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Deliverable 1.3. Map of potential beneficiaries of a coordinated PRV fleet

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Abstract

Recent environmental changes and the associated potential for increased economic activity in the Arctic have triggered a demand for accurate sea-ice and weather forecasts, information on the environmental status of the Arctic Ocean, and predictions for future conditions in this region. Many of the consequent science and policy reports have highlighted how meeting this demand requires the establishment of an internationally coordinated sustained data stream from the Arctic Ocean, which relies on a sustained observation programs, in part supported and serviced by polar research vessels (PRVs) and research icebreakers (RIs). At present, these infrastructures are nationally owned and operated with limited possibilities for international coordination of efforts. This report studies the potential benefits of a better coordinated European PRV fleet. Four overarching categories of beneficiaries are identified: a) research, monitoring and observations b) PRV and RI operators c) institutions and funding agencies and d) society. The conclusion of the comparison of these beneficiaries is that bettering European coordination of PRVs would require significant, but mutually beneficial to all these four groups, changes in the ways the funding of research on and access to RIs and PRVs is organized. It would have high societal relevance by reducing the national cost of marine polar research through cost-sharing. It would also provide the data necessary for the local and global adaptation to the challenges and opportunities in a changing Arctic.

1. Introduction

The Polar Regions are undergoing rapid transformations with consequences for ecosystems, societies, economies and the whole global climate system (*Report of the 2nd Arctic science Ministerial 2018*, 21). Many international reports that assess the challenges and opportunities associated with these changes highlight how responding to them requires the establishment of a permanent Arctic observing system for the Arctic Ocean (IASC 2016, 5; AMAP; 2014; 2017; AMSA 2009; Arctic Council 2016; IDA Science and Technology Policy Institute and Sustaining Arctic Observing Networks 2017). This system would provide continuous, year-round access to data from Arctic waters with an emphasis on winter observations, and the use of Remote Operated Vehicles (ROVs) and Autonomous Underwater Vehicles (AUVs) capable to navigate under or close to ice. This kind of information is needed e.g. for the improvement of global and regional climate models and development scenario-building of Arctic sea ice variation. Without this knowledge further development of societal services such as search and rescue, as well as industries like shipping, extraction of minerals, tourism, hunting, and fishing will be difficult (AMSA 2009; AMAP 2014; Arctic Council 2016).

The scope of the challenges and opportunities in the changing Arctic has led many countries with history in polar science, but without their own PRVs or RIs necessary to conduct sustained Arctic marine operations, to develop Arctic research programmes. However, because of the high operating costs of Arctic marine research the necessary investments into technology and infrastructures are beyond the capacities of one single nation (*Report of the 2nd Arctic science Ministerial 2018*, 13).

The 2nd Arctic Science Ministerial held 25 and 26 October 2018 in Berlin identified three themes where an improved and better-coordinated international scientific effort could advance the understanding of the impact of rapid Arctic changes and to respond to major societal challenges in the Arctic and globally: 1) Strengthening, integrating and sustaining Arctic observations, facilitating

access to Arctic research infrastructure 2) Understanding regional and global dynamics of Arctic change and 3) Assessing vulnerability and building resilience of Arctic environments and societies (*Report of the 2nd Arctic science Ministerial 2018,* 10). The common denominator between all three themes was that the that high operational and observational costs associated with them could be reduced by sharing research infrastructure and observing systems (*Report of the 2nd Arctic science Ministerial 2018,* 13). This is especially true on research cooperation in the Arctic Ocean (AMSA 2011, 32).

Towards a harmonized EU Arctic Research Fleet

As shown in the ARICE "Deliverable 1.2. Guidelines on the conditions to access European PRVs", at present there are fifteen PRVs between Polar Code Category A and C operated by countries within the European Economic Area (EEA). These vessels are nationally owned and funded serving primarily national research interests and needs. Access to them is regulated nationally making admission for researchers belonging to a different country difficult (ARICE 2019).

The lack of international coordination of the operation of PRVs and RIs leads to multiple problems including duplication of efforts and diminishing ship-time availability on RIs in the ice-covered Arctic Ocean due to the usage of these vessels in operations elsewhere - especially as supply vessels in Antarctica. Together these problems impede Europe's capacity to investigate the polar regions – especially areas only accessible with RIs in the wintertime (Lugdwigsen et al. 2018; Dañobeitia et al. 2014).

Better coordination of the European PRV fleet would allow a better use of these costly polar marine research infrastructures. It would i.e. facilitate the international leveraging of funds to operate them and open access for ship-time for scientists from nations, which do not operate PRVs or RIs or whose vessels operate in different locations. Achieving this would require more than just coordination at the operational level. It would demand the development of possibilities for transnational funding and access of research expeditions on nationally operated European PRV fleet. Together these would optimize operational costs and to fulfil the needs of scientifically and politically agreed prioritized European polar research themes (IASC 2016, EU-PolarNet 2019; ERICON-AB 2015; *Report of the 2nd Arctic science Ministerial* 2018; IASC 2016; Agreement on Enhancing International Arctic Scientific Cooperation 2016).

ARICE aims at the optimal use of existing PRVs and RIs at a European and international level by improving their coordination and avoiding duplication of efforts and by working towards an International Arctic Research Icebreaker Consortium, which would share and jointly fund operational ship time on the available PRV fleet. The final goal is the creation of an Arctic Research Icebreaker Consortium, able to fund and implement international research expeditions in the High Arctic onboard existing RIs and PRVs.

2. Map of beneficiaries

In this study we have used a desktop analysis of recent national and international polar science and policy reports to review the potential beneficiaries of a better coordinated European RI and PRV fleet. In this process four overarching categories of beneficiaries have been identified: a) research, monitoring and observations, b) PRV operators, c) institutions and funding agencies, and the d) society. Due to differences in national organisation of polar research the categories sometimes overlap, but they all are present in the different national and international reports.

a) Research, monitoring and observations:

A better coordinated PRV fleet would benefit research, monitoring and observations by leading to:

- **Sustainability of monitoring systems:** One of the major obstacles for a sustained monitoring system of the Arctic Ocean is that in-situ observing systems lack sustainability (Ludwigsen et al. 2018, 101). In order to understand trends and variability of the individual components of the Arctic Ocean including its physics, biology, chemistry, as well as the coupling to the sea ice cover, atmosphere, glacial ice masses, and sediments through exchange of heat, water, gases, and particles, repeated sections and observations are necessary. These multi-disciplinary section data samplings should be repeated at least every three to five years in areas that are geographically as close as possible to eliminate spatial aliasing (Matrai, et al. 2015, 13-14). Prediction for changes in biological productivity, biodiversity and rates of biological change associated with climate change would require an even more often updated sampling system such as the pilot project of a "Distributed Biological Observatory (DBO)" along a latitudinal gradient extending from the northern Bering Sea to the Barrow Arc (NOAA 2014). Better coordination of PRVs would facilitate the execution of this kind of repetitive data collection through international projects with possibilities for ongoing and more sustained long-term planning of operations and their funding than the current impressive, but so far one-time efforts such as **Synoptic Arctic Survey (SAS)** and **Multidisciplinary drifting Observatory for the Study of Arctic Climate (MOSAiC)** allow. The need for this kind of system of systems is recognized internationally by both the scientific and political community (AMSA 2011; *Report of the 2nd Arctic science Ministerial 2018*; IASC 2016; EU-PolarNet 2019).

- **Possibilities to use multiple vessels in the same programme**: A coordinated Arctic fleet would open new possibilities for multidisciplinary observation networks and initiatives that require the simultaneous coordination of more than one vessel such as SAS. The logistical backbone of MOSAiC i.e. is German RV Polarstern, which will be drifting with the sea ice across the central Arctic from autumn 2019 to autumn 2020. The program was initiated by AWI in 2011 but is only possible because of strong partnership between seventeen nations including Germany, Russia, USA, China, United Kingdom, and Norway and the usage of some their PRVs and RIs in Polarstern's resupply and science collaboration. Multiple vessel coordination is also required for visiting specific key sites at different times for the early detection of changes like in DBO.

- **Maximising synergies and cooperation between Arctic and Antarctic research communities**: European PRVs and RIs operate often in both the Arctic and the Antarctic. The Antarctic activities often constrain research capabilities in both regions because the long round trips to Antarctica and the resupply of the national research stations there reduces PRVs availability to carry out marine based research activities (ARICE 2019). A coordinated PRV fleet would allow for the pooling of resources in the Antarctic resupply efforts increasing research-based ship-time on RIs and PRVs.

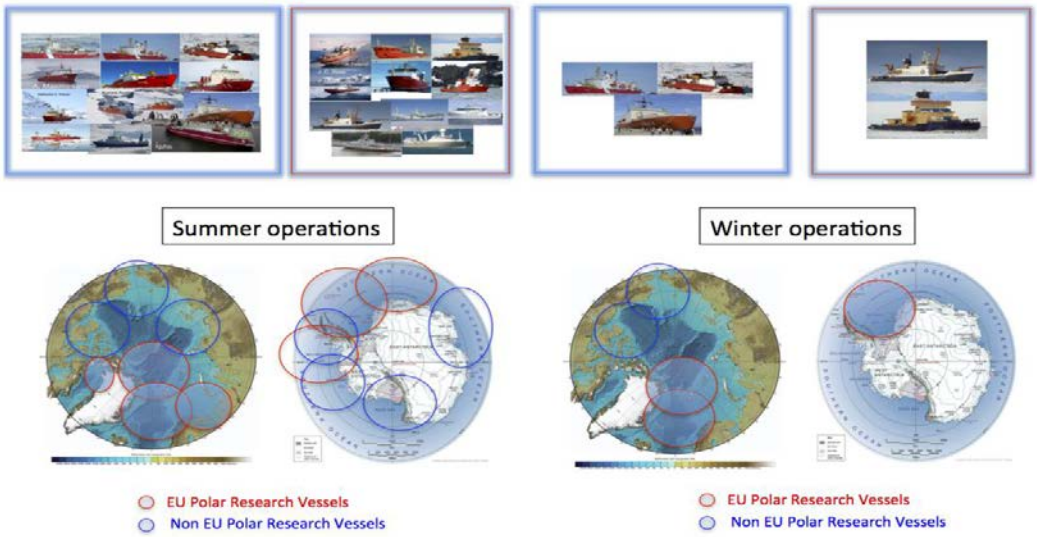

Figure 1. – Worldwide PRVs operational areas between 2009-2014 in the Arctic and Antarctic Polar regions (Dañobeitia et al. 2015, 9).

- **Increased geographic scope of PRV operations**: Knowledge of ocean-land and land-ice interactions in the Arctic region is limited as the few measurements are typically biased to the ice-free period (Matrai, et al. 2015, 9). The existing in-situ data from the Arctic Ocean is also often regionally focused on icebreaker expeditions, aircraft surveys, and manned drifting platforms from specific areas (Ludwigsen et al. 2018, 69, 101). A better coordinated European PRV fleet would allow to improve the temporal and geographic scope and add value to observations made on single independent expeditions especially if the timing and location across the fleet was coordinated in advance. It would also expand the national scope of Arctic marine research.

  With an international Arctic icebreaker consortium countries that have a strong history in polar research but do not have vessels regularly operating in the high Arctic like France, Netherlands, Spain and Italy would be able to offer opportunities for their scientific community to conduct and lead marine research at both poles (*Report of the 2nd Arctic science Ministerial*, 46-47, 56-57, 60-61, 74,75; Ministère des affaires étrangères et du développement international 2016; The Netherlands Organisation for Scientific Research

2014; Ministerio de Ciencia, Innovación y Universidades 2016; Ministry of Foreign Affairs and International Cooperation 2016). Researchers who work in countries operating PRVs would, in turn, be able to increase the geographical scope of their work because they would not be bound by the operational area and or capacities of their national PRVs.

- **Strengthening of international research networks**. Having access to a coordinated European PRV fleet would facilitate access to better training, international and inter-disciplinary collaboration and career-development possibilities especially for early-career researchers. All of these elements have been noted to contribute to future innovation and further development of research excellence (Majaneva et al 2011; Friedshahn and Beaudry 2014).

b) PRV and RI Operators:

Operators of PRVs and RIs would benefit from the harmonization of the polar vessel fleet through:

- **Avoidance of duplication of efforts:** In a workshop held at the European Research Vessel Operators (ERVO) annual meeting in June 2019 all onsite survey participants answered that they had experienced duplication of efforts or not optimal use of their national vessels. Through a coordinated organization of research cruises and initiatives, ship-time would be optimized, i.e. avoiding or minimizing unnecessary transits and expeditions to the same area as other national programs.

- **Cost-sharing:** PRVs and RIs are very expensive assets with high development, investment, operation, maintenance and implementation costs (EUROFLEETS2 2013). A harmonized European Arctic Research fleet and an international Arctic Research Icebreaker Consortium would allow for the sharing of these costs through transnational co-funding of research expeditions.

- **Optimizing the use of infrastructures:** The lack of coordination of PRVs and RIs leads to non-optimal use of these infrastructures. The science plan for IB Polarstern operated by AWI is i.e. determined until the end of its lifetime. The other heavy icebreaker within EEA, IB Oden, is owned by the Swedish state, operated by the Swedish Maritime Administration, and not connected to a specific national research institute. In the wintertime Oden is not used for research but used icebreaking in the Baltic Sea. For research expeditions it is chartered by the Swedish Polar Research Secretariat. In practice this means that core funding from the Swedish Polar Research Secretariat is for running the vessel and logistics rather than direct research costs. Research groups must come with their own funding for expeditions. A harmonization of European PRVs would allow to use another vessel, such as the Finnish MSV Fennica or a new vessel for the Swedish Maritime Administration, to fulfil the demand of icebreaker services in Sweden freeing Oden to do research in areas where only it or other Polar Code A class icebreakers can access.

- **Continued, coordinated long-term planning for operators of PRVs:** In the abovementioned ERVO workshop, the operators of European Polar Research Vessels all agreed that existing platforms for sharing vessel schedules and other operational information are not sufficient.

They highlighted that there is a need for a solution that would not require additional man-hours to operate but could be connected to existing forums of cooperation such as ERVO.

- **Better coordination and cooperation of the supply of Antarctic research bases**. Several European PRVs have the primary mission to resupply their national Antarctic stations (Dañobeitia 2014, 6). Better coordination would allow nations doing research on both poles to avoid the trip across the ocean for the other poles leading to further efficiency in logistical use.

c) Institutions and funding agencies:

Some of the reasons behind the limitations in in-situ data collection from the Arctic Ocean are the vastness, low population density, and extreme conditions in the Arctic, which together amount to high costs of operations and difficulties of access (*Report of the 2nd Arctic science Ministerial 2018*, 13). Another limitation are PRVs and RIs, which represent very expensive assets with high development, investment, operation, maintenance and implementation costs (EUROFLEETS2 2013).

A harmonized European Arctic Research fleet would:

- **Reduce operating costs** by better use of the infrastructures and avoiding or minimizing transit time between Arctic and home bases.

- **Allow funding agencies** from countries which do not own or operate a PRV but with strong polar programmes, **to invest in polar science** without committing to the high costs of constructing, operating and maintaining such costly infrastructures.

- Facilitate the **co-design and co-**funding of international expeditions tackling common European research interests.

More specifically, national funding agencies would be able to support research in the priority areas of their national polar programs but would not be bound to invest into new national vessels with the costs associated to running and operating them. The institutions and agencies operating vessels would, in turn, benefit from being able to do both, operate them in the geographical areas they are best suited for and provide their research access to a more comprehensive geographical area.

There are many ongoing efforts at a sporadic and smaller scale bilateral cooperation, for example between Swedish Polar Research Secretariat and National Science Fund (US), Belmont Forum Collaborative Research Actions Calls focused on Arctic region, Eurofleets2 and Ocean Facilities Exchange Group (OFEG) for the facilitation of cost of polar research through co-funding (Belmont forum 2019; EUROFEELTS2 2013, OFEG 2019; Matrai et al. 2015). They all manifest the interest and benefits of increased international logistical and research coordination as well as in cost for national institutions and funding agencies at present.

d) Societal benefits

The Sustaining Arctic Observing Networks (SAON) is a joint initiative of the Arctic Council and the IASC that aims to strengthen multinational engagement in pan-Arctic observing. Its vision is a

connected, collaborative, and comprehensive long-term pan- Arctic Observing System that serves societal needs (SAON 2018). In 2017 SAON, in cooperation with IDA Science and Technology Policy Institute, held a value-tree exercise to explore how Earth observations in the Arctic contribute to key societal objectives in a range of domains, including; food, energy, and water security; transportation; and natural resource development (IDA Science and Technology Policy Institute and Sustaining Arctic Observing Networks 2017, 1). These societal benefits have later been quantified through the value tree method to services in the field of climate environmental information, marine, research and weather (Strahlendorff et al. 2019, 11).

A coordinated European PRV fleet would contribute to all of the aforementioned areas of societal benefits. More specifically, it would benefit the European society through:

- **Improved observational services:** Harmonization of PRV fleet would allow for the collection of data to deliver services in all of the societal domains identified by SAON including better weather prediction models and weather forecasts, improved disaster preparedness, better monitoring of environmental impacts and quality of ecosystem functions, and improving the understanding of environmental effects on infrastructure operations (IDA Science and Technology Policy Institute and Sustaining Arctic Observing Networks 2017). These would improve the safety of Arctic navigation. Better knowledge of the Arctic Ocean would also benefit industries operating in the Arctic Ocean such as fishing, bioprospecting, and oil and gas (EU-PolarNet 2016). In addition, improved observations would not only enhance marine safety but also marine environmental protection, management and knowledge-based decision-making (AMSA 2011, 33).

- **Facilitating adaptation to climate change**: As many politicians and scientist highlight, what happens in the Arctic does not stay in the Arctic. In other words, the increase access to in-situ data especially in the High Arctic would not only allow for better predictions and adaptation to a changed climate locally but as globally (IASC 2016, 5: *Report of the 2nd Arctic science Ministerial 2018*). The harmonization of the European PRV fleet is not only a question of increased data but also decreased costs.

- **Better usage of public resources:** All of the groups of beneficiaries include examples illustrate how better coordination of PRV and RI fleet would lead to more cost-efficient solutions. This could benefit the public through a more cost-efficient use of resources to the management of national infrastructures.

- **Confidence and peace building through science diplomacy:** Next to quantifiable societal benefits in services and reduced costs, the harmonization of the European PRV fleet would also have 'soft' societal benefits. Past experiences in international science cooperation have shown how international cooperation in research can even built trust among improve relations between nations partaking in it (Crawford, Shinn, and Sörlin 1993; Stuart 2013; Su and Mayer 2018). These were summarized in the following words in the context of the first Arctic Science Ministerial meeting in 2016: "Ultimately, the process of science diplomacy builds common interests among allies and adversaries alike across a continuum of urgencies, spanning security to sustainability time scales with efficiencies and synergies that transcend the geopolitics of today." (Berkman et al. 2017, 598)

3. Conclusions

During the past two decades many international policies and science reviews have highlighted the need to establish a well-coordinated and Sustained Arctic Observing Network to fulfil different scientific and societal needs in a changing Arctic. They have underlined how the responses to the societal and environmental concerns associated with these changes require increased international coordination of polar research. Despite of the acknowledgement of the need for increased international coordination of polar science the management of these infrastructures in the Arctic remains largely a national effort with limited possibilities for international coordination. This is true especially to the operation of PRVs and RIs, which are operated and maintained by national programmes and devoted to serve national scientists and priorities.

This report has illustrated how despite of the traditional national coordination of PRVs and RIs at a first glance there does not seem any obvious initiative for increased coordination, this effort would benefit both national and international policy making and science plans for the Arctic.

The better coordination of national facilities across Europe would benefit a range of stakeholders, in a "win-win" situation by; limiting duplication of efforts; reducing operational costs; increasing number of operative days at sea; and ensuring appropriate vessels are used for specific tasks. Additionally, not all European nations own or operate PRVs, and especially (but not exclusively) those with strong polar programmes, would benefit from European access, cruise co-funding and co-design mechanisms.

More specifically, a coordinated PRV fleet would benefit research, observation and monitoring, vessel operators, funding agencies and institutions and the society by:

- Facilitating the international coordination and execution of research interests especially to regions where data is missing.

- Allowing international participation through international leverage of funds and co-design of expeditions.

- Reducing PRV and RI operating costs by providing the most advantageous combination of

  cost, quality and sustainability for these infrastructures.

- Providing the necessary data, knowledge and observation for resilient and sustained adaptation to the changing global climate.

In sum, examples from each of the four stakeholder groups have illustrated how even though the tradition of national research planning in the polar regions is still strong there are already many international harmonization initiatives. These success stories highlight how making the Arctic Ocean accessible to excellent science through the harmonization of infrastructures leads to national as well as international benefits beyond the capabilities of individual national polar programmes.

4. Bibliography:

Agreement on Enhancing International Arctic Scientific Cooperation. 2017. (https://oaarchive.arctic-council.org/bitstream/handle/11374/1916/EDOCS-4288-v2-ACMMUS10_FAIRBANKS_2017_Agreement_on_Enhancing_International_Arctic_Scientific_Cooperation.pdf?sequence=2&isAllowed=y). Last visited June 25, 2019.

AMAP. 2004. *Impacts of a Warming Arctic: Arctic Climate Impact Assessment (ACIA) Overview Report.* (https://www.amap.no/documents/doc/impacts-of-a-warming-arctic-2004/786). Last visited June 03, 2019.

AMAP. 2017. *Snow, Water, Ice and Permafrost. Summary for Policy-makers*. (https://www.amap.no/documents/download/2888/inline). Last visited May 13, 2019.

Anderson, L.G., Ashjian, C., Azetsu-Scott,K., Bates,N.R., Carmack, E., Chierici,M., Cho, K-H., Deming, J., Edelvang, K., Gerland, S., Grebmeier, J., Hölemann, J., Itoh, M., Ivanov, V., Kang, S-H., Kassens, H., Kikuchi, T., Lien, V., Mathis, J., Novikhin, A., Olsen, A., Paasche, Ø., Schlosser, P., Swift,J., Stedmon, C., Sørensen, L., Titov, O., Tyrrell, T., Wilkinson, J., Willams, B. 2018. *Synoptic Arctic Survey. -a pan-Arctic Research Program Science and Implementation Plan*. Available at: http://www.synopticarcticsurvey.info/splan.html. Last visited April 26, 2019.

Arctic Council. 2016. *Arctic Resilience Report*. M. Carson and G. Peterson (eds). Stockholm Environment Institute and Stockholm Resilience Centre, Stockholm. Available at: http://www. arctic-council.org/arr. Last visited June 03,2019.

ARICE. 2019. *Deliverable 1.2. Guidelines on the conditions to access European PRVs*. *Available at:* https://arice.eu/about/work-packages/wp1-towards-an-arctic-research-icebreaker-consortium

Belmont forum. 2019. *ANNOUNCEMENT of Research Funding Opportunity for ARCTIC research Belmont Forum Collaborative Research Action on Resilience in Rapidly Changing Arctic Systems (CRA Arctic II).* Available at: https://www.belmontforum.org/news/arctic-announcement/. Last visited May 13, 2019.

Berkman, P.A., Kullerud, L., Pope, A., Vylegzhanin, A.N., Young, O.R. 2017. "The Arctic Science Agreement propels science diplomacy". In *Science* 03 Nov: Vol. 358, Issue 6363, pp. 596-598.

Crawford, E., Shinn, T., and Sörlin, S. 1993. *Denationalizing Science. The Contexts of International Scientific Practice*. Dordrecht: Springer.

Dañobeitia, JJ, Biebow, N., Willmott, V, Ojeda, MA, Thomsen, H., Tannerfeldt, M., 2014. *Status and foreseeable evolution of the European and International Polar Research Fleets & Equipment*. Available at: EUROFLEETS2-WP3-D3.1-210114-V0.7.doc. Last Visited April 25, 2019.

Dañobeitia, JJ, Ojeda MA, Nieuwejaar, P, Willmott, V, 2015. *Report on the feasibility of year round, regular research operations in ice-covered areas*. Available at: EUROFLEETS2-WP3-D3.1-210114-V0.7.doc. Last visited April 25, 2019.

English, J.M., A. Gettelman, and G.R. Henderson. 2015. "Arctic Radiative Fluxes: Present-Day Biases and Future Projections in CMIP5 Models". In *J. Climate,* 28, 6019–6038.

ERICON-AB. 2015*. Final Report Summary - ERICON-AB (The European Polar Research Icebreaker Consortium AURORA BOREALIS).* Available at: https://cordis.europa.eu/project/rcn/89039/reporting/en. Last visited May 07, 2019.

EUROFLEETS2. 2013. *Concept and project objectives.* Available at: http://www.eurofleets.eu/np4/64/. Last visited May 12, 2019.

EU-PolarNet. 2016. *Deliverable No. 4.5 A Stakeholder Map.* Available at: https://www.eu-polarnet.eu/fileadmin/user_upload/www.eu-

polarnet.eu/Members_documents/Deliverables/WP4/EU-PolarNet_D4_5_A_stakeholder_map.pdf. Last visited May 13, 2019.

The EU-PolarNet, 2019. *White Papers*. Available at: https://www.eu-polarnet.eu/fileadmin/user_upload/www.eu-polarnet.eu/user_upload/EU_PolarNet_White_Papers.pdf. Last visited April 25, 2019.

Grebmeier, J.M, L.W. Cooper, C.A. Ashjian, B.A. Bluhm, R.B. Campbell, K.E. Dunton, J. Moore, S. Okkonen, G. Sheffield, J. Trefry, and S.Y. Pasternak. 2015. *Pacific Marine Arctic Regional Synthesis (PacMARS) Final Report, North Pacific Research Board*. 259 pp. (https://pacmars.cbl.umces.edu/Documents/PacMARS%20Final%20Report_2015.pdf) Last visited, April 18, 2019.

Friesenhahn, Irene and Beaudry, Catherine. 2014. *'The Global State of Young Scientists' Project Report and Recommendations* (https://globalyoungacademy.net/wp-content/uploads/2015/06/GYA_GloSYS-report_webversion.pdf). Last visited April 24, 2019.

Grote, Sebastian. 2018. "This will take us to areas that are beyond anything we can imagine". (https://www.mosaic-expedition.org/about-mosaic/the-expedition/interview.html). Last visited May 13, 2019.

IASC, 2016*. Integrating Arctic Research - a Roadmap for the Future 3rd International Conference on Arctic Research Planning ICARP III*. Available at: https://icarp.iasc.info/images/articles/downloads/ICARPIII_Final_Report.pdf. Last visited April 24, 2019.

IDA Science and Technology Policy Institute and Sustaining Arctic Observing Networks. 2017. *International Arctic Observations Assessment Framework.* IDA Science and Technology Policy Institute, Washington, DC, U.S.A., and Sustaining Arctic Observing Networks, Oslo, Norway, 73pp.

Jakobsson,M., Mayer,L., Coakley,B., Dowdeswell, J.A., Forbes,S., Fridman, B., Hodnesdal,H., Noormets,R., Pedersen, R., Rebesco,M., Schenke, H.W., Zarayskaya, Y., Accettella,D., Armstrong, A., Anderson, R.M., Bienhoff, P., Camerlenghi, A., Church, I., Edwards, M., Gardner, J.V., Hall J.K., Hell, B., Hestvik, O., Kristoffersen, Y., Marcussen, C., Mohammad, R., Mosher, D., Nghiem, S.V., Pedrosa, M.T., Travaglini, P.G. and Weatherall. P. "The international bathymetric chart of the Arctic Ocean (IBCAO) Version 3.0." 2012. In *Geophys. Res. Lett*., 39, L12609.

Ludwigsen, C.A., Pirazzini,R., Sagen, H., Hamre, T., Sandven, S., Stette, M., Babiker, M., Schewe, I., Soltwedel, T., Behrendt, A., Andersen, O.B., Beszczynska-Möller, A., Walczowski, W., Ottersen, G., Renner, A., Morvik, A., Sejr, M.K., King, A., Gustavsson, D., Johannessen,T., Smedsrud,L.H., de Lange, T., Ardhuin, F., Heygster, G., Buch, E., Storvold, E., Falck, E., Houssais, M-N., Aarnes, Ø. 2018. *Deliverable 2.1 Report on present observing capacities and gaps: ocean and sea ice observing system.* Available at: https://intaros.nersc.no/sites/intaros.nersc.no/files/D2.1%20final_31May2018_0.pdf. Last visited April 18, 2019.

Majaneva, S., Hamon, G., Fugmann, G., Lisowska, M., and Baeseman, J. 2016. "Where are they now? – A case study of the impact of international travel support for early career Arctic researchers". In *Polar Science*, Volume 10, Issue 3, Pages 382-394.

Matrai, P., C. Leck, P. Minnett, L. Anderson. 2015. *U.S-Swedish Planning Workshop on Joint Arctic Research using the I/B Oden*. Sigtuna, Sweden. 27pp. (https://polar.se/dok/oden-arctic-report-final.pdf). Last visited April 17, 2019.

Ministère des affaires étrangères et du développement international 2016; *The Great Challenge of the Arctic: National Roadmap for the Arctic*. (https://www.diplomatie.gouv.fr/IMG/pdf/frna_-_eng_-interne_-_prepa_-_17-06-pm-bd-pdf_cle02695b.pdf) Last visited April 25, 2019.

Ministerio de Ciencia, Innovación y Universidades, 2016. Guidelines for a Spanish Polar Strategy. (http://www.ciencia.gob.es/stfls/MICINN/Investigacion/FICHEROS/Comite_Polar_definitivo/Directrices_estrategia_polar_espanola.pdf). Last visited April 25, 2019.

Ministry of Foreign Affairs and International Cooperation 2016. *Towards and Italian Strategy for the Arctic.* (https://www.esteri.it/mae/en/politica_estera/aree_geografiche/europa/artico). Last visited April 25, 2019.

The Netherlands Organisation for Scientific Research, 2014. *Pole Position - NL 2.0 Strategy for the Netherlands Polar Programme 2016-2020*. (https://www.nwo.nl/en/documents/alw/netherlands-polar-programme---strategy---pole-position---nl-2.0) Last visited April 25, 2019.

NOAA (National Oceanic and Atmospheric Administration). 2014. *Distributed Biological Observatory – Linking Physics and Biology.* (https://www.pmel.noaa.gov/dbo/). Last visited June 25, 2019.

OFEG. 2019. *Ocean Facilities Exchange Group. A bottom-up approach towards research fleet co-ordination and harmonization.* http://www.ofeg.org/np4/home.html. Last visited May 13, 2019.

Report of the 2nd Arctic Science Ministerial. 2018. CO-OPERATION IN ARCTIC SCIENCE – CHALLENGES AND JOINT ACTIONS. 25–26 October 2018. Berlin, Germany. (https://www.arcticscienceministerial.org/files/190402_ASM2_Bericht_V2_bf.pdf) Last visited April 25, 2019.

SAON. 2018. *Sustaining Arctic Observing Networks Strategy: 2018-2028.* (https://www.arcticobserving.org/images/pdf/Strategy_and_Implementation/SAON_Strategy_2018-2028_version_16MAY2018.pdf). Last visited May 13, 2019.

Strahlendorff, M., Veijola, K., Gallo, J., Vitale, V., Savela, H., Smirnov, A., Tanaka, H., Sueyoshi, T., Nitu, R., Larsen, J.R.. 2019. *Value tree for physical atmosphere and ocean observations in the Arctic*. (https://helda.helsinki.fi/bitstream/handle/10138/300768/Value%20tree%20for%20physical%20atmosphere%20and%20ocean%20observations%20in%20the%20Arctic.pdf?sequence=1&isAllowed=y). Last visited May 13, 2019.

Stuart, Sam. 2013. *The Histories of the International Polar Years and the Inception and Development of the International Geophysical Year: Annals of The International Geophysical Year, Vol. 1*. London: Pergamon Press.

Su, Ping and Maximilian Mayer. 2018. “Science Diplomacy and Trust Building: ‘Science China’ in the Arctic”. In *Global Policy,* Volume 9, Issue S3, Pages 23-28.

Swedish Polar Research Secretariat. 2018. *Expedition, Arctic Ocean 2018*. (https://polarforskningsportalen.se/en/arctic/expeditions/arctic-ocean-2018) Last visited April 25, 2019.

Synoptic Arctic Survey. 2019. *Synoptic Arctic Survey.* (http://www.synopticarcticsurvey.info/) Last visited April 26, 2019.