Report on horizontal ERAPLANET collaboration

T. Petäjä[1], A. Mahura[1], K. Tabakova[1], S. Chabrillat[2], C. Kyba[2], J. Sonke[3], R. Salzano[4], S. Noe[5], A. Dommergue[3], A. Baklanov[6], J. Schmale[7], K. Law[8], Igor Esau[9], P. Konstantinov[10], M. Varentsov[10], W. Simpson[11], R. Graversen[12], A. Dekhtyareva[12]

[1]Institute for Atmospheric and Earth System Research/Physics, Faculty of Science, University of Helsinki, Finland
[2]Helmholtz-Zentrum Geesthacht (HZG), Centre for Materials and Coastal Research, Geesthacht, Germany
[3]Geosciences Environnement Toulouse, CNRS/IRD/Universite Paul Sabatier, Toulouse, France
[4]Institute of Atmospheric Pollution Research, National Research Council of Italy (CNR), Sesto Fiorentino (FI), Italy
[5]Institute of Agricultural and Environmental Sciences, Estonian University of Life Sciences, Tartu, Estonia
[6]World Meteorological Organization, Geneva, Switzerland
[7]School of Architecture, Civil and Environmental Engineering, École Polytechnique Fédérale de Lausanne, Switzerland
[8]LATMOS/IPSL, Sorbonne Université, UVSQ, CNRS, Paris, France
[9]Nansen Environmental and Remote Sensing Center, Bergen, Norway
[10]Faculty of Geography, Moscow State University, Moscow, Russia
[11]Department of Chemistry & Biochemistry, University of Alaska Fairbanks, USA
[12]UiT The Arctic University of Norway, Tromsø, Norway

Helsinki, November 2021

WP6 Dissemination and strategic development

Task 6.2 ***Interactions within ERA-PLANET strands****, Del. 6.2.1*

Version 1.0

1. Introduction

The ERA-PLANET includes four topic specific projects addressing different aspects of the Earth system:

- **SMURBS** (Strand 1) —smart cities and resilient societies, addressing issues such as urban growth, air quality, disasters, health, contaminated sites.
- **GeoEssential** (Strand 2) —resource efficiency and environmental management, including water, energy, food security, biodiversity.
- **iGOSP** (Strand 3) —global change and environmental treaties, addressing global observing systems for toxic and persistent pollutants, harmonization of monitoring and coupled atmosphere-ocean-terrestrial models, evaluation of ecosystem response to regional/global emission changes, support to policy implementation, and climate forcing in assessing global change patterns and analysis of policy scenarios.

- **iCUPE** (Strand 4)—polar areas and natural resources in highly climate-sensitive regions, including the evaluation of the impact of energy resource exploitation, the impact of long-range transport of air pollutants and their atmospheric deposition, air-surface exchange mechanisms, and environmental pressure from increasing anthropogenic activity in areas with sensitive ecosystems.

1.1 iCUPE

The project “iCUPE - integrative and Comprehensive Understanding on Polar Environments“ is motivated by the fact that the role of polar regions will increase in terms of megatrends such as globalization, new transport routes, demography and use of natural resources. These megatrends have environmental effects and will drastically affect e.g. regional and transported pollutant concentrations. Overall, land and ocean areas located in the polar latitudes are undergoing and will undergo substantial changes due to increased anthropogenic activities during the next 40 years. As a consequence, the polar areas face interconnected grand challenges. The iCUPE project answers to ”European network for observing our changing planet” (ERA-PLANET) thematic strand 4 (Polar areas and natural resources).

By combining integrated in-situ and satellite EO with a modelling platform, iCUPE had:

1. synthesized data from comprehensive long-term measurements, intensive campaigns and satellites, collected during the project or provided by on-going international initiatives;
2. related the observed parameters to impacts, and
3. delivered novel data products, metrics and indicators to the stakeholders concerning the environmental status, availability and extraction of natural resources in the polar areas.

These data, metrics and indicators will be targeted to identified stakeholders. They will be useful for policy development and for improving and clearly communicating our multidisciplinary understanding of the status of the polar environment and pollution dynamics in the future. The knowledge generated is relevant to the general population, policy makers and scientists.

In collaboration with the other projects in ERA-PLANET, iCUPE aimed to foster collaboration and interoperability with relevant Joint Programming Initiatives e.g. on air pollution and health aspects. The iCUPE project endorsed open data policies and Key Enabling Technologies (KET) via horizontal work within the ERAPLANET strands. This horizontal work enabled harmonization of ERA-PLANET work and outcomes. It facilitated a common voice for the ERA-PLANET to maximize the impacts within the European research and development landscape via planning of joint dissemination work to the external audiences.

1.2 SMURBS

SMURBS ultimate goal is to promote the "smart-city" approach, serving the need for a common approach to enhance environmental and societal resilience to specific urban pressures, through the integration of EO. In view of this goal, its objectives were divided into 3 categories:

A. **Overarching**, which targeted to the alignment with and exploitation of existing programmes, strategies, data, networks, services and goals;
B. **Vertical**, which defined the targeted urban pressures (air pollution, disasters, urban growth) and their reciprocal relations with health, migration and other inequalities, and
C. **Horizontal**, to assure interoperability of the produced data and services within ERA-PLANET and other infrastructures.

The overall ambition of SMURBS was to improve the quality of life of citizens and enhance cities' resilience with respect to air pollution and both natural and manmade disasters, through a chain of "smart urban solutions", that take into account existing rates of urban growth, long standing impacts like on health and newly rising pressures like migration. Existing smart-cities or networks of them, do not fully exploit the capacities provided by EO, to deliver holistic approaches to modern environmental pressures. SMURBS main aspiration was to bring together a vast array of partners of a high degree of expertise in EO, pooling national resources, facilities and coordinating national/regional research programmes, cultivating exchange of know-how and enforcing interdisciplinary action to overcome the currently fragmented status of EO under the common banner of the smart-city concept.

1.3 GeoEssential

GEOEssential is addressing the need for trusted sources of data and information to monitor the progress made on environmental conditions towards policy targets. The project aimed to demonstrate the feasibility of Essential Variables across GEO Societal Benefit Areas. It created cross-thematic workflows to evaluate, predict and monitor natural resources to inform via Earth Observations the Sustainable Development Goals. Existing structures and platforms were analysed in order to identify substantial gaps and synergies for addressing the needs of environmental policy in agriculture, soil, water, biodiversity, energy, light and raw materials. Solutions for improvements were provided in cooperation with GEO and Copernicus programmes. GEOEssential created a Knowledge Base infrastructure to facilitate the collection and formalization of the knowledge (i.e. user needs, gaps recognition and recommendations for closing gaps, best practices, Community of Practice lexicon, etc.) stemming from the European NetworkEarth Observation Networks (http://www.eneon.net/graph) and from other significant Earth Observations (EO) initiatives and programs at the National and European levels.

1.4 iGOSP

Overarching objective of iGOSP is development of a Transnational Environmental Observation System in Support of European & International Policies through the Integration of real-time monitoring data from various platforms, modelling tools and advanced global cyber-infrastructure for data sharing and

interoperability as well as the development of a fully integrated system of advanced sensors (based on nano-structured advanced materials) for major persistent pollutants coupled with state-of-the-art interoperable systems for data sharing and data management. The overall goal of Strand-3 was to develop a new paradigm for real-time monitoring of the quality of our environment with reference to the contamination of air, water and terrestrial ecosystems by persistent pollutants. IGOSP adopted a methodology aimed to integrate real-time monitoring of persistent pollutants derived from different platforms into an advanced interoperable data infrastructure for data sharing and web services release. For this purpose, IGOSP developed and improved existing sensors, explored new sensor frontiers based on nanotechnologies as well as construct, test and validate sensors and multi-sensor platforms. The combination of different sensor technologies in environmental monitoring provided further information on the dynamic mechanisms of pollutant cycling as well as better monitoring reliability.

2. Horizontal activities

The aim of this section is to introduce bilateral collaboration between iCUPE and each of the ERA-PLANET projects. The joint work enabled harmonization of projects' work and outcomes, aiding quick mobilization of novel results and internal expertise sharing between Strands.

2.1 iCUPE-SMURBS

The urbanization is accelerating globally including the northern high latitudes. Cities are a complex and highly dynamic interface between the Earth components and societal factors (health, social equity, life quality, etc.). The northern cities are more sensitive to climate change, especially in the Arctic, which has direct and indirect impacts on local livelihoods, infrastructure, water resources, ecology and air quality. Due to specific climatic conditions and societal organization the northern cities face many various challenges in advancement of knowledge about physical, chemical, ecological, socio-economic and environmental changes, their relationships and implications for the human-environment system. In the Arctic, the population density is very low, about 90% of people live in urban areas, and only about 100 urban settlements have more than 5000 inhabitants. The peculiarities of such cities are that small size settlements dominate, and they have higher vulnerability and lower sustainability with a cold climate as the dominant environmental factor. Among factors of critical importance are: snow (impact on city management and planning), permafrost (stability of infrastructure including transportation ways), frozen surface water (water supply and sewage), dormant vegetation (reduced ecosystem services), stagnant atmosphere (stable boundary layer, air pollution, urban heat island), low temperatures (working and lifestyles, health issues), high energy consumption (extended heating period due to long winter). Therefore, a multiscale approach is necessary to understand the effects of urbanization under rapid climate change.

iCUPE & SMURBS work contributed to the definition of the northern (Arctic) twin city concept and sustainability of Arctic cities/ settlements. For building climate and environmentally sustainable cities in the Arctic regions, a complex multidisciplinary approach is needed. Through collaboration both projects contributed to improvement and adaptation of the WMO concept for Integrated Urban Services (IUS) for Arctic and winter cities. Among identified northern twin cities several are proposed from meteorological point of view - Rovaniemi (Finland); Apatity, Murmansk, Salekhard, Norilsk, Nadym (Russia); Tromso (Norway); and Fairbanks (Alaska, USA) - considering also stability of boundary layer, cities and their interactions with urban processes, air pollution and climate change. For these cities, the pilot services delivering information (relying on existing essential climate variables, Copernicus services) for response to extreme weather/ atmospheric pollution events and longer-term climate change adaptation - are of importance. Utilizing existing Copernicus services (e.g. Copernicus Emergency Management Service (CEMS) for floods and forest fires risk assessments; Copernicus Atmosphere Monitoring Service (CAMS) for air quality and emissions), CMIP6 climate modelling data for scenarios, online integrated regional-urban-city-scale and -processes modelling for meteorology/climate and atmospheric composition, source apportionment - all these bring added value to services. Moreover, data fusion (from existing in-situ monitoring networks, satellite remote sensing, targeted field campaigns, citizens observations) to Arctic urban areas, integration of modeling results, combined pre/post-processing generate products in a form of essential (climate related) variables (air and surface temperature, wind characteristics, precipitation, etc.) and varios indices with focus on Arctic (Arctic urban inversion index, Arctic fires pollution index, Arctic urban air pollution index, Arctic dust urban impact index, Arctic avalanche probability index, Arctic extreme precipitation index). Such multidimensional data indices are important to inform decision/policy-makers and the public (by illustrating potential impacts on population health and ecosystems related to urban development and energy choices).

Papers in preparation & delivered presentations:

Baklanov et al., (2021+): Northern Urbanization under climate change and its sustainable development: Challenges, gaps, needs and future directions. MS: in preparation

Esau I. et al. (2021+): Winter Cities: Socio-environmental challenges in changing urban climate. MS: in preparation

Baklanov A., Schmale J., Law K., Vitale V., Mahura A., Petäjä T. (2019): Northern Urbanization under global- and climate change: challenges and strategies with respect to weather and pollution for sustainable development. *Geophysical Research Abstracts. Vol. 21, EGU2019-14165, 2019, EGU General Assembly 2019, online*

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

Konstantinov P., Baklanov A., Mahura A., Tuukka Petäjä T., Sokhi R., Law K., Arnold S., Schmale J. (2021): Integrated Urban Systems - Twin Cities - WMO GURME. *4th PACES Open Science Meeting, 26-28 May 2021, online*

2.2 iCUPE-iGOSP

One of the important goals consisted in the conveying of GMOS network to GOS4M in order to increase the availability and quality of in situ mercury information thus contributing to the Earth Observation data in the environment. Specifically, we reinforced and established new monitoring stations for atmospheric mercury (Hg) particularly in areas with scarce Hg data coverage, such as in the Southern Hemisphere.

Thanks to a joint effort of iGOSP, national programs and the IPEV-French Polar Institute, CNRS maintained mercury monitoring activities at Amsterdam Island (remote southern Indian Ocean) and in Concordia station in Antarctica (Slemr et al, 2021). These stations have been active since 2012. Using model simulations incorporating recent developments in the photoreduction mechanisms of the oxidized forms of mercury (Saiz-Lopez et al, 2020), we show a significant model underestimation of global observations of these oxidized species in the troposphere and their surface wet deposition. This implies that there must be currently unidentified mercury oxidation processes in the troposphere.

CNRS implemented in 2016 a new monitoring station for gaseous mercury at the Maido Observatory at La Reunion, 21°S (2200 m asl). After 1 year of continuous measurements with automated instruments, atmospheric Hg is now continuously measured on a low frequency with passive sampling techniques (Koenig et al., 2021). Through a joint effort with iCUPE project, we developed and/or investigated new methodologies to address key features of the atmospheric mercury cycle with:

1. new measurements of reactive mercury (RM) species,
2. determination of RM compounds by thermal desorption procedures and
3. calculation of RM compound-specific dry deposition velocities.

This was first implemented in the Arctic within iCUPE (Osterwalder et al, 2021) but also expanded in iGOSP for remote sites of the Southern Hemisphere such as Maido, Amsterdam Island and Concordia station in Antarctica. CNRS also participated in the testing and validation of passive samplers system for gaseous mercury to access places with inexpensive and easy-to-use sensors. In order to adapt current sampling protocols, we probed the limits of sampling in the remote atmosphere and deployed passive samplers for periods of up to two years in some of the most extreme, remote and challenging global environments: at Concordia station on the Antarctic plateau, on Amsterdam Island in the remote Southern Indian Ocean and at several sites on the tropical island of La Réunion. The results will

be soon published and will help to adapt Standard Operating Procedures (under preparation). Finally, CNRS was involved in the support of GOS4M by both providing specific mercury data and by playing a role in the governance of this flagship (website: http://www.gos4m.org/home/). CNRS took leadership in the iGOS^{4}M initiative to develop the first online database for mercury stable isotope observations in support of the Minamata Convention on Mercury.

Joint work from the bi-lateral action:

Osterwalder, S., Dunham-Cheatham, S. M., Ferreira Araujo, B., Magand, O., Thomas, J. L., Baladima, F., Pfaffhuber, K. A., Berg, T., Zhang, L., Huang, J., Dommergue, A., Sonke, J. E., and Gustin, M. S.: Fate of Springtime Atmospheric Reactive Mercury: Concentrations and Deposition at Zeppelin, Svalbard, ACS Earth and Space Chemistry, 10.1021/acsearthspacechem.1c00299, 2021.

Slemr, F., Martin, L., Labuschagne, C., Mkololo, T., Angot, H., Magand, O., Dommergue, A., Garat, P., Ramonet, M., and Bieser, J.: Atmospheric mercury in the Southern Hemisphere – Part 1: Trend and inter-annual variations in atmospheric mercury at Cape Point, South Africa, in 2007–2017, and on Amsterdam Island in 2012–2017, Atmos. Chem. Phys., 20, 7683-7692, 10.5194/acp-20-7683-2020, 2020.

Koenig, A. M., Magand, O., Verreyken, B., Amelynck, C., Schoon, N., Colomb, A., Brioude, J., Ramonet, M., Regis, J., Belloir, A., Metzger, J. M., Cammas, J. P., Sonke, J., and Dommergue, A.: Dynamics of atmospheric mercury at Maïdo observatory in the tropical Indian Ocean, Goldschmidt, Lyon, 4-9 July, 2021.

Saiz-Lopez, A.; Travnikov, O.; Sonke, J. E.; Thackray, C. P.; Jacob, D. J.; Carmona-Garcia, J.; Francйs-Monerris, A.; Roca-Sanjuбn, D.; Acuca, A. U.; Dбvalos, J. Z.; Cuevas, C. A.; Jiskra, M.; Wang, F.; Bieser, J.; Plane, J. M. C. & Francisco, J. S. (2020), 'Photochemistry of oxidized Hg(I) and Hg(II) species suggests missing mercury oxidation in the troposphere', Proceedings of the National Academy of Sciences 117(49), 30949--30956.

2.3 iCUPE-GeoEssential

Within iCUPE, we used the Radiance Light Trends webapp developed by GEOEssential in order to examine artificial light sources in the Arctic. In one case study, we demonstrated how the webapp could be used to observe changes in light emissions, using lighting from the Colville Delta region of Alaska. We also used the webapp to examine sources of lights in the Yamal Peninsula in Russia, and classified these according to the type of infrastructure they were associated with. Finally, we performed another analysis (outside of the app) to look at how the number of lit places and their areas increased during 2012-2019.

References:

Beamish, A., Kyba, C., Coesfeld, J., Chabrillat, S., Salzano, R., Salvatori, R. (2020): Deliverable 3.2.1: A technical report on the assessment of the capabilities and limitations of advanced optical satellite missions for snow, vegetation, and gas flaring mapping applications in Arctic areas, Potsdam, 30 p., https://doi.org/10.2312/GFZ.1.4.2020.001

3. ERA-PLANET - wide joint actions

iCUPE has worked together with other Strands on the vision and implementation of the ERA-PLANET Knowledge Platform, discussing and experimenting the functionalities and planned enhancements of the Virtual Laboratory Platform (VLAB) - a tool for publishing and running scientific models for knowledge generation. iCUPE attended all annual conferences and joint workshops where knowledge and progress within projects was shared.

3.1 VirtualLab

Backbones of building iCUPE horizontal activities on the level of data mobilisation are cloud based computing solutions like the VirtualLab or general cloud deployable techniques such as Docker. Within iCUPE and the three other ERA-PLANET strands, as well as broader user base (e.g. DIAS, GEOSS), stakeholders and science community these technologies allow to develop use cases and workflows that generate knowledge from data. Within iCUPE, the CNR research group involved in the optical remote sensing activities focused on the snow cover contributed to the horizontal collaboration between iCUPE and GeoEssential project. The development of a workflow aimed at assessing the snow cover in an Arctic site supported the integration of data chains implemented in the R Programming Environment into the VLAB platform. The considered model included different data sources, combining satellite imagery at different spatial scales (MODIS and Sentinel-2 data) with in-situ observations about the atmospheric composition. The workflow supports the assessment of site-specific relationships between the optical behaviour and the fractional distribution of the snow cover. The developed synergy between different strands allowed the development of a modular workflow useful for enhancing the opportunities offered by the VLAB platform. The potentiality to share the developed knowledge with inexperienced end-users will be optimized connecting such models to cloud data services. The outcome of this horizontal collaboration has been presented in joint papers aimed at evidencing such a good practice for transferring knowledge to policy makers and stakeholders.

Further we developed a set of flexible tools that are able to mobilise diverse data formats (web-based, database), automatically augment these and generate metadata. The benefit of such tools lies in the flexibility so they can be used in concert with solutions such as VirtualLab. These can provide services

to prepare data before they are used in a VirtualLab solution or on the backend side, to further transform and transport data or results after they have been passed the VirtualLab.

3.2 Joint workshops

- VirtualLab workshop, 26-28.02.2019, Florence, Italy.
  Participants: representatives of 4 ERA-PLANET strands.
  Goal: expand use of VirtualLab to all strands

- ERA-PLANET Annual Meeting, 10-11.10.2019, Brussels, Belgium
  Participants: 4 ERA-PLANET strands representatives, EC representatives.

- ERA-PLANET Annual Meeting 3-4.12.2020, Virtual
  Participants: 4 ERA-PLANET strands representatives, EC representatives.

- ERA-PLANET final meeting, 20-21.10.2021, Virtual
  Participants include 4 ERA-PLANET strands representatives, EC, UNEP, NASA representatives.

4. Summary

We have presented results of the continuous bilateral and ERA-PLANET-wide actions that took place during iCUPE project's lifetime. Joint efforts as it was envisioned by the ERA-PLANET programme and facilitated by it, enabled bi- and pan-directional information, knowledge and data flow. Achieved results as well as established scientific collaborations and communications will serve as the basis for the future projects and initiatives.