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ESTABLISHING THE PAN-EURASIAN EXPERIMENT (PEEX) LAND-ATMOSPHERE IN SITU OBSERVATION NETWORK ACROSS THE NORTHERN EURASIAN ARCTIC-BOREAL REGIONS – INTRODUCTION TO THE RUSSIAN STATIONS' METADATA ENQUIRY

ABSTRACT

Pan-Eurasian Experiment (PEEX) initiative (https://www.atm.helsinki.fi/peex/), initiated in 2012, is an international, multidisciplinary, multiscale program focused on solving interlinked global challenges influencing societies in the Northern Eurasian region and in China. As a part of the program, PEEX is aimed to establish an in situ observation network, which would cover environments from the Arctic coastal regions, tundra to boreal forests, from pristine to urban megacities. The PEEX network will be based on two components: (i) the existing stations activities and (ii) establishing new stations. The upgrading plans of the existing stations as well as the new stations will be based on a SMEAR (Stations for Measuring Earth surface – Atmosphere Relations) concept. The development of the coordinated, comprehensive PEEX observation network is contributing to the sustainable development of the Northern Eurasian regions. It is aimed at providing quantified information on climate relevant variables for the research communities and for constructing services, such as early warning systems, for the society.

KEYWORDS:

observation systems, in situ observations, early warning, climate predictions, land – atmosphere interactions, atmospheric composition, photosynthesis, boreal forests, Stations for Measuring Earth surface – Atmosphere Relations, SMEAR concept

INTRODUCTION

The boreal forests dieback and the permafrost-tundra loss of the Northern Hemisphere have been indicated as a policy relevant tipping points of the Earth system, which could exhibit threshold-type behavior in response to anthropogenic climate forcing [Lenton *et al.*, 2008]. To better understand the processes, feedbacks and biogeochemistry related to these critical areas we need more measurements on the relevant atmospheric variables such as CO_2, CH_4 CO, O_3, aerosols (incl. black carbon) and on the variables describing the ecosystem biological activity (GPP, NEE) [Paris *et al.*,

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2008; Sasakawa *et al.*, 2013; Kozlova *et al.*, 2008, Kulmala *et al.,* 2011]. This type of comprehensive ground-based measurements together with the remote sensing data over the currently under-documented regions of Siberia and Arctic coastal line are also needed to validate different types of land and atmospheric models.

In 2012, when the PEEX Program [Kulmala *et al*., 2015, 2017; Lappalainen *et al*., 2014, 2017, https://www.atm.helsinki.fi/peex/] was initiated, it was evident that one of the main focus areas of interests would be the filling of the observational gap, especially over the Siberian region, and the development of the coordinated in situ observation networks across the Northern Eurasian region and in China [Kulmala *et al.*, 2016]. The backbone of the station network is based on the existing atmospheric, biosphere – ecological or urban stations. The first step towards a coordinated, comprehensive observation network is an overview of the measurement capacity of the existing stations. After having detailed information, the station metadata, it would be also possible to make the station specific upgrading plans and having added new instruments and measured variables to the observing program of the station.

The collection of the preliminary information of the existing stations activities started in 2012. The first inventory on over 200 in situ stations operating in the Arctic and Subarctic Eurasian regions was conducted by the Russian Academy of Sciences (RAS) and Moscow State University together with the University of Helsinki [Alekseychik *et al.,* 2016]. Based on the first inventory we started a collection of more detailed information, called “station metadata”. A station metadata, the detailed descriptions of measured variables and the observation site, enables one to categorize the stations in a systematic manner and to connect them to international observation networks, such as WMO-Global Atmospheric Watch Program, China Ecosystem Network (CERN), and carry out standardization of data formats. Here we introduce the current state of the station metadata work in Russia.

MATERIALS AND METHODS OF RESEARCH

For collecting metadata information from the Russian stations we drafted out a “metadata enquiry”, which has been sent, as of today, to over 60 Russian stations. A metadata enquiry is asking information on station’s facilities, environments, on atmospheric, ecosystem measurements with a specific focus on different surfaces such as forest, lake, peatland, and urban. Furthermore, information is asked on data collections and their availability for external users, on collaboration and participation in different networks such as Carbon Flux network. We have also set up a relation database for archiving the collected station metadata and for carrying out comprehensive map based analysis on different variables and their geographical coverage across Russian Arctic – boreal regions.

The metadata enquiry and the questions are compiled basing on the measurement ensemble carried out at the SMEAR-II station (Station for Measuring Atmospheric Ecosystem Relation, 61^{o}51’N, 24^{o}17’E) in Finland, and currently called “SMEAR Measurement Concept” (APPENDIX-1). All the station carries out around year measurements of 1200 variables in 24/7 and is a qualified flagship measurement station participating in the Integrated Carbon Observation System (ICOS) network [www.icos-infrastructure.eu/] and European Research Infrastructure for the observation of Aerosol, Clouds, and Trace gases (ACTRIS) [www.actris.eu] as well as in The Long Term Ecological Research (LTER) Network and International Network for Terrestrial Research and Monitoring in the Arctic (INTERACT2).

The SMEAR II station is the most comprehensive station investigating biosphere-atmosphere interactions and atmospheric processes in the world and is the prototype of the flagship station for the PEEX observation network. The main components of SMEAR II are 127 m tall mast instrumented with meteorological measurements and gas profiles (7 levels), systems for monitoring physical, optical and chemical properties of aerosols, air ions and high resolution mass spectrometry for atmospheric chemistry, instrumentation for monitoring tree and soil functioning and radiation, two instrumented mini water catchments, two above-canopy and one sub-canopy eddy covariance

(EC) measurement setups for ecosystem-scale biosphere-atmosphere exchange of GHGs and SLCFs. Emissions of CO_2 and volatile organic compounds from the biosphere are monitored with various enclosure setups. Additional flux measurements are carried out at nearby wetland, Siikaneva fen. The longest time series in Siikaneva has been CO_2, H_2O and CH_4 fluxes – since 2005. The auxiliary measurements include meteorological variables, peat temperature, water table depth and oxygen concentration.

PRELIMINARY RESULTS OF RESEARCH AND DISCUSSION

The Russian station metadata collection will be carried out in 2016-2017. So far our database covers metadata over 50 stations. Metadata has been received from stations such as NESS "Chersky" 68,64 N. 161,39E, Tiksi, 71.586 N, 128.77E, Belyy 73.335N, 70.075 E, Mukhrino Field Station, 60.54N, 68.42 E, Seida Vorkuta, 67.05N, 62,92E, Heiss Island, 80.60N, 58,03E, Zvenigirod 55.695N, 36.775E and SMEAR – Fyodorovskoe, 56.461N, 32.922E. Basing on the metadata inventory PEEX will publish a station catalogue introducing the measurements and contact information of the "Russian stations – PEEX collaboration network". The aim of the catalogue is to promote the research collaboration, indicate the station as partner in Russian stations – PEEX collaboration network and to give positive visibility to the station activities.

The map based analysis of the station metadata, preliminary scheduled to take place in 2018, will give guidelines and frameworks for detailed planning of the PEEX observation network such as optimal locations of different atmospheric – ecosystem measurements. Furthermore, it will demonstrate the observational gaps in a comprehensive and systematic way and provide background information for the specific upgrading plans such as new instrumentation needed for capturing specific events related to long-term atmospheric pollution or epidemical dispersion. The upgrading plans would be based on a SMEAR concept, the measurement theory and techniques as a result of a 20 year development at the SMEAR-II flagship station situated in Hyytiälä, Finland [Hari *et al.* 2017]. The options for upgrading the existing station network or building new stations based on SMEAR concept is under evaluation. Also some other relevant measurements to be included in the coordinated monitoring program are under consideration such as borehole data relevant to permafrost monitoring. The most active partners here have been Tyumen State University, A.N. Severtsov Institute of Ecology and Evolution (RAS), Tver State University and Moscow State University.

CONCLUSIONS

The comprehensive observation network is a crucial tool for environmental monitoring and is contributing to the sustainable environmental, economic and social development of the Northern Eurasian regions under changing climate. PEEX recognizes the unique opportunity to explore cooperation with all exiting ecosystem, atmospheric and meteorological stations. PEEX has capacity and know-how to establish an observation framework for solving environmental problems in the Northern Eurasia, and to become a community of shared interests. PEEX research outcome and observation activities and the new methodological concepts are providing new information not only for the climate policy making on a global scale but also for the regional infrastructure planning, urban design, construction of early warning systems (natural hazards), for the mitigation and adaption planning. Thus PEEX is aimed at deepening the collaboration with the European, Russian, Chinese and global partners to maximize the impact of the PEEX infrastructure development in the climate policy relevant processes. The key partners and stakeholders here are International Institute for Applied Systems Analysis (IIASA), Digital Earth, Future Earth, Arctic Council Sustainable Arctic Observation Network (SAON), WMO and Group of Earth Observation (GEO) – GEOCRI Cold Regions Initiative the in situ component.

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APPENDIX-1

PEEX METADATA

PEEX METADATA

1. CONTACT INFORMATION

Station official name: *

Station acronym (if any):

Station's host institute name: *

Station address: *

Station zip code: *

Station country: *

Station www address:"
Site name: *

Site acronym: *

Site owner (for example University of Helsinki)

Opening year: *

Opening year: *

Operational period:

Site contact person coordinating the measurements:

First name: *

Last name: *

E-mail: *

2. SITE DESCRIPTION

Site coordinates (For example 58.083 N, 38.683 E):

Site elevation a.s.l (m): *

Ecosystem type (accorind to Koppen-Geiger climate type):

Name of the nearest town/settlement: *

Distance (km) to the nearest town/settlement

Is the site accessible by car?

Distance from nearest road (km):

Mean annual temperature:

Mean temperature in Jan:

Mean temperature in July:

Total annual precipitation:

Facilities

- ☐ **no permanent buildings**
- ☐ **permanent building, laboratory**
- ☐ **permanent building, computing and instrument cottage**
- ☐ **accommodation facilities**

Accommodation (number of persons in summer/winter) *

Number of staff on site: *

Does the site have electricity?

Which laboratory / storage facilities are available at the site:

- ☐ **basic chemical and physical analyses of water, soil and plant material**
- ☐ **refrigerator(+4C)**
- ☐ **freezer (-20C)**
- ☐ **deep-freeze (-80C)**
- ☐ **drying oven**

Analytical instruments available (e.g. GC-MS, HPLC, spectrophotometer....). Specify

Other, specify: (For example; short description of type power supply ?)

Climate/vegetation zone:

3. MEASUREMENTS:

Please, mark your measurements in the lists below under each topic: (i) ATMOSPHERE – (ii) FOREST – (iii) PEAT LAND / TUNDRA and give information on the measurement interval.

(i) ATMOSPHERIC MEASUREMENTS

Standard meteorological parameters:

- [ ] **temperature**
- [ ] **relative humidity**
- [ ] **wind direction**
- [ ] **wind speed**
- [ ] **precipitation**
- [ ] **solar radiation**

Extended meteorological parameters:

- [ ] **global radiation**
- [ ] **photosynthetically active radiation**
- [ ] **net radiation**
- [ ] **UV-A radiation**
- [ ] **UV-B radiation**

Other meteorological parameters (describe):

Measurements:

Concentration../..

- [ ] **CO**
- [ ] **CO_2**
- [ ] **O_3**
- [ ] **SO_2**
- [ ] **VOC**
- [ ] **NO_x**
- [ ] **N_2O**
- [ ] **CH_4**

Flux

- [ ] **CO**
- [ ] **CO_2**
- [ ] **O_3**
- [ ] **SO_2**
- [ ] **VOC**
- [ ] **NO_x**
- [ ] **N_2O**
- [ ] **CH_4**

Other atmospheric measurements:

- [ ] **aerosol number concentration**
- [ ] **aerosol number size distributions 1 nm – 100 nm**
- [ ] **aerosol number size distributions 100 nm – 1 µm**
- [ ] **aerosol number size distributions 1 µm – 100 µm**
- [ ] **other trace gas concentrations (e.g. carbonyl sulfide, sulfuric acid, HONO, ammonia, amines)**
- [ ] **atmospheric ions**
- [ ] **cloud characterization (cloud radar)**
- [ ] **spectral characterization of solar radiation**
- [ ] **diffuse radiation**
- [ ] **heat flux**
- [ ] **advanced characterization of atmospheric turbulence inside the surface layer (e.g. below canopy)**
- [ ] **reflected global radiation**
- [ ] **wet deposition**
- [ ] **dry deposition**

Rainfall chemical analysis (NO_{2^-}, NO_{3^-}, NH_{4^+}, DOC, nutrients …)

(specify):

Other site-specific features:

☐ **hosting intensive field studies**

☐ **inter-platform calibrations and verifications (in-situ, satellite, airborne)**

☐ **development of novel instrumentation**

☐ **focused campaigns to determine the connections between the fluxes and environmental and ecosystem factors**

Short description of the measurement instrument setup you are using (names/ manufacturer of the instruments)

Short description of the measurement frequency of different parameters (hourly/daily/seasonal/ annual etc.)

Other relevant information on your measurements (for example field campaigns)

(ii) ECOSYSTEM MEASUREMENTS: soils - forest – lakes - urban

Stand history

Stand age (yr):

Soil type

Soil texture

☐ **soil water holding capacity (%)**

Hydraulic conductivity (K)

☐

Cation exchange capacity (cmol+/kg)

☐

pH.

☐

snow depth (cm)

☐

Snow cover duration (months)

☐

Description of ground vegetation (name of species in Latin)

Description of fire history

Soils

- ☐ **soil bulk density**
- ☐ **amount of soil organic matter**
- ☐ **soil water content**
- ☐ **soil temperature profile**
- ☐ **soil nutrient concentrations**
- ☐ **soil solution samplings (e.g. DOC, nutrients)**
- ☐ **soil chemical characteristics (pH, CEC, C and N content)**
- ☐ **CO_2 surface flux (chamber measurements)**
- ☐ **CH_4 surface flux (chamber measurements)**
- ☐ **N_2O surface flux (chamber measurements)**
- ☐ **VOC surface flux (chamber measurements)**
- ☐ **isotopic ratios of carbon in soil organic matter**
- ☐ **soil microbiology**
- ☐ **soil enzyme concentrations**
- ☐ **characteristics of soil organic matter (e.g. lignin, sugars, cellulose, proteins)**
- ☐ **belowground biomass**
- ☐ **water storage in the soil**
- ☐ **snow depth and snow water content**
- ☐ **discharge (catchment)**
- ☐ **runoff (catchment)**
- ☐ **groundwater level**

Gas profile in soil layers (specify which gases)

Other soil measurements:

Forests

- [ ] **tree species distribution**
- [ ] **tree density**
- [ ] **tree volume**
- [ ] **tree height**
- [ ] **ground vegetation species characterization**
- [ ] **aboveground biomass**
- [ ] **leaf area index (LAI)**
- [ ] **dendrochronological measurements**
- [ ] **net ecosystem carbon dioxide, water and heat exchange (Eddy covariance)**
- [ ] **exchange of carbon dioxide, water and heat within the stand (sub-canopy Eddy covariance)**
- [ ] **amount of precipitation above and below the canopy**
- [ ] **sapflow**
- [ ] **diurnal stem diameter variation**
- [ ] **isotopic ratios of carbon in biomass**
- [ ] **chlorophyll fluorescence**
- [ ] **hyperspectral canopy measurements**
- [ ] **light profile within canopy**
- [ ] **litterfall**
- [ ] **species richness**

Biodiversity

- [ ] **vascular plants**
- [ ] **bryophytes**

- [ ] **fungi**
- [ ] **mammals**
- [ ] **birds**
- [ ] **other fauna**
- [ ] **microbial**

Short description of the measurement instrument setup you are using (names/ manufacturer of the instruments):

Short description of the measurement frequency of different parameters (hourly/daily/seasonal/ annual etc.):

Other relevant information on your measurements (for example field campaigns):

Lakes

- [ ] **CO_2 continuous eddy covariance measurements**
- [ ] **H_2O continuous eddy covariance measurements**
- [ ] **CH_4 continuous eddy covariance measurements**
- [ ] **PAR in the water**
- [ ] **Chamber measurements for CO_2**
- [ ] **Chamber measurements for CH_4**
- [ ] **Chamber measurements for N_2O**
- [ ] **Gas concentration measurements throughout the water column (CO_2 /CH_4 / N_2O)**
- [ ] **Continuous CO_2 concentration measurements at different depths of the water column**
- [ ] **Continuous temperature measurements throughout the water column (thermistor chain)**
- [ ] **Continuous measurements for surface water pH**
- [ ] **Continuous measurements for surface water oxygen**
- [ ] **Continuous measurements for surface water conductivity**
- [ ] **Secchi depth determinations**
- [ ] **Discrete sampling for water column DOC concentration**
- [ ] **Discrete sampling for water column nutrient concentrations**

☐ **Discrete sampling for water column chlorophyll concentration**

☐ **Discrete sampling for water column phytoplankton community composition (biodiversity)**

Net radiation

Relative humidity (%)

PAR in the water

☐ **at what depth (m)?**

Other lake measurements

Urban

☐ **CO_2 continuous eddy covariance measurements**

☐ **H_2O continuous eddy covariance measurements**

☐ **Upward shortwave radiation (W/m^2)**

☐ **Upward longwave radiation (W/m^2)**

☐ **Continous surface temperature measurements (deg)**

☐ **Continuous measurements of traffic rate (veh/hr)**

☐ **Surface runoff**

☐ **Quality of surface runoff**

Leaf area index (m^2) ?:

Traffic rate (veh/day)?

Population density (pop/ha) ?

Land cover fraction of buildings?

Land cover fraction of paved surfaces ?

Land cover fraction of vegetation ?

Land cover fraction of water surfaces ?

(iii) ECOSYSTEM MEASUREMENTS: peatland and tundra

Age of the peat:

☐ **yr**

Depth of peat layer:

☐ **m**

Permafrost depth:

☐ **m**

Active layer max depth:

☐ **m**

- ☐ **temperature profiles of the soil/peat layers**
- ☐ **soil/peat temperature profile down to the bed rock (bore hole)**
- ☐ **soil/peat water content**
- ☐ **CO_2 surface flux (chamber measurements)**
- ☐ **CH_4 surface flux (chamber measurements)**
- ☐ **N_2O surface flux (chamber measurements)**
- ☐ **VOC surface flux (chamber measurements)**
- ☐ **CH_4 concentrations in the peat profile**
- ☐ **CH_4 concentration in the air**
- ☐ **isotopic ratios of CH_4 in air**
- ☐ **isotopic ratios of CH_4 in peat**
- ☐ **upward and downward net radiation fluxes**
- ☐ **upward and downward radiation fluxes**
- ☐ **precipitation**
- ☐ **water table depth**
- ☐ **snow depth and snow water content**
- ☐ **discharge (catchment)**
- ☐ **runoff (catchment)**
- ☐ **nutrient concentrations in peat**
- ☐ **carbon and nitrogen concentration in peat**

☐ carbon and nitrogen isotopes in peat profile

☐ methane storage in the peat

☐ enzyme concentrations in peat layers

☐ net ecosystem carbon dioxide, water and heat exchange (Eddy covariance)

☐ exchange of carbon dioxide, water and heat within the stand (sub-canopy Eddy covariance)

☐ ground vegetation species characterization

☐ aboveground biomass

☐ leaf area index (LAI)

☐ hyperspectral canopy measurements

☐ litterfall

☐ biodiversity

Other gas profiles in soil layers (specify which gases):

Short description of the measurement instrument setup you are using (names/ manufacturer of the instruments):

Short description of the measurement frequency of different parameters (hourly/daily/seasonal/ annual etc.):

Other relevant information on your measurements (for example field campaigns):

4. DATA COLLECTION AND AVAILABILITY FOR EXTERNAL USERS

Methods of data collection and storage:

☐ digital

☐ manual

☐ stored in database online

☐ not stored in database

Time interval for data stored in the database (specify: days/weeks/months/years/on request only)

Methods for collection of metadata:

☐ handwritten lab or field notebooks

☐ free text electronic documents

☐ formal metadata annotation system

- [ ] specified templates
- [ ] controlled vocabulary

Other methods for collecting metadata:

What kind of data quality procedures are routinely applied:

- [ ] automatic logical checks (e.g. ranges)
- [ ] automatic statistical checks (e.g. regular checking for outliers)
- [ ] manual
- [ ] ad hoc tests (specify)
- [ ] not applied

Freely available via internet: *

○ Yes

○ No

Available on request: *

○ Yes

○ No

5. COLLABORATION ACTIVITES AND PARTICIPATION IN NETWORKS

Names of the national programs or projects the site is participating:

Names of the international programs or projects the site is participating:

Short description of field campaigns: name(s) of the campaign(s), year, measurements performed:

Interested in participating in PEEX RI Preliminary Station network: *

○ Yes

○ No

Other comments:

6. DATASET FOR THE PEEX – View

We are interested in receiving one example of a dataset measured in your station. We would like to include a one month dataset in our PEEX View tool advertising your station. We PEEX demo visualizes the time series for the modeled data vs. observed data. NOTE: You may submit atmospheric, biological or societal datasets. Examples of a data file formats (i) advanced (ii) basic.

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РЕАКЦИЯ ЛЕДНИКА ФИШТ (ЗАПАДНЫЙ КАВКАЗ) НА СОВРЕМЕННЫЕ ИЗМЕНЕНИЯ КЛИМАТА

АННОТАЦИЯ

Обобщены данные наблюдений за ледником Фишт – самым западным ледником Кавказа, расположенным на высотах 2450–2750 м. Географическое положение ледника Фишт позволяет считать его одним из наиболее чувствительных к изменениям климата ледников на Кавказе. Источники сведений – схема (1909 г.), аэрофотосъемка (1954 г.), тахеометрическая съемка (1982 г.), воздушное лазерное сканирование (ВЛС) и аэрофотосъемка (2010 г.), съемка с помощью малого беспилотного летательного аппарата (БПЛА) (2015 г.). Установлено, что за 1909–2015 гг. площадь ледника сократилась с 0,9 до 0,5 км^2, отступание двух языков в плане составило 200±20 м (восточный язык) и 350±20 м (западный язык). При этом в течение 1982–2010 гг. ледник находился в квазистационарном состоянии. В 2011–2015 гг. зафиксировано скачкообразное сокращение размеров ледника. Этому способствовали пониженные суммы осадков в октябре – мае, повышенные температуры воздуха в июне – сентябре, существенно меньшие снегозапасы в 2010–2015 гг. в сравнении с периодом 1982–2010 гг. В 2010–2015 гг. среднее значение абляции оказалось примерно на 800 мм водного эквивалента больше, чем в 1982–2010 гг. По нашим оценкам, если в 1982–2010 гг. средняя годовая аккумуляция на леднике Фишт составляла около 4500 мм, то в 2011–2015 гг. она уменьшилась до 3900 мм. Одновременно в 2010–2015 гг. годовой баланс массы ледника оказался не менее чем на 1500 мм меньше, чем в 1982–2010 гг.

Полученные результаты позволяют, вкупе с другими сведениями, уточнить внутрирегиональную (Кавказ) изменчивость отклика ледников на современные изменения климата. Апробированные на леднике технологии измерений средствами ВЛС и БПЛА показали их применимость в горных условиях в части высокоточного моделирования ледниковой поверхности и последующих картометрических расчётов.

КЛЮЧЕВЫЕ СЛОВА:

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