Arctic in Rapid Transition

ART

Implementation plan

ART Executive Committee

20 June 2011

Arctic Ocean Sciences Board: Marine Working Group/
International Arctic Science Committee

Executive Summary

Arctic sea ice extent and thickness are declining rapidly, simplifying access to oil and gas resources, enabling trans-Arctic shipping, and shifting the distribution of harvestable resources. These projected socio-economical opportunities have brought the Arctic Ocean to the top of national and international political agendas. Alarmingly, current sea-ice loss appears to be unmatched over at least the last few thousand years (Polyak et al., 2010) and is taking place more rapidly than projected by any of the 18 global climate models used by the IPCC (IPCC, 2007). The persistent mismatch between observed and projected patterns makes planning and mitigation activities in the Arctic region complicated. Therefore, scientific knowledge of the present and past status of the Arctic Ocean and the process-based understanding of the mechanics of change are urgently needed to make useful projections of future conditions throughout the Arctic region.

The Arctic in Rapid Transition (ART) Initiative is an integrative, international, interdisciplinary, pan-Arctic network to study the spatial and temporal changes in sea ice cover, ocean circulation and associated physical drivers over multiple timescales to better understand and forecast the impact of these changes on the ecosystems and biogeochemistry of the Arctic Ocean. The ART Initiative was initiated by early career scientists in October 2008 and subsequently endorsed by the Marine Working Group of the International Arctic Science Committee (IASC), formerly the Arctic Ocean Sciences Board. ART will be implemented via a three-phase approach:

PHASE I: The development of an active international and multidisciplinary network of scientists sharing a common interest in improving our understanding of the implications of sea ice transitions in the Arctic Ocean.

PHASE II: The coordination of dedicated, multi-country, inter-disciplinary field campaigns and data collection activities that would provide input into an integrated modelling effort.

PHASE III: The synthesis of knowledge including the development of robust scenarios regarding the future state of Arctic marine ecosystems and their role in global processes.

Mentoring and educational programs will be integral to all three phases to help maintain the organic identity of ART as a network led by early-career scientists. The implementation of ART will rely on the successful integration and collaboration with many scientific programs that are already active or in development. The legacy of ART will be a robust set of predictive tools that will enhance the integration of Arctic marine sciences into global assessments of climate change and help manage increased human activity in the Arctic.

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What is ART and what makes ART unique?

The ART Executive Committee originates from a network of early-career Arctic marine scientists who have been involved in multidisciplinary national and international research programs during the last decade. The unique characteristics of the ART Initiative (Figure 1) are arrayed along four axes:

- *International:* ART is an international effort both in terms of geographic scope (pan-Arctic) and of the nationalities of the founding and participating scientists.

- *Interdisciplinary:* ART fosters communication and data exchange among disciplines and will improve our understanding of the response of the Arctic marine realm as a whole (i.e. ecosystems and biogeochemistry) to changes in climate and Arctic sea ice.

- *Temporal Linkages:* ART has an important focus of bridging temporal aspects, including paleorecords, current observational studies and modelling efforts

- *Early Career Involvement:* ART was conceived, developed and remains steered by early-career scientists, with ongoing intellectual support from dedicated senior scientists who serve an advisory role. The program aims to continue and support the active involvement of early-career scientists in ongoing Arctic research.

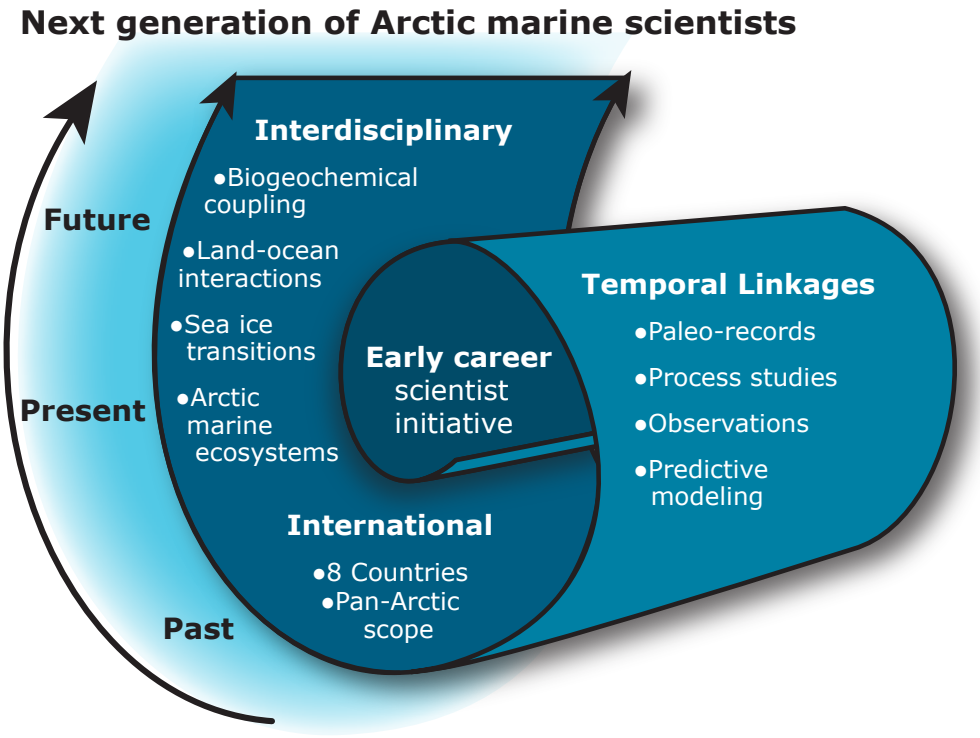

Figure 1. Schematics illustrating the characteristics of ART. An initiative undertaken by current early-career scientists leads to the development of an international network that aims to bridge disciplines and time scales in order to better understand the response of Arctic marine ecosystems to climate change and sea ice transitions. ART also reinforces the mentoring of emerging early-career scientists in multidisciplinary aspects of Arctic marine system sciences.

Background and Rationale

ART is an initiative developed by early-career scientists as a continuation of the International Conference on Arctic Research Planning II (ICARP II) Marine Roundtable, an initiative of the Arctic Ocean Sciences Board (AOSB), now the Marine Working Group of the International Arctic Science Committee (IASC). The ART Science Plan (Wegner et al., 2010) developed after the ART Initiation Workshop held in November 2009 in Fairbanks, Alaska, USA (Frey et al., 2010) was endorsed by the AOSB during the Arctic Science Summit Week in Nuuk, Greenland in April 2010. In October 2010, the ART Implementation Workshop was held in Winnipeg, Manitoba, Canada (Wegner et al., 2011) in order to develop the implementation plan to accompany the ART Science Plan. The two ART workshops were supported by AOSB/IASC, the International Arctic Research Center at the University of Fairbanks, the Department of Fisheries and Oceans Canada, the US National Science Foundation, the Research Council of Norway, IFM-GEOMAR in Germany, and the Association of Polar Early Career Scientists (APECS).

ART originated from the impetus to merge the three marine ICARP II working group reports; Deep Central Basin of the Arctic Ocean (WG4), Arctic Margins and Gateways (WG5) and Arctic Shelf Seas (WG6) to provide for a pan-Arctic interdisciplinary approach to studying Arctic marine change. Given that the ICARP II meeting occurred in 2005, ART aims at updating and refreshing the scientific issues raised within the ICARP II reports to a post International Polar Year 2007–2009 perspective. A cross-cutting and inter-disciplinary initiative (such as ART) is essential to meet the need for increased interdisciplinary knowledge related to ongoing climate change and increased human activity in the Arctic marine regions. There is a need for an understanding of the spatial and temporal dynamics of the Arctic marine system as a whole, including transitions in sea ice, terrestrial input and gateway processes, and the impacts on marine ecosystems, their productivity and the consequences for biogeochemistry. An identification and understanding of projected and ongoing changes requires a pan-Arctic perspective and the inclusion of geological records.

Objectives of ART

The central objective of ART is to develop and structure an active international scientific network focused on bridging time scales, marine science disciplines, and geographic regions in order to better understand the past, present and future response of Arctic marine ecosystems to sea ice transitions. Within this objective, the ART network aims at improving our predictive capability with respect to consequences for biological productivity, ecological functions and biogeochemical cycling in the Arctic. A primary goal of ART is to support the development of paleoproxies from periods of reduced ice cover and/or ice-free intervals in the geologic past (Polyak et al., 2010) in order to provide analogues of the current sea-ice transition. ART also endeavours to increase and integrate our knowledge of modern Arctic marine ecosystems in order to augment their representation within global impact assessments of climate change and human activity. Despite the steep rate and alarming nature of change taking place in the Arctic, impacts on Arctic marine biological systems are often overlooked (Wassmann et al., 2011) owing that the changes have been primarily reflected and detected in the physical and geochemical domains (Carmack and McLaughlin, 2011). However, environmental changes have a fundamental impact on carbon/nutrient cycling and ecosystem function, which has to be addressed in order to, understand feedbacks between the physical and biological components of the Arctic Ocean.

Toward these goals, ART proposes three overarching science questions that serve to unify marine science disciplines rather than questions along traditional disciplinary partitions. The role of the key questions is to frame ART within an integrated science concept (Figure 2). This framework emphasizes the central role of sea ice transitions and the importance of linkages and feedbacks between atmospheric, climatic and oceanic forcings, and the biological, chemical, and geochemical processes that are fundamental to regional ecosystem function and to the productive capacity of the Arctic Ocean. The scientific rationale underlying the three overarching questions, as well as further sub-questions, is detailed within the ART Science Plan (Wegner et al., 2010).

Science Questions

1. How were past transitions in sea ice connected to energy flows, elemental cycling, biological diversity and productivity, and how do these compare to present and projected shifts?

2. How do temporal and spatial variability in sea ice transitions affect biogeochemical fluxes in coastal, ocean-gateway and shelf-to-basin environments?

3. How does the Arctic marine biota respond to sea ice transitions, and what are the implications for productivity, ice-pelagic-benthic coupling, trophic transfer and air-ice-sea exchange?

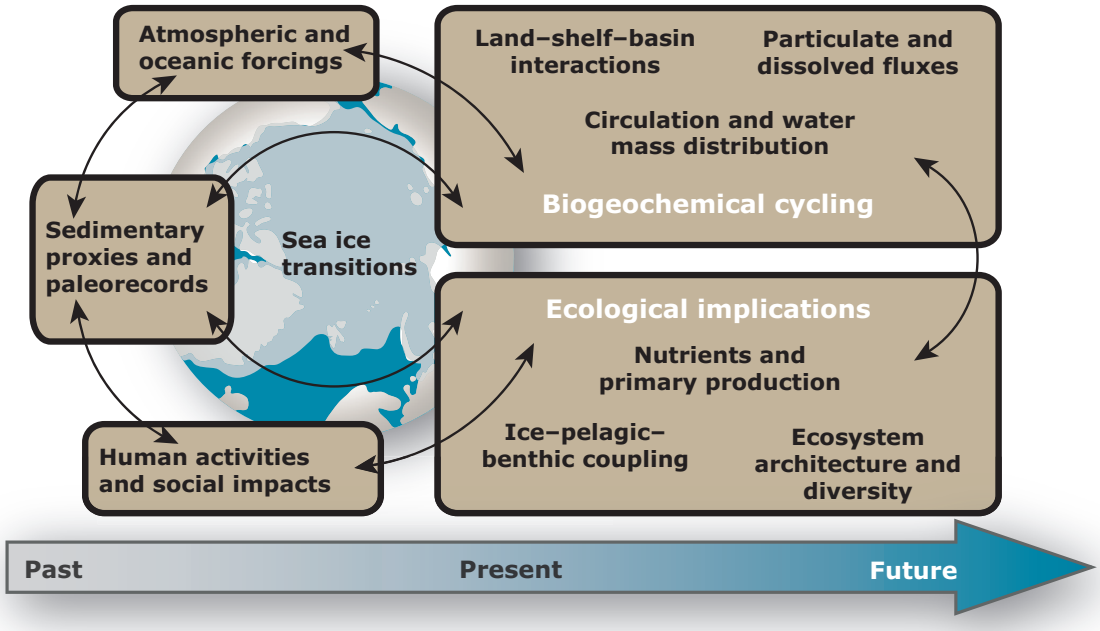

Figure 2. Conceptual diagram summarizing the ART Science Questions. The influence of sea ice transitions on Arctic marine ecosystems is central, and emphasizes the need for a multi-disciplinary and pan-Arctic approach.

Scientific Focus

ART will investigate changes and feedbacks among the physical drivers, ecosystem functions and biogeochemical processes related to sea ice transitions in the Arctic Ocean. The primary focus of ART is to develop an international and multi-disciplinary scientific

network with the aim to decipher the biogeochemical and ecological implications of changing ice conditions over a pan-Arctic domain and a broad temporal scale. This includes:

- A spatial domain focused on comparative knowledge where:
  - current sea ice conditions are changing (e.g. Figure 3) and ecosystem dynamics as well as biogeochemical processes can be effectively evaluated as part of national science efforts that reflect individual national interests;
  - a baseline for past, present, and future changes can be defined;
  - paleorecords can identify geological changes in sea ice conditions and provide relevant proxies for interpreting past biological responses;
  - commercial activities and political interest are focused, such as Arctic continental shelves where marine shipping and resource harvesting are expected to increase;
  - gradients in bathymetry and/or environmental conditions are steep, such as across land-shelf-basin transects or from areas of first-year fast ice to multiyear pack ice.

- Temporal scales aiming at resolving how:
  - changes in the pre-conditioning, onset and duration of the productive period affect the nature and magnitude of biological productivity, impact biogeochemical fluxes and feedbacks to the climate system;
  - seasonal and inter-annual shifts in freshwater loads, river run-off patterns, air-sea exchange and Atlantic and Pacific water inputs influence the structure and function of marine food webs as well as the conditions for biogeochemical transformation;
  - time windows critical for the growth and reproduction of organisms are altered by sea ice transitions and the consequence for match-mismatch scenarios;
  - current transitions in sea ice and ecosystem processes compare to the timing, strength and dynamics of environmental and biological changes in geological times.

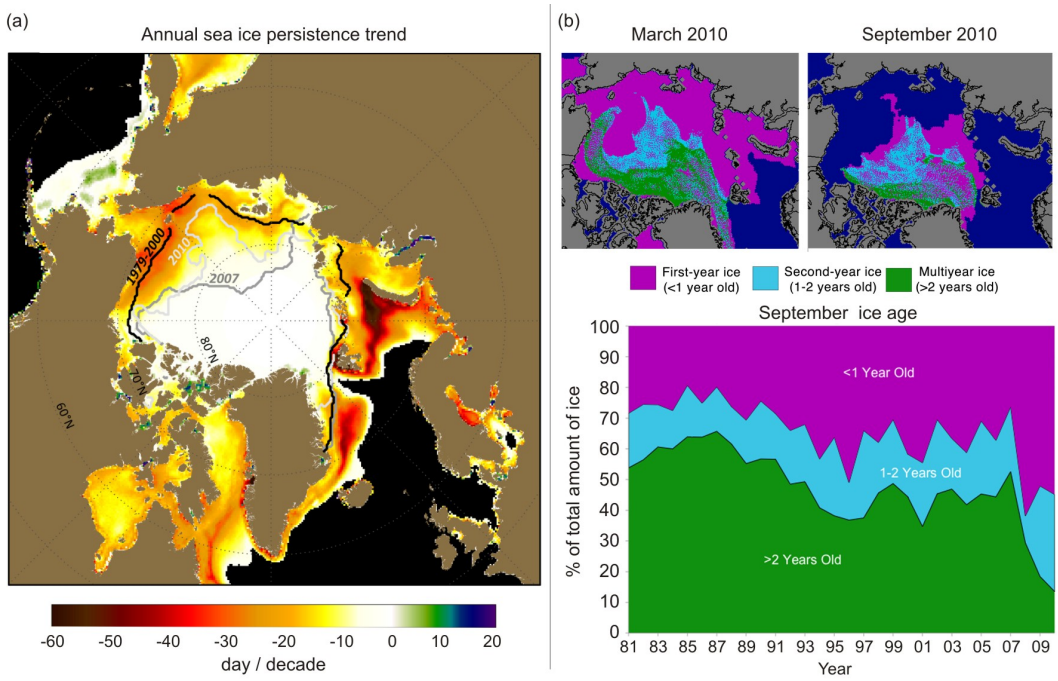

Figure 3. Examples of sea ice transition zones as illustrated by: (a) trend in sea ice cover persistence and edges of annual minimum ice extent as measured in September from 1979-2000 (median), in 2007 and in 2010 (figure by K. Frey); (b) change in ice age from March to September 2010 (i.e. annual maximum and minimum in sea ice extent) and throughout the 1981-2010 period for the month of September. Images courtesy of the National Snow and Ice Data Center (http://nsidc.org/).

Work Plan/Approaches

The implementation of ART will follow a three-phase approach extending from 2010 to 2020 (Figure 4).

Phase I (2010-2014)

The first phase will be committed to developing a formal and active scientific network to bring together scientists working in different geographic areas and disciplines, who share a common interest in improving our understanding and the implications of Arctic sea ice transitions and their impacts on multiple timescales. This scientific network will foster communication, exchange of datasets, integration of knowledge, and identify efforts to tackle the key science questions of ART.

Phase I will include networking using existing Arctic science meetings (e.g. ASSW, Arctic Frontiers, IPY 2012) and appropriate special sessions (e.g. AGU), opportunistic field sampling as part of ongoing programs, retrospective analysis and literature review, as well as preliminary modelling. Two dedicated ART Science Workshops are planned during *Phase I*, with the first one to be convened in autumn 2012 at the Institute of Oceanology, Polish Academy of Sciences (IOPAN) in Sopot, Poland. This workshop will be open with targeted invited scientists and will thematically address the issue of "Overcoming challenges of observation to model integration in marine ecosystem response to sea ice transitions". This theme will provide opportunity for reviewing and synthesizing the knowledge required for the modelling of marine ecosystem processes in relation to changing ice conditions.

The key challenges that are anticipated during the first ART Science Workshop include geographic integration and comparative assessments of driving forces in contrasting or similar systems, how to advance present day scenarios and projecting tools based on knowledge of past transitions, and the critical development of Arctic ecosystem indicators to monitor on-going change. One of the major outcomes of the first ART Science Workshop will thus be a set of synthesis papers written and lead by early career scientists with the support of dedicated senior scientists. The synthesis papers of *Phase I* will be due for the fall of 2013 and presented officially to the community during the Arctic Frontiers Conference taking place in January 2014 in Tromsø, Norway. A second ART Science Workshop will take place in concomitance with Arctic Frontiers 2014 and will include short courses to engage early-career and established scientists in the interdisciplinary nature of Arctic marine sciences and to facilitate cooperation among participants. The primary papers and scientific reviews developed in 2012-2013 will be translated into original publications in early 2014 as part of ART special issues in appropriate international peer-reviewed journals. The scientific papers will be further gathered into a first ART Science Compendium that will be delivered to the Marine Working Group of IASC at the ASSW 2014.

Phase II (2014-2018)

The second phase of ART will be centered on developing a networked field program and the coordination of active data collection to feed the modelling effort undertaken in *Phase I* and continued throughout all *Phases* of ART (Figure 4). Field campaigns developed for *Phase II* are intended to be multidisciplinary in scientific nature and dispersed in geographic scope. The coordinated ART field effort will not be a unique, stand-alone oceanographic expedition, but rather a pan-Arctic matrix of international and multidisciplinary research

efforts scientifically linked to the ART framework. Since the field activities should start during *Phase* II, the ART networked field campaign will be developed during planning workshops that will take place in conjunction with the two ART Science Workshops of *Phase I*, throughout *Phase II* (e.g. as part of the Arctic Science Summit Week and the Arctic Frontiers Conference), and via a third ART Science Workshop taking place at mid-*Phase II*. These meetings will provide opportunities to entrain and update participants on the progress of the various projects in order to adopt and adjust the coordinated fieldwork to new findings, and to identify evolving needs identified during *Phase II*. A program of mentoring and education will also be an integral part of ART during the science planning workshops. This program will be undertaken in collaboration with APECS. The third ART Science Workshop will also set the stage for data analysis and integration that will be translated into original research papers and synthesis products during *Phase III*.

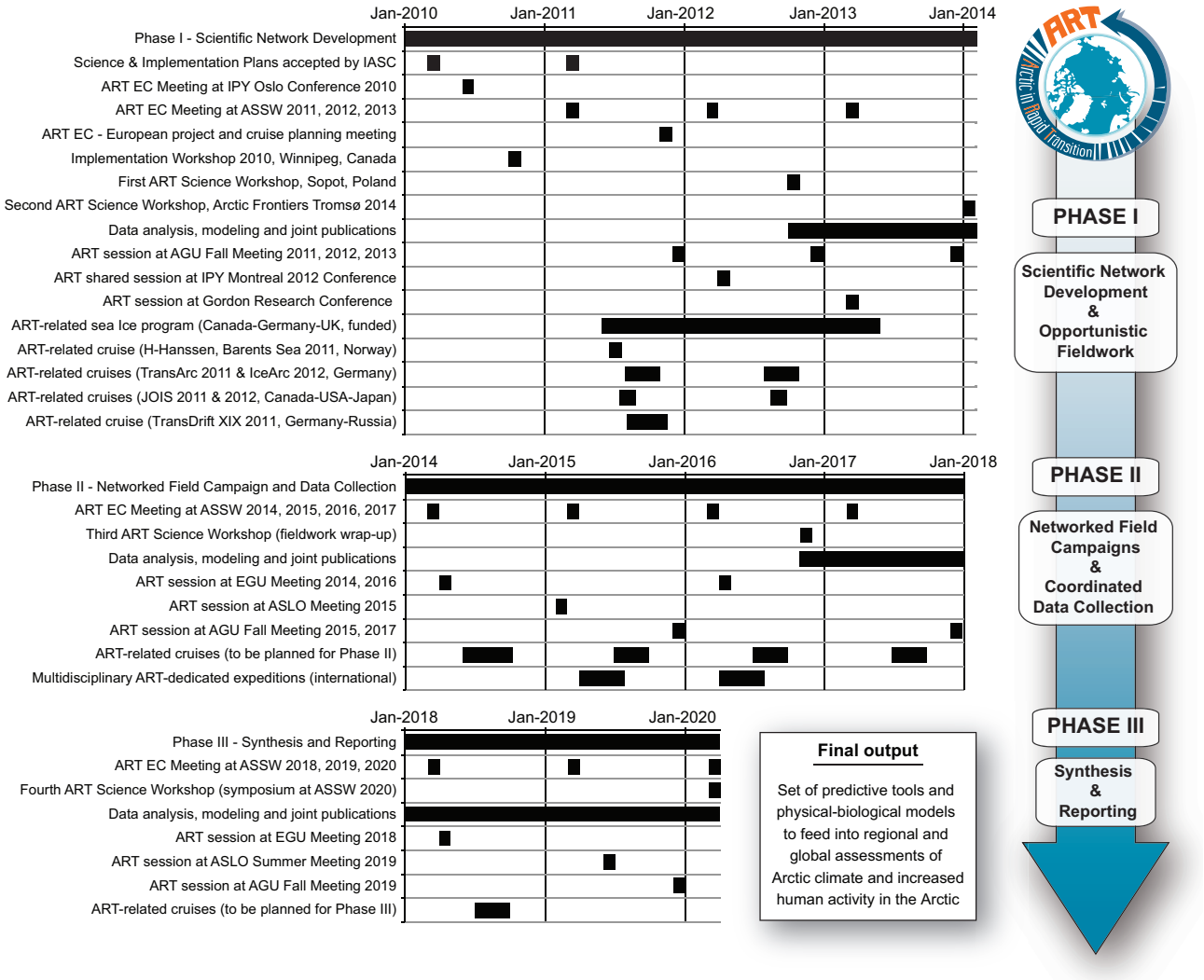

Figure 4. Timeline of the 3-phase approach of the ART Network including key meetings and outcomes. ART milestones are detailed in text, such as the timing of deliverables and to whom it will be provided.

Phase III (2018-2020)

The final phase of ART will be a synthesis and reporting stage of the networked field program and initial process-oriented modelling of *Phase II*. Last opportunistic fieldwork could also occur in early *Phase III* in order to fully acquire the multidisciplinary dataset needed to develop the ART data integration. The results issued from the dedicated ART field effort will refresh and update the baseline knowledge available during *Phase I* through a

fourth ART Science Workshop/Symposium and summary publication(s) developed since late *Phase II*. The final ART Science Workshop is intended to take place as part of ASSW 2020. The legacy of ART will be a coherent set of new knowledge on the impacts of (and feedbacks between) sea ice transitions on Arctic marine ecosystems, that would translate into coupled physical-biological models at various spatial and temporal scales. This knowledge will help develop better predictive tools and more robust scenarios regarding the future state of Arctic marine ecosystems and their productive capacity, as well as how they impact the exchange of greenhouse gases with the atmosphere and their role in global processes. Accordingly, ART will contribute to a reinforcement of Arctic system sciences into impact assessments of climate change and increased human pressures in the Arctic.

Funding for Phases I-II-III

The ART Network will seek for financing possibilities at both national and international levels. For *Phase I* (workshops, synthesis papers), a primary funding opportunity could be the cross-cutting fund that IASC has set aside to support innovative and state-of-the-art projects. The ART EC will put forward a proposal for the IASC cross-cutting fund in September 2011. Fieldwork activities already funded by ART Investigators are also integral part of *Phase I* (Figure 4).

For implementation of *Phase II* (funding of research projects, multidisciplinary field campaigns) and *Phase III* (publications, outreach) national funding sources such as Natural Sciences and Engineering Research Council of Canada (NSERC, Canada), National Science Foundation (NSF, USA), Federal Ministry of Education and Research (BMBF, Germany), National Science Centre (NSC, Poland) and Research Council of Norway (RCN, Norway) have been already contacted or will be approached. International proposals addressing THE European Commission within the Seventh and eighth Framework Programmes (FP7 and FP8) will be submitted in order to obtain financing for networking, field campaigns and outreach activities. Bilateral activities will be encouraged by ART seeking possible funding through e.g. Norwegian Financial Mechanism (Polish-Norwegian cooperation) or International Bureau of the BMBF for initiation of bilateral cooperation. Smaller, ART-related projects will look for funding opportunities through German Science Foundation (DFG, Germany), Fisheries and Oceans Canada (DFO; Canada; e.g. International Governance Strategy Science Program), Arctic Field Grant (research conducted in Svalbard, Norway), National Science Foundation (NSF, USA) or National Science Centre (NSC, Poland).

Management structure

Integration with other Arctic initiatives and on-going projects

The ART Network will contribute to the integration, updating and development of priorities for Arctic marine ecosystem sciences over the next decade. The main focus of ART is on the oceanic and marine ecosystem components of Arctic change at different temporal and geographical scales. Accordingly, ART will contribute to answering the marine-related research questions of ongoing international programs including, for example, ISAC (International Study on Arctic Change), SAON (Sustaining Arctic Observing Networks), SEARCH (Study of Environmental Arctic Change), ArcticHydra (Arctic Hydrological Cycle), and APEX (Arctic Paleoclimate and its Extremes). An overview of potential synergies between ART and existing programs and projects is provided in the ART Science Plan (Wegner et al., 2010). Ongoing and newly-developed science activities contributing to ART

can thus be linked to a network of existing projects dedicated to improving our knowledge of Arctic Ocean ecosystems and of the Arctic system as a whole.

The ART Network will foster research between different Arctic marine regions and increase international cooperation. The integrated research concept on sea ice transitions developed within ART (Figure 2) bridges cross-cutting scientific activities across time scales, nations and scientific disciplines.

Data management and exchange

The ART Network (http://www.iarc.uaf.edu/ART/) will make use of and provide input for existing Arctic science databases to manage the datasets issued from scientific activities conducted within the ART science framework. The primary database will be the International Polar Year Data and Information Service (IPYDIS, http://ipydis.org/), which will ensure that the ART data will be available to the wider community. The IPYDIS is a global partnership of data centers, archives, and science networks working together to guarantee the adequate stewardship of Arctic data. It is currently coordinated by the National Snow and Ice Data Center (NSIDC), which ensures the long-term preservation of data. All ART-related projects will be requested to submit their results to national databases linked to IPYDIS via arrangements through a management point of contact at the national level. Examples of such national efforts are the German-led PANGAEA Publishing Network for Geoscientific and Environmental Data (http://www.pangaea.de/), the US-led Arctic Observing Network currently supported through the Cooperative Arctic Data and Information Service (http://www.aoncadis.org/), or the Canadian-based Polar Data Catalogue that comprises a wide range of datasets from natural sciences and policy, to health and social sciences (http://polardata.ca/).

The ART Network will foster data availability, including historical data from Arctic shelves, in order to facilitate the establishment of relevant ecosystem baselines comprising geological, chemical and biological data in areas subject to rapid change. The ART Science Workshops will be instrumental in fostering historical and current Arctic data exchange.

Framework for implementation

The ART Network will utilize existing bilateral agreements to facilitate international collaboration and development of networked field campaigns in the Arctic Ocean. Best practices require the best use of existing and future data, and aims towards the achievement of a holistic and pan-Arctic understanding of Arctic Ocean transitions that will depend on the synergy between ART and other large initiatives, such as ISAC.

The successful implementation of the ART Network will further depend on the validity of comparative analyses of datasets acquired in different Arctic regions. Hence, one aspect of ART is the adoption of standardized methodologies and analyses of biogeochemical data and/or samples. This is particularly true for *Phase II* during which multiple field campaigns and active data collection will take place. The implementation of common methodological approaches will be carried out over *Phase I* in order to be ready for the acquisition stage. The use of new numerical tools, sampling technologies and analytical methods will also be encouraged in order to provide innovative perspective on the functionality and evolution of Arctic marine ecosystems. For example, ART will encourage the use of automated underwater vehicles (AUVs) to explore inaccessible marine systems, the development of

new sediment proxies based on current field observations, innovative process-oriented studies and experiments to elucidate the metabolism of key organisms, and the application of new statistical and predictive models to understand ecological thresholds and directions.

ART organizational structure

The ART Network will be structured around an Executive Committee (EC) primarily composed of early-career scientists (Figure 5). The EC receives scientific materials and logistical advices from a broad Science Advisory Committee (SAC), composed of leading international scientists in Arctic system studies. In the eventually of conflicts/grievances within the EC, the SAC will recuperate the lead of ART. The EC is presently constituted of members from eight initiating countries and is led by a chair elected by its members. The EC is responsible for decisions regarding budgetary allocations, network and Science Workshops activities, as well as program activities and international representation within ART. The EC will ensure that the directions and goals of ART will be followed through the implementation stage. The SAC is international, pan-Arctic and multi-disciplinary, therefore providing a broad perspective and context for implementing ART. In addition to these two overarching Committees, the ART organizational structure comprises an International Program Committee (IPC) that interfaces directly with the EC for the development and implementation of ART activities. The IPC will be composed of representatives of pan-Arctic ART projects and will be most active during the networked field campaigns of *Phase II*.

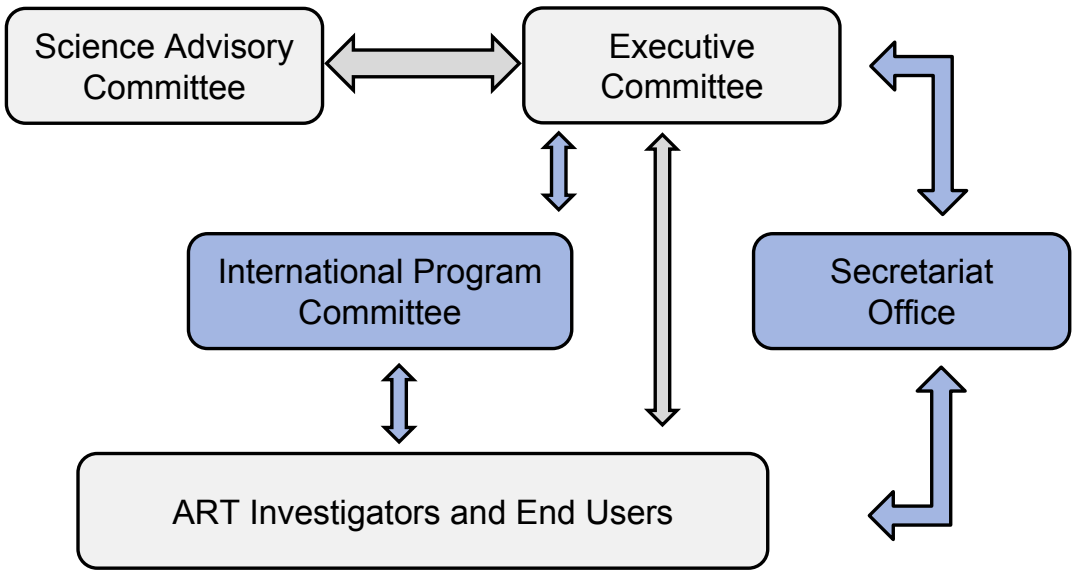

Figure 5. ART organizational structure.

The ART Network is supported by a Secretariat Office hosted by the International Arctic Research Center (IARC) located at the University of Alaska, Fairbanks. IARC has the mission of fostering Arctic research in an international setting in order to support the community to understand, prepare for, and adapt to pan-Arctic impacts of climate change. The Secretariat Office is a network node for the ART Program; it will facilitate communications between ART investigators and Committee Members, provide support for web and workshops activities, and serve as a central hub for data management. National program managers and participants will be linked to the ART Secretariat Office via the ART website hosted within the IARC homepage (http://www.iarc.uaf.edu/ART).

Outreach activities

Knowledge arising from ART will be disseminated to the scientific community and to the public. For the scientific community, topical workshops and sessions during conferences will be arranged (e.g. during the second ART Science Workshop taking place as part of Arctic Frontiers 2014). Special efforts will be made to facilitate presentations by early-career scientists and results presented during these workshops will be compiled in peer-reviewed papers. Regular updates on the state of ART will be reported on the ART web page developed as part of the IARC homepage (http://www.iarc.uaf.edu/ART), as well as in scientific-news journals, (e.g. Eos or PAGES NEWS).

Training and transmission of knowledge to the younger generation of future scientists will be achieved through various channels, e.g. international multi-disciplinary courses, summer schools dealing with the overarching questions of ART, or more specific research topics. In the context of educating and involving of future scientists, regular web updates and a close collaboration with APECS (http://apecs.is/) and other appropriate organizations is essential. The ART Secretariat hosted at IARC will play a key role in these activities.

An essential element for the transfer of ART-related information to the public and schools would be the involvement of high-school teachers. Enthusiastic teachers who are kept abreast of cutting-edge research will provide very efficient ways to transmit knowledge to students and to increase their interest in the natural sciences in general and high latitude research. This goal can be achieved by inviting teachers to join fieldwork campaigns hosted by ART-networked researchers (e.g., PolarTREC, Schools on Board), or by arranging courses at home institutions where teachers can get up-to-date information about ongoing research within the ART network. This will be particularly useful for ART since this process will specifically target young students (e.g. high school age). Hence, the young generation that will come on age during *Phases II-III* could join the ART Network as it is still underway.

ART will encourage all projects and partners to actively disseminate results and knowledge about the Arctic marine sciences. A list of ART principal investigators (PI) will be established and published on the ART web site. PIs will be encouraged to distribute ART's materials to early-career scientists, young researchers and graduate students to incite them to contribute to the ART program and join the PI list. The ART web page containing information on ongoing projects, opportunity of collaboration, field campaigns, workshops, outreach programs, publications and other topics, should provide such a successful platform for the exchange of information with the scientific community and the public.

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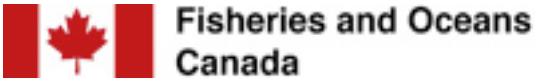
Sponsors



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