# 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 2021 to June 2021 |
| **Project Title:** | **Enviro-PEEX(Plus) on ECMWF**<br>*Research and development for integrated meteorology – atmospheric composition multi-scales and – processes modelling for the Pan-Eurasian EXperiment (PEEX) domain for weather, air quality and climate applications* |
| **Computer Project Account:** | SPFIMAHU |
| **Principal Investigator(s)** | Dr. Alexander Mahura |
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| **Start date of the project:** | January 2021 |
| **Expected end date:** | December 2023 |

## 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 | - | 4000 kSBU | 221.28 |
| **Data storage capacity** | (Gbytes) | 9000 | - | 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 improving: (i) numerical weather prediction with short-term feedbacks of aerosols and chemistry on meteorological variables; (ii) atmospheric composition forecasting with two-way feedbacks between aerosols/chemistry and meteorology; (iii) coupling of aerosols and chemistry aiming towards better description of aerosols and relevant microphysical processes, and their effect on radiative fluxes and clouds; and (iv) 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)

The current project followed the procedures for issuing and activating of new ECWMF tokens (temporarily (before tokens arrived) access was granted to leaders of the teams: RSHU – Prof. Sergei Smyshlayev, SPBU – Dr. Evgeny Panidi, and KSC – Dr. Pavel Amosov), assigning to the fi-group/domain at ECMWF, getting access to the hirlam- and herald-groups as well as to hirlam.org for new members of the project. All was realised successfully and in time manner, and 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 plans for the continuation of the project

(10 lines max)

The workplan outlined in the proposal will be continued according to the planned activities. 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 downscaling forecasting to evaluate sensitivity of aerosol effects on meteorology, atmospheric composition and climate; (ii) episodes for weather, climate and air quality applications to evaluate possible effects; (iii) testing parameterisations, meteorological and chemical initial and boundary conditions, and chemical data assimilation.

## List of publications/reports from the project with complete references

Mahura et al. (**2021a**): Enviro-HIRLAM seamless modelling approach for environmental studies: recent research and development. *International Conference «Marchuk Scientific Readings 2021» (MSR-2021), 4-8 Oct 2021, Novosibirsk, Russia*

Mahura A., Nuterman R., Baklanov A., Zilitinkevich S., Kulmala M. (**2021b**): Numerical experiments on sensitivity of local meteorology vs. land-cover changes in the Arctic through seamless Enviro-HIRLAM modelling. *EGU21-13613, European Geoscience Union General Assembly, Apr 2021*

Mahura A., Amosov P., Baklanov A., Nuterman R., Losev A., Maksimova V., Petaja T., Kulmala M. (**2021c**): Apatity City Studies: Seamless Multi-Scale Approaches. *Online 4th PACES Open Science Meeting, 26-28 May 2021*

Mikhailenko N. (**2021**): Study of the atmospheric boundary layer regimes over land and water surfaces with online integrated meteorology-aerosols interactions Enviro-HIRLAM model. *BSc thesis, Russian State Hydrometeorological University (RSHU), June 2021, (in Russian)*

## Summary of results (from January 2021 to June 2021)

### 1. Implementation concept: "The Pan-Eurasian Experiment Modelling Platform (PEEX-MP)"

The PEEX-MP is one of key blocks of the PEEX Research Infrastructure. It includes more than 30 different models. The approach taken is directed towards the concept of the online integrated or seamless environmental prediction which 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 geographical domain of interests. The PEEX-MP presents a strategy for best use of current generation modelling 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. 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. In particular, the Enviro-HIRAM modelling system continues further development and application (*Mahura et al., 2021a*) for different research tasks according to the PEEX Science Plan (https://www.atm.helsinki.fi/peex/images/PEEX_Science_Plan.pdf).

### 2. Study: "Sensitivity of local meteorology vs. land-cover changes in the Arctic"

In the recent decade, the Arctic as a whole is subject to amplified warming and well documented changes in the Arctic ecosystems, and especially, these changes are became more and more pronounced over territories of the Russian Arctic. In this study (*Mahura et al., 2021b*), to investigate atmosphere-land-sea surfaces interactions, and in particular, heat-moisture exchange/ regime between these surfaces and for better understanding and forecasting of local meteorology in the Arctic, the seamless modelling approach (with Enviro-HIRLAM model) is tested and applied.

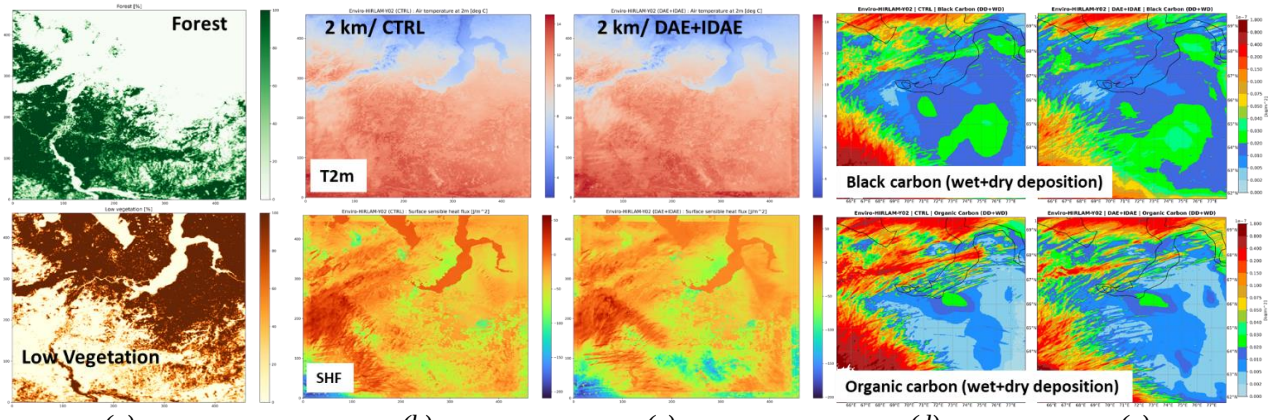


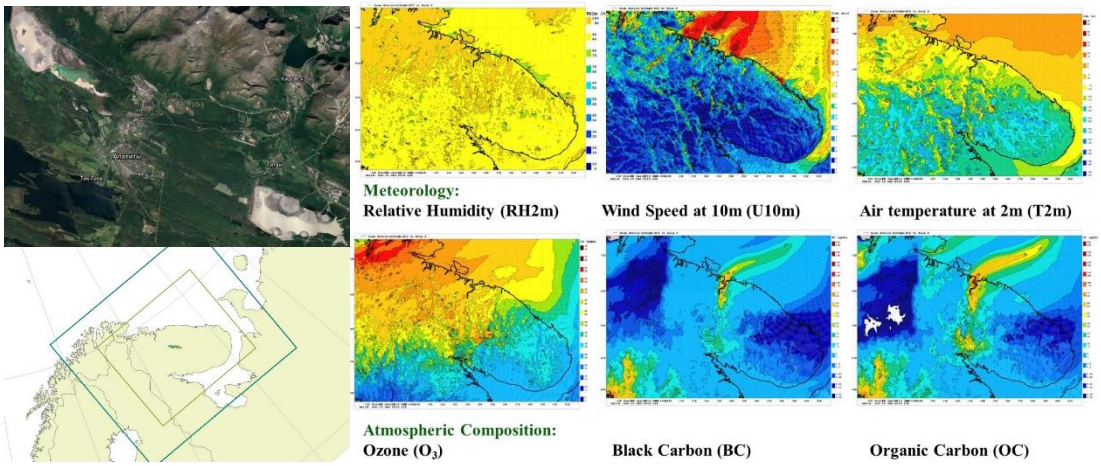

***Figure 2**: (a) Fraction of forest and low vegetation & example of the Enviro-HIRLAM model output at 2 km horizontal resolution for: (bc) air temperature, T2m and sensible heat flux, SHF – without (CTRL) / with (DAE+IDAE) aerosol effects; (de) black and organic carbon dry and wet deposition – with aerosol effects included.*

The model was adapted for a region of interest located in the Russian Arctic covering the inland, seashore and adjacent seas territories with the Yamal Peninsula in the center of the domain. Two short-term periods during summer (in July) and winter (in January) of 2019 were chosen. The model runs include changes in vegetation and land-cover (Fig 2a) as well as with/ without direct and indirect aerosol effects considered (Fig 2bc; for summer), which is needed to estimate interactions and feedbacks between meteorology – atmospheric

composition – land cover changes. The model run in downscaling chain with 5 and 2 km horizontal resolutions. The meteorological (ERA5) and aerosols/ gases (CAMS) initial and boundary conditions required were extracted from ECMWF. The model output includes both 3D meteorology and atmospheric composition (with focus on aerosols in this study; Fig 2de) in the surface, boundary layer and free troposphere. The analysis of variabilities on a diurnal cycle (for key selected meteorological parameters such as air temperature, relative humidity, wind characteristics, boundary layer height, latent and sensible heat fluxes; Fig 2bc) due to changes in vegetation and land-cover was performed for selected warm and cold periods is in focus.

## 3. Study: "Dust Storms due to Tailing Damps - Local Pollution on Kola Peninsula"

On occasion dust storms from locations of artificial tailing dumps (Fig 3a) are observed on the Kola Peninsula in vicinity of the Apatity-Kirovsk urban district. In particular, air quality measurements (during 2014-2018) at local stations showed a number of cases with exceeding maximum permissible concentrations (MPC) for dust. Such cases are more frequently observed during summer months. In this study, the Enviro-HIRLAM model to be used to perform simulations of meteorological and atmospheric composition (with focus on dust) fields in a downscaling mode (5 and 1.5 km horizontal resolution; Fig 3a) for July 2017, when a large number of days with elevated dust concentrations was recorded. The meteorological (ERA5) and aerosols/ gases (CAMS) initial and boundary conditions required were extracted from ECMWF. Intensity and conditions of dust blowing and emissions from tailing dumps will be considered in more details. The atmospheric flows and dust atmospheric transport, dispersion and deposition and influence of dumps on potential pollution of environment in different meteorological conditions will be studied.




*(a)* *(b)*

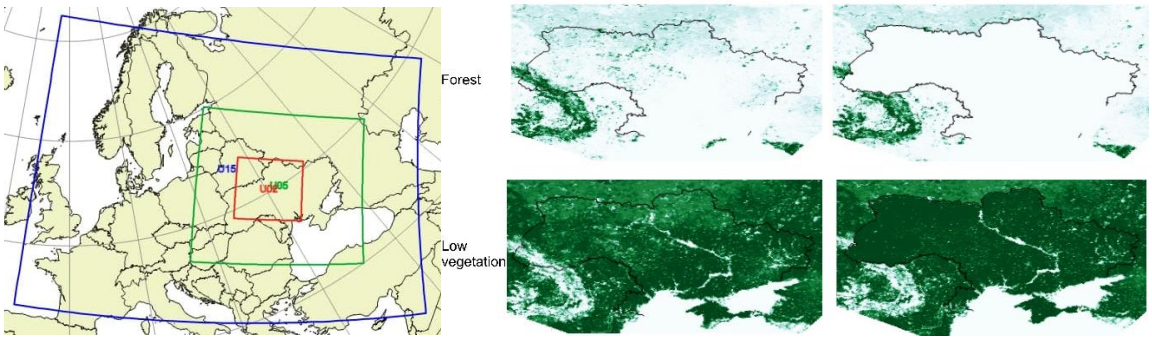
***Figure 3**: (a) Tailing dumps in vicinity of the Apatity-Kirovsk urban district on the Kola Peninsula & boundaries of model domain with 5 and 1.5 km resolutions; (b) example of Enviro-HIRLAM model output for selected meteorological (relative humidity, win speed, air temperature) and atmospheric composition (ozone, black and organic carbon).*

## 4. Study: "Influence of Land Cover Changes on Regional Weather Conditions/ Patterns"

The land cover has a significant influence on weather and climate in general by means of variety factors such as albedo, roughness, process of photosynthesis, evapotranspiration, energy fluxes and biogeochemical cycles between land and atmosphere, etc. anthropogenic contribution to land use/ land cover (LULC) change is tangible and has a profound effect on regional and local climate through replacement one type of vegetation to another or by urban landscape. Climate in turn, also effects on vegetation causing e.g. shifts of some forest species and changes in biodiversity. In context of climate change it is necessary to estimate possible effects of land cover change, which is mostly manmade, on weather.

The Enviro-HIRAM model (in downscaling chain, see Fig. 4a, down to urban scale) to be utilized for simulating extreme meteorological situations with currently existing (and modified by scenarios) land cover to estimate impact on regional weather patterns. Necessary initial and boundary conditions for meteorology and atmospheric composition were extracted from the ECMWF's ERA5 and CAMS, and pre-processed for the model runs. Case studies (heatwave and heavy rains in August 2010 & heavy snowfall in March 2013) with several scenarios of land cover changes (Fig. 4bc) will be considered, including hypothetical (complete deforestation), replacing forests by other vegetation types and gradually changing percentage of forested areas. It will allow to reveal feedbacks between land cover changes and meteorological characteristics including chemical composition in the atmospheric boundary layer for the most frequent extreme weather events (heatwave and heavy precipitation) projected in future decades. Obtained modelling results on meteorological

parameters and atmospheric composition due to forest changes will provide useful information for decision-makers in recommendations and planning adaptation measures to climate change.




*(a)* *(b)* *(c)*

***Figure 4**: (a) Enviro-HIRLAM downscaling chain (with horizontal resolutions of 15, 5, and 2 km); & spatial distribution of land cover (fractions of forest and low vegetation) for the U05 domain for the (b) real/existing and (c) deforestation scenarios.*

## 5. Study: "Atmospheric boundary layer regimes over land and water surfaces"

The atmospheric boundary layer (ABL) plays important role in human activities. Accurate prediction of the boundary layer's temperature-humidity-wind regimes is very important for both understanding of various processes occurred there as well as its influence on human activities for safe and efficient functioning of various industries, agriculture, transport, daily life and much more. And here, a seamless online integrated modeling approach was selected as promising direction to forecast weather conditions and studies of the Earth's atmosphere.

In this study, the Enviro-HIRLAM model was employed (with direct and indirect aerosols effects included) with focus on unfavourable weather episodes with evaluated air pollution for warm and cold (August and January 2013) conditions over land and water surfaces (Fig. 5 ac). The territory of the North-West Russia and Scandinavian countries was in focus (Fig. 5b). The spatio-temporal variabilities of the air temperature (at 1st model level, 500 - 1000 – 1500 m asl), total cloud cover and precipitation at ground level, specific humidity and wind speed and direction at model levels – were evaluated. It was found (*Mikhailenko, 2021*) that temperature-humidity-wind regimes, and in particular, the diurnal cycles showed in August a strong variability for temperature (up to 12°C), moderate – for wind (up to 4 m/s), and moderate – for humidity (up to 0.002 kg/kg); and showed low variability for all evaluated parameters in January. The vertical structure showed strong variability for all studied parameters. For January, the air temperature inversions were well modeled and confirmed by radio sounding measurements. For August, the elevated air pollution episodes in the cities of Nickel, Svetogorsk, and St. Petersburg of Russia may have lead to increased air temperature. Further focus will be on in depth analysis of boundary layer regimes and vertical structure over the regions of interests; analysis of influence of urban areas on formations and development of selected meteorological and atmospheric composition fields; and impact of aerosol effects on humidity parameters over land and water surfaces.


*(a)* *(b)* *(c)*

***Figure 5:** Enviro-HIRLAM model output (examples): air temperature field on 19 Aug 2013, 12 UTC – for analysis of pollution episode; (b) model domain, N05; (c) accumulated convective precipitation field on 15 Aug 2013, 00-03 UTC – for analysis of cyclonic influence.*