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Deliverable 6.7. Assessment report of the "programme of ships and opportunity" for the Arctic Ocean"

Submission of Deliverable

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1. Abstract

The Arctic region is changing fast in the warming climate, but environmental observations are very limited due to difficult access.

In the ARICE Ships and Platforms of Opportunity (SPO) Program the aim is to enhance observing capacities in the Arctic by engaging private sector operators to participate in data collection. Private sector operators include a wide range of commercial vessels such as merchant ships, tourism ships, fishing vessels, or offshore platforms.

This document provides an assessment report of the ARICE Ships and Platforms of Opportunity (SPO) Program.

2. Introduction

Ship-based observations have a long history, over 150 years, and they are still a substantive part of marine observing systems. Despite of increasing use of satellites and automated measurement buoys, recruiting voluntary observing ships (VOS) outside of research fleet is seen as important (Smith et al. 2019). The largest program is the VOS Scheme, which has been coordinated by the World Meteorological Organization (WMO) and Joint Technical Committee for Oceanography and Marine Meteorology (JCOMM) since 1994. The World Ocean Council (WOC) has initiated the SMART Ocean SMART Industries (SO-SI) program to accelerate and scale up the number and location of vessels and platforms involved in data collection, providing a business organization to build on and support existing schemes, such as VOS. The Arctic is a geographic priority for the WOC SO-SI program overall, and via the ARICE project specifically.

A good understanding of the changing Arctic requires comprehensive monitoring but in the Arctic Ocean the collection of environmental observations has been and is very limited due to difficult access. The VOS Scheme does not currently cover the Arctic Ocean and the goal of ARICE Ships and Platforms of Opportunity (SPO) Programme is to extend VOS type work to the Arctic Ocean.

In view of engaging private sector operators to participate in data collection in the Arctic, we collaborated with WP2 in the organisation of the science-industry meetings. These meetings built the momentum necessary to a closer collaboration between the two communities, notably resulting in an ARICE-PONANT partnership and calls for ship-time proposals. Further details about the four meetings between the ARICE ILP and the scientific community can chronologically be found in D2.2; D2.5; D2.6 and D2.8.

In addition, feeding into the effort to expand the monitoring and observation capacities in the Arctic Ocean by using the increase in maritime traffic in the Arctic, an article was drafted and published in The Maritime Executive on 29th August 2022. To date, the article was viewed 2066 times. The article focuses on voluntary observations from ships navigating the Arctic Ocean. It first explains why it is crucial to continue and enhance these observations, and then goes on describing the three ways by which ship-owners can contribute to environmental data collection in the Arctic Ocean (sharing data collected for navigational purposes, collecting visual observations, additional automatic measurement systems).

3. Calls for ship-time proposals

In 2022, under the supervision of World Ocean Council (Task 6.2's lead), the SPO program achieved concrete collaboration with French cruise ship operator PONANT which offered to take scientific teams on-board *Le Commandant Charcot*. *Le Commandant Charcot* is a polar expedition ship state-of-the start icebreaker (PC2 Class). It is equipped with scientific laboratories and facilities including a FerryBox, and can host up to four scientists conducting research during the ship's regular cruises.

Two successive calls for ship-time proposals were launched in December 2021 and in May 2022 to access the Arctic Ocean. Proposals were welcome to carry out research activities within any field of polar science, including marine-based and terrestrial sciences (this including geology and biology in Greenland, Svalbard or the Canadian Peninsula), and social sciences.

In addition, in November 2022, a third call for proposals was open to access the Southern Ocean in the Antarctic season 2023 – 2024 and beyond. Again, scientific teams will be able to carry out research activities within any field of polar science including marine-based and terrestrial sciences (i.e. including geology and biology in the North Antarctic Peninsula, Bellingshausen Sea, Marguerite Bay, Weddell Sea, Snowhill Island, Charcot Island and Peter 1st Island, Svalbard or the Canadian Peninsula), and social sciences.

3.1. General funding and access conditions

The access provided on board Le Commandant Charcot has been offered by the company PONANT completely free of charge to ARICE and the scientific community. The following access conditions apply.

1. Up to four scientific berths on board the vessel "Commandant Charcot" are provided free of charge by the company PONANT in single or multiple legs.

2. Travel and shipping expenses to and from the port of departure/arrival to the institutes of origin must be covered by the applicants. However, PONANT contributes with a grant of 2000€ per scientist per leg for all projects as contribution to travel costs and logistics.

3. Navigation in these extreme lands is at the mercy of weather and ice conditions. Navigation will be determined by the type of ice the vessel come across; itineraries may vary.

4. Grantees will not invoice the ARICE Consortium or PONANT for any additional or third-party costs, such as salary costs, equipment manufacture, repair and rental of equipment, consumables, sub-contracting and assistance, publication costs and overheads.

5. If the number of days is reduced by PONANT for any reason or if the vessels are prevented from working (e.g. by poor weather or technical difficulties) no form of compensation shall be payable in respect of any time lost. Please note that cruise schedules could change during the year.

6. Vessel users should note that installation and operation of any equipment that they bring on board the vessels is done at their own risk, even when it is carried on board or deployed from the vessel. Further details will be provided during the negotiation phase.

7. The Principal Investigator is obliged to comply with the cruise reporting within two months after cruise completion.

8. A contract will be signed between the PI's institution and PONANT laying out terms and conditions of access, including the support granted, reporting, liability, applicable safety/security regulations and other topics under consideration.

Access limitation

Access will be provided to conduct research, with an exclusive focus on civil applications and comply with ethical principles. Access may be limited, amongst others, by the following: national security and defence, privacy and confidentiality, commercial sensitivity and intellectual property rights and ethical considerations in accordance with applicable laws and regulations.

3.2. First call for ship-time proposals

A first call for ship-time proposals was advertised between December 2021 and January 2022. Twelve research proposals were submitted. A scientific evaluation of the submitted proposals was carried out by ARICE Scientific Liaison Panel. 4 proposals were recommended for implementation with high priority; 6 proposals were recommended for implementation with lower priority; and 2 proposals were rejected.

Project name	**Affiliation, Country**	**Number of days at sea (Arrival to departure date)**	**Number of female participants (on-board)**	**Number of male participants (on-board)**	**Total number of participants (on-board)**
Ecotip	UiT The Arctic University of Norway, NO	12 days at sea (10/05/22 to 22/05/22)	1	1	2
Nanoplartic	Laval University, CA	13 days at sea (22/05/22 to 03/06/22)	1	1	2
ReHadiCC	AWI, DE	12 days at sea (03/06/22 to 15/06/22)	0	2	2
GOOD-OARS-IMDOS	GEOMAR, DE	13 days at sea (03/06/22 to 15/06/2022)	1	3	4
GOOD-OARS-IMDOS	GEOMAR, DE	9 days at sea (15/06/2022 to 23/06/2022)	3	1	4
Underway Measurements of Essential Marine Biogeochemical Variables in the Arctic	University of Calgary, CA	6 days at sea (23/06/2022 to 28/06/2022)	2	0	2
GOOD-OARS-IMDOS	GEOMAR, DE	5 days at sea (23/06/2022 to 28/06/22)	1	1	2
Underway Measurements of Essential Marine Biogeochemical Variables in the Arctic	University of Calagary, CA	11 days at sea (28/06/2022 to 08/07/2022)	2	0	2

GOOD-OARS-IMDOS	GEOMAR, DE	11 days at sea (28/06/2022 to 08/07/2022)	1	1	2
Arctic sea ice and Antarctic sea ice	AWI, DE	16 days at sea (08/07/2022 to 23/07/2022)	0	2	2
Phytoplankton distribution and diversity across poles	Oregon State University, USA	16 days at sea (08/07/22 to 23/07/22)	0	2	2
Drone Experiment for Sea Ice Retrieval (DESIR)	LEGOS/OMP, FR	16 days at sea (08/07/22 to 23/07/22)	1	1	2
Nanoplartic	Laval University, CA	16 days at sea (07/08/2022 to 22/08/2022)	2	0	2
Phytoplankton distribution and diversity across poles	Oregon State University, USA	16 days at sea (22/08/22 to 06/09/22)	1	2	3
Nitrarc	Duke University, USA	25 days at sea (07/09/22 to 01/10/22)	1	1	2
MoRaCCA	CNR, IT	N/A. Installation of sensors during stopover. NB: To date, sensors are still on board and collecting data.	0	3	3

ECOTIP

ECOTIP aimed to collect observational data (hydrography, water samples for eDNA, phytoplankton and parameters, zooplankton samples) in the ice-covered pelagic ecosystem in the western Greenland Sea. At the same time as the expedition takes place, the annual ice algae and phytoplankton spring bloom occurs, tightly followed by an efficient carbon pump and a build-up in zooplankton biomass. These events are a key period of primary and secondary production in the Arctic and observations from this time of the year provide a great, complementary data set to the one to be gathered by ECOTIP in August 2022 (in the same area). Further, data from spring (May) and summer (August) would be an excellent basis for ECOTIP to estimate the potential of ecological tipping cascades in the western Greenland Sea during different seasons.

In detail, ECOTIP collected hydrographical data (CTD) and water samples (Niskin bottle, surface and 3-4 water depths in the upper 200 m) during the “Le Commandant Charcot” expedition. The water samples will be analysed for nutrients, particulate organic carbon and nitrogen, chlorophyll a, phytoplankton abundance and composition and eDNA. If possible, also zooplankton samples (upper 100-200 m) will be collected (plankton net WP-2).

NANOPLARTIC

The main expedition's objective was to document the presence, fate, and impact of nanoplastics and anthropogenic nanoparticles in the Arctic Ocean. In this context, several questions are raised: - What is the distribution of nanoplastics from land-source to the North Pole and open oceans? - Does the Arctic play as a sink or a catalyst for their transportation?

The applicants have developed and validated an autonomous ultrafiltration system for nanoparticle fractionation and detection (AUSNP) that is designed to be directly plugged onto specific piping and equipment already installed in the vessel's laboratories (peristaltic and centrifugal pump) allowing them to take direct clean seawater samples. The AUSNP allows concentrating a large volume of nanoparticles and microparticles in water (i.e., concentration factor > 10000, from 100 liters to a final volume of 10mL). Then it fractionates microorganisms and microparticles from nanoparticles continously during the sampling campaign' on the Oceanographic vessel.' The samples are frozen at -20°C until reaching the TAKUVIK laboratory for complete analysis.

At each vessel stopping (4h/day), up to 300 liters of seawater have been automatically concentrated for posterior analysis.

ReHadiCC

The combination of higher water temperature, increased nutrient availability, and stratified water column promotes growth of dinoflagellates, a group of marine plankton that harbors many toxigenic species that produce a multitude of different marine phycotoxins. These toxins can enter the marine food web by trophic transfer and have deleterious effects on top predators as seabirds, marine mammals, and even humans

Whereas the occurrence of HAB species in the Arctic have been well documented for Alaska, West Greenland, Iceland, and the Chukchi Sea, hardly any data are available for East Greenland and Svalbard.

The project had the following objectives: 1) Determination of the presence of toxigenic plankton species in coastal waters of East Greenland and Svalbard by collection of plankton samples with special emphasis on toxigenic dinophyceae. 2) Assessment of phycotoxins presence in the study area. 3) Establishment of monoclonal cultures of potentially harmful algal species for subsequent physiological laboratory experiments under different temperature and pH regimes to assess their potential behavior in future climatic scenarios. 4) Taxonomic and phylogenetic characterisation of these cultures as well as their phycotoxin profiles.

GOOD-OARS-IMDOS

The expedition focused on the role of climate change and ocean pollution in the Atlantic sector of the Arctic Ocean, in particular on the role of warming and meltwater on upper-ocean stratification, deoxygenation and acidification and the resulting impacts on marine ecosystems.

The research objectives are:

1/ Assess the role of warming and meltwater input on upper ocean oxygen levels on the east Greenland shelf, in the East Greenland Current and around Spitsbergen (Nordvest Spitsbergen)

2/ OARS scientific objective is to assess ocean acidification (OA) data targeting SDG 14.3 and address the impacts due to climate change, such as warming, increased freshwater from melting glaciers, sea ice and increased landriver runoff, and permafrost melting due to climate change.

3/ Monitor the biomass and taxonomic composition of zooplankton (the crucial trophic link between primary producers and higher trophic levels) in relation to changing environmental parameters.

4/ Document the distribution of microplastics during the upcoming summer 2022 Ponant cruise campaigns

5/ Demonstrate that innovative user-friendly tools may underpin a sustainable citizen Oceanography 3.0 providing critical new knowledge on global plankton ecology, morphology and genetics.

Underway Measurements of Essential Marine Biogeochemical Variables in the Arctic.

The expedition's goal was to instrument Le Commandant Charcot with a suite of underway instruments to:

1) Determine pCO2 and concentrations of other greenhouse gases (CH4 and N2O) in under-sampled areas.

2) Measure pH and other carbonate system variables to build baseline data on ocean acidification state, and identify regions that may be vulnerable to acidification.

3) Measure phytoplankton primary productivity and physiology in the changing Arctic Ocean.

The equipment has been installed on the ship's dedicated scientific water sampling line, near the existing thermosalinograph during the expedition.

Arctic sea ice and Antarctic sea ice

The seasonal ice thinning during summer and changes of melt pond coverage and depth provide important insights into the surface energy budget of melting ice and related feedback processes (e.g. von Albedyll et al., 2021).

The team proposed to carry out ship-based ice thickness observations during all upcoming North Pole voyages of Le Commandant Charcot (LCC) using it's on-board Sea Ice Monitoring System (SIMS). In addition, to carry out as many in-situ ice thickness measurements with sledge-mounted EM systems towed on the ice while LCC is stationary with in the ice, and, if possible, to use the on-board helicopter to carry out airborne ice thickness surveys with EM Bird.

The repeated North Pole cruises of LCC in a given summer provide unique opportunities to study the melt of nearly the same ice during several months in summer. The team plans to observe this with the SIMS during all cruises as proposed above, and will in addition observe melt pond coverage, floe size, and other surface properties visually/photographically from the bridge as well as by as many drone flights as possible. Melt pond depths were measured in-situ while walking over the ice during the EM surveys, or photogrammetrically with the drone.

DESIR

The project aimed at undertaking measurements using lidars carried by drones. The aim of this project was to demonstrate the feasibility of this approach for measuring the thickness of the ice pack from

ships. This experimental phase would also require the ability to validate the measurements made by the drone.

The cruise report for this project was not yet available at the time of drafting this deliverable.

Phytoplankton distribution and diversity across poles

The project's primary question was: How does phytoplankton community composition and pigment diversity change with decreasing sea ice thickness and increasing under-ice light, and what are the biological transitions between sea ice environments and the open ocean environment?

142 samples were collected (particulate organic carbon; nutrients; pigments; samples for genomic analysis), in addition to ice core measurements and images of cells living in sea ice.

The final version of the cruise report was not yet available at the time of drafting this deliverable.

NITRARC

The applicants proposed to deploy high-resolution underway instruments to study how glacial melt influences the flow of energy and matter across Arctic oceanic ecosystems. The applicants declared in their proposal that their proposed work had multiple synergies with another group who would also be on-board the Charcot. The applicants stated that Dr. Marion Fourquez would be conducting measurements of O2 and CO2 flux and the applicant's underway high-resolution estimates of biological O2- based net community production would be of direct relevance to Dr. Fourquez's observations. Prior to the cruise, PI Cassar was in the Arctic studying N2 fixation in mosses and lichens in Alaska, Greenland and Svalbard. The team also proposed to sample mosses and lichens for the study of terrestrial BNF whenever the Charcot stopped at terrestrial sites. Mosses and lichens are often the dominant source of new nitrogen in Arctic terrestrial ecosystems.

Overall, the expedition a success and the scientific team was satisfied. They submitted two new projects proposals for future work on *Le Commandant Charcot*.

MoRaCCA

The proposed activity aims to take the opportunity offered by PONANT cruises to implement a very cost-effective monitor programme for surface radiation fluxes and cloud measurements over five years in the Arctic Ocean.

Scientific objectives: continuous observation with allow characterization of downwelling radiation at the surface, its Shortwave (SW) and Longwave (LW) components, cloud coverage and radiative impact over a very wide range of latitudes along the whole summer season. In addition, collected data provides useful ancillary information to researchers interested in marine ecosystems. To this scope we also add to the instrumental suite, UV-A and UV-B surface flux measurements.

Technical objectives: new technical solutions to improve atmospheric measurements over a ship will be implemented.

- inertial platform to collect SW and LW radiation components as well as cloud's characteristics
- automatic sun-spectrometer for columnar aerosol characterization.

The experience acquired on previous cruises (e.g. High-North 17) and ognoing projects in the frame of Italian Antarctic Programme (PNRA) will help to develop and test these solutions.

Specific outputs (deliverables) of the project together with datasets will be

(i) Characterization of the radiative flux balance in the Arctic Ocean; (ii) summer cloudiness index and cloud cover estimates; (iii) estimate of cloud radiative forcing (CRF);

3.3. Second call for ship-time proposals

A second call for ship-time proposals was advertised between May and July 2022. Seventeen research proposals were submitted before the deadline, including 12 marine based proposals, 2 terrestrial based proposals, and 3 social science proposals. The ARICE Scientific Liaison Panel recommended eleven projects for implementation with high priority, five with lower priority, and one proposal was rejected. Selected projects will be able to bring a team aboard to carry out scientific research in the Arctic Ocean for up to five Arctic seasons from 2023 on.

At the time of drafting this deliverable, the preliminary schedule of proposals selected for funding is as follows:

Project name	**Affiliation, Country**	**Number of days at sea (Arrival to departure date)**	**Number of female participants (on-board)**	**Number of male participants (on-board)**	**Total number of participants (on-board)**
AP-2023-Drivers x2	Biodiversity Research Institute (IMIB),Spain	10+14 days 15/05/2023 to 25/05/2023 08/06/2023 to 22/06/2023	0	2	2
AP-2023-NFIX x2	Duke University, USA	14+14 days 25/05/2023 to 08/06/2023 08/06/2023 to 22/06/2023	0	2	2
AP-2023-GOOD-IMDOS x4	GEOMAR, Germany	18 days 22/06/2033 to 10/07/2023	2	2	4
AP-2023-DeepSea x2	GEOMAR, Germany	17 days 10/07/2023 to 27/07/203	0	2	2
AP-2023-NANOPLARCTIC-25 x2	Université Laval, Canada	15+14 days 27/07/2023 to 11/08/2023 25/05/2023 to 08/06/2023	2	1	3

AP-2023-SeaIce x 1-2	AWI, Germany	15 days 11/08/2023 to 26/08/2023	0	2	2
AP-2023-PHENOLIGHT x1	Yale University, USA	15 days 11/08/2023 to 26/08/2023	1	0	1
AP-2023-PARTICIPATION x2	University of Oulu, Finland	15 days 11/08/2023 to 26/08/2023	1	1	2
AP-2023-ELENO x4	Institute of Polar Sciences (CNR-ISP), Italy	15 days 26/08/2023 to 10/09/2023	2	2	4
AP-2023-PhytoChAOs x 4	AWI, Germany	24 days 11/09/2023 to 08/11/2023	1	3	4
AP-2023-ArcticAir x2	Northumbria University, UK	24 days 11/09/2023 to 08/11/2023	1	1	2

The cruises to be implemented are as follows:

SeaIce: Arctic and Antarctic Sea Ice – Thickness variability and change, ice loads, and navigability

This project proposes to carry out extensive ship-based and on-ice measurements of sea ice thickness and other ice properties like, e.g., melt pond coverage, to complement our own long-term observations in the central Arctic and North Pole, as well as for satellite and model validation, and for the study ship-ice interaction and performance. This proposal is based on the successful outcomes of Ponant's demonstration cruise to the North Pole in 2021, and the team's participation in July 2022.

PhytoChAOs: Assessing impacts of phytoplankton community changes in two climate-sensitive arctic ecosystems

This project aims to establish a baseline of the phytoplankton community composition in two understudied Arctic systems heavily impacted by global warming. Results obtained from this project will highlight possible plankton community shifts and their drivers and help predict future consequences of global warming in these two sensitive and changing arctic ecosystems.

ELENO: Habitat templatE, microbiaL signaturEs and icoNic life in a changing Arctic Ocean

ELENO project seeks to quantify the present state of the physical, chemical, biological and biogeochemical systems of the Arctic Ocean. As part of the Synoptic Arctic Survey 2020/23 (SAS), ELENO will operate with a multidisciplinary approach, making use of common protocols. Emphasis of the project will be also devoted to understanding the major ongoing transformations on the water

masses, the marine ecosystem and the carbon cycle. ELENO aims at expanding the marine Arctic study area of the ongoing project CASSANDRA funded by the Italian Arctic Research Program (PRA). ELENO will therefore generate a dataset that will lead to an almost complete characterization of the Arctic Ocean by focusing on hydrography, carbon remineralization and ecosystem functioning, and iconic life. The obtained results will provide a unique baseline that will contribute to track climate change and its impacts as they unfold in the Arctic over the coming years and decades.

GOOD-IMDOS: Global Ocean Oxygen Decade - Global Ocean Observing System

Following the successful pilot phase in year 2022, this project proposes to participate in the Iceland-Svalbard legs over the next 4 years to monitor changes in oxygen levels, planktonic ecosystems and microplastic pollution in the Atlantic Sector of the rapidly changing Nordic Seas.

DeepSea: Deep Sea Ecosystem Monitoring from Pole to Pole

The proposal addresses the investigation of Arctic deep-sea plankton on two cruise legs from June to July 2023. The research is embedded into a larger framework addressing other ecosystems beyond the Arctic.

ArcticAir: ArcticAir: Arctic Aerobiology

The ArcticAir project will characterize airborne communities in the Arctic region, identify potential drivers, determine the risks of microbial invasion and, most importantly, monitor the interannual variability of these airborne communities and the associated environmental drivers. Overall, the ArcticAir project will answer key ecological knowledge gaps concerning airborne microbial communities and their changing roles in ecosystem function, helping us understand (and monitor) the impacts of climate change on airborne microbial communities in the region.

NANOPLARCTIC

The expedition's objective proposed here is to document the presence and impact of nanoplastics and anthropogenic nanoparticles in the Inuit Communities and evaluate the transportation pathways of these emerging contaminants in the Arctic Ocean.

DRIVERS: Drivers of trophic interaction structures in Arctic environments

The overall objective of this project is to quantify the structures of trophic networks in the Arctic, and evaluate how these network structures vary along latitude gradients. In addition, it will investigate how the structures are related to abiotic and biotic factors.

NFIX: Response of Nitrogen Fixation in Lichens and Mosses to a Rapidly-Changing Arctic Environment

The work carried out by this project will be part of a larger study to address some of the outstanding questions that have hindered projections of how the Arctic environment will respond and adapt to climate change by making the first measurements of Arctic terrestrial BNF with ARACAS, a state-of-the-art instrument developed in the Cassar Lab.

PHENOLIGHT: Phenomenology of light in the Arctic environment: ethnography of expedition

The Arctic provides unique settings for studying human relations with light. This project aims to explore the phenomenology (human perception) of light in the Arctic environment by ethnographic study of the expedition. This project focuses on the expedition as a site for ethnographic inquiry. The objective

of this project is to conduct an ethnographic study of light in the Arctic environment during the polar day and its influence on human perception of the Arctic landscape in the course of the expedition at high latitudes.

PARTICIPATION: Advancing visitors' participation in citizen science: the new appeal for the Arctic?

This proposed ship-time research onboard Le Commandant Charcot focuses on citizen science in expedition cruising. It is part of the 'Advancing visitors' participation in citizen science: the new appeal for the Arctic?' project we began in 2021 with the support of the Arctic Interactions (ArcI) programme of the University of Oulu (Finland). By investigating people's motivations to visit the most remote parts of the Arctic, our project aims to situate and assess citizen science in the span of travel motivations.

4. Future and legacy of the ARICE-PONANT collaboration

This ARICE-PONANT collaboration fulfilled the SPO program's goal to enhance observing capacities in the Arctic by engaging the private sector operators to participate in data collection. Since some of the successful projects might be implemented for several years, the program's impact will go beyond the lifetime of ARICE, serving as a fertile ground for a long term and systematic collaboration between PONANT and scientific research institutions even after ARICE has ended. Innovative further developments potentially include a collaboration with existing observation and data networks; and a collaboration with cruise ship companies operating in the Antarctic region.

