

Internationally Coordinated, Cooperative Arctic Marine Science during the Fourth International Polar Year: Lessons for Future Arctic Ocean Science Agreements

by Hajo Eicken

I. Introduction

The Arctic Ocean region has undergone major changes over the past decade, many of them linked to a transformation of the sea ice cover from predominantly perennial to predominantly seasonal ice.¹ In parallel, and partly as a result of milder ice conditions, resource development and ship-based tourism have driven up Arctic maritime traffic and fostered geopolitical discourse at the national and international level concerning future uses of the Arctic Ocean and associated international agreements and regulatory regimes.² As illustrated by the Arctic Council's recent search and rescue agreement,³ tracking of maritime activity as well as effective regulation and emergency response require data on environmental and other hazards at high spatial and temporal density. At present, it is largely an emerging network of Arctic observing systems that is providing what little information is available to effectively govern and manage different maritime uses and responses,⁴ with different entities, including academia, federal agencies and international programs contributing to these efforts. However, given the scope of such an endeavor once fully implemented and its inherently transboundary nature in an Arctic

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¹ J Maslanik et al., 'Distribution and Trends in Arctic Sea Ice Age through Spring 2011', *Geophysical Research Letters* 38 (2011) L13502.

² LW Brigham, 'The Fast-Changing Maritime Arctic', *Proceedings of the U.S. Naval Institute* 136 (2010) 55 et seq.; PA Berkman and OR Young, 'Governance and Environmental Change in the Arctic Ocean', *Science* 324 (2009) 339 et seq.; AL Lovecraft and H Eicken (eds), *North by 2020: Perspectives on Alaska's Changing Social-Ecological Systems* (2011) 681 et seq.

³ Arctic Council, 'Agreement on Cooperation on Aeronautical and Maritime Search and Rescue in the Arctic' (May 2011), see <http://arctic-council.org/filearchive/Arctic_SAR_Agreement_EN_FINAL_for_signature_21-Apr-2011.pdf> (24 June 2011).

⁴ H Eicken et al., 'Environmental Security in Arctic Ice-covered Seas: From Strategy to Tactics of Hazard Identification and Emergency Response', *Marine Technology Society Journal* 45 (2011) 37 et seq.

Ocean with highly dynamic sea ice and surface waters, future uses and stewardship of the Arctic Ocean will be closely tied to internationally coordinated, collaborative marine scientific research and operational environmental observations.

Such activities may be impacted by pending and future claims that seek to confirm jurisdiction of Arctic coastal States over the extended continental shelves under the provisions of the United Nations Convention of the Law of the Seas ('UNCLOS').⁵ This development warrants an examination into current practice and potential recommendations concerning international scientific research and long-term observing programs that may play an important role as the Arctic Ocean continues on its trajectory of major environmental and socio-economic change. The Fourth International Polar Year ('IPY', March 2007 through March 2009) as a major international collaborative effort underway at a time of punctuated change, such as the record summer sea ice minimum of 2007,⁶ provides an opportunity for such a review and analysis of current practice and implications for future collaborative regimes and scientific access in the Arctic. This brief contribution focuses on studies of the sea ice cover as a helpful illustration of broader issues concerning best practices and potential recommendations for Arctic maritime research and operations. Specifically, Section II below presents a brief overview of selected efforts underway during and beyond the IPY to help illustrate key requirements for successful international cooperative efforts. Section III examines the traits of successful frameworks and best practices to foster cooperative scientific approaches that can bear on present-day and future maritime activities as well as improved understanding of the fundamentals of Arctic environmental change.

II. The 4th IPY as a Testbed of Internationally Coordinated, Cooperative Research: Examples From Sea Ice Research

⁵ United Nations Convention on the Law of the Sea (concluded 10 December 1982, entered into force 16 November 1994) 1833 UNTS 397.

⁶ Maslanik et al., see note 1.

The activities of the 4th IPY were overseen by the International Council for Science ('ICSU') and the World Meteorological Organization ('WMO') and fully endorsed and supported by the nations represented in these bodies, including the Arctic coastal States.⁷ In many respects, the IPY served as a testbed for technologically or conceptually advanced approaches to the study of the polar regions, with a focus in the Arctic on environmental and socio-economic change, including its impact on and tracking by Arctic residents.⁸ Out of a total of roughly 90 endorsed Arctic IPY projects, more than 20 included a major (if not central) sea ice component. Since these projects cover five of the seven IPY research themes, they can serve to illustrate overarching challenges and opportunities in pursuing internationally coordinated, cooperative research.

1. A Nascent, Internationally Coordinated Arctic Observing System

The 4th IPY provided a major push towards the implementation of a pan-Arctic, networked and internationally coordinated observing system on land and in particular in the Arctic Ocean. Arctic coastal States invested heavily in observing system infrastructure, including Canada's ArcticNet program with its dedicated research icebreaker, the *Amundsen*, the European Union's Developing Arctic Modeling and Observing Capabilities for Long-Term Environmental Studies ('DAMOCLES') program with major deployment of advanced sensor technology throughout the Eurasian Arctic, and Russia's investment into coastal observing stations such as the Tiksi Observatory, a cooperative effort between Russian and US research and operational agencies. In the US, the National Science Foundation ('NSF'), along with support from partners such as the National Oceanic and Atmospheric Administration ('NOAA'), made major investments into the Arctic Observing Network ('AON'), an IPY initiative under the auspices of the US interagency Study of Environmental Arctic Change ('SEARCH').⁹ The AON

⁷ I Krupnik et al. (eds), *Understanding Earth's Polar Challenges: International Polar Year 2007-2008* (2011) 87 et seq.

⁸ Krupnik et al., *ibid.*, 357 et seq.

⁹ Arctic Observing Network (ed.), *Arctic Observing Network (AON) Program Status Report – 2009* (2010); MO Jeffries et al. (eds), 'Arctic Observing Network: Toward a U.S. Contribution to Pan-Arctic Observing', *Arctic Research of the United States* 21 (2007) 3 et seq.

illustrates two important aspects of modern environmental observing systems in the service of society.¹⁰

First, it was implemented as an effort driven by the scientific community with international coordination of deployment of sensors and resources from the very start, such as through coordination with DAMOCLES¹¹ and other international programs.¹² This was achieved through the long history of existing international ties and collaborative frameworks which had prepared the ground for the intensive observations conducted during the IPY, with the density of observations greatly increased (see example shown in Figure 1). This type of bottom-up collaboration has been highly effective in combining infrastructure and resources internationally (including substantial support by non-Arctic nations in Asia and Europe) in order to sustain observations in challenging and remote Arctic environments to benefit all nations.

Second, the AON is one of the first large-scale international programs that has included a stipulation enforced by the funding agency (NSF) for immediate release of data collected through the observing network without any of the traditional embargo period - typically between 1 and 3 years - that has commonly limited initial data access to the principal investigators for a given set of measurements.¹³ This approach was based on recommendations made by a Data Working Group assembled under SEARCH that recognized the importance of such open data policies to encourage collaboration and discovery in a rapidly changing Arctic, requiring quick access to data in order to effectively track and respond to major changes such as the 2007 record ice minimum.

¹⁰ J Calder et al., 'Community White Paper: An Integrated International Approach to Arctic Ocean Observations for Society', in J Hall, DE Harrison and D Stammer (eds), *Proceedings of OceanObs '09: Sustained Ocean Observations and Information for Society*, Vol. 2 (2009).

¹¹ DAMOCLES and SEARCH formed a joint project ('S4D') to this end, with activities including joint workshops and model intercomparison projects.

¹² B Dickson and E Fahrback, 'Observing Our Northern Seas during the IPY: What Was Achieved, What Have We Learned, Where Do We Go From Here? A Report of the Arctic Ocean Sciences Board and of the IPY Joint Committee' (2010), see <<http://iasc.arcticportal.org/index.php/home/groups/working-groups/marineaosb/publications>> (1 August 2011).

¹³ AON data are available through the portal maintained by the Cooperative Arctic Data and Information Service; see <<http://aoncadis.org>> (1 August 2011).

Furthermore, this data policy was also seen as an important step in addressing the information needs of Arctic residents and other decision-makers responding to Arctic change.

2. Cooperative Activities to Improve Understanding and Prediction of Sea Ice: The Arctic Sea Ice Outlook

The rapidity and magnitude of Arctic environmental changes has challenged the scientific community and government agencies to analyze, digest and respond on time scales much shorter than the traditional cycle of research planning, data analysis, review and publication of results. This development was highlighted by the record summer sea ice minimum extent of 2007,¹⁴ almost one quarter below the previous record set in 2005 that had immediate impacts ranging from major effects on marine ecosystems to increases in ship-based tourism.¹⁵ In response to this challenge, and under the leadership of the SEARCH and DAMOCLES programs, the international sea ice observation and modeling community created a forum for the synthesis, discussion and review of seasonal ice predictions, the SEARCH Arctic Sea Ice Outlook.¹⁶ Each year since 2008, between May and October, around 20 of the leading sea ice research and modeling groups have prepared and updated a monthly prediction of pan-Arctic and regional September minimum ice extent, along with a detailed explanation of the approach taken, its uncertainties and indications on what type of observations would help improve these projections.

The Outlook has spawned a number of research projects, increased insight into the degree of predictability of different sea ice processes and advanced the evaluation and

¹⁴ For the period 1979 through 2011 for which consistent, reliable satellite records of ice extent are available; Maslanik et al., see note 1.

¹⁵ LW Cooper et al., 'Rapid Seasonal Sea-Ice Retreat in the Arctic Could be Impacting Pacific Walrus (*Odobenus rosmarus divergens*) Recruitment', *Aquatic Mammals* 32 (2006) 98 et seq.; Brigham, see note 2.

¹⁶ J Overland et al., 'International Arctic Sea Ice Monitoring Program Continues Into Second Summer', *Eos Trans AGU* 90(37) (2009) 321 et seq.; see also <<http://www.arcus.org/search/siwo>> (1 August 2011).

development of prediction models. However, in the context of internationally coordinated research an important outcome has been to serve as a testbed for improved coordination of observations that can help reduce uncertainties in tracking and predicting seasonal ice evolution. This has been achieved in part by creating an informal, internet-based forum for collaboration and exchange of information between operators and research scientists, currently representing all Arctic coastal States and many non-Arctic nations. As an example of this approach, consider how in 2009 uncertainty about the ice evolution in the North American Arctic and discussion of the long-term outlook provided by the US National Ice Center prompted near real time transmission of information about the state of the ice cover via satellite phone by the DAMOCLES lead scientist onboard the Chinese research vessel *Xuelong*, operating in the Canadian Basin.

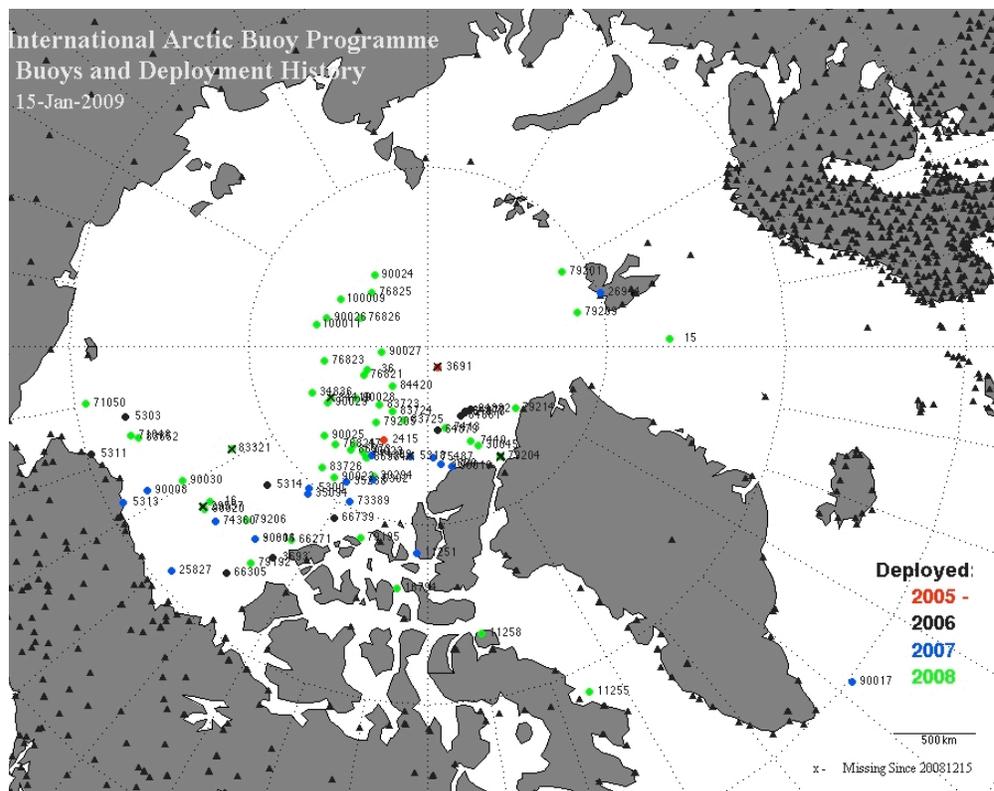


Figure 1: Distribution of sea ice buoys in the Arctic Ocean on 15 January 2009 towards the end of the IPY. Note the surge of deployments associated with the IPY in 2007 and 2008 (shown in blue and green color).

The comparative lack of buoys in the Eurasian Arctic is a result of the lack of perennial sea ice in this region with reductions in summer ice extent.¹⁷

3. Improving Weather and Sea Ice Prediction, Understanding of Change and Emergency Response Through the International Arctic Buoy Program ('IABP')

The IABP is a highly successful example of how the pooling of resources between different countries and between research and operational agencies can provide information that is now critical to improved weather forecasts for the northern hemisphere and Arctic maritime operations, as well as for understanding large-scale Arctic environmental variability and change.¹⁸ IABP data are collected in support of the WMO, the World Climate Research Program and the World Weather Watch Program. Buoy resources are pooled among the IABP partners which come from both Arctic coastal States and non-Arctic nations, and deployed by research vessels, operational agencies and on occasion by residents in Arctic communities. Buoys are deployed throughout the Arctic and the operating principles of the IABP govern deployment from or drift into the respective partner countries' exclusive economic zones ['EEZ(s)'].¹⁹ As evident from Figure 1, the IPY has resulted in a major boost in the number of deployed buoys, but also in the number of countries involved in deployment and the sophistication of sensor packages. Thus many buoys are now capable of measuring ice surface and bottom melt and thickness, improving understanding and prediction of seasonal ice retreat at the regional level.²⁰ Typically, all the data from buoy sensors (position, surface air pressure, air temperature and potentially other variables such as ice thickness) are transmitted in near real time, including data feeds into the WMO operational networks, which have been shown to substantially improve weather forecasts and assessment of

¹⁷ Image courtesy of IABP, see <<http://iabp.apl.washington.edu/>> (1 August 2011).

¹⁸ IG Rigor and JM Wallace, 'Responses of Sea Ice to the Arctic Oscillation', *Journal of Climate* 15 (2002) 2648 et seq.; see also <<http://iabp.apl.washington.edu/>> (1 August 2011); J Inoue et al., 'Impact of Observations from Arctic Drifting Buoys on the Reanalysis of Surface Fields', *Geophysical Research Letters* 36 (2009) L08501.

¹⁹ IABP operating principles are laid out in the following document accessible online: IABP, 'Operating Principles' (Revised May 2007), see <http://iabp.apl.washington.edu/overview_principles.html> (1 August 2011).

²⁰ C Polashenski et al., 'Seasonal Ice Mass-Balance Buoys: Adapting Tools to the Changing Arctic', *Annals of Glaciology* 52 (2011) 18 et seq.

impacts of sea ice change within and outside of the Arctic.²¹ Due to the dynamic nature of sea ice and uncertainties in predicting ice drift over periods of weeks, let alone years, it is not possible to anticipate the trajectories of these buoys. Thus, deriving the full benefits from such a hybrid operational and research sensor network also requires international agreements on access over the continental shelves.

4. Technological Advances Transform Marine Science and Improve Emergency Preparedness and Response

Over the past decade, a number of substantial advances have begun to transform research in the ice-covered Arctic Ocean. This includes major advances in the technology and data transmission from ice-tethered platforms,²² with increasing coverage in the Arctic²³ as well as increasing use of autonomous underwater and aerial vehicles. In addition to the mature and comprehensive set of instruments monitoring Arctic sea ice from space,²⁴ airborne measurements in particular of ice thickness, snow depth and other ice characteristics have now reached a stage where airborne surveys can provide data that may enter directly into seasonal forecasts of ice evolution and provide updates on the state of the Arctic sea ice cover.²⁵ In some Arctic locations, industrial activity such as offshore oil and gas exploration and development have resulted in substantially increased observation and data density employing state-of-the-art methods.

Hence, at present and in the near-term foreseeable future the infrastructure and resources available to operational agencies and others involved in emergency preparedness and response are likely to consist to a significant degree of a mix of marine scientific research

²¹ Inoue et al., see note 18.

²² R Krishfield et al., 'Automated Ice-tethered Profilers for Seawater Observations Under Pack Ice in All Seasons', *Journal of Atmospheric and Oceanic Technology* 25 (2008) 2091 et seq.

²³ More than one tenth of the buoys shown in Figure 1 for January 2009 possess capabilities that extend to measurements in the ice or ocean underneath; in 2011 this fraction is at roughly one fifth of all drifters.

²⁴ RA Massom, 'Principal Uses of Remote Sensing in Sea Ice Field Research', in H Eicken et al. (eds), *Field Techniques For Sea Ice Research* (2009) 405 et seq.

²⁵ C Haas et al., 'Synoptic Airborne Thickness Surveys Reveal State of Arctic Sea Ice Cover', *Geophysical Research Letters* 37 (2010) L09501.

assets described above, along with instrumentation deployed by industry, rather than dedicated operational monitoring networks. The scientific community increasingly acknowledges the research opportunities and societal mandates of use-inspired research.²⁶ Since there is substantial overlap in the methodology and instrumentation employed by the scientific community and operators, it can be postulated that any future Arctic observing system is likely to be a hybrid construct, overseen by a consortium of stakeholders and with blurred boundaries between operational and academic research components.

III. Building Frameworks and Best Practices to Foster Internationally Coordinated, Cooperative Arctic Marine Science

The advances made during the 4th IPY as a testbed of state-of-the-art marine science (as outlined in Section II), offer important lessons for the implementation and support of internationally coordinated, collaborative research. As emphasized by several contributors at the conference on ‘Arctic Science, International Law and Climate Change – Legal Aspects of Marine Science in the Arctic Ocean’ in March 2011, international coordination and collaboration in marine science builds on successful international science partnerships, but also requires consistent and transparent application of existing rules and regulations governing Arctic marine science within different countries’ EEZs or territorial waters. In this context, the scientific community can help advance cooperation by working towards internationally agreed-upon best-practices and (non-binding) statements to sustain and improve access and collaboration within the legal frameworks and international agreements governing such observation programs. Based on an evaluation of IPY outcomes (focusing on the sea ice themes) four principal sets of conclusions and recommendations have been derived.

²⁶ For sea ice, parallel and potential conflicting uses of ice-covered regions by different stakeholders can be tracked and parsed effectively in the context of ice uses or services delivered by sea ice; see H Eicken et al., ‘Sea-ice System Services: A Framework to Help Identify and Meet Information Needs Relevant for Arctic Observing Networks’, *Arctic* 62 (2009) 119 et seq. (132).

1. International Collaboration

The expansion of Arctic observing network components during the IPY was driven partly by urgent information needs of decision-makers and stakeholders. For example, an increasing number of surface drifters (Figure 1) is now deployed by industry to improve understanding of sea ice circulation in regions of planned oil and gas development.²⁷ At the same time, the urgency of some of the questions emerging from the observed reductions in summer ice extent have promoted community-based observations and participation by Arctic residents in research activities, including deployment of surface drifters.

The increasing involvement of such groups in defining the aims of an observing system is guiding an expansion of sea ice research into the operational, applied sector. With a burst of activity during the IPY, the focus is now on consolidation and optimization of a pan-Arctic observing system through international collaboration and coordination. Initiatives under the International Arctic Science Committee ('IASC'), such as the International Study of Arctic Change, the World Climate Research Program ('WCRP'), or the Arctic Council, such as the Sustained Arctic Observing Network initiative, are working towards this goal and may be able to provide important perspectives on how international agreements that are part of the legal regime can work in concert with such efforts at consolidation. Of particular value at the present time would be a survey of past and ongoing cooperative observation efforts that have successfully addressed key challenges with respect to international coordination, cooperation and scientific access. Developing best-practices documents and guidance based on such efforts will help achieve broader success.

2. Lessons Offered by IABP

²⁷ Eicken et al. [2011], see note 4.

The remoteness and harsh environment of the Arctic have fueled advances in autonomous sensor systems and remote sensing as important elements of an observing network. The IABP is an excellent example of how an existing collaborative framework can help maximize the benefits derived from technological advances – within the context of international agreements and legal regimes governing marine research. IABP is particularly relevant because it is a collaboration between research scientists and government agencies that provides operational data in near real time. Similar to other networks that have undergone a comparable evolution (e.g., the Argo profiling float network²⁸), IABP may thus help ensure that as sensor capabilities expand and a more mobile, less predictable ice cover may disperse sensors more widely, buoy deployment can continue to serve the information needs of Arctic nations. In particular, since ice drift of sensors such as those shown in Figure 1 cannot be controlled and only poorly predicted on timescales of the lifetime of such buoys, a key point to resolve along the lines of current practice with Argo concerns the need to inform or notify a partner to the IABP agreement (equivalent to informing International Oceanographic Commission Member States in the case of the Argo network²⁹). Such questions are of increasing importance because of increases in the drift velocity and improvements in sensor technology and buoy design that increase the lifetime of such drifting sensors. At the same time, with data on the location of drifters typically available in near real time, the act of ‘information’ in regards to drifter position takes on a different meaning as potentially all the data collected by such buoys is accessible online, with no embargo or withholding of data.

3. Open Data/Access: A Proposal for Coupling Data and Scientific Research Access

In light of the developments outlined in the previous section, the IPY has also helped advance the concept of rapid - ideally real time - access to all data collected within the context of an evolving Arctic observing system. In the US, the National Science

²⁸ A Mateos and M Gorina-Ysern, ‘Climate Change and Guidelines for Argo Profiling Float Deployment on the High Seas’, *ASIL Insight* 14 (2010), see <<http://www.asil.org/insights100408.cfm>> (2 August 2011).

²⁹ Mateos and Gorina-Ysern, *ibid.*

Foundation as a major supporter of the AON, reflected decision-maker and scientific community interests (as expressed in the SEARCH Data Policy³⁰) in stipulating that data from the AON cannot be embargoed and has to be made available immediately after collection. Due to the size of the AON with more than 50 projects, this open-access policy has had a significant impact, and ensures that long-term Arctic observations collected through a research network can also help serve increasingly important operational needs. In the context of UNCLOS, operational research (typically characterized by unrestricted data release and real time integration into operational networks such as those overseen by the WMO) is not subject to the permission scheme required for ‘marine scientific research’, an undefined term of art in the Convention. This exception implies recognition of the broader value of such data in service of mankind or a larger group of nations. Here, it is argued that the idea of coupling data access and scientific access (Open Data/Access or ‘OD/A’), as implicit in the UNCLOS regime and agreements governing programs such as IABP, is a potentially helpful concept that can inform the development of best practices and guide the international coordination and harmonization of observing network activities.

In contrast with Argo, where similar questions have surfaced, the IABP has the great advantage that data can be made available any time and potentially at high sampling and transfer rates, since the buoys are surface-based and can hence communicate information without the restrictions of the submerged Argo drifters which have to surface to relay data. The International Polar Decade, as a WMO endorsed endeavor, provides an ideal framework to build on the IPY and explore viable ways to implement OD/A guidelines in different settings.

4. A Case in Point: Safety of Maritime Operations

Maritime traffic and coastal and offshore oil and gas development are on the rise in several Arctic nations, often in locations where ice drift and currents may quickly

³⁰ SEARCH Data Policy, see <<http://www.arcus.org/search/searchscience/data.php>> (2 August 2011).

disperse pollutants beyond a country's borders. As a result, emergency preparedness, prevention and response ('EPPR') are of increasing importance, as underscored by the Arctic Council's recent agreement on search and rescue.³¹ Effective EPPR activities will have to draw on data from pertinent observing systems, with high demands placed on data availability and spatio-temporal resolution during an emergency.³² Hence, such information needs may turn into a powerful driver outside of the research community towards collaborative, internationally coordinated activities governed by OD/A practices outlined above. In some regions, such as the Canadian Mackenzie Shelf and the shelf off Sakhalin, where oil and gas exploration and development is moving forward, one might argue that key principles of OD/A are already being followed. Thus, sensor deployment and long-term observations by scientific research groups is integrated into multilateral industry partnerships. By agreeing to the coordination practices of the overarching program, improved access has been obtained in exchange for collaborative contributions to industry program goals.³³

IV. Conclusions

The comparative lack of observing assets in a remote Arctic Ocean combined with technological advances and increasing recognition of the value of near real time open data access by the scientific community has resulted in increasing recognition by all major stakeholders that cooperative, coordinated approaches towards environmental observations are in the best interests of all involved. Furthermore, the boundaries between fundamental and operational research have been blurred by the increasing recognition of the value of use-inspired science on the part of the scientific community and major advances in sensor technology that allow scientifically and operationally relevant measurements to be taken by the same set of instruments. Finally, the ever-increasing

³¹ Arctic Council, 'Agreement on Cooperation on Aeronautical and Maritime Search and Rescue in the Arctic', see note 3.

³² Eicken et al. [2011], see note 4.

³³ For example, sea ice and ocean measurements by Japanese research groups have been facilitated through such agreements with industry; e.g., K Shirasawa et al., 'The Thickness of Coastal Fast Ice in the Sea of Okhotsk', *Cold Regions Science and Technology* 42 (2005) 25 et seq.

degree of international collaboration in science and operations, along with new partnerships being built between industry, Arctic communities, agencies and academia has prepared the ground for a major review and potentially substantial advance in the practice and theory of scientific access in an Arctic Ocean that is undergoing substantial, rapid change. At this point, the scientific community needs to develop and articulate a vision for coordinated and cooperative international marine science that maintains and ideally improves EEZ and extended continental shelf access,³⁴ while working with legal scholars and the relevant stakeholders to explore pragmatic approaches that ensure improved understanding of and effective responses to a changing Arctic Ocean. In this setting, IASC as a consultative body to the Arctic Council may help advance the dialog and provide a framework for emerging best practices that meets the requirements and information needs of all involved.

³⁴ On this topic, see also the contributions by B Baker, 'Common Precepts of Marine Scientific Research Access in the Arctic', in this volume and B Baker and H Eicken, 'Marine Research Access in the Arctic Ocean: Background for Potential Guidelines in a Changing Arctic', unpublished White Paper (10 March 2010), see <<http://www.iarc.uaf.edu/workshops/2009/4/>> (8 June 2011) (click on 'download whitepaper'); the paper is also attached as an Appendix to the contribution of B Baker, in this volume.