Integrated Arctic Observation System

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Collaboration establishment

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EXECUTIVE SUMMARY

One of the specific objectives of INTAROS WP1 is to establish collaboration with research groups and other actors who play an important role to develop multidisciplinary observing systems for the Arctic. This report described the activities and results of the connections and collaboration during the first 2.5 years of the project. In this period INTAROS has been present and given presentations at ≈ 150 meetings, workshops and conferences in order to establish collaboration with other projects, organisations and stakeholder groups involved in Arctic observing systems.

The development of collaboration is a continuous ongoing process, in particular collaboration with EU Polarnet and the other H2020 projects under the Arctic Cluster is in progress. Also, collaboration with other projects and programmes in Europe, North America and Asia is under development. This includes SAON, Arctic Science Summit Week, Arctic Observing Summit, European projects, and projects in USA, Canada, Russia, China, Japan and South Korea. Such collaboration is required in order to build an integrated Arctic Observing System covering the pan-Arctic region.

The collaboration includes participation in and organization of conference sessions, workshops, and stakeholder events across the pan-Arctic area. Furthermore, joint projects are established to fund more collaboration activities, including joint field experiments and data sharing agreements. Also MoUs are developed between institutions to enable long-term collaboration. In Europe, collaboration with Copernicus programme and various research infrastructure programmes is in progress, because these programmes have long-term funding perspectives and build on research priorities which incorporate Arctic observing. Through Copernicus services and Polar programmes under the Space Agencies, the production and delivery of satellite data for Arctic observing is growing strongly. The INTAROS consortium is well-connected to these programmes and exploits satellite data in a number of Arctic obsering case studies.

The connection with research groups, operational agencies and other actors who play a role in developing Arctic observing systems is an important pre-requisite for the Roadmap, which is under development and will be a major deliverable in INTAROS. The plan was to establish a Pan-Arctic Observing Forum as a milestone towards the Roadmap, but this plan has been changed as a result of the collaboration with SAON. In the SAO Implementation plan, one of the goals is to “create a roadmap to well-integrated Arctic observing system” and INTAROS is invited to participate in this work. The role that was envisaged for the Pan-Arctic Observing Forum is already taken care of by SAON. It is therefore not necessary to establish this forum. Instead, INTAROS has now become a member of the SAON Roadmap Task Force, which has started to develop documents related to the Roadmap. Key milestones for the Roadmap work will be the Arctic Observing Summit/Arctic Science Summit Week in March and the Third Arctic Science Ministerial in autumn of 2020. The INTAROS Roadmap document is due in autumn of 2021. This mean that the INTAROS Roadmap can incorporate the outcomes from the Ministerial meeting.

Table of Contents

1. Introduction

This report describes the existing programmes, projects, networks and stakeholder interaction where INTAROS has established connections and collaboration in the first 2.5 years of the project. The report is an intermediate milestone in the development of the Roadmap for a Sustainable Arctic Observing System, which is a major deliverable from INTAROS by the end of the project (autumn 2021). The development of the Roadmap has started in collaboration with the Roadmap Task Force established by SAON.

The Roadmap need to be connected to ongoing and planned observing systems, which evolve through different channels:

Channel 1: Space-based observing systems. The Copernicus programme in collaboration with a number of space agencies play a key role to develop global observing systems. These systems need validation data from in situ and airborne systems. For many applications and services using observing systems in the Arctic it is necessary to integrate data from satellite, airborne and in situ platforms.

Channel 2: European and national Research Infrastructures for observation of climate and environment. These include terrestrial stations, community-based monitoring, aircraft, ships and ocean/sea ice platforms. Existing European infrastructures which are in operation are partly covering Arctic areas or plan to extend to the Arctic (e.g. Euro-ARGO, ACTRIS, ICOS, EPOS), see http://roadmap2018.esfri.eu/. Some are established as legal entities (ERIC), and others are in the process of becoming an ERIC. National infratructures include a number of icebreakers, seafloor observatories, aircraft and stations in Arctic regions. A pan-Arctic network of terrestrial station network is supported by the H2020 project INTERACT.

Channel 3: Global programmes under WMO, IOC or UN are allocating efforts to include observations in the Polar regions, realizing that there are specific challenges to implement and operate in situ observing systems in these regions. Satellite earth observation data play an increasingly important role in the observing systems, but many important variables cannot be observed from space. Major observing programmes include GCOS (Global Climate Observing system), Global Ocean Observing System (GOOS), GAW (Global Atmosphere Watch), GCW (Global Crysophere Watch), WIGOS (WMO Integrated Global Observing System) and various systems dedicated to emergency and security.

Channel 4: Community-based monitoring (CBM) and evolution of local observing systems play an important because they are designed to serve the needs of communities in the Arctic. They provide data that are usually not included in scientific or large-scale observing systems. CBM programmes are based on Indigenous and local knowledge systems that cannot be directly compared with science-driven monitoring programmes. Therefore, CBM systems represent important complementary information to the science systems.

Channel 5: Several platform-dependent and scientific-thematic observing systems are being develop in the Arctic. They are usually operating as networks with contribution from participating institutions. They are not necessarily established as formal Research Infrastructures (described in channel 2), but operate under an agreement signed by the participants. Such networks can evolve to become formal

Research Infrastructures. Example of platforms operating in a network is the International Arctic Buoy Programme (http://abp.apl.washington.edu/overview_principles.html) where meteorological, sea ice and oceanographical ice buoys (e.g. ITPs, SIMBA buoys), are deployed and transmit data to a central repository. A common data management and open data distribution policy is an important part of the operating principles for the programme.

The subsequent sections of this report describes the activities and results of building collaboration between INTAROS and projects and programmes during the first 2.5 years of the project.

2. Collaboration activities in the first two years

INTAROS has been presented at ≈ 150 meetings, workshops and conferences in order to establish collaboration with other projects, organisations and stakeholder groups involved in Arctic observing systems. Such collaboration is required in order to build an integrated Arctic Observing System covering the pan-Arctic region.

- INTAROS has started collaboration with the EU Arctic cluster projects (EU-PolarNet, Blue Action, APPLICATE, INTERACT, NUNATARYUK, ARICE, KEPLER, ARCSAR) regarding communication and stakeholder interaction events, where joining resources with other projects is cost-effective and impactful.
- In order to build longterm observing systems INTAROS has established collaboration with infrastructure projects such as ICOS, EPOS, EURO-ARGO ERIC, INTERACT, ACTRIS, ENVRI PLUSS, SIOS and other national and international infrastructures that provide observations in the Arctic
- Progress in management and integration of Arctic observations has been made within the consortium where more that 30 institutions have collaborated in an extensive assessment of existing systems in the atmospheric, terrestrial and marine sphere. The assessment was done under WP2 and is the basis for selecting data repositories that the consortium members will use for data integration later in the project.
- Collaboration with US and Canadian partners has started, including also institutions who are not partners in INTAROS. A networking project between Norway, USA and Canada was established with funding from the Research Council of Norway to strengthen INTAROS work to link science and education in the Arctic. The project Useful Arctic Knowledge (UAK), has organised a workshop in Canada and a research school in Svalbard jointly with US and Canadian partners.
- INTAROS has organised two workshops on data management and one two day workshop on Platforms and technologies for Arctic Ocean Observing Systems in collaboration with Ocean Network Canada and Norwegian industry partners. The workshops have been supported by the Research Council of Norway.
- INTAROS partners has started collaboration with the field programs of MOSAIC and YOPP in order to improve the in situ data collection. These programs will have intensive observation campaigns from 2019 to 2020.
- The collaboration with MOSAIC will be materialized though the Coordinated Arctic Acoustic Tomography Experiment (CAATEX) funded jointly by the Research Council of Norway and ONR in the US. The project is led by NERSC and SIO and will demonstrate a pan-Arctic Ocean Observing System, extending across the deep Arctic Ocean from Svalbard to Alaska. This project is also a response to the Transatlantic Ocean Research Alliance under the Galway Statement on Atlantic Ocean Cooperation, an agreement between the United States, Canada, and the European Union.
- Meetings have been organised with partners and collaborators in USA, Canada, Russia, China, Japan and South Korea to plan how they can contribute to an integrated Arctic Observing System.

All these countries are extending their activities in the Arctic. South Korea has annual expeditions to the Arctic with their icebreaker ARAON. Japan has a major Arctic interdisciplinary programme, ArCS, for the period 2015-2020. INTAROS collaborates with the Chinese icebreaker during Arctic expeditions to collect sea ice and oceanography data.

- INTAROS has signed a MoU with the Chinese DBAR HiMAC programme (*Digital Belt and Road Program - High Mountain and Northern Cold Region)* led by RADI. This MoU will facilitate collaboration with China in Earth Observation topics related to the Arctic and the high mountains.
- INTAROS is directly involved in work with the Arctic Data Committee and the Committee on Observing Networks under SAON (Sustaining Arctic Observing Networks). This is a very important connection since they are established as pan-Arctic and multidisciplinary committees under SAON
- working towards the same goals as INTAROS. INTAROS has been invited to give presentation at the SAON Board meetings. SAON's vision is to facilitate a connected, collaborative, and comprehensive, long-term, pan-Arctic Observing System that serves societal needs. SAON is therefore important as a mechanism for future continuity of the INTAROS work.
- The first stakeholder workshop was organised in Brussel on 5 May 2017 with EuroGOOS as local host. High-level requirements and challenges regarding development of Arctic Observing Systems were discussed from a European perspective. A second workshop was organised at the Research Council of Norway in Oslo on 9 November 2017 with Norwegian institutions who play a key role in developing and maintain observing systems in the Svalbard region and who are representatives for various stakeholder groups.
- Two workshops were organised with representatives from community-based observing, one in Fairbanks in May 2017 and one in Quebec City in December 2017. The workshops helped raise awareness on good practices and challenges of community-based observing among local and civil society organisations, mainly in Alaska and Canada.
- An excursion to Longyearbyen with students and teachers from Bergen was organized in August 2017 in order to understand the impact of climate change in Svalbard and get insights into the present life of the inhabitants. The excursion was also used to discuss new methods and approaches to environmental monitoring with decision-makers in Svalbard.
- INTAROS contributed to the project “Impact Assessment on a Long-Term Investment on Arctic Observations (IMOBAR)” conducted by the Joint Research Centre (JRC) and Directorate General for Research and Innovation (DG RTD). The project provided input and justification for the large investments needed to develop sustainable Arctic observing systems. Results of the project was presented at the upcoming Second Arctic Science Ministerial in Berlin in October 2018.
- INTAROS has prepared a letter to the Arctic Science Ministerial 2018 with a pledge to establish long-term sustainable observing systems in the Arctic. INTAROS was represented by several scientists during the Arctic Science Forum meeting in Berlin, connected to the Arctic Science Ministerial 25-26 October
- INTAROS has been invited to give presentation at the Norwegian Environmental Agency and the Norwegian Ministry of Climate and Environment. The latter has granted a project to NERSC with the objective to make Arctic marine data more accessible to Norwegian ministries and agencies. This is a direct follow-up of the INTAROS work.
- INTAROS played an active role during the Arctic Science Summit Week and the Arctic Observing Summit in Davos, 2018, with oral and poster presentations, panel discussion and working groups
- INTAROS was presented by a poster at the GEO Plenary Week in Kyoto, 29 Oct – 02 Nov 2018

- INTAROS has organised and co-organized sessions at international conferences on Arctic Observing topics e.g. at the Acoustical Society of America (November 2018), American Geophysical Union (December 2018), and European Geophysical Union (April 2019).

The following reports have been produced in WP1:

• The *Initial Requirement Report (D1.1)* has been prepared where the theme leaders provided significant description of what observations are needed for the atmospheric, ocean and terrestrial themes. Essential variables to observe and observational technologies to obtain data are described.

• The *Engagement Strategy* (D1.3) has been prepared where stakeholder groups are identified, measures to involve data providers, users and other stakeholders are described. It is a baseline document for developing cooperation and establish the Roadmap for an integrated Arctic Observing System.

• The first version of the *Data management plan – DMP* (D1.2) has been prepared and was updated after one year. The DMP describes how new datasets collected or generated by partners in the frame of the project, will be managed according to guidelines for FAIR (Findable, Accessible, Interoperable, Reusable) data management in H2020.

3. INTAROS connection with programmes in Arctic Observing

Development of collaboration is a continuous ongoing activity in INTAROS, contacting governmental, non-governmental programmes and projects in the pan-Arctic region. The programmes can be global with an Arctic extension, pan-Arctic under Arctic Council, regional, national or community-based. In the following we describe some of the collaborations and nature of collaboration.

GEO – Group on Earth Observations

This is a global partnership of governments and organizations from 100 countries (members of UN) and the European Commission. GEO was formally established in 2005. Their vision is that in future decisions and actions for the benefit of humankind are informed by coordinated, comprehensive and sustained Earth observations.

The establishment of the Global Earth Observation Systems of Systems (GEOSS) is major mission of GEO. GEOSS is to be composed of coordinated, independent Earth Observation, information and processing systems that interact and provide access to information to a broad range of public and private sector stakeholders. In particular GEO will advocate the value of EO, engage communities and deliver data and support to UN development goals. More details about GEO work is found in their GEO strategic plan 2016-2025. INTAROS participated in the 11th GEO European Projects Workshop, Helsinki (June 2017) and the EuroGEOSS workshop in Geneva (Sept 2018) with poster presentations.

GEO – Cold Region Initiative (GEOCRI) was established in 2015. The goal is to provide coordinated Earth observations and information services across a range of stakeholders to facilitate well-informed decisions and support the sustainable development of the Cold Regions globally. So far the GEO activities has been focused on access to and utilizing EO from satellite remote sensing towards different stakeholder groups. INTAROS is represented in GEOCRI by the leader Yubao Qiu (RADI, CAS) and other scientists from the INTAROS consortium.

Nature of collaboration: INTAROS participated in two workshops (2017 and 2018), had a poster presentation at GEO Plenary in Kyoto in 2018 and is represented in the leader group of GEOCRI.

Global Climate Observing System (GCOS)

The Global Climate Observing System (GCOS) is co-sponsored by the World Meteorological Organization (WMO), the Intergovernmental Oceanographic Commission of the United Nations Educational, Scientific and Cultural Organization (IOC-UNESCO), the United Nations Environment Programme (UN Environment), and the International Science Council (ISC). It regularly assesses the status of global climate observations of the atmosphere, land and ocean and produces guidance for its improvement. In the GCOS 2016 Implementation Plan (341 pages), there are 192 actions related to establishing atmospheric, ocean and terrestrial observing systems on global scale, and many of them are related in the Arctic. For example, Action O15 states that the Integrated Arctic Observing System design and demonstration project funded by EU for 2017–2020 (INTAROS) is a key project contributing to in situ sea ice observations. Also other actions are related to collection of in situ data in the Arctic.

INTAROS participated in the GCOS Science day in Helsinki on 22 October 2018.

Global Cryosphere Watch (GCW)

The World Meteorological Organization's Global Cryosphere Watch (GCW)[1] is an international mechanism for supporting all key cryospheric in-situ and remote sensing observations. To meet the needs of WMO Members and partners in delivering services to users, the media, public, decision and policy makers, ***GCW provides authoritative, clear, and useable data, information, and analyses on the past, current and future state of the cryosphere***. GCW includes observation, monitoring, assessment, product development, prediction, and research. It provides the framework for reliable, comprehensive, sustained observing of the cryosphere through a coordinated and integrated approach on national to global scales to deliver quality-assured global and regional products and services. GCW organizes analyses and assessments of the cryosphere to support science, decision-making and environmental policy. INTAROS supports some of the stations (Finland, Greenland) contributing to the GCW surface network.

INTAROS participated in the GCW Steering Group at its fifth meeting in Oslo, Norway, 10-12 January 2018, hosted by the Norwegian Meteorological Institute.

Global Ocean Observing System (GOOS)

GOOS is a programme executed by the Intergovernmental Oceanographic Commission (IOC) of the UNESCO, but its success relies on the coordinated contributions of several people and organizations worldwide. The GOOS governance model is divided in three tiers: a multinational Steering Committee to provide oversight, scientific Expert Panels to guide system requirements, and Observation Coordination Groups that implement global unified network execution. Three discipline-based GOOS Expert Panels provide scientific oversight on Physics and Climate, Biogeochemistry, and Biology and Ecosystems. GOOS Regional Alliances (GRAs) identify, enable, and develop sustained GOOS ocean monitoring and services to meet regional and national priorities, aligning the global goals of GOOS with the need for services and products satisfying local requirements. EuroGOOS is the European GRAs with responsibilities in the European Arctic through ArcticROOS. There are now ongoing initiatives to create a Pan Arctic component of GOOS as described in Lee et al. 2019. SAON is asked to be representative in GOOS.

The connection to GOOS is well established as EuroGOOS is part of the INTAROS consortium. INTAROS is also well connected to the ArcticROOS.

Copernicus services

Copernicus is the European Union's Earth Observation Programme, looking at our planet and its environment for the ultimate benefit of all European citizens. It offers information services based on **satellite Earth Observation and in situ (non-space) data**. The Programme is coordinated and managed by the European Commission. It is implemented in partnership with the Member States, the European Space Agency (ESA), the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), the European Centre for Medium-Range Weather Forecasts (ECMWF), EU Agencies and Mercator Océan. Vast amounts of global data from satellites and from ground-based, airborne and seaborne measurement systems are being used to provide information to help service providers, public authorities and other international organisations improve the quality of life for the citizens of Europe. The information services provided are **freely** and **openly** accessible to its users. More info at https://www.copernicus.eu/en/about-copernicus.

INTAROS has collaboration with the Copernicus Marine Environment Monitoring Service (CMEMS) regarding satellite observations as well as in situ observations in the Arctic seas. Several of the INTAROS partners play a key role in the Arctic services from CMEMS, in particular IMR who is responsible for the in situ component in the Arctic (http://www.marineinsitu.eu/about-us/).

The In Situ Thematic Assembly Centre (INS TAC) integrates near real-time in situ observation data, which mainly come from Argo floats and icebuoys that transmit ocean and sea ice data in near-real time supporting the ice-ocean forecasting system in the Arctic (http://cmems.met.no/) . Delayed mode data are also used for model validation and reanalysis studies. The data are collected from the Arctic ROOS members and complemented by the observation collected by the Global INS TAC in the area. The data are quality controlled using automated procedures. It is updated continuously and provides observations within 24-48 hours from acquisition in average.

Copernicus is a major driver for satellite-based global observing systems, which are the main providers of data in the Arctic. The in situ component, however, is provided by the countries and depend therefore on national programmes and EU-funded research projects.

Arctic Council and the working groups

The mission of the Arctic Council is described in the following way on their web-pages: "The Arctic Council is the leading intergovernmental forum promoting cooperation, coordination and interaction among the Arctic States, Arctic indigenous communities and other Arctic inhabitants on common Arctic issues, in particular on issues of sustainable development and environmental protection in the Arctic." The members are the Arctic Countries: Canada, Kingdom of Denmark, Finland, Iceland, Norway, the Russian Federation, Sweden and the United States. Other countries with interest in the Arctic can obtain Observer status. Most of the work in the Arctic Council is carried out in Working Groups. There are six different Working groups under the Arctic Council:

- Arctic Contaminants Action Programme (ACAP) responsible for increasing efforts to limit and reduce emissions of pollutants into the environment and promote international cooperation.
- Conservation of Arctic Flora and Fauna (CAFF) responsible for addressing conservation of Arctic biodiversity.
- Emergency Prevention, Preparedness and Response (EPPR) responsible for addressing various aspects of prevention, preparedness and response to environmental emergencies in the Arctic.
- Protection of the Arctic Marine Environment (PAME) responsible for addressing policy and non-emergency pollution prevention and control measures related to the protection of the Arctic marine environment from land and sea-based activities.
- Sustainable Development Working Group (SDWG) responsible for advancing sustainable development in the Arctic, enhancing the environment, economies, culture and health of Indigenous Peoples and Arctic communities, and improving the environmental, economic and social conditions of Arctic communities.

Arctic Monitoring and Assessment Program

AMAP is 'responsible for monitoring and assessing the status of the Arctic region with respect to pollution and climate change issues; documenting levels and trends, pathways and processes, and effects on ecosystems and humans, and proposing actions to reduce associated threats for consideration by governments; and producing sound science-based, policy-relevant assessments and public outreach products to inform policy and decision-making processes.' AMAP has been working for more that 25 years, analyzing data to provide assessment reports. The mandate of AMAP relies on the development of a sustained multi-disciplinary Arctic Observing System covering the ocean, land and atmosphere. This is exactly what INTAROS is aiming for.

We have had several meetings with the current Chair of AMAP, Marianne Kroglund, who is also member of the Advisory Panel of INTAROS. We have also good contact with Jan Rene Larsen (deputy secretary). There has been contact with EPPR (Jens Peter Holst-Andersen, chair of the working group) where we discussed how to better make data available. INTAROS plans to make contact also with the other Working Groups dealing with and relying on Arctic observing.

Sustainable Arctic Observing Network - SAON

In the last decade SAON has developed and attained a governance mandate to coordinate Arctic observing, extending the efforts previously done by AMAP since 1991. SAON was jointly initiated and later formalized by the Arctic Council and IASC through the 2011 Nuuk Declaration. This mandate has been renewed and reinforced through the Joint Statement of the 2016 and the 2018 Arctic Science Ministerials (https://www.arcticscienceministerial.org/en/conclusions-1740.html)

While the Arctic Council and AMAP only have members from the Arctic countries the SAON members represents the nations and organizations with specific interest in Arctic Observing. INTAROS is listed as one SAONs partners, and INTAROS is indirectly represented in the SAON board through Agnieszka Beszczynska-Möller representing Poland, Marie-Noëlle Houssais representing France and Hiroyuki Enomoto representing Japan. SAON has two committees Arctic Data Committee (ADC) and the Committee on Observations and Networks (CON). Since 2013 three Arctic Observing Summits has been organized bi-annually, with support from SAON and ISAC. The driving force behind the AOS has been US. AOS is not an organization with funding.

INTAROS is directly represented in CON and the newly established Roadmap Task Force. INTAROS has also been invited the Board meetings. INTAROS was strongly represented at the AOS 2018 in Davos. It is now planned to integrate the AOS into the SAON-CON launched by Hajo Eichen in a brief presented at the Science Forum at the 2nd Ministerial meeting in Berlin October 2018. INTAROS (Stein Sandven) is also working with the Roadmap Task Force under SAON.

The EU Arctic Cluster

The EU Arctic Cluster is a network of Horizon 2020 and a Framework Programme 7 funded Arctic projects. Currently it comprises ten projects: APPLICATE, ARICE, BLUE-ACTION, EU-PolarNet, ICE-ARC, iCUPE, INTAROS, INTERACT, KEPLER, ARCSAR and NUNATARYUK. The cluster thus merges a broad spectrum of research and coordination activities - ranging from the most up-to-date findings on permafrost and sea ice, from enhancing observation to improving predictions, and from networking research stations to coordinating access to icebreakers. The Cluster is an informal network without any committments, but is encouraged by EU to seek collaboration when it s beneficial. The network has annual meetings with focus on planning coordinated efforts within communication, stakeholder involvement, and data management. INTAROS has collaboration with several of the Cluster projects

To increase the strength and impact of the Arctic-Cluster we recommend to establish a board with members from each project. This will increase the collaboration and ownership of the Cluster. We also recommend that a Terms of Reference is established for the Cluster.

A summary of the Cluster projects are presented below:

ARICE

The main goal of ARICE is to improved access to world-class research icebreakers in the Arctic, able to operate in the Arctic Ocean outside the summer season. ARICE will develop strategies to ensure the optimal use of the existing polar research vessels at a European and international level, provide transnational access to a set of six key European and international research icebreakers (Polarstern, Oden, Kronprins Haakon, Sir David Attenborough, Amundsen, Sikuliaq) for European scientists, and improve the research icebreakers' services by partnering with maritime industry on a "ships and platforms of opportunity" programme and by exploring into new key technologies that could lead to an improvement of ship-based and autonomous measurements in the Arctic Ocean. Since access to the ice capable research vessels is the key requirement for the future sustained Arctic Observing System, all ARICE activities are highly relevant to INTAROS. Many of INTAROS partners are also involved in ARICE (AWI, IOPAN, FMI, CNRS-LOCEAN and others). More info at www.arice.eu

APPLICATE

The goal of APPLICATE is to enhance weather and climate prediction capabilities not only in the Arctic, but also in Europe, Asia, and North America. A focus on the Arctic is important for improved predictions of weather and climate in the mid-latitudes because the changes taking place in the Arctic due to climate change—the retreat of sea ice, warming seas and a warming atmosphere—have the potential to influence weather and climate in the mid-latitudes. The APPLICATE project is bringing together an international team of experts in weather and climate prediction to improve climate and weather forecasting models to work on improving prediction tools while expanding and improving observational capabilities in the Arctic. INTAROS can contribute to APPLICATE with more data from the central Arctic, especially data from ice buoys which can transmit ice-ocean data in near realtime. More info at https://applicate.eu/

ARCSAR

The overall aim of ARCSAR is to fast-track uptake of existing innovations and knowledge by practitioners, predict future needs for innovation and knowledge, and identify priorities for security and standardisation across the Arctic and North-Atlantic (ANA) region. The ARCSAR project will establish international best practice and propose innovation platforms for the professional security and emergency response institutions in the Arctic and the North-Atlantic. The project will look into the need for enhanced measures to respond to composite challenges including surveillance of and mobilization in case of threat situations, and emergency response capability related to search and rescue (SAR), environmental protection and firefighting. ARCSAR has recently started. INTAROS has not established collaboration yet, but there can potentially be collaboration between the two projects regarding observing technology, natural hazards and risk assessment for arctic operators. More info at www.arcsar.eu

Blue Action

Blue-Action will provide fundamental and empirically-grounded, executable science that quantifies and explains the role of a changing Arctic in increasing predictive capability of weather and climate of the Northern Hemisphere. To achieve this Blue-Action will take a transdisciplinary approach, bridging scientific understanding within Arctic climate, weather and risk management research, with key stakeholder knowledge of the impacts of climatic weather extremes and hazardous events; leading to the co-design of better services. INTAROS collaborates with BLUE ACTION on climate modelling work as well as on stakeholder interaction. More info on www.blue-action.eu

EU-PolarNet

EU-PolarNet is a Coordination and Support Action to develop and deliver a strategic framework and mechanisms to prioritise science, advise the European Commission on polar issues, optimise the use of

polar infrastructure, and broker new partnerships that will lead to the co-design of polar research projects that deliver tangible benefits for society. By adopting a higher degree of coordination of polar research and operations than has existed previously the consortium engages in closer cooperation with all relevant actors on an international level. INTAROS is using the documents provided by EU-Polarnet in the assessment of existing observing systems. INTAROS is also collaborating in dissemination activities at Arctic conferences and stakeholder events. More info at www.eu-polarnet.eu

ICE-ARC

This project was completed soon after INTAROS started

iCUPE (Integrative and Comprehensive Understanding on Polar Environments)

iCUPE answers to ERA-PLANET (European network for observing our changing planet) thematic strand 4 (Polar areas and natural resources). The project 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. The core idea of iCUPE is the development of novel, integrated, quality-controlled and harmonized in-situ observations and satellite data in the polar areas, as well as data products to the end users. No direct collaboration between INTAROS and iCUPE yet, but this is expected to evolve in the next couple of years. More info on https://www.atm.helsinki.fi/icupe/

INTERACT

INTERACT is an infrastructure project under the auspices of SCANNET, a circumarctic network of currently 79 terrestrial field bases in northern Europe, Russia, US, Canada, Greenland, Iceland, the Faroe Islands and Scotland as well as stations in northern alpine areas. INTERACT specifically seeks to build capacity for research and monitoring in the European Arctic and beyond, and is offering access to numerous research stations through the Transnational Access program. More info on http://www.eu-interact.org/

KEPLER

KEPLER is a Coordination and Support Action, built around the operational European Ice Services and Copernicus information providers, to prepare a roadmap for Copernicus to deliver an improved European capacity for monitoring and forecasting the Polar Regions. INTAROS collaborates with KEPLER on stakeholder interaction. More info on https://kepler-polar.eu/home/

NUNATARYUK

A main goal of NUNATARYUK is to determine the impacts of thawing coastal and subsea permafrost on the global climate, and will develop targeted and co-designed adaptation and mitigation strategies for the Arctic coastal population. INTAROS collaborates with NUNATARYUK on a case study to assess the impact of climate warming in Svalbard involving the local community in Longyearbyen. More info on http://www.nuntaryuk.org

Research Infrastructures projects contributing to Arctic Observing

Research infrastructure projects linked to INTAROS are described in this section.

European and national Research Infrastructures for observation of climate and environment represent important resources for building and maintaining observing system. They are usually operated with long-term national funding, with the objective to support research and monitoring activities. These include terrestrial stations, aircraft, ships, icebreakers and ocean/sea ice platforms. Some of the existing European infrastructures under the Theme “Environment” are partly covering Arctic areas or plan to extend to the Arctic (e.g. Euro-ARGO, ACTRIS, ICOS, EPOS). Some are established as legal entities under European law (European Research Infrastructure Consortium - ERIC), and others are in the process of becoming an ERIC.

European Strategy Forum on Research Infrastructures (ESFRI) prepares a European Roadmap for research infrastructures (new and major upgrades, pan-European interest) for the next 10-20 years, stimulates the implementation of these facilities, and updates the roadmap as needed (http://roadmap2018.esfri.eu/). The mission of ESFRI is to support a coherent and strategy-led approach to policy-making on research infrastructures in Europe.

Research infrastructure projects with relevance for the Arctic are described in the following sections.

ACTRIS

ACTRIS (Aerosol, Clouds and Trace Gases Research Infrastructure) is a pan-European initiative consolidating actions amongst European partners producing high-quality observations of aerosols, clouds and trace gases. Different atmospheric processes are increasingly in the focus of many societal and environmental challenges, such as air quality, health, sustainability and climate change. ACTRIS aims to contribute in the resolving of such challenges by providing a platform for researchers to combine their efforts more effectively, and by providing observational data of aerosols, clouds and trace gases openly. Observing stations in Svalbard and northern Finland represent the Arctic component of ACTRIS. In 2016 ACTRIS was accepted into the ESFRI Roadmap. This means that ACTRIS has been identified as a new important pan-European research infrastructure mature enough to be operational within the next ten years. INTAROS is connected to ACTRIS through the partner FMI (Sanna Sorvari) who is the coordinator of the ACTRIS PPP project. More info at https://www.actris.eu/

EMSO ERIC

EMSO - the European Multidisciplinary Seafloor and water-column Observatory is a European Research Infrastructure that includes open-ocean, seafloor observatories down to 4.850 metres depth, and shallow-water test sites from the Northeast Atlantic, across the Mediterranean to the Black Sea. EMSO became an ERIC in 2016, with the goal of ensuring long-term, sustained, continuous data streams from the ocean, the majority of the biosphere of our planet. The Arctic is not included in EMSO network http://www.emso.eu

EPOS

The European Plate Observing System (EPOS), launched in 2018 aims to support innovative multidisciplinary research is made possible for a better understanding of the physical processes controlling earthquakes, volcanic eruptions, unrest episodes and tsunamis as well as those driving tectonics and Earth surface dynamics. EPOS has a long-term plan to facilitate integrated use of data, models and facilities from mainly distributed existing, but also new research infrastructures, for solid Earth science. INTAROS has deployed Ocean Bottom Seismometers in the Fram Strait, which will contribute to the EPOS seismology data. More info: https://eudat.eu/communities/european-plate-observing-system

Euro ARGO ERIC and national contributing projects

EuroARGO is the European component of the global Argo network consisting of nearly 4,000 autonomous profiling floats drifting at set depths all over the world ocean and taking measurements of temperature and salinity from the sea surface down to 2,000 m depth. Observations are delivered via satellites within a few hours from acquisition to data centers where the data are processed and provided to users through a free and open-data access. In 2014, Euro-Argo became an ERIC (European Research Infrastructure Consortium), a legal entity that ensures its funding in the medium term through commitments of its members and observers at state level. In 2017, Euro-Argo involves 11 countries: 9 members and 2 observers. INTAROS is linked to the EuroARGO programme through partners in Norway, Poland and France (described below).

The NorArgo Infrastructure project is funded by the Norwegian Research Council (2018-2023) as a contribution to the European and global Argo programme. NorArgo is an ocean observing system for the Nordic Seas and the Arctic coordinated by Institute of Marine Research. It operates an array of ~30 Argo floats carrying various sensors (pressure, temperature, salinity, oxygen, pH, nitrate, etc.). More info at https://norargo.hi.no/

The ArgoPoland project is funded by Polish Ministry of Science and Higher Education. The project is a component of global array of temperature/salinity profiling Argo floats. The Polish Argo programme is carried out by the Institute of Oceanology Polish Academy of Sciences (IOPAN). Since 2009 our Institute has deployed twenty-one floats. Fourteen of them were launched in the Nordic Seas from the board of r/v Oceania and three in the same region aboard r/v Horyzont II. Data from Polish Argo floats will contribute with data provided by INTAROS. More info: https://www.euro-argo.eu/About-us/Euro-Argo-in-brief

The project Euro-Argo Research Infrastructure Sustainability and Enhancement (EA-RISE) is funded by the H2020 Infradev 2018-2020 to sustain the existing global ARGO array and extend its capabilities to greater depths (at least 4,000m) and to biogeochemistry (i.e. adding new sensors such as oxygen, nitrate, chlorophyll a, optics and pH). The project is coordinated by EuroARGO, includes 19 partners and will run from 2019 to 2023. The project has activities focused on using Argo floats in the partially ice-covered waters that are relevant for INTAROS. More info on: https://www.euro-argo.eu/EU-Projects/Euro-Argo-RISE-2019-2022/Overview

FRAM - FRontiers in Arctic marine Monitoring

Since autumn 2014, the Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research (AWI) has been implementing the modular observation infrastructure FRAM in the Fram Strait and in the central Arctic Ocean. The infrastructure comprises fixed - point and mobile platforms including ice-tethered and moored modules, autonomous and remotely operated vehicles. FRAM includes the two AWI long term observatories: the moorings in West Spitsbergen Current and „HAUSGARTEN“, both exisitng for more than 15 years. The platforms host clusters of sensors and samplers for multidisciplinary observations including essential ocean variables for climate, biogeochemical and ecological research. FRAM has become a major research infrastructure in the Arctic funded through the German Helmholtz Association. More information: https://www.awi.de/en/expedition/observatories/ocean-fram.html

ICOS

Integrated Carbon Observation System (ICOS) is a pan-European research infrastructure (ICOS RI) which provides harmonised and high-precision scientific data on carbon cycle and greenhouse gas budget and perturbations. ICOS RI integrates atmosphere, ecosystem and ocean greenhouse gas observations to provide timely and reliable data for research, policy making, and the general public. Presently ICOS RI has more than 100 stations in 12 European countries. The current ICOS Atmosphere and Ecosystem Networks include more than 30 atmospheric and around 70 ecosystem stations located across Europe. The ICOS Ocean Network covers the North Atlantic and European marginal seas. INTAROS contributes with ocean observations in the Arctic, north of Svalbard. More info: https://www.icos-ri.eu/home

SIOS

Svalbard Integrated Arctic Earth Observing System (SIOS) is a regional observing system for long-term measurements in and around Svalbard addressing Earth System Science questions. SIOS became a legal entity in 2018 with funding from the Norwegian government and the partner institutions. SIOS integrates the existing distributed observational infrastructure and generates added value for all partners beyond what their individual capacities can provide. Within SIOS, researchers can cooperate to access instruments, acquire data and address questions that would not be practical or cost effective for a single institution or nation alone. INTAROS collaborates with SIOS regarding data management and distribution of data from the Svalbard region. More info on https://sios-svalbard.org/

NorSOOP

Norwegian Ships of Opportunity Program for marine and atmospheric research, NorSOOP is a research infrastructure project funded by the Research Council of Norway for the period 2018-2023, with plan for extension after 2023. The objective of NorSOOP is to support oceanic and atmospheric research and observations, and to help find ways to detect and manage human impacts on the ocean. NorSOOP will

have ships that operate regularly in the North Sea, the Norwegian Sea (including coastal Norway and fjords), and the Barents Sea in the Arctic. The ships will be outfitted with state-of-the-art environmental sensors and samplers to measure physical, chemical, and biological processes in Norwegian waters. Some of the ships also have lab space available for advanced tasks and experiments. NorSOOP contributes to INTAROS with the Tromsø-Svalbard line operated by the cargo vessel MS Norbjørn. More info at https://www.niva.no/en/water-data-on-the-web/ferrybox-ships-of-opportunity/ms-norbjorn-tromso-longyearbyen

Research projects contributing to Arctic Observing

In the period from 2018-2021 there is a substatial Arctic observing taking place in a number of national and internationally funded projects. In the following we are presenting a few of them.

CAATEX

CAATEX (Coordinated Arctic Acoustic Thermometry Experiment, 2018-2022) has focus on climate change in the central Arctic Ocean, including the Eurasian Basin as well as the Canadian Basin. The project is funded by the Research Council of Norway and coordinated by the Nansen Center. The project will

1) Collect new ocean and sea ice observations covering the central Arctic Ocean
2) Obtain new knowledge about the decadal changes in heat content of the central Arctic Ocean
3) Improve our understanding of uncertainties in heat content estimates from climate models

The CAATEX observational program will be implemented using Norwegian and US icebreakers to deploy 7 moorings with acoustic and ocenaographic instruments. The CAATEX field observations will run from September 2019 to September 2020, in close coordination with the Norwegian funded HAVOC (led by M. Granskog), and in coordination with the MOSAiC drift (Multidisciplinary drifting Observatory for the Study of Arctic Climate). CAATEX will collaborate and share resources with INTAROS, regarding fieldwork, equipment, data management and dissemination. CAATEX is funded by Office of Naval Research, Defence Research and Development Canada / Government of Canada, the Research Council of Norway. More info at https://www.nersc.no/project/caatex

HAVOC

HAVOC (Ridges - Safe HAVens for ice-associated Flora and Fauna in a Seasonally ice-covered Arctic Ocean) is a research project with funding from the Research Council of Norway. The project will study the role sea ice ridges play in the thinner ice pack in the Arctic Ocean. The project will take part in the MOSAiC expedition. More into: https://www.npolar.no/en/projects/havoc/#toggle-id-1

MOSAIC

MOSAiC (Multidisciplinary drifting Observatory for the Study of Arctic Climate) will be the first year-round expedition into the central Arctic exploring the Arctic climate system. The project with a total budget exceeding 120 Million € has been designed by an international consortium of leading polar research institutions, under the umbrella of the International Arctic Science Committee (IASC), led by the Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research (AWI), Arctic and Antarctic Research Institute (AARI) and the University of Colorado, Cooperative Institute for Research in Environmental Sciences (CIRES). A total of 600 people from 17 countries, who will be supplied by other icebreakers and aircraft, will participate in the expedition – and several times that number of researchers will subsequently use the data gathered. https://www.mosaic-expedition.org

The Nansen Legacy

The Nansen Legacy consortium are formed by ten Norwegian research institutions. The research team includes interdisciplinary arctic marine expertise within physical, chemical, and biological oceanography, as well as geologists, modelers and underwater robotic engineers. Jointly they will investigate the past, present and future climate and ecosystem of the northern Barents Sea.
The Nansen Legacy is built around the new Norwegian research icebreaker 'Kronprins Haakon'. The ship-based sampling is complemented by the use of underwater robotics, year-round moored observing platforms and satellite-based observations. The Nansen Legacy runs for six years (2018–

2023), and is funded by the Research Council of Norway and the Norwegian Ministry of Education and Research. They provide 50% of the budget while the participating institutions contribute 50% in-kind. The total budget for the Nansen Legacy project is 740 mill. NOK. More information: https://arvenetternansen.com

SnowAPP

SnowAPP ("Modelling of the Snow microphysical-radiative interaction and its APPlications") funded by the Academy of Finland, and that will run in 2019-2022. FMI will participate to the SnowEx field campaign organized by NASA that will take place in Alaska/Canada at the beginning of 2020. SnowEx is a very big 5-year long terrestrial snow campaign involving a massive amount of aerial and in situ snow observations, with the purpose of improving the retrieval of snow parameters from satellites. Our SnowAPP project is also international, in the sense that, beside the participation to SnowEx, it involves snow-radiative transfer specialists from Japan, Switzerland, France, UK, and US. Objectives of SnowAPP is to develop a new model for the snow-radiative interaction that will enable significant improvement in the retrieval of snow properties from satellites and in the modelling of snow albedo in numerical weather prediction and climate models. We will have a close collaboration with ECMWF to improve their snow-radiative transfer scheme. For SnowAPP FMI will organize a field campaign in Sodankylä in spring 2019, where we will use the instruments partly developed in INTAROS WP3 (the new automatic SVC spectro-albedometer, a polarized radar, an automatic system to retrieve the snow surface roughness). The principal PI of SnowAPP is Petri Räisänen (FMI) coPI is Roberta Pirazzini. More info on http://space.fmi.fi/2019/04/08/unique-field-observations-will-improve-snow-monitoring-from-space/

DEARice

DEARice **("DEvelopment of snow/ice/ecosystem models using winter-to-summer ARctic observations of coupled snow, ice, and ecosystem processes")** was funded through the H2020 project ARICE, which aims to provide ship time to EU institutions that do not have research vessels to carry out research in the Arctic. DEARice is closely connected to INTAROS through FMI. The plan to use there the same instrumentation that is described in INTAROS WP3 to be used in ship-of-oppotunity-based campaigns. FMIs role in DEAR-ice is to provide a unique monitoring of the surface broadband and spectral albedo and surface roughness using an automatic station for broadband albedo and surface roughness and a drone for aerial measurements of broadband and spectral albedo. In particular the drone measurements will be coordinated with the helicopter-based broadband albedo measurements. PI of DEARice is Martin Schneebeli, WSL Institute for Snow and Avalanche Research SLF, Davos, Switzerland.

Greenland Ecosystem Monitoring (GEM)

Greenland Ecosystem Monitoring (GEM) is an integrated long-term monitoring and research programme on ecosystems and climate change effects and feedbacks in the Arctic, started in 1995. Glaciers and ice caps independent from the Greenland ice sheet, being located at lower elevation and closer to the sea than most of the ice sheet, account for 14-20 % of the total sea level rise contribution from Greenland. Started in 2008, the GEM GlacioBasis programme, operated by GEUS at two sites in West and North East Greenland, is currently monitoring the surface mass balance and ice flow of two ice caps through five automatic GPS and weather stations covering the entire elevation range from the summit to the lower ablation zone. The funding source is DANCEA (Danish Cooperation for Environment in the Arctic). More info on: https://g-e-m.dk/

PROMICE

The Programme for Monitoring of the Greenland Ice Sheet (PROMICE) is launched to assess changes in the mass balance of the ice sheet. The project is funded by Danish Ministry of Energy, Utilities and Climate. The two major contributors to the ice sheet mass loss are surface melt and a larger production of icebergs through faster ice flow. PROMICE is focused on both processes. Ice movement and discharge is tracked by satellites and GPSs. The surface mass balance is monitored by a network of weather stations in the melt zone of the ice sheet, providing ground truth data to calibrate mass budget

models. Note that PROMICE and GEM are both key Danish contributions to AMAP (Arctic Monitoring and Assessment Programme). More info on https://www.promice.dk/home.html

Marine Data in the Arctic (MD): from mapping to knowledge

MD will develop existing questionnaires established in the INTAROS project in order to collect and systematize information about marine observation systems, data collections, and data management systems in an efficient and repeatable manner. A method for repeatable collection and analysis of information on observation and data management systems will be developed in order to provide an updated status for observation capacity in the Arctic. The tools will be tailored to extract key information (indicators) from the responses so that we can assess the situation for key users. A survey of observation and data management systems focusing on the Arctic marine environment will be carried out. The results of the survey will be used to evaluate the usefulness of different types of marine data against user needs. This knowledge will form the basis for an action plan to improve information access and increase data collection for important environmental parameters in the Arctic Ocean. The project is funded under the Arctic 2030 programme 2018-2020 by the Norwegian Ministry of Climate and Environment. The project will provide input to the INTAROS roadmap in WP 1.

Other projects relevant for Arctic Observing

ARCPATH

The Nordic Center of Excellence project "Arctic Climate Predictions: Pathways to Resilient, Sustainable Societies" (ARCPATH) is supported by NordForsk. The objective of ARCPATH is to establish a creative, innovative and cross-disciplinary Nordic Centre of Excellence with a primary focus on the opportunities and challenges involved in promoting responsible and sustainable development in Arctic regions. ARCPATH will address the overall objective of the NordForsk call for the "Responsible Development of the Arctic: Opportunities and Challenges" with the corollary - "Pathways to Action". The overarching goals of the project are three-fold: 1) To improve Arctic climate prediction by using innovative methods to capture both anthropogenic and natural factors in global and high-resolution regional models; 2) To increase understanding and reduce uncertainties regarding how changes in climate interact with multiple societal factors including the development of local and regional adaptation measures; and 3) To supply this knowledge as potential "pathways to action" to the specific Arctic regions singled out for special focus in the project.

Barents-Risk

Barents-Risk (Assessing risks of cumulative impacts on the Barents Sea ecosystem and its services) will establish the first unifying framework for risk assessment of multiple, interacting pressures related to climate variability and change, fisheries, petroleum, transportation and invasive species in the Barents Sea. It is funded by Research Council of Norway with a total of 20 mill NOK for the period 1/-2019 to 31/12 2022 (four years). Barents-Risk is to be led by Mette Skern-Mauritzen and INTAROS WP6 lead Geir Ottersen, both IMR. Main partners are the University of Tromsø, Norwegian Institute of Nature Research (NINA), University of Hamburg, PINRO Russia, and NOAA (USA). Barents-Risk links nicely in with the work to be carried out in INTAROS WP6 on marine ecosystems and fisheries (tasks 6.2 and 6.8).

The project builds on the Ecological Risk Assessments framework and includes a structured approach to i) identify the most critical present and emerging future pressures, with extensive stakeholder involvement across sectors and with natural and social scientists, ii) apply qualitative and quantitative approaches in a hierarchical manner to assess current and future risks of cumulative impacts on ecosystem components, structure and functioning, including strengthening and weakening interaction effects, iii) efficiently and transparently communicate risks and associated uncertainties, and iv) determine how these ecological risks are linked to ecosystem services provided by the Barents Sea, and thus to societal aspects important for management, policy makers and the public in general. Interaction between natural and social scientists from Norway and abroad and close cooperation with stakeholders

from Norwegian management agencies and industry through the whole project is an essential part of Barents-Risk.

ARCONOR

ARCONOR - Arctic cooperation between Norway, Russia, India, China and US in satellite Earth observation and Education, is a project funded by the INTPART programme (under Research Council of Norway) from 2017 - 2019. The overall objective of ARCONOR is to sustain long-term international partnership and cooperation between Norway, Russia, India, China and US through advancing research, higher education and recruitment within satellite Earth observations for monitoring and forecasting of the Arctic in support of shipping in the Arctic. ARONOR organizes exchange visits, including guest lectures, for scientists, students and institution leadership among the partners. The project develops, implements and hosts summer schools and scientific workshops including the project partners and external participation. An interdisciplinary university education related to shipping in the Arctic will be developed, with focus on the Northern Sea Route. Together the partners will submit future research project proposals within and beyond the ARCONOR participation. More info on https://www.nersc.no/project/arconor

UAK - Useful Arctic knowledge

UAK (Useful Arctic Knowledge) develops long-term collaboration between Norway, Canada and USA to improve multidisciplinary in Arctic research and education. The project funded by the INTPART programme (under Research Council of Norway) from 2018 - 2020. UAK is focused on selected topics of importance to local communities and operators in the Arctic. The research and training activities are implemented through Research School, workshops and exchange visit program for PhD students, Post-Docs and senior scientists. UAK contribute to establishment of educational programs within Arctic research supporting the cross-disciplinary activities in INTAROS. In UAK addresses the following topics: Cross-disciplinary data management and integration; Natural and man-made hazards; Ocean acoustic environment; Community based monitoring; Communication between academic research groups and local communities. This project is funded by the Research Council of Norway and Norwegian Center for International Collaboration in Education. The partnership consists of Nansen Environmental and Remote Sensing Center, University in Bergen - Earth Science, Western Norway University of Applied Science, The Norwegian Meteorological Institute, University of Colorado, University of Manitoba, and University of Calgary.

NextGEOSS

NextGEOSS is a European Commission's contribution Global Earth Observation System of Systems (GEOSS), funded by the H2020 research and innovation programme under grant agreement no. 730329. NextGEOSS is a centralised European Earth observation data hub and platform, where the users can connect to access data and deploy applications. The concept revolves around providing the data and ICT resources needed, together with cloud services, seamlessly connected to provide an integrated ecosystem for supporting Earth observation based applications and services. INTAROS has close collaboration with NextGEOSS, as NERSC contributes with a sea ice case study in the Arctic, while Terradue is developing data integration in both projects. More info on https://nextgeoss.eu/about/

4. Networks and coordination activities

Polar Space Task Group

The Polar Space Task Group (PSTG) operates under the auspices of the World Meteorological Organization's (WMO) Executive Council Panel of Experts on Polar and High Mountain Observations, Research and Services (EC-PHORS). The group's mandate is to provide coordination across Space Agencies to facilitate acquisition and distribution of fundamental satellite datasets, and to contribute to

or support the development of specific derived products for cryospheric, polar, and high-mountain(1) scientific research and applications.

The PSTG shall actively seek realisation of benefits from the growing constellation of polar orbiting satellites by mobilising the unique and complementary capabilities of each of the respective participating Agencies, whether research and development or operationally oriented. In the case of the latter, the role is to support the scientific activities that may lead to improved numerical weather and climate forecasting, or development of improved operational polar products and services, to the extent that these activities fall within each Agency's mandate.

The PSTG is a successor of the successful International Polar Year Space Task Group (IPY-STG), established for the purpose of Space Agency planning, processing and archiving of the IPY Earth Observation legacy dataset. PSTG is an independent working group which reports to the EC-PHORS via common membership of its Observational Task Team. A suitable reporting mechanism shall be established to inform CEOS, CGMS and WMO Consultative Meetings on High-Level Policy on Satellite Matters on relevant PSTG progress and issues.

Membership of the PSTG is established by invitation from the WMO Secretary General and nomination by the respective Space Agency.

Objectives of the group:

- The group shall review cryosphere, high-mountain, and polar scientific requirements, including user needs and observational requirements stemming from, but not limited to GCOS, the IGOS-P Cryosphere Theme Report, the WMO Inter-Programme Expert Team on Satellite Utilization and Products (IPET-SUP), and the specific needs of the WMO Global Cryosphere Watch (GCW), the World Climate Research Programme (WCRP), SCAR/IASC and the Group on Earth Observations (GEO);
- The group shall develop a mechanism to source these requirements, through workshops, meetings, etc.;
- The group shall develop a set of key strategic goals to meet user needs and observational requirements and prioritize them considering existing Agency-specific programmes (in collaboration with the WMO Expert Team on Satellite Systems (ET-SAT)), or international project frameworks;
- The group shall develop a short-, mid- and long-term implementation strategy covering atmosphere, ocean and terrestrial domains, based on the strategic goals and requirements;
- Members shall establish commitments on behalf of their Agency to support data acquisition, and support for product development and establishment of relevant accompanying scientific studies, as appropriate for the Agency;
- Members shall participate in the joint development and coordination of mission acquisition plans with consideration of:
    - existing *in-situ* observing system infrastructure;
    - individual agency mandates and resources, including space-segment and ground-segment assets;
    - time-space distribution of planned in-situ and air-/ship-borne campaign activities;
- The group shall develop and coordinate plans for satellite data product distribution and archiving;
- The group shall develop indicators or metrics of success of data use;
- PSTG meetings shall be held at least once each year, with:
    - Intermediate Working Group meetings as needed;
    - Quarterly teleconferences as needed;
    - Standing invitation to Members for hosting meetings at their respective premises or suitable local venues.

More info on http://www.wmo.int/pages/prog/sat/pstg_en.php

Ocean networks

Global networks and JCOMMOPS

The JCOMM in situ Observations Programme Support Centre (JCOMMOPS) was established by the Joint WMO-IOC Technical Commission for Oceanography and Marine Meteorology (JCOMM) in 2001 based upon coordination facilities provided by the Data Buoy Cooperation Panel (including drifting and moored buoys), the Ship Observations Team (SOOP - XBT, TSG. ASAP - Atmospheric soundings from ships. VOS - Meteorological observations from ships) and Argo profiling float programme. JCOMMOPS acts as a focal point for implementation and operation of relevant observing platforms. The Centre which is located in Brest (France) is funded thanks to voluntary contributions from IOC/UNESCO and WMO Member States, through the marine observing programmes and panels. At present these include the following systems Argo, DBCP, OceanSITES, GO-SHIP, SOT, GLOSS. More info below and on https://www.jcommops.org/board

- **Argo:** global network of about 4000 profiling floats, transmitting data in real time when the floats are at surface, ca. every 10 days. More info on http://www.argo.ucsd.edu/ and https://www.euro-argo.eu/
- **Global drifter array** (Data Buoy Cooperation Panel) observing surface variables for distribution via GTS. Total of ca 1500 drifters, of which ≈ 100 north of 60N (Dec. 2018).
- **Moored buoy networks** (Data Buoy Cooperation Panel) providing a range of metocean variables at surface and subsurface. About 500 buoys globally, of which ≈ 300 are in national/coastal areas (Dec. 2018). Almost non at high latitudes (above 60 S and 60 N), except Station M in Norwegian Sea.
- **OceanSITES** – collects multidisciplinary data from the full depth water column at fixed depths. Focus on long-term and high frequency observations, mainly in open water. At present (De. 2018) 282 operational platforms. Data delivered to GDAC (Global Data Assembly Center), not all are delivered to GTS in real-time.
- **GO-SHIP:** Ship-based hydrography of the whole water column including physical, chemical, and biological parameters at 62 reference stations/lines covering the global ocean in the period 2012-2023. More info on http://www.go-ship.org/About.html
- **SOT** – ship observations including The Voluntary Observing Ships (VOS – weather stations), Ship Of Opportunity Program (SOOP: ocean profiles with eXpendable Bathy-Thermograph, XBT) and the Automated Shipboard Aerological Programme providing radiosonde profiles (ASAP)
- **GLOSS** – Sea level observing network, consisting of about 290 tide gauge stations, delivering data through GTS and IOC Sea Level Station Monitoring Facility (Dec. 2018). More info on https://www.psmsl.org/gloss/

In addition to the established networks described above, there are several emerging networks using new platform technologies. These include

- **Ocean gliders**, providing profiles along sections of physical and biogeochemical variables down to 1 km. Most used in research programmes, typically 30 gliders are in operation at any given time. More info on https://www.oceangliders.org/

- **Animal-borne instruments**. Satellite tracking of seal and other marine mammals is being coordinated through the MEOP consortium (Marine Mammals Exploring the Oceans Pole to Pole). Data are complementary to Argo and uses the same data transmission and dissemination system. Most of the data are collected from marine mammals in the polar regions. More info on http://www.meop.net/

- **HF-radar:** Provides realtime ocean surface current. Around 400stations are in operation in 25 countries. More info on http://global-hfradar.org/

- **SOCONET:** Surface water CO2 network based on data collected form about 50 ships and 17 moorings providing data for the Surface Ocean CO2 Atlas – SOCAT. More info on https://www.socat.info/

- **Unmanned Surface Vehicles (USV):** An increasing number of long endurance USV are becoming available for data collection. Examples are Saildrone (US), Sailbuoy (Norway), AutoNuk (UK), ASV C-Enduro (UK) and Liquid Robotics wave glider (US). The systems primarily being used/developed for research but with potential to deliver real-time met/ocean data for operational use - Saildrone data from NOAA are now exchanged on the WMO GTS

European networks: EuroGOOS, EMODNET and SeaDataNet

EuroGOOS is an international non-profit association of national governmental agencies and research organisations, committed to European-scale operational oceanography. EuroGOOS is the European component of the Global Ocean Observing System of the Intergovernmental Oceanographic Commission of UNESCO (IOC GOOS). EuroGOOS Secretariat is located in Brussels, serving 44 members and supporting five regional systems in Europe. Since February 2013, EuroGOOS is established as an international non-profit organisation in Belgium (EuroGOOS AISBL) financed by the member organisations who are all key players in ocean monitoring and forecasting in Europe. They are active contributors to the various observing networks described under JCOMMOPS. EuroGOOS operates in five regional sea areas where operational systems have been set up: the Arctic (Arctic ROOS), the Baltic (BOOS), the North West Shelf (NOOS), the Ireland-Biscay-Iberian area (IBI-ROOS) and the Mediterranean (MONGOOS). Strong cooperation within these regions, enabling the involvement of many more regional partners and countries, forms the basis of EuroGOOS work, and is combined with high-level representation at European and Global forums. More inof on www.eurogoos.eu

EMODnet (The European Marine Observation and Data Network) is a central gateway to marine data in Europe. EMODnet consists of more than 150 organisations assembling marine data, products and metadata to make these fragmented resources more available to public and private users relying on quality-assured, standardised and harmonised marine data which are interoperable and free of restrictions on use. The concept of a European Marine Observation and Data Network (EMODnet) was first launched in a Green Paper by the European Commission in 2006: "Towards a future Maritime Policy for the Union: A European vision for the oceans and seas". This concept would continue to develop until 2008 when the European Commission took the necessary steps to enable the setting up of six pilot portals conveying marine data on Bathymetry, Geology, Seabed Habitats, Chemistry, Biology, and Physics. The EMODnet Central Portal allows users to access data products from each of the thematic portals under one single interface. For example, the EMODnet Physics portal is available at http://www.emodnet-physics.eu/Portal. EMODnet is currently in its third development phase with the target to be fully deployed by 2020. EMODnet is financed by the European Union under Regulation (EU) No 508/2014 of the European Parliament and of the Council of 15 May 2014 on the European Maritime and Fisheries Fund. More info on http://www.emodnet.eu/

SeaDataNet provides a standardized infrastructure for managing the large and diverse data sets collected by the oceanographic fleets and the automatic observation systems. SeaDataNet been developed since 2006 through EU-funded research projects into an operationally robust and state-of-the-art Pan-European infrastructure for providing up-to-date and high quality access to ocean and marine metadata, data and data products by: setting, adopting and promoting common data management standards, realizing technical and semantic interoperability with other relevant data management systems and initiatives on behalf of science, environmental management, policy making, and economy. Through the ongoing SeaDataCloud project (2016-2020) the SeaDataNet Services are further advanced, increasing their usage, adopting cloud and High Performance Computing technology for better performance. More info on https://www.seadatanet.org/About-us

WMO Technical workshop, February 2019

The workshop entitled "Enhancing ocean observations and research, and the free exchange of data, to foster services for the safety of life and property" was organized at WMO Headquarter in Geneva, 5 – 6 February 2019. The workshop was a contribution to the planning phase (2019-2020) of the United Nations Decade of Ocean Science for Sustainable Development (2021-2030), *http://oceandecade.org.* The workshop was organized in conjunction with the 2018 face-to-face meeting of UN Oceans, the UN interagency coordination mechanism on ocean affairs, hosted by WMO at the Headquarters. It also entailed the demonstration of the role of the WMO-IOC JCOMM in situ Observations Programme Support Centre (JCOMMOPS) for the distribution of ocean data.

The workshop provided a state-of-the-art status reporting on ocean observing and perspectives for the next decade. The report and presentations from the workshop are available: https://public.wmo.int/en/events/meetings/technical-workshop-enhancing-ocean-observations-and-research-and-free-exchange-of

A summary of the ocean observing systems from the workshop stated the following (Ref. Jon Turton)

- Ocean observing system encompasses meteorological, physical oceanographic and increasingly bio-geochemical ocean variables
- Observing system serves a wide range of user applications, including operational weather and ocean forecasting, climate and ocean science
- Mix of operational and research funded platforms and networks, with partnerships between NMSs and research institutes internationally within JCOMM, GOOS RAs and nationally
- Relies on multiple networks/platforms for most (if not all) variables
- Coastal metocean observations mainly from moored met buoys, waverider buoys and ship-borne AWS
- Sub-surface gliders and USV are technologies well suited for coastal observations
- Wave drifters offer a new global capability

A number of challenges related to sustained ocean observing were identified, guiding the conclusion of the report:

- The issue of access within Exclusive Economic Zones (EEZs) for deploying observing system elements, or for the drift of mobile plat- forms such as Argo floats, remains a challenge and can act as a disincentive to deployment in some regions of the global ocean.
- The absence of an overarching long-term (e.g., 10-year) national plan with associated resource commitments and lack of strong leader- ship presents a challenge for sustaining U.S. contributions to ocean observing, by inhibiting effective coordination and multiyear investments in the many components of the observing system.

- The long-term investment required to develop and sustain the necessary expert workforce of the future is a challenge due to limited professional rewards or career incentives at research institutions and laboratories to ensure intergenerational succession of scientists, engineers, and technical staff.
- The limited investment in advancing technological capabilities is a challenge that, if addressed, will yield significant returns over the life- time of sustained observing platforms through development of more robust and efficient sensors and platforms and through the maturation of observing methods to address existing and new scientific challenges.
- The decreasing number of global and ocean class research vessels is creating a shortfall in the infrastructure required for sampling the global ocean and expanding data collection into poorly sampled regions such as the polar seas.

OceanObs 2019 conference white paper on Arctic Ocean observing

A community whitepaper with title: "A Framework for the Development, Design and Implementation of a Sustained Arctic Ocean Observing System" has been submitted to the OceanObs conference in September 2019, with 30 authors from USA, Europe and Asia (Lee et al., 2019). The abstract of the paper is the following:

Rapid Arctic warming drives profound change in the marine environment, including accelerated sea ice loss, ecosystem shifts and increased coastal erosion. These changes have significant socio-economic impacts within the Arctic and far beyond, including climate and weather hazards, food security, transportation, infrastructure planning and resource extraction. These concerns drive efforts to understand and predict Arctic environmental change and motivate development of an Arctic Region Component of the Global Ocean Observing System (ARCGOOS) capable of collecting the broad, sustained observations needed to support these endeavors.

ARCGOOS development must be underpinned by a broadly-endorsed framework grounded in: (i) high-level policy drivers and (ii) scientific and operational objectives that stem from these drivers. This should be guided by a transparent, internationally accepted governance structure that has recognized authority and includes organizational relationships with the national agencies that ultimately execute observing network plans. A governance model for ARCGOOS must guide selection of broad objectives, assess performance and fitness-to-purpose, and advocate for resources.

A requirements-based framework for an ARCGOOS begins with the identification of Societal Benefit Areas (SBAs), the societal requirements underpinning the system. SBAs should motivate investments and define the system's science and operational objectives. Objectives can then be used to identify key observables and their scope. Once these are defined, quantitative methods can be combined with expert input to guide ARCGOOS build-out. The domains of planning/policy, strategy, and tactics define system scope ranging from decades and basins (planning/policy) to focused observing with near real time data delivery in support of immediate human activity (tactics). Patterns emerge when this analysis is integrated across an appropriate set of SBAs and science/operational objectives, identifying a set of most impactful variables and the scope at which they must be measured. When weighted for technological readiness and logistical feasibility, this can be used to select Essential ARCGOOS Variables (EAVs), analogous to Essential Ocean Variables of the Global Ocean Observing System (GOOS) as defined by the Framework for Ocean Observing (FOO).

The Arctic presents distinct needs and challenges, demanding observing strategies that may differ from those at lower latitudes. Effective approaches for observing system design vary with system scope. Cost, traceability and ability to integrate region-specific knowledge have to be balanced, in an approach that builds on existing and new observing infrastructure. Likewise, ARCGOOS should benefit from established data infrastructures following the FAIR (Findable, Accessible, Interoperable, Reuseable) Principles to ensure cost effective preservation and sharing of the collected data and derived products. Linking to the Sustaining Arctic Observing Networks (SAON) process and involving Arctic

stakeholders, for example through liaison with the International Arctic Science Committee (IASC), can help ensure success.

Atmosphere, cryosphere, terrestrial and community networks

This section describes a few networks, programmes and projects related atmosphere, cryosphere or terrestrial topics with more or less funding where INTAROS partners are involved. Some of the networks dealing with data have also been addressed in the assessment in WP2 and some are already described in earlier sections (e.g. ICOS, ACTRIS, PROMICE).

Arctic Challenge for Sustainability (ArCS). This is a large Japanese Arctic programme operated by a consortium of institutions in Japan. The program runs for five years (2016-2020) and includes observations of atmosphere, ocean, cryosphere and other terrestrial variables in the Pan-Arctic region. ArCS is a national flagship project funded by the Ministry of Education, Culture, Sports, Science and Technology. The National Institute of Polar Research (NIPR), Japan Agency for Marine-Earth Science and Technology (JAMSTEC) and Hokkaido University are playing the key roles in this project. The project aims to elucidate the changes in the climate and environment, clarify their effects on human society, and provide accurate projections and environmental assessments for internal and external stakeholders so that they can make appropriate decisions on the sustainable development of the Arctic region. More info on https://www.arcs-pro.jp/en/about/

Greenland Climate Network. The Greenland Climate Network is an effort originally initiated through the *Program for Arctic Regional Climate Assessment* (PARCA) and has been funded since 1995 by *NASA* and the *National Science Foundation* (NSF). The GC-Net stations were primarily deployed in the period 1995-2000. Currently, some 20 automatic weather stations (AWS) are collecting climate information on Greenland's ice sheet. GC-Net was initiated as a research project and remains an independent effort supported by project funds, rather than an institutional or national monitoring effort. Data is provided on request with basic post-processing and data quality flagging. With a time span of over 20 years (some stations approaching 30 years of operation) the time series available from GC-Net are of primary importance and yet remain vulnerable in terms of funding sustainability. More info on https://www.re3data.org/repository/r3d100011010

IASOA. International Arctic Systems for Observing the Atmosphere (IASOA) activities and partnerships were initiated as a part of the 2007–09 International Polar Year (IPY) and are expected to continue for many decades as a legacy program. The IASOA focus is on coordinating intensive measurements of the Arctic atmosphere collected in the United States, Canada, Russia, Norway, Finland, and Greenland to create synthesis science that leads to an understanding of why and not just how the Arctic atmosphere is evolving. The IASOA premise is that there are limitations with Arctic modeling and satellite observations that can only be addressed with boots-on-the-ground, in situ observations and that the potential of combining individual station and network measurements into an integrated observing system is tremendous. The IASOA vision is that by further integrating with other network observing programs focusing on hydrology, glaciology, oceanography, terrestrial, and biological systems it will be possible to understand the mechanisms of the entire Arctic system, perhaps well enough for humans to mitigate undesirable variations and adapt to inevitable change (Uttal et al., 2016, https://doi.org/10.1175/BAMS-D-14-00145.1)

Polar Prediction Project. The World Weather Research Programme (WWRP) of WMO has established the Polar Prediction Project (PPP), 2013-2022, whose mission is to "promote cooperative international research enabling development of improved weather and environmental prediction services for the polar regions, on time scales from hours to seasonal." The International Coordination Office (ICO), hosted by the Alfred Wegener Institute Helmholtz-Centre for Polar and Marine Research, supports the implementation of PPP and ensures coordination with PCPI and other related activities with the aim to

advance polar prediction capabilities. The Year of Polar Prediction involves a large international and interdisciplinary network of scientists and operational forecasting centers who will jointly undertake intensive observation and modeling activities in the Arctic and Antarctic in the period 2017 – 2019 in both the Arctic and Antarctic. A number of projects and field expeditions are contribution to the enhanced activities supporting the Year of Polar Prediction, such as APPLICATE and the MOSAiC experiment. More info: https://www.polarprediction.net/background/ and https://www.mosaic-expedition.org/

Integrated Global Radiosonde Archive (IGRA). The global radiosonde network was established for operational weather service purposes. The goals of IGRA are to: 1) combine as many reliable data sources as possible into one radiosonde archive; 2) develop and apply quality assurance algorithms removing gross errors in the data; 3) implement an automatic system for updating the archive on a daily basis; 4) provide unrestricted online access to the data (Durre et al. 2006). IGRA provides a comprehensive set of radiosoundings from historical times to present, updated in near real time. Radiosoundings are provided by national meteorological institutes and transmitted over *Global Telecommunications System* (GTS). The set of sounding stations has varied over time and equipment has also been developed and changed. More information on https://www.ncdc.noaa.gov/data-access/weather-balloon/integrated-global-radiosonde-archive

Atmospheric Radiation Measurement program (ARM) is operated by the US Department of Energy, which also include cloud profiling sites in Arctic sites (Barrow and Oliktok, Alaska), Summit (Greenland) and Eureka (Nunavut, Canada). All data obtained through the ARM Facilities are monitored for quality and available free of charge through the *ARM Data Center* (https://www.archive.arm.gov/discovery/)

GCOS Reference Upper Air Network (GRUAN) consists of a global collection of stations undertaking high quality, metrologically traceable measurements of the atmospheric column. GRUAN sites in the Arctic are located in: Ny Alesund, Barrow and Sodankyla. More info on www.gruan.org

Pan-Eurasian Experiment (PEEX) is an international, multidisciplinary, multiscale program focused on solving interlinked global problems 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 backbone of the station network is based on the existing atmospheric, biosphere - ecological or urban stations. More info on https://www.atm.helsinki.fi/peex

UArctic Thematic Network in Collaborative Natural Resource Management. In the framework of INTAROS, NORDECO has established a UArctic Thematic Network on interdisciplinary training in collaborative natural resource management and monitoring in the Arctic and Sub-Arctic. As part of this effort, the project will organize an interdisciplinary course in Greenland and an experience-exchange workshop in Japan. The course aims at enhancing the capacity of people in public natural resource management positions, with a focus on community-based approaches, and MSc students to work with collaborative management and monitoring of living resources.

Svalbard Social Science Network. Based on initiative from INTAROS and other projects working on Svalbard, a Svalbard Social Science Network is being established and will have its first workshop during the Svalbard Science Conference in Oslo, on 4 November 2019. The network will create linkages and enhance the communication among social scientists and related disciplines working on/with issues concerning Svalbard. The network will facilitate the communication between scientists the local community in Svalbard.

SAON networks in USA and Canada

U.S. AON: The development of the U.S. Arctic Observing Network initiative originated from the White House Arctic Science Ministerial in September 2016, where over 25 countries and the European Union committed to strengthening and expanding observing capacity in the Arctic. U.S. AON primarily funded by NOAA's Arctic Research Program,. More info on https://www.arctic.noaa.gov/Arctic-News/ArtMID/5556/ArticleID/386/United-States-Arctic-Observing-Network

SAON Canada: Canada has established a SAON National Coordinating Committee (SAON Canada), more info on http://arcticobservingcanada.ca/SAON-homepage-English.html

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