

To solve our world's environmental challenges, we require knowledge-based actions that overcome national borders in a committed, inclusive effort: the Institute for Atmospheric Earth System Research (INAR) is showing us a way

Facing global Environmental challenges

IT is estimated that we will reach a world population of 10 billion people by 2050.¹ Within the same timeframe, climate change is expected to cause disruptive and, in some cases, irreversible changes to the ecosystem. In this future scenario, the growing population will require more fresh water, food and energy, all of which are in peril due to climate change.

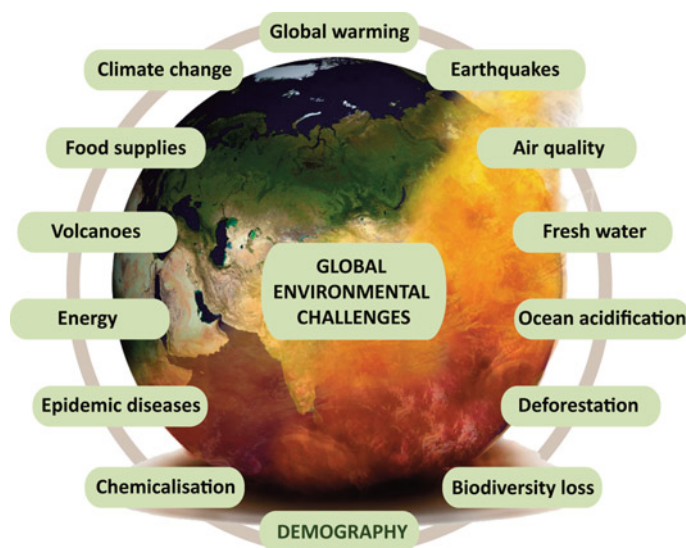
These are the 'Global Environmental Challenges' we face, which include declining air quality, ocean acidification, loss of biodiversity and shortages of fresh water and food supplies. The Grand Challenges are the main factors controlling human well-being and the security and stability of future generations.

However, these challenges are highly interconnected and cannot be solved separately. Therefore, we need a framework based on multidisciplinary science and international collaboration that gives way to knowledge-based actions and fast-tracked policymaking.

INAR: multiscaled, multidisciplinary, excellent science

At the University of Helsinki, the Institute for Atmospheric and Earth System Research (INAR) provides cutting-edge research on climate change, air quality, biogeochemical cycles and ecosystem processes. Headed by Director Academician Markku Kulmala, INAR places among the world's top ranked institutions for atmospheric sciences (Shanghai Ranking 2019). It hosts ten of the highest cited geoscientists in the world and offers innovative pedagogical research-based courses. Beyond academia, INAR has founded international environmental programmes and spin-offs in research infrastructure and aerosol technology.

To solve the global environmental emergencies, we need to take collaborative, knowledge-based actions. To enable this, science and research institutions need to help re-design the process of policy-making and international relations. INAR is an example of a research institute that has evolved beyond the limitations of traditional higher education. It is exemplary in its pursuit excellent science, training the



next generation of researchers, building collaboration networks that cross international borders, and creating services aimed at a multi-stakeholder society.

Preparing for our future world

We need to prepare for, adapt to and mitigate the changes that are coming. To do so, we need a holistic, multidisciplinary understanding of how the Earth System works, how it will respond, and how it links to the socio-economic component of our world. INAR Director Academician Markku Kulmala has founded two initiatives to meet these challenges:

The Pan-Eurasian Experiment (PEEX)

The PEEX programme is working to establish a coordinated, coherent research infrastructure network, to implement its research agenda and offer a knowledge exchange platform over the Arctic, boreal Pan-Eurasian region and China. The Pan-Eurasian Arctic-boreal environment is seeing and expecting marked changes, both from natural responses to a changing climate and to increasing human activities in the Arctic. Warming will affect demographic trends by increasing urbanisation and migration to Northern regions, introducing changes to Northern societies and their air quality. The global climate is highly sensitive to changes in the Northern area via the changes in albedo, carbon sinks and emissions, methane emissions and a greening of the

Arctic that could increase aerosol production and affect cloud dynamics.

Moreover, massive changes to the ecosystem include the expansion of new species and the extinction of existing ones. The warming, additionally, will accelerate global trade activities in the Arctic region if the Northern sea route opens for shipping between the Atlantic and Asia's Far East. There is a prospect of extracting major natural resources such as oil, natural gas and minerals in the North, which would introduce natural and social consequences. The PEEEX initiative emphasises the converging understanding of physical and socio-economic processes within the Earth system in the changing pristine and urban environments of the Northern regions and in China.

GlobalSMEAR

At a broader scale, GlobalSMEAR (Station for Measuring Earth surface – Atmosphere Relations) offers the know-how and implementation services to build such a Global Earth observatory. The aim is to integrate and harmonise regional research efforts that build up to a global monitoring network to tackle the Grand Challenges together. Such an international effort will prioritise a wide representation of environments and hotspot areas currently understudied, such as regions in Africa, Latin America and Siberia.

Ground data from GlobalSMEAR stations will combine with remote sensing data, laboratory experiments, and computer models assimilated together with machine learning tools to enable us to understand and to quantify land, atmosphere, and ocean feedbacks under the changing climate. GlobalSMEAR will also solve the air quality at a regional and global scales and to facilitate open use of the data for services that extend to policy-making, early warning systems and businesses.² In a race to design our transition into a carbon neutral world, we need data and experts to provide the pathways. The GlobalSMEAR concept will facilitate such data services for researchers, policy makers, and companies.

The Pan-Eurasian Experiment initiative

The mission of PEEEX is to be a next-generation natural sciences and socio-economic research initiative using excellent multi-disciplinary, multi-scale research and research infrastructure aimed at resolving the major uncertainties in Earth System science and sustainability in the Arctic and boreal Pan-Eurasian regions and China.³ PEEEX began in 2012 and developed a science plan with four major activity types:

PEEX Research Agenda

The PEEEX Research Agenda focuses on the multidisciplinary understanding of the Earth System on all relevant spatial and temporal scales, ranging from nano-scale to global scale. It aims to understand the processes relevant to climate change, demographic development and use of energy resources in the Northern Eurasian regions. The research agenda defines the large-scale key

topics and research questions of the land-atmosphere-aquatic-anthropogenic systems in an Arctic-boreal context as well as megacity-climate interactions and air quality issues.⁴

PEEX Research Infrastructure

The Research Infrastructure introduces the current state of art observation systems in Pan-Eurasian regions. One of PEEEX's concrete tasks is to establish a coordinated, coherent land-based, airborne and seaborne PEEEX observation network to cover environments that span from the Arctic coastal regions to the tundra and boreal forests, including marine areas such as the Baltic, the North Sea and the Arctic Ocean, and from pristine locations to urban megacities.⁵ The strategic focus is to ensure the long-term continuation of comprehensive measurements in the land-atmosphere-ocean continuum as well as the interactions and feedbacks related to urbanisation and megacities. The development of such comprehensive data sets will produce validated and harmonised data products for models of various spatial and temporal scales. Moreover, PEEEX will contribute to the sustainable development of the Northern Eurasian regions by providing quantified information on climate and sustainability relevant variables from such an integrated observation and modelling framework to the research communities, as well as to construct data services for various sectors of society (such as early warning systems).

The PEEEX observational network is based on two components:

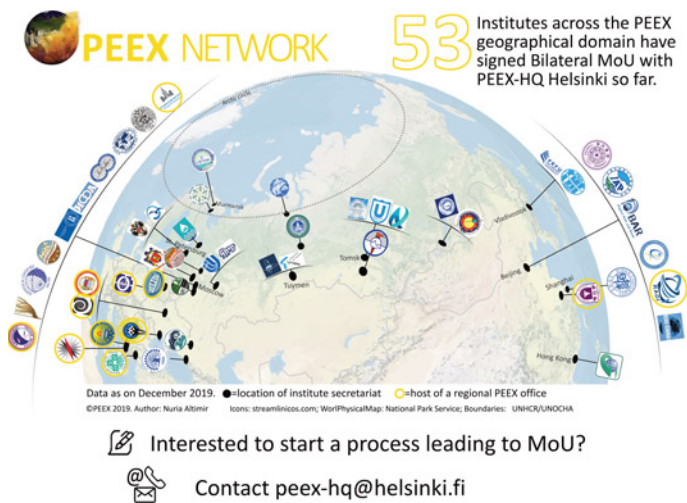
- 1) The existing stations and their activities; and
- 2) The establishment of new stations.

The upgrading plans of the existing stations as well as the new stations are based on the SMEAR (Stations for Measuring Earth Surface – Atmosphere Relations) concept and can be further implemented via GlobalSMEAR – the PEEEX observational network is open for new members. Further information is described at the end of this section.

The PEEEX e-Catalogue is a working tool towards the construction of the PEEEX observational network. It collects information on the Russian stations in the PEEEX collaboration network, introducing an overview of their measurements and providing contact information. The aim of the catalogue is to promote the research collaboration, indicate the station as partner in Russian Federation stations - PEEEX collaboration network, and give positive visibility to the stations activities.

PEEX Impact on Society

The 'Impact on Society' addresses key aspects related to mitigation and adaptation strategies. It involves preparing Northern societies to cope with environmental changes, developing reliable early-warning systems, and addressing the role of new technology in the implementation of these strategies and plans. PEEEX scientific results will be used to develop new climate scenarios on global and regional scales of the PEEEX domain. Furthermore,



Contact the PEEEX-HQ (peex-hq@helsinki.fi and/or hanna.k.lappalainen@helsinki.fi) to connect to the PEEEX network and research community. You will receive information on the joint funding proposals, training and education courses, as well as become an active PEEEX partner in our working groups. For institutes we are also offering an opportunity to sign the Memorandum of Understanding (MoU) with the PEEEX-Program and be an official part of the PEEEX collaboration network.

PEEX aims to use the new research knowledge together with the research infrastructure services to provide fast-track assessments of environmental change issues for climate policy-making, and for the mitigation and adaptation strategies for the Northern Pan-Eurasian region.

PEEX Knowledge Transfer

Under 'Knowledge Transfer', the PEEEX community will include scientists from various disciplines, funders, policy-makers and stakeholders from industry, transport, renewable natural resources management, agricultural production and trade, and it will aim at co-designing research in the spirit of the Future Earth initiative. PEEEX is working to educate the next generation of multidisciplinary scientists and technical experts capable of solving the large-scale research questions with societal impact on the PEEEX geographical domain. PEEEX at INAR is working on education programs at multiple levels and provides an exchange platform between Europe, Russian and Chinese university students, thereby strengthening future research international communities.

PEEX benchmarked courses are especially suitable for networking and collaboration and are typically intensive hands on data-analysis field or laboratory courses. The courses bring together experts of the PEEEX topics and facilitate horizontal learning among the participants and teachers. Courses organised by PEEEX contributing institutes are opened, when possible, to other communities. Some examples of courses are: 'Air pollution – from local to global' in Nanjing, China, 'Atmospheric optics' in Moscow, Russia, 'Paleolimnology of Northern Eurasia' in Petrozavodsk, Russia, and 'Application of weather and cloud radars' in Hyttälä, Finland.

The PEEEX assessment process

PEEX aims at resolving sustainability questions in the Northern Eurasian region. In implementing the PEEEX research agenda, PEEEX opened a special issue in the Journal of Atmospheric Chemistry and Physics to serve as a primary platform to collect relevant scientific results for the periodic PEEEX science assessment.

The assessments will be distributed to different stakeholders and policy-making processes and the

European, Russian and Chinese ministries. The themes covered by this special issue include: climate change, air quality, biodiversity loss, chemicalisation, food supply, fresh water and the use of natural resources through mining, industry, energy production and transport.

Join the PEEEX Community

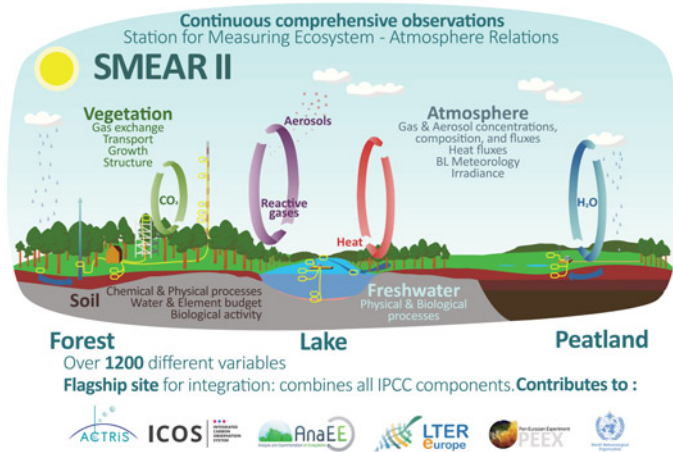
PEEX Headquarters is coordinating the PEEEX network at different levels (researchers, institutes and organisations) and the governance activities together with the regional offices in Russia and in China. This activity is facilitated by different tools such as a website, e-newsletter, e-mailing lists, social media (@PEEX_News), a blog, and in person through the organisation of conferences, conference sessions, meetings and dialogue forums (such as the Sofia Earth Forum).

The future of monitoring and data services: GlobalSMEAR

We require science-based, independent data on the state and quality of the environment. GlobalSMEAR is working towards an integrated Global Earth observatory for continuous, comprehensive environmental information, data services, and capacitation of local technicians and early career researchers from a local to a global scale. The GlobalSMEAR approach is based on the "Stations Measuring Earth Surfaces and Atmosphere Relations" (SMEAR) station concept, which was developed at the flagship observatory 'SMEAR II' station in Finland (61°51' N, 24°17' E) with the longest and most comprehensive measurement series in the world on atmospheric aerosols and energy flows since 1995.

SMEAR II currently carries out comprehensive measurements on land-atmosphere interactions 24/7 on 1200 parameters on its boreal forest, wetland and lake ecosystems and delivers data products based on the European Research Infrastructures ICOS, ACTRIS and eLTER standards. GlobalSMEAR offers the experience of INAR / University of Helsinki of over 20 years running and building up the SMEAR II station, which has led to over 2500 scientific publications, and over 15 European Research Council (ERC) grants.

The long-term vision for GlobalSMEAR is to have a network of approximately 1000 highly instrumented environmental observatories within 10-15 years, carrying out observations on Earth surface -



atmosphere relations. GlobalSMEAR aims to provide monitoring of regional and long-range, transboundary pollution transport; to offer a quantitative budget of greenhouse gases and sources and their development over time; to provide data on ecosystem processes including water use efficiency, photosynthesis and carbon allocation; to enable the identification of particular pollutant sources, such as a ship or a manufacturing plant; and, to produce an early warning system and mechanism for safe operation/evacuation in the case of industrial accidents. Furthermore, comprehensive ground data from GlobalSMEAR can serve to verify and be coupled with satellite-based remote sensing data and computer models in our pursuit to better understand the Earth System.

Make your station part of the GlobalSMEAR network

The GlobalSMEAR station network consists of SMEAR-certificated stations. The membership of the GlobalSMEAR network provides a contact platform, opportunities for training, capacity building, data exploitation, station upgrades and technology development in a coordinated manner, as well as collaborative research via joint peer reviewed papers and participation of conferences and workshops.

The network members take full advantage of the integrated SMEAR approach, which is based on co-location of integrated and standardised measurements of European research infrastructures (ICOS, ACTRIS, LTER) together with Group on Earth Observations - Global Earth Observation System of Systems (GEO-GEOSS), Digital Bel & Road (Guo 2018 6) and World Meteorological Organization – Global Atmospheric Watch Program (WMO-GAW).

GlobalSMEAR works to improve the use of existing infrastructures, their data and institutional resources by modernising monitoring methodologies. A station can be upgraded utilising the available infrastructure and complementing it if needed, through its modular structure concept. The capacity and the installation of the SMEAR modules is flexible and designed based on the local requirements of the site. Staff training helps to improve the technical and scientific skills of your team by providing:

- On-site training of local staff during installations;

Join the GlobalSMEAR network

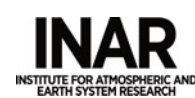
The membership of the GlobalSMEAR network is free of charge and is requested by filling in a SMEAR-Application form. The applicant can be an observation station, research infrastructure, research group or public organization. A development plan can be discussed with the SMEAR board and the candidate to reach the required capacity level.

- Dedicated courses and training at the flagship station SMEAR II in Finland;
- Training in data analysis; and
- Scientific education via graduate and doctoral studies.

A vital component of the GlobalSMEAR concept is the data itself. As part of the instrument installation, we set up a data processing system from raw data to data products, data curation, end-user data accessibility through various interfaces, and assign unique persistent identifiers (PID) for data citation.

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