SPECIAL PROJECT PROGRESS REPORT

Progress Reports should be 2 to 10 pages in length, depending on importance of the project. All the following mandatory information needs to be provided.

Reporting year	Reporting period from January 2018 to June 2018
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)*
Computer Project Account:	SPFIMAHU
Principal Investigator(s)	Dr. Alexander Mahura
Affiliation/ Address:	Institute for Atmospheric and Earth System Research (INAR) / Physics, Faculty of Science, University of Helsinki (UHEL), Finland Address: Physicum, Kumpula campus, Gustaf Hällströmin katu 2a, FI-00560 Helsinki Postal: P.O.Box 64, FI-00014, University of Helsinki, Helsinki, Finland
Other Researchers (Name):	Risto Makkonen, Jukka-Pekka Keskinen, Michael Boy, Roman Nuterman, Eigil Kaas, Serguei Ivanov, Igor Ruban, Larisa Poletaeva, Julia Palamarchuk, Eugeny Kadantsev, Sergej Zilitinkevich, Kairat Bostanbekov, Daniyar Nurseitov, Rossella Ferretti, Gabriele Curci, Sergey Smyshlayev, Georgy Nerobelov, Margarita Sedeeva, Natalia Gnatiuk, Svitlana Krakovska, Larysa Pysarenko, Mykhailo Savenets, Anastasia Chyhareva, Olga Shevchenko, Sergiy Snizhko, Alexey Penenko, Huseyin Toros, Sergey Chalov, Pavel Konstantinov, Putian Zhou, HIRLAM-C members
Start date of the project:	January 2018
Expected end date:	December 2020

Computer resources allocated/used for the current year and the previous one

(if applicable)

Please answer for all project resources

		Previous year		Current year	
		Allocated	Used	Allocated	Used
High Performance Computing Facility	(units)	-	-	4000 kSBU	353.185
Data storage capacity	(Gbytes)	-	-	9000	

Summary of project objectives
(10 lines max)

The main objectives of the Enviro-PEEX on ECMWF Special Project are 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 main application areas to be considered include: (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.

Summary of problems encountered (if any)
(20 lines max)

None of problems were encountered.
Compared with previous ECWMF HPC projects – "Enviro-Chemistry" & "Enviro-Aerosols" (coordinated from the Danish Meteorological Institute, DMI), the current "Enviro-PEEX" project required establishing of the linkage with the National Meteorological Service of Finland (Finnish Meteorological Institute, FMI), and to follow the procedures for issuing and activating of new ECWMF tokens for majority of the project participants (with assigning to the fi-group/domain at ECMWF) and getting access to the hirlam- and herald-groups as well as to hirlam.org for new members of the project. Here, we would like to express our especial gratitude to Dr.-Ing. Carsten Maass (ECWMF) and Dr. Daniel Santos Muñoz (HIRLAM-C Project Leader for System) for assisting with all mentioned above procedures.

Summary of results of the current year (from July of previous year to June of current year) / *in case of the Enviro-PEEX on ECMWF project (started from January 2018)* ***the reporting is covering the period January – June 2018***.

1. Conceptual: "The Pan-Eurasian Experiment Modelling Platform (PEEX-MP)"
The PEEX-MP (https://www.atm.helsinki.fi/peex/index.php/modelling-platform) being one of key blocks of the PEEX Research Infrastructure and having more than 30 different models, is directed towards the concept of the seamless environmental prediction (*Mahura et al., 2018acd*). The PEEX-MP models cover several main components of the Earth's system such as the atmosphere, hydrosphere, pedosphere and biosphere and resolve the physical-chemical-biological processes at different spatial and temporal scales and resolutions. The Earth system, online integrated, forward/ inverse, and socio-economical modelling, and other approaches are applicable for the PEEX domain studies. The employed high performance computing facilities and capabilities as well as dataflow for modelling results are of importance. Several virtual research platforms (PEEX View, Virtual Research Environment, Web-bases Atlas) are useful for handling modelling and observational results. The proposed combined overall approach allows to better understand physical-chemical-biological processes, Earth's system interactions and feedbacks, and to provide valuable information for assessment studies on evaluation of risks, impact, consequences, etc. for population, environment and climate in the PEEX domain of interests.

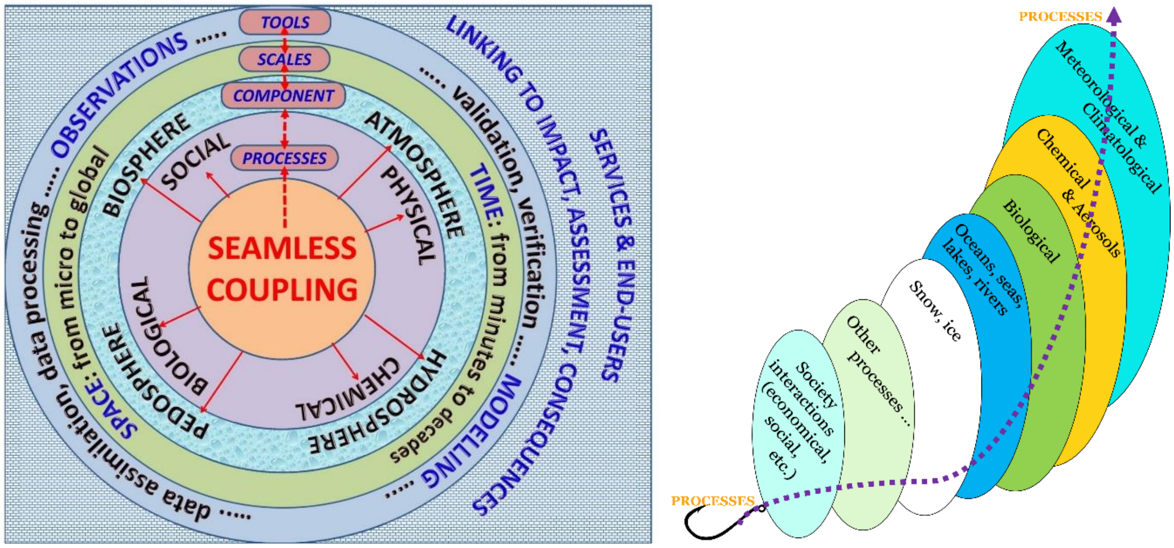


Figure 1: Seamless coupling approach: multi-dimensions (tools, scales, components and processes) and linking to services and end-users through evaluation of impacts and consequences and assessments.

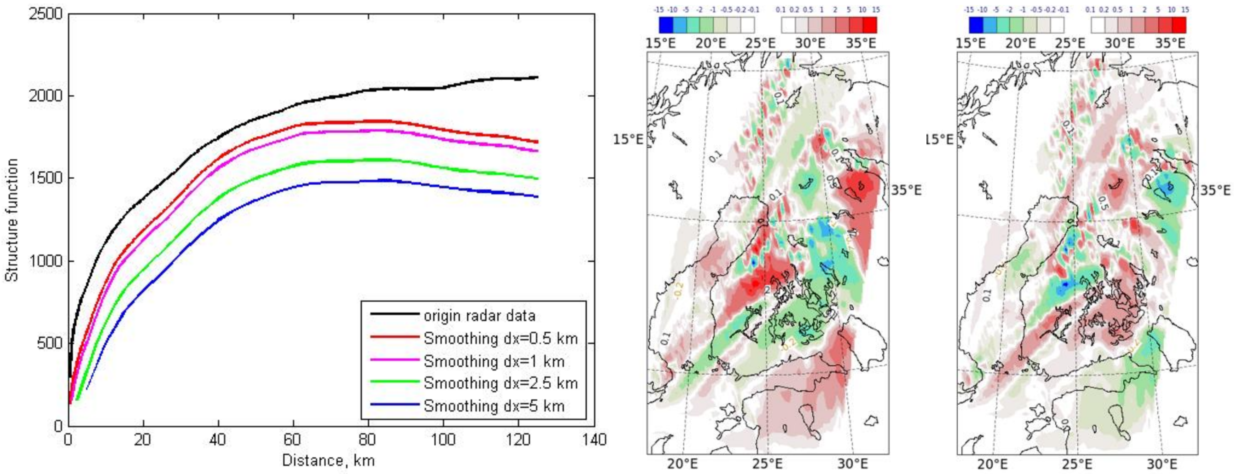
The PEEX-MP presents a strategy for best use of current generation modeling tools to improve process understanding and improve predictability on different scales in the PEEX domain. The on-line integrated/ seamless coupling includes different processes, components, scales and tools (Figure 1). The scales to be considered cover scales from micro- to local, urban, sub-regional, regional, hemispheric, global; and from box-model to large eddy simulations, meso- and climate scales. The horizontal resolutions for models runs are ranging from a few meters to more than a degree in the latitudinal-longitudinal domain. The processes, at the current moment studied at different degree of understanding and to be considered include meteorological and climatological, chemical and aerosols, biological, hydrological, and others as well as taking into account society interactions. Available observations for atmosphere and ecosystems (in particular, from the SMEAR-type stations and PEEX metadatabase stations) are to be used for data assimilation and data processing as well as for the models validation and verification studies. The models are also planned to be further developed and applied for different research tasks according to the PEEX Science Plan (http://www.atm.helsinki.fi/peex/images/PEEX_SP__27052015.pdf). At INAR-UHEL, in particular, a number of application areas of new integrated modelling developments are expected, including research and developments for: (i) improved numerical weather prediction and chemical weather forecasting 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.

2. Study: "Mesoscale resolution radar data assimilation experiments"

Precipitation play an important role in the water cycle and energy balance of the atmosphere, as well as in physical-chemical interactions and feedbacks with aerosols. However, due to the high spatial and temporal variability of precipitation on mesoscales the obtaining of their accurate quantitative estimates is still a "first-line frontier" task. Being assimilated in convective permitted models, radar data could allow significantly improve the representation of clouds and precipitation, both spatial distribution and rates. Further improvement of assimilation systems is seen in optimization of pre-processing radar data in meaning of homogenizing data coverage along with increasing confidence for them by averaging stochastic errors.

This study proposes a slightly modified approach for smoothing high-resolution radar data at pre-processing step (*Ivanov et al., 2018ab*). The proposed method firstly creates a 3D regular grid in which a horizontal size of meshes coincides with a horizontal model resolution. This should minimize the error associated with the discrepancy between resolutions of informational sources. Structure functions for radar reflectivity from lower bins, which with certain assumption measure horizontal size and shape of precipitation patterns, are saturated at a few kilometre distances (Figure 2a). Smoothing with 0.5 km provides very similar both the value and behaviours of the gradient as original data. Namely, saturation of the structure functions occurs at the shortest lag of about 1 km confirming dominant role of meso-scales. At difference, smoothing with 5 km shows weaker gradients at the smallest resolved scales, but also background (secondary) phenomena appear at the scales of about 20-30 km. This numerical (artificial) effect is one from reasons leading to a systematic phase error in modelling of precipitation. All structure functions saturate above 60 km lag, where the large-scale circulation dominates.

Radar reflectivity data from the BaltEx experiment (www.baltex-research.eu) covering the Finnish domain were used in this study. Numerical experiments were performed with the HARMONIE-40h1.1 model with 2.5 km horizontal resolution. Three runs have been carried out with the same model configuration except the data assimilation procedure. The control run (CNTR) included for assimilation all the available SYNOP, TEMP and AIREP observations.



(a) (b) (c)

Figure 2: (a) Structure functions of radar reflectivity measurements for original data and after pre-processing with various smoothing parameters; & Spatial distribution of precipitable water over the Finland domain for 14 August 2010 18:00 UTC for differences between runs: (b) FINE-CNTR and (c) COARSE-FINE.

Two radar reflectivity data assimilation (RDA) runs used the following approaches: 1) FINE - "cube-smoothing" described above with the horizontal resolution equal to the model 2.5 km resolution; and 2) COARSE - explores operationally implemented procedure based on double consequent smoothing of the radar network with 15 and 8 km resolutions. Analysis shows rather homogeneous field of precipitable water over this area. RDA allows to specify and redistribute this variable among several areas, as it points out in Figure 2bc. The first area associats with the increased precipitation rate in both RDA runs, while the gain is sufficiently higher in the FINE run. This reflects in negative values at Figure 2c (COARSE-FINE runs). Over the second area, both RDA runs decreased the water content in the atmosphere, which is actually reallocated toward the first neighbouring one. As in the previous site, changes are larger in the FINE run, which result in the area of positive values at Figure 2c. A belt of lower precipateble water amount in the FINE run corresponds to the third area, which however, does not appear in the COARSE run. The changes in the vertical distribution of precipitable water (not shown) in RAD simulations occur within the layer of 1-6 km with major variations at the 2.5-3 km, where values are increased/decreased up to 5-7 mm/hour. Similar, but less propounced changes occur in the other atmospheric fields, such as specific and relative humidity, rain water as well as simulated reflectivity.

3. Study: "Wind dynamics in the planetary boundary layer"

The wind dynamics in the planetary boundary layer will be studied with the HARMONIE modelling system, which will be run at high horizontal resolution (~1 km). Previous study using different models showed difficulties in accurate simulation of the wind diurnal cycle in breeze-dominated conditions. These difficulties are mostly because of excessive vertical turbulent transport of the momentum. The data collected during spring campaign (April 2016) in the port side of Civitavecchia (Figure 3) of the Central Italy will be used as case study to analyze wind dynamics in the planetary boundary layer. The observations, detailed in space and time, of the wind structure, together with comprehensive measurements of the atmospheric composition (gas and size-resolved aerosol), offer an opportunity to validate and understand the behaviour of the used in the model the boundary layer turbulent mixing parameterizations. The HARATU scheme will be tested with the model settings

Figure 3: Geographical domain in focus with the port side of Civitavecchia (Central Italy).

For this study, at initial steps, among a series of measurement dates the most representative were selected for April 2016, the geographical boundaries of the modelling domain were defined; with a set of numerical parameters for the model setup and attempted to compile and run the model.

4. Study: "Aerosols influence on meteorology with zoom to St. Petersburg, Russia"

In this study, the main aim was to evaluate the aerosols influence on the meteorological parameters (such the air temperature on 2 m, T2M and total cloud cover, TCC) with focus on the St. Petersburg metropolitan area (Russia). The modelling of the aerosols influence was performed using the Enviro-HIRLAM model. These simulations were realized for a short-term (i.e. case study with the most unfavourable meteorological and air pollution conditions - 10-12 Jul 2010). The summer case was chosen because of specific weather conditions (high atmospheric pressure, low wind speed) and big aerosols source such as large-scale forest burnings. These factors gave better representation of the aerosols influence on the meteorological parameters. The simulation as 4 model runs were made: control/reference (CTRL); with the direct aerosol effect (DAE), with the indirect aerosol effect (IDAE), and with both effects included (COMB).

Analysis of the modelling results was performed and the most important findings on the aerosols influence are the following (*Nerobelov et al., 2018; Mahura et al., 2018b*). The IDAE effect influence on T2M and TCC with a zoom to St. Petersburg was insignificant. As seen in Figure 4 (top-left), the indirect effect was mostly reflected as the temperature decrease, but also the increase was observed. For example, it was decreased on the south and south-east (on 0.4°C), and increased - on the east (on 0.4°C). The DAE influence (Fig. 4, top-center) was stronger than the indirect. In most of the cases, it was observed in the eastern part of the research area. This effect increased T2M on the south-east, east and north (on 0.8°C) and decreased on the west (on 0.4°C) of the domain. The COMB effect influence (Fig. 4, top-right) was almost similar to the direct effect. The main differences between them were in sizes of the influence zones wider and the values inside were higher in case of the combined effect. This effect decreased the temperature on the west and north-east (on 0.4°C) and increased in the eastern and northern parts (on 0.4-1.0°C).

In the case of the TCC, the IDAE effect (Fig. 4-bottom-left) increased it (on 3-15%) on the south, south-west, north-east, east and decreased (on 3-6%) on the south-east. The DAE effect (Fig. 4, bottom-center) led to decrease in most of the cases. It decreased the TCC (on 3-18%) on north-east, north, south-east and south-west. The COMB effect (Fig. 4, bottom-right) looked like the direct effect – it led to the TCC decrease (on 6-21%) on north-east, north, south-east and south-west. But the zones of influence for the combined effect case were wider and the values inside them were higher. This effect was stronger than the direct and indirect effects.

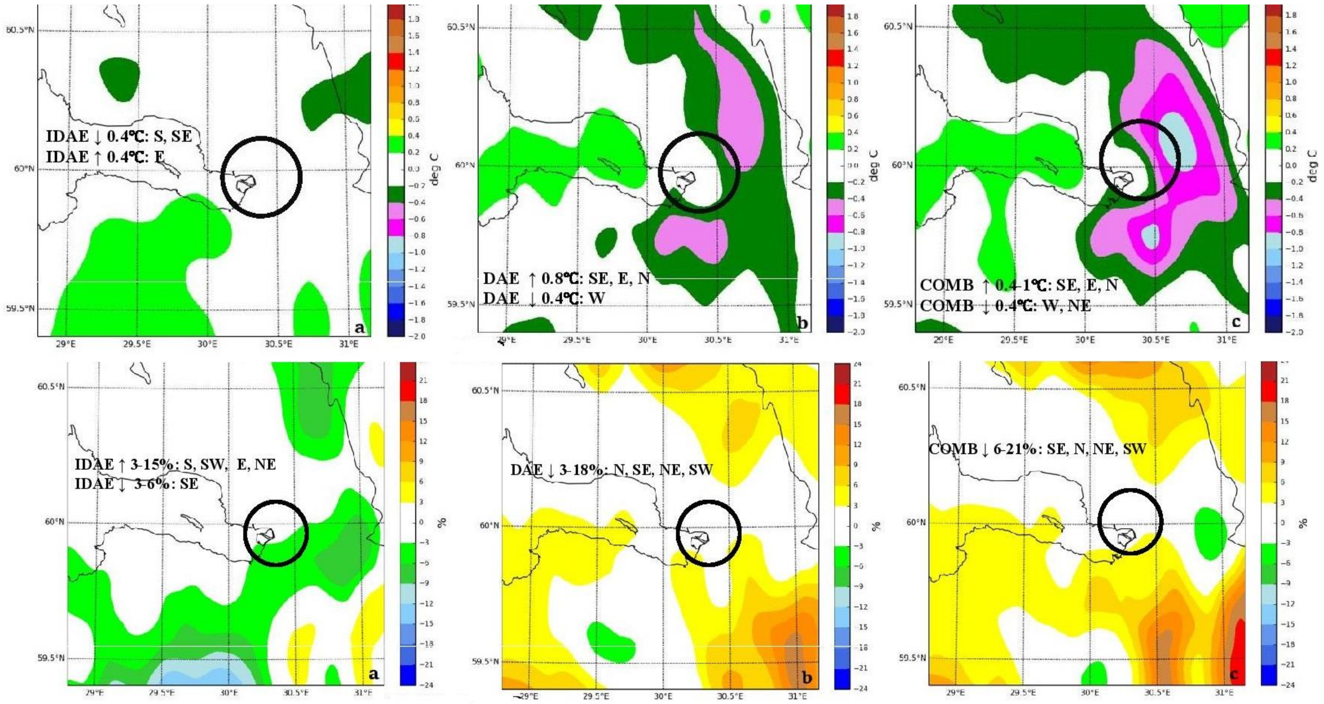


Figure 4: 3-day (10-12 Jul 2010) averaged (top) air temperature at 2 m (T2M) and (bottom) total cloud cover (TCC) fields of differences at 12 UTC for the Enviro-HIRLAM model runs: reference/control-indirect aerosol effect (CTRL-IDAE), control-direct aerosol effect (CTRL-DAE) and control-combined aerosol effect (CTRL-COMB) (from left to right).

5. Study: "Energy Flux Balance Scheme for Stable Boundary Layer"

The weather forecasting in the Arctic regions is still requiring improvements in physics core of the numerical weather prediction models. During winter-time, and especially, during polar night period the stale boundary layer conditions might be dominating in these high-latitudes areas. The EFB (energy flux balance) scheme will be implemented and tested in the HARMONIE model at 2 km horizontal resolution. At first stage, the single column 1D MUSC will be re-implemented and tested with the HARMONIE-38h model (stable version) for cases of idealised and stable conditions (using GABLS dataset). For the EFB module implementation, the focus will be on modification in physics subroutines, prognostic variables, and matching length scales between stable/ neutral/ convective conditions. At second stage, the same 1D MUSC will be implemented in the HARMONIE-43h model. This version of the model is to be used as one of operational model setups at FMI. A series of sensitivity tests will be performed. At third stage, the focus is on 3D case, and the HARMONIE model setup will be linking to domain of AROME-Arctic (with focus on the northern territories of the Scandinavian and Kola Peninsulas). The selected period for simulations is December-January with prevailing low wind conditions. The sensitivity tests will be also done for different horizontal resolutions of 2, 1.5 and 1 km with tuning of the model at finer scales.

List of publications/reports from the project with complete references

Ivanov S., Michaelides S., Ruban I., (**2018a**): Precipitation simulation with radar reflectivity pre-processing in the HARMONIE model. *EGU General Assembly 2018, Geophysical Research Abstracts, Vol. 20, EGU2018-3315.*

Ivanov S., Toros H., Ruban I., Poletaeva L. (**2018b**): Mesoscale resolution radar data assimilation experiments with the HARMONIE model. *Manuscript to be submitted to Remote Sensing Journal.*

Mahura A., R. Nuterman, A. Baklanov, B. Amstrup, G. Nerobelov, M. Sedeeva, R. Makkonen, M. Kulmala, S. Zilitinkevich, S. Smyshlyaev (**2018b**): Enviro-HIRLAM: research and operational applications for PEEX studies. *EGU General Assembly 2018, Geophysical Research Abstracts, Vol. 20, EGU2018-19408.*

Mahura A., A. Baklanov, S.R. Arnold, R. Makkonen, M. Boy, T. Petäjä, V-M. Kerminen, H.K. Lappalainen, M. Jochum, R. Nuterman, A. Schvidenko, I. Esau, E. Gordov, A. Titov, I. Okladnikov, V. Penenko, A. Penenko, M. Sofiev, A. Stohl, T. Aalto, J. Bai, C. Chen, Y. Cheng, M. Cherepova, O. Drofa, M. Huang, L. Järvi, H. Kokkola, R. Kouznetsov, T. Li, K.S. Madsen, P. Malguzzi, K. Moiseenko, S. Monks, S. Myslenkov, G. Nerobelov, S.B. Nielsen, S.M. Noe, Y. Palamarchuk, E. Pyanova, T.S. Rasmussen, J. She, A. Skorohod, S. Smyshlyaev, J.H. Sørensen, D. Spracklen, H. Su, J. Tonttila, E. Tsvetova, S. Wang, J. Wang, T. Wolf-Grosse, Y. Yu, Q. Zhang, W. Zhang, W. Zhang, X. Zheng, P. Zhou, S. Zilitinkevich, M. Kulmala (**2018c**): PEEX Modelling Platform for Seamless Environmental Prediction. *Atm Chem & Phys Discuss, acp-2018-541, 49 p., Manuscript in Review.*

Mahura A., Makkonen R., Boy M., Petäjä T., Kulmala M., Zilitinkevich S., and “Enviro-PEEX on ECMWF” modelling team (**2018a**): Seamless multi-scale and -processes modelling activities at INAR. *In Proceedings of the NOSA-FAAR Symposium 2018, p. 88; (Eds) P. Clusius, J. Enroth, A. Lauri. Report Series in Aerosol Science, N208 (2018), 142 p., ISBN 978-952-7091-98-2, http://www.atm.helsinki.fi/FAAR/reportseries/rs-208.pdf*

Mahura A., Baklanov A., Arnold S.R., Makkonen R., Boy M., Petäjä T., V-M. Kerminen, H.K. Lappalainen, M. Jochum, Nuterman R., Shvidenko A., Esau I., Gordov E., Penenko V., Penenko A., Sofiev M., Stohl A., Zilitinkevich S., Kulmala M., and PEEX-Modelling-Platform team (**2018d**): PEEX Modelling Platform: concept, models, components, infrastructure and virtual research platforms – applicability for seamless environmental prediction. *Abstract submitted for the International Conference IBFRA18 “Critical role of boreal and mountain ecosystems for people, bioeconomy, and climate” (17-20 Sep 2018, Laxenburg, Austria), ID-173.*

Nerobelov G., Sedeeva M., Mahura A., Nuterman R., Mostamandi S., Smyshlyaev S. (**2018**): Online integrated modeling on regional scale in North-West Russia: Evaluation of aerosols influence on meteorological parameters. *Geography, Environment, Sustainability journal. 11(2): 73-83. https://doi.org/10.24057/2071-9388-2018-11-2-73-83*

Summary of plans for the continuation of the project

(10 lines max)

The workplan outlined in the proposal will be continued according to the planned tasks and deliverables for the first year 2018. These developments towards the PEEX-Modelling-Platform will provide additional scientific value for the numerical weather prediction, atmospheric composition forecasting, and climate modelling communities. In particular, 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; and (iii) testing of parameterisations, meteorological and chemical initial and boundary conditions, and chemical data assimilation.