Integrated Arctic Observation System

Research and Innovation Action under EC Horizon2020
Grant Agreement no. 727890

Project coordinator:
Nansen Environmental and Remote Sensing Center, Norway

Deliverable 1.7

Report on stakeholder interaction in year 4 and 5

Start date of project:	01 December 2016	Duration:	60 months
Due date of deliverable:	31 May 2021	Actual submission date:	31 May 2021
Lead beneficiary for preparing the deliverable:		EuroGOOS	
Person-months used to produce deliverable:		8.7 pm	

Authors: Erik Buch, Vicente Fernandez, Gro van der Meeren, Mathilde Sørensen, Stein Sandven, Agnieszka B. Möller, Mikael Sejr, Ruth Higgins, Michael Tjernstrøm, Roberta Pirazzini, Eija Asmi, Shaun Quegan, David Gustavsson, Andreas Ahlstrøm, Lena Lappanen. Geir Ottersen, Lisbeth Iversen, Marie Maar

Version	DATE	CHANGE RECORDS	LEAD AUTHOR
1.0	23/04/2019	1. version	Erik Buch
2.0	20/05/2021	2. version	Erik Buch
2.1	31/05/2021	Review and submission	Kjetil Lygre

Approval	Date:	Sign.
X	31 May 2021	Coordinator

USED PERSON-MONTHS FOR THIS DELIVERABLE					
No	***Beneficiary***	***PM***	***No***	***Beneficiary***	***PM***
1	NERSC	***0,5***	**24**	TDUE	
2	UiB	***0,2***	**25**	GINR	
3	IMR	***3***	**48**	UNEXE	
4	MISU	***0,1***	**27**	NIVA	
5	AWI	***0,1***	**28**	CNRS	
6	IOPAN	***0,2***	**29**	U Helsinki	
7	DTU		**30**	GFZ	
8	AU	***0,5***	**31**	ARMINE	
9	GEUS	***0,2***	**32**	IGPAN	
10	FMI	***0,5***	**33**	U SLASKI	
11	UNIS		**34**	BSC	
12	NORDECO		**35**	DNV GL	
13	SMHI		**36**	RIHMI-WDC	
14	USFD	***0,2***	**37**	NIERSC	
15	NUIM		**38**	WHOI	
16	IFREMER		**39**	SIO	
17	MPG		**40**	UAF	
18	**EUROGOOS**	***3,0***	**41**	U Laval	
19	EUROCEAN	***0,2***	**42**	ONC	
20	UPM		**43**	NMEFC	
21	UB		**44**	RADI	
22	UHAM		**45**	KOPRI	
23	NORCE		**46**	NIPR	
			47	PRIC	

Listed person-months (PM) include all work leading up to the deliverable.

DISSEMINATION LEVEL		
PU	Public, fully open	X
CO	Confidential, restricted under conditions set out in Model Grant Agreement	
CI	Classified, information as referred to in Commission Decision 2001/844/EC	

EXECUTIVE SUMMARY

In the light of the COVID-19 restrictions on working and meeting conditions the INTAROS Stakeholder Task Team decided to concentrate stakeholder activities during the last two years of the project on:

- Dialog meetings with relevant European Research Infrastructures
- A survey among sensor and instrument manufacturers.
- Meeting with representatives of national managing authorities.
- Attending relevant virtual conferences, webinars and networking events wherever possible

Successful dialog meetings were performed with 12 European Research Infrastructures revealing a good insight in their Arctic engagement, strategies and priorities for in situ observation, data management, focus on best practices, technology development, cooperation and coordination among themselves, funding situation and willingness to engage in future Arctic Observing System.

More than 100 sensor and instrument manufacturers were invited to respond to a web-based technology survey – disappointingly on 16 companies responded. The survey showed that there is a group of sensor and instrument manufacturers that have experience, capability and interest in participating in innovation of new technology in the harsh Arctic environment.

The marine and maritime management authorities expressed great interest in gaining environmental data from the Arctic region. Especially timeseries and trends are of importance, but also data in support of reliable ecosystem modelling was highlighted.

The INTAROS achievements have been broadly promoted by the consortium members at conferences, workshops, webinars etc. primarily via virtual technology whereby the personal contact and networking has been lost. Some relevant events have been postponed or cancelled, so the outreach activity has not been so high as in the early part of the project.

Table of Contents

1. Introduction

The INTAROS DoW includes several stakeholder activities:

- Task 1.2 – three stakeholder meetings – of which the first two has been implemented in 2017 and 2019, respectively
- WP4 – several activities toward indigenous people groups and organisation
- WP6 – several one-to-one and larger meetings with dedicated stakeholder communities
- Generally, INTAROS has an obligation to inform on its activities and achievements and specially to promote the importance of a sustained Arctic Observing System towards authorities in nations with an Arctic interest and international cooperative bodies

In order to ensure coordination of the stakeholder activities in the latter part of the project an INTAROS stakeholder Task Force was formed by the INTAROS Steering Group in Spring 2020.

A major activity and deliverable of INTAROS in the final year is the development of a "Roadmap for a future Arctic Observing System" (D1.10), and the aim of the third stakeholder meeting of Task 1.2 was to directly involve stakeholders in this process. In the early stage of planning, it was considered to organise the Roadmap kick-off meeting and the third Stakeholder meeting as joint event in autumn 2020 inviting high-level representatives from key stakeholder groups such as the science community (science teams from various disciplines); regional stakeholder groups (Europe, USA, Canada, Russia); users (service providers, private sector users (shipping, oil/gas, fishing, aquaculture, recreation) and assessment users (governmental agencies, AMAP, IPCC special report, civil society organisations, NGOs); national funders of observing systems and observation providers (in situ and satellite, public and private, scientists and community members).

This plan together with other planned stakeholder activities unfortunately had to be given up due to the COVID-19 restrictions introduced in early 2020. The INTAROS Stakeholder Task Team therefore decided, taking into account previous performed stakeholder activities as reported in INTAROS Report D1.5, to concentrate the stakeholder work during 2020-21 on:

- Organising virtual dialog meetings with relevant European Research Infrastructures since they are strong representatives for the European research community and for the Roadmap process it is relevant to have their input on:
  - Present activities and future plans in general and for the Arctic region in particular
  - Possible involvement, contribution and cooperation on the implementation of a Sustained Arctic Observing System
- A survey among sensor and instrument manufacturers. Since development of new sensor and instrument technology able to measure and deliver timely (often near-real-time) good quality in situ data from the harsh Arctic environment has been identified as a key activity necessary to build a fit-for-purpose Arctic Observing System, it is of

interest to map the sensor and instrument manufacturer community's capability and interest in participating in such developments.

- Meeting with representatives of national managing authorities to map their requirements for information, products and services to carry out their obligations.
- Attend relevant virtual conferences, webinars and networking events wherever possible to present INTAROS achievements and activities as well as collecting stakeholder requirements as input to the Roadmap process, see Appendix 1.

The present report will summarise the outcome of these activities.

2. Dialog with Research Infrastructures

A major task of INTAROS in year five is to prepare and deliver a *Roadmap for a future Sustainable Arctic Observing System*, (D1.10). The roadmap shall be based on:

- synthesis of results from INTAROS work
- national plans and strategies for the Arctic (countries involved in the Arctic Science Ministerial)
- European plans and strategies for the Arctic
- Plans and recommendations from the Arctic Council and its working groups

To address the third bullet-point the INTAROS Stakeholder Task Force organized a consultation process with relevant European Research Infrastructures to:

- Get an overview on their present activities and future plans in general and for the Arctic region in particular
- Discuss possible involvement, contribution and cooperation on the implementation of a Sustained Arctic Observing system

By Research Infrastructures is understood organisations that enable the research community to use specific facilities, resources and services in order to accelerate scientific achievements and promote sustainable research.

Due to the Corona situation the consultation process was organised as four individual virtual meetings as follows:

- Hydrosphere Infrastructures 4 February 2021
- Atmosphere Infrastructures 10 February 2021
- Geosphere Infrastructures 11 February 2021
- Biosphere Infrastructures 16 February 2021

Relevant Research Infrastructures within these four groups were invited to attend – a few did not accept the invitation. All attending Research Infrastructures came well-prepared, gave detailed and informative presentations and took part in discussions with a positive and constructive approach. In the following a short overview of the outcome of the four dialog meetings will be given attempting to reflect -when possible - the following themes which are key elements in the INTAROS Roadmap structure:

- For each Research Infrastructure
    - General description (vision, mission)
    - Arctic strategy – present and future
    - Requirements for observations
    - Implementation and operation
        - Best practices, standards and protocols
        - Technology development
    - Data management
        - Structure

        - Policy
    - Organisation, governance, economy and sustainability
    - Education and training
    - Cooperation
- General discussion

2.1 Hydrosphere Infrastructures

The meeting was attended by:

DANUBIUS	Adriana Maria Constantinescu
EuroARGO	Claire Gourcuff
JERICO	Laurent Delauney
EUROFLEETS+	Aodhan Fitzgerald
ARICE	Nicole Biebow, Veronica Willmott
INTAROS	Erik Buch (facilitator), Stein Sandven, Agnieszka B. Möller, Mikael Sejr, Ruth Higgins, and Vicente Fernandez

2.1.1 DANUBIUS

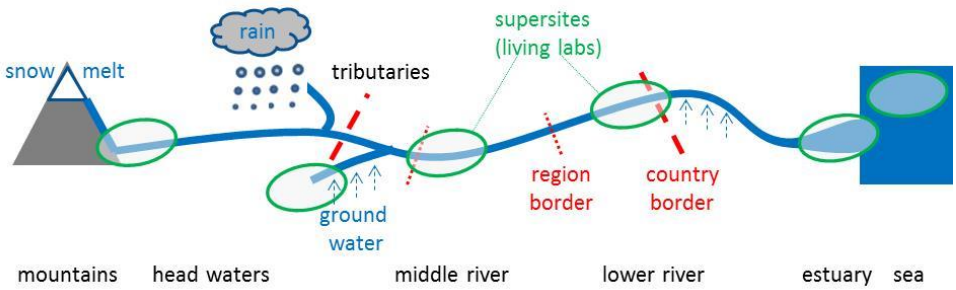
DANUBIUS-RI's Vision is to achieve healthy River Sea Systems and advance their sustainable use, in order to live within the planet's ecological limits by 2050. DANUBIUS-RI's Mission is to:

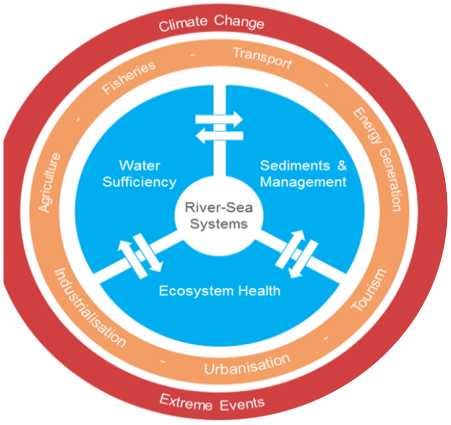
- facilitate excellent science on the river source to sea continuum;
- offer state-of-the art research infrastructure;
- provide the integrated knowledge required to sustainably manage and protect River-Sea Systems.

DANUBIUS-RI's goal is to overcome the current fragmentation of science, knowledge, data and management with respect to rivers and seas by integrating spatial, temporal, disciplinary and sectorial thinking. It will provide science-based solutions to environmental and societal challenges arising from global and climate change and will offer a source to sea perspective to resolve problems arising from human impacts on River-Sea Systems.

Many societal challenges related to River-Sea Systems are multi-faceted and require new approaches to research, spanning traditional disciplines, with a RI that:

- spans the catchment from source to coastal sea
- provides innovative opportunities for boundary spanning
- facilitates knowledge exchange
- attracts young people to science
- maximises the impact of investments in environmental research,
- driving innovation





Guiding Questions for DANUBIUS-RI are:

- What constitutes a healthy River-Sea System in the Anthropocene?
- How are River-Sea Systems changing due to multiple and interacting pressures?
- How do processes and changes in parts of the River-Sea System propagate within the River-Sea continuum, both up and downstream?
- How are these changes affecting ecosystem health, its functioning and services?
- How can we sustainably balance use, protection and development of River-Sea Systems?
- How can we define and implement a management regime that can sustain the ecosystem services of a River-Sea System?

DANUBIUS is a distributed, pan-European Research Infrastructure, and its work is implemented around the following components:

HUB:

- Hosted in Romania, in the Danube Delta
- Provides the management, coordination and communication among:
  - the DANUBIUS-RI components
  - the main DANUBIUS-RI stakeholders.
- Provides a critical role in extending capacity within Europe in river-sea systems (research and education)
- Champions the innovative distributed infrastructure to build partnerships around the world.

Observation Node:

Hosted in the United Kingdom, focuses on:

- In-situ measurements and satellite imagery integration
- *In situ* sensor networks
- Real-time observations
- Water quality
- Emergent pollutants
- Biogeochemical cycles
- Terrestrial coverage
- Standardization of field measurement equipment (in situ stations) and sampling in supersites
- Calibration
- Training

Observations are presently done in Europe i.e., no Arctic activities or plans; but the consortium is open to include observation sites in the Arctic in cooperation with relevant research groups.

Analysis Node:
Hosted in Germany, its work focuses on:

- Maintenance and updating a set of harmonized common standards and analytical techniques implemented across DANUBIUS-RI to guarantee the quality and consistency of scientific
  - methods
  - protocols
  - instruments
  - data acquisition
  - management
- Offering of scientific expertise, laboratories and instruments
- Innovative methods for biotic and abiotic conditions and interactions
- Integration of disciplines from Geology, Hydrogeology and Hydromorphology, Chemistry, Biology, Ecotoxicology and Hygiene
- Working framework for all labs working with DANUBIUS-RI

Modelling Node (hosted in Italy):
Data from the Observation and Analysis Nodes and Supersites on morphology, process type and interaction between different large-scale (basin) or small-scale hydro-morphological processes are integrated into models that:

- simulate the processes
- interpolate the measurements
- elaborate forecasts and scenarios
- provide methods and appropriate techniques that can be applied effectively in different Supersites and other locations

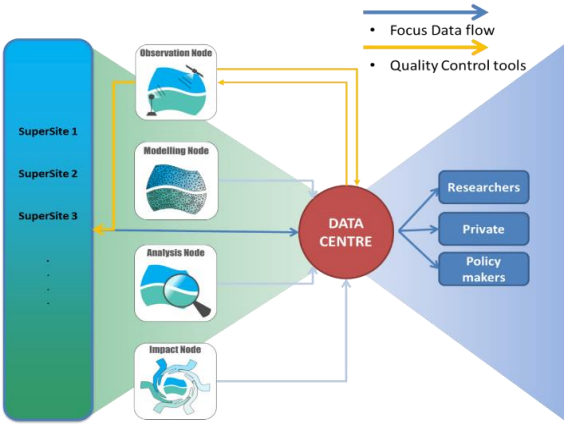
Impact node (hosted in the Netherlands):
Constitute the link between society, relevant stakeholders and the scientific community to identify requirements for future work. It integrates technical knowledge with governance and policy-making to solve problems in complex River-Sea Systems:

- resolving problems
- confronting uncertainties in making decisions
- involving stakeholders
- bringing together different disciplines from different fields
- elaborating management scenarios

SUPERSITES:

- Natural laboratories for observation, research, modelling and innovation at locations of high scientific importance and opportunity
- Covering River-Sea Systems from river source to transitional waters and coastal seas
- Ranging from the near pristine (e.g., Danube Delta) to the heavily impacted (e.g. Thames Estuary)

- Identifying, modelling and defining system states and conditions for naturally and anthropogenically triggered transitions in the physical, biogeochemical and biological state
- There are 12 Supersites across Europe, in different regions of River-Sea Systems, from the Black Sea to the Atlantic and the North Sea to the Mediterranean



Data Management:

DANUBIUS operates a Data Centre that collects:

- Digital data from:
  - remote sensing
  - automatic stations (real time and periodic downloading)
  - cruises
  - computer models
  - physical, sedimentological, chemical, biological and ecotoxicological analyses
- Non digital data (e.g., biota samples, sediments, DNA)

Digital and non-digital data are stored at distributed data repositories but data information collected by the Data Centre. Research data stored, processed and made available (open access) to participants and public.

Technological Transfer Office:

- Hosted in Ireland, it brings the intellectual property generated by the Project into public use as efficiently and effectively as possible whilst:
- protecting academic and research freedom *and*
- providing a financial return to the RI, inventors and innovators and generating economic growth and employment
- The primary objective of the TTO will be to increase the number of developments and innovations and ensure these are effectively exploited for the advantage of both individual innovators and DANUBIUS-RI as a whole

E-learning Office

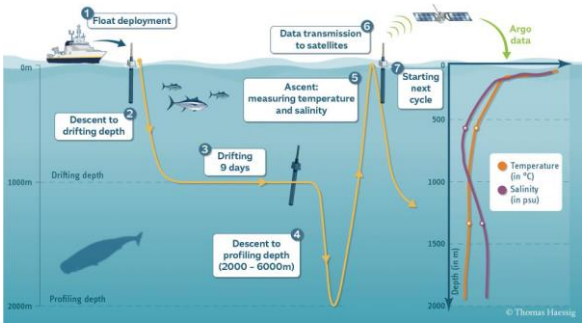
- Hosted in Spain, the e-Learning Office will use Information Communication Technology for training and education in the field of River-Sea Systems of the next generation of researchers and practitioners, including:
  - organizing Master programmes with a blended learning approach recognized by several European universities;
  - organizing courses and summer school programmes on aspects of River-Sea Systems (e.g., assimilation of data, early warning systems, solutions based on natural processes);
  - organising e-learning programmes for postgraduate students on issues in observation, analysis, modelling, and impact;
  - developing plans for Master and Doctorate research projects jointly supervised by DANUBIUS-RI Partners;

- developing ad-hoc training courses for administrators or third party interested in sustainable management; and
- offering a virtual meeting point for academia, administration and industry

DANUBIUS has partners from 17 countries in Europe, including three international organisations/programmes. The work is funded via a H2020 Grant but consortium is in the process of becoming an ERIC – application was sent in August 2020.

2.1.2 Euro-Argo

The Euro-Argo ERIC was created in May 2014 and has 12 member countries. It is composed of:

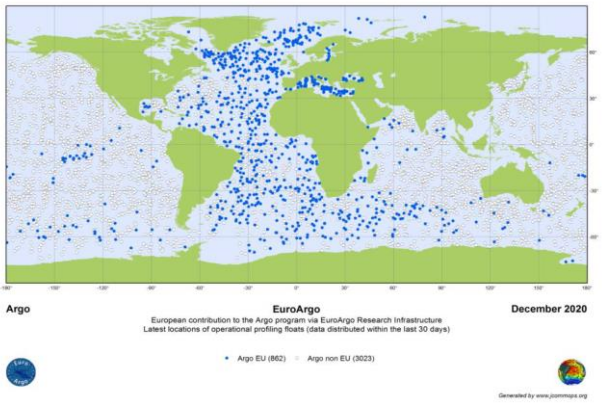


- A central unit – Euro-Argo Office that is responsible for the overall coordination of Euro-Argo. It also participates in the procurement and deployment of floats; it has expertise in all aspects of the programme, and it acts as a resource centre for all participants and users
- Distributed national facilities - that are the participating Agencies, who operate with direct national resources. As part of the Euro-Argo ERIC, they agree to a multi-annual commitment of resources (in particular in terms of floats to be deployed and for the data system), and to coordinate their activities through the ERIC Office. All resources engaged by the National Agencies in support of Argo objectives will be considered as contributions to the Euro-Argo Research Infrastructure. The participating Agencies may be called upon to perform some activities under contract from the Euro-Argo ERIC, in particular some tasks necessary for the deployment and data management of European Commission funded float

Euro-Argo allows active coordination and strengthening of the European contribution to the international Argo programme. Its aims are to:

- provide, deploy and operate an array of around 800 floats contributing to the global target of one profile every 10 days in each 3° x 3° horizontal grid box (a European contribution of ¼ of the global array)
- provide enhanced coverage in the European regional seas
- implement the new phase of Argo, with extensions towards biogeochemistry, greater depths and high latitudes
- provide quality-controlled data and access to the data sets and data products to the research (climate and oceanography) and operational oceanography (e.g. Copernicus Marine Environment Monitoring Service - CMEMS) communities

Argo must be considered in its ensemble: not only the instruments, but also the logistics necessary for their preparation and deployments, field operations, the associated data



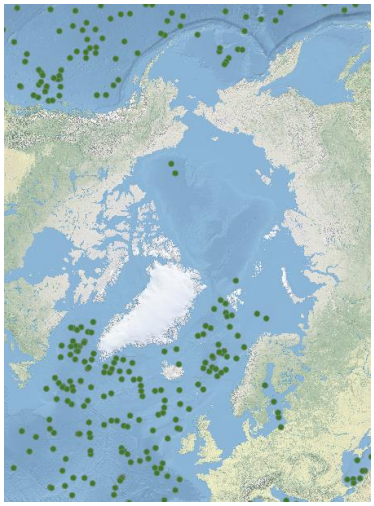
streams and datacentres. That's why Euro-Argo establishes a high level of cooperation between partners in all implementation aspects:

- operation at sea, array monitoring and evolution,
- technological and scientific developments,
- improving data access for research and operational oceanography e.g., CMEMS,
- link to the international management of the Argo programme,
- promote Argo, enlarge the Argo data user's community and help answering its needs.

The Euro-Argo currently has the means to acquire and deploy about 250 floats per annum and to monitor them appropriately. European deployment is undertaken via the efficient coordination of activities between members: the acquisition of floats is supported either by National Members or by the Euro-Argo Office through floats funded under European projects. The Euro-Argo Office offers the service of centralised float procurement at significant discounted rates, providing substantial value for members buying small numbers of floats per annum. The Euro-Argo technical team also conducts pre-deployment tests on the floats at IFREMER facilities.

The deployment of floats is carried out by Euro-Argo national members, usually in collaboration with neighbouring countries in the case of marginal seas. In the open ocean, Euro-Argo benefits from the support of international scientific collaborations.

Once floats are deployed, it is essential that critical technical parameters (i.e. energy budget, transmission power, battery voltage or data transmission) can be monitored. The Euro-Argo ERIC Office has developed an at-sea-monitoring system allowing continuous observation of floats' technical parameters. This service allows the performance of instruments to be evaluated, and malfunctions to be detected at an early stage. An alert system has been developed to trigger corrections in delayed mode in the case of sensor drifts.



The Argo floats are not in its present version well-suited for use in ice covered waters like the Arctic Ocean since they have to surface on a regular basis to send data. So, the present Euro-Argo/Argo activity in the Arctic Region is primarily limited to the Nordic Seas.

For this reason, focus is on technical modifications of standard Argo-float enabling them to work in such ice-covered waters by adapting ice-avoidance algorithms or ice detection and ice-hardened antennas. Such floats are programmed not to surface during ice covered

situations and store data to an internal memory in such situations. They will send the observations when they are able to surface. Technology for these ice floats has been developed already, and is tested under field conditions.

The standard Argo floats operate down to 2000m and only carry sensors for measuring temperature and salinity; but the ARGO community invest large resources in developing floats able to operate down to 6000m and carry several additional sensors especially biogeochemical variables.

Euro-Argo devote strong effort on delivery of data with the shortest delays possible and with extensive quality control. Hence there are real-time (order of 12hrs), and delayed mode delivery systems. The quality control procedures are the highest and most stringent for the delayed-mode data stream which is designed to deliver data of climate quality.

Formal data management procedures are implemented under the auspices of the international Argo Data Management Team. All procedures and data formats are fully compliant with recommendations from international bodies such as the WMO-IOC Collaborative Board (former JCOMM). A network of centres is in charge of collecting and processing data from the floats. All data are available to operational users via the WMO Global Telecommunication System (GTS) and also via 2 Global Data Assembly Centres internet portals for all users. Euro-Argo ensures:

- A free and open data policy relying on an organised data management system and an international community
- 100% quality-controlled dataset
- Two versions of Argo data:
    - Real Time data
    - Delayed Mode data
- NetCDF Format
- Ongoing activities towards implementation of FAIR principles for *machine2machine* access.

Euro-Argo has formulated an ambitious 5-year strategy for the period 2019-2023 focussing on observing inadequately understood regions and properties of the ocean such as Polar Regions, deep-ocean and marine ecosystems that is of paramount importance for the European community. The strategy includes five objectives:

Euro-Argo has established strong cooperation's with many relevant organisations within the field of marine observations and does also reach out for new member countries e.g. Iceland and Russia – which could be relevant for future Arctic activity

2.1.3 JERICO-RI

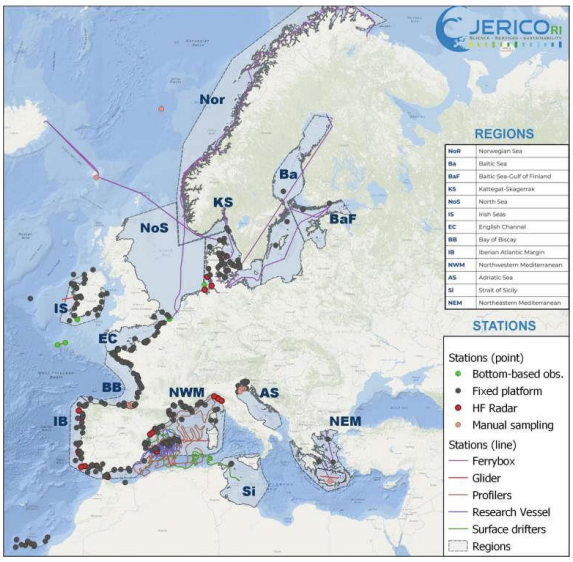
The coastal area is the most productive and dynamic environment of the world ocean, offering significant resources and services with many potentials for innovation and growth in the blue economy sectors. Coastal observations are important for improving our understanding of the complex biotic and abiotic processes in many fields of research such as ecosystem science, habitat protection, and climate change impacts. They are also important for improving our understanding of the impacts of human activities such as fishing and aquaculture, and underpin risk monitoring and assessment, but a major challenge in monitoring the coastal marine environment is to integrate observations of Essential Ocean Variables for physical, biogeochemical, and biological processes on appropriate spatial and temporal scales, and in a sustained and scientifically based manner.

JERICO-RI is an integrated pan-European multidisciplinary and multiplatform research infrastructure dedicated to a holistic appraisal of coastal marine system changes that is established and structured through JERICO-FP7 and JERICO-NEXT.

JERICO-RI, has gathered and organized key communities embracing new technologies and providing a future strategy, with recommendations on the way forward and on governance. Particularly, the JERICO-RI community acknowledges that the main providers of coastal observations are:

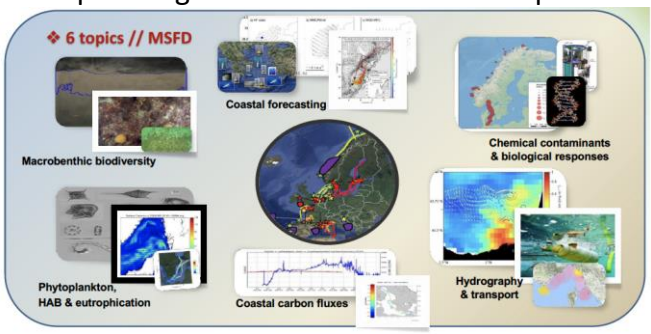
- Research infrastructures,
- National monitoring programmes,
- Monitoring activities performed by marine industries.

JERICO-RI aim to contribute to a better understanding of the functioning of coastal marine systems and thus to a better assessment of their changes caused by the combined effects of natural and anthropogenic changes. By 2030, the JERICO-RI aims to be the European gateway to long-term observations and related services for European coastal marine systems at the convergence between the land, open ocean and atmosphere; empowering European research excellence and expertise for the benefit of society.



JERICO-RI embraces emerging technologies which will revolutionize the way the ocean is observed. Developments in biotechnology (molecular and optical sensors, omics-based biology) will soon provide direct and online access to chemical and biological variables including in situ quantification of harmful algae and contaminants. Using artificial intelligence (AI), Internet of Things will soon provide operational platforms and autonomous and remotely operated smart sensors. Embracing key technologies, high quality open access data, modelling and satellite observations, it will support sustainable blue growth, warning and forecasting coastal services and healthy marine ecosystem. A substantial effort has been devoted towards establishing best practices on specific variables and instrumentations data treatment.

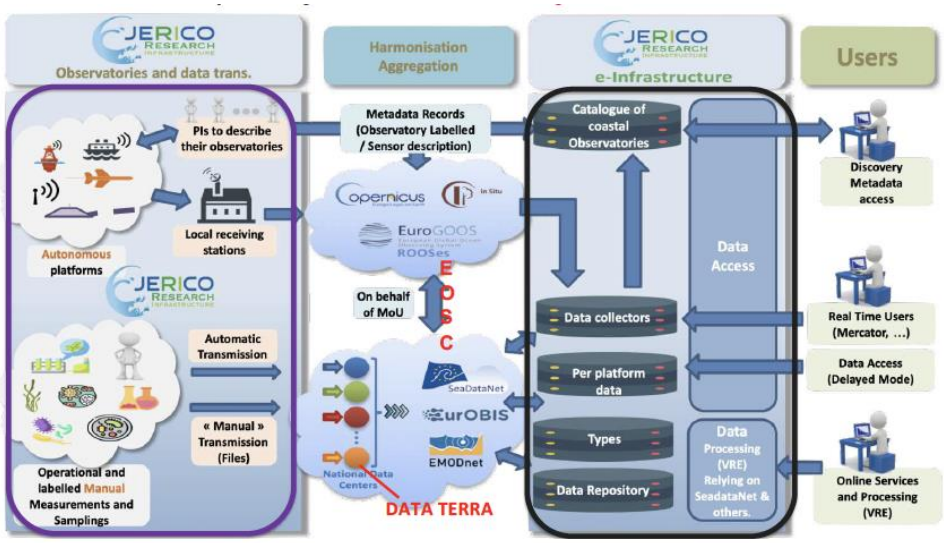
JERICO-RI has 40 partners from 19 European countries, the activities are focussing on 13 European regions where more than 500 platforms are operated. The JERICO-RI organisational setup covers the spectrum from in-situ observation, data management, delivery to data aggregation, data and product delivery to users. They have in this context established strong cooperation with other RI's and ERIC's in Europe, but have also established cooperation with similar initiatives in other continents around the Atlantic Ocean.



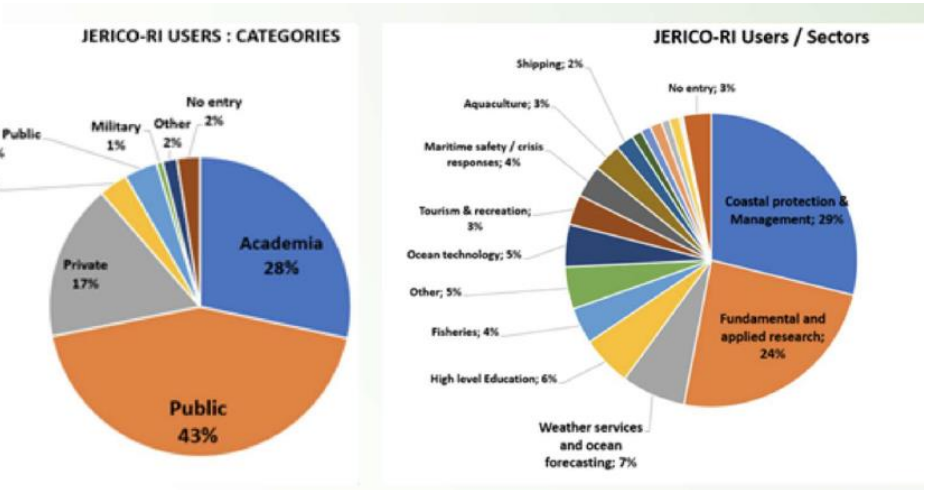
JERICO-RI do not at present have activities in the Arctic Region - except for the region covering the Norwegian coast - and it is not part of the strategy for the immediate future; but several partners of JERICO-RI do have observation activities in the Arctic so a potential for a future engagement is present.

The JERICO-RI community acknowledge the major importance of sound data management procedures, from acquisition to long-term archiving and open access following the Fair principle. For that purpose, JERICO-RI made a clear distinction between real time, near real time and delayed data. JERICO-RI has additionally proposed the creation of a JERICO-RI accreditation label acknowledging a set of criteria ensuring that some standardization and

interoperability, and the quality of data for coastal observatories are set. These include sustainability, operability and interoperability, and observing purpose. Sustainability aims to ensure the existence of a minimum time-frame during which the system is operational and observations available. Operability and interoperability aim to check that the system is following the best practices during the whole process linking data acquisition and data management.



As part of the process towards becoming an ERIC JERICO-RI has performed a substantial user survey to collect an overview of requirements for products and services and thereby requirements for observations – the result is displayed in the figure below.



2.1.4 EUROFLEETS+

EUROFLEETS+ is an H2020 project funded under the Infrastructures initiative, that brings together a significant group of key marine research actors (in particular research vessel

operators) in Europe, North America and Oceania – 42 marine institutes, universities, foundations and SMEs from 24 countries.

The EUROFLEETS+ project will facilitate open free of charge access to an integrated and advanced research vessel fleet, designed to meet the evolving and challenging needs of the user community. European and international researchers from academia and industry will be able to apply for several access programmes, through a single-entry system. EUROFLEETS+ will prioritise support for research on sustainable, clean and healthy oceans, linking with existing ocean observation infrastructures, and it will support innovation through working closely with industry.

The project will enable access to a unique fleet of 27 state-of-the-art research vessels from European and international partners. Through competitive Calls, researchers will be able to access the entire North Atlantic, Mediterranean, Black Sea, North Sea, Baltic Sea, Pacific Southern Ocean and Ross Sea. In addition to ship time, researchers will also have access to new AUVs and ROVs. In addition to comprehensive transnational access activities, the project will undertake joint research in challenging and highly relevant areas, including deep ocean research and exploration, data management, and enabling future virtual access. To maximise the impact of the project, EUROFLEETS+ will implement diverse training and education activities, strong management of innovation in collaboration with industry, and widespread dissemination and communication actions.

The EUROFLEETS+ project is a 4-year project running between 2019 and 2023, it has 42 partners. The objectives of the projects are:

- Transnational Access Applications: Priority given to research on sustainable, clean and healthy oceans
- Linking with existing ocean observation infrastructures
- Support innovation through working closely with industry
- Training & Education – emerging scientists, technicians
- Stakeholder Engagement & Legacy Road Map

with the purpose to achieve the following impacts:

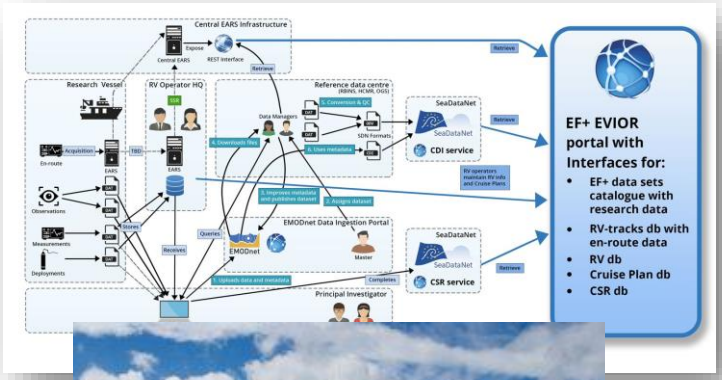
- Wider, simplified & more efficient access to the best research infrastructures irrespective of location
- Access to new of more advanced research infrastructure services enabling leading edge research
- Foster innovation through reinforced partnerships between research institutes and industry
- Development of synergies and complimentary capabilities across related research infrastructures leading to economies of scale through optimization of operations
- Education of the next generation

of researchers so that they are ready to optimally exploit all of the tools essential for their research

- Better management of the continuous flow of data collected or produced by the facilities

Important components of the EUROFLEET implementation are:

- Investigating and developing equipment and rigs for deep sea operations from vessels - exploration of the deep sea is a major challenge and opportunity in marine research. Rigs and related technologies are fundamental to the study of the sea as they are needed to deploy equipment. Therefore EUROFLEETS+ will conduct investigations concerning deep sea research from vessels aiming at achieving interoperability of rigs to be able to deploy different equipment, enabling installation of mobile equipment when needed, and facilitating sharing and installation of equipment across different ships.
- Developing innovative methods and strategies for intelligent exploration, mapping and control using cooperative navigation - innovative methods and strategies will be analysed and developed for intelligent exploration, mapping and control using cooperative navigation. New technologies will be developed for Autonomous Surface Vehicles (AUVs) and Autonomous Underwater Vehicles (ASVs) and the innovations will be validated prior to field testing during operational cruises. Focus is also on improved operational sustainability via reduced emissions from diesel engines, acoustically silent vessels, compliance in IMO Requirements and the Polar Code.



EUROFLEETS+ is actively supporting activities in the Arctic region. Since 2013 several cruises have been implemented primarily in Greenland waters and the Nordic Seas and 6 cruises are already planned for 2021 -23 period. Additionally, several of the research vessels being part of the EUROFLEETS+ perform their normal institutional operations within or at the rim of the Arctic region and 13 out of the 27 EUROFLEETS+ vessels are capable of working in ice infested waters.

EUROFLEETS+ Data Management Policy for funded cruises is subject to the FAIR data Principles, so it works towards implementation of an active open data management strategy

and associated procedures including adoption of SeaDataNet standards will ensure capture, transmission and publishing of information about the cruises, their data collection, and involved researchers, and data collected underway and processed later in time. Publication takes place through the EVIOR portal (European Virtual Infrastructure in Ocean Research – an integral part of the EUROFLEETS+ website) and the larger community SeaDataNet and EMODnet portals. The shipboard data management system, the (near) real-time transfer to shore, and the EVIOR portal for receiving and publishing metadata and data, will be advanced from their current state.

EUROFLEETS+ is working on a strategy for the period beyond 2023 which includes consideration on becoming a legal entity.

2.1.5 ARICE

ARICE (Arctic Research Icebreaker Consortium: A strategy for meeting the needs for marine-based research in the Arctic) is a H2020 funded project running from 2018 to 2022. The ARICE consortium of 14 partners from 12 different countries – 10 European plus Canada and USA. for marine-based research in the ice-covered Arctic Ocean.

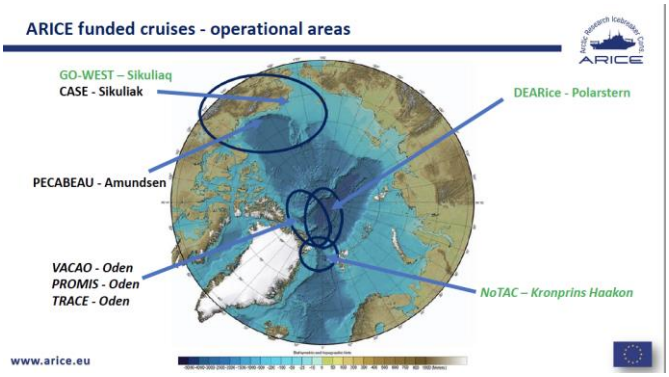
ARICE´s overall goal is to provide Europe with better capacities for marine-based research in the ice-covered Arctic Ocean.

ARICE aims at reaching this goal with the existing polar fleet by:

- Networking - ARICE will develop strategies to ensure the optimal use of the existing polar research vessels at a European and international level. The aim is to establish an International Arctic Research Icebreaker Consortium which shares and jointly funds ship time for scientists on the available research icebreakers
- Transnational access - ARICE will provide transnational access to four European and two international research icebreakers. Access is granted based on scientific excellence of the research proposals, which researchers need to submit during the application process. The participating icebreakers are:
  - PRV Polarstern, Germany
  - IB Oden, Sweden
  - RV Kronprins Haakon, Norway
  - MSV Fennica, Finland
  - CCGS Amundsen, Canada
  - RV Sikuliaq, United States of America
- Joint Research Activities - ARICE will improve the research icebreakers' services by working closely together with maritime industry on a so called "ships and platforms of opportunity" programme. Through this programme, commercial vessels operating in the Arctic Ocean will collect oceanic and atmospheric data on their cruises. At the same time, science and industry will work together to explore new technologies, which can improve ship-based and autonomous measurements in the Arctic Ocean. ARICE will also implement virtual and remote access of data via an innovative 3D Virtual Icebreaker, which will provide anyone with real-time information from the Arctic.

The work in ARICE is organised around 7 specific objectives:

1. Harmonisation of the European Arctic research fleet
    - Improve the coordination of the available heavy icebreakers, the ice-strengthened RVs and the ice-classified RVs across Europe
2. Develop an International Arctic Research Icebreaker Consortium
    - Multi-national collaboration on the planning and implementation of Arctic research cruises with heavy icebreakers
    - A European Consortium able to fund and implement cruises in the High Arctic
3. Establish a regular dialogue with the maritime industry
    - To identify opportunities for collaboration between the science community and industry
    - Implementation of the Industry Liaison Panel (ILP)
4. Educate a new generation of polar researchers and professionals
    - Targeted to PhD students, postdoctoral researchers, technicians and engineers
        - Online Training & resources for multiple audiences



        - MOSAiC School 2019 - 6-week training on board RV Akademik Fedorov during 1 stleg of MOSAiC expedition (+multiple training material, videos, etc)
        - ARICE SUMMER School 2020 & technician training - planned for summer 2020 on board of RV Heincke & at AWI Helgoland but due to COVID-19 it was cancelled and will be implemented in 2021 as online training.
5. Provide access to European and international research icebreakers in the Arctic Ocean
    - 8 project proposal out of 19 applications has been selected for funding. 4 cruises have already been implemented, the remaining cruises has been postponed due to COVID-19 and is now planned for 2021.

6. Expand the monitoring and observation capacities in the Arctic Ocean (SOP programme)
    - Use the increase in marine traffic in the Arctic to:
        - implement a “programme of ships and platforms of

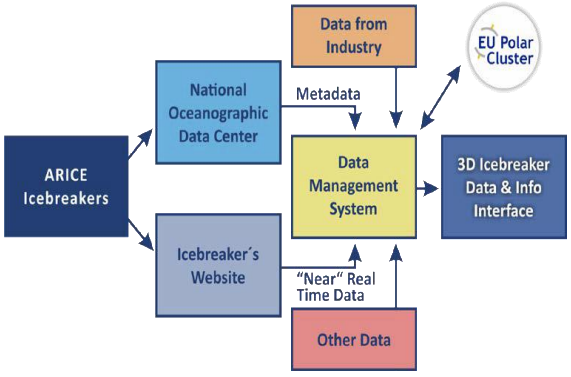
opportunity" in the Arctic Ocean
    - to identify key technologies that could lead to an improvement of ship-based and autonomous measurements in ice-covered seas
7. Enhance virtual and remote access to data
    - Establish the project data management system and develop and adapt strategies and tools for efficient data access and data dissemination
        - Data belong to the individual scientists but ARICE support open and free access to data according to FAIR principle.
    - Development of a "novel" 3D icebreaker to visualize data and research equipment.

ARICE has established cooperation with a large number of projects and since ARICE was formed out of EUROFLEET, because EU requested special focus on the Arctic, there are naturally closely linked to EUROFLEETS+.

2.1.6 Discussion

At the end of the meeting some cross-cutting items were discussed:

- Sustained funding
    - Infrastructures registered as an ERIC (legal entity) primarily rely on national contributions – financial as well as in-kind via national priorities activities. The advantage of being an ERIC is the possibility to apply for external funding.
    - The ships included in the EUROFLEETS+ and ARICE projects are operated and funded by national institutions – the two projects in principle buy/fund ship time for selected research activities. This implies:
        - Funding of the ships is fairly well sustained, however based on national priorities, e.g., some of the icebreakers within ARICE soon need replacement but this is presently not high on the agenda.
        - EUROFLEETS+ and ARICE are time-limited projects which put severe constraints on the continuity of support to research projects that need these platforms. This is especially problematic for Arctic science community since there are so few ships available that operate there. It is therefore important that the Arctic Science community unitedly put pressure on national and EU funding agencies to secure sustained availability of relevant observation platforms.



- Cooperation
    - All participants report on

cooperation with each other and other relevant infrastructures especially on best practices, joint workshops etc. This cooperation is regarded important and needed in order to establish a coordinated observing system.

- Cooperation with Russian institutions and colleagues is regarded crucial for the Arctic; but is for the time being difficult for political reasons. There are relatively good contact on a personal level, but formalised cooperation needs action on a high political level – a process that needs EU involvement.

- Requirements for observations (spatial and temporal resolution, timeliness and quality)
  - The Argo formulated during the 1990ies clear goals for spatiotemporal resolution for the traditional floats and has achieved them in large parts of the world ocean. They now work on formulating equally ambiguous goals for deep and BGC floats. They believe these clearly articulated goals has helped them in getting funded.
  - All have focus on formulating best practices on observing procedures , quality control etc. and this work is subject for coordination and cooperation between the various Research Infrastructures.

2.2 Atmosphere Infrastructures

The meeting was attended by:

ACTRIS	Eija Juurola, Paolo Laj
IAGOS	Hannah Clark
INTAROS	Erik Buch (facilitator), Michael Tjernstrøm, Roberta Pirazzini, Eija Asmi, Ruth Higgins, and Vicente Fernandez

2.2.1 ACTRIS

ACTRIS - Aerosol, Clouds and Trace Gases Research Infrastructure - is the fundamental European Research Infrastructure for short-lived atmospheric constituents increasing the excellence in Earth system observation and research and providing information and knowledge for developing sustainable solutions to societal needs.

ACTRIS establishes, operates, and develops a pan-European distributed research infrastructure for short-lived atmospheric constituents and provides effective access for a wide user community to its resources and services, in order to facilitate high-quality Earth system research.

The primary goal of ACTRIS is to produce high-quality integrated datasets in the area of atmospheric sciences and provide services, including access to instrumented platforms, tailored for scientific and technological usage and will provide:

- Information on the composition and variability and of the physical, optical and chemical properties of short-lived atmospheric constituents, from the surface throughout the troposphere to the stratosphere, with the required level of precision, coherence, and integration;
- Information and understanding of the atmospheric processes driving the formation, transformation, and removal of short-lived atmospheric constituents;
- Coordinated open physical and remote access to National Facilities for effective scientific, technological, and innovative use of ACTRIS tools and services for a wide range of users;
- Efficient open access to ACTRIS data and services and the means to effectively use our products;
- Access to enhanced data quality and state-of the-art technology; training for operators and users and enhanced linkage between research, education, and innovation in the field of atmospheric science.

ACTRIS is built on various EU-funded research projects dating to 2000, and the transnational cooperation initiated via these projects formed the basis to enter into becoming a Research Infrastructure under the ESFRI umbrella in 2016 and the preparations for becoming an ERIC which is scheduled for 2021. ACTRIS has 22 countries participating in its activities of which 17 is formal members.

The work in ACTRIS is organised around two components:

1. Central Facilities (CFs) - operate on European level and include:
    a. Head Office
    b. Data Centre (DC) - is responsible for handling the ACTRIS data. The primary role the DC is to compile, archive, and provide access to well documented and traceable ACTRIS measurement data and data products, including digital tools for visualisations, data analysis, and research. As a tool for science, the highest priority for the DC is to maintain and increase the availability of ACTRIS data and data products relevant to climate and air quality research for all interested users. All primary measurement data and produced data products are made available to the users via the ACTRIS data portal. The DC provides scientists and other user groups with free and open access to all measurements, both quality-assured data and near-real-time data, archived in interoperable topical data repositories handling diverse types of data. ACTRIS is also member of the ENVRI FAIR initiatie cooperation on easy and free access to data according to the FAIR principle.

The Main ACTRIS Variables

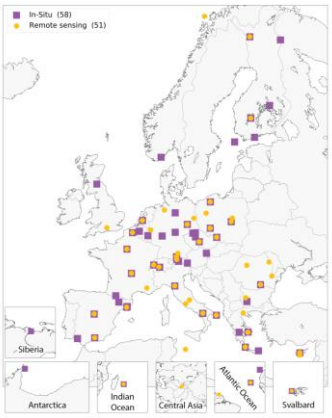
	In-situ near surface	Column Integrated	Profiling
Aerosol	Chemistry, Size, Scatt, Abs. (BC-related)	AOD (and retrived parameters)	Aerosol Extinction
Trace gases	VOC, NOx	NO_2, HCHO, O3	O_3, NO_2
Clouds	LWC, Re	LWP	LWP, Type of Hydrometeors Cloud Phase

    c. 6 Topical Centres
        i. the Centre for Aerosol In Situ - European Centre for Aerosol Calibration (CAIS-ECAC)
        ii. the Centre for Aerosol Remote Sensing (CARS)
        iii. the Centre for Cloud in-situ (CIS)
        iv. the Centre for Cloud Remote Sensing (CCRES)
        v. the Centre for Reactive Trace Gases in-situ (CiGas)
        vi. the Centre for Reactive Trace Gases Remote Sensing (CREGARS)

- The key services and operation support provided by the TCs are:
    - procedures and tools for quality assurance and quality control of ACTRIS measurements and data,
    - transfer of knowledge and training to ACTRIS operators and users,
    - c) improvements of measurement methodologies for aerosols, clouds, and reactive trace gases.
- The ACTRIS CFs represent the key operative entities of ACTRIS and have a fundamental role as they provide services to the users according to the ACTRIS access policy as well as operation support to the National Facilities (NFs) to increase their performance. Each CF may have several operational units that can be situated in the same or different locations and are operated by the more than 120 research performing organizations (RPOs). The CFs link the National Facilities, i.e., the observational and exploratory platforms, which are operated at the national level and produce the

majority of the ACTRIS data.

2. National Facilities (NF) - comprise over 200 observational and exploratory Platforms, both within Europe and at selected global sites and provide users with physical access to state-of-the-art, well-characterised and versatile facilities. NFs support long-term observations and research related to atmospheric aerosol, clouds and reactive trace gases and are:



   a. Committed to long-term operation
   b. Operated by personnel with identified expertise in running the platforms ensuring:
      i. Instrumentation follows the recommendations and is approved by the Topical Centres
      ii. Specific technical requirements are followed
      ii. Measurement methodologies and procedures are compliant with the standards of calibration, operation and quality assurance defined by the Topical Centres
      iv. Data are made available to users through the ACTRIS Data Centre

NFs can provide physical access for users, if respective capacity and expertise is proven.

ACTRIS do only have a few observation points in the Arctic and Sub-Arctic region.

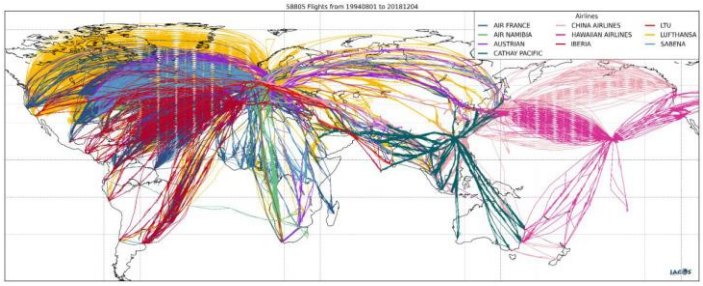
ACTRIS cooperates closely with similar activities in other parts of the world coordinated by the WMO Global Atmosphere Watch Programme (GAW). Some of them also have a few observation sites in the Arctic, but the general conclusion is that the Arctic clearly is undersampled. ACTRIS do not have any formal links to international Arctic organisations like SAON- this would be regarded valuable in the future.

ACTRIS is working towards delivery of near real-time data especially important data provision to Copernicus Atmosphere Monitoring Service (CAMS).

2.2.2 IAGOS

In-service Aircraft for a Global Observing System (IAGOS) is a European Research Infrastructure for global observations of atmospheric composition from commercial aircraft. IAGOS combines the expertise of scientific institutions with the infrastructure of civil aviation in order to provide essential data on climate change and air quality at a global scale.

The IAGOS cooperation was initiated 1994 and was formalised via a registration as an International not for profit Association (AISBL) under Belgian Law in 2014, and it has 8 member organisations.



IAGOS combines the expertise of European scientific institutions and weather services with the global infrastructure of civil aviation to provide essential data on climate

change and air quality. It builds on the scientific and technological experience gained within the research projects MOZAIC (Measurement of Ozone and Water Vapour on Airbus in-service Aircraft), which was funded by the EC between 1993 and 2004 under FP 4 and FP 5, and CARIBIC (Civil Aircraft for the Regular Investigation of the Atmosphere Based on an Instrument Container).

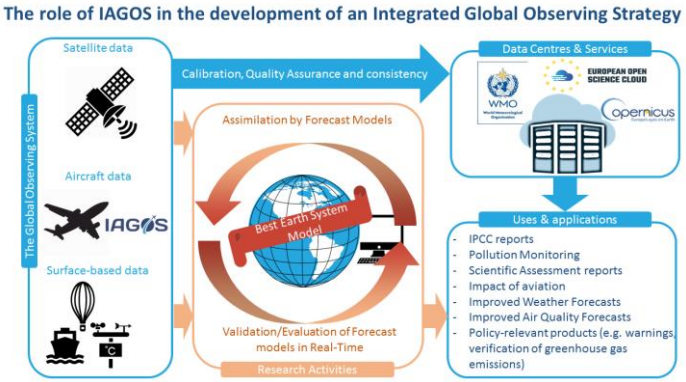
IAGOS has established cooperation with six airline companies and the observation equipment is installed in eight aircrafts that visit 330 airports around the world. In order to provide optimal information IAGOS has implemented two complementary concepts developed in MOZAIC and CARIBIC:

- IAGOS-CORE delivers continuous data on trace gases, aerosol and cloud particles from a growing fleet of aircraft providing global coverage on a day-to-day basis using 7 aircrafts where instruments is permanently installed. This provides data from around 500 flights per aircraft per year.
- IAGOS-CARIBIC observes approximately 100 trace gases and aerosol parameters from one aircraft providing a more in-depth and complex set of observations with lesser geographical and temporal coverage. This system is operated 4 times per month from one aircraft. The IAGOS-CARIBIC aircraft has now been retired due to the coronavirus pandemic and work is underway to equip an A350 aircraft.

The IAGOS Maintenance Centre provides the logistics for all IAGOS instruments. The main Task of the Maintenance Centre is to provide serviceable instruments to the airlines with airworthiness certificate to allow replacement after scheduled or unscheduled events. The replaced instruments are sent to research institutes that maintain and recalibrate them.

IAGOS observations are stored in the IAGOS Database that ensures quality controlled delivery of time and spatially resolved multi-component dataset on Essential Climate Variables and Air Pollutants. The data provide information on:

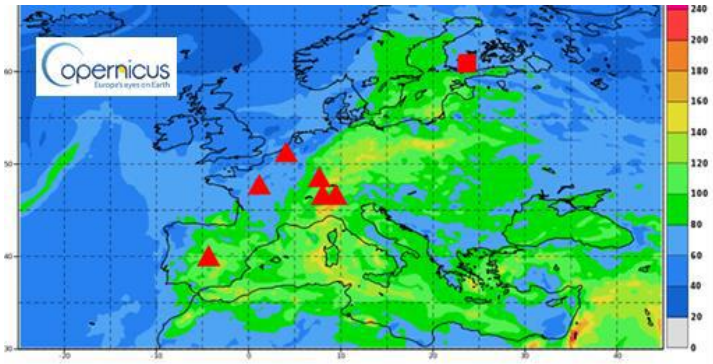
- Distribution and long-term changes in the troposphere and lower stratosphere
- Regular vertical profiles over major cities



The IAGOS Data Base is used by researchers world-wide for:

- Process studies
- Trend analysis
- Validation of climate and air quality models
- Validation of space borne data retrievals
- Impacts of aviation on climate
- Scientific publications making use of IAGOS

Use of the IAGOS data is free for non-commercial users. For operational users, particularly the COPERNICUS Atmosphere Monitoring Service (CAMS), data are provided in near real-time through the WMO Information System (WIS). IAGOS also has close cooperation with ACTRIS, ICOS and ENVRI FAIR.



The IAGOS flight routes do not cover the Arctic region due to the fact that the airline companies that IAGOS cooperate with do not have routes crossing the Arctic region. To improve this situation will require cooperation with airline companies flying over and within the Arctic using Airbus A330 or A340 airplanes. Potential airlines could be Finnair and SAS. It is believed that including observation in the Arctic region into the future portfolio of IAGOS could have the following advantages:

- Flights over Siberia are expected to provide important data on CH_4 and CO_2 emissions from Siberian tundra as predicted in a warming climate, these data can be linked to coordinated ground-based observations along the Arctic circle by inverse modelling
- Regular vertical profiles over Nordic capitals would serve as first climatology of trace species and air quality parameters at high latitudes (60 °N) and offer direct validation for SILAM (Finland), MATCH (Sweden), DEHM (Denmark), EMEP (Norway), air quality models
- Daily vertical profiles of measured parameters for Nordic capitals
- Better tracking of fire plumes across Atlantic from boreal fires
- Stratosphere troposphere exchange along polar-jet

IAGOS has fairly sustained funding via membership fee and participation in research projects.

2.2.3 Discussion

- ACTRIS is open for new countries to enter, once the cooperation with the ERIC is established – Denmark is a possible new member country which possibly mean observations from Greenland.
- It is possible for member countries to add new observations sites to the ACTRIS network. It is also possible to include data from observation points, although the site does not include the full ACTRIS observation package – this could for instance be relevant for time-limited research project field campaigns. The quality of produced data must in any case be documented and live up to the quality requirements and procedures for the variables in question.
- ACTRIS allows for different brands of instruments if the required performance and quality can be documented.
- ACTRIS is working on including data from moving platforms e.g ships, although it needs to resolve some data handling issues. This would be very relevant for the Arctic in order to obtain observations from the Arctic Ocean area.

- Airlines cooperating with IAGOS see a benefit in demonstrating their focus on environmental sustainability and contributing to monitoring of the effects of air traffic.
- The 2020 Covid-19 crisis has affected the IAGOS data collection, but not as drastic as feared, because some of the plains used in the IAGOS programme have been converted to cargo planes.
- Neither ACTRIS nor IAGOS see an urgent need for instruments improvements for use in the Arctic since they are used to work in harsh conditions:
    - ACTRIS operate station in high mountains and in subarctic environment. There may be an issue of instrument innovation in connection with establishment of remote stations e.g. seldom control visits. This could be a possible solution in the Arctic.
    - IAGOS instruments are used to cold conditions as aeroplanes fly at 10 - 12 km altitude.
- Main users of data from the two Infrastructures are academia, CAMS and GAW. Good contacts are established to the modelling and remote sensing community. The private sector is marginally using the data but some private companies use ACTRIS facilities to test instruments. There are for the time being no formal procedure for monitoring user requirements but a willingness to cooperate on this was expressed.
- Regarding observation requirements both infrastructures have clear requirements for data quality and also policies concerning time resolution. There is however no articulated spatial resolution but areas that need more observations have been identified: Arctic, Africa, South America, Indian Ocean, South Pacific etc.

2.3 Geosphere Infrastructures

The meeting was attended by:

INTERACT	Margareta Johansson
Arctic HYCOS	Alain Pietroniro, Jeffrey Karn
INTAROS	Erik Buch (facilitator), Stein Sandven, Shaun Quegan, David Gustavsson, Roberta Pirazzini, Andreas Ahlstrøm, Lena Leppanen, Ruth Higgins

2.3.1 INTERACT

International Network for Terrestrial Research and Monitoring in the Arctic - INTERACT is an infrastructure project under the auspices of SCANNET, a circumarctic network of currently 89 terrestrial field bases in northern Europe, Russia, US, Canada, Greenland, Iceland, the Faroe Islands and Scotland as well as stations in northern alpine areas. The Research stations are funded by national programmes and funds and run their own research and national monitoring programmes. INTERACT specifically seeks to build capacity for research and monitoring all over the Arctic, and is offering access to the numerous research stations through supporting the Transnational Access Program.

INTERACT is funded by EU H2020 programme and are right now in the transition between phase 2 running from 2016-2020 (extended to 2021 due to COVID-19 restrictions) having 43 partners and Phase 3 running from 2020-2023 having 63 partners. Being an Infrastructure project INTERACT is not allowed to do monitoring itself but can develop ways to improve monitoring. Infrastructure projects can work along three lines:

- Networking
- Transnational access – supporting scientists work at the research stations
- Joint Research Actions

INTERACT has registered as an International Non-Profit Organisation (INPO) and is now in the process of establishing membership, governance structure etc. Being a legal entity allows INTERACT to be a partner in various research projects.

This EU project has a main objective to build capacity for identifying, understanding, predicting and responding to diverse environmental changes throughout the wide environmental and land-use envelopes of the Arctic. This is necessary because the Arctic is so vast and so sparsely populated that environmental observing capacity is limited compared to most other latitudes.

INTERACT is multidisciplinary: together, the stations in INTERACT host thousands of scientists from around the world who work on projects within the fields of glaciology, permafrost, climate, ecology, biodiversity and biogeochemical cycling. The INTERACT stations also host and facilitate many international single-discipline networks and aid training by hosting summer schools.

INTERACT station managers and researchers have established partnerships that are developing more efficient networks of sensors to measure changing environmental conditions and the partnerships are also making data storage and accessibility more efficient through a single portal. New communities of researchers are being offered access to terrestrial infrastructures while local stakeholders as well as major international organisations are involved in interactions with the infrastructures.

The trans-national access component is crucial to building capacity for research in the European Arctic and beyond. INTERACT is offering transnational access to 53 research stations located in the Arctic, and northern alpine and forest areas in Europe, Russia and North-America. It is providing opportunities to researchers to work in the field in often harsh and remote locations that are generally difficult to access. In return, the input of new researchers has led to cross fertilisation, comparative measurements at different locations and new research directions at the individual infrastructures. There is an annual call for proposals to use this facility and INTERACT is allowed to define the priorities or focus areas e.g., INTERACT wishes to put focus on permafrost monitoring in the coming years. As part of this activity INTERACT has managed to establish important science diplomacy resulting in cooperation and data sharing between partners from all Arctic nations incl. Russia (not all Russian data are accessible).

Under the Joint Research Action INTERACT engaged in:

- Developing technology and procedures for sampling from lakes using drones in cooperation with the drone manufacturer.
- Developing standardised biodiversity monitoring in cooperation with CAFF on three reference stations. This development included:
    - Test the Freshwater & Terrestrial Monitoring Plans in the field
    - Identify existing biotic and abiotic monitoring
    - Identify monitoring gaps
    - Develop a data management plan for the Rif station (Iceland)
    - Develop a user manual for implementing CBMP at INTERACT stations

Data collected by scientists using the INTERACT facilities belong to the scientists and their home organisation. It has turned out that many of these do not have a proper data management plan or facility, so INTERACT has developed a data management guide providing basic guidelines for handling data and ensuring free accessibility. INTERACT has additionally over the past years developed a data portal that will be officially launched during the Arctic Science Summit Week 2021.

2.3.2 Arctic HYCOS

The Arctic-HYCOS is a component of the World Hydrological Cycle Observing System, WHYCOS, which was launched in 1993 by WMO in co-operation with the World Bank. WHYCOS is a worldwide network of key stations linked with a quality controlled data base.

The Arctic-HYCOS is the core network for the monitoring of the Arctic Hydrological Cycle (AHC) and will serve as a key component within the IPY endorsed project Arctic HYDRA: The Arctic Hydrological Cycle Monitoring, Modelling and Assessment Program. This system will provide an important benchmark for understanding future change to the AHC; information essential to the longer term ICARP-II WG7 Program. The project aims to collect and share hydrological data and information for the transnational Arctic basin, which includes the Arctic Ocean, Northern Seas, and land areas of contributing streamflow (to ~45°N).

Arctic HYCOS is led by a Project Steering Committee (PSC) composed of one representative from each Arctic Council Member State, principally coming from the National Hydrological Service, WMO Executive Council Panel of Experts on Polar Observation, Research and Services (EC-PORS), WMO Hydrology and Water Resources Programme and Global Runoff Data Centre (GRDC). The first annual PSC meeting was held in Geneva in 2014, after initial discussions dating back to 2000.

The objectives of Arctic-HYCOS are to:

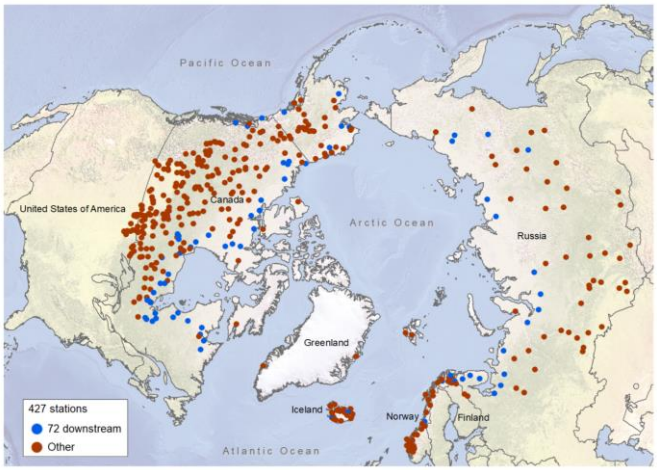
- Establish and operate regional networks for measuring basic hydrological components within the territory of the Arctic drainage basin. Existing observation networks should be fully utilized and the decline of networks in some countries should be counteracted.
- Establish and operate a hydrological information system. The information system shall generate and provide regularly reliable data on the hydrological cycle, and information needed for water resources management and research. Data management practice must respect the WMO Resolution 25 on hydrological data exchange.
- Provide reliable assessment of freshwater inflow and energy flux into the Arctic Ocean in both the short and longer term. Long-term objectives should include sediment transport and other selected water quality parameters.
- Assist National Hydrological Services (NHSs) in the Arctic region with regard to improved data management, hydrological observation methodology and generation of information products by adopting international standards.
- Facilitate co-operation among countries sharing the same water resources.
- Stimulate international co-operation in studying and assessing hydrological processes in the Arctic, in particular those related to climate change.
- Serve as a contribution to other Arctic observation systems, in particular to research groups and monitoring programmes dealing with Arctic snow hydrology, permafrost, glaciers and glacial runoff.
- Serve as a contribution to Global observation systems, in particular to the Global WHYCOS network, GOS, STOS, GCOS and GTN-H.
- Improve methods for hydrological computations and forecasting in poorly gauged basins, thereby contributing to solving scientific as well as applied problems.

The project implementation focuses on regularly collecting, managing and sharing high quality hydrological data from a defined Basic Network of Hydrological Stations (BNHS) in the Arctic basin. The network includes stations collecting the following data:

- daily discharge data; and
- daily water temperature data.
- Both quality assured historical data and provisional near real-time data
- Data to be shared freely in an online database

The station lists were created from existing stations of the national hydrological networks in the Arctic basin:

- Hydrological Regime Network A: Stations suited to study changes in the Arctic hydrological regime (covering the entire land mass draining into the Arctic Ocean and northern seas)
- Flow-to-Ocean Network B: Freshwater Flux to the Arctic Ocean (the most downstream stations, but restricted to stations with a drainage area >5000 km^2)



The network consists of totally 428 station of which 72 are flow-to-ocean stations, but as seen on the above figure the density of station varies and there are severe gaps e.g. Greenland.

The WHYCOS data policy states that countries are the owners of the data they generate and that the respective National Hydrological Services are responsible for the validation of their data in accordance with national regulations and for making data available via the Global Runoff Data Centre (GRDC) that provides the central depository for all Arctic-HYCOS data and metadata. Data from the 428 stations on the station list are already included in the GRDC's Arctic Runoff Data Base (ARDB) and are from there fed into the Arctic-HYCOS web portal (https://hydrohub.wmo.int/en/projects/Arctic-HYCOS) that offers:

- Free and unrestricted access to data and metadata
- Metadata to sort/filter stations and download subsets
- Data hosted by GRDC but accessed through this "window"

Arctic-HYCOS aims to provide a list of recommended practices and procedures to be considered for adoption by all Arctic-HYCOS countries. This document could serve as a reference document for all cold climate countries and may also lead to potential improvements to existing WMO standards and recommended practices and procedures. The set of practices and procedures will:

- Summarize and recommend standard international practices for hydrological data collection in northern environments
- Currently review standard procedures to includes:

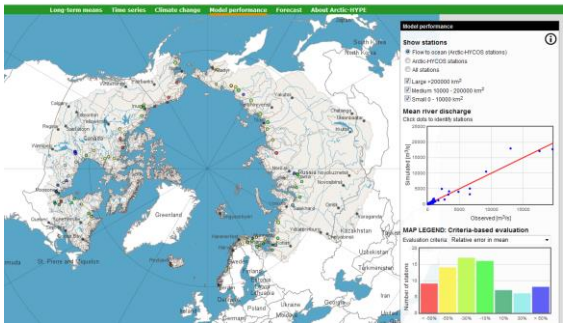
    - flow estimation techniques during ice covered conditions
    - Water temperature monitoring
    - River and lake ice: ice-thickness, freeze-up and break-up dates
- Address future work:
    - measurement of flow using hydro-acoustics (under-ice)
    - metadata definitions and standards

A trend analysis using Arctic-HYCOS data revealed a general increase in freshwater flow to the Arctic between 1975 and 2015, with this increase being more prominent from the Eurasian rivers than from the North American rivers:

- Annual discharge increase:
    - Total flow to the Arctic Ocean and related waterbodies = 8.7 $km^3/y/y$
    - Direct flow to Arctic Ocean (AO) = 5.8 $km^3/y/y$
- Cumulative discharge increase in 2015 compared to 1975:
    - 357.6 km^3/y to the Arctic Ocean and related waterbodies (11.9% increase in mean Q)
    - 239.6 km^3/y in direct discharge to the Arctic Ocean (11% increase in mean Q)

A pan-arctic application of the Hydrological Predictions for the Environment model (Arctic-HYPE) was developed as a contribution to the Arctic-HYCOS project to run hydrological forecasts of flow to the Arctic Ocean:

- Developed by SMHI in collaboration with U Manitoba and Melnikov Permafrost Institute (http://hypeweb.smhi.se/)
- Semi-distributed catchment based multi-basin hydrological model
- Forcing hydrological and meteorological data for 1961 – present, assimilating Arctic-HYCOS station discharge data
- Model key water storages and fluxes in the Arctic Ocean drainage basin:
- Explain observed trends in river flow (hydrological regimes)
- Estimate flow in non-gauged basins (flow-to-ocean)
- Daily hindcasts and 10-day forecasts have running since June 2017



2.3.3 Discussion

- Water quality parameters (carbon, oxygen, nutrients) are not at present part of the Arctic-HYCOS programme, but are certainly something that needs attention in the future. This has to be argued via WMO and/or directly to the members of Arctic-HYCOS.
- There are more hydrological stations in Greenland than the two presently part of Arctic-HYCOS, but they are operated by a Greenland organisation that has

a restrictive data policy, so data are not freely available

- Getting access to Russian data has also been challenging since Russia has a rather restrictive data policy, but Arctic-HYCOS managed over 2-3-year period to include a number of Russian stations into its network.
- At the moment there are no discussions on the spatial resolution of the hydrological station network within Arctic-HYCOS. The existing network is based on existing stations that member countries operate and are willing to share data from. The modelling initiative may however open a discussion of this issue in order to get enough measurements from representative locations up-stream as well as downstream to assimilate into and validate the models.
- Arctic-HYCOS find the present instrument technology suited for its purpose.
- It has proven hard to use modelled precipitation data in the hydrological work because of the poor quality of model forecast of precipitation. The situation improves when using reanalysis model data.
- Many of the INTERACT stations are manned year-round and could therefore easily be included in a plan for an Arctic Observation System, e.g. for meteorological observation. Most stations do actually perform meteorological observation but not in a structured way – some follow the procedures from WMO/National Meteorological Institutes but not all; but it is on the INTERACT agenda to set up recommendations to follow the same and official procedures.
- There is a need to develop new technologies and instruments for Arctic monitoring, especially automated stations could be very useful in the future. INTERACT is involved in some testing of new technology. It was pointed out that it is problematic to replace an existing long time series of observations obtained with manned observation technology with an automatic technology.
- INTERACT is involved in the SAON ROADS process; but could wish for speed in the process.

2.4 Biosphere

The meeting was attended by:

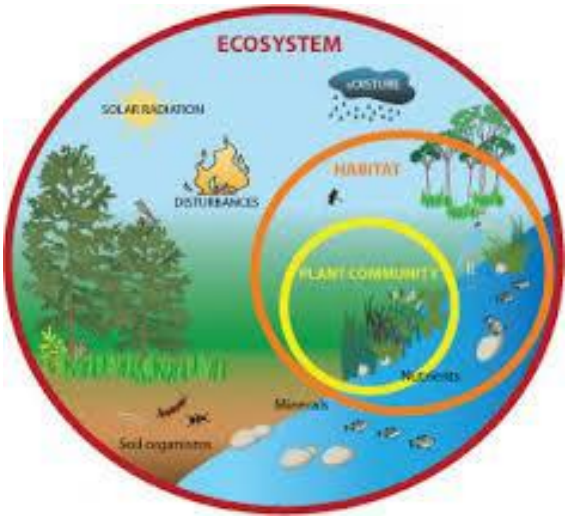
LifeWatch Eric	Christos Arvanitidis
EMBRC Eric	Nicolas Pade
INTAROS	Erik Buch (facilitator), Stein Sandven, Geir Ottersen Gro van der Meeren, Ruth Higgins

Representatives from eLTER RI was unable to attend the meeting so a separate dialog meeting took place 18 March 2021 between Jaana Bäck, eLTER RI and Erik Buch, INTAROS

2.4.1 LifeWatch Eric

LifeWatch ERIC is a European Infrastructure Consortium providing e-Science research facilities to scientists seeking to increase our knowledge and deepen our understanding of Biodiversity organisation and Ecosystem functions and services in order to support civil society in addressing key planetary challenges.

In setting up LifeWatch ERIC, the EC is seeking to address, by means of long-term investment, the global factors (climate, demographic pressure, pollution, soil consumption, etc.) responsible for ongoing loss of biological diversity and ecosystem functioning, with direct impacts on the well-being and development of today's society. Understanding the evolution and functions of biodiversity and ecosystem services is now of crucial importance, not only for scientific reasons, but also to meet the demand from policy makers, managers and stakeholders for scientific-based tools. This requires analysis of both impacts and managerial decisions on a range of spatial and temporal scales; observation (and monitoring) of data from both ecosystems and laboratory experiments; and appropriate storage and management of relevant data. It also implies the setting of standards to ensure interoperability and accurate models of ecosystem dynamics.



LifeWatch seeks to understand the complex interactions between species and the environment, taking advantage of High-Performance, Grid and Big Data computing systems, and the development of advanced modelling tools to implement management measures aimed at preserving life on Earth.

Combining a wide range of ICT tools and resources with deep knowledge of the domain, LifeWatch's mission is to be a "first class" worldwide provider of content and services for the Biodiversity research community by:

- Offering new opportunities for large-scale scientific development
- Enabling accelerated data capture with innovative new technologies
- Supporting knowledge-based decision-making for biodiversity and ecosystem management
- Providing training, dissemination and awareness programmes.

LifeWatch is organised as a distributed research infrastructure consortium founded by seven European Member States. Its structure mirrors its nature, with central components and Common Facilities located in three Member States:

- Lecce, Italy – Service Centre
- Sevilla, Spain – statutory and ICT e-infrastructure technical office
- Amsterdam, Netherlands – virtual laboratories and innovation centre

Additionally, there are national nodes in all other member countries. LifeWatch's current members are Belgium, Greece, Italy, Netherlands, Portugal, Slovenia, Spain. Furthermore, Slovakia participates as an observer.

LifeWatch relies on a multi-level governance model to ensure effective decision-making, smooth management, scientific soundness and transparency of processes. The infrastructure includes two main Statutory Bodies to carry out these functions:

- The General Assembly, the highest governing body, in charge of the overall direction and supervision of infrastructure activities
- The Executive Board, responsible for day-to-day management, ensuring the consistency, coherence and stability of infrastructure services and coordination between the Common Facilities and Distributed Centres.

These are supported by four Subsidiary Bodies:

- The Standing Committee, supervising the management of LifeWatch-ERIC
- The Financial Committee,
- The Scientific and Technical Advisory Board,
- The Ethics Committee.

The activities of LifeWatch are funded via member fee's, in-kind contributions from member and participation in research projects.

LifeWatch's work is concentrated on addressing the following challenges:

- Modelling Biodiversity on Earth
  - Mapping of diversity, biomass, productivity
  - socio-economics (including Ecosystem Services)
  - Patterns, processes and consequences from change
  - Prognosis under certain scenarios
- VRE: Virtual Research Environment
  - e-Services (electronic services)
  - vLabs (virtual laboratories)
  - Computational capacity and storage unlimited space
  - "Incubation chambers" for technology developed in projects
  - Transparency in scientific research practice
- Culture
  - Shift scientists' attitude from working in isolation, on single-core PC's into using and benefiting from an ecosystem of web services available on www.lifewatch.eu with the capacity to scale up researchers' interest and work on global hypotheses, ensuring transparency, repeatability and

attribution of their endeavour

The LifeWatch provides:

- Accessibility and use of data, services and VRE's according to FAIR principle
- Engagement, tracking, accounting and securing biodiversity and ecosystem resources and service provision through the LifeWatch ERIC blockchain platform
- Cloud and computational power and storage capacity to create models for future scenarios
- Support to smart ecosystem management in context of climate change using innovative technologies like deep learning and artificial intelligence
- Facilities for citizens to engage with science and contribute to their own well-being
    - Training opportunities on services and scientific issues
    - Master and PhD programmes
    - Summer schools
    - Webinars
    - Educational initiatives
    -

LifeWatch has decided to boost its construction and to engage users in developing their research activities into the Virtual Research Environments of the e-Science Infrastructures, by clearly demonstrating and documenting the added value these new technologies bring to address challenging hot topics. LifeWatch has therefore started an Internal Joint Initiative with the exact aim of addressing these needs and reinforcing the positioning of LifeWatch ERIC within the biodiversity and ecosystem scientific community. As a subject for the demonstration case, LifeWatch has selected non-indigenous and invasive species (NIS). Essential to this work is cooperation with many other European Research infrastructures.

Some member country institutions have interests and responsibilities in the Arctic, so Arctic issues are included in the LifeWatch portfolio

Future priorities of LifeWatch are:

- Develop LifeWatch common facilities in a fully operational mode;
- Construct and operate the urgently needed distributed and federated infrastructure in order to integrate, organically link and make all the web services developed by the national biodiversity centre's available through a single stop-over spot;
- Bring back and unite the much fragmented scientific and other type of biodiversity and ecosystem functioning user communities to their natural home, the LifeWatch Research Infrastructure;

2.4.2 EMBRC ERIC

The European Marine Biological Resource Centre (EMBRC) was established in 2013 and registered as an ERIC in 2018 to advance fundamental and applied marine biology and ecology research – while promoting the development of blue biotechnologies. This is achieved by enabling access to services, facilities, and technology platforms in its 45 marine stations in 9

European countries in support of robust, cost-effective and efficient research. EMBRC work across a wide range of marine biology areas and with diverse stakeholders including users from academia, industry, technology and education.

The vision of EMBRC is to develop a better understanding of the connections between marine systems, humans and the environment to develop 'blue solutions' to society's grand challenges such as climate change, food shortages, and new treatments and drugs. This will be addressed via promotion of the sustainable use of marine resources; deepen the fundamentals of knowledge on marine organisms and ecosystems; promotion of the use of marine experimental models in mainstream science, and raise the profile of marine biological sciences. EMBRC provides:

- Access to Ecosystems and biodiversity from Arctic to tropical, coastal to deep sea
- Access to research facilities & platforms enabling research close to source of marine resource experimental facilities (aquaria, mesocosms), technical and analytical platforms
- Development of tools & techniques Cryopreservation, husbandry, genomic tools, experimental systems, omics observation

EMBRC can be regarded as a multi-disciplinary RI addressing two important areas:

- "Life Science RI" supporting fundamental biology, physiology, evo devo, gene expression, bioprospecting:
  - Culturing of marine models & maintenance of organisms
  - Supplying micro-organisms for experimental purposes
  - Development of post genomic tools
- "Environmental RI" Environmental science, conservation, climate change impact, biodiversity, ecology:
  - In situ & ex situ experiments
  - Scientific diving teams
  - Maintenance and study of collected samples

EMBRC is organised around providing six services:

- Biological resources - the provision of marine biological resources for research purposes
  - Sampling upon request
  - Culture collections
  - Preserved samples collections
  - Biobank material

- Ecosystem access – EMBRC provides access to a range of marine ecosystems, including kelp forests, coral reefs, intertidal rocky shores, lagoons,

mudflats, deep sea environments as well as planktonic and pelagic communities. Access to ecosystems is provided through the following platforms
    - Coastal research vessels
    - Scuba diving facilities
    - Submersibles (ROVs, AUVs9
    - Sampling facilities and equipment
- Experimental facilities – provides access to modular experimental facilities, and can accommodate a wide breadth of experimental designs, for research, education, and training activities. The facilities include:
    - Aquaria and mesocosms
    - Wet laboratories
    - Dry laboratories
    - Climate rooms
    - Field experiments (in situ experimental platforms)

- Technology platforms - provides access to the latest technologies in support of on-site research projects and include
    - Biological analysis
    - Imaging
    - Molecular biology and omics
    - Structural and chemical analysis
    - Remote sensing and telemetry
- Training and Education
- Supporting facilities - offers a large range of supporting facilities to facilitate long visits and projects, offering lodging and catering close to the laboratories, conference and meeting facilities

EMBRC has presently only limited activity in the Arctic.

EMBRC presently focuses several of its activities on a "flagship" project "European Marine Omics Biodiversity Observation Network – EMO BON focussing on:

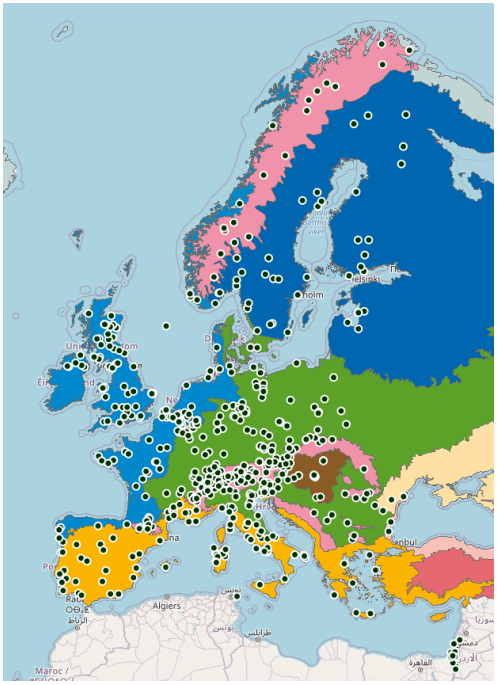
- Establish first coordinated, long term Marine Omics Observatory in Europe
- European contribution to international networks, such as GLOMICON, contributing to:
    - Quality controlled, baseline genomic biodiversity data
    - Essential Ocean Variables (EOVs) monitoring
    - Microbiome research
    - Ensure continuity element between project-based monitoring at sites
- Build European Omics Observation community and contribute to global community

EMBRC seeks close cooperation with other relevant Research Infrastructures in Europe to implement EMO BON and make it a success, and will explore possibilities for cooperation outside Europe.

Data generated by the EMBRC cooperation will go to existing databases and will be freely accessible.

2.4.3 eLTER

In a world of global *Grand Challenges*, multiple stressors act at different temporal and spatial scales with significant losses of biodiversity and ecosystem functions that eventually affect human life. While in the short-term such effects are well studied, little is known about long-term and systemic effects and cross-scale interactions. Closing these knowledge gaps requires a deep understanding of the multifaceted environmental system in order to develop appropriate mitigation measures.



The Long-Term Ecosystem Research in Europe (eLTER) is a new distributed Research Infrastructure, which aims at integrating traditional natural sciences and holistic ecosystem research approaches, including studies of the human component, to better understand ecosystems. Through research and monitoring, eLTER seeks to improve our knowledge of the structure and functions of ecosystems and their long-term response to environmental, societal and economic drivers.

The eLTER cooperation is supported 26 countries that operates around 450 sites distributed all over Europe, these sites constitute the foundation for the eLTER activities. Approximately 60 of the 450 sites are situated north of 60°N and can therefore be regarded as Arctic stations. The operation of the sites is a national responsibility.

The eLTER cooperation dates back to 2006 but the national sites have in operation for much longer and therefore possess long time series of data making eLTER able to put recent findings in a historic perspective

eLTER is running two EU funded project that involve additional counties and sites.

eLTER is actively working towards becoming a legal entity – and ERIC – which is expected to be formalised in 2025.

eLTER contributes to the knowledge base informing policy and to the development of management options in response to the Grand Challenges. Activities are centred around four focus areas:

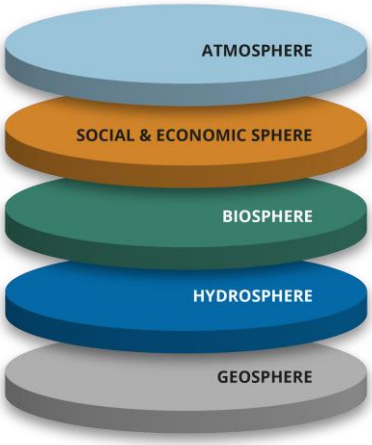
- Biodiversity loss and land use change
    - EU Biodiversity Strategy, Water Framework Directive, Habitats Directive
- Climate change
    - European Green Deal, Strategy on adaptation to Climate Change,

UNFCCC Paris Agreement

- Eutrophication and pollution – Reactive N in the environment
  - Water Framework Directive, UNECE-CLRTAP
- Environmental protection, sustainable management of natural resources, water, soils, biodiversity & ecosystems
  - CAP, Strategy on adaptation to Climate Change, Soils thematic strategy

eLTER implementation comprises in situ, long-term, cross-disciplinary, multiple-use, large-scale coverage of major European socio-ecological systems. The aim is to secure scientific excellence through the highest quality interoperable services in close interaction with related European and global RIs. This implies both increased research quality through scientific cross-disciplinary synthesis at the system level – including human-environment interactions – and quantity in terms of the number of appropriately designed and equipped research sites. eLTER contributes to the European environmental RI landscape by building up a pan-European network of long-term ecological research sites addressing the following features:

1. Wide scale and systematic coverage of major European terrestrial, freshwater and transitional water environments
2. Integrated observations across the critical zone, supporting whole ecosystem science
3. Investigation of interactions between abiotic and biotic ecosystem components at multiple scales, including human-environment interactions
4. Enables research into ecosystem processes influenced by multiple drivers, as well as socio-ecological research relating to ecosystem services



5. Central Services provided by: Head office, Service Portal and thematic Topic Centres
6. Strong links with other European environmental RIs encouraging, for example, co-location of measurements. Close cooperative links has been established to ICOS, DANUBIUS, DISECO, LifeWatch

Hereby eLTER has established a unique integrated system approach in a nested design, allowing for interdisciplinary natural science research as well as investigating human/environment/systems at landscape scales. The design of the eLTER is guided by two overarching scientific concepts, applicable from point to continental scales: the Press Pulse Dynamic Model as *horizontal* component, and the spatially-nested hierarchical feedback paradigm of Macrosystems Ecology as a *vertical* component. Standard observations include:

- Energy budget – input, storage, efficiency
- Water budget – water balance
- Matter Budget – input, storage, output
- Abiotic heterogeneity – soil, air, habitat
- Biotic diversity – fauna, flora
- Socio Economy – demography economic density

Long-term management of data and information is a central component of eLTER cooperation, and since the activities have a long-term view, careful consideration is given to data management, storage of specimens, locations of measurement plots etc. of access to data. Data as well as metadata are managed by the different sites and platforms and because there are many different data owners, storage systems and data formats, using these data in an combined way often presents technical and legal challenges. The eLTER community is, therefore, working hard to overcome these difficulties.

A central component in the data management system is DEIMS-SDR (Dynamic Ecological Information Management System Site and Dataset Registry) that provides extensive metadata on sites, platforms, datasets and personnel. Its functions and content are being further developed in the eLTER H2020 project.

The eLTER Data Integration Platform (DIP) is providing a single access to resources provided by the eLTER network. This encompasses datasets and services as well as simple descriptions of the eLTER sites.

EnvThes (Environmental Thesaurus) is a controlled vocabulary developed for the eLTER community in order to provide a unified semantic backbone for the provision of data in the eLTER context. It compiles a set of terms in order to describe in a harmonised way data resulting from observations and measurements of ecosystem processes across different domain specific sciences. It is used by DEIMS-SDR for common keywords for annotation and quiring metadata purposes.

eLTER is a member node of the Data Observation Network for Earth (DataONE), a community driven project providing access to data across multiple member repositories, supporting enhanced search and discovery of Earth and environmental data.

eLTER data policy is compliant with the FAIR principle.

2.4.4 Discussion

- The Research Infrastructure engage with time-limited projects in two ways:
  - They engage directly in the project as a partner which is possible since they are legal entities
  - They contact relevant projects collaboration and help, access to facilities etc.
- ICES has established a WG on omics.
- Regarding requirements for observations (resolution in time and space) it was pointed out that there is a huge difference between physical oceanography and biology in the sense that physical oceanographic observation is highly automated while biological sampling, analysis and data handling requires

human resources, which are very expensive. So, from a resource point of view it is not possible to have a dense observation network in time and space.

- Development of new technology will be a way to address to above mentioned resource issue, and the use of acoustics and video observations incl. automated processing methods have started to be developed and used more broadly for monitoring purposes. The developments of these new technologies could possibly benefit from establishing expert centers, and Research Infrastructures could possibly play a central role in this. It additionally important to pursue funding possibilities for technology innovation possibly in cooperation with instrument developers and manufactures.
- Use of satellite observations is limited and mostly restricted to observations of Chlorophyll at the sea surface. Europe could actually do much more in the field of animal tracking via satellites - USA use this method widely in the Pacific Ocean.
- EMBRC has great focus on establish and update best practices for their analysis methods and they form the basis for work on all stations.

3. Instrument and sensor manufacture survey

Analysis of gaps in the existing Arctic observing system carried out by INTAROS (INTAROS Deliverable 2.12)[1] and Copernicus In Situ Coordination Group (Buch et al, 2019) have identified a lack in the existing observing technology to meet the demanding requirements for use in the harsh environment of the Arctic. Additionally, attention was brought to the lack of good communication facilities resulting in an untimely delivery of many data, which is, in particular, inappropriate for Near Real Time (NRT) operational products and services. It is therefore important to pursue innovative cost-effective technological solutions for Arctic observations securing continuous NRT data transmissions from this harsh environment, also during wintertime. This can be fostered by liaising with relevant funding agencies, like Horizon Europe programme, and instrument/sensor manufactures to promote that Arctic observing technology and data communication development is on the instrument business agenda and included in future funding mechanisms.

On this background the INTAROS Stakeholder Task Force decided to perform a survey among instrument and sensor manufactures to collect information on:

- Present focus and availability of instruments and sensor fit for use in the Arctic
- Interest and capabilities for new business developments

The survey was performed via a web-based questionnaire (see Appendix 2), which was kept relatively simple and easy to reply to, hoping that it would generate many responses. Invitation to participate in the survey was sent to more than 100 manufactures based on information's collected from INTAROS partners and the EOOS technology forum (https://www.eoos-ocean.eu/eoos-technology-forum/). The survey was open from 23 November 2020 to 15 January 2021 and, disappointingly, only generated response from 16 companies.

3.1 Survey results

3.1.1 Profile of the respondent companies

16 answers were received from 6 countries, 4 European countries (France, UK, Germany, Norway) and 2 in America (Canada and US), Fig. 3.1. 15 respondents belong to private sector and 1 to the public. Responding companies:

- Aanderaa – Xylem (Norway)
- ClearWater Sensors Ltd. (United Kingdom)
- Seaproven (France)
- 4H-JENA engineering GmbH (Germany)
- National Oceanography Centre (United Kingdom)
- Pro-Oceanus Systems (Canada)
- RBR Ltd. (Canada / France)
- Ocean Sonics Ltd (Canada)
- Remote Ocean Systems, Inc. (United States)

[1] https://intaros.nersc.no/list-of-open-deliverables?page=1

- HS engineers (Germany)
- Sonardyne International Ltd (United Kingdom)
- AML OCEANOGRAPHIC (Canada)
- RPG Radiometer Physics GmbH (Germany)
- Spectra Vista Corporation (United States)
- A2 Photonic Sensors (France)
- Marine Biological Association (United Kingdom)

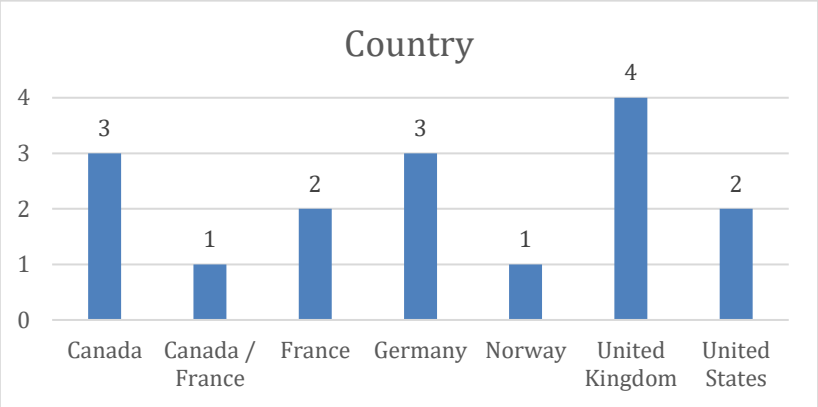


Figure 3.1. Nationality of respondents

The thematic focus of the respondents is displayed in Fig. 3.2 displaying a strong dominance on ocean observations.

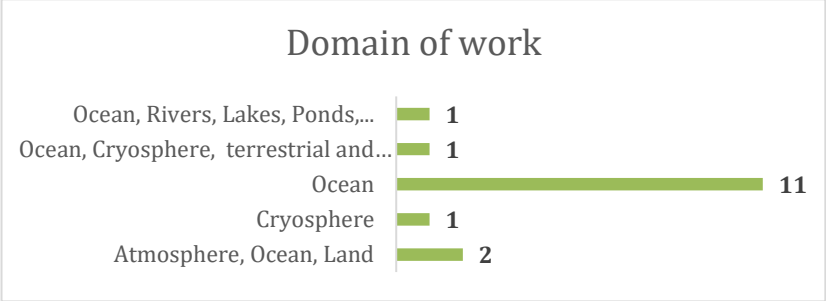


Figure 3.2. Thematic focus of responding companies

3.1.2 Questions on how the existing observing technologies, platforms and sensors are adapted to the Arctic environments

The aim of this group of questions is to map product portfolio of the manufactures, their focus on and experience with the Arctic both with regard to sensors, instruments and data transmission.

The instrument/sensors manufactured by the respondents can measure a wide variety of parameters:

- Ocean
  - Temperature
  - Salinity
  - sea level

  - Sea state
  - Currents
  - Ocean surface heat flux
  - Sea surface stress
  - Oxygen
  - Nutrients (Nitrate, Nitrite, Phosphate, Silicate, Iron), with further sensors (e.g., TA, DIC, ammonia, trace iron) in development / negotiation with inventors,
  - Ocean colour
  - Inorganic Carbon (pH)
  - Plankton,
  - Chlorophyll
  - pCO2
  - dissolved CH4
  - ocean noise (ships)
  - sounds (marine mammals, ice, glaciers, seismic activity etc)
- Atmosphere and land
  - Temperature and temperature profile (boundary layer, low-level inversions),
  - Precipitation
  - Pressure
  - Wind speed and direction
  - Water vapour Radiation budget
  - Humidity profile, integrated water vapor, integrated cloud water
  - Cloud + precipitation in all detail (RR, drops size distribution retrieval, LWC, particle classification, cloud dynamics)
  - Latent heat flux (together with sensible heat flux) for energy balance considerations;
  - Downwelling irradiance
  - Upwelling radiance or irradiance
- Cryosphere
  - glacier mass loss
  - snow depth
  - water level (also snow liquid water content and snow specific surface area)

On the question on whether the instruments/sensors are developed specifically for use in the Arctic, 25% replied positively while almost 70% responded that their instruments/sensors were not developed specifically for Arctic use, but have proven capable for that purpose while the remaining small part need modifications to be ready for Arctic use, Fig. 3.3.

75% of the manufactures respond that their instruments/sensors have been used for Arctic observations over several years, 19% claim they have 1 year of experience and 6% none, Fig. 3.4.

Almost 70% of the respondents have experience in data communication, Fig. 3.5, and 54% have experience in data communication in the Arctic region, Fig. 3.6.

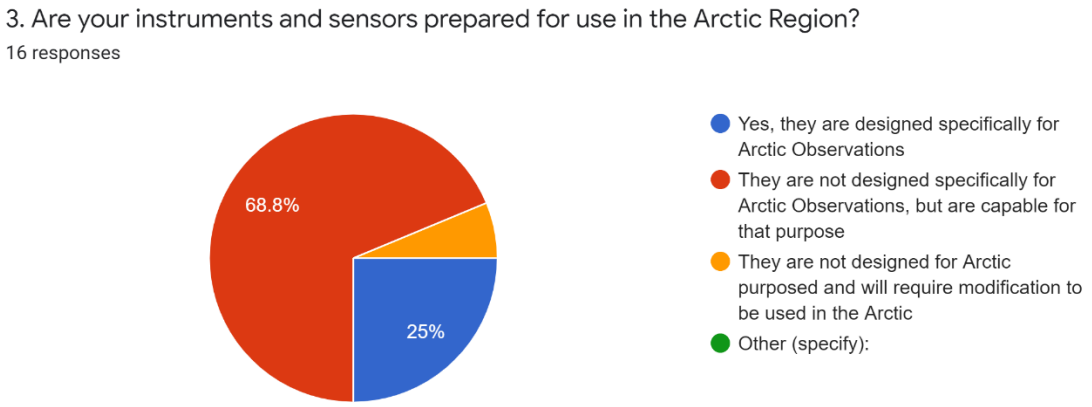


Figure 3.3. Instrument preparedness for Arctic use

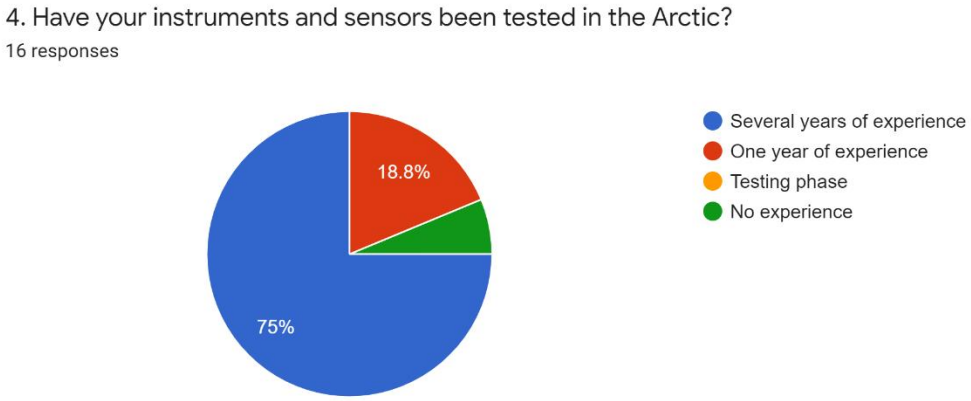


Figure 3.4 Experience in Arctic usage

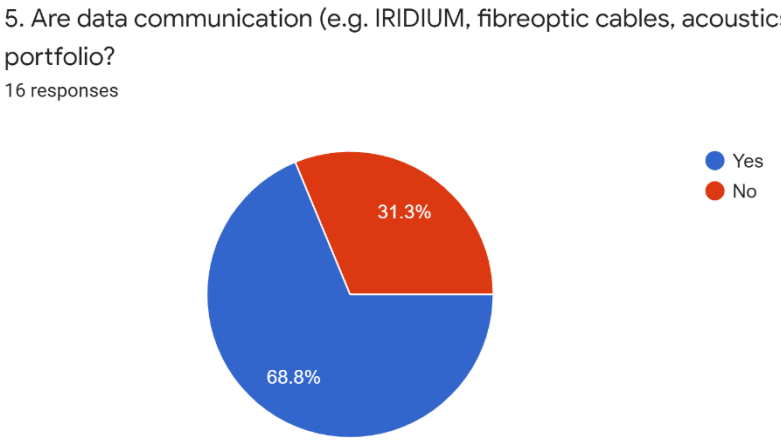


Figure 3.5 Experience in data communication in general

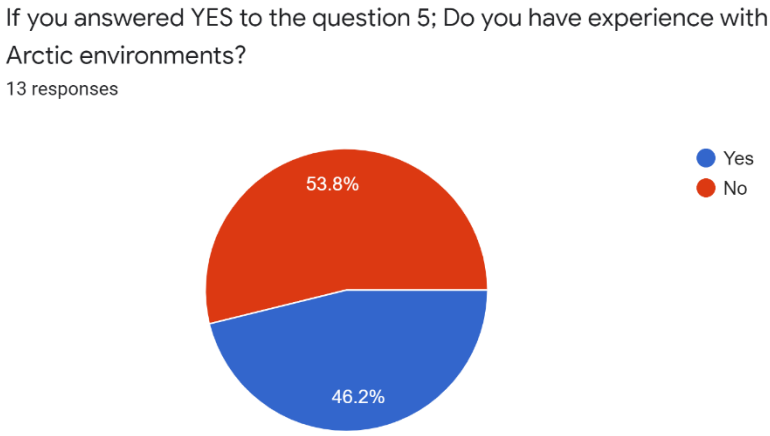


Figure 3.6 Experience in data communication in the Arctic

3.1.3 Questions on how the development of new technology - instrument/sensors - is being carried out

The focus of this section is to map the manufactures priorities of and ability to engage in developments of new technology/instruments/sensors from an organisational and economical point of view.

A majority of the respondents (81%) reports to have a development department as an integrated part of the company structure, while additionally 12% do developments on an ad hoc basis, Fig. 3.7. 60% of the companies have strict procedures for the development of new sensors, Fig. 3.8.

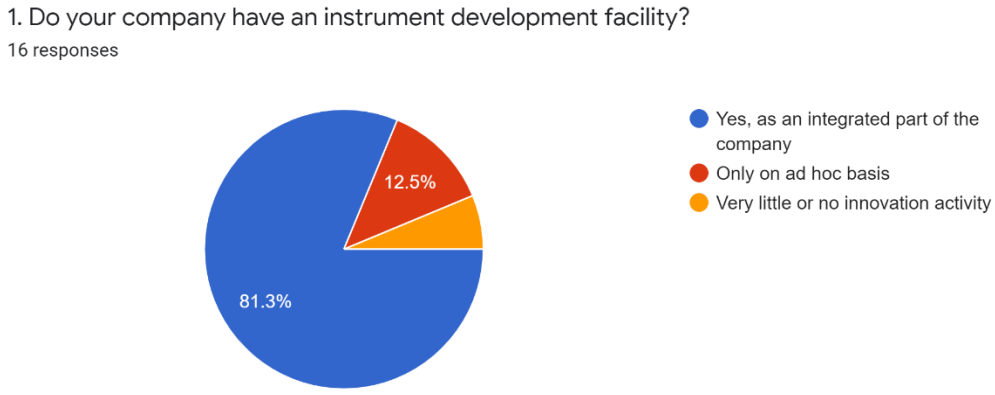


Figure 3.7 Focus on sensor and instrument development

.

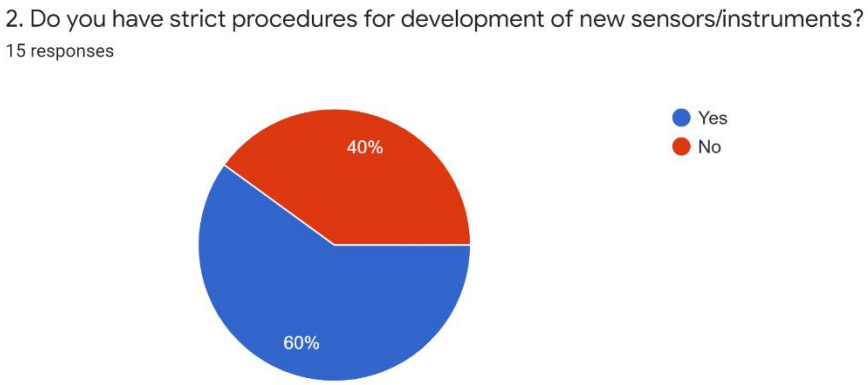


Figure 3.8. Development procedures

Field tests of new instruments/sensors is an important component of making the instruments/sensors ready for the commercial market. The survey showed that a majority of tests is done in close cooperation with potential customers or research centres; one company reports testing of new instruments/sensors solely by themselves and one company uses a special in vitro test facility, Fig 3.9.

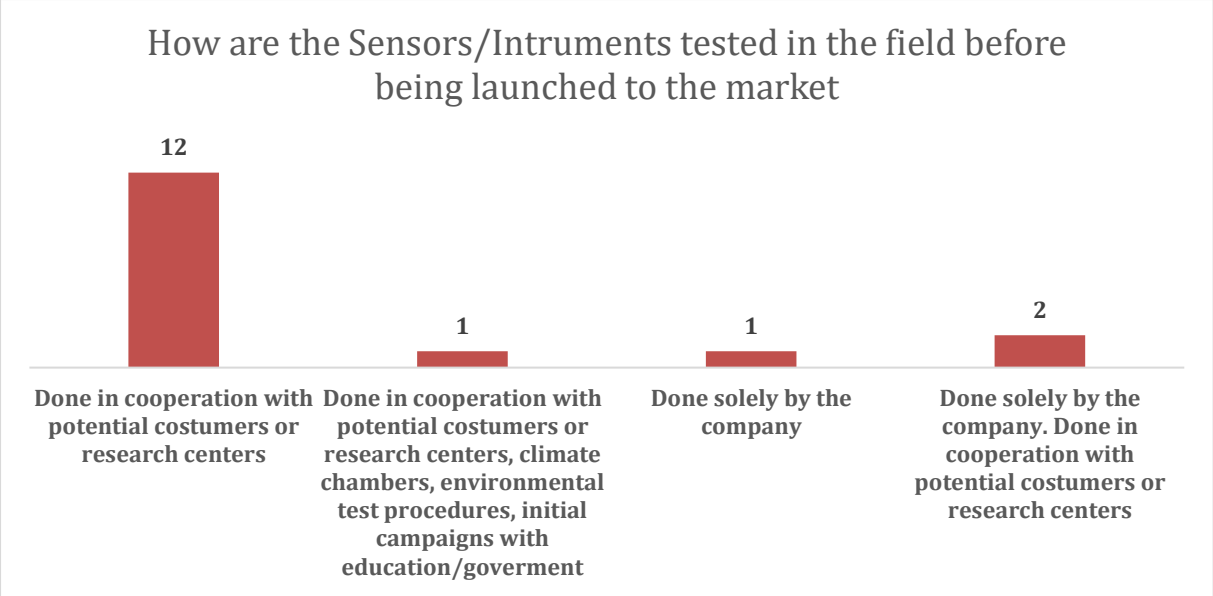


Figure 3.9. Test strategy for newly developed instruments and sensor

Generally, instruments used for in situ observations are robustly constructed and meant for several years of use with regular service, maintenance and calibration; but innovation during the recent decades on instruments/sensors and communication technology has allowed for an increasing use of expendable instruments. There are many advantages of this approach, but it puts special requirements on the material used in the production of the instruments, in order to avoid harm to the environment. It was therefore of interest in the survey to map the distribution between the production of re-usable and expendable instruments and sensors.

None of the respondents, however, replied that they are producing expendable instruments/sensors, and three respondents detailed their main focus, Fig. 3.10.

14 companies are working with the development of re-usable instruments/sensors.

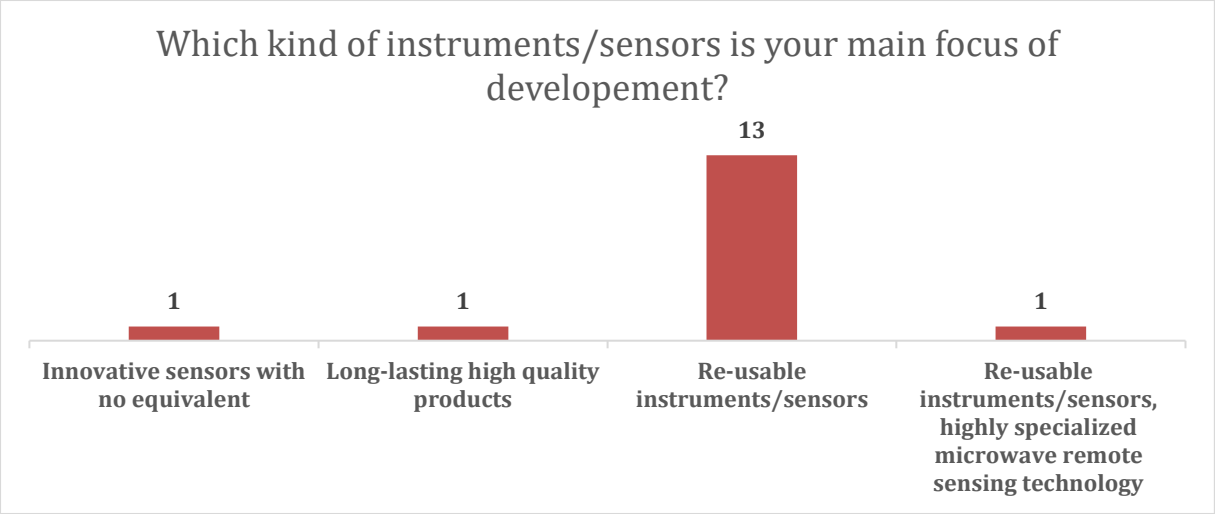


Figure 3.10 Re-usable versus expendable instruments/sensors

Development of new instruments/sensors can be very time consuming and costly, and in combination with a fairly limited market requires availability of venture capital based on a detailed analysis and understanding of the market potential. It was therefore of interest to explore how the respondents are financing their instrument/sensor developments.

The majority of companies uses a mixed funding scheme: own resources combined with joint ventures with public research institutions and/or public R&D funds and/or customers/partners. Four respondents reply that their development costs are financed entirely by own resources. Fig. 3.11.

To the question: *"Would you be interested in developing and manufacture new instruments and sensors for Arctic observations in the future??"* all respondents expressed a potential interest, two companies however articulated clear conditions for entering into this business area:

- needs to fit into their core competences (high-frequency /microwave technology, remote sensing) and there need to be a promising market (no one-time or niche projects)
- their capabilities have to be able to suit the requirements.

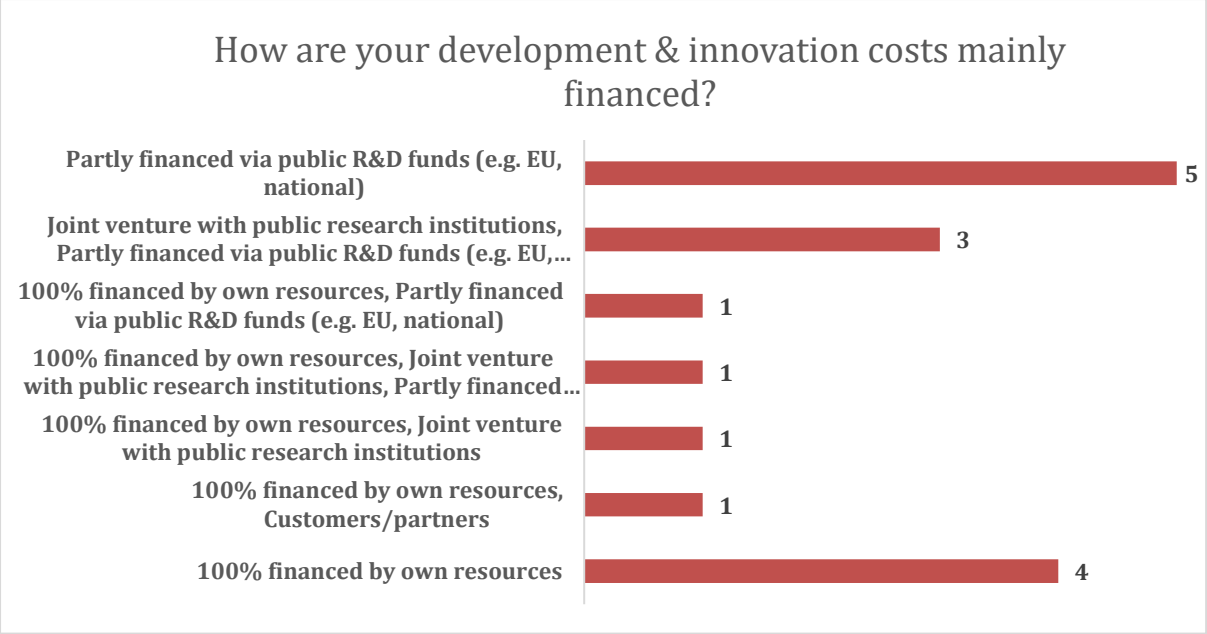


Figure 3.11 Financing of development costs

The respondents were also asked to address which challenges new observing technologies are facing in the Arctic region. The robustness of instruments against low temperatures and harsh environments were pointed out as the biggest challenge followed by robust data communication in near real time and instruments deployment and/or recovery, Fig.3.12

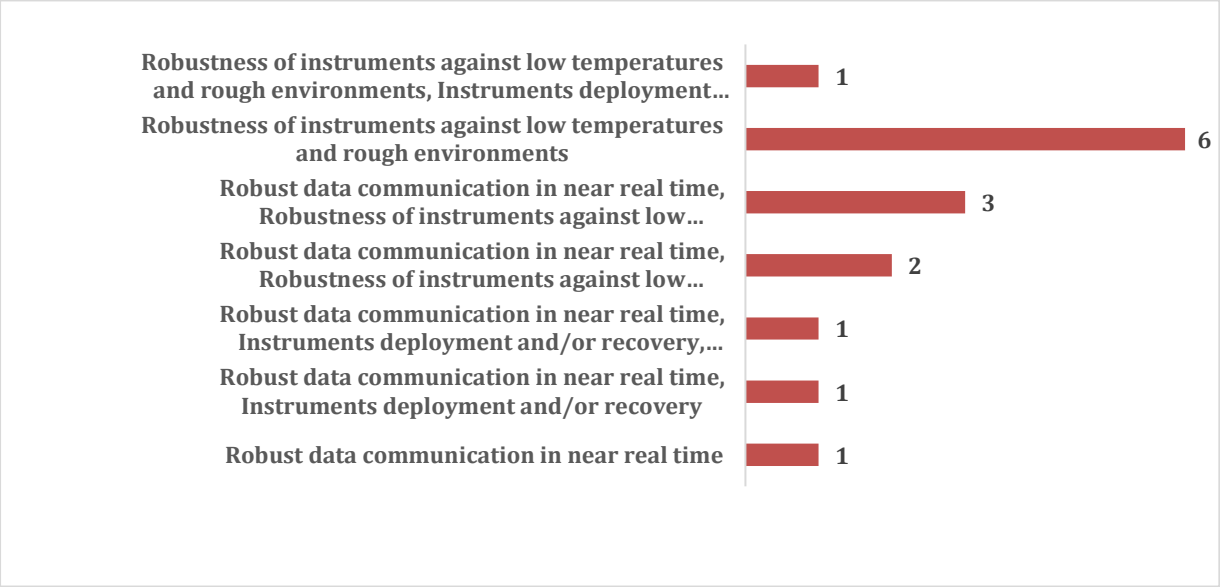


Figure 3.12 Technology challenges related to Arctic observing

3.1.4 Other comments

The respondents were given the opportunity to provide additional comments and information and the following was received:

- Some additional info on robustness / cold performance, metrology and communication would be helpful.

- Our sensors are robust, with NOC (who invented the technology) having deployed over 200 times including in the arctic (e.g. FixO3 Fram Strait for >1yr), in glacial melt streams and profiling to >4800 m depth (6000 m rated) including on autonomous platforms such as webb slocum and Seagliders.
- The sensors carry reagents / standards in liquid form but using salt and antifreeze compounds we have successfully frozen the sensors into ice (-16 C) and they operate normally as soon as liquid water sample is present.
- Our expanding portfolio of in situ submersible sensors enables metrology equal or better than sampling and laboratory analysis and can be operated by inexpert users (for example reagents can be pre-supplied in a ""plug in"" cartridge). When communication is not supplied by the platform in which we integrate we use third party communication systems and have experience of integrating with a wide range of providers such as iridium, Argos, orbcom as well as GSM and other wireless standards."
- SEA PROVEN designs, manufactures and operates a constellation of "Autonomous Surface Vessel" in order to collect oceanic data #OceanBigData. Similar to satellites in the sea, our vessels are 15m long, remote-controlled with an operational autonomy of 10 months thanks to solar and wind energy production. Thanks to our space partners, our boats can collect no less than 50 different types of data, transmitted in real time via satellite communications.
- One of our ambition is deploying sensors integrated on long-range AUVs for under-ice deployments in the Arctic
- Since 1973, RBR has been designing and manufacturing oceanographic instruments in Ottawa, Canada, and has steadily expanded to include offices in Atlantic Canada, and China, with direct sales in USA, France, and Australia. From the ocean abyss to the polar ice cap; lakes, rivers and coastal zones, RBR’s sensors and loggers track water parameters including conductivity, temperature, depth, salinity (CTD), dissolved gases, pH, and many others.
- As ocean noise was not one of the parameters on the GCOS page, it should be considered as a required sensor for ocean observation as it can sense anthropogenic noise and natural sounds and help understand the effects of human intervention in the Arctic.
- The whole questionnaire is (maybe unavoidable) vague and broad: what does "Arctic" mean? What does data transmission in the Arctic mean?
- Ny Aalesund station is Arctic, I would believe, but easy-going in terms of data connection and climate. Greenland summit is a different story. What would be the regime we need to cover? Temperature down to -45°C? Or down to -80°C? If you would think of Antarctica, for a change. Wind speed of 50 m/s at -45°C? or more like 75 m/s? Some customers have funny ideas?
- Our company is constantly looking for new opportunities and collaborations (joint development of instruments). Our fields of expertise include, but are not limited to, optics, photonics and electronics.

4. Norwegian Management Agencies

The Institute of Marine Research (IMR) organised several meetings with Norwegian management agencies. These included workshops also involving other projects than INTAROS, and one dedicated INTAROS stakeholder seminar. For the INTAROS stakeholder seminar, IMR invited all relevant Norwegian marine and maritime-related authorities and directorates. The outcome of INTAROS Task 6.2 was presented, followed by comments, requests and an open discussion. The discussion focused on how results from INTAROS tasks 6.2 and 6.8 can be refined and angled to be of most relevance and use for these stakeholders.

The digitally arranged seminar took place 20 January 2021, with 34 participants from:

- Norwegian Environment Agency (NEA),
- Norwegian Directorate of Fisheries (DF),
- Norwegian Mapping Authority (NMapA),
- The Norwegian Coastal Administration (NCA),
- Norwegian Maritime Authority (NMarA) and
- Norwegian Radiation and Nuclear Safety Authority (NRSA),
- Norwegian Polar Institute,
- INTAROS representatives
    - Institute of Marine Research (IMR), Organizer
    - Aarhus University, Denmark (AU*)*

4.1 Introduction and participants

Norway is responsible for huge areas of the North-eastern Atlantic Ocean, large parts of the Barents Sea as well as part of the Arctic Ocean north of Svalbard. The invited authorities and agencies are all responsible for separate sectors of human activity (fisheries, hunting, shipping and tourism, oil- and gas extraction, seabed mapping and environmental health, littering and radiation). Institute of Marine Research, the Norwegian Polar Institute and Aarhus University all represent research institutes with experience in arctic environment, ecosystems and animal populations, as well as ecosystem modelling.

The authorities depend on the research institutions to collect natural science information, but they collect social and economic data from each sector on human activities, as well as the trends in activities. The statistics based on the human activities monitoring are free and openly available from the agencies and from the national statistical office (SSB).

The separate sector agencies made requests for different types of data, while the NEA and the shipping-related administration and authority found climate trends of interest, the FD also needed the time series on stocks and also improved methods in data sampling and data analyses to reduce the uncertainty in the stock assessments.

4.2 Requests from the sector agencies

Norwegian Environment Agency (NEA) - responsible for reporting on trends in the environment, including climate and human impacts. It is managing human activities as tourism in natural protected areas and impact from industrial activities in the Norwegian

Arctic areas, including Jan Mayen and Svalbard. **The Norwegian Polar Institute** is a branch of NEA, responsible for scientific knowledge and advice to the Norwegian authorities about the Arctic and the Antarctic. For Arctic matters, the Polar Institute is a pure research institute.

NEA emphasized the need to find ways to build on all sources for information, including the INTAROS deliverables and outcome, also after the termination of the projects. The Norwegian management plan, scientific and advisory committees would like to reap benefits from the project achievements in the future.

NEA asked for common model analyses to include indicators that may be guidelines also for climate and other human impacts. They asked for modelling incorporating several human impacts simultaneously to look at joint impacts.

Integration of data and knowledge between the INTAROS and other Arctic programmes integrated in INTAROS and the Arctic Council Committee *Conservation of Arctic Flora and Fauna* (*CAFF*) would be useful to look for synergy and shared information. That would be of value in further analyses on climatic changes and impact over time.

NEA and others have requested ecosystem modelling for a long time.

Directorate of Fisheries - responsible for regulations of the fisheries within the Norwegian economic exclusive zone, for monitoring the fishing vessels, collecting position and landing data, and for mapping lost or found lost gear at sea and along the coast.

Cross-sectorial communication and data sharing should be encouraged.

Developing improved analyses and models for combined data to add information beside the single stock data would be useful for manager and therefore welcome.

International indicators on ecosystem state and trends ought to be checked out for possible national implementation. The scientific monitoring and management are set up to meet the need from a range of international and national agencies and tractates, to monitor ecosystem changes. It would be inefficient and costly if Norway should report by different sets of ecosystem indicators, with overlapping intensions.

The Norwegian Coastal Administration is a national agency for coastal management, maritime safety and preparedness against acute pollution, while the **Norwegian Maritime Authority** is responsible for life, health, working conditions onboard Norwegian registered ships and ships at Norwegian ports.

It is a desire to include human activities, climate and pollution to the ecosystem models for more holistic scenarios**.** It is and will be a growing conflict of area use between sectors, also including shipping, particularly in the Arctic with diminishing ice cover.

Norwegian Radiation and Nuclear Safety Authority - responsible for monitoring of and reporting on radiation in air and water, responding to accidents and monitoring nuclear sources in Norwegian territories.

NRSA would like to have environmental polluting components included to the ecosystem models**.** There are 40 different components listed as pollution indicators in the marine management plan. INTAROS look at littering and social activities for monitoring them. At IMR several projects - published, running and planned - study pollution impacts, as it is a field of high priority.

The Norwegian Mapping Authority - responsible for producing maps and interactive map layers for Norway and Norwegian marine areas, from topographic maps to environment, human activities, protected areas, nature types and species distributions, all kind of geographical regulations etc.

All data on time and space should be made convertible to the Norwegian Areal Tool programme and included in this mapping service.

4.3 Final plenary requests

Three topics turned out to be of special interest for the participants in general:

1. Access to data and request for data types
    - The INTAROS data catalogue will inform about the data providers and allow users to find out who would be the best source and contact person to turn to directly. The data sets will be kept and the catalogue available on net, although it is not certain it will be maintained and updated. Inclusion of socioeconomic indicators for analysing impact and consequences of state and trends in the marine ecosystems.
2. Choices of indicator types and sets
    - A close dialogue should be kept between the INTAROS participants and the Norwegian Surveillance Group, as well as keeping track of international indicator development and the project developing the Science Panel Method for Ecosystem State Assessments.
    - Make sure to put the INTAROS indicator tests and analyses in a wider context. Make sure INTAROS adds to and seeks to improve on the use of indicators and avoiding suggestion of new and even more complicated indicator systems.
3. Data sufficiency and uncertainty within available data material
    - Testing models against historic data and trends will continue for a long time still, for verification of the reliability of the model outcomes, as tools and scenario building. Well used and considered models will be valuable for making sustainable management decisions.

5. Nordic Seismology Seminar and Workshop

The Nordic Seismology Seminar and workshop were organized by GEUS and University of Bergen on 28/9 – 2/10 2020. The Nordic Seismology Seminar gathers seismologists from the Nordic countries once a year. The event has a long tradition going back more than 50 years. Both the seminar and the workshop were planned as onsite events, but due to the COVID-19 pandemic, both events were changed to online events. This affected the planning and preparation of both events.

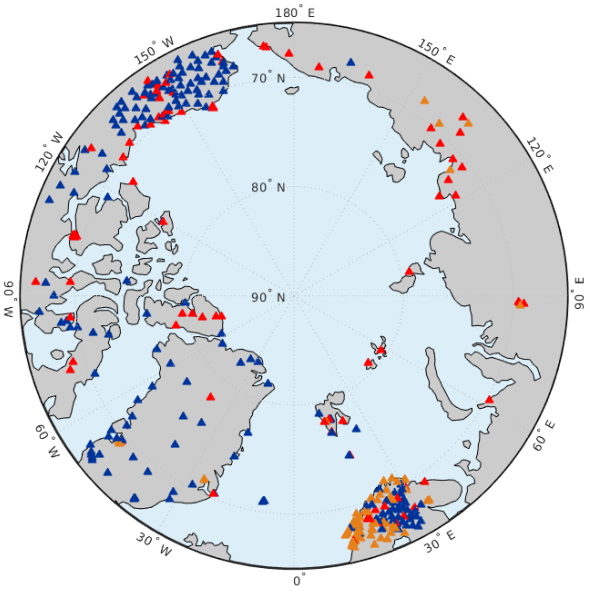
The online workshop from 28-30 September 2020 focused on "Advanced processing of seismological data". The workshop combined presentations of software tools and user experiences with time for the participants to experiment and develop experience with new software tools. The workshop was led by Lars Ottemoller, Jens Havskov and Mathilde B. Sørensen (University of Bergen) and Peter Voss (GEUS). The target audience was scientists (young as well as experienced) working on various aspects of seismological data processing.

Two presentations were strongly focused on INTAROS: In the presentation "QuakeML and Nordic format conversion" (presented by Christian Rønnevik, University of Bergen), the INTAROS iAOS was presented as a case, demonstrating the INTAROS earthquake catalogue for the Arctic region. In the presentation "Using SEISAN for hazard analysis" (Mathilde B. Sørensen, University of Bergen), challenges and solutions in seismic hazards analysis were discussed.

The workshop had 36 participants. The online setup enabled participants from countries all over the world to participate: Denmark, Norway, U.S.A., Turkey, Egypt, Palestine, Argentina, India, Morocco, Romania, Spain, Costa Rica, Brazil, Lebanon, Portugal, Albania, and Sweden.

In addition to INTAROS funding, the workshop was supported by Nordic EPOS – A FAIR Nordic EPOS Data Hub project, NordForsk grant number 97318, and EC H2020 project SECURe, grant agreement No. 764531.

The online seminar "The joint 2020 Nordic Seismology and Nordic EPOS Seminar" on 30 September to 2 October 2020 focused on seismological monitoring networks (including spatial coverage and monitoring gaps), best practice in data management and FAIRness of the infrastructures, data transfer, exchange and cooperation. The target audience was seismologists from the Nordic countries.



Map of seismic stations in the Arctic. Red: No data is currently being sent (usually station closed), Orange: Restricted/unavailable data, Blue: Data is being sent.
Source: INTAROS deliverable D2.9.

The Finnish representatives informed on a new project to improve their monitoring

capacity to close exiting gap by the use of joint infrastructure[2]

The QuakeML data service provided through the INTAROS iAOS for the arctic earthquake catalogue was presented and discussed by Christian Rønnevik, University of Bergen. The EIDA platform, on which the INTAROS OBS data will be made available, was presented and discussed by Jan Michalek, University of Bergen. Representatives from the EPOS ERIC IT team shared knowledge on the FAIR principles. Representatives from the International Seismological Centre, that will compile the analysis results from the INTAROS OBS recordings in a global context, presented recent developments.

The seminar had 64 participants, from Finland, Sweden, Norway, Iceland, Italy, UK, Germany, Holland, France, Russia, Estonia and Denmark. The seminar was a joint meeting by the Nordic Seismology Community and the Nordic EPOS– A FAIR Nordic EPOS Data Hub project, NordForsk grant number 97318.

[2] https://researchportal.helsinki.fi/en/projects/flex-epos-flexible-instrument-network-for-enhanced-geophysical-ob

6. Summary and conclusions

The present report summarises the main INTAROS stakeholder activities in 2020-2021. The main activities have been:

- Dialog meetings with relevant European Research Infrastructures
- Survey among sensor and instrument manufacturers
- Seminar with marine and maritime authorities
- Attendance to conferences, workshops, webinars and networking events.

The work has been performed in the shadows of the COVID-19 pandemic with its restrictions on working conditions, possibilities to meet etc. Despite these limitations INTAROS Stakeholder Task Force has managed to achieve some valuable stakeholder input that will support the INTAROS Roadmap work that constitute a major obligation in the final part of the project.

The dialog meetings with the European Research Infrastructures were very productive and informative; the Infrastructure representatives attended the meetings well-prepared and with a constructive and cooperative attitude. In summary,

- 15 Research Infrastructures were invited to the dialog meetings of which 12 accepted.
- The meetings were organised thematically – Hydrosphere, atmosphere, geosphere and biosphere
- Out of the 12 Infrastructures 3 have full focus on the Arctic, 6 have some or few activities and 3 do not presently have any engagement in the Arctic
- The dialog meetings clearly revealed the need for a more sustained and coordinated observing system within all thematic areas (atmosphere, hydrosphere, geosphere and biosphere) especially the central Arctic is severely undersampled.
- Most of the Infrastructures are or are in the process of becoming a legal entity – registered either as an ERIC or and AISBL. This provides some sustained funding via member fees from member countries, but most importantly being a legal entity allows them to become partners in externally funded projects.
- All infrastructures were engaged in discussion and formulation of observational requirements:
    - Generally, they have clear and ambitious policies on data quality, resolution in time and timelines of data delivery.
    - Requirements for spatial resolution are, however, more uncertain where discussions often end in a conflict between scientific requirements and what is feasible from a logistic and financial point of view. In this context it was stressed that biological observations presently are very expensive since they require human resources for sampling, analysis and data handling resulting in compromising the spatial resolution. The ARGO community constitute an exception by

formulating ambitious goals for spatial resolution several years ago.

- The infrastructures generally have an open and free data policy compliant with the FAIR principle, although a few members may have a more restrictive data policy but that is being worked on. All face problems in data exchange with Russian partners.
- There is great focus on formulation and implementation of "Best practises" on observation procedures, quality control, data management etc.
- Sensor and instrument development is high on the agenda for some but not all Infrastructures. Automated measuring technology and stations are in focus in particular for biogeochemical observations
- There is established close cooperation between the infrastructures primarily via the ESFRI and ENVRI systems. The three Infrastructures with full focus are engaged in Arctic cooperative bodies like SAON.
- Many of the INTERACT research stations are manned year-round and constitute thereby potential platforms that can be incorporated in an Arctic Observing System e.g. for meteorological observations in real-time.

In addition to the dialog meetings with the research Infrastructures INTAROS has also collected stakeholder inputs via conferences, workshops and meetings, see Appendix 1. A couple of meetings are highlighted in the report:

- The marine and maritime management authorities expressed great interest in gaining environmental data from the Arctic region (time series and trends are especially important), but also data in support of reliable ecosystem modelling was highlighted. The participating authority representatives highlighted three priorities
  - Access to data and request for data types
  - Choices of indicator types and sets
  - Data sufficiency and uncertainty within available data material
- Nordic seismologists with focus on monitoring the Arctic region have a long tradition of cooperation with focus on gaps in the observing system and advanced data analysis.

Building a sustained fit-for-purpose Arctic Observing System will require investments in innovative cost-effective technological solutions securing continuous NRT data flow from this harsh environment also during wintertime. The aim of the survey was to collect information on sensor and instrument manufactures experience, capability and interest in manufacturing instrument/sensors for Arctic use.

A web-based questionnaire was sent to more than 100 relevant companies. 16 companies responded to the survey, which is a relatively low and disappointing response, but likely on the level that can be expected in times with many questionnaire surveys. In a non-COVID time, a better approach would most likely have been achieved via personal contact/interview performed at various exhibition events for sensor/instrument manufactures. Key findings were:

- The manufacturers responding to the survey generally report on strong year-long experience in producing instruments/sensors usable in the Arctic – some

specifically designed for Arctic use. Most of the respondents have data communication as part of their product portfolio but less than half have experience in the special conditions for Arctic data communication.

- Most of the responding companies have a development activity as an integrated part of their organisation and 60% of them follow strict procedures for instrument/sensor development. Almost all companies have field test of new instruments/sensor as part of the production line which in most cases is done in cooperation with potential customers or research centres. The financing of development activities is for some companies carried using their own sources but in most cases via joint ventures with research institutions and/or supported from public Research and Innovation funds (EU, National).
- The responding companies point to robustness of instruments against low temperatures and rough environments to be the largest challenge for Arctic observations followed by robust data communication in near real time and instruments deployment and/or recovery.

In conclusion, there is a group of instrument/sensor manufacturers that have experience, capability and interest in participating in innovation of new technology for observation in the Arctic.

It is recommended to establish a forum for closer dialog and cooperation between the observing community and the instrument/sensor manufactures to:

- Define requirements for new technology incl. data communication
- Map the market potential
- Liaise with relevant funding agencies like Horizon Europe to promote and ensure Arctic relevant observing technology and data communication development is included in future funding strategies

References

Erik Buch, Marianne Sloth Madsen, Jun She, Martin Stendel, Ole Krarup Leth, Ann Mari Fjæraa, Mikael Rattenborg, 2019. Arctic In-Situ Data Availability. https://insitu.copernicus.eu/library/reports/CopernicusArcticDataReportFinalVersion2.1.pdf

7. Appendices

Appendix 1: List of INTAROS stakeholder event in 2020-21

Activity	WP	WHO	WHY	WHEN	HOW	Responsible	Impact
Dialog with Research infrastructures	1	European Environmental Research Infrastructures	Map their present and planned activities in the Arctic and their willingness for cooperation in the future. Activity shall support the INTAROS Roadmap process	February 2021	Virtual workshops, due to Corona restrictions	EuroGOOS	Far for all are active in the Arctic. Great interest for Cooperation in the future in support for Arctic Observations.
Stakeholder workshop	6	Fisheries, environmental, shipping and petroleum managing agencies	Involve and discuss with them how they find the model results we have produced useful, or have suggestions for what they may find more useful	20 January 2021	Stakeholder workshop in Norway	IMR	Good contact established and data requirements from these authorities was identified.
Instrument manufacturers survey	1	Instrument manufactures	Map their ability and interest to produce instruments usable in Arctic environment	December 2020	web-based questionnaire	EuroGOOS	16 companies replied. There are a group of instrument/sensor manufactures that have experience, capability and interest in participating in innovation of new technology for observation in the Arctic.

Svalbard Social Science Initiative	4	??	Planning for and leading seminar and workshop	10-11 December 2020	Digital seminar and workshop	NERSC	
Nordregio Forum 2020	4	Inclusive cities	Planning and policies for inclusive towns and cities	November 2020	Panel discussion	NERSC	Presentation og INTROS work on CBM and co-creation in planning and development processes
Series of meetings	6	the Greenland Ecosystem Monitoring (GEM) community in Disko Bay	Presentation of modelling results and potential collaboration	Autumn 2020	Meeting in Denmark	AU	Has resulted in an application for improvement of the marine biodiversity
EU Polar Cluster	1	EU funded polar projects	Coordination with other EU funded projects	27 October 2020	workshop - an open part and a closed part	NERSC, EUROCEAN, EuroGOOS	Coordination between projects as well as dedicated focus on Stakeholder-, information, and data work
EO4 Arctic Science organised by EU and ESA	1	Scientific community	Overview of status and plans for European scientific research in the Arctic: focus on remote sensing combined with in situ observations and modelling	26-30/10/2020	Virtual conference	Several INTAROS partner attended and contributed actively	GOOD inspiration for the ROADMAP process.
SEATECH WEEK International Marine Sciences and Technology week	3.3	Scientific community	Laurent Chauvaud organized an ecological-acoustic conference session at the 2020 sea tech week	12.10.2020	Virtual conference	CNRS	The conference has an impact on both scientific and technology communities

Nordic Seismology Seminar	2.3;3.2	Scientific community	Make stakeholders aware of INTAROS earthquake catalogue web service	01.10.2020	Virtual seminar	GEUS, UIB	The seminar had a broad participation from institutions in the Nordic region and neighboring countries, all potential user of the web service.
Nordic EPOS Seismology workshop	2.3;3.2	Scientific community	Demonstrate to stakeholders the INTAROS earthquake catalogue web service	28.09.2020	Virtual workshop	GEUS, UIB	The workshop participants came from institutions mainly in Europe and the Americas, some are potential user of the web service.
Correspondence among FMI, UNIS, Norwegian Water Resources and Energy Directorate (NVE), and MET Norway	6.4	NVE and MET Norway	Illustrate to stakeholder the planned method to improve snow avalanche forecasting in Svalbard	autumn 2019-autumn 2020	Email correspondence	FMI, UNIS	The results have not been completed/delivered yet.
ESA CCI Climate Science Working Group Meeting	6.1	Scientific Community (ESA)		23.10.2020	Virtual meeting	BSC	Presenting work on the impact of assimilating INTAROS data on seasonal prediction capacity
EU Polar Expert Forum III		ESA and Copernicus	map requirements for In situ data for future satellite missions	15.10.2020	Virtual meeting	EuroGOOS	The meeting was very satelite technical focussed so the value was limited

EOOS Technology Forum		Instrument manufactures, Science	Link to observing technology providers	13.10.2020	Webinar	EuroGOOS	The value of the webinar itself was minor, but there has been established in list of any instrument manufactures and their contact points
NAOS Final meeting		Scientific community, technic community	Final meeting of the NAOS project (French Argo floats)	17.09.2020	Virtual meeting	CNRS	presentation of Technical progress on Argo floats (dedicated to icy waters) and unprecedented Scientific results (under-ice timeseries for BGC Argo)
BarenntsRisk, stakeholder meeting	6.2; 6.8	Fisheries Management, Scientific community	Introduction to INTAROS and WP6.2	26.08.2020	Presentation on: Del 6.3 Barents Sea ecosystem indicator models	IMR	Prepare the Fisheries Directorate before planned stakeholder seminar
EGU General Assembly 2020	2.1	Scientific community	Make stakeholders aware of the availability of INTAROS Deliverable 2.7, in which the GlaThiDa data base is assessed	08.05.2020	Integrating and assessing Arctic glacier thickness data into Glacier Thickness Database (GlaThiDa) Version 3.0	UPM	GlaThiDa contributors' managers (WGMS) were made aware of the GlaThiDa assessment in INTAROS deliverable 2.7

INTAROS Ocean Workshop Virtual Meeting	3.1, 3.2, 3.3, 6.3	Scientific community	Share dataset and results with other WP scientists.	24.04.2020	Oral Presentation "Underwater soundscape in Kongsfjorden "	CNRS	Develop collaborations between scientists.
Arctic Observing Summit	WP2	Scientific community, Policy makers	Presentation of INTAROS WP2 conclusions and recommendations for the optimisation of the observing system	01.04.2020	Synthesis of gap analysis and exploitation of the existing Arctic observing systems	MISU	
Annual meeting of Marine Stewardship Council, Norway (in Norwegian):		Industry, Civil society, Policy makers		02.03.2020	Presentation on: Ny havrapport fra FNs klimapanel: Klimaendringer og konsekvenser for fisk, fiskerier og havbruk	IMR	
??		Scientific community		20.02.2020	OBS deployments and data investigation in the Arctic, Fram Striat	UiB	

Cooperation Calving Workshop, 4-6 th of February 2020		Scientific community		04.02.2020	Tidewater glaciers in Hornsund	U Slaski	
NAG Meeting		Scientific community		30.01.2020	Snow Cover Reflection Properties on Hansbreen (South Spitsbergen)	U Slaski	
Arctic Frontiers Conference, towards UN Decade of Ocean Science		Scientific community, Industry, Civil society, Policy makers, Media		29.01.2020		EUROCEAN	
IASC-Network on Arctic Glaciology (NAG), Obergurgl, Austria	2.2; 6.4	Scientific community	Make stakeholders aware of the availability of INTAROS Deliverable 2.8, in which the methods to estimate glacier ice discharge to the ocean from in-situ and satellite observations are presented	28.01.2020	Fjord stratification controls surface emergence of glacial plumes (Network on Arctic Glaciology annual meeting & IASC cross-cutting activity on "Glacier-	UPM	The scientific community involved on the Network on Arctic Glaciology was made aware of the advances in this methodology reached within INTAROS

					ocean interactions and their impact on Arctic marine ecosystems")		
AGU Ocean Sciences, San Diego, CA	6.4	Scientific community	Make stakeholders aware of the INTAROS products from task 6.4: ice discharge and freshwater flux from Greenland.	2020-01-16 – 2020-01-20	Presentation and discussions	GEUS	Engagement of the larger geo-scientific community in the existence and use of the new operational products from INTAROS task 6.4.
IASC-Network on Arctic Glaciology (NAG), Obergurgl, Austria	6.4	Scientific community	Make stakeholders aware of the INTAROS products from task 6.4: ice discharge and freshwater flux from Greenland.	28.01.2020	Presentation and discussions	GEUS	Engagement of the larger geo-scientific community in the existence and use of the new operational products from INTAROS task 6.4.
Interview on IPCC SROCC on aftenposten.no: Derfor stiger havet! Forklart på 35 sekunder	WP6	General Public		29.11.2019		IMR	

Polar data Forum III, Helsinki	WP1	Polar Data specialists	Promote exchange of data according to the FAIR principle	18.11.2019	Workshop om Marine Data, Posters, presentations	S.Sandven, H. Sagen, T.Hamre. E. Buch. R. Pirazzini, Erik Buch	INTAROS contributed to the organisation of a workshop on Arctic Marine Data exchange resulting in a proposal for establishing a Arctic portal for marine data in cooperation with EMODnet
Klimamarin konference: Hovedfunn fra FNs klimapanels spesialrapport om hav og islagte områder.	WP6	Scientific community, Industry, Civil society, Policy makers		12.11.2019	Presentation	IMR	
Svalbard Science Conference		Arctic science community, policy makers		05.11.2019	Presentation	S. Sandven	
Nordic Centre of Excellence CLINF Science Meeting	WP2	CLINF scientists	Promote exchange of data relevant to climate-sensitive infections	04.11.2019	Presentation	J. Lemmetyinen	
Side meeting on the Svalbard Social Science Initiative, SSSI,		Social Science community, Local community,		04.11.2019		L. Iversen	
IMBER Future Oceans2, Brest		Scientific community		01.11.2019	Poster on Carbonate system time-series in the coastal Arctic.	CNRS	

Appendix 2: Manufacturer questionnaire

Sensor and instrument technologies for observing the Arctic environment

The EU funded H2020 project INTAROS (www.intaros.eu) will, as one of its major deliverables in 2021, launch a Roadmap towards a Sustained Arctic Observing System (SAOS). The Roadmap will address gaps in the present Arctic Observing System identified by INTAROS and other initiatives such as SAON (https://www.arcticobserving.org/) or Copernicus In Situ Coordination (https://insitu.copernicus.eu/)

Development of new sensor and instruments technology able to measure and deliver timely (often near-real-time) good quality in situ data to users from a harsh Arctic environment has been pointed out as a key activity necessary to build a fit-for-purpose Arctic Observing System, realising that data communication from this remote region is a central issue to address and solve.

The INTAROS consortium is therefore interested in establishing a constructive dialog with sensor and instrument manufactures and developers to get a detailed overview of what are the existing observing technologies and, in particular, what are the plans for new developments of observing technologies adapted to Arctic environments.

We kindly invite you, as observing technology manufacturers and developers, to reply to the questionnaire below, as an initial step to open a dialog on improving the observing capabilities in the Artic and to help your company take advantage of a growing market in the Arctic.

The questionnaire is divided in 3 sections (Company identification, existing technologies and developing technologies) and will take less than 15 minutes to be filled.

All the information collected will be analysed and reported anonymously. We would ask you to reply to the survey BEFORE THE 15 JANUARY 2021.

All the information you provide will be treated according to the European General Data Protection Regulation (GDPR, no 2016/679). If you wish to change or delete your data, you can do so at any time by contacting: dataprivacy@eurogoos.eu

*Required

Company identification

1. Name of Company *

2. Country

3. Contact person (Optional)

4. Phone number (Optional)

5. E-mail address (optional)

6. Type of company
Mark only one oval

- ◯ Private
- ◯ Public
- ◯ Mixed Public-private
- ◯ Other: _____

7. Are the instruments/sensors you manufacture meant for observations of*: *
Tick all that apply.

- ☐ Atmosphere
- ☐ Ocean
- ☐ Cryosphere
- ☐ Land
- ☐ Other: _____

8. Please, provide a link to a webpage with information on your most important instruments/sensors, including price level if possible

Existing observing technologies, platforms and sensors

In this section you will be asked which existing observing technologies are currently available and being offered by your company

9. What are the variables measured by the instruments/sensors you provide (please use the list from https://gcos.wmo.int/en/essential-climate-variables/table)?

10. Are your instruments and sensors prepared for use in the Arctic Region?
Mark only one oval

- ◯ Yes, they are designed specifically for Arctic Observations
- ◯ They are not designed specifically for Arctic Observations, but are capable for that purpose
- ◯ They are not designed for Arctic purposed and will require modification to be used in the Arctic
- ◯ Other (specify):

11. Have your instruments and sensors been tested in the Arctic?
Mark only one oval

- ◯ Several years of experience
- ◯ One year of experience
- ◯ Testing phase
- ◯ No experience

12. Are data communication (e.g. IRIDIUM, fibreoptic cables, acoustics etc.) part of your product portfolio?
Mark only one oval

- ◯ Yes
- ◯ No

13. If you answered YES to the question 5; Do you have experience with data communication in the Arctic environments?
Mark only one oval.

- ◯ Yes
- ◯ No

New technology/Instrument/ sensors development

In this section you will be asked about on-going developments and/or innovation in new observing technologies being carried out in your company

14. Do your company have an instrument development facility?
Mark only one oval.

- ◯ Yes, as an integrated part of the company
- ◯ Only on ad hoc basis
- ◯ Very little or no innovation activity
- ◯ Other: _____

15. Do you have strict procedures for development of new sensors/instruments?
Mark only one oval.

Yes

No

16. How are sensors/instruments tested in the field before launching them to the market??

Tick all that apply.

- [ ] Done solely by the company
- [ ] Done in cooperation with potential costumers or research centers
- [ ] Other: _____

17. Which kind of instruments/sensors is your main focus of developement?

Tick all that apply.

- [ ] Re-usable instruments/sensors
- [ ] Expendable low-cost instruments/sensors
- [ ] Other: _____

18. If you work on the development of expendable, low cost instruments, do you have a strategy for protection of environment when selecting material for instruments? (If YES, please specify)

_____

19. How are your development & innovation costs mainly financed?

Tick all that apply.

- [ ] 100% financed by own resources
- [ ] Joint venture with other instrument manufactures
- [ ] Joint venture with public research institutions
- [ ] Partly financed via public R&D funds (e.g. EU, national)
- [ ] Other: _____

20. Would you be interested in developing and manufacture new instruments and sensors for Arctic observations in the future??

Mark only one oval

- Yes
- No
- Maybe, under certain circumstances

21. If you answered 'Maybe' to question 20, please specify under which circumstances

22. What are, according to you, the most important new observing technological challenges in the Arctic environments?

Tick all that apply.

- [ ] Robust data communication in near real time
- [ ] Robustness of instruments against low temperatures and rough environments
- [ ] Instrument deployment and/or recovery
- [ ] Other: _____

23. Please, add any general comment you may have about the questionnaire

INTAROS

This report is made under the project
Integrated Arctic Observation System (INTAROS)
funded by the European Commission Horizon 2020 program
Grant Agreement no. 727890.

Project partners: