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PanEurasian Experiment (PEEX): Modelling Platform for Earth System Observations and Forecasting

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As the part of the PEEX initiative, for the purpose of supporting the PEEX observational system and answering on the PEEX scientific questions, a hierarchy/ framework of modern multi-scale models for different elements of the Earth System integrated with the observation system is needed.

One of the acute topics in the international debate on land-atmosphere interactions in relation to global change is the Earth System Modeling (ESM). The question is whether the ESM components actually represent how the Earth is functioning. The ESMs consist of equations describing the processes in the atmosphere, ocean, cryosphere, terrestrial and marine biosphere. ESMs are the best tools for analyzing the effect of different environmental changes on future climate or for studying the role of whole processes in the Earth System. These types of analysis and prediction of the future change are especially important in the Arctic latitudes, where climate change is proceeding fastest and where near-surface warming has been about twice the global average during the recent decades.

The processes, and hence parameterization, in ESMs are still based on insufficient knowledge of physical, chemical and biological mechanisms involved in the climate system and the resolution of known processes is insufficient. Global scale modeling of land-atmosphere-ocean interactions using ESMs provides a way to explore the influence of spatial and temporal variation in the activities of land system and on climate. There is a lack, however, ways to forward a necessary process understanding effectively to ESMs and to link all this to the decision-making process. Arctic-boreal geographical domain plays significant role in terms of green-house gases and anthropogenic emissions and as an aerosol source area in the Earth System.

The PEEX Modelling Platform (PEEX-MP) is characterized by:
• An ensemble approach with the integration of modelling results from different models/ countries etc.;
• A hierarchy of models, analysing scenarios, inverse modelling, modelling based on measurement needs and processes;
• Model validation by remote sensing data and assimilation of satellite observations to constrain models to better understand processes, e.g., emissions and fluxes with top-down modelling;
• Geophysical/ chemical model validation with experiments at various spatial and temporal scales.

Added value of the comprehensive multi-platform observations and modeling; network of monitoring stations with the capacity to quantify those interactions between neighboring areas ranging from the Arctic and the Mediterranean to the Chinese industrial areas and the Asian steppes is needed. For example, apart from development of Russian stations in the PEEX area a strong co-operation with surrounding research infrastructures in the model of ACTRIS network needs to be established in order to obtain a global perspective of the emissions transport, transformation and ageing of pollutants incoming and exiting the PEEX area.

The PEEX-MP aims to simulate and predict the physical aspects of the Earth system and to improve understanding of the bio-geochemical cycles in the PEEX domain, and beyond. The environmental change in this region implies that, from the point-of-view of atmospheric flow, the lower boundary conditions are changing. This is important for applications with immediate relevance for society, such as numerical weather prediction. The PEEX infrastructure will provide a unique view to the physical properties of the Earth surface, which can be used to improve assessment and prediction models. This will directly benefit citizens of the North in terms of better early warning of hazardous

events, for instance. On longer time-scales, models of the bio-geochemical cycles in the PEEX domain absolutely need support from the new monitoring infra-structure to better measure and quantify soil and vegetation properties.

In the most basic setup, the atmospheric and oceanic Global Circulation Models (GCMs) are connected to each other, sharing e.g. fluxes of momentum, water vapour and CO_2. Traditionally, the land compartment has been an integral part of the atmospheric model, but in most modern ESMs the land model has been clearly separated. In most cases, the GCMs are complemented by other additional sub models covering, for example, atmospheric chemistry and aerosols, biogeochemistry or dynamic vegetation. Although the models can communicate also directly with each other, usually a separate coupler is used as an interface between different sub models.

One of the main PEEX modelling activities is to evaluate process-models of chemistry-biota-atmosphere interactions in Pan Eurasian region and to improve GCM parameterizations. PEEX scientific plan is designed to serve a research chain that aims to advance our understanding of climate and air quality through a series of connected activities beginning at the molecular scale and extending to the regional and global scales. Past variations in climate in Pan Eurasian regions and corresponding forcing agents would be revealed by analysis of firn and ice cores in glaciers and ice sheets.

A combination of direct and inverse modelling will be applied to diagnosing, designing, monitoring, and forecasting of air pollution in Siberia and Eurasia. Regional models coupled with the global one by means of orthogonal decomposition methods allow one to correctly introduce data about the global processes onto the regional level where environmental quality control strategies are typically implemented.
Proceeding from the above mentioned limitations, a new concept and methodology considering the concept of 'one-atmosphere' as two-way interacted meteorological and chemical processes is suggested. The atmospheric chemistry transport models should include not only health-effecting pollutants (air quality components), but also green-house gases and aerosols effecting climate, meteorological processes, etc. Such concept requests a strategy of new generation integrated chemistry-climate modelling systems for predicting atmospheric composition, meteorology and climate change. The on-line integration of meteorological/ climate models and atmospheric aerosol and chemical transport models gives a possibility to utilise all meteorological 3D fields at each time step and to consider feedbacks of air pollution (e.g. aerosols) on meteorological processes and climate forcing, and further on the chemical composition (as a chain of dependent processes). This promising way for future atmospheric simulation systems (as a part of and a step to ESMs) will be considered in PEEX. It will lead to a new generation of models for climatic, meteorological, environmental and chemical weather forecasting.