov
- Svitlana Krakovska
- Rossella Ferretti
- Georgy Nerobelov
- Natalia Gnatiuk
- Olga Shevchenko
- Alexey Penenko
- Sergey Chalov
- Pavel Konstantinov

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Resulted presentations/ publications from previous project - Enviro-Aerosols on ECMWF HPC (2015-2017)

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