Science, Technology and the Path Forward for a New Arctic

Papers from the 2021 North Pacific Arctic Conference

Co-editors:
Jong Deog Kim and Charles E. Morrison

With Lawson W. Brigham, Sung Woo Lee, Nancy D. Lewis, Arild Moe, Natsuhiko Otsuka, Francis A. Ulmer, Jian Yang, and Oran R. Young

KMI KOREA MARITIME INSTITUTE

EAST-WEST CENTER

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The Eleventh Volume in the KMI/EWC Series: *The Arctic in World Affairs*

KMI/EWC SERIES ON THE ARCTIC IN WORLD AFFAIRS

The Korea Maritime Institute (KMI) is a government-affiliated research organization under the umbrella of the National Research Council for Economics, Humanities and Social Science (NRC) in the Republic of Korea (hereinafter Korea). Since its establishment in 1984, the KMI has been a major think tank in the development of national maritime and fisheries policies, including shipping and logistics, port development, coastal and ocean management, maritime safety and security, and fisheries affairs.

The East-West Center promotes better relations and understanding among the people and nations of the United States, Asia, and the Pacific through cooperative study, research, and dialogue. Established by the U.S. Congress in 1960, the Center serves as a resource for information and analysis on critical issues of common concern, bringing people together to exchange views, build expertise, and develop policy options.

The KMI/EWC series *The Arctic in World Affairs* publishes work from the North Pacific Arctic Conference. This forum enables key individuals from relevant countries and major stakeholder groups to develop relations of trust, allowing them to discuss complex and sometimes difficult issues pertaining to the maritime Arctic in a spirit of problem solving rather than advocacy.

The first volume in the series, *A North Pacific Dialogue on Arctic Transformation*, based on the 2011 North Pacific Arctic Conference, was edited by Robert W. Corell, James Seong-Cheol Kang, and Yoon Hyung Kim.

The second volume, *A North Pacific Dialogue on Arctic Marine Issues*, from the 2012 conference, was edited by Oran R. Young, Jong Deog Kim, and Yoon Hyung Kim.

The third volume, *A North Pacific Dialogue on the Future of the Arctic*, from the 2013 conference, was edited by Oran R. Young, Jong Deog Kim, and Yoon Hyung Kim.

The fourth volume, *A North Pacific Dialogue on International Cooperation in a Changing Arctic*, from the 2014 conference, was edited by Oran R. Young, Jong Deog Kim, and Yoon Hyung Kim.

The fifth volume, *A North Pacific Dialogue on the Arctic in the Wider World*, from the 2015 conference, was edited by Oran R. Young, Jong Deog Kim, and Yoon Hyung Kim.

The sixth volume, *A North Pacific Dialogue on Arctic Futures: Emerging Issues and Policy Responses*, from the 2016 conference, was edited by Robert W. Corell, Jong Deog Kim, Yoon Hyung Kim, and Oran R. Young.

The seventh volume, *A North Pacific Dialogue on Building Capacity for a Sustainable Arctic in a Changing Global Order*, from the 2017 conference, was edited by Robert W. Corell, Jong Deog Kim, Yoon Hyung Kim, and Oran R. Young.

The eighth volume, *A North Pacific Dialogue on Arctic 2030 and Beyond—Pathways to the Future*, from the 2018 conference, was edited by Robert W. Corell, Jong Deog Kim, Yoon Hyung Kim, Arild Moe, David L. VanderZwaag, and Oran R. Young.

The ninth volume, *A North Pacific Dialogue on Global-Arctic Interactions: The Arctic Moves from Periphery to Center*, from the 2019 conference, was edited by Robert W. Corell, Jong Deog Kim, Yoon Hyung Kim, Arild Moe, Charles E. Morrison, David L. VanderZwaag, and Oran R. Young.

The tenth volume, *A North Pacific Dialogue on Will Great Power Politics Threaten Arctic Sustainability?*, from the 2020 conference, was edited by Lawson W. Brigham, Robert W. Corell, Jong Deog Kim, Yoon Hyung Kim, Arild Moe, Charles E. Morrison, David L. VanderZwaag, and Oran R. Young.

This volume, *Science, Technology and the Path Forward for a New Arctic*, from the 2021 conference, was edited by Jong Deog Kim and Charles E. Morrison. Lawson W. Brigham, Sung Woo Lee, Nancy D. Lewis, Arild Moe, Natsuhiko Otsuka, Francis A. Ulmer, Jian Yang, and Oran R. Young were also organizers and chairs of the 2021 conference.

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Foreword

NPAC 2021 marked the beginning of a new decade of Korea Maritime Institute and East-West Center collaboration in support of the North Pacific Arctic Conference. This collaboration was grounded in the recognition of the importance of the Arctic for the countries of the North Pacific; its potentials for new shipping routes, enhanced economic development in the Arctic itself, and particularly the impacts of climate change, happening as much as three times more rapidly in the polar regions than the global average. It was also grounded in the need to view contemporary changes in the Arctic not just from the traditional North Atlantic perspective, but also from a North Pacific one. The countries of the North Pacific are the world's largest emitters of the greenhouse gases that scientists regard as the biggest driver of climate change. Since they are also the most likely largest users and beneficiaries of newly available Arctic sea routes and resources, their impact on the Arctic and its residential and Indigenous communities is enormous.

Over the years, NPAC has brought together analysts and practitioners from different countries and backgrounds for in-depth, frank and confidential discussions about the multiple challenges facing the Arctic and how to address them. NPAC has always regarded science and technology (S and T) as of critical importance, both to assess and document what is going on and to understand the implications of rapid changes in this dynamic region, as well as providing guidance on to the best ways and tools to address these challenges. NPAC 2021, however, was the first of our series to be mainly devoted to S and T as a theme, addressing several important dimensions. We are grateful to Sung Woo Lee of the Korea Maritime Institute for suggesting this theme and to Oran R. Young for his lead in shaping the basic conceptual framework used. We are also grateful to Arctic Senior Officials and Ambassadors Nikolay Korchunov of Russia and Youngki Hong of South Korea for joining our virtual conference.

NPAC 2021, like NPAC 2020, had to be held virtually and featured conversations around questions rather than presentations of papers. We appreciate the willingness of the chapter authors in this volume to supplement their conference ideas with formal papers. Conference session organizers and chairs included Lawson W. Brigham, Nancy D. Lewis, Jong Deog Kim, Arild Moe, Charles E. Morrison, Francis A. Ulmer, Jian Yang, Natsuhiko Otsuka, and Oran R. Young. Morrison, as chair of the NPAC

Steering Committee, coordinated the process and was the principal editor of this volume. He was very ably supported by Jaymen Laupola, senior program officer, and Justina Leach, program assistant at the East-West Center. Senior Arctic scientist Dr. Robert W. Corell and Dr. Malgorzata Smieszek, project coordinator at the Arctic University of Norway in Tromsø and an adjunct fellow at the East-West Center, provided input and played instrumental roles throughout the process. We are deeply grateful to retired East-West Center senior fellow, Yoon Hyung Kim, for his extended and dedicated work on NPAC in prior years that helped give it the shape it has today. We are grateful for the editorial support and thoughtful suggestions from Daniel Glick, in his fifth year as an NPAC copy editor.

We also want to give special credit to the Indigenous scholars and early career specialist (NPAC fellow) participants who were participants and/or chapter authors, funded through the Korea Maritime Institute, the East-West Center, and the National Science Foundation. Their contributions were invaluable. One conclusion of this volume is that Indigenous Knowledge is a powerful and often corrective complement to information gathered by modern technologies such as remote sensing, and it can often provide guidance as to how these new technologies can be most effectively deployed.

The NPAC fellows are the Arctic specialists of the future. We are honored to have their presence and pleased that they appreciate their association with NPAC's mid-career and senior scholars and practitioners. The sobering reality of climate change underscores the need for greater resources to be devoted toward developing new Arctic research and community leaders in all the North Pacific societies.

Tragically, as we write this foreword, war is raging in Ukraine and many countries are applying sanctions against Russia, with long-term consequences. This surely will affect the future of international cooperation in the Arctic. However, as this volume makes clear, there are many common or complementary interests of concern not just to Arctic states or North Pacific states, but to the whole world. We hope that the current conflict will be resolved in a way that respects national sovereignty and territorial integrity and re-opens the doors to a needed more robust degree of international cooperation in the Arctic.

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1. Science, Technology and the Path Forward for a New Arctic

Charles E. Morrison

A New Decade

In 2021, the North Pacific Arctic Conference (NPAC) began its second decade. For the second year in a row, it was held virtually due to the pandemic. The first decade of NPAC had a broad focus on how the region was being transformed from a remote area at the margins of global society to a "new" Arctic of increasing centrality, with interests and involvements moving far beyond eight Arctic territorial countries. The primary drivers for this transformation include multiple impacts from climate change and new technologies that generate realistic prospects of new sea routes and enhanced access to the region's mineral and other resources.

The second NPAC decade will expand on this theme, but with a "planetary" dimension. The Arctic is not just an increasingly important place of human activity but also a critical region of rapid geophysical change with enormous, potentially devastating impacts on the rest of the planet. It was first suggested by Sung Woo Lee of the Korea Maritime Institute that NPAC's second decade begin with an examination of the role of science and technology in the contemporary Arctic. This is an especially important framing, since science is so critical to understanding the scope and implications of geophysical changes, and technology critical to monitor and address these challenges. In previous years, NPAC has included presentations and sessions on science- and technology-related topics and promoted scientist-policymaker dialogue. However, 2021 was the first time NPAC specifically addressed science and technology issues through an integrated series of sessions.

Oran R. Young elaborated on Sung-Woo Lee's idea and helped create the conceptual framework used for the conference, as well as the organization of this volume and the papers prepared in association with it. The framework called for beginning with a geopolitical overview, as is customary, and for topical sessions on developments in Arctic science and technological applications there. This included developments in Arctic science, the interface of science, technology, and policy in adapting to the impacts of climate change, the role of innovative, "Fourth Industrial

Revolution" technologies in developing a sustainable maritime-based Arctic "Blue Economy," and the interaction between technologies and governance since technologies can facilitate informed and enforced governance and may also create new areas where governance is needed. The final session of the virtual conference provided opportunities for a crafted intergenerational discussion of take-aways.

This volume includes only the written papers that served as background to the discussion and which are associated with their authors. These were not presented in traditional academic fashion, but were prepared as background for the conference. There were other conference participants who made conference contributions but did not write papers. For more information on the conference, each section of this book is introduced by a short summary of highlights from the corresponding session of the virtual conference. Since conference proceedings take place according to the "Chatham House Rule" promising confidentiality to promote exploration and frankness, the highlights are not associated with particular speakers.

The North Pacific Lens

A distinctive feature of NPAC is its perspective on the Arctic through a "North Pacific lens." When NPAC began in 2011, most international discussions of the Arctic had a decidedly North Atlantic flavor. Although Japan, Korea, and China had interests and scientific engagements in the Arctic, particularly within the International Arctic Research Committee, they were not engaged at the Arctic Council. Soon afterwards (2013), the Council approved these three nations as Non-Arctic State Observers, a status that allowed them to engage in the activities of the Council's working groups. Outside the Council, they and other nations are also active in numerous other governmental, private, and hybrid networks engaged with various Arctic issues.

The North Pacific lens sought to add a new perspective on Arctic issues by drawing attention to the geographical proximity of three non-territorial Northeast Asian countries and showing how their interests are intrinsic to the region's development, its resources, its sea routes, and its potential impact on their own countries. This perspective draws attention to how important non-Arctic states are to any sustainable future of the Arctic and their responsibilities, along with the special responsibilities of Arctic states, for mitigating climate change and protecting the region's human and wildlife populations. (Yoon H. Kim, Oran R. Young et. al., 2020)[1]

The North Pacific lens is an important but not exclusive perspective, and that is why NPAC includes representation from countries outside the region and, of course, the region's Indigenous and resident populations in its discussions. It hopes to complement, not substitute for, other important Arctic forums.

Finding Common Ground in an Era of Peaceful Competition

The 2021 conference was grateful for the presence of two senior officials, Ambassador Nikolay Korchunov of Russia, chair of the Arctic Senior Officials during the 2021-23 period, and Ambassador Youngki Hong, Korea's Senior Official, for opening the meeting with verbal remarks. They explained the Russian agenda for its chairmanship and Korea's engagement with the Arctic, respectively.

Following the dialogue with policymakers, the conference addressed the question of finding a solid longer-term basis for continued international cooperation in the Arctic. In previous years, NPAC has heard different perspectives from individuals from different countries. But this year, Oran R. Young, Jian Yang, and Andrei Zagorski collaborated on a joint effort (chapter 2), uniting perspectives from their different vantage points in the United States, China, and Russia. This chapter, like all those appearing in the volume, were written before the February 2022 outbreak of hostilities in Ukraine.

The three authors write of two contrasting views of the region in international affairs. The first dates from the 1990s, that the Arctic should be a self-contained zone of peace isolated from geopolitical affairs. The second, commonly associated with the Trump administration, some strategic studies think tanks, and the media, argues that Arctic issues are now dominated by great power competition. Young, Yang, and Zagorski argue that both these offer simplistic and distorted views of the region. The prospects of new resources and trade routes have undeniably introduced an element of geopolitical competition in the region, as has the intensification of great power tensions elsewhere in the world. But the Arctic itself is an area of low tension in military terms and is marked by considerable cooperation in addressing numerous practical issues.

The authors suggest that the region could be more accurately described as a region of "peaceful competition." Keeping it peaceful requires a vigorous agenda of cooperation where this is possible, and they sketch out several broad areas to pursue: Codes of conflict to avoid military confrontations where military forces are near and in the Arctic; addressing climate change issues; regulating shipping and other resource uses to protect Arctic peoples and environments, protecting biodiversity; and meshing scientific research programs more efficiently to understand the region's biophysical changes and their broad implications. The authors show that despite increased geopolitical competition, multilateral and bilateral forms of cooperation on these and other issues is also occurring, and on a fairly steady, incremental basis. Although not dramatic to the general public, this should clearly register in our view of political developments in the new Arctic.

In chapter 3, Mia Bennett expands upon the Young-Yang-Zagorsky description of the "regime complex." She posits the situation as a "three-dimensional" rather than a tripolar chess game, in which governments, Indigenous groups, corporations, scientists, and other interests are all part of the growing web of Arctic bilateral, plurilateral, and larger international governance relationships. She sees the Arctic Council as having incrementally and quite successfully consolidated its central position, demonstrating an ability to continue and deepen work on sustainable development and environment protection despite the first Ukrainian crisis in 2014 and Russia's annexation of Crimea and ensuing sanctions on that country. At least, she writes, for the time being.

New Dimensions of Arctic Science

Part II seeks a better understanding the dynamics and trends of scientific research in the Arctic. It focuses on two aspects: The growing scope of Asian Arctic science efforts, and the Arctic Science Ministerial (ASM) meetings that began in 2016 to provide a high-level venue for sharing information on national science efforts and collaborating on international activities.

China, Japan, and South Korea all have robust Arctic research programs and are committed to being full partners in advancing Arctic scientific research to better understand the rapid changes in the Arctic environment in an era of unprecedented climate change. These countries' polar science originated with the Antarctic, but in the past three decades they have taken a growing interest in the Arctic. Each of these nations has its own research interests and priorities converging around environmental studies, strong polar-oriented scientific institutions, national Arctic research stations (particularly in Svalbard where all have stations at Ny-Ålesund), and advanced research vessels. China has recently built its second research icebreaker, Korea has a second vessel on the books, and Japan will have built its first true ice-breaking, state-of-the-art research vessel by 2026. Since they are not territorial Arctic states, each of them depend on sea-going research vessels or collaborative work on land with territorial states.

Japan's program has the oldest Arctic research history, with origins in the 1950s, according to Dr. Hiroyuki Enomoto (chapter 4). These efforts accelerated in the 1980s and early 1990s when the National Institute for Polar Research and Japan's Svalbard station were established. In the 1990s, Japanese scientists joined scientists from Norway and Russia in assessing the potential of the Northern Sea Route, long before it was considered economically feasible. In the past ten years, the GRENE Arctic project and the Arctic Challenge for Sustainability (ArCS) extended Japan's activities to new thematic and geographical areas and sought to link the hard sciences with the humanities and natural sciences to provide a more comprehensive view of the changing Arctic. This effort is being refreshed and expanded with the new ArCS2 and will be enhanced by the upcoming advanced polar research vessel.

China's first Arctic expedition came in 1999. In chapter 5, Huigen Yang recounts how China has moved quickly to augment its Arctic research, with an emphasis on climate and environmental change and their implications for shipping routes and conditions in mid-latitude countries. The China National Antarctic/Arctic Research Expeditions, operated through the Polar Research Institute of China (PRIC), have provided a major research instrument. In the Arctic, China established research stations in Svalbard in 2004 and Iceland in 2018. The Chinese efforts have resulted in many data sets that feed into larger research networks and projects. By way of illustration, Yang details some of the important research conclusions of Chinese scientists.

Korea's contributions have been outlined in an earlier NPAC volume (Corell *et al.*, 2019)[2] and were discussed again during the virtual conference. Its baseline Arctic scientific survey took place in 1991; the Korean Polar Research Institute's (KOPRI) Svalbard station was established in 2002; and its ice-breaking research vessel, Araon, was commissioned in 2009. Korea has given priority to environmental research and impacts. As Sung-jin Kim observes later in this volume (chapter 15), KOPRI was listed as the second-leading polar research institute in the world in the 2018 Nature index for the number of peer-reviewed journal articles.

While most Asian Arctic research is national team oriented, reflecting differences in priorities, research cultures, budgeting procedures, and even periods available for field research, Asian scientists are also increasingly active in multilateral endeavors, such as the 20-country MOSAiC expedition. Other collaborative networks include the International Arctic Science Committee. It can be anticipated that Asia will become an even more significant player in multilateral efforts.

One sign of the increase in Asian Arctic research contributions was Japan's collaboration with Iceland in organizing the Third Arctic Science Ministerial in 2021 and its role as the actual host of this event. For this reason, it was opportune to describe and evaluate this five-year-old process, and two chapters do so: Chapter 6, written collaboratively by Francis Ulmer and Malgorzata Smieszek, and chapter 7 by Chairin Jung, a 2021 early career "NPAC Fellow." While the ASM is relatively new, the two chapters detail an on-going process of institutionalization. Both see a need for increased coordination among national science efforts and find the equal status of Arctic states, non-Arctic states, and Indigenous organizations a strength of the ASM process. Ulmer and Smieszk point to the encouragement of observation monitoring and increasing participation in MOSAiC as successful outcomes, while Jung also notes efforts to provide regular, systematized information on on-going scientific projects.

Despite these accomplishments, there are questions about the future. Can the ASMs be enhanced with more continuous follow-up between sessions? Will there be some sharing of research visions and concrete efforts at collaboration and coordination in the face of increased needs, especially because of climate change? How will the ASMs relate to the Arctic Council? This evolving institution bears further watching.

Arctic Communities Adapting to Climate Change

While globally-generated greenhouse gases (GHGs) are a major driver of climate change, the Arctic itself is not a significant source of anthropogenic GHGs. The amplification of climate change in the polar regions, however, means that the peoples, communities, and wildlife of the Arctic are experiencing climate-related impacts more quickly and forcefully than other parts of the world, causing enormous adaptation challenges. A session of the virtual conference focused on these challenges and the strategies to meet them at the local level and considered how modern science, Indigenous Knowledge, and community observations interact with technology to help in understanding and addressing them. In the larger panel, Brendan Kelly, Jackie Qataliña Schaeffer, and Bernard Funston contributed the written papers included as chapters 8, 9, and 10 in this volume.

Kelly sets the stage by explaining the changing geophysical features of the Arctic that have occurred since the onset of the Industrial Revolution, largely due to the widespread combustion of fossil fuels. These impacts include amplified global warming in the Arctic and pose growing threats to wildlife and communities in the region. He reminds us that the current fluctuation of the climate is associated with human activity and threatens to cause the sixth great planetary extinction event. Schaeffer draws upon her experience and that of her Elders to explain the traditional cycle of life in rural and native Alaska and how it has changed. Today, 43% of Alaska's rural communities are threatened by environmental changes. She urges the adoption of a different mindset: Embracing scientific tools and Indigenous Knowledge in a holistic manner, since impacts in the region are not just environmental but are also physical, spiritual, and cultural. While Schaeffer notes that the Alaska Native Claims Act of 1971 created bureaucracy and regulations in Alaska that must be navigated, there are numerous entities and programs that are creatively addressing the issues. While adaptation challenges differ from locality to locality, inclusiveness and collaboration ultimately give strength to Indigenous communities to adapt.

Canadian Bernard Funston zooms out to the broader social and political context. He shows how his country's government, like many others, keeps promising more ambitious carbon reduction targets while the factual record shows year-by-year increases in carbon emissions. With a deficiency of national and international political will, mitigation and adaptation efforts will continue to be defining challenges of this century. He is particularly concerned about the perniciousness of disinformation in the media and its influence on the public in democratic countries, in particular the susceptibility of some American political leaders to manipulation of facts for perceived political gain, as illustrated by the Trump administration. The unwillingness to accept science, whether with regard to climate change or in the case of COVID-19, will test the Arctic Council framework for collaboration and add immensely to the adaptation challenges faced by local communities. But Funston also points to the human capacity to adapt over the long term during previous environmental upheavals.

The Blue Economy as an Economic Driving Force?

Session four of the conference and the chapters in this section looked at new frontiers in selected marine technologies and addressed the question of whether they could drive sustainable economic development. Four chapters examine advanced technologies in shipping, icebreaker development, submarine cables, and deep-sea mining, while a fifth chapter looks at various technologies being developed in South Korea that may contribute to sustainable Arctic development.

Two chapters, those by James Bond (chapter 11) and Alexey Shtrek (chapter 12), address different aspects of shipping technology: Technologies to operate under and comply with the International Maritime Organization's Polar Code and the technologies of advanced icebreaking ships.

Bond shows how the Polar Code, the result of a 20-year process of discussions and negotiations among many public, private and Indigenous stakeholders, culminated in a comprehensive binding agreement to enhance ship safety and diminish the environmental impacts of increased Arctic shipping that entered into force in 2017-2018. Compliance with the Code involves many variables, including ship design, quality of steel, training levels, awareness of local uses and other sensitivities, hydrology, and measures of ice-load, given fluctuating sea and ice conditions. The last is an example where advanced technologies not only to measure ice load, but also indicate paths of least resistance through the ice that can lead to reduced fuel needs and accident risks, thus increasing crew and environmental safety. Diminishing sea ice is expected to lead to more use of Arctic routes with crews less experienced in the high north, so compliance with the Code and technology-enhanced awareness may help offset this effect.

Shtrek examines a technology developed specifically for polar and seasonally ice-covered seas: Icebreaking vessels. Historically, propulsion, design, and convoy or independent vessel technologies have evolved differently in different regions. Today, a range of technologies are available that can be tailored to the economic and environmental needs of specific projects. For example, Shtrek notes the development of LNG-fueled icebreaking tankers for the Yamal Peninsula gas developments. These can normally operate independently, as opposed to requiring Russian heavy nuclear icebreakers for convoy on the Northern Sea Route. There are also challenges and risks associated with each technology, but the biggest risk may be that of private operators trying to save money by using old ships in seas for which they were never designed, a risk that should be eliminated with strict Polar Code compliance.

Submarine fiber optic cables are essential to the modern economy. Globally, there are 1.2 million kilometers handling 99% of the international internet data traffic. As Juha Saunavaara (chapter 13) points out, interest in Arctic fiber optic routes has accelerated, driven by the shorter distances across the Northern Hemisphere, the ability to diversify old routes that are vulnerable at chokepoints, and the ability to enhance overall capacity. He details the current state of several plans, including the Russian state's Polar Express. While the environmental impacts are relatively small, there are other constraints, including financing and the relatively risk-adverse posture of many telecommunications companies. How valuable fiber optic cables may be to local communities depends on land points and availability of transmission beyond them through local servers. With enhanced broadband, Arctic-based data centers may become a possibility in the future.

Deep-sea mining remains more a distant prospect, affected by commodity prices as well as still-needed technologies. In chapter 14, Steinar L. Ellefmo explains these and other variables affecting the potential of deep-sea mining. Mining sites include manganese modules on the Pacific and Indian Ocean floors as well as vents along rifts that extend from the North Atlantic into the Arctic. However, so far, responsible and cost-efficient mining on the deep ocean floor has not succeeded even in more environmentally friendly regions. While deep-sea mining is thus currently a longer-term prospect in the Arctic, the continuing demand for minerals and metals, as well as advances in technologies to mine and recycle them sustainably, may allow movement in this direction. However, much more basic research on the resource deposits, the costs and benefits of mining them, the broader implications of mining, and appropriate regulatory systems are needed.

In chapter 15, Sung-jin Kim posits that developing 4th Industrial Revolution technologies for use in the Arctic can be a huge contribution of non-Arctic nations such as Korea to sustainable development of the region. He reviews Korea's ambitious plans to develop many new technologies in such areas as autonomous ships, LNG icebreaking vessels, telecommunications, medical technologies, and advanced port infrastructure. But he also notes the constraints that need to be overcome: Developing tools to permit public use of private intellectual property, establishing a high-level of broadband in the region, "winterizing" technologies originally developed for less hostile environments, and training users, including Indigenous communities, in their application.

The Technology-Governance Interface

Part V chapters focus on the way technologies and governance interact with each other. The conference panel, whose participants each contributed a chapter, was designed to bring together specialists in certain technologies with those in governance for dialogue. Several overall themes stood out: That the paucity and fragmentation of data in the Arctic region is a major governance impediment; that the application of advanced technologies, when integrated with other sources of data and knowledge, can help close the gaps; that regular and continued contact between technology providers and users of data is required to help tailor data collection, analysis, and presentation for the user community; and that when it comes to technologies, non-Arctic states are essential partners.

Chapter 16 by Jian Yang and Guijie Shi broadly examines innovations in maritime technologies, which they categorize as including: Improvement of existing models; new technologies explicitly to meet environmental needs; innovations "winterized" for Arctic applications; and innovations aimed at information integration. They see relevant technologies, especially in shipping and observation monitoring, as important contributions that Northeast Asian countries can make to Arctic countries and peoples.

Yap Xiao-shan (chapter 17), co-authors Misako Kachi and Naoko Sugita (chapter 18), and Paul A. Berkman (chapter 19) focus on satellite technology. Yap shows how satellite technologies, driven by innovation and privatization, have increased relevance for governance globally but are especially useful where remoteness and weather limit ground monitoring. She cites concrete examples, such as tracking movements of whales, arctic foxes, and polar bears, allowing for more precise information and adjustments of the boundaries of protected areas.

Also addressing satellites, Kachi and Sugita note that observation from space is not "an almighty tool," but an increasingly essential method to provide data not otherwise available. Satellites are particularly critical in monitoring climate change, since more than half of the internationally agreed Essential Climate Variables are amenable to satellite observation, and changes in the region have implications not just for the Arctic but how the global community addresses the climate change crisis. Other uses include navigation, detecting pollution (such as oil spills but not yet plastics), and in marine life impacts (plankton but not yet individual marine species). But gaps exist between what governance users want and the technology available, and this requires on-going interaction to ensure that technological advances are directed towards the most critical governance needs.

Berkman shows how satellite observation of shipping traffic in the Arctic over time can help discern patterns, project trends, inform decision-making and improve the enforcement of binding Arctic agreements, especially the 2018 one to prevent unregulated fishing in the Central Arctic Ocean. Informed decision-making requires integrating of these data with other sources of information, but satellite observations have the advantage of being comprehensive to a broad area, objective and factual, and adaptable to meet the needs of specific governance users.

Karen Pletnikoff in chapter 20 draws on her experience as an Indigenous Aleut working in the Bering Sea/Aleutian chain to show that remote sensing can be combined with Indigenous Knowledge to provide a more holistic perspective of environmental conditions. She points out that there are many new pressures on sea and wildlife resources, including thousands of vessel transit passages along the Great Circle Route in the Pacific, greater fishing, and the past use of one island for atomic testing. In relation to shipping and fishing, Indigenous Knowledge has brought insights such as "Areas-to-Be-Avoided," since historically and culturally accumulated insights on sea and land animal movements may show specific environmental sensitivities not evident, as Kachi and Sugita have suggested, from remote instruments.

In chapter 21, Tom Barry provides a case study of his own organization, the Arctic Council's Working Group on the Conservation of Arctic Flora and Fauna (CAFF), which lies at the intersection of science and policy. There are many data challenges, including the fact that data of Arctic territorial states are not standardized, which makes it difficult to filter information to meet particular policymaker demands in an easily understood or authoritative way. However, the Arctic Council has declared that good data and its accessibility are essential to addressing Arctic problems, and he shows how CAFF is making use of remote sensing and advanced data management and sharing tools.

The Planetary Dimension

With their collective vision, the specialists writing for NPAC 2021 demonstrate how critical science and technology are to manage challenges emerging in the new Arctic at a time of planetary change. Science is desperately needed to understand and document what is happening, and point to areas where critical policy actions should be taken. Arctic science has become much more robust than in earlier decades, with literally hundreds of projects. However, there remain many gaps, inconsistencies in data collection and reporting, and much to be desired in coordinating national efforts around common endeavors in scientific discovery and monitoring and in encouraging more rapid advance of environmentally-needed technologies. Even then, the science needs to be accepted by the public and policymakers who resist inconvenient results. In addition, these emerging technologies need to be deployed to consumers trained in their uses.

Technologies from earlier eras, beginning with the first Industrial Revolution, whether in extraction, transportation, or chemicals such as plastics, instigated many of the unintended consequences that have led to the most significant climate and other environmental challenges of today. Today, however, technological innovations are viewed as critical to helping mitigate, adapt to, and overcome these challenges, both in replacing older resource-intensive technologies and in helping monitor and enforce policies intended to achieve sustainability.

In this context, the new Arctic is a critical arena for the future of the planet. The shrinking of sea ice, the melting of the Greenland icecap and the enormous amount of water that will release into the sea, and the thawing of permafrost, which will release trapped carbon and methane gases, will combine to produce dramatic effects far beyond the Arctic. These impacts will affect climate, sea levels, human settlement patterns, ocean currents, freshwater availability, and biodiversity the world over. But most immediate affected are the ~4 million people in Arctic Indigenous and settler communities. During the coming decade, NPAC will continue its work to build networks of individuals and institutions that understand these issues and are anxious to address them through meaningful, concrete actions.

Notes

1. For elaboration, see "Overview: Will Great Power Politics Threaten Arctic Sustainability?" in Lawson W. Brigham *et al.*, The Arctic in World Affairs: A North Pacific Dialogue on Will Great Power Politics Threaten Arctic Sustainabiliy? the Korea Maritime Institute and East-West Center, 2020.
2. See chapter by Heung Kyeong Park in Robert W. Corell et al, The Arctic in World Affairs: A North Pacific Dialogue on Global-Arctic Interactions: The Arctic Moves from Periphery to Center, Korea Maritime Institute and East-West Center, 2019, pp. 37-40.

PART I

THE POLICY ENVIRONMENT FOR ARCTIC COOPERATION: FINDING COMMON GROUND

Highlights from Session 1 of the North Pacific Arctic Conference 2021

The Policy Environment for Arctic Cooperation: Finding Common Ground

Session 1 explored the current policy environment for Arctic international cooperation with two government officials: The Russian chair of the Arctic Council's Senior Arctic Officials and the Korean Senior Arctic Official. It also featured discussion based on a trilateral paper in which American, Chinese, and Russian co-authors sought to evaluate changing conditions in the Arctic and to identify specific opportunities for cooperation in the 2020s.

Chair and Organizer:

Charles E. Morrison, Adjunct Fellow, East-West Center

Panel Members:

Mia Bennett, Assistant Professor, University of Washington
Hong Youngki, Ambassador and Senior Arctic Official, Republic of Korea
Nikolay Korchunov, Ambassador and Chair of the Arctic Senior Officials
Sara Olsvig, PhD Fellow, University of Greenland, Nuuk
Jian Yang, Vice President, Shanghai Institute for International Studies
Oran R. Young, Professor Emeritus, Bren School of Environmental Science and Management, University of California, Santa Barbara
Andrei Zagorski, Head of Department for Disarmament and Conflict Resolution Studies, Primakov National Research Institute of World Economy and International Relations (IMEMO), Moscow

Discussion Highlights:

- The agenda of the 2021-2023 Russian chairmanship of the Arctic Council focuses on sustainable socio-economic development of people, resources, and environmental stewardship, especially regarding issues posed by climate change, as well as implementing the Arctic Council's new strategic plan.
- Korea provides an example of an observer nation with more than 20 years

of engagement in the Arctic that believes its balanced research approach and development of efficient transportation systems represent significant contributions to the international community. The Arctic Council framework has helped stimulate national attention and actions related to the Arctic and strengthened relations between Korea and Arctic residents.

- Conditions prevailing in the Arctic have changed dramatically since the Arctic Council was created a quarter century ago. These changes require a new narrative for those seeking to understand the nature of international relations in the Arctic and opportunities for collaboration in "the new Arctic." The region is no longer, as once conceived, a "zone of peace" isolated from great-power competition. Nor is it dominated by geopolitical tension, since there have been few significant conflicts strictly involving Arctic issues. A more suitable interpretative framework is to think of the region as a zone of peaceful competition, characterized by some geopolitical competition but with significant common or converging interests.
- Specific areas of cooperation may include developing codes of conduct to avoid armed clashes, collaborating on a range of climate change and environmental protection issues, regulating shipping and other resource uses in the interests of sustainability and peoples' livelihoods, and meshing national scientific research programs more efficiently to generate a shared means of understanding regarding large biophysical and other changes.
- The Arctic Council provides a flexible and adaptable governance framework. This includes input from Indigenous Peoples organizations as permanent participants, expanded opportunities for non-Arctic states to engage in the region, the formation of numerous associated entities such as the Arctic Economic Council and the Arctic Coast Guard Forum. The Council also interacts with global organizations or ad hoc processes to generate rulemaking, as happened on the Polar Code for shipping and on fishing regulation in the Central Arctic Ocean. Nonetheless, new voices are needed in the Arctic Council to enhance its convening and catalytic power to address issues and to coordinate and monitor actions.
- The Arctic Council lacks a forum to engage on issues of economic policy. Cooperation with the Arctic Economic Council can and should be strengthened not only to draw in the business community, but also to improve outreach to economic ministries and international economic organizations.
- There are changes within the region itself with Indigenous peoples and

other Arctic residents demanding stronger roles in shaping the region's agenda and future. Indigenous peoples have numerous ways of influencing these agendas through direct participation in intergovernmental processes, through their own governing entities such as Greenland's self-government system, and through their relevant national governments. But they feel that their voices are not yet adequately heard or heeded.

2. The "New" Arctic as a Zone of Peaceful Competition

Oran R. Young, Jian Yang, and Andrei Zagorski

Overview

The Arctic has emerged in the 2020s as a critical arena in the global climate emergency and as an area of increasing sensitivity in terms of great-power politics.

Some see this "new" Arctic becoming a zone of conflict; others react to these developments by doubling down on the established view of the Arctic as a zone of peace.

This chapter puts forward an alternative narrative that treats the "new" Arctic as a zone of peaceful competition, recognizing the increasing role of large power competition but alive to the many opportunities for cooperation across a host of issues.

These include developing codes of conduct to avoid armed clashes, responding to climate change, managing commercial shipping, protecting biodiversity, and integrating scientific activities. This agenda involves a complex of stakeholders—national governments, intergovernmental organizations, Indigenous People's organizations, and many others—but the Arctic Council stands at the center.

We believe the Arctic can be maintained as an area of low military tensions and strengthened arrangements for addressing climate impacts, while sustainably using its resources. This requires specific changes to enhance the operation of the Arctic Council to take advantage of its broad convening power to identify and monitor the challenges and bring together those empowered to address them in informal non-negotiating or pre-negotiating discussions.

The Arctic in the 2020s

Conditions arising in the Arctic today differ substantially from those prevailing in the aftermath of the Cold War, when Arctic states took the initiative to create a distinctive regional governance system by launching the Arctic Environmental Protection Strategy in 1991 and then moving to establish the Arctic Council in 1996 as a "high level forum" with a mandate to promote "cooperation and interaction among the Arctic States, with the involvement of the Arctic indigenous communities and other Arctic inhabitants on common Arctic issues" (Arctic Council, 1996). Underpinning this arrangement was a vision of the Arctic as a somewhat peripheral region in international affairs of interest primarily to the Arctic states and featuring a policy agenda of its own that focused for the most part on issues relating to environmental protection and, somewhat more broadly, sustainable development (Young, 2020). On this account, it made sense to foreground the role of the eight Arctic states in the Arctic Council, to provide Indigenous Peoples' organizations with the special status of Permanent Participants, and to restrict others, including non-Arctic states, intergovernmental organizations, and nongovernmental organizations, to the status of Observers.

Now, 25 years later, changing conditions are raising fundamental questions about the adequacy of this vision as a basis for addressing issues of Arctic governance arising in the 2020s. It has become clear that the high latitudes of the northern hemisphere play a crucial role in the dynamics of Earth's climate system. The Arctic's deposits of natural resources, including large reserves of hydrocarbons, have attracted the attention of policymakers not only in Arctic states but also in non-Arctic states such as China and in multinational corporations such as TotalEnergies, ExxonMobil, and Shell. Shifts in the political configuration of international society as a whole have heightened tensions among China, Russia, and the United States. While the Arctic itself is not a locus of severe conflict, great-power politics are spilling over into the Arctic, raising questions about its status as a peaceful region somewhat separated from the mainstream of international affairs (Brigham *et al.*, 2020).

Some have responded to these developments by deploying a neorealist or geopolitical narrative and treating the Arctic as an emerging arena for the interplay of great-power politics. Former U.S. Secretary of State Michael Pompeo asserted in a speech preceding the 2019 Ministerial Meeting of the Arctic Council that "the region has become an arena of global power and competition" (Pompeo, 2019). In this account, the trajectory of Arctic affairs in the coming years will be driven in large measure by spillovers from global interactions among China, Russia, and the United States into the regional arena. Increasingly prominent in the reports of journalists looking for provocative angles on current developments in the Arctic, this narrative is also evident in the newfound interest in Arctic affairs among foreign policy analysts and students of international relations who have a limited grasp of the region but little difficulty in applying a neorealist narrative to events unfolding anywhere in the world.

Others have responded by reemphasizing the suitability of the 1990s Arctic governance system. They ground their thinking in the terms of the vision statement adopted at the 2013 Arctic Council Ministerial Meeting, asserting that the Council "has become the pre-eminent high-level forum of the Arctic region and we have made this region into an area of unique international cooperation" (Arctic Council, 2013). At the 2021 Ministerial Meeting, ministers adopted a Strategic Plan for the Council reaffirming this vision and asserting that "[i]n 2030 we envision the Arctic to remain a region of peace, stability and constructive cooperation, that is a vibrant, prosperous, sustainable and secure home for all its inhabitants, including Indigenous Peoples," and "the Arctic Council will remain the leading intergovernmental forum for Arctic cooperation" (Arctic Council, 2021). In this account, while modest adjustments in the architecture of Arctic governance might be entertained, there is no need for more far-reaching proposals such as altering any of the constitutive features of the Arctic Council.

We argue that neither response provides an adequate point of departure or interpretive framework for coming to terms with Arctic issues in the 2020s. The geopolitical or neorealist narrative ignores a range of areas where the major players have clear-cut common interests in cooperative responses. For its part, the strategy of reinforcing existing arrangements ignores fundamental changes that have occurred since the 1990s that limit their effectiveness. To unpack these propositions and to explore their implications for Arctic governance, we proceed in three steps. In the next section, we introduce the "new" Arctic, highlighting how conditions in the 2020s differ from those of the 1990s. This sets the stage for an examination in the following section of illustrative areas of common ground that give rise to opportunities for cooperative responses to emerging Arctic issues. It also provides a point of departure for an additional substantive section in which we discuss adjustments to the existing architecture of Arctic governance needed to take advantage of these opportunities. The result would be an Arctic governance system retaining key existing features but incorporating significant adjustments to enhance the prospects for success in dealing with the Arctic as a zone of peaceful competition during the 2020s.

The Rise of the "New" Arctic Calls for Innovative Perspectives

An unusual constellation of conditions arising in the 1990s following the end of the Cold War and the collapse of the Soviet Union led many to embrace a perspective often referred to as "Arctic exceptionalism." The essential elements were the propositions that the Arctic itself was an area of low tension and, as peripheral to the main currents of world affairs, it was possible to deal with Arctic issues on their own merits with little reference to events elsewhere. The Arctic zone of peace narrative captured this perspective and provided the conceptual foundation for the development and operation of institutional arrangements such as the Arctic Council.

From a variety of biophysical and socioeconomic perspectives, Russia is the preeminent Arctic state. But in the 1990s, Russia was struggling with the impacts of the recent collapse of the Soviet Union. The new Russian Federation was preoccupied with creating the legal and political institutions needed for a new governance system and a significantly reduced territorial reach. The capacity of the central government to exercise effective control over remote oblasts and republics was limited. The national economy had experienced a sharp decline. Clearly, Russia was in no position to launch ambitious initiatives in the Arctic. Many Soviet military installations in the Far North were closed or abandoned and traffic along the Northern Sea Route declined sharply.

China's economic miracle was in full swing during the 1990s, following the dramatic reforms initiated at the end of the 1970s. In due time, this would create the basis for China's rise as an economic powerhouse and a fully-fledged great power. It is worth noting that the experience of these years played an important role in establishing China's preference for deploying economic instruments in efforts to exercise influence at the international level, a preference that has become a striking feature of China's international activities in recent years. But China's policymakers were not thinking about Arctic initiatives at this time, much less about articulating an explicit Chinese Arctic policy.

As a result, many thought of the United States during the 1990s as the sole remaining superpower. But this did not result into U.S. policies featuring any explicit concern for Arctic affairs. The Clinton Administration, enjoying the benefits of a robust economy, was largely focused on domestic issues. To the extent that the U.S. was active on the international stage during the 1990s, the center of attention was the consolidation of the nuclear nonproliferation regime, the violence associated with the breakup of the former Yugoslavia, and, to a lesser extent, continuing tensions arising in the Middle East. Preoccupied with its image as a global power, the U.S. showed little interest in regional concerns in low-tension areas such as the Arctic. In fact, it was the United States, more than any other Arctic state, that resisted ambitious Arctic initiatives and insisted on limiting the Arctic Council to matters of low politics such as environmental protection and sustainable development (English, 2013).

Given these circumstances, the central premises embedded in the Arctic zone of peace narrative seemed perfectly reasonable. Contrast this situation with the conditions arising in recent years and likely to dominate the politics of the Arctic during the 2020s. Russia has reemerged with a strong central government and a reconstituted economy heavily dependent on the exploitation of large deposits of natural resources, notably natural gas, located in the Arctic (Mitrova, 2020). Russian policymakers understandably seek an acknowledgement that Russia remains a great power of global influence. In the Arctic, this has led to a stream of developments, including the modernization of the Northern Fleet, the reoccupation or strengthening of old military installations, a rapid growth in the extraction of hydrocarbons in northwestern Siberia, and the development of the Northern Sea Route into an important commercial artery.

China now regards itself as a global power on par with the United States and thereby entitled to take an interest in issues arising in seemingly remote areas such as the Arctic. Exercising its preference for economic policy instruments, China has taken an interest in assisting in the development of the Arctic's natural resources and exploring use of its commercial shipping routes. Chinese actors have explored investment opportunities in a variety of projects ranging from Canada and Greenland to Iceland, Fennoscandia, and Russia. While many of these have stalled, China has become both a major investor in natural gas projects in northwestern Siberia and a market for liquefied natural gas (LNG) shipped in state-of-the-art tankers eastward along the Northern Sea Route (Yang and Tillman, 2018).

For its part, the United States discovered the frustrating limits of its position as a remaining superpower in Afghanistan and elsewhere. As a result, the U.S. has become increasingly sensitive to what it perceives as actions that present challenges to its geopolitical dominance, including in the Arctic. Concretely, the United States has responded in several ways, including deploying warships to Arctic waters adjacent to the North

Atlantic, taking steps to replenish its severely depleted fleet of icebreakers, and conducting exercises with NATO allies such as Norway designed to enhance military capabilities in Arctic conditions.

A series of specific events in the 2010s focused and lent immediacy to these general trends, with significant consequences for Arctic international relations (Lanteigne, 2020). In 2014, the Russian annexation of Crimea and involvement in eastern Ukraine triggered an international crisis. The United States and its NATO allies responded by imposing sanctions on Russia, which forced Western companies such as ExxonMobil to end their engagement in the Russian Arctic. Triggering an action-reaction process, this led to a general deterioration of United States-Russian relations and gave rise to more pragmatic cooperation between Russian and Chinese policymakers on Arctic issues. China, which had unveiled a comprehensive Belt and Road Initiative in 2013, articulated the idea of a Polar Silk Road using the Northern Sea Route as a commercial artery. Additionally, Chinese energy companies compensated for the sanctions-related retreat of Western companies by making investments in infrastructure to facilitate the extraction of fossil fuels on the Yamal and Gydan Peninsulas.

Donald Trump's election in 2016 added a further element of volatility and unpredictability to international relations in the Arctic. While Trump tried to be personally friendly toward Vladimir Putin, the Trump administration intensified the post-2014 sanctions and allowed several strategic arms limitation agreements to lapse. Trump also initiated an unprecedented trade war with China and decried what he saw as China's efforts to achieve parity with the U.S. as a global superpower. The result was a growing sense of turmoil regarding the future of the global political order. In the Arctic, these developments created a tense atmosphere that made international cooperation much more difficult. Former Secretary of State Pompeo's 2019 assertion that the Arctic had become an "arena of global power and competition" was followed by this list of U.S. responses: "… hosting military activities, strengthening our force presence, rebuilding our icebreaker fleet, expanding Coast Guard funding, and creating a new senior military post for Arctic Affairs inside our own military" (Pompeo, 2019).

One striking result of these developments is a newfound interest in the Arctic among foreign policy analysts, students of international relations, and journalists who follow issues of international security broadly defined. In the 1990s, it was hard to stir up any real interest in Arctic affairs beyond a few specialists. Now, a remarkable range of practitioners and analysts are eager to share opinions about the region. In the absence of in-depth knowledge of Arctic issues, however, it is all too easy for such commentators to fall back on applying general international political narratives to the Arctic with little serious effort to see if these fit local conditions.

More often than not, the result is a neorealist narrative as a basis for analyzing the international politics of the Arctic. This narrative sees nation states (especially major states) as self-interested actors motivated largely by a desire to maximize relative power in competition with others. Conflict among the major powers is regarded as the normal condition of international society; international institutions are of limited value in high politics. Thus, individual states must assume that others will pursue their interests by all available means and prepare to protect their own interests. While cooperation may be feasible regarding matters of low politics such as environmental protection, there is no escaping the force of geopolitical pressures when it comes to dealing with matters of high politics arising in specific international regions. This analysis suggests that the 2020s are likely to be dominated by a three-way competition among China, Russia, and the U.S. in a region now seen as a theater of operations for increasingly sophisticated military assets and as a critical source for raw materials. (Pincus, 2020).

Without losing sight of the political ambitions of Arctic states and those with growing interests in the Arctic, this narrative is inadequate as a framework for thinking about Arctic international relations today. All informed observers acknowledge that the Arctic remains an area of low tension. There are, of course, disagreements and even disputes about issues arising in the Arctic, such as the legal status of the waters of the Northwest Passage, the legitimacy of Russian regulations pertaining to parts of the Northeast Passage, overlapping claims to portions of the deep seabed in the Central Arctic Ocean, and the compatibility of Norway's Svalbard Fisheries Protection Zone with the 1920 Treaty of Paris. But these are not issues likely to generate international crises, much less cause armed clashes. The key players have repeatedly expressed their commitment to the UN Convention on the Law of the Sea principles and pledged to resolve these Arctic issues peacefully. None seems likely to become a focus of escalating claims and counterclaims.

No doubt the links between the Arctic and the outside world have become stronger. This is true whether we think about the escalation of climate change impacts, the dynamics of global energy markets, or the efforts of countries such as Russia and China to hasten the decline of the American-dominated postwar world order. But it is a mistake to conclude from this that the reemergence of great-power politics in the Arctic will ensure the failure of all efforts to promote international cooperation regarding specific Arctic issues (Brigham *et al.*, 2020).

Russia is rebuilding and modernizing its armed forces to reassert its great-power status on a global scale. Given Russian geography, the Arctic inevitably figures prominently in this effort. But Russia is not deploying its armed forces as a means of exercising influence over current Arctic issues.

China is endeavoring to lend substance to its 2018 Arctic policy statement claim to be a "near Arctic state." So far, however, this effort has been limited to a modest growth of investments in projects involving the extraction of Arctic resources, a rising interest in the commercial shipping potential of the Northern Sea Route, and the enhancement of Chinese scientific Arctic research.

In the United States, various branches of the American armed forces have announced newfound interests in Arctic issues, at least at the declaratory level. But the Biden Administration has toned down American rhetoric about these matters and increased emphasis on cooperation on climate and other issues. Little evidence suggests a sharp rise in U.S. military deployments in the Arctic in the foreseeable future.

A reasonable conclusion is that the Arctic still remains peripheral to mainstream great-power politics. The central focus of Sino-American strategic competition is located in the South and East China Seas and does not extend north. The resumed mutual deterrence postures of Russia and the U.S. still emphasize Europe and the North Atlantic, especially with the escalation of tension surrounding Ukraine in 2022. Recent Russian and United States/NATO Arctic military activities are concentrated largely in the Norwegian and Barents Seas, properly understood as extensions of the North Atlantic. This is an area of sensitive strategic competition but does not affect the core of the Arctic, which will remain inaccessible for conventional maritime operations except in the unlikely event that major players invest heavily in special capabilities that can operate sustainably in harsh conditions (Zagorski, 2020).

However, the international relations of the "new" Arctic are also hard to square with the Arctic Council's vision that "we have made this region into an area of unique international cooperation," an oasis of peace in a stormy world. In our judgment, the idea of Arctic exceptionalism is not useful for addressing Arctic issues today. Great-power politics will be a prominent feature of Arctic international relations during the coming years. However, this underlying reality will not transform the Arctic into a zone of conflict, nor will it preclude cooperation on a range of specific but significant issues arising in the region.

Thus, the question is not whether the Arctic of the 2020s will be a zone of peace or a zone of conflict. There is room to address specific issues in a cooperative manner, without losing sight of the differences between the Arctic of the 1990s and the Arctic of the 2020s. In this regard, it is notable that at their May 2021 meeting the foreign ministers of the G7 countries included "peaceful, sustainable economic development and environmental protection in the Arctic" on a short list of issues where cooperation with Russia is desirable and feasible, despite continuing stalemate on others (G7 Communique, 2021).

Areas of Cooperation Despite Competition

It makes sense to shift attention away from broad efforts to characterize the international relations of the "new" Arctic simplistically as either cooperative or conflictual. Instead, it is useful to direct attention toward those issues where the interests of the Arctic states and other interested parties are evolving to generate opportunities for fruitful cooperation. The result is a more complex picture in which mixed-motive interactions can result in cooperation on specific issues, even while political maneuvering driven by global competition is becoming more prominent.

To enlarge upon this view of the Arctic as a zone of peaceful competition, we consider opportunities for cooperation in five areas: (i) avoiding armed clashes, (ii) climate change, (iii) commercial shipping, (iv) biodiversity protection, and (v) scientific research. The initiatives we propose are innovative but broadly compatible with themes outlined in the "Arctic Council Strategic Plan 2021-2030" adopted at the May 2021 Ministerial Meeting (Arctic Council, 2021).

Avoiding armed clashes

Although the Arctic itself remains an area of low military tension, this does not eliminate the need to develop informal, effective practices to minimize the danger of unintended clashes and to defuse any prospect of their escalation. Several states are deploying more advanced military systems in the Arctic. War gaming and military exercises are increasingly common, especially where the Arctic borders the North Atlantic. There are recurrent reports of aircraft engaging in provocative activities, leading others to scramble their aircraft to intercept them.

No one would benefit from incidents or armed clashes in the Arctic. But experience in many other places makes it clear that unintended incidents can and do occur in such settings and that these incidents can have consequences harmful to the interests of all concerned. What is needed is the creation and adherence to codes of conduct designed to minimize the likelihood of clashes and subsequent escalation of tensions. Even during the Cold War, codes of conduct emerged and played a positive role in interactions between Soviet and American armed forces. In the Arctic, there have been repeated calls for resuming the informal meetings of the chiefs of defense broken off in 2014 after Crimea. That would be helpful, but more specific measures are needed.

Recently, the U.S. and Russia have reinvigorated arrangements based on an agreement dating back to 1972 and designed to prevent the occurrence or escalation of dangerous military incidents at sea and in the airspace above it. These arrangements are applicable to the Barents and Norwegian Seas where operations of Russia's Northern Fleet and the reactivated American 2nd Fleet overlap. Military risk-reduction mechanisms covering activities of China and the U.S. and some of its allies are also in place for the Western Pacific. China does not deploy military assets in the Arctic and has no plans to do so during the foreseeable future. But in the unlikely event of a future extension of Chinese naval operations farther north, it would be possible to make use of these mechanisms.

The most urgent need for an effective code of conduct is in the Barents Sea. There, the U.S. and its NATO allies are now carrying out naval operations in the same region that provides home ports for Russia's Northern Fleet, including the bulk of Russia's nuclear-powered submarines equipped with sea-launched ballistic missiles. The operations of U.S. attack submarines near Russia's naval bases and the reliance of Russian attack submarines on the Barents Sea to move between these bases on the Kola Peninsula and the North Atlantic are of particular concern.

Responding to climate change

The impacts of climate change are showing up more rapidly and more dramatically in the Arctic than elsewhere on the planet. Accelerating losses of sea ice and glaciers, severe coastal erosion, rapid thawing of permafrost, massive wildfires, uncontrolled flooding, and rising threats to wildlife are current realities rather than future prospects (Blunden and Boyer, 2020). Despite American denialism under the Trump Administration and recurrent expressions of hope on the part of some Russian policymakers that climate change may produce positive effects in the Russian North, almost everyone now understands that issues relating to climate change must move toward the top of the Arctic policy agenda. Both the most recent Russian Arctic strategy adopted in 2020 and the Russian program for its 2021-2023 chairmanship of the Arctic Council, for example, indicate clearly that there is no time to waste in countering this rising threat (Russian Arctic Strategy, 2020, Arctic Council, 2021a). This consensus suggests two avenues for fruitful initiatives: Measures designed to adapt to the impacts of climate change in the Arctic itself and Arctic initiatives that may help to promote global efforts to reduce the severity of future climate change worldwide.

Whereas reduction of emissions of greenhouse gases anywhere helps to mitigate climate change globally, efforts to adapt to the range of climate-related impacts are typically local. Still, there is much to be said for encouraging collaboration with regard to protecting the integrity of socioecological systems in the Arctic. Communities throughout the Arctic face similar impacts. There is considerable room for comparing experiences and exchanging expertise on the effectiveness of concrete measures taken and technologies used. The Arctic Council might well become a clearinghouse of information on strategies that have proven successful—or failed—in responding to specific problems. Educational activities, such as those designed especially for young people and coordinated by the University of the Arctic, also may help to increase adaptive capacity.

Although the Arctic is not a significant source of GHG emissions, regional initiatives may offer opportunities to get the ball rolling regarding measures that could be used, adapted, or amplified in other settings. A case in point involves black carbon and methane, both important short-lived climate pollutants and subjects of growing interest (Miller, Zaelke, and Andersen, 2021). The Arctic Council has adopted a framework for action to reduce emissions of these in the Arctic and beyond and established an

Expert Group on Black Carbon and Methane, which has advanced a pan-Arctic aspirational goal of reducing emissions of these pollutants by 25-33% below 2013 levels by 2025. The Council may provide a convenient venue for promoting a binding agreement on these pollutants, extending ultimately to both Arctic and non-Arctic states. An Arctic-only agreement would not address the global threat associated with these emissions, but it could lead the way (Smieszek, 2021).

Managing commercial shipping

In the past two decades there has been a marked increase in international cooperation to regulate commercial shipping in the Arctic. Starting with voluntary guidelines in 2002 and stimulated by the Arctic Council's 2009 Arctic Marine Shipping Assessment, the International Maritime Organization (IMO) developed the Polar Code, which became legally binding at the beginning of 2017. Featuring measures dealing with both maritime safety and environmental protection, the Polar Code stands as a clear example of the ability to make progress on concrete issues of real importance when the interests of key players can be brought into alignment. Every indication is that commercial shippers are taking the necessary steps to comply with the Polar Code in its current form.

As Arctic commercial shipping continues to grow and concern about its environmental impacts rises, it has become clear that more needs to be done regarding the regulation of commercial shipping, together with related matters such as improving hydrographic charts and augmenting search-and-rescue capabilities. Currently, a campaign to ban the combustion and carriage of heavy fuel oils has emerged as the top priority. But other concerns are coming into focus as well, including ship strikes on marine mammals, underwater noise pollution, dangers of invasive species making their way to the Arctic, and potential interference with the subsistence activities of coastal Indigenous Peoples. Progress will not be easy regarding any of these issues, given the divergent interests of shippers, environmentalists, coastal communities, and others. The recent decision by the IMO to strengthen the Polar Code by adding a ban on heavy fuel oils in the Arctic from 2024, to take a concrete example, has come in for intense criticism from environmentalists as inadequate to address what many see as a pressing problem (Reuters Staff, 2020). More likely is a pattern of incremental advances that environmentalists criticize as inadequate and shippers fear as increasingly burdensome. Conditions in the Arctic during the 2020s should not present insurmountable obstacles to continuing the established process of hammering out mutually acceptable additions to the governance system for commercial shipping.

Protecting biodiversity

There is a substantial record of international cooperation regarding the development and implementation of measures to protect wildlife moving across international boundaries in the Arctic or living in or migrating through Arctic waters. Aboriginal subsistence whaling is managed under the provisions of the 1946 International Convention on the Regulation of Whaling. The five Arctic coastal states coordinate to protect polar bears throughout their range under the 1973 Agreement on the Conservation of Polar Bears. There are bilateral arrangements that help protect wildlife and conserve habitat essential to the welfare of different species for example, between Norway and Russia on the Barents Sea and between Canada and the U.S. on migratory caribou. A recent addition to this network is the Arctic Migratory Bird Initiative, an activity spawned by the Arctic Council's Working Group on the Conservation of Arctic Flora and Fauna and designed to foster collaboration among states with jurisdiction over stretches of the Australasian Flyway from Siberia and Alaska to Australia. A notable feature of these arrangements is that they facilitate effective cooperation among issue-oriented national agencies quite apart from the overarching dynamics of high politics.

Again, more is needed, especially in the context of new threats to wildlife arising from biophysical changes and other impacts of climate change. Ice-dependent species such as polar bears and walrus are threatened by the dramatic decline of sea ice. Terrestrial species such as caribou/reindeer are facing increasing difficulties in securing adequate food supplies during winter. Changing conditions in areas such as the Bering Sea are triggering large-scale die-offs of a number of seabird species. Ultimately, addressing these challenges requires effective responses to the climate change challenge on a global scale. In the meantime, however, there are opportunities to launch protective local measures to alleviate some of these threats. One particularly promising approach is to focus on "ecologically or biologically significant marine areas" (EBSAs), taking steps to protect these specific areas from the impacts of certain human activities, including fishing and shipping. In addition, this approach includes monitoring these areas closely to provide early warnings of developments likely to prove harmful to key species (Convention on Biological Diversity, 2021). Another significant initiative is the development of the Arctic Council's Regional Action Plan on Marine Litter (Arctic Council, 2021b).

Meshing scientific research

Unlike Antarctica, where scientific research constitutes the principal ongoing human activity, the Arctic is a permanent home to some four million people involved in intensive human activities, ranging from fishing and resource extraction to tourism and providing public services. All the Arctic states and several non-Arctic states support sizable research programs in the Arctic and have developed of a web of cooperative scientific arrangements. The International Arctic Science Committee, established in 1990, has 23 institutional members (mostly national academies of sciences) and represents the views of the science community regarding priorities and opportunities for cooperation in the conduct of Arctic science. Since 2016, ministers of research and education (or their functional equivalents) have met informally on a biennial basis to exchange information on their nations' Arctic work and discuss opportunities for collaboration. In 2017, the eight Arctic states entered into a legally binding agreement designed to enhance scientific cooperation through practical measures such as improving access to field sites, easing restrictions on the movement of scientific equipment and materials, and facilitating the exchange of data.

These are all constructive efforts. What is missing is an effort to harmonize the elements of this web so that national funding agencies are working closely with the science community regarding the identification of research priorities, and representatives of foreign offices who control the movement of people and materials across borders work closely with agencies responsible for funding research and representatives of the science community to minimize obstacles to collaborative research and to support the activities of multinational teams of researchers working in areas beyond national jurisdiction. Some constructive responses are currently underway. A case in point is the ICES/PICES/PAME Working Group on an Integrated Ecosystem Assessment for the Central Arctic Ocean (WGICA). But much more is needed on a systemic basis, especially in the context of the escalating climate emergency.

Science programs understandably reflect the interests of governments and other organizations that support them. This means that priorities sometimes diverge and there are significant limits to cooperative practices even in the generally apolitical world of scientific research. Nevertheless, there are substantial common interests in this realm, and cooperation can play a constructive role in the coproduction of knowledge needed to monitor and implement international agreements effectively. An example involves the knowledge required to operationalize the "precautionary approach" called for in the 2021 Central Arctic Ocean Fisheries Agreement. (Balton and Zagorski, 2020). We should be on the lookout for other cases in which scientific cooperation can play a helpful role in the creation and implementation of international agreements on matters of wide concern to the Arctic states and key non-Arctic states.

This account of opportunities for international cooperation regarding specific Arctic issues is illustrative, not exhaustive. But these examples demonstrate that the conditions prevailing in the Arctic during the 2020s do not rule out focused efforts to promote international cooperation, especially in more apolitical, technical arenas. In effect, we seek a middle way. The idea of Arctic exceptionalism is no longer realistic as a basis for dealing with the international relations of the Arctic. But neorealist accounts stressing the reemergence of great-power politics in the Arctic convey an excessively pessimistic view of the prospects for cooperation. We suggest a perspective that avoids both extremes and a process designed to flesh out this perspective as a basis for thinking constructively about concrete new issues. For shorthand purposes, we characterize this narrative as one of peaceful competition.

Adjusting the Architecture of Arctic Governance to the Issues of the 2020s

The existing architecture of Arctic governance, with the Arctic Council as its centerpiece, has proven more effective than many of those present at the creation anticipated. While the Council lacks the authority to make binding decisions and the capacity to take the lead in implementing substantive programs, there is convincing evidence that it has played constructive or catalytic roles in a number of areas (Barry *et al.*, 2020). Yet the narrative underlying the creation of the Council and articulated explicitly in the vision statement of the 2013 Ministerial Meeting does not offer an appropriate lens for viewing issues arising under conditions prevailing today or provide a convincing rationale for the framing of measures to address new governance needs for issues such as those discussed above. In this concluding section, we address questions of needed adjustments to the existing architecture and how to maximize their acceptability to all parties concerned. We start with a discussion of Arctic Council and move to the overall architecture of Arctic governance.

Arctic Council

The constitutive provisions of the Arctic Council are set forth in a ministerial declaration rather than an international legally binding instrument (Arctic Council, 1996). Some view this as a weakness and are inclined to take steps as quickly as possible to turn the Council into a full-fledged intergovernmental organization with a recognized legal personality. In our judgment, this reflects a mistaken perception of the role of the Council in addressing issues of governance in the high northern latitudes. The Council is not destined to become a body capable of making and implementing authoritative decisions. Rather, its influence lies in a capacity to identify emerging important issues, to provide well-respected monitoring services, and to offer an informal venue for those seeking to explore possible terms of agreements on a variety of issues, using its convening power to facilitate the interactions of a wide range of governmental and nongovernmental parties on issues of common concern. Adjustments to existing practices should seek to strengthen these forms of influence while avoiding changes that would serve only to muddy the waters or even undermine its contributions.

With regard to early warning, agenda formation, monitoring, and the incubation of policy initiatives, the key to the success of the Arctic Council lies in its working groups. To illustrate, consider the work of the Arctic Monitoring and Assessment Programme (AMAP) in enhancing understanding of the role of the Arctic in Earth's climate system, the initiatives of the Working Group on the Protection of the Marine Environment (PAME) in identifying the need to regulate commercial shipping in the Arctic and framing issues for treatment in the IMO, and the efforts of the Working Group on the Conservation of Arctic Flora and

Fauna (CAFF) in incubating the Arctic Migratory Bird Initiative. What is needed now is to reconfirm the central role of these activities in the Council's work, while avoiding developments likely to complicate or detract from the role of these working groups. We would recommend reverting to the early practice of treating meetings of the Senior Arctic Officials (SAOs) as opportunities to engage in extensive substantive conversations between the leaders of the working groups and these representatives of the foreign ministries of the Arctic states.

There is a need also to proceed with care in articulating the mission of new arrangements, such as the recently created SAO-based Marine Mechanism (SMM). In this case, the danger is that its activities will overlap with the work of PAME, running the risk of politicizing the Council's work on marine issues in a manner that detracts from PAME's efforts to address similar concerns. The Arctic Council created the SMM in 2019 following a failure to agree on a mandate for a new subsidiary body to deploy an ecosystem-based approach to marine management in the Arctic. So far, the mechanism has been confined to organizing webinars dealing with current marine issues. To achieve a distinct and lasting place in the architecture of the Arctic Council, the SMM must take advantage of the convening power of the Council to provide a venue in which a wide range of players are able to engage in policy-relevant discussions of marine issues on an informal basis (Young, 2021).

An important development since 2009 has been the establishment of task forces to provide an informal setting for those engaged in efforts to hammer out the terms of agreements that are not formally Arctic Council agreements. The examples of the 2011 search-and-rescue agreement, the 2013 oil spill preparedness and response agreement, and the 2017 scientific cooperation agreement make clear that these have produced significant results even in the face of the shifting geopolitical conditions of the 2010s. Notably, Russia and the U.S. served as co-leads for all three of these task forces. The key issue going forward is to clarify the relationship between working groups and task forces and to exercise extreme care in framing the remit of any new task force created to deal with any specific issue. Though misunderstandings have arisen in several cases, it should be possible to draw a clear distinction between the roles of the working groups and task forces. The working groups are ongoing bodies with broad mandates in their areas of jurisdiction, while task forces are transient and intended to focus on a specific issue.

The convening power of the Arctic Council has grown substantially in recent years. With the participation of 38 Observers divided almost equally among non-Arctic states, intergovernmental organizations, and nongovernmental organizations, meetings of the Senior Arctic Officials now bring together most of the important players around the world who are concerned with Arctic issues. Such gatherings provide opportunities for informal consultations regarding emerging issues above and beyond the formal agenda. This is an important function that can be enhanced by adjusting the existing practices of the Council. The goal should be to welcome input from the Observers without triggering opposition arising from sensitivities over terminology. Constructive measures may include eliminating or modifying obsolete procedural rules dealing with the suspension of Observers, self-reporting as a condition for the continuation of observer status, and financial contributions on the part of Observers (Zagorski, 2019). The recent practice of organizing special sessions of the SAOs in which observers are given the floor is a step in the right direction. There may also be opportunities to take advantage of the Council's convening power by organizing special sessions on the day before or the day after SAO meetings in which all participants can discuss issues of current interest in a setting not subject to the Council's formal procedures. No doubt other innovations are also worthy of consideration. But the general point is clear: Constructive engagement of many actors should be encouraged without distorting the architecture of the Arctic Council or undermining its unique features.

Coordinating the Arctic regime complex

If the Arctic Council is the centerpiece, the Arctic "regime complex" involves an extensive network of discrete institutional arrangements dealing with interrelated issues but not organized into a hierarchical structure (Young and Kim, 2021). Thus, there are distinct arrangements for fishing, shipping, oil and gas development, wildlife management, environmental protection, and scientific research that apply to all or parts of the Arctic but are not linked to one another in any explicit way. In fact, new arrangements featuring international cooperation on specific issues are continuing to emerge despite the geopolitical competition stressed by neorealists. The Central Arctic Ocean Fisheries Agreement, involving both Arctic and non-Arctic members, entered into force in June 2021. We have referred to the

IMO's ongoing efforts to regulate and eventually ban the use of heavy fuel oils in Arctic shipping and the growing interest in an Arctic agreement on methane and black carbon. This raises two issues: One involves the content of specific additions to this regime complex; and the other deals with the need to coordinate its various elements to avoid fragmentation and promote harmonization.

With regard to specific elements, there is no alternative to proceeding case-by-case. But perhaps a way forward is to provide opportunities for those working on specific issues to compare notes regarding their experiences. This might encourage constructive exchanges between practitioners working to achieve progress on specific issues and analysts who think in more general terms about what works and does not work in efforts to promote international cooperation in broad issue domains.

As the density of the Arctic regime complex increases, the need to pay attention to avoiding fragmentation and encouraging harmonization is rising (Biermann *et al.*, 2020). How should we deal with the interface between the regulation of commercial shipping in the Arctic and arrangements designed to protect marine mammals such as whales and walrus as well as their human harvesters? Is there a need to think about interactions among emerging proposals dealing with Arctic sea ice restoration and regimes dealing with artisanal and commercial fishing, commercial shipping, and offshore oil and gas development (Strawa *et al.*, 2020)? In our judgment, the case for creating a new mechanism to deal with this function is not compelling; nor is it likely that proposals for such a mechanism would gain traction under current conditions. Proceeding carefully, however, it should be possible to use the Arctic Council's convening power to address this matter effectively. SAO meetings today bring together representatives of most of the major players, including key non-Arctic states such as China, relevant intergovernmental organizations such as the IMO, and important nongovernmental organizations such as IASC. These all need to be parties to efforts to coordinate the expanding Arctic regime complex. This function of the Council should be identified explicitly, and every effort made to enhance it. For example, it would be relatively easy to organize informal consultations on specific issues among interested parties alongside formal SAO meetings.

Conclusion

We have sought to articulate a view of Arctic international relations during the 2020s that recognizes the limits of the Arctic exceptionalism embedded in the Arctic zone of peace narrative, yet still provides an alternative to the proposition that the Arctic has become an "arena of global power competition." We characterize our perspective as a view of the "new" Arctic as a zone of peaceful competition. We cannot ignore the growing links between the Arctic and the global system or fail to recognize that the currents of great-power politics will affect the treatment of issues on the Arctic policy agenda. This should not blind us to the successes of many continuing efforts to promote international cooperation on specific issues and prospects that similar opportunities will arise in the future. We have suggested a number of specific areas where cooperative initiatives seem feasible and discussed ways to adjust the existing machinery of Arctic governance to capitalize on such opportunities. We believe the individual adjustments in existing practices we have suggested, when taken together, can make a real difference in addressing the rising Arctic challenges of the 2020s.

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3. The Future of the Arctic: Tripolar or Three-dimensional Chess?

Mia Bennett

In the last days of the Trump administration, the U.S. Department of Homeland Security released its first Arctic strategy. For the first time, the department, which originated in 2001 in response to the September 11 attacks, formally cast its sights all the way up to the circumpolar north. The landmark 25-page Arctic strategy document outlines a region that the Department sees not only as environmentally precarious, but geopolitically sensitive as well. The report contends that, "Left unchallenged, Russia and China will continue malign activities in the region to further their insular agendas and desire for dominance in the Arctic Region" (U.S. Department of Homeland Security Office of Strategy, 2021:13). In this neorealist mindset, the Arctic is on the verge of fracturing into a tripolar zone of competition in which a defensive United States, resurgent Russia, and trespassing China are vying for dominance.

Yet the geometry of Arctic politics transcends a triangular game of Risk, as Young, Yang, and Zagorski make clear in Chapter 2, "The 'New' Arctic as a Zone of Peaceful Competition" (2022). Successfully tackling the region's collective problems requires more than just interstate cooperation. It demands governance involving everyone from members of Indigenous Peoples' organizations to municipal leaders and even scientists. The capitals of the eight Arctic territorial states, which remain the region's dominant governance actors, recognize the importance of diplomatic and paradiplomatic efforts that are both expansive and inclusive. For this reason, analyses of geopolitical dynamics in the Arctic that focus myopically on great power politics and tensions can underestimate the cross-cutting and deep-seated cooperation that has successfully managed a multitude of shared interests and activities in the region, from fisheries to climate change mitigation and shipping. The careful, deliberative, and under-the-surface work of actors who comprise the growing "Arctic regime complex," in the words of Young, Yang, and Zagorski (2022), is what renders Arctic geopolitics a game of three-dimensional rather than tripolar chess.

Regime Change or Regime Complex?

In the late 2000s, some foreign policy analysts called for a wholesale revision to the Arctic's system of governance. Such calls were most prominent between 2008-2010. At the time, two major turning points in the Arctic thrust the region into the global spotlight. The first was the dramatic, 23% decline in annual minimum sea ice extent in 2007 compared to the previous low set in 2005 (Stroeve *et al.,* 2008). The second was the publication of the U.S. Geological Survey's *Circum-Arctic Resource Appraisal* in 2008, which estimated that the region held 90 billion barrels of oil and 1.7 trillion cubic feet of natural gas (Bird *et al.,* 2008). These dual environmental and economic shocks led some to surmise that the Arctic governance system would not be sufficiently resilient to weather the storm. Analysts argued that organizations such as the Arctic Council, the leading intergovernmental regional organization in the region established in 1996, were unable to manage the new challenges facing the region, among them "the environment, national security, management and exploitation of natural resources, Inuit interests, and governance of waterway usage" (Watson, 2009, p. 338). Others suggested that a new treaty—perhaps one modeled on the Antarctic Treaty System (Rothwell, 2008)—could offer a better, more closely codified way forward. The *Ilulissat Declaration* issued in 2008 by the five Arctic coastal states vocally opposed such a notion, however, expressing that they saw "no need to develop a new comprehensive international regime to govern the Arctic Ocean" (The Ilulissat Declaration, 2008). The five states also underscored their continued dedication to the Arctic Council. Mettle tested, by 2013, the organization proved that it was in the region for good. That year, the Arctic Council's admission of five Asian states plus Italy as observers and its creation of a permanent secretariat in Tromsø, Norway granted the body enough visibility and legitimacy to put a stop to calls for overhauling the organization—at least for a few years.

Yet now, in the 2020s, Russia's remilitarization of the Arctic, China's self-proclamation as a "near-Arctic state" and release of an Arctic Policy, and deteriorating relationships between these two countries and the West are again fueling calls to revisit the Arctic Council's mandate. This time, the desire is not so much to disband or replace the organization, but rather to create new avenues for discussing—and hopefully dispelling—military tensions. Boulègue and Depledge (2021), for instance, push for a "new military security architecture for the Arctic." This revised blueprint would include an "Arctic military code of conduct" to guide what types of military activities were legitimate in peacetime. Within the current Arctic regime complex, it is taboo for the eight member states to discuss military issues at a regional scale. Instead, such topics are negotiated on a bilateral or multilateral level between and among Arctic states. The Arctic Council's founding document, the Ottawa Treaty, specifically bars discussion of military issues. This prohibition is expressed in a tiny footnote, which states, "The Arctic Council should not deal with matters related to military security" ("Declaration on the Establishment of the Arctic Council," 1996: 2). Yet moving the touchy topic of security from the bottom of the page to the front page, so to speak, is easier said than done. Previous efforts to establish regional security forums in 2011 and 2012, such as the Northern Chiefs of Defense Conference and the Arctic Security Forces Roundtable, respectively, fell apart by 2014.

Nevertheless, by avoiding hot-button discussions of guns and subs, the Arctic Council has arguably contributed to Arctic security and stability. This was no clearer than during the 2014 Ukraine crisis. In an earlier article, Young (2016) traced the emergence of the "Arctic regime complex" to the overlapping yet non-hierarchical mandates of organizations with a focus on the Arctic, from the Arctic Council to the International Maritime Organization and UNCLOS. This type of nestled governance structure is visible within the Arctic Council itself, too. As Gracyzk and Rottem (2020: 231) explain, the Arctic Council has cohered "as a focal point within a unique network of linkages with other, more specialized international institutions that to a large extent rely on the information and arrangements produced within it. Immunity and sturdiness displayed during the Ukraine crises, embedded in well-established structures and procedures, may be seen as the best guarantee for Arctic stability and security we have today."

Indeed, despite accelerating environmental and geopolitical shifts and renewed calls to overhaul the Arctic Council's mandate, the organization has emerged larger and stronger than before. Its expansion and consolidation has happened through a process that, due to its bureaucratic incrementalism, has largely failed to attract the attention of the media. News coverage has instead preferred to spotlight spectacles such as Russian flag-planting and Pompeon fits of rage. The admission of five Asian applicants for observer status—China, Japan, the Republic of Korea, Singapore, and India—did attract media attention, in part because journalists perceived a watershed moment in Arctic politics (even if the media failed to notice Italy's acceptance as observer at the same Kiruna Ministerial (Steinberg *et al.*, 2014)). Notably, the Asian states' admission as observers was historic for signifying the Arctic states' willingness to extend olive branches to non-Arctic states rather than leaving them out in the cold. Working late into the night, President Barack Obama's Secretary of State, John Kerry, rallied some of the more reluctant member states—namely Canada and Russia—to agree to accept these new parties as observers (Nord, 2017).

Just as important to the organization's growth yet less sensationally, the Arctic Council has also formed new working groups, task forces, and even spin-offs such as the Arctic Economic Council, established in 2014. New forms of scale-jumping diplomacy are taking place among the various stakeholders and rightsholders both within the Arctic Council and the region at large, too. For instance, the Republic of Korea, an Arctic Council observer, has partnered with Arctic Council permanent participants such as the Aleut International Association to engage in marine mapping (Bennett, 2020). Such efforts highlight the novel forms of cooperation that are unfolding as the Arctic regime complex widens.

Governing Across Domains and Dimensions

Avoiding armed clashes, climate change, commercial shipping, wildlife protection, and scientific research are five areas that Young, Yang, and Zagorski (2022) highlight as offering opportunities for Arctic cooperation. The latter four of these areas represent the tried-and-true avenues that drive camaraderie and collaboration—much of which can be found within the Arctic Council's working groups. The authors argue that these six groups—the Arctic Contaminants Action Program, Arctic Monitoring and Assessment Programme (AMAP), Conservation of Arctic Flora and Fauna (CAFF), Emergency Prevention, Preparedness and Response (EPPR), Protection of the Arctic Marine Environment (PAME), and the Sustainable Development Working Group (SWDG)—are "the keys to the success" of the Arctic Council. This alphabet soup of bureaucratic bodies nestled within the architecture of the Arctic Council is neither sensational nor easily understood. Yet their steadfast efforts, which materialize through regularly scheduled meetings, frequent reports, and multiyear projects, provide a robust foundation for Arctic cooperation that is not only wide, but deep, too. Over time, the working groups have targeted new areas, dimensions, and sectors ranging from the seabed to the atmosphere. The six working groups' efforts are also at times strategically coordinated. For instance, in 2015, the Arctic Council Ministerial in Iqaluit established the Task Force on Telecommunications Infrastructure in the Arctic in response to "the importance of telecommunications to Arctic communities, science, navigation and emergency response." The executive summary of its Circumpolar Assessment report published in 2017 explained that the Council "saw that telecommunications is a truly cross-sectoral issue, and touches the areas of focus of the Council's six Working Groups and other subsidiary bodies" (Arctic Council Secretariat, 2017).

Another example of regional cooperation, albeit one outside the auspices of the Arctic Council, is the 2018 Agreement to Prevent Unregulated High Seas Fisheries in the Central Arctic Ocean. The document, which was negotiated among six Arctic Council members with coastal access (the United States, Canada, Denmark in respect of Greenland and the Faroe Islands, Iceland, Norway, and Russia) as well as four major fishing powers (China, Japan, the Republic of Korea, and the European Union), demonstrated the successful implementation of the precautionary principle in regulating newly emerging Arctic conditions. The moratorium, which finally went into effect in 2021 after China's approval, will prohibit fishing in the Central Arctic Ocean's high seas for 16 years and allow scientists more time to collect data regarding the region's sensitive fisheries. Notably, China's long-awaited ratification, which was carried out as Russia took over the chairmanship of the Arctic Council, suggests that the country "is willing to cooperate with the West on certain issues, the Arctic being one" (Liu, 2021).

In this spirit, the Arctic Council's working groups and its members, permanent participants, and observers must continue working across borders and boundaries to ensure dialogue and cooperation on emerging subregions such as the high seas of the Central Arctic Ocean before they become overtly politicized. While new innovations and increased regional access promise social and economic opportunities for Arctic residents, these changes may also open new arenas for geopolitics. Tourism represents one sector which may be subject to unanticipated forms of (geo)politicization. China's cruises through the South China Sea, which have occasionally ferried passengers to disputed islands to raise the national flag, offer one example (Mostafanezhad, 2019). So, too, does the 2018 spat between China and Sweden regarding the treatment of Chinese tourists checking in late to a hotel in Stockholm (Bennett & Iaquinto, 2021). While one of the Arctic Council's six working groups, Protection of the Arctic Marine Environment, established a project to examine Arctic Marine Tourism in 2009, its focus has been on promoting sustainability rather than delving into geopolitics. If partners across all scales in the Arctic, from the local to the global, are involved in conversations about an emerging sector from the early stages of its development, this may help to institutionalize cooperation.

Ultimately, some form of geopolitical competition can be healthy. Competition can even occasionally introduce opportunities for small states, such as Greenland or the Faroe Islands, to triangulate between more powerful actors and bolster their own importance within international relations. Yet the existing Arctic regime complex should strive to ensure that competition does not turn into conflict.

Conclusion: Complicating the Chessboard

The Arctic Council's existence should not be interpreted as synonymous with unanimity of opinion among all of its Member States, not to mention the eight Permanent Participants and, as of 2022, 38 Observers. As Ingimundarson (2014, p. 185) cautions, "What needs to be taken into account is that the multilateral Arctic framework is based on various types of open and latent sub-hierarchies, reflecting the power disparities of stakeholders: Between the Arctic Five and the Arctic Three; between the Arctic Eight and the Indigenous populations; and between the Arctic Council states and the Observers." Contradictions can even be found in how these individual groups of stakeholders do and do not work together amongst themselves. For instance, the U.S. and Canada jointly defend the airspace above the Northwest Passage even as they disagree on whether its waters are international or internal.

Although the three-dimensional nature of Arctic governance is self-evident, the "tripolarization" of the Arctic should not be fully discounted. In 2021, Russia assumed chairmanship of the Arctic Council and the Arctic Coast Guard Forum, the latter established in 2015. When Russia was last chair of the Arctic Council from 2004-2006, the still-youthful body was not yet a decade old, climate change was acknowledged but not fully recognized as a crisis, and the U.S. was hegemon of a more unipolar world. The 2004-2006 Program of the Russian Federation Chairmanship of the Arctic Council expressed, "Due to historic reasons the environmental component still prevails in the activities of the Arctic Council which has emerged from the international cooperation in the framework of the Arctic Environment Protection Strategy of 1991."

Russia's stated chairmanship priorities for the Arctic Council 2021-2023 still maintain a focus on sustainable development and responsible governance. Yet some analysts are concerned that underneath these green and global discourses, the Kremlin may seek to more directly address Arctic security. As evidence, they point to how several representatives from the Russian Security Council suggested that it might be appropriate to do so during the country's chairmanship (Staalesen, 2021). Such developments could destabilize an organization that has long considered the topic a no-go zone. Others, however, are more sanguine; Sergunin (2021: 8) believes Russia is unlikely to "initiate any radical institutional reforms," for he argues that the country believes the organization will be better able to promote regional cooperation if it retains its current informal, flexible structure in contrast to more rigid regimes.

Speculation also still persists regarding whether China might seek to implement its own vision of governance in the Arctic Council. China's 14th Five Year Plan (2021-2025) explains, in a section entitled, "Deeply participate in global ocean governance," "We will participate in pragmatic cooperation in the Arctic and build the "Ice Silk Road" ("冰上丝绸之路")" (People's Republic of China, 2021). Whether ambitions to unfurl an Ice Silk Road will drive the Chinese state to erect its own organizations to govern the Arctic is unclear. For the time being, at least, Beijing is likelier to insert its norms and standards into the international realm by participating in existing international organizations and regulatory bodies (Kynge & Liu, 2020), such as the International Telecommunication Union to the International Maritime Organisation.

It is thus important to underscore that the Arctic's "tripolarization" between the United States, Russia, and China is taking place atop deeply institutionalized cooperation. Throughout the Arctic Council's 25 years of existence, the organization has withstood rapid changes to the Arctic's environmental and security dimensions. The Arctic Council's ability to not only survive these changes, but emerge stronger in the face of them, testifies to the willingness of the diverse governance actors it unites to cooperate in the Arctic, even as bilateral and multilateral efforts between and among these same actors in other parts of the world fracture. During the COVID-19 crisis, the Arctic Council yet again demonstrated the ability of the regional regime complex to work together under high stress. By June 2020, just a few months into the pandemic, it had already published a Briefing Document for Senior Arctic Officials, which stressed “the value of enhancing international collaborations to support research and policy actions for current and future pandemic realities” (Arctic Council, 2020: 63). The document—the result of “contributions and input from more than fifty researchers affiliated to the Council’s Working Groups, policy makers, Indigenous representatives and Indigenous knowledge holders from all Arctic States and Permanent Participants”—testified to, in its own words, “the strength and capacity of the networks of experts and knowledge holders associated with the Arctic Council and their commitment to the Arctic Council’s work on COVID-19 in the Arctic” (Arctic Council, 2020: 10). The body’s origins in the end of one crisis, the Cold War, and its responses to ongoing crises, from climate change to the COVID-19 pandemic, should provide some assurance that the Arctic’s tripolarization will not be the endgame to regional cooperation that some fear.

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PART II

NORTH PACIFIC PERSPECTIVES ON ARCTIC SCIENCE AND INTERNATIONAL COOPERATION

Highlights from Session 2 of the North Pacific Arctic Conference 2021

North Pacific Perspectives on Arctic Science and International Cooperation

Session 2 of NPAC 2021 conference explored Asian contributions to Arctic science and examined venues for coordination of national science efforts as well as the prospects for collaborative work pursuant to the new Central Arctic Ocean Fisheries Agreement, agreed to by Arctic and non-Arctic countries to protect potential fishery resources and to ensure sustainability. This session also examined the six-year history, accomplishments, and future prospects of the Arctic Science Ministerial meetings.

Chairs and Organizers:

Lawson W. Brigham, Global Fellow, Wilson Center Polar Institute.
Natsuhiko Otsuka, Professor, Arctic Research Center, Hokkaido University.

Panelists:

Hiroyuki Enomoto, Vice-General, National Institute of Polar Research and Professor, Arctic Environment Research Center, Tokyo
Chaerin Jung, Senior Administrative Associate, Korea Polar Research Institute, Incheon
Malgorzata Smieszek, Project director and Researcher, The Arctic University of Norway, Tromsø
Frances A. Ulmer, Visiting Senior Fellow, The Belfer Center for Science and International Affairs, Harvard Kennedy School, Harvard University, Cambridge
Huigen Yang, Research Professor and former Director, Polar Research Institute of China, Shanghai

Discussion Highlights:

China, Japan, and South Korea all have robust Arctic research programs and are committed to being full partners in advancing Arctic scientific research to better understand the Arctic environment in an era of unprecedented climate change. They have their own research interests, strong scientific institutions, advanced research vessels, and national Arctic research stations, particularly in Svalbard. The three Asian nations are non-Arctic state Observers to the Arctic Council.

International Arctic research is critical to maintaining a stable, peaceful, and cooperative region for all mankind. Effective Arctic and non-Arctic state cooperation in research is necessary for the future sustainable use of the Arctic Ocean. For China, Japan, and Korea, scientific cooperation in the Arctic provides key avenues to have enhanced influence in the region on issues related to climate change, sustainable development, commercial opportunity, and Arctic governance.

The Arctic Council's Working Groups provide an opportunity for the observer states to enhance their influence and to join in shaping the agenda of Council projects/initiatives that are responding to a host of challenges. Working Group chairs should provide a welcoming atmosphere for Observers, and non-Arctic state Observers should be selective in sending experts who are aligned with their national interests and international research priorities.

The Arctic Science Ministerial (ASM) meetings have developed into a new and flexible high-level forum for advancing Arctic scientific research. All the North Pacific nations (Russia, the United States, Canada, China, Japan, and South Korea) have participated actively in the first three ASMs and will be leading players in the next ASM scheduled to be hosted by Russia and France in 2022 or 2023.

The Central Arctic Ocean Fisheries Agreement, which entered into force in 2021, provides an innovative long-term approach for advancing multi-disciplinary study of the Arctic Ocean. It provides for a Joint Program of Scientific Research and Monitoring to determine fish stocks and sustainable use, thus heralding a new era of international cooperation in Arctic marine research. Greater marine access and longer seasons of navigation will increase the tempo of marine exploration. As parties to the agreement and major distant-water fishing nations with Arctic research capabilities, China, Japan, and South Korea can play leading roles in planning and conducting CAO expeditions.

4. A Strategic Approach for Japanese Arctic Scientific Research

Hiroyuki Enomoto

Establishing a Base for Observation and Research

This paper discusses the evolution of Japanese Arctic research over the last three decades. Arctic studies in Japan often referred to the work conducted by snow and ice researchers from Hokkaido University, Dr. Ukichiro Nakaya's stay at Site-2 on the Greenland Ice Sheet in 1957. Since then, research by individual scientists, often short-term, has been conducted on various subjects.

The momentum for establishing international Arctic science collaborations increased in the 1980s, and the International Arctic Science Committee (IASC) was established in 1990. Japanese polar researchers showed their intention to participate and the Japanese national contact point of the IASC was set up in 1990 at the National Institute of Polar Research (NIPR). Dr. Nobuo Ono, the leading sea ice researcher at the Institute of Low Temperature Science at Hokkaido University, was moved to the NIPR and became the first director of the Arctic Environment Research Center (AERC). In 1991, Dr. Yoshihide Ohta of the Norwegian Polar Institute (NPI) advised Japanese scientists to set up a Japanese stational observation site at Ny-Ålesund, Svalbard. Political tensions in the east and west had eased after the Cold War ended and Arctic research was promoted in the early 1990s. Svalbard became a place for continuous observation, the dispatch of researchers, activities in the local research community, and training of researchers for leadership roles. It was important to have stable base in the Arctic for initiating new era of Japanese Arctic science. (https://www.nipr.ac.jp/aerc/document/Ny-Alesund-25th-v1-1-20180625.pdf)

Progress in Japanese Arctic Research in the 1990s

From 1993 to 1999, Japan, Norway, and Russia collaborated on the International Northern Sea Route Programme (INSROP) to survey Arctic Sea route. This was a forward-looking campaign, because in the late 1990s the sea ice situation still made it difficult to navigate. It wasn't until 20 years later that ice-free navigation became realistic for some seasonal traffic. In addition, as a World Climate Research Program (WCRP) activity, Japanese and Russian researchers conducted joint research in Siberia. Since 1998, the Japan Agency for Marine-Earth Science and Technology's (JAMSTEC) ocean-earth research vessel *Mirai's* Arctic voyage began, and long-term observations have continued to the present day.

In addition, the International Arctic Research Center (IARC) at the University of Alaska, Fairbanks was founded in 1999 at UAF through an agreement between Japan and the United States "to demonstrate our ability to solve, jointly, problems that are beyond what any one nation can address". Japanese researchers and many early career scientists have visited there, with the encouragement of founding director Dr. Syun-ichi Akasofu. At the IARC, information was exchanged between Japanese researchers from different fields. The Japan Aerospace Exploration Agency's (JAXA) Earth observation satellites have significantly contributed to linkages with field measurements. These new initiatives stimulated the creation of subsequent Arctic activities in Japan.

Japanese Arctic Research into the 2000s

In the 2000s, the Arctic environment changed rapidly. Scientists measured a rapid decrease in sea ice since 2007, the accelerating melting of the Greenland Ice Sheet, and the increased availability of Arctic Sea routes. However, even with such diverse research subjects, research activities were rather limited to individual, short-term, and specific elements. There have been a large contribution from Hokkaido University for conducting permafrost research in the Arctic and training graduate students.

The *International Conference on Global Change: Connection to the Arctic* (GCCA) was held as a science symposium, which led to the *International Symposium on Arctic Research* (ISAR). Initially, it was a domestic symposium, but has developed into an opportunity for international research presentations. The content has expanded from the natural sciences to include social and human sciences.

By 2010, there was a growing awareness of the need to bring together the collective strengths of Japanese researchers more effectively.

New Arctic Research Trends since 2011

GRENE Arctic Project

In 2011, the Ministry of Education, Culture, Sports, Science and Technology's (MEXT) Green Network of Excellence Arctic Climate Change Project (GRENE Arctic Project, hereafter) was initiated. Over the next 10 years, the trend in Japanese Arctic research has changed significantly. The GRENE Arctic Project sought to consolidate research activities previously undertaken in Svalbard, Alaska, the Arctic Ocean, and Siberia. This project constitutes research activities that transcend the boundaries of research institutes and universities. A consortium was created to summarize and share the information and expectations of individual researchers.

The GRENE Arctic Project aims to link various arms of Arctic research, which have been conducted as mostly independent activities by researchers from various institutes and universities, into a venture for Japan as a whole. With the overarching theme of studying Arctic climate change, 300 researchers in each field of the natural sciences collaborated on four strategic research goals of the GRENE Arctic Project. It also promoted collaboration among researchers on observations and models.

In addition to research activities in Svalbard, Alaska, Siberia, the Bering Sea, and the Arctic Ocean, Greenland Ice Sheet research is essential for Arctic research. Research exploring the paleoenvironment from deep ice coring in the inland ice sheet and research on modeling long-term ice sheet fluctuations has been conducted, but the GRENE Arctic Project hypothesized that glacier research should also be undertaken. Amid long-term and sizable projects in Europe and the United States researching the Greenland Ice Sheet, Japanese researchers discussed whether Japan should proceed with its own work there or if other issues or regions should be considered. As this region is largely unknown, an opportunity presented itself to conduct observations in the northern part of Greenland, since central Greenland area already had sites by many countries.

The Japanese team selected the northwestern region, where Japan has built a trusted track record as a science activity area and carried out cutting-edge research activities despite being a small team. By utilizing the knowledge obtained to improve the modeling accuracy of the receding ice sheet, the team expanded the observational range over a larger area and timeframe.

Subsequent Arctic project activities (such as the Arctic Challenge for Sustainability, or ArCS) in the region led to a better understanding of the interplay among glaciers, fjords, marine ecosystems, and local populations. An information exchange that included the collaboration of observation activities with Indigenous Peoples and the local community was presented by Japan as a research model at the second Arctic Science Ministerial (ASM2) and the third (ASM3). Amid restrictions on local activities due to the spread of COVID-19 in 2020, requests for cooperation from local researchers and residents have nonetheless been ongoing.

Arctic Challenge for Sustainability (2015-2020)

In 2015, the Arctic Challenge for Sustainability Project (ArCS) was launched to develop the GRENE Arctic Project's scientific results and incorporate issues in the social sciences, humanities, and natural sciences. The ArCS had a mission to convey scientific results to domestic and foreign stakeholders.

During this project, "Japan's Arctic Policy" was released in 2015. As a result, domestic ministries and agencies promoted discussions on Arctic issues. At the same time, the use of Arctic Sea routes continued to increase due to greater access resulting from the retreat of Arctic sea ice. Science was required to provide more reliable information to the private sectors and policy makers. Internationally, a working group of the Arctic Council also discussed issues related to Arctic environmental conservation. The ArCS project provides these researchers with scientific information to inform their findings and recommendations.

At the ASM2 in 2018 and the Arctic Circle Meeting in Iceland previously, Japan's Minister of Education, Culture, Sports, Science and Technology and the Minister of Foreign Affairs also spoke about Japan's activities and future Arctic research ship plans. In this way, significant developments are taking place in Japan's Arctic scientific research and policies.

Arctic Challenge for Sustainability II Project (2020-2025)

ArCS II began to accelerate this trend. Natural changes, social changes, and social demands in the Arctic have changed significantly over the last decade. We will search for and propose what we should aim for in the future, how science should allocate resources and determine research directions, and how we can approach societal goals as well. For this reason, the project was started as an endeavor that incorporates natural sciences, humanities/social sciences, disaster prevention and engineering, and the fields of law and policy surrounding the Arctic.

This figure shows the ArCS II project goals, including four strategic goals, two priority issues, and the organization of the research infrastructure. The project goal is "to realize a sustainable society by promoting advanced research, such as grasping the actual situation and ongoing processes of environmental changes in the Arctic region and advancing meteorological and climate prediction, as well as the rapid progress of the Arctic. To evaluate the impact of environmental changes on human society, including in Japan, one key goal is to provide scientific knowledge that will provide the basis of legal and policy responses that will aid all countries in forming international rules for Arctic governance.

The Arctic region maintains a fragile balance, and scientists still need to know much more to understand how this balance is tipping. To date, the observation areas and data are still limited, yet it is possible to enhance the observation areas and expand our understanding of the manifold changes

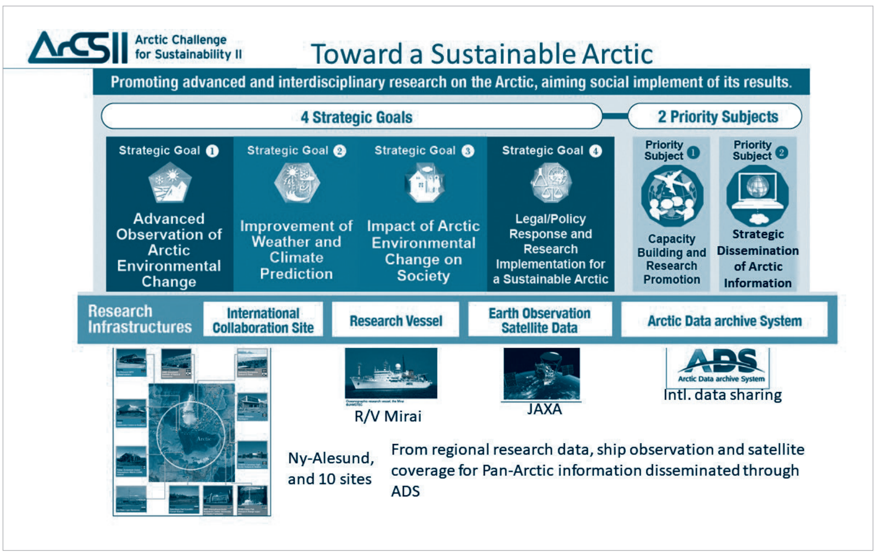

Figure II.1 *Four strategic goals for a sustainable Arctic* taking place in the Arctic region. There is an urgent need to obtain precise and highly accurate future forecasts, understand the impacts on society, reduce vulnerabilities, and develop countermeasures. In addition, scientific knowledge is required to deal with the problems of Indigenous Peoples' rights and the development and utilization of resources due to changes in the environment.

To achieve this, Japan has set four strategic goals and two priority issues and created a plan to develop the necessary research infrastructure. The four strategic goals are: (1) understanding the actual state of changes in the Arctic environment using advanced observation systems, (2) increase the sophistication of meteorological climate forecasting, (3) continue assessments of the impact of changes in the natural environment in the Arctic on human society, and (4) explore how to use research results to develop laws and treaties that can encourage the sustainable use of the Arctic. The two priority issues are (1) human resource development/strengthening research capabilities, and (2) strategic information dissemination. The research infrastructures are international cooperation bases, observation vessels, earth observation satellite data, and the Arctic Data archive System (ADS).

Research subjects are included under each strategic goal, but we will also work toward other strategic goals, such as developing a legal policy on advanced atmospheric, ocean, sea ice, and terrestrial Arctic observations. This may result in improved meteorological history and predictability, understanding the impacts of changes in the natural environment on society, and international rule making. Regarding social impacts, the humanities and social sciences should work together with the natural sciences. We will also address engineering issues such as forecasting ice and weather conditions along the Northern Sea Route and their impact on shipping. We will also focus on keeping up to date with the latest information and social interests to respond promptly to the development of international law applicable to the Arctic.

The four strategic goals are expected to interface with each other and produce collaborative results by promoting scientific activities. The scientific field incorporates the natural sciences, engineering, humanities, and social sciences. Through this, we will work on research on the changing Arctic and aim to realize a sustainable society around the Arctic.

Fostering the next generation, it is essential to establish who will play active roles in sustainable research progress and international discussions.

Priority Issues in ArCS II

1) For examining human resource development and strengthening research capabilities, we explored a new mechanism. The ArCS dispatched young people to support individuals who desired opportunities for overseas activities. In ArCS II, we created a system that allows organizations to interact with each other and make reciprocal visits, including invitations from abroad and support for individuals. Inspired by researchers from different countries, we aspire to travel abroad or obtain cooperation from visiting scientists and researchers. We hope that more young researchers and students will take advantage of this opportunity. 2) In the realm of strategic information dissemination, we have strengthened our activities and considered a new mechanism: Both the Arctic Environmental Information Website and the Arctic Sea Ice Information Center were newly established.

The Arctic Environmental Information Integrated Website aims to unify the provision of information and provide effective information in a timely manner. The current topic is: “Construction of a New Arctic Research Vessel with Icebreaking Capacity” (https://www.nipr.ac.jp/arctic_info/e/columns/2021-02-16-1/), and it is noted that “the vessel is planned to be designed to take into account an international research platform, diversity and environmental preservation. Described below are the main characteristics of the new ship being examined by JAMSTEC.

As Arctic research increases in importance for scientific reasons amid the changing climate and for geopolitical reasons as well, melting sea ice reveals new resources and affects global trade routes. Regarding the policies and social implementations that are the outcomes of this activity, a “policy dialogue coordinator” and a “social implementation coordinator” were

Figure II.2 *Strategic dissemination of information* assigned, respectively. The ArCS was aimed at the relationship between natural change and human societal needs and structures. Exchanges of views with domestic decisionmakers have also begun. As a result, each ministry and agency has been able to listen to the voices of Arctic science researchers.

The ArCS II aims to further strengthen this mechanism and build a way to deliver practical information to those involved in decision making in a timely manner. The policy dialogue working group and coordinator will develop and plan dialogue with recipients. Social implementation creates a link with industry.

Regarding data usage, it was emphasized that data should be disseminated and made publicly available. The Arctic Environmental Integration WEB and the Sea Ice Information Center will work together to encourage researchers to use it and convey observational data that are usually difficult for the public to use.

Japan Consortium for Arctic Environmental Research

The Japan Consortium for Arctic Environmental Research (JCAR) was established at the same time as the GRENE Arctic Project in 2015. It is worth noting that the consortium JCAR was born before the start of research project activities and set up as a place to exchange information according to Japanese principles while using as a guide the Arctic Consortium of the United States (ARCUS). In 2015, JCAR summarized proposals for long-term research plans over the next ten years by 140 researchers. JCAR collected proposals for research activities that should be promoted by taking advantage of the strengths of Japanese researchers. It did not prioritize activities and did not require budgets. There may be a risk in scientific competition for researchers to analyze their target issues and promote other research ideas. Nevertheless, the researchers agreed that compiling this report was a significant step forward in Japan's Arctic research. In addition, it was very useful to learn about scientific target activities and researchers in other fields. Knowing activities outside of the field of one's individual expertise, having the location of researchers in different venues, and learning of the existing results all contribute to future research proposals and scientific activities.

The plan was compiled during the GRENE Arctic Project and incorporated the wishes of researchers. However, the process of budgeting and accomplishing those wishes was still left to the efforts of individual researchers. However, in the subsequent ArCS, the plan was used as a reference when observing the development and progress of research activities in Japan, and also influenced the concept of the subsequent ArCS II project. In 2021, Japan began building an Arctic research vessel with considerable icebreaking capacity. JCAR has also summarized the opinions of researchers regarding scientific expectations for this vessel.

Supervising Arctic Environmental Research

Thirty years have passed since the establishment of IASC, collaborative movement from Japan, and the establishment of the Ny-Ålesund Research Station. During this time, Ny-Ålesund has continuously monitored the polar environment with high precision. From the perspective of monitoring environmental changes at Ny-Ålesund, this is a crucial part of long-term observations, with continuous execution, new research methods, and the accumulation of knowledge. In addition, the observation data obtained here are combined with the data of observation points collected in various parts of the Arctic terrestrial area, and the observation data of the research vessel *Mirai* have been used to cover ocean area. These data help enable the pan-Arctic observations. Such spatial and diverse coverage should be encouraged. These long-term efforts of Japanese observation play an important role as the reliable partner in the Arctic scientific community. This is the fundamental point which forms strong base of in the Japan's Arctic Policy.

However, scientists and society have also experienced dynamic changes in the political and ecological situation due to recent changes in the Arctic. They often require immediate action. For example, the agreement of restricting fishing activities in the Central Arctic Ocean, which were formulated in 2018, were examined very quickly after the topic arose and were decided in just a few years. It is expected that there should be flexible responses to changes in the Arctic environment. There are expanded roles of environmental research to social implementation by catching up on the emerging issues.

At same time, the project should encourage the basic science intents as the motivation of the science. This may be essential to attract next generation researchers. Long-term monitoring are often also based on the individual scientist's motivation. We are advancing a big national project, but we need the activities of every one of us, especially to encourage future experts and identify future science research subjects.

Toward the Construction of Integrated International Frameworks

Thirty years ago, Japan entered the research community at Ny-Ålesund. Then, NIPR joined the Svalbard Integrated Arctic Earth Observation System (SIOS), which started with EU activities, and established a system to cooperate with European countries as a founding member. Japan collaborates with the Asian Forum for Polar Science (AFoPS), created in Asia, and the Pacific Arctic Group (PAG) with the United States, Canada, Korea, and China. Approaches to connect these regional initiatives over Asia, Pacific and Europe are needed to take the next steps to in international collaboration.

Japan's Arctic research has been trying to pull together the power of individual domestic research activities by repeating the Arctic project every five years. Research topics have also expanded from regional to Arctic and global. In addition, research is expanding from the natural sciences to also include the human and social sciences. The research activities also attempt to create mechanisms to provide information to private sector activities as well as policymaking.

The question is how to continue scientific activities and create a place for international collaboration while observing the changes in nature and the demands of society. Finally, I would like to conclude this report with the wish of Japanese movement toward "Sustainable Arctic by Sustainable Science" and emphasize its importance of seeking ways to expand internationally. And again, parallel to proceeding with the big national project and/or agreement of institutions/states, we need the activities of every one of us as the personal reliabilities are essential and driving force for realizing and sustaining international collaboration.

Figure II.3 *Sustainable Arctic by sustainable science*

5. China's Arctic Research Interests and the Roles of CHINARE

Huigen Yang

Introduction

China is geographically close to the Arctic Circle and has published its Actic Policy in 2018. China's Arctic research goals stem from interests in understanding the Arctic and benefiting from a future sustainable Arctic.

Using the Arctic as a vantage point to study the earth system and its interaction with the sun

- The Arctic is a unique region that contains both the earth's rotational axis and magnetic pole, which makes it a globally singular region with global significance and implications.
- The Arctic is an atmospheric circulation driver. As a cold source, the Arctic atmosphere builds up a polar vortex in the stratosphere, which drives atmospheric circulations in the northern hemisphere.
- The Arctic is a global conveyor belt driver. The global ocean conveyor belt is a constantly moving system of deep-ocean circulation driven by temperature and salinity. It is in the Arctic where the north Atlantic deep water is formed that drives the global ocean conveyor belt.
- The Arctic is an amplifier of global warming. In the Arctic, changes in atmosphere, land, cryosphere, ocean, cloud cover, aerosol concentrations, permafrost thawing rates, ice sheet melt patterns, sea-ice and snow cover reduction, and ecosystem changes combine to cause further global warming. These factors are interwoven in a complex feedback system and result in a more rapid temperature rise than other regions.
- The Arctic is a focal entry of solar-wind plasma. Along magnetic field lines focal into the Arctic region, solar-wind plasma gains a direct access in the northern hemisphere and produces the spectacular Aurora Borealis.

Thus, its geographic location and magnetic configuration make the Arctic a unique vantage point to study the earth and its interaction with the sun. Chinese scientists pursue freer access to the Arctic for scientific observations and international cooperation there.

Seeking understanding on Arctic changes and their global connections

Arctic surface warming is occurring between twice and three times faster than the global mean. Accompanied by global warming and sea ice loss, the ecological environment in the Arctic has been changing rapidly. Such changes in the Arctic have various impacts on China's climate, environment, and agriculture. For example, the Arctic sea ice extent retreated to a record low in September 2007. In January 2008, a series of snowstorms hit central and southern China. Millions of people suffered persistent snow, freezing rain, and cold temperatures, along with unprecedented agricultural damages and disruptions to transport, energy supply, and power transmission. Excessive precipitation greater than 60 mm per month was observed in the Yangtze River Basin and southern China in January 2008, accompanied by pronounced cold anomalies (←2°C) over an area spreading from Central China to much of southern China, when compared to the climatological record between 1951–2007. Anomalies in high latitudes might have also resulted from the January 2008 anomaly in southern and central China (Liu *et al.*, 2012).

Responding to the threat of sea level rise from melting polar glaciers

Sea level rise (SLR) is one of the largest climate-change-driven factors that threaten the habitability of coastal zones. Rising seas may cause submergence, flooding, erosion, and shoreline changes as well as saltwater intrusion to groundwater. If all the ice sheets in the Arctic and Antarctic melt, the consequent sea level rise would cause China's shoreline to retreat 400 km inland; the most populated and prosperous parts of China, such as Guangzhou, Shanghai and Tianjin, would be totally inundated by the sea.

The melting of the Greenland Ice Sheet has accelerated rapidly since the 1990s. From 1992 to 2018, meltwater from Greenland alone has raised sea levels by 10.16 mm, and it is currently the world's biggest contributor to sea level rise. The melting of polar ice sheets is driven primarily by greenhouse gas emissions. Under a scenario where greenhouse gas emissions continue to increase, Greenland's ice loss could reach unprecedented levels and give rise to about 101.4 mm of SLR by the end of this century.[1] This SLR from the Greenland ice sheet melting may cause land submergence of 20,836 km^2 and the migration as many as 15.59 million people from the inundated area, based on an estimation with altimetry data and population along China's current coastal regions. The conclusion is that China is under a real threat of SLR from melting Arctic glaciers (Li, Guoshuai *et al.*, 2019). (Thermal expansion, another major contributor to SLR, is not discussed here.)

Benefits of using Arctic sea routes and natural resources

The Arctic has abundant resources but a fragile ecosystem. China advocates the protection and rational use of the region and encourages its enterprises to engage in international cooperation on the exploration for and utilization of Arctic resources by making the best use of their advantages in capital, technology, and domestic markets.[2]

The opening of Arctic sea routes (ASRs) will give China potential options for new shipping passages. China is the second-largest economy in the world, and more than 90% of China's exports travel by sea. As Arctic sea ice continues to melt and retreat in the summer, ASRs will provide a shorter passage from northern China to Northern Europe and Northern America. For example, *Tianjian*, a multi-function cargo ship under COSCO Shipping, loaded with over 36,000 tonnes of machinery, set off from east China's port of Lianyungang on Aug. 31, 2017 and reached the port of Esbjerg, Denmark, 7,670 nautical miles away, after 25 days. Compared with the conventional route via the Suez Canal, the Arctic passage saved 3,400 nautical miles in distance, 12 days in time, 320 tonnes of fuel, and reduced emissions of more than 1,000 tonnes of CO2. ASRs provide global customers with potentially seasonal faster, greener, and more economic delivery, and ship owners will not have to worry about monsoons and pirates in the Indian Ocean.[3]

The natural resources of the Arctic can provide utility and economic benefit to humans. China engages in the Arctic economy through active participation in major projects as well as through expressing support for initiatives proposed by the Arctic states. The Yamal LNG project is an example of China's economic involvement in the Russian Arctic. It is a multilateral venture involving companies in several countries, with a majority of shares owned by the Russian company Novatek (50.1%), followed by the French company TOTAL and the Chinese National Petroleum Corporation (both at 20%), and China's Silk Road Fund (9.9%). The project has taken environmental protection measures that are compliant with ISO 14000 environmental standards and Occupational Health and Safety Assessment Series (OHSAS) health and safety standards, as certified by the British Standards Institute (BSI).

Taking advantage of international cooperation on Arctic research

China's Arctic research interests are focused on trans-regional and global issues in the Arctic, especially in areas such as climate and environmental changes, solar-terrestrial interaction, utilization of shipping routes, and global governance. The Arctic is such a huge region and an enormous system with complex global connections; no individual country can carry out Arctic research alone. China has taken advantage of international cooperation through its initiation of Arctic research. China became a member of the International Arctic Science Committee in 1996, three years before it dispatched its first national Arctic research expedition into the Arctic Ocean in 1999. Since then, China furthered its international cooperation by establishing the Yellow River Station in Ny-Ålesund on Svalbard in 2004, signing the Framework Agreement on Arctic Cooperation with Iceland in 2012, and becoming an accredited, non-Arctic observer state to the Arctic Council in 2013. China has made great progress in international cooperation by publishing its Arctic Policy, establishing the China-Iceland Arctic Science Observatory (CIAO) in 2018, and ratifying the Agreement to prevent unregulated high seas fisheries in the central Arctic Ocean (CAOFA) in 2021.

China's Research Instrument: The Chinese National Arctic Research Expedition (CHINARE)

Located mainly in mid-latitudes, China has developed the Chinese National Arctic/Antarctic Research Expeditions (CHINARE) as its polar research instrument. CHINARE is organized under the Ministry of Natural Resources (MNR) with an advisory committee and participation by related ministries and agencies of the central government. CHINARE is managed by the Chinese Arctic and Antarctic Administration (CAAA) and operated by the Polar Research Institute of China (PRIC).

CAAA is an agency within the MNR, whose mandates are to draft polar strategy, policy and law; administrate polar affairs; manage the CHINARE program; and organize polar studies and international cooperation. Founded in 1989, PRIC in Shanghai plays the roles as a national center for polar research and environment monitoring and as national operator of CHINARE in both the Arctic and Antarctic. PRIC keeps and shares scientific data and samples taken from the polar regions, hosts the Chinese Symposium on Polar Science annually, and the secretariat of the China-Nordic Arctic Research Center (CNARC)

CHINARE operates one domestic base in Shanghai and operates two icebreaking research vessels, the *Xuelong* and *Xuelong 2*, and one research airplane, the *Xueying 601*. In the Antarctic, CHINARE has established four research stations and one camp on the Antarctic continent and organized 38 cruise investigations to the southern oceans. In the Arctic, CHINARE established the first research station, the Yellow River, at Ny-Ålesund on Svalbard in 2004, based on the Spitsbergen Treaty. The second research station, the China-Iceland joint Arctic scientific Observatory (CIAO) was established in collaboration with Iceland in 2018, based on a framework agreement on Arctic cooperation between China and Iceland. CHINARE has developed these research stations to conduct long term climate and environmental monitoring and to facilitate field investigation, experiments, and observations in the Arctic. Since 1999, CHINARE has carried out 12 research cruises into the Arctic Ocean, mainly from the Pacific Arctic, with research vessels *Xuelong, Xuelong 2* and the *Akademik M.A. Lavrentyev* of Russia, in order to study Arctic rapid changes and their impacts on mid-latitudes. (L. Chen *et al.*, 2000; Z. Zhang *et al.*, 2004; H. Zhang *et al.*, 2009; X. Yu *et al.*, 2011; D. Ma *et al.*, 2013; D. Pan *et al.*, 2015; Y. Li *et al.*, 2018; R. Xu *et al.*, 2019)

Contributions to Understanding Arctic Changes and Their Global Consequences

With polar programs on basic research, technology development, and environmental monitoring by NSFC, MOST, and MNR, a multi-disciplinary and comprehensive observing system has been developed in the Arctic. This system has been integrated into regional observing networks, such as the Pacific Arctic Group's Distributed Biological Observatories (DBO) and the Svalbard Integrated Observing System (SIOS), and the global Sustaining Arctic Observing Network (SAON). Chinese scientists have accumulated many important data sets about Arctic rapid changes, such as sea ice extent retreat, CO_2 uptake, and ocean acidification, and achieved understanding on the global consequences of these changes, especially impacts on mid-latitudes.

Summertime sea-ice loss amplifies decadal CO_2 increases in the western Arctic Ocean

The Arctic Ocean has experienced dramatic physical and ecological changes, including warming and increased sea-ice loss, freshened surface water, altered surface circulation, and enhanced primary production. Arctic Ocean sea ice loss serves as an amplifier of the seasonal variation and decadal increase of sea surface partial pressure of CO_2 (pCO_2) in the Canada Basin. On a decadal scale, the pCO_2 has increased almost everywhere in the world at rates roughly comparable to that of the atmospheric CO_2 increase. During the period between 1994 and 2017, summer pCO_2 in the Canada Basin increased at twice the rate of atmospheric increase. Warming and ice loss in the basin have strengthened the pCO_2 seasonal amplitude, resulting in rapid decadal increase. Consequently, the summer air–sea CO_2 gradient has reduced rapidly and may become near zero within two decades. In contrast, there was no significant pCO_2 increase on the Chukchi Shelf, where strong and increasing biological uptake has held pCO_2 low, and thus the CO_2 sink has increased and may increase further due to the atmospheric CO_2 increase. Chinese researchers have elucidated the contrasting physical and biological drivers controlling sea surface pCO_2 variations and trends in response to climate change in the Arctic Ocean (Ouyang *et al.*, 2020).

Pacific sector of the Arctic Ocean (PAO) is a critical area of ice-albedo decrease in the Arctic

Reduced summer albedo over the Arctic Ocean caused by sea ice retreat and surface melting is one of major causes of Arctic Amplification. The darkening of the Arctic Ocean surface, resulting from the decrease of albedo, introduced an additional 6.4 ± 0.9 W/m^2 of annual average solar heat input into the ocean. The long-term trends and seasonal evolutions of sea ice concentration were analyzed in the Pacific sector of Arctic Ocean (PAO) during the period 1982–2009. The decreases in regional composite albedo and sea ice albedo were both about twice those of the entire Arctic Ocean. Thus, PAO is considered as a critical area for the Arctic ice-albedo feedback. Chinese polar researchers have shown a positive polarity in the Arctic Dipole Anomaly that could be partly responsible for the rapid loss of summer ice, by bringing warmer air masses from the south and advecting more ice toward the north. Both these effects would enhance ice-albedo feedback. (Lei *et al.*, 2016, Lei *et al.*, 2021)

An ice-free Arctic Ocean basin wouldn't increase CO_2 uptake capacity as expected

The CO_2 concentration in the atmosphere has increased significantly since the Industrial Revolution, and ~30% of it has been taken up by the ocean. The Arctic Ocean has great potential for up-taking atmospheric CO_2 owing to high biological production in the large ocean margin areas and low temperatures. A high-resolution underwater survey of pCO_2 by the CHINARE-8 in 2008 reveals that, in the ice-free region of Canada Basin to the northeast, there was a large area of relatively high pCO_2 (320 to 365 μatm) that had not been observed before. It contrasts sharply with the values of 260 to 300 μatm in the summer of 1999 and that (<260 μatm) in the summer of 1994. Rapid invasion from the atmosphere and low biological drawdown are the main causes for the higher CO_2, which also acts as a barrier to further CO_2 absorption. Contrary to the common expectation, an ice-free Arctic Ocean basin might not become a large atmospheric CO_2 sink. (Cai *et al.*, 2010)

Ocean acidification amplified in the western Arctic Ocean, making it more vulnerable to rapid chemical changes than any other ocean basin.

Over the past two decades, global warming and climate change have caused rapid changes in the Arctic, especially in the western Arctic Ocean. The uptake of anthropogenic CO_2 by the ocean decreases seawater pH and carbonate mineral aragonite saturation state (Ωarag), a process known as

Ocean Acidification (OA), which can be detrimental to marine organisms and ecosystems. The Arctic Ocean is particularly sensitive to climate change and aragonite is expected to become undersaturated ($\Omega arag < 1$) there sooner than in other oceans.

Data from trans-western Arctic Ocean cruises show that, between the 1990s and 2010, low Ωarag waters have expanded northwards at least 5°, to 85° N, and deepened 100 m, to 250 m depth. In addition, $\Omega arag < 1$ water has increased in the upper 250 m from 5% to 31% of the total area north of 70° N. Tracer data and model simulations suggest that increased Pacific Winter Water transport, driven by an anomalous circulation pattern and sea-ice retreat, is primarily responsible for the expansion. These results indicate more rapid acidification is occurring in the Arctic Ocean than the Pacific and Atlantic oceans, with the western Arctic Ocean the first open-ocean region with large-scale expansion of 'acidified' water directly observed in the upper water column. (Qi *et al.*, 2017)

Planetary heat sink leading to recent global-warming slowdown in the Atlantic and Southern Oceans

Increasing anthropogenic greenhouse-gas emissions perturb Earth's radiative equilibrium, leading to a persistent imbalance at the top of the atmosphere (TOA) despite some long-wave radiative adjustment. Energy balance requires that this TOA imbalance for the planet equals the time rate of increase of the total heat content in the atmosphere-ocean system.

A vacillating global heat sink at intermediate ocean depths is associated with different climate regimes of surface warming under anthropogenic forcing. The latter part of the 20th century saw rapid global warming as more heat stayed near the surface. In the 21st century, surface warming slowed as more heat moved into deeper oceans. In situ and reanalyzed data are used to trace the pathways of ocean heat uptake. In addition to the shallow La Nina–like patterns in the Pacific, the slowdown is mainly caused by heat transported to deeper layers in the Atlantic and the Southern oceans, initiated by a recurrent salinity anomaly in the subpolar North Atlantic. Cooling periods associated with the latter deeper heat-sequestration mechanism historically lasted 20 to 35 years. (Chen andTung, 2014, 2018)

Impacts of Arctic sea ice loss and air circulation on mid- and low-latitude regions

The Arctic has always been one of the key regions affecting the weather events and climate variability in the Northern Hemisphere, especially during winter, when the strong cold air mass originated in the Arctic frequently outbreaks southward, leading to severe cold waves and gale weather processes in mid-latitudes and even affecting tropical regions.

Over the past two decades, accompanied by Arctic warming and sea ice loss, the association between Arctic changes and mid-latitude extreme weather events has become more robust. As one result, the weakened Arctic polar vortex frequently releases cold air mass into the mid-latitudes and causes extreme cold and heavy snowfall.

Impacts of autumn-winter Arctic sea ice loss on mid-latitudes have been investigated in the Northern Hemisphere. The results showed that sea ice loss in the Barents-Kara Seas can either enhance the Siberian high or weaken the East Asian winter monsoon. The impact effects on winter atmospheric circulation over East Asia depends on the preceding summer Arctic atmospheric circulation conditions, the location and amplitude of Arctic sea ice loss, and the location of the winter atmospheric response (Wu, 2018).

Anomalous summer sea ice melting has occurred since 2007, which is closely associated with a phase shift of the Arctic dipole anomaly. Simulation experiments indicate that anomalous sea ice melting significantly raises summer surface air temperatures (SATs) and increases frequencies of heatwaves in the mid- and high latitudes of both Asia and North America and decreases SATs in Europe and parts of the Asian continent. (Wu *et al.*, 2021)

Arctic atmospheric circulation conditions in the summer of 2011 significantly enhanced a negative feedback of Arctic sea ice loss on atmospheric circulation over the Aleutian region and central Eurasia during the ensuing winter months, which could have led to the occurrence of anomalous cold events in 2012. (Wu *et al.*, 2017)

Arctic summer cold anomalies have frequently taken place since 2005, with strengthened tropospheric westerly winds over the Arctic and weakened westerlies over the mid- and low latitudes of Asia. A systematic northward shift of Asian zonal winds dynamically links Arctic cold anomalies with East Asian heat waves and produces a seesaw structure in zonal wind anomalies over the Arctic and the Tibetan Plateau. (Wu *et al.*, 2018)

Scientific Engagement in Arctic Affairs

Incorporating social science into polar research

The Arctic is a place where natural processes and social developments are closely coupled, and both have global significance. As a legacy of the IPY in China, in order to incorporate social science into polar research, PRIC has established a research division named "Polar Strategic Studies" and developed a nationwide network of polar social science since 2010. Since then, there has been always one session dedicated to social and human science in the Chinese Symposium on Polar Science. With this social science network, more than 60 social scholars have been engaged in studies on polar laws, economics, governance, geopolitics, shipping routes, and international cooperation, among other fields. Coordinated social science studies have bridged scientific research with economic exploitation and resulted in a series of publications detailing a comprehensive understanding of important Arctic issues. In 2013, with joint efforts by Chinese and Nordic research institutes, the China-Nordic Arctic Research Center (CANRC) was established and has evolves to functioning entity that is to eventually develop into a full-fledged platform for academic and policy exchanges between China and Arctic states. These efforts have greatly increased public awareness about the global connections of Arctic issues and improved communication among research scientists, policymakers, and interested stakeholders in China. (Huigen Yang, 2012; Jiansong Zhang, 2019; Jian Yang, 2015; Deng Beixi & Yang Jian, 2015; Lulu Zhang *et al.*, 2019.)

Dissemination of polar science

Young people have been engaged in the Arctic research in China. In March 2008, for example, a Chinese undergraduate Arctic research expedition entitled "For the first sunshine of the Arctic" was jointly organized by the IPY China Program and the Ministry of Foreign Affairs of Norway. Ten successful students out of 10 million Chinese undergraduates conducted a research expedition on Svalbard and disseminated their inspirations and findings nationwide.

CHINARE scientists have held dialogues with the Arctic public. In August 2012 when R/V *Xuelong* visited Iceland, the ship was opened to the public at Reykjavik and Akureyri, and the CHINARE-5 researchers held joint symposia with Icelandic scientists and representatives from civil society.

To disseminate polar science, science and art have also been fused in a unique program. A polar theme dance drama entitled *Paradise of Extremes* has been jointly produced and performed by the Shanghai Theatre Academy (STA), Polar Research Institute of China (PRIC), and the Shanghai Association of Science and Technology (SAST).

Scientific engagement in Arctic collaboration

As a council member, China has played active roles in IASC collaboration. Chinese scientists have joined IASC's five working groups on atmosphere, marine cryosphere, terrestrial, and social and human; one Chinese scientist served in its executive committee. China hosted the 2005 Arctic Science Summit Week. As an organizing member, China participated the IASC flagship project, the Multidisciplinary drifting Observatory for the Study of Arctic Climate (MOSAiC), which was the first year-round expedition into the central Arctic exploring the coupled Arctic climate system.

As an observer state, China has joined the Arctic Council working groups' work, including Protection of the Arctic Marine Environment (PAME), Conservation of Arctic Flora and Fauna (CAFF), the Arctic Monitoring and Assessment Program (AMAP) and the Scientific Cooperation Task Force (SCTF). On that basis, China has recommended more than 25 experts to relevant programs, including two for the Global Ocean Acidification Observing Networks of PAME, two for recommendation and review of relevant reports of the Arctic Contaminants Action Program (ACAP), three for the Arctic Migratory Birds Initiatives (AMBI) of CAFF and one for the Adaptation Actions for a Changing Arctic (AACA) report by AMAP. For example, Dr. Jun Lu from the National Birds Banding Center (NBBC) has joined CAFF and provided information on Arctic migratory birds en route from East Asia to Australia. NBBC has formulated technical regulations for the national birds, a manual of bird logos, and bird blight monitors, and established a bird-banding network of nearly 1000 trained local participants. NBBC promotes migratory route protection by cooperating with local governments, establishing a national reporting hotline and educating the public. Therefore, Chinese involvement in the Arctic Council working groups has significant potential to strengthen the conservation of migratory birds. (Su & Huntington, 2021)

China has attended all three Arctic Science Ministerial (ASM) meetings in Washington D.C., Berlin and Tokyo, respectively, with an increasing range of participation. In order to strengthen international cooperation and respond to the severe threat of climate change and biodiversity loss in the Arctic, Chinese scientists will be involved in future ASM meetings and provide more theme-based project updates and new project proposals, create tools for cooperation, and deepen our understanding of Arctic systems.

Concluding Remarks

The Arctic is a remote, huge and complex system. Its innately harsh conditions and breadth of scientific uncertainties create a situation whereby no single country can conduct all of Arctic research necessary to understand the implications of all the rapid changes in the region. International cooperation is a central component of all Arctic research. Mid-latitude China has become an integral part of Arctic research and will make further contributions to in understanding and sustaining development of the Arctic and planet Earth.

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Notes

1. Greenland's ice sheet is melting as fast as at any time in the last 12,000 years, study shows. By Drew Kann, CNN, September 30, 2020.
2. China's Arctic Policy, Information Office of the State Council of P.R. China,www.scio.gov.cn, 2018-01-26.
3. Arctic sea route strengthens Sino-Europe trade bonds, Xinhua News, Information Office of the State Council of P.R. China, www.scio.gov.cn, 2017-09-01.

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6. The History, Outcomes, and Potential of the Arctic Science Ministerial Meetings

Malgorzata Smieszek and Frances A. Ulmer

Introduction

Science and research are essential components of international circumpolar collaboration. As the speed of climate change and related natural and social transformations in the Arctic accelerate, scientific research and observations, along with local and Indigenous Knowledge,[1] are key to identifying, understanding, predicting, and responding to challenges and opportunities that arise with changes in the region, as well as their impacts from local to global scales. While the Arctic emerges as "a critical region of inquiry" (Anderson *et al.*, 2018), so is Arctic science moving faster than ever (International Arctic Science Committee, 2021).

Reflecting the increasing global interest in the Arctic as well as the desire for improved collaboration and data sharing, there has been a surge of initiatives, forums, platforms, instruments, and institutions focused on Arctic science. They include the establishment of the Sustaining Arctic Observing Network (SAON), a joint body of the Arctic Council (AC) and of the International Arctic Science Committee (IASC); the official signing of the Agreement on Enhancing International Arctic Scientific Cooperation by foreign ministers of eight Arctic states at the AC Ministerial meeting in Fairbanks, Alaska in May 2017; and the launch of the Arctic Science Ministerial (ASM) meetings during the second United States AC Chairmanship (2015-2017). Even though the ASM is not directly related to the AC, it represents an important legacy of the time when the U.S. was at the helm of the Council. The ASM is also an important addition to the institutional landscape of Arctic science collaboration and one that thus far has not received much systematic attention. In an attempt to start filling this gap, this paper provides an overview of the history and main outcomes of the three ASM meetings. In light of that review and considering the way other entities focus Arctic research and scientific collaboration, we ask: What is the ASM uniquely positioned to do and where could its contributions be the most meaningful in the future? At this early stage of inquiry, the aim of this paper is not to provide any definite answers, but rather to encourage further discussion and reflection on the topic.

International Arctic Scientific Cooperation

Arctic science is largely an international endeavor. Since the Arctic Climate Impact Assessment (ACIA) in 2004/2005 and the fourth International Polar Year (IPY) (2007-2008), international Arctic research collaboration has expanded significantly. This growth has been driven by the recognition of the accelerating pace and increasing scope of Arctic socio-environmental change, of the role that the region plays in global climate system, and of the multiple and tightening connections between the Arctic and the rest of the world. As shown by the most recent studies, the Arctic over the last 50 years has warmed up three times more than the rest of the planet and it is transitioning to a new climate state (AMAP 2021; IPCC 2018, 2021; Meredith *et al.,* 2019). Arctic science has increased its global relevance due to strong teleconnections between the circumpolar North and areas outside the Arctic Circle.

At the same time, the scale and complexity of Arctic change exceed the capabilities of any individual country or actor to fully understand and prepare for the changes ahead. In terms of scientific research, the region's vastness, low population density, remoteness of observation sites, and harsh conditions remain an ongoing challenge and generate costs on average eight times higher than pursuing similar research at southern locations (Hoag, 2018; Mallory *et al.*, 2018). Costs of Arctic research can be reduced by sharing and optimizing the use of research infrastructure, integrating observing systems, making data freely and openly accessible in a timely fashion, and by improving its interoperability (EU-PolarNet, 2020). To achieve those, a high level of collaboration is key and there are numerous bodies that work to facilitate scientific collaboration and support the conduct of research in the circumpolar North. Among them are the International Arctic Science Committee (IASC), the Forum of Arctic Research Operators (FARO), and the Association of Polar Early Career Scientists (APECS).

Beyond multilateral bodies and platforms for cooperation, both Arctic and non-Arctic states maintain very active polar research programs and communities, provide significant resources for Arctic infrastructure, and have dedicated institutional structures to support Arctic science. Actors such as the EU play a very important role in providing funding for polar research and encouraging the pursuit of international, interdisciplinary Arctic research. They also undertake continuous efforts to improve coordination among various Arctic science initiatives, programs, and instruments.

Nonetheless, current levels of Arctic monitoring and research remain insufficient to understand, much less predict, changes unfolding in the region at unprecedented speed. There is a continuous need to improve mechanisms to facilitate, support, and enhance Arctic science. The launch of the Arctic Science Ministerial meetings was partly a response to this ongoing challenge.

The Arctic Science Ministerial Meetings

The first ASM originated from discussions during the time the United States was preparing for its second Chairmanship of the Arctic Council (2015-2017). It was clear that the U.S. Chairmanship agenda would focus on climate change and its impact on the two principal themes of the AC: Sustainable development and environmental protection. What was less clear was the way in which Arctic science cooperation could be elevated and advanced beyond the work done by the AC Working Groups. That work was undoubtedly important, but often followed the rhythm of the two-year chairmanship agendas, which did not always provide for multi-year continuity. President Barack Obama Administration officials who worked on preparing for the Arctic Council meetings considered various ways to convene a gathering to focus on increasing Arctic science collaboration. What evolved was a proposed meeting of science ministers from all countries with Arctic science expertise, in addition to Arctic Indigenous people. This would become the first Arctic Science Ministerial held in Washington September 28, 2016. It was chaired by John Holdren, President Obama's Science Advisor, with support from France Cordova, Director of the National Science Foundation, and Frances A. Ulmer, Chair of the U.S. Arctic Research Commission (and co-author of this chapter).

The first ASM brought together science ministers from 25 governments, the EU, and representatives from Arctic Indigenous Peoples' Organizations, which set an important precedent for the ASMs that followed. This broad-based composition of the ASM came from an initiative of the United States that actively engaged Alaska Native leaders in preparations prior to the Ministerial meeting to discuss key questions facing Arctic Indigenous People.

The White House organized the ASM around four themes reaching across national boundaries and calling for enhanced international effort: (1) Arctic-science challenges and their regional and global implications; (2) strengthening and integrating Arctic observations and data-sharing; (3) applying expanded scientific understanding of the Arctic to build regional resilience and to shape global responses; and, (4) empowering citizens through science technology, engineering, and mathematics (STEM) education leveraging Arctic science (The White House Office of the Press Secretary, 2016).

The second Arctic Science Ministerial (ASM2) was co-organized by the European Commission, Finland, and Germany in October 2018 in Berlin. ASM2 focused on 3 themes, which largely followed from the discussions initiated at the ASM1: (1) strengthening, integrating and sustaining Arctic observations, facilitating access to Arctic data, and sharing Arctic research infrastructure; (2) understanding regional and global dynamics of Arctic change; and (3) assessing vulnerability and building resilience of Arctic environments and societies (2nd Arctic Science Ministerial, 2018). In addition to science ministers or their representatives and Indigenous Peoples´ Organizations, the meeting was attended by representatives of several international organizations with interest in Arctic science: APECS, IASC, International Arctic Social Sciences Association (IASSA), SAON, International Council for the Exploration of the Sea (ICES), University of the Arctic (UArctic), UN Environment (UNEP), World Meteorological Organization (WMO), and Group on Earth Observations (GEO).

In Berlin, a day-long Arctic Science Forum preceded a meeting of science ministers, where 250 scientists, policymakers, and representatives of Indigenous and international organizations discussed scientific advances since ASM1 and proposed opportunities for additional collaboration across borders. The Forum provided not only space for networking and relationship building, but discussions therein provided a science-informed basis for the ministerial meeting and helped to direct more attention to initiatives like the Multidisciplinary Drifting Observatory for the Study of Arctic Climate (MOSAiC) expedition. In addition, through a working session on observing networks, they provided renewed momentum and alignment regarding next steps on Arctic observation systems.

The third Arctic Science Ministerial (ASM3) was originally scheduled to take place in autumn 2020 but was postponed due to the COVID-19 pandemic. It was co-hosted by Iceland and Japan and eventually organized virtually and in Tokyo in May 2021. In addition to the themes of earlier ministerial meetings—to observe, understand, and respond to Arctic change—ASM3 emphasized the urgent need to strengthen education, capacity building, and networking for future generations, including young scientists and knowledge holders. Empowering citizens was also highlighted as important for fostering a stable observation system that includes community-driven observations (3rd Arctic Science Ministerial, 2020).

Moreover, in preparations toward the ministerial, Japan and Iceland convened multiple virtual events that enabled hundreds of people from all over the world to engage in discussions on several key topics. These included addressing gaps and barriers in international Arctic science research and Indigenous Peoples´ participation in the ASM process. Another evolution in the functionality of the Arctic Science Ministerial meetings was the establishment of a Science Advisory Committee that reviewed all countries´ submissions and organized them into themes that facilitated tracking of countries´ past and new research projects and helped with formulating actions recommended for moving forward.

The fourth Arctic Science Ministerial (ASM4) will be co-organized by Russia and France and held in early 2023.

ASMs' Outcomes

Evaluating the Arctic Science Ministerial process is difficult because of the variety of ways in which the events were organized and conducted, and the numerous submissions and discussions that were not formally recorded. Moreover, it is always challenging to establish a direct cause-effect relationship between institutions and the effects they produce. Likewise, it is not easy to determine to what extent certain developments can be convincingly attributed to the ASMs and to what extent they arose from the impact of a wide range of other sources that operated at the same time. With that in mind, this section presents some broad observations about ASM results based on direct participation in the ministerial meetings and interviews with those engaged in their preparation and some of the participants.

First, it is important to recognize that what began as a one-time initiative of the United States without any clear plans for its continuation, today emerges as a fairly institutionalized practice, which is an outcome is its own right.

Second, the organization of the meetings at the level of science ministers from more than two dozen countries helped to draw attention and elevate the profile of Arctic science. This is especially the case among some non-Arctic nations which, even though they conduct research activities in the circumpolar North, typically do not consider the Arctic among their primary scientific areas of interest.

Third, the inclusion of representatives of Indigenous Peoples' Organizations from the outset of the ASM meetings set an important precedent for discussions about Arctic science at the highest ministerial levels. Multiple statements, presented projects, and ministerial declarations underlined a vital role of Indigenous, local, and Traditional Knowledge in effective research efforts. In this context, it is worth emphasizing that whereas participation and meaningful consultation with Arctic Indigenous Peoples is considered today a standard in most Arctic institutions, the recognition of the value and importance of Traditional Knowledge only recently emerged as a topic of discussion in some other scientific forums and is far from being realized internationally.

Fourth, one of the most enduring results of the ASM meetings has been to boost Arctic observations and monitoring and provide renewed support to Sustaining Arctic Observing Networks (SAON). While long-term monitoring continues to be crucial to building improved understanding of the Arctic, monitoring initiatives are still sparse in the Arctic compared to other parts of the world. There is a lack of base funding, funding stability, and prioritization of sustained baseline monitoring. Furthermore, there is a need to design or refine monitoring programs in support of societal benefit (International Arctic Science Committee, 2021). Partly thanks to the endorsement that SAON received via the ASM meetings, it was possible to mobilize new resources to advance SAON's work and support the implementation of its 10-year Strategic Plan. Examples include the following: 1) the United States funded the position of U.S. SAON coordinator through the U.S. National Oceanic and Atmospheric Administration (NOAA); 2) the EU Horizon2020 call on supporting the implementation of Global Earth Observation System of Systems (GEOSS) in the Arctic included a requirement of partnership with SAON and the call specifically referred to the Joint Statement from the ASM2; 3) the EU and Japan provided funding that enabled the conduct of societal benefit assessments of Arctic observation systems; and 4) more generally, the ASM helped enlarge the group of public officials aware of the value and necessity of strengthening Arctic observing data, services and collaboration.

A fifth outcome is that although Germany and the Alfred Wegener Institute (AWI) had a well-developed plan in place for the MOSAiC expedition before the ASM2, the Arctic Science Ministerial meeting in Berlin undoubtedly helped to create additional interest in and support for countries´ participation in MOSAiC, including increasing country-level contributions of resources and people that strengthened the project. Ultimately, it enabled the success of the largest polar expedition in history that lasted for a year from 2019 until 2020 and involved hundreds of researchers and staff from 20 countries to better understand the Arctic climate system and its representation in global climate models.

Furthermore, in order to enable international, interdisciplinary projects, international funding vehicles are essential. Discussions both at the ASMs and elsewhere frequently have raised the frustrations associated with current funding structures in multiple countries, where the usual funding mechanisms have historically been limited to individuals and entities based on national jurisdiction. These discussions led to the establishment at the ASM2 of the Arctic Science Funders Forum, which is envisaged as a multilateral discussion platform for possible strategies to find ways to financially support international efforts and as a gateway for information about international funding calls for Arctic research. At this point, however, it remains to be seen if the Forum can significantly improve financing conditions for international research efforts in the Arctic.

Finally, part of the agenda of all the ASM meetings was dedicated to questions of data policies and improving data sharing, which is vital to improving the understanding of Arctic change and informing local, regional, and global responses to Arctic climate transformation. In contrast to Arctic observations and MOSAiC, it remains difficult to identify concrete outcomes of the ASMs concerning Arctic data. Hence, it might be one area worth a more systematic reflection moving forward.

Moving Forward

Russia and France are committed to organizing the fourth ASM in early

2023, so it is fair to assume that the meetings launched in 2016 will continue into the future. Five years since their beginning, it is also possible to offer some initial reflections as well as pose questions about potential and desirable changes in thematic focus and organization of the ministerial events.

All three ASMs have focused on the same basic themes. The resulting discussion areas have reinforced well-accepted goals: A desire for more resources for Arctic monitoring and observing, and more international collaboration. These two areas have benefitted significantly from the ASM process, including commitments for further Arctic observations and monitoring and the successful MOSAiC expedition. Considering the profound environmental transformations taking place in the Arctic, documenting those changes is an ongoing and enormous challenge. Even more difficult is the effort to anticipate and respond to these rapid changes in a manner informed by science (IASC State of the Arctic Report 2021). Even though there is an increased interest in and support for Arctic science, current levels of resources provided for observations, monitoring and data management are not sufficient; they require heightened and steady levels of funding.

MOSAiC is another example of international science work that benefitted from increased international participation and financial support after ASM1 and ASM2. The ASMs provided a platform and opportunity for the decision-makers and science community to unify behind this historic international and multi-disciplinary research project—and offered momentum that benefitted the expedition. While MOSAiC helped fill essential gaps in multi-season datasets on the high Arctic, there are many other areas of the Arctic with limited data coverage, including the Central Arctic Ocean, Canadian Arctic waters, and the East Siberian Sea. Scientists point out that more campaigns such as MOSAiC are needed. This raises the question of what role could future ASM meetings play in advancing and supporting major international expeditions? There are also discussions about holding the fifth International Polar Year (IPY) in 2032/2033, 25 years after the success of the fourth IPY, in recognition of the global importance of the Arctic and the Antarctic and the need to deepen our understandings of changes at both poles. Could the Arctic Science Ministerial play an important role in developing, supporting and advancing the next IPY?

Questions about the meeting structure are worth considering, as well. Both the composition and the format of the ASM meetings have been basically the same since their inception. All three ASMs involved science ministers and scientists from more than two dozen countries, with each country allowed three designated representatives. Indigenous representatives from the Permanent Participants of the Arctic Council have also participated in all three Ministerials, as have representatives of selected Arctic and international organizations active in Arctic research. Each country and Indigenous group had an opportunity to briefly describe their Arctic research priorities, and brief summaries of those priorities have been included in a final report prepared for all of the ASMs and available online. At the same time, there were also helpful additions to the programs of the meetings, including a day-long Arctic Science Forum in Berlin and an extended series of online consultations and webinars organized ahead of the meeting in Tokyo. Both mechanisms ensured greater outreach and provided additional avenues for the scientific community and a wider audience to engage in the process.

What appears to be missing, however, is a follow-up or tracking mechanism in between the meetings held at biennial intervals. There is no ongoing organizational support for the ASMs between events that could carry over some of the recommendations from the ASM reports. Although organizers of each ASM convene teams to assemble this information ahead of the meetings, could the process benefit from sustained work in between the ASMs? Could some or all the ASM countries contribute to that effort in ways that would enhance the systematic collaboration that is articulated as the principal goal? Alternatively, could for example IASC play a role in this context? If yes, how could then the relationship between the ASM and IASC be structured to further strengthen and facilitate international Arctic scientific work?

It is useful to consider the relationship and interactions between the ASM and other Arctic institutions, specifically the Arctic Council. Many issues discussed at the ASMs are directly relevant to work conducted by the AC, including questions of enhanced monitoring systems and Arctic data policies. There is also some overlap in attendance by both science and policy people involved in Arctic matters. Yet there are no official connections between the ASM and the Council, even though, so far, all ASM meetings were hosted or co-hosted by the Arctic state that held the AC Chairmanship at the same time. This pattern is slated to be repeated with Russia, in collaboration with France. Will Norway and other Nordic nations (Denmark, Sweden) continue this pattern? If yes, will non-Arctic states co-host the ASM meetings, as it was with Finland in 2018 and Iceland in 2021? It was also noted that there has been an evolution from ASM1 to ASM3 to prioritize projects that emphasize science that informs decision making, as evidenced by statements and descriptions of presented research. Could that support development of closer ties between some of the work done by AC working groups and the focus of ASM agendas? If yes, how could it be accomplished while acknowledging different membership in both forums?

Finally, another interesting question arises with respect to the implementation of the legally binding Agreement on Enhancing International Arctic Scientific Cooperation in the Arctic that was negotiated under the auspices of the AC and signed by Arctic states at the AC Ministerial meeting in Fairbanks, Alaska in May 2017 (Agreement on Enhancing International Arctic Scientific Cooperation, 2017; Smieszek, 2017). The agreement entered into force in May 2018 and Denmark is its depositary state, but it appears that thus far progress in its implementation has been relatively slow given the inability of country representatives to meet in person to establish relevant protocols. So far, there is no established institutionalized mechanism to track steps in moving the agreement from paper to practice. Given its high profile and the ministerial level, could the ASM play a role in reinforcing the Agreement's intent (improved access) and strengthening its effectiveness?

These are a few of the questions worth considering as the Arctic Science Ministerial meetings evolve. In light of pace and scale of Arctic transformation and ongoing paramount challenges to understand and respond to that change, it is clear that international Arctic scientific collaboration needs additional resources and more international collaboration. Exploring new ways to strengthen the potential contribution of future ASM meetings, including the analysis of their connections with other Arctic science organizations, are important ways to advance these goals.

Notes

1. As recognized in the Joint Statement from the ASM3, "traditional knowledge including indigenous knowledge and scientific research are both valid systems of knowledge that should complement each other within the context of collaborative and co-produced research".

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7. Achievements of the Arctic Science Ministerial and Future Tasks

Chaerin Jung

Introduction

The Arctic Science Ministerial (ASM) was first convened in 2016 by the United States in the wake of the GLACIER conference,[1] in recognition of the rapid changes in the Arctic and their impacts across the globe (Brigham, 2015). Science has been brought to the center of attention as an instrument to understand the pace and degree of these changes. The Ministerial meeting provided a venue for Arctic science ministers and their representatives to convene and discuss priorities for Arctic science and ways to enhance international research collaboration.

The ministerial meeting started out as a one-off event but gained momentum as it was recognized for its utility as a high-level, top-down intergovernmental forum for international cooperation in Arctic science (The White House, 2016). The ASM has served as a platform among Arctic and non-Arctic countries to share up-to-date information on Arctic science and research and brings recent developments in Arctic science to the attention of those at the ministerial level. The series continued biannually, taking place in Germany in 2018 (ASM2) and Japan in 2021 (ASM3). The next meeting will be organized by Russia and France in 2023 (ASM4).

Should the ASM continue and become a tradition as one of the regular Arctic science-related meetings, it would need to distinguish itself from other existing meetings by leading to tangible progress that moves scientific cooperation forward. This article examines the ASM's formation process, reviews its structural characteristics and achievements, and proposes future tasks that lie ahead of the ASM for it to empower Arctic science in the coming years.

Formation and Progress of ASM

As the United States assumed its role as chair of the Arctic Council from 2015-2017, it articulated a need to enhance coordination of national efforts in the Arctic in order to "provide guidance to executive departments and agencies and enhance coordination of Federal Arctic policies across agencies and offices" (United States, Executive Office of the President, 2015). To this end, the Arctic Executive Steering Committee was established in January 2015 through an executive order by then-U.S. President Barack Obama. Following the GLACIER conference held in Alaska in August 2015, the first Arctic Science Ministerial was held in August 2016 at the initiative of the Steering Committee.

The first Ministerial invited ministers in charge of Arctic science from 25 governments, as well as the EU and Arctic Indigenous Peoples' organizations (United States Arctic Research Commission and Arctic Executive Steering Committee, 2016). Their membership offered a unique opportunity to highlight initiatives of the participating governments and discuss sustainable research and observation in the Arctic, while charting a way forward by signing and publishing a joint statement.

The second ASM in 2018 followed the assumption of the chairmanship of the Arctic Council by Finland from 2017-2019. The ASM2 was held in Berlin and was co-hosted by AC chair Finland, along with Germany and the European Commission. The organizers were able to utilize the opportunity to bring forth their Arctic policy and endeavors. Germany, while contributing to the meeting by taking on the role of local secretariat, took the opportunity to bring attention to the MOSAiC project, a high-level international flagship project that was being designed to observe the central Arctic year-round. Along with the Year of Polar Prediction (YOPP) by the World Meteorological Organization (WMO), the MOSAiC project was recognized as one of the most ambitious international scientific efforts, and Germany successfully encouraged participation among the countries present at the meeting. As chair of the Arctic Council, Finland was also able to contribute to the ASM meeting by setting themes and priorities. As it was the first ASM held in the EU, the European Commission was included as co-host and funded the meeting as part of the EU Framework Programme for Research and Innovation 2014-2020 (Horizon, 2020).

While the scope of participating countries remained similar to its predecessor, the ASM2 meeting saw an increase in the number of participants, as Arctic Indigenous Peoples' groups gained more visibility and international science organizations were also invited. The Ministerial was preceded by a Science Forum, which provided the scientific basis for later higher-level discussions. Ten international science organizations participated and contributed to the meeting by providing overviews of their research, which allowed the ASM to paint a more comprehensive picture of scientific efforts in the Arctic (German Arctic Office at the Alfred Wegener Institute, 2018).

Building on the first ASM, which sought to deepen international collaboration that would enable countries to collectively address large-scale research questions, the second ministerial meeting emphasized the Arctic region's importance in the global climate system and reiterated that joint research and observational efforts are essential in predicting changes in the Arctic. Participants also advocated for shared access to research infrastructure and data and addressed the threats and risks posed to the local communities. To achieve these goals set out in the joint statement, the ministerial meeting also recommended "exploring the possible call of a forum of Arctic science funders" that would serve as a venue to discuss strategical research support that would not be limited by national boundaries (ASM2 2018). This led to the establishment of the Arctic Science Funders Forum in March 2020 (ASM3 2021, Working Group on the Forum of Arctic Science Funders, 2019).

The third ASM in 2021 retained the newfound tradition of the Arctic country sitting as chair of the Arctic Council to partner with a non-Arctic country to organize the meeting, and was co-hosted by AC chair Iceland and Japan. Although the meeting was held virtually due to the global travel limitations posed by the COVID-19 pandemic, ASM3 was able to fulfill its primary role as a high-level gathering to share information and discuss the priorities of Arctic science among Arctic and non-Arctic countries as well as Indigenous communities. The list of countries and Indigenous organizations remained similar in scope, while the number of international science organizations increased. The Arctic Council Working Groups, which were relevant to the theme of the ministerial meeting, participated and provided overviews of their respective research. A series of pre-planned online events was convened in the months leading up to the ASM3, to enhance the consultation process with the wider Arctic research community and strengthen the outcomes of the Ministerial (Ministry of Education, Science and Culture, 2021).

As with previous ASM meetings, the role of Arctic observation and monitoring as a means to assess the impacts and risks of global climate change was once again highlighted. Participants also stressed the importance of observation networks and the need to share data for the purpose of more comprehensive science assessments. They also mentioned taking the science and applying it to support sustainable development in the region, as well as emphasizing the importance of contributing towards ongoing climate adaptation and mitigation efforts. Particularly noteworthy was the active participation of Indigenous groups; sessions for each of the themes featured at least one presentation from an Indigenous representative. As Arctic Indigenous Peoples are among the first to experience rapid climate change, its impact on the health and wellbeing of Indigenous communities is a critical area of scientific inquiry as well. At the same time, partnership with Indigenous communities and co-production of knowledge to address such issues and recognize Indigenous rights was recognized as a meaningful next step (ASM3, 2021).

During ASM3, Russia and France shared their intent to host ASM4 in 2023, with Russia as the AC chair and France as the local host. This announcement was made during the Arctic Science Ministerial hand-over ceremony during the 2021 Arctic Circle Assembly (The Arctic Circle 2021). The theme of the next ASM meeting is yet to be decided, but it is most likely to not diverge much from the current themes. It may bring in elements from whatever priorities are set by the Russian chairmanship of the Arctic Council and from the first polar strategy of France, which is being prepared to go through an approval process and is expected to be announced early 2022 (Grosmolard, 2021).

Achievements of the Ministerial

A first in the history of Arctic cooperation, ASM1 set an example by bringing together science ministers and representatives of both Arctic and non-Arctic states, a gesture that recognized that Arctic science transcends national borders. The meeting further emphasized that in order to effectively monitor the vast region, expanding joint collaboration and coordination is of crucial importance. The joint statement produced at the meeting reflected these ideas and restated that our understanding of the Arctic changes should inform the relevant policies that would shape the Arctic, including the lives of Indigenous Peoples. Another noteworthy aspect is that, since the meeting was the first of its kind, this joint statement may be the first document signed by science ministers of both Arctic and non-Arctic countries that recognizes Indigenous perspectives related to

Arctic science.

Prior to the meeting, each government representative was asked to provide a summary outlining their country's Arctic science activities, major projects, and research infrastructure. The information, compiled and coordinated by the U.S. Arctic Research Commission, provided a comprehensive overview of existing Arctic research and served as basis for discussions at the Ministerial as well as background upon which to develop the deliverables. The comprehensiveness of the initial information package (approximately 220 projects were submitted to ASM1 and 2, while updates of 170 projects and 190 new projects were submitted to ASM3) provided an understanding on what the priorities of each country's Arctic research were and highlighted areas that would benefit from concerted efforts. Together with the joint statement, the ASM1 information package was one of the initial achievements of the Ministerial. It was reviewed and updated during the following two Ministerials.

The second ASM discussed more concrete efforts for research coordination, such as improving Arctic observation, sharing access to infrastructure and data, and enhancing international cooperation through large-scale, cross-cutting projects. At the same time, the joint statement from the meeting called for a structure that would facilitate scientific research collaboration by bringing together the funding bodies of each Arctic program (ASM, 2018).

The speed of Arctic ecological changes has raised alarm across the world, and research programs run by each country were subsequently designed to observe and analyze its implications. However, expanding Arctic monitoring research still remains a challenge due to the high costs of performing field activities in the Arctic and the vastness of the region. The ministerial meeting aimed to address this challenge by creating a structure that would allow funding agencies to "discuss strategies for supporting the research that is necessary to achieve the goals agreed at this Ministerial meeting," so that funding agencies could better plan for research support, and international and national research efforts could complement each other. As a response, a working group (WG) was established to discuss and prepare a set of recommendations pertaining to the review and establishment of the Arctic Science Funders Forum.

The working group was comprised of voluntary representatives from the Arctic science funders, all Indigenous organizations that participated in the ASM2, and the International Arctic Science Committee (IASC).

After a pre-meeting that was held in conjunction with the Arctic Circle Assembly in October 2019 and the Arctic Science Summit Week (ASSW) in March 2020 (both hosted by Iceland during its chairmanship of the Arctic Council), the working group recommended that such a forum could be a tool "encouraging international scientific cooperation and research funding beyond national opportunities," which led to a preparatory meeting and the Forum's establishment on 30 March 2020 (Working Group on the Forum of Arctic Science Funders, 2019). Iceland assumed the role of the AC chair in April 2020 and held the first meeting in November 2020.

The WG's recommendation states that the purpose of the Forum is to coordinate the existing efforts and resources in Arctic science, while remaining as a light structure without additional commitments or resources from the funders (Working Group on the Forum of Arctic Science Funders, 2019). In order to do so, the IASC took on the role of providing the necessary infrastructure, such as the logistics needed in procuring a meeting venue and the management of a website. Taking advantages of these resources, the Forum is to coordinate Arctic science activities and provide information on national and international funding opportunities. The Forum's working procedure describes its role as "work as a soft coordination body" rather than "organizing research calls or fund research projects" (Arctic Science Funders Forum, 2021).

ASM3 expanded the work of the previous meetings and attempted to provide better access to the outcomes of webinars and science sessions that were held in the days leading up to the Ministerial. The collected information was developed into an online resource to make it available to a wider audience. The research overview, previously distributed in the form of a summary paper, was also converted into an online database that provides a visual aid in highlighting geographical areas where research overlaps (Ministry of Education, Science and Culture, 2021).

Characteristics: Strengths and Shortcomings

The Arctic Science Ministerial is a high-level forum of science ministers that operates loosely when compared to other high-level forums in the Arctic, and whose outcomes are non-binding. One of the key characteristics of the ASM is that the eight Arctic states, non-Arctic states, and Arctic Indigenous organizations all participate with equal standing.

The discussions within the meetings lead to "soft" recommendations that call attention to priorities for Arctic science. The main deliverables from the previous three ASMs included joint statements and a collection of information on science projects. To date, there have been no concrete discussions about new visions, collaboration plans, or coordination of ongoing activities. The relative looseness of the meeting might encourage more states and actors to participate, but it also entails no responsibilities or concrete follow-up efforts on the participants. As such, it could end up merely as a channel for information sharing without producing significant actions. While its use as an information-sharing platform is useful to a certain extent, it takes more to coordinate each country's efforts, and information could be shared in a more functional meeting form than the Ministerial, such as the Funders Forum.

There is also a plan being contemplated for a similar meeting. For Russia's Arctic Council chairmanship from 2021-2023, it plans to hold a meeting of the eight Arctic states' science ministers. Russia plans to follow up on the Agreement on Enhancing International Arctic Scientific Cooperation, signed in May 2018, and will consider how to raise the efficiency of science cooperation among the Arctic states (Arctic Council, 2021). If the ASM is not to be overshadowed by this planned meeting, it needs to place more effort into producing concrete deliverables. It will also be interesting to see how the ASM can interact with the newly formed ministerial meeting so that there are no duplication of efforts from the participants, and have synergizing effects with.

On the other hand, the ASM is the only government-level platform that provides non-Arctic states with the opportunity to participate on equal footing in such a high-level meeting with Arctic nations. Participating countries have much to gain from the Ministerial. Previous meetings showed that active participation and hosting the meeting can strengthen trust between Arctic and non-Arctic states, have a positive influence on the host countries' domestic public opinion, and provide opportunities to expand major research projects to incorporate international partners. For Arctic science communities and Indigenous groups, the meeting provides a venue to effectively deliver the priorities of Arctic science directly to decision-makers, who otherwise would have little exposure to voices coming directly from the Arctic.

The ASM is also in a unique position of having a greater number of national members than any other Arctic-related intergovernmental meeting. It also shares an overlap with the membership of the International Arctic Science Committee (IASC), the non-governmental international organization devoted to international cooperation in Arctic sciences. Some strength lies in this large membership itself, as deliverables from the ASM can encourage support from almost all funding agencies of the countries participating in Arctic sciences, thus shaping the future of Arctic science.

A Way Forward for the ASM: Aligning Resources

With the Arctic warming at three times the global average, the role of the Arctic in the global climate system will assume even greater importance in the future. The science that records and deciphers these changes should be comprehensive and cross-cutting in order to provide an accurate portrayal of the changes and their implications at both the local and global levels. Although many national actors and scientific entities are invested in Arctic sciences, the issue of coordinating efforts and efficiently aligning resources has been an ongoing process.

The Arctic Science Ministerial recognized this issue and has made efforts to catalogue the activities and priorities of each country by sharing the list of pre-existing research projects during the past three meetings. The next step should be to align research projects with the identified key priorities of Arctic science and link projects that make use of common sets of data or infrastructure for the sake of effectiveness. This will help reduce the costs of scientific research and expand the areas covered. However, there is a limit when connecting research projects that are already up and running. More beneficial, therefore, would be the systemic organization and streamlining of different funding sources, so that components of research from different Arctic programs would be aligned in their initial planning stages.

To date, the outcomes of the ASMs are mainly centered on updates regarding the existing Arctic research projects and discussions around desirable scientific priorities; tangible progress and implementable coordination schemes remains absent. The ASM is an intergovernmental meeting that brings together science ministers in the Arctic region and beyond, and participants to the meeting are government agencies that ultimately sponsor each country's Arctic research programs. Instead of taking advantage of the opportunity within the meeting structure, the

Arctic Funders Forum was created as a separate gathering, which will be convened as part of the Arctic Science Summit Week in 2022. Although the Forum plans to address practical aspects such as the sharing of funding opportunities, coordinating bilateral and multilateral research, encouraging enhanced data, and interoperability, it is unlikely to have the same impact as when these issues are dealt with within the ministerial meeting.

For the Arctic Science Ministerial to move Arctic science cooperation forward and make unique contributions otherwise unavailable, the meeting should make the most of its ability to approach relevant issues both from the bottom up and the top down. The meeting has already been invested in the bottom-up approach in designing the themes and identifying the priorities. There are other planning efforts to examine the issues of Arctic science and determine the priorities for the coming years, such as the work of IASC towards the 4th International Conference in Arctic Research Planning (ICARP IV) in 2025. It is ineffective for the ASM to duplicate these efforts or compete with them. ASM's next step should be to make use of its unique ability to empower ongoing and emerging Arctic science and provide fuel for its advancement, which would clearly be more beneficial when approached from the top-down. Such examples would include jointly funding co-designed research projects, synchronizing funding schemes, and having practical discussions on the impediments to data sharing, such as standardization or conversion of data and intellectual property rights. As a result, the ASM could play a greater role as Arctic research assets from many different countries expand in the near future. But this enhanced role would only be possible if the Ministerial takes on a larger and better-defined role in Arctic science coordination.

Notes

1. The Global Leadership in the Arctic: Cooperation, Innovation, Engagement and Resilience (GLACIER) Conference was hosted by the U.S. Department of State and was held in Alaska on 31 August 2015. Then-U.S. President Barack Obama and foreign ministers and experts gathered at this conference in the months leading up to the 2015 United Nations Climate Change Conference (COP21), which was held three months later. Through the "Joint Statement on Climate Change and the Arctic," the conference reaffirmed the participating countries' commitment in taking action against climate change.

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PART III

INTEGRATING SCIENCE AND POLICY TO ADAPT TO CLIMATE CHANGE IMPACTS

Highlights from Session 3 of the North Pacific Arctic Conference 2021

Integrating Science, Technology, and Policy in Adapting to Climate Change Impacts

Session 3 reviewed how science, technology, and policy interact in addressing the increasingly severe adaption challenges for Arctic nations and local Arctic communities arising from the onset of climate change. This session paid particular attention to challenges in Alaska and the Russian Far East.

Chair and Organizer:

Frances A. Ulmer, Visiting Senior Fellow, The Belfer Center for Science and International Affairs, Harvard Kennedy School, Harvard University.

Panelists:

Bernard Funston, President, Northern Canada Consulting, Victoria, B.C.
Brendan Kelly, Director of the Study of Environmental Arctic Change.
Nicholas Parlato, Ph.D. student, University of Alaska – Fairbanks (NPAC Fellow).
Vladimir Romanovsky, Professor of Geophysics, University of Alaska, Fairbanks
Jackie Qataliña Schaeffer, Community Development Manager, Alaska Native Tribal Health Consortium.

Discussion Highlights:

Temperatures associated with climate change in the Arctic are rising three times faster than the global average. Melting snow and sea ice mean that the Arctic reflects less solar radiation back into space. Thawing permafrost releases carbon dioxide and methane gases into the atmosphere.

Because small Arctic communities and traditional lifestyles are so closely intertwined with nature, the effects of climate change are felt not just in the form of visible infrastructural problems arising from thawing permafrost and coastal or riverbank erosion, but also in the form of changes in animal habitats, the introduction of new parasites, and impacts on traditional cultures and rhythms. Indigenous communities have long and successful histories of adapting to changing environmental conditions. They are naturally resilient, but the speed of contemporary changes increases the pressures on Indigenous communities.

The thawing of permafrost, which is present in a quarter of the land area of Alaska and 60% of Russia's Arctic, is a long-term process that has enormous impacts on communities, including threats to the integrity of infrastructure, food and water supplies, and traditional hunting patterns and herding routes.

While there are engineering "solutions" for some permafrost problems, they are enormously expensive. Large companies, such as the oil and gas operations in the Yamal Peninsula, may find these solutions attractive. But they are beyond the capacity of individuals, small businesses, and local communities in the absence of significant subsidies.

Monitoring technologies are used increasingly to gather information on climate change impacts, such as permafrost thawing. But monitoring systems in Russia are still limited as compared, for example, to those in Alaska.

While public policies regarding mitigation are mostly systemic, those addressing adaptation are more localized. Conditions affecting specific communities vary. Nonetheless, the Arctic Council can play a useful role as a clearinghouse for information and sharing experiences regarding adaptation strategies. It also serves as a vehicle for amplifying messaging to world policymakers and the general public.

8. Arctic Climate: Context for Ecological and Social Change

Brendan P. Kelly

The sun came up here this morning here, as it probably did where you are. We have confidence that it will do so again tomorrow and the next day and the next, because we and our ancestors have directly observed this phenomenon for close to 300,000 years. Even before people figured out how Earth's rotation and orbit drive the daily and seasonal rhythms, the regularity of the earth's relationship to the sun allowed us to predict the future, harvest food and fuel in the growing seasons, and store them for winter. But the regularity also lulls us into imagining that the future can only be the same as the past; seeing the reliable sun always seemed sufficient to explain what makes life sustainable on this planet. We cannot, however, directly see the effect certain atmospheric molecules have on how much of the sun's energy is retained by our planetary home and how much escapes back to space.

Carbon dioxide, methane, and other greenhouse gas molecules in the atmosphere strongly influence the earth's thermal balance. We have learned that not from direct experience but from instruments that detect molecules we cannot see and from scientific reasoning (Anderson *et al.*, 2016). So, it should not be too surprising that we long assumed we could have little effect on the climate on which we and other organisms depend. We cannot overcome the orbital interplay between the earth and sun, but we unfortunately do have the power to change how much of the sun's energy earth retains. And—worse—we have used that power to substantially alter the balance of energy in and out of the planet, primarily by burning a staggering volume of fossil fuels (Hansen *et al.*, 2013).

Life as we know it evolved during a period when warming and cooling were roughly in balance. That balance, however, has invisibly tipped, as increasing greenhouse gas concentrations re-radiate more and more energy back to earth instead of to space (Feldman *et al.*, 2015). The resulting warming is amplified by Arctic processes, including diminished reflectivity as snow and ice cover diminishes and by additional carbon released from thawing permafrost (Serreze and Barry, 2011).

In some parts of the Arctic, warming is leading to more plant growth, which removes, at least temporarily, carbon from the atmosphere (Berner *et* *al.,* 2020). At the same time, warming is thawing permafrost over much of the Arctic, allowing microorganisms to breakdown the plant and animal matter in the soil and release carbon dioxide and methane into the atmosphere (Schuur *et al.*, 2015). The balance between plant uptake and microbial release has tipped to net increases in carbon dioxide and methane in the atmosphere. How much of the vast stores of carbon in northern soils will be released is a vitally important area of on-going research (Jentzsch *et al.*, 2021).

The amplification of warming in the Arctic resulting from diminishing reflectivity is more readily visible and better quantified. When I began studying Arctic mammals in the 1970s, sea ice provided close to 16 million km2 of habitat for seals, walruses, and polar bears in the winter months and about about 7 million km^2 by the end of the summer melt seasons. Since then, the habitat has declined in every month of the year but especially rapidly—13% per decade—in summer. The result is 1.5 million km^2 less sea ice habitat than at the start of my career (Lindsey and Scott, 2021). That rapid loss of Arctic sea ice habitat eclipses even the loss of Amazonian rain forest, which shrunk by about 1 million km^2 over the same period (Butler 2021). In addition to habitat for seals, walruses, bears, and other animals, the ice provided a hunting platform for Indigenous Peoples and it provided a massive reflector that helped to keep the planet cool. Globally, if seasonal sea ice had been a continent, it would have been second only to Eurasia in area. Most of the solar energy reaching that highly reflective, continental-sized surface was reflected back to space (Perovich *et al.*, 2008). As the ice continues to melt, however, it leaves behind open ocean, a surface that absorbs most of the energy from the sun. Thus, every square kilometer of ice that melts accelerates global warming by replacing that reflective surface with an equivalent area of absorbing surface. The resulting increase in absorption of solar energy is equivalent to 25% of the global warming from carbon dioxide accumulated in the atmosphere (Pistone *et al.*, 2014).

The amount of energy reflected to space and the amount retained by greenhouse gases have varied and impacted life on earth throughout the planet's history, yet it is important to understand the recent and profound role of human activities in changing that equation (Anderson *et al.*, 2016; Grossman *et al.*, 2002; Royer *et al.*, 2004).

Four hundred and forty million years ago, long before we were on scene, the earliest land plants were evolving and beginning to reduce carbon dioxide in the atmosphere (Lenton *et al.*, 2016). For most of the past 500 million years, temperatures were considerably higher than in recent decades (Royer *et al.*, 2004). One hundred and fifty million years ago, dinosaurs lived in a very warm Arctic (Rich *et al.*, 2002). Fifty million years ago, a long cooling trend ensued, and 20 million years ago, the Arctic was dominated by pine and spruce forests. With continued cooling, ice sheets and glaciers appeared in the Arctic five million years ago, and by three to four million years ago, the Arctic Ocean surface froze in the winter months. We know about these ancient environmental changes not from written or oral history—there were no humans then—but from stories written in soil and ice; fossils buried in the ground, and bubbles of past atmospheres frozen in ice sheets.

Two million years ago, the cooling continued and ice sheets expanded. Then, about one million years ago, Earth's temperature began regularly alternating between colder and warmer periods, driving cycles of advancing and retreating glaciers (Lisiecki and Raymo 2005; Hansen *et al.*, 2013). During the glacial cycles, grizzly bears gave rise to polar bears—a new species adapted to preying on seals inhabiting sea ice (Harington 2008; Ingólfsson and Wiig, 2009)—and modern humans emerged in Africa (Kissel and Fuentes, 2018). By 45,000 years ago, humans were in the Eurasian Arctic, and they were in the North American Arctic about 15,000 years ago (Pitulko *et al.*, 2016; Vachula *et al.*, 2019). Humans arguably began affecting atmospheric greenhouse gases with the invention of agriculture about 10,000 years ago. But there is no argument that we began seriously altering the atmosphere with the massive burning of fossil fuels that characterized the industrial revolution (Fyfe *et al.*, 2013; Najafi *et al.*, 2015).

In the very short time that we have been burning fossil fuels, we have increased the concentration of CO_2 in the atmosphere by 50 percent (Friedlingstein *et al.*, 2019); this abrupt and massive contribution of greenhouse gases to the atmosphere is warming the planet, acidifying the ocean, disrupting ecosystems, and driving extinctions (Barnosky *et al.*, 2011; Ceballos *et al.*, 2020). Thus, we have created a new epoch that has been dubbed the Anthropocene (Crutzen and Stoermer, 2000). Assuming middle-of-the-road efforts to control our carbon emissions, the major climate models all predict global temperatures will rise to more than 2°C warmer than the late 19th century. Such an increase will have catastrophic impacts on ecosystems and societies. We know that from the record of past climate changes that dramatically reduced biodiversity (Ceballos *et al.*, 2020).

Paleontology records five past events in which 75% or more of living species went extinct. In the most severe event, 250 million years ago, a massive release of underground carbon in Siberia resulted in dramatic ocean warming and acidification (Brand *et al.*, 2016). Ninety-six percent of living species went extinct. The other mass extinctions similarly came about as a result of large, abrupt changes in climate.

The magnitude and speed of anthropogenic heating of the climate contributes to what is now understood as the sixth mass extinction (Barnosky *et al.* 2011). Climate change is a major contributor to current extinction rates that are hundreds if not thousands of times faster than background rates (Ceballos *et al.*, 2020). Arctic animals are experiencing diminished food supplies, increasing disease and parasitic infections, and increasing predation rates as species migrations and distributions are upended (IPCC, 2019).

Snow that shelters Arctic seals as they rear their young is diminishing, threatening seal populations and subsistence harvests (Kelly, 2001; Kelly *et al.*, 2010). One threat comes from increased predation by polar bears. The bears themselves also depend on snow dens for rearing their young, yet diminishing snow and ice habitat forces bears to spend more and more time on land without access to seals (Regehr *et al.*, 2016). Stranded ashore, the bears turn to eating birds, which are an inadequate food source for large carnivores. Nonetheless, the bears are depleting bird populations (Dey *et al.*, 2016). Arctic bird populations are declining not only in the face of increased predation, but with novel outbreaks of malaria and cholera and diminished fish prey in a warming Arctic Ocean (Meixell *et al.*, 2016; Henri *et al.*, 2018; Piatt *et al.*, 2020).

Still, I remain confident that the sun will rise again tomorrow. Sadly, I am also confident that the earth will retain more of its heat energy than it radiates back to space and that processes in the Arctic will amplify the resulting warming. The confidence in future sunrises and in the effects of excess carbon in our atmosphere results from seeing the sun with my own eyes and seeing the greenhouse gases with technology and scientific reasoning. I am hopeful that Arctic peoples will continue to adapt to the extreme ecosystem changes, and I have to hope and work toward all of us seeing what the earth's history, Traditional Knowledge, satellite sensors, and careful analyses are telling us that we must do.

With scientific, Indigenous, and policy-making colleagues in the Study of Environmental Arctic Change, I am focused on helping people see what is not readily apparent but is nonetheless vital to the persistence of civilization. We are seeking experts with diverse backgrounds to help us synthesize and make accessible what is known about the changing Arctic. Please go to our website and consider nominating yourself or someone else to join our efforts.

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9. Climate Change and Its Impacts on Indigenous People in the Arctic

Jackie Qataliña Schaeffer

Rural Alaskans, Adaptation, Mitigation, and Indigenous Knowledge

Climate change, Indigenous Knowledge and modern science, converging in the Arctic: 229 tribes, 11 distinct cultures, 20 languages, hundreds of dialects, 12 regions across 424 million acres of land, and 144 environmentally threatened communities—43% of ALL communities in the state of Alaska. The inability to simply adapt and migrate seasonally with our food resources, as our ancestors had for more than 10,000 years, is the compounding factor that is most left out of the conversation on climate change. Alaska's Native peoples are experts in their environment. We live in a symbiotic, harmonious dance with nature. We have done this for 500 generations. Acknowledgement, acceptance, and a shift in mindset is needed for the creation of sustainable solutions that not only focus on the people who are impacted the most, but also embraces the available scientific tools that exist in our modern world. Our approach must be holistic: Linking energy, transportation, infrastructure, housing, food and water security and most importantly cultural appropriation and people to the climate impacts that affect us. The impacts are not just environmental; they are physical, spiritual and cultural to the people of the Arctic.

Life Then and Now

When sitting with an Elder recently, I realized that the oral history I was hearing and learning was no different than knowledge that was passed down for thousands of years in our Inuit culture. During times of change, be it climate or societal, the community banded together and listened to the wisdom bearers, our Elders. Shared in story-form, this history is filled with richness, love and, most importantly, knowledge of how to respond. Adaptation was part of life, not an action that was planned for. Planning was a seasonal response, not a document. This cycle of life was rhythmic and reflected the changes of the seasons. The food resources also reflected planetary change, thus providing much needed preparation in order to survive. This connection with nature was woven into the life of the Inuit. The life of Arctic people was not easy, but they did not have a word for "hard." It was simply life. No different than an eagle who hunts to feed its young, the Arctic hunter too mimicked those movements and fed his family. In that time, the seal oil lamp provided light, heat, and comfort. When lit, it provided light inside the dwelling to cook. It also provided ambient heat, which in a small space provided adequate heat to warm you up, even in a cold snap. With wet clothing hung above, it also provided the comfort of dry clothing for the next day. It is said that the seal oil lamp was so precious to the woman of the iġlu (home) that it was buried with her when she died. Something as simple as a carved shallow bowl provided so much. The Elder sighs and pauses, as if to remember a simpler way of life. This Elder now sits in a Western house, built by a Federal program. It is drafty and cold. The Elder shares that change is not always good, but it is constant. Her home is next to go into the river due to extreme erosion along the riverbank. She is not sure if the community will move it in time. When asked if she is afraid, she says, "No, I've lived a wonderful life. We come from the land and return to it when it is our time." She reminds me to listen closely to the lessons woven into the story. They are the whispers of our ancestors, who will provide answers to our survival.

Our Current Life Cycle is a Story of Trauma

Most rural Alaskans are born hundreds of miles away from home due to the lack of infrastructure in their communities. The Alaska Tribal Health Compact is a comprehensive system of health care that serves all 228 federally recognized tribes in Alaska. IHS-funded, tribally managed hospitals are located in Anchorage, Barrow, Bethel, Dillingham, Kotzebue, Nome, and Sitka. Each expectant mother must travel to either a regional hospital or to Anchorage to give birth, leaving behind her family, support-network and in many cases, her husband. The baby is born in a Western, sterile hospital, then travels back to the rural community via the "hub" (regional City for a defined ANSCA region). The infant is born in trauma, displaced from home, and then travels back to meet their family and community. This child grows into an adult, then an Elder in this place called home, but may again be displaced back to the big city when they fall ill in their later years, or recently when a pandemic hits. If this Elder passes away in Anchorage, the financial burden falls on the family to bring them home. These costs range between $8,000-$15,000, depending on location. Not only is this baby born displaced and in trauma but may die as an Elder in the same manner. This is the year 2021. Couple this life cycle with the stress of climate change impacts that require mitigation in place or complete relocation, and it is truly a story of resilience and survival of our Arctic people. Rural Alaskans have continued to adapt, even in trauma. They continue to do this today. As well as adapting, Indigenous People continue to seek solutions to minimize these negative cycles. Why does this matter? Rural residents know the value of community connection and if we do not recognize the current life cycle, we will not be able to create solutions to climate adaptation that truly impacts the people of the Arctic. The incorporation of Indigenous Knowledge and 21st Century technology is vital to our future.

One major shift has been to gain control of the tribal healthcare network. In 1999, the formation of the Alaska Native Tribal Health

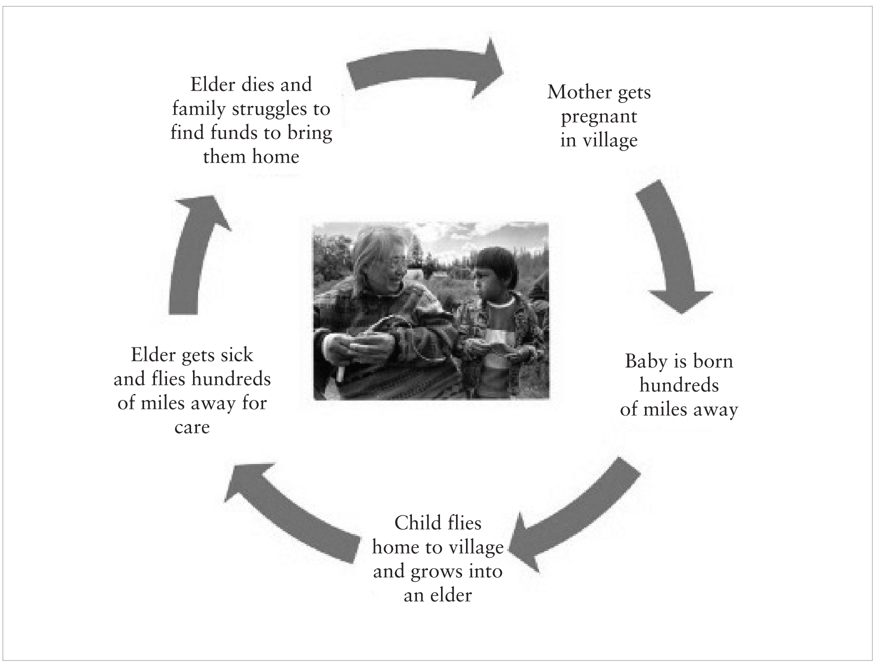

Figure III.1 Life cycle of rural Alaskans

Consortium (ANTHC) launched a new era for tribal healthcare in our state. Today, ANTHC is the largest, most comprehensive Tribal health network in the U.S. and Alaska's second largest health employer. Climate change and its impacts on the health of indigenous populations is a prime focus of ANTHC. Providing access to healthcare, safe drinking water and sanitation, and resources to assist in accessing climate impacts and response to adaptation allows a direct link to the people who live and witness these impacts on a daily basis. Innovative engineering and engineering in the Arctic, where extreme conditions can vary from -70°F to +110°F, pushes the solutions to be locally focused and driven. The Center for Environmentally Threatened Communities (CETC) provides a support network for threatened communities seeking to mitigate or relocate due to climate impacts. Community Environment and Health (CEH) provides tribal capacity building, the Local Environmental Observation platform, and a unique set of services to help strengthen our tribal response to climate change.

Governmental Layers and Regulation

When addressing any type of disaster, layers of governance and regulation become the timekeeper. In Alaska, the layers vary by community and region due to the Alaska Native Claims Settlement Act (ANSCA) of 1971. The ability to maneuver state, regional and local governmental layers either allows response in a swift manner or it completely stops all responses until consensus is reached. With 229 tribal governments, one federal Indian Reservation, 12 regional corporations, 198 village corporations and 143 incorporated municipal cities, this layered authority creates a very site-specific response to individual communities, leaving no "one-size fits all" remedy. This in turn creates a very difficult system to successfully maneuver when responding to climate disasters. Indigenous people of the Arctic are inter-connected to the land, air and sea because it provides life sustenance in a traditional lifestyle that still is practiced today. When food security is threatened by climate impacts, a ripple effect is felt not only physically, but also spiritually. The Inuit Circumpolar Council—Alaska worked collaboratively across the Arctic to show how vitally important this interconnection is to the future of Arctic people. When governmental layers and regulation disrupt the response timeframe, Arctic people suffer.

If not acknowledged and addressed, these obstacles would be no different from the continuance of colonization to these populations. Incorporating Indigenous Knowledge and understanding the value system, as well as the respect to the planet that Indigenous People practice, which reflects the natural environment, is a human behavior that the whole world could learn from.

A New Age

In my lifetime, I have witnessed much change. The creation of America and modern technology in the past 100 years is truly remarkable. When logistical challenges keep this from you, you tend to take it as it comes, sometimes up to 10 times later than mainstream America. Sometimes it never comes. With more than 3,000 homes in rural Alaska without basic water and sanitation services, much is needed to create an equitable response. Climate change impacts only accentuates this gap. In this modern age, Inuit across the Arctic work tirelessly to respond in a more ethical and equitable way. In the age of internet and video, we are now able to co-create solutions. However, we must also protect our Indigenous Knowledge and value our ancestors' ways of life. Tatiana Achirgina, Former ICC-Chukotka Vice Chair states in an Inuit Circumpolar Council report, "*Indigenous knowledge and Indigenous knowledge holders must be secure, and we should recognize that Indigenous knowledge is the intellectual property of Indigenous peoples*." The Ethical and Equitable Engagement Synthesis Report shares the importance of living in a modern era with ancient traditional values and practices across the Arctic. The world without boundaries is long gone, but the Inuit people continue to adapt. The future of our planet is viewed very differently when you are intimately connected. The ability to adapt using ancient protocols and guidelines, infused with modern technologies, is the key to our survival.

Western Tools to Infiltrate and Create Change

In 1995 the University of Alaska started a STEM-based (science, technology, engineering, math) scholarship program for university students. Today, the Alaska Native Science and Engineering Program has become a sequential educational model, with a variety of opportunities for students from kindergarten to the PhD level. It is a perfect example of a public-private partnership. Programs like this open doors for integrated education, worldviews, and technologies that will shape the future of the Arctic. Our Elders speak of walking in two worlds with one spirit. This worldview is making its way into Western systems that do not necessarily weave philosophy with science. Yupik professor Angayuqaq Oscar Kawagley taught, "The incursion of Western society has brought about many cultural and psychological disruptions to the flow of life in traditional societies." (Kawagley, 2006) Kawagley's book shows the link of ecology and spirit in a storytelling format. Taking this connected worldview back even further, we hear Chief Seattle state "This we know: The earth does not belong to man, man belongs to earth. All things are connected like the blood that unites us all. Man did not weave the web of life; he is merely a strand in it. Whatever he does to the web, he does to himself." (qtd. in Vanderwerth, 1971) In order to create new outcomes, we must acknowledge our personal role in the climate crisis. It requires taking responsibility for our own actions, united with the masses in a ripple effect, to save the planet we live on. The shift from one worldview to another has proven to be very uncomfortable for some. This feeling tends to enhance fear, thus proving again and again the same outcomes are the result of fear-based thinking and reacting vs. responding. It is time to create a shift in our way of thinking.

Life by Example

Climate impacts in the Arctic are not just impacts on our planet, but to all mankind. No different from the mindset or worldviews of Professor Kawagley or Chief Seattle, our interconnectivity with the planet still exists. This life by example is a reflection of us in nature and nature in us. When our planet is sick, we are sick—and vice versa. We have created the climate problem, yet we choose not to take responsibility. The planet needs us no different than we need the planet. This reflection is shown in many of our traditional hunts. On the North Slope of Alaska, the bowhead whale is hunted in an *umiaq* (traditional boat). The women of the community maintain the umiaq seasonally, in between hunts. The umiaq is built without nails, screws or any type of fasteners. The frame is made by lashing strips of wood together. The frame is then covered with bearded sealskin that has been tanned in a traditional manner. The cover is sewn with the tendons from caribou legs. The entire community relies on the umiaq during the hunt. The boat itself is made from materials that are found in nature. Inuit believe it is the gift of the whale that has sustained our people since time immemorial. This tradition continues today, using modern tools (outboard motors, blasting harpoons, etc.), and the whale harvest is shared across the state and northern Canada. No modern materials perform like the traditional umiaq. It is believed that this reflection of nature allows safe passage to the whale and its gift that continues to sustain our people. This symbiotic dance with nature is what we should be watching. It is in these examples of life that the answers lie.

A Changing Arctic People

Economics, politics, control and commerce are intertwined in the Arctic, yet are constantly conflicting and create a very difficult environment to exist in. Yet the people of the Arctic continue to show resilience and adapt in this rapidly changing world. Organizations like International Climate Council and the Arctic Council continue to forge new ways to approach these challenges. It has been the insistence of inclusion by Indigenous populations in the decision-making process that moves for change. If successful, we may see not only a changing planet, but also a changing people. Inuit developed rules, laws, values, guidelines and protocols that exist today are examples of this new Arctic people. The fight to protect and heal the land, air, and sea that sustains us will continue. It is in this that we learn and grow with one another. The effects of climate change on our homelands only creates a larger need for a co-production of response across Inuit *Nunaat*–our homelands. New ways of knowing and acceptance of different worldviews will be key as we forge new territories of response. The Study of Environmental Arctic Change (SEARCH) seeks to begin to bridge those gaps. The three-pronged approach shows the need for co-production of knowledge and the interconnectivity of human well-being, environmental Arctic change and the geopolitics and economics. The National Science Foundation's creation of Navigating the New Arctic tackles the convergence of scientific challenges with a framework of inclusion of Indigenous populations. We are moving into a new age of worldviews, one that will allow the strengths of multiple disciplines and cultures to converge and create solutions for our future. Finally, in this we must remember the words of my dear friend and Professor Paul Ongtooguk. "We've lived in places with such efficiency and grace that later people who have come to our homelands have considered them to be empty of human beings; and they've called this a wilderness because they didn't see us in those places. They could not imagine that a people could live so well in a land that it would appear untouched by them. And we live with that dilemma to this day."

Climate change and its impacts on the Indigenous People who live in the Arctic is one of survival. Their stories of survival, forgiveness and love outweigh the societal views of despair and destruction that our changing world brings. It really is the story of human behavior and the willingness to change and accept responsibility for a future that we envision to be better. If the Inuit can do this for 500 generations, I believe we can do the same. It will never look the same, but neither did our past.

10. Domestic and International Political Trends and Their Impact on International Adaptation Cooperation

Bernard W. Funston

"A fire broke out backstage in a theatre. The clown came out to warn the public; they thought it was a joke and applauded. He repeated it; the acclaim was even greater. I think that's just how the world will come to an end: To general applause from wits who believe it's a joke."

— Soren Kierkegaard

The Climate Situation Today

Delegates to COP26, the UN climate summit, met at the end of October 2021 in Glasgow, Scotland. Many climate experts believed this conference would be critically important to the future of planetary health and consequently for humanity itself. A positive outcome would be an agreement on a plan for the way forward—in other words "a credible description of a way out of the problem"—which would lead to real actions to significantly limit carbon emissions and thereby reduce the rate of climate change. Failure to do so will almost certainly lead to rapid temperature rises, more extreme weather events, increased sea level rise, and further destabilizing of the global economy, with all its social and political implications. In the words of Sir David King, head of the Climate Crisis Advisory Group (CCAG), "Really we're at the last-chance saloon."[1]

A 2016 TV documentary called *The Age of Consequences* examined the impact of climate change on increased resource scarcity, human migration, and conflict through the lens of U.S. national security and global stability. Using case-study analysis and interviews with military leaders and veterans, the program looked at the conflict in Syria, the social unrest of the Arab Spring, the rise of radicalized groups like ISIS, and the European refugee crisis to illustrate how climate change stressors interact with societal tensions and spark conflict.[2] Among the consequences of climate change identified in the film are droughts resulting in water and food shortages, extreme weather, sea-level rise, increased poverty, and human migration. These factors act as "accelerants of instability" and "catalysts for conflict" in volatile regions of the world. Interviews with Pentagon officials suggested that if states continue a "business as usual" approach in the context of climate change, the consequences—waves of refugees, failed states, terrorism, civil unrest, uprisings—will continue to grow in scale and frequency and lead to grave implications for peace and security in the 21st century."[3]

Climate change appears to be moving faster than predicted and years of missed commitments have left states far behind schedule in implementing necessary responses:

> *"At Paris [COP21, in 2015] we said: 'Okay, we've got to have a review process in five years' time, and at that review, when we sum up all the nations' contributions, we'll be able to put pressure on countries to make even greater reductions if necessary.... Now, we're six years on and we still haven't got all of the nationally determined contributions in from all countries.... When we look at where we stand, we are not even close to getting that 1.5 degrees Celsius or less."*[4]

> *"We've got no time left....We've been messing about and not taking this problem seriously, so now every year counts."*[5]

There is much political posturing around commitments to address climate change. For example, In April 2021, Prime Minister Justin Trudeau announced that Canada would cut its CO_2 emissions by 45 per cent below 2005 levels by 2030, surpassing its previous target of 36 per cent reduction by that period.[6] More recently, Canada's new Environment and Climate Change Minister stated proudly that the country "has one of the world's most detailed and credible climate plans, including the second most stringent carbon pricing system in the world."[7] And yet, when "aspirational climate promises get measured against real-world pollution levels... for Canada, the latest results are terrible. The new data show that in 2018, [Canada's] annual emissions rose yet again."[8] In 2019, in its annual *Emissions Gap Report*, the United Nations Environment Programme reported that Canada was set to miss its 2030 emissions target by 15%.[9]

Despite its vital importance, expectations for COP26 were already being downplayed by the time it started.

The Challenge

It is not uncommon for people confronted by this sort of bleak analysis to declare "I'm an optimist." Optimism is all well and good, but it is not a defense, nor an adequate response, to the harsh impacts of climate change. It is no substitute for, nor can it justify avoiding, detailed analysis and discussion of the current difficult situation. Mitigation of relentless increases in greenhouse gas emissions, and adaptation in the context of the most serious impacts of climate change will be priorities for the remainder of the 21st century. This is not to say that we should abandon optimism, but what is required now is a steely-eyed realism regarding the barriers to serious multilateral collective action. In this time of need, selfless, informed, strategic leadership in key states will be essential; however, it seems in short supply. In the absence of commitments by states to a global strategy for mitigation and adaptation in the face of climate change, responsible individuals, corporations, and local communities might have to "go it alone" for the foreseeable future. Adaptation efforts at the local and subnational levels will likely be coping mechanisms to withstand incremental impacts, rather than broad strategic initiatives.

Arctic Council

Today the Arctic Council is the most comprehensive and elaborate forum for Arctic cooperation. When we look back in future years, we might conclude that the period from 1996 to 2016 was indeed the golden age of Arctic cooperation. From a foundation of scientific cooperation, begun in 1991 under the Arctic Environmental Protection Strategy (AEPS), the Arctic Council blossomed into a truly unique organization that includes broad scientific collaboration in the natural and social sciences, as well as policy engagement among Arctic states and non-Arctic states. By 2004, Asian countries were considering a greater role in Arctic affairs, in part because of a realization that Arctic change also held significant implications for them. In 2013, China, India, Japan, the Republic of Korea, and Singapore, among others, were admitted to the Council as new Observer States. The governments of these nations represent more than three billion people, roughly 40% of the global population.[10]

However, a continuing challenge within the Council has been to apply the growing Arctic knowledge base in ways that inform policy-making and decision-making, particularly in the context of climate change. Politics is a process for shaping human agendas, making choices among competing interests and allocating scarce resources. It has been frequently shown that political processes cater to special interests and do not necessarily respect scientific facts or indeed the truth. In normal times, key features of the Arctic Council system present both strengths and weaknesses where scientific and political cooperation are concerned. A few of these include:[11]

- The consensus rule for all Arctic Council decisions ensures broad support;
- Arctic Indigenous Peoples have influence through active participation and full consultation within the Council;
- Ministerial Declarations and directions from Senior Arctic Officials provide flexibility in adjusting mandates and work priorities;
- Strong networks allow science to be a foundation for policy discussions among the members, permanent participants, and observers;
- There is broad public access to the Council's cutting-edge Arctic knowledge bases developed through science and Indigenous Knowledge;
- There has been a strong culture and tradition of cooperation among all participants in the Arctic Council, including non-Arctic states and other observer organizations.

Since the inception of the Council in September 1996, the developments in Arctic science networks and the growth in Arctic knowledge, including Indigenous Knowledge, have been considerable. Beginning in the Norwegian chairmanship (2006-2009), the Council began to take on initiatives that specifically examined adaptation to climate change.[12]

However, during the period 2016-2020, Arctic cooperation veered into some rough terrain. While the consensus rule for all Arctic Council decisions ensures broad support, it also allows one or more parties to block decisions and frustrate cooperative activities. Since its inception, the Arctic Council has depended heavily on the positive participation of the United States to develop the Council's international standing and relevance in relation to Arctic-related knowledge production and policy dialogue. Ministerial declarations adopt, approve, and direct the work of the Arctic Council. This foundational feature of the Council process began to show significant cracks during the Trump era, as was evidenced in the Ministerial meetings in both Fairbanks (May 2017) and Rovaniemi (May 2019).[13]

Issues and Trends

We can anticipate that the Arctic issues of primary interest to the international community for the remainder of the 21st century will include maritime/marine issues such as shipping, energy supply, marine infrastructure, navigation, ocean mapping, ocean acidification, plastics and other marine pollution, loss of sea ice, sea level rise, ocean temperatures, thermohaline circulation and weather, fisheries and other marine resources, tourism, and ocean governance. Within the Arctic Council, some member states will no doubt continue to stress the primacy of local and regional issues.[14]

There is now a critical mass of scientific activity that makes Arctic science cooperation likely to continue for the foreseeable future. Its breadth and longevity will ultimately be determined by domestic politics, especially where government scientists are concerned. Generally speaking, science is a disciplined method of inquiry that builds understanding of the world around us. Science depends on demonstrable facts proven through systematic, replicable methodologies based on evidence.[15] Science in the service of policy is necessary for effective adaptation and mitigation of climate change.

However, today there are several worrisome trends that could have severe consequences for the Arctic Council and for other forums of cooperation. These include upwellings of disinformation, conspiracy theories, and anti-science sentiments coupled with challenges to law and order, distrust of democracy and repudiations of governmental authority.

The COVID-19 pandemic has provided a case study not only for the benefits of scientific cooperation (the powerful story of success in creating vaccines), but also for the disturbing effects of disinformation which has fed anti-vaccination militants along political lines, threatened health workers, and worse:

> *"In the case of coronavirus disinformation, similarly, there was certainly danger in the individual falsehoods that surged through social media channels, but each erroneous claim or wild fantasy could at least be*

addressed and debunked. (It is not that difficult, for example, to persuade people not to drink Javex, no matter who may have suggested disinfecting the body from the inside.) The greater danger lay in the accumulation of falsehoods that not only polluted the provision of sound health information but amounted to a rejection of the counsel and reasoning of the health authorities themselves.

In a moment of collective jeopardy, the real threat was to the underpinnings of a sound public policy response to the disease. What was at stake was the sway of scientific rationalism."[16]

Perhaps the greatest concern for coming years in the battle against climate change will be the exponential growth of disinformation and the creation of separate realities that divide/polarize society today in the U.S. and elsewhere: "… the algorithms of the new media environment reward ever more outrageous content."[17]

"Whether malicious in design or merely misguided, disinformation aims to convince people not to believe what they are told by official sources, subject area experts or media outlets responsibly guided by corroboration and verification. The effect of disinformation is to weaken the hold of those agencies tasked with providing the public with trustworthy information, or certainly to make their job more difficult….The purpose of disinformation was to sow confusion and distrust, exacerbate division, inflame internal hostilities and so provoke a legitimation crisis whereby essential civic institutions could no longer command sufficient public trust."[18]

A shared understanding of climate issues and their impacts on human populations is a prerequisite to any international cooperation to create effective adaptation strategies. Scientists can inform us about trends and impacts. They can offer recommendations to address potential scenarios. But in the end, allocating resources and implementing measures will be political decisions.

"In the case of the emergence of COVID-19, the virologists and epidemiologists could speak with confidence about the damage the disease would do and they were able to recommend measures that would manage its transmission so as to lessen its impact, but the decision to implement those measures was ultimately political, taken on the principle that the

> *moral priority should be to do everything possible to save lives. One could imagine a different society, in which other considerations might be given greater weight. Indeed, by May 2020 it was no longer necessary to imagine this hypothetical alternative society. It was showing itself to be the United States of America."*[19]

Richard Hofstader observed in "The Paranoid Style in American Politics":

> *"One of the impressive things about paranoid literature is the contrast between its fantasied conclusions and the almost touching concern for factuality it inevitably shows. It produces heroic strivings for evidence to prove that the unbelievable is the only thing that can be believed."*[20]

U.S. Leadership?

In the early and mid-1990s, talk of an Arctic Council was not of particular interest to the United States despite its position as an Arctic state. With the collapse of the Soviet Union in the fall of 1989, the United States became the unilateral policeman and choreographer for the planet. Many commentators considered the international system to be unipolar, with the U.S. at its center. Beginning in the late 1970s, China had begun to reform its economy. By the 1990s it was averaging yearly double-digit growth in GDP. But at that time China was still emerging from a form of centuries-old self-imposed isolationism.

Nonetheless, discussions on the formation of an Arctic Council took place among the participants on the margins of Arctic Environmental Protection Strategy (AEPS) meetings, with little progress. European Arctic states, including Russia, were not particularly interested in forming an Arctic Council without the United States. In 1995 U.S. President Clinton signaled a willingness to move this initiative forward and negotiations began in earnest. The result was *The Declaration on the Establishment of the Arctic Council* signed in Ottawa in September 1996.[21]

But 25 years on, the future of U.S. leadership in Arctic and global climate change forums is uncertain. The Trump presidency (2016-2020) was a roller coaster of unreliability, unpredictability, disruptiveness, vindictiveness, instability, and chaos. The last thing the world needs is more of the addled brain of Donald J. Trump or his acolytes directing American foreign and domestic policy through directives on Twitter. And yet this prospect still looms over the U.S. and the world. With the petulance of an adolescent child, Trump undermined the Paris Agreement, repealed many environmental regulations,[22] opened the Arctic National Wildlife Refuge to petroleum development,[23] and offered to buy Greenland. This sort of behaviour in a country of lesser importance would be disturbing, but in the United States—given its economic and political dominance in world affairs over the past century—it is of the highest concern.

As suggested in the NPAC 2021 concept paper by Young *et al.*,[24] the recent construct that Arctic cooperation exists in some sort of bubble and operates untarnished by the ebbs and flows of larger geopolitical and geoeconomic forces, is at best wishful thinking. Arctic cooperation is also highly dependent on domestic political and economic forces. A major determinant of global and Arctic cooperation on climate change mitigation and adaptation in the near future could be the outcomes of the mid-term elections in 2022 and the presidential election in 2024 in the United States.

This is not to suggest that the United States is solely responsible for what comes next. It does imply that without serious U.S. leadership, the chances for any effective international cooperative action on climate change will be seriously curtailed. The world has come to rely on U.S. leadership over the past century, and dysfunction in U.S. domestic affairs can and does have worrisome geopolitical consequences.

The dysfunction in America today has created deep uneasiness elsewhere in the world, not least among its allies. Daily news feeds from the U.S. suggest that America is beset by worrisome trends that are eroding norms of decency, truth, and ethical behaviour, honour and integrity, the rule of law, accountability, belief and reliance on science, and even democracy itself. EKOS chairman Frank Graves noted: "The massive partisan divide on climate change was not nearly as acute not that long ago.… A modest 12-point gap in 2015 has exploded to a 46-point gap in four years."[25]

Whether Donald J. Trump is responsible for all these trends will be debated into the future. What is clear is that he has given licence to some of the basest human tendencies and behaviours and has ravaged American institutions that have relied on norms and conventions of propriety. Not to be ignored, he has also unleashed the hounds of irrationality, subscribed to mindless conspiracy theories, and beat the drum of disinformation with outright lies. Accountability seems to be an extinct commodity in America where Trump is concerned. In Trump's America, which did not end with election in 2020, anti-science attitudes, climate change denial, and the unchecked growth of disinformation continues to undermine domestic and international efforts to respond to global problems like the COVID-19 pandemic and climate change. The ongoing effects of these forces at the state level in the U.S. signal a period of even greater dysfunction to come in American politics, which makes international cooperation on climate matters not only difficult but potentially impossible.

In some western capitals China is perceived as the greatest threat to the security of the democratic world. For others, that honour falls on the Republican party led by Trump. While some claim that during the Trump years the guardrails of the American system held, this is no particular comfort to those who see political forces at work daily in the U.S. supporting Trump's claim to govern in his own self-interest. In February 2021 President Biden announced that "America is back" and declared that "diplomacy is back at the center" of U.S. foreign policy. However, the fact that 74 million Americans appear to support Trumpist views is ample warning that the outcomes of the mid-term elections in 2022 and the Presidential election in 2024 might spell the end of the return.

A former speech writer[26] for Republican President George W. Bush recently wrote:

> *"Trump has to be considered the massive front-runner for the 2024 Republican nomination…. Well-sourced reporters carefully detail the comeback's mechanics. But almost nobody is prepared for the malicious destructiveness of what is to come…. In a 2011 speech, Donald Trump explained his single top rule in life: "Get even with people. If they screw you, screw them back 10 times as hard. I really believe it." He's repeated the same idea over and over again in speeches, tweets, and books published under his byline. In 2024, the targets of Trump's revenge are American law and American democracy."*

Dysfunction, disruption, instability, and the growth of authoritarianism in the United States will inevitably lead to even further erosion of America's effectiveness and reliability in global leadership.

Time will tell if the large American constituency in support of Trumpism will result in new cycles of uncertainty and instability in international relations as Trumpist administrations come and go.

Concluding Observations

In the coming years there can be some comfort in optimism—we should have confidence in humanity's ability to solve "wicked problems". However, we must be equally prepared to be candid about the increasingly difficult political and social context in which we work.

Professor Christopher Dornan has described the situation vividly in a recent study entitled *Science Disinformation in a Time of Pandemic*.[27] He notes that that the U.S. has a:

> *"…flourishing homegrown media ecosystem of hyper-partisan outlets dedicated to enraging their audiences against their ideological enemies—which is to say, their fellow citizens…. Here, pseudoscience and baseless conspiracy theories entwine with political vilification. In the world these sites describe, school shootings are a hoax perpetrated by the state to provide a pretext for gun control; the weather has been weaponized by the military; the 9/11 attacks on the World Trade Center were an inside job; vaccines cause autism; climate change is a myth; condensation trails from jet aircraft are in reality chemical and biological agents being sprayed by government agencies for purposes of psychological manipulation; and a sinister "Deep State," answerable to no one, is at work to strip the citizenry of freedom of thought and regiment their behaviour. Meanwhile, the lowermost cloisters of the Internet—subreddits, Gab, message boards and instant messengers such as 4chan, 8kun, Telegram and Discord—seethe with even more fevered claims, which from time to time bubble up into public view, shrieking for attention. In addition to its hysterical partisanship, the chief characteristics of this sphere of public discourse are its suspicion of established authority, its rejection of supposed "expertise," its paranoid reflex to see conspiracies at every turn, and its ready embrace of pseudoscience."*[28]

The situation he describes is not restricted to the United States. He offers a recommendation on a way forward and indeed this is a prerequisite for any serious international cooperation and collaboration in response to climate change:

"Responding effectively to the prevalence of science disinformation and irrationalism will not only require coming to grips with why science is viewed distrustfully by so many, but why attitudes toward science have taken on a political colouration. Absent such an understanding, it may not be possible to have a true dialogue with those in the thrall of anti-vaccination arguments, or convinced the threat of COVID-19 has been overblown, or unpersuaded by the scientific consensus on global warming. The two camps run the risk of talking past one another."[29]

We currently have all the technology we need to make a huge difference in how we live on the planet. But we lack the political leadership and self-discipline to do so. We live on a dynamic planet. The archaeological record is full of villages, towns and cities that for one reason or another disappeared because they did not adapt to change. But humans, modern *homo sapiens* and Neanderthals, adapted to some pretty amazing changes in the planet from 40,000 years ago to the present, including an ice age that saw ice more than a mile thick across vast stretches of North America, Europe, and Asia.

Today there appears to be a misalignment between humankind's desires for ever-growing consumption and the planet's finite capacity to tolerate economic growth. Can existing governance systems lead to shared values and shared understandings that ensure the necessary collective behaviour required to respond to climate change? The current pandemic provides a preview of some of the challenges ahead. In some societies it has been very difficult to get people to adjust to even short-term behavioural modification (e.g. wearing masks to reduce transmission of the virus or getting vaccinated), notwithstanding that failure to do so could quickly result in serious illness or even death. How then will we make the necessary transition to broader, longer-term measures to mitigate and adapt? This might be the critical question for the 21st century.

Notes

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PART IV

WILL NEW FRONTIERS IN ARCTIC MARINE TECHNOLOGY SUPPORT A BLUE ECONOMY?

Highlights from Session 4, North Pacific Arctic Conference 2021

New Marine Technologies: Can They Support a Blue Arctic Economy?

Session 4 focused on marine technologies that can underpin development in the Arctic through use of the Arctic's maritime resources in a sustainable fashion. The session addressed the prospects for technologies relating to shipping, icebreaking, submarine cables, and deep-sea mining with experts in these sectors assessing the progress, constraints, and business viability of these technologies in the real world.

Chairs and Organizers:

Sung Woo Lee, Senior Research Fellow, Korea Maritime Institute
Arild Moe, Research Professor, Fridtjof Nansen Institute

Panelists:

James Bond, Director, Polar Research and Ice Class Ships, American Bureau of Shipping, Canada.
Steinar Ellefmo, Associate Professor, Norwegian University of Science and Technology.
Sung Jin Kim, Former Minister of Maritime Affairs and Fisheries, Republic of Korea
Juha Saunavaara, Assistant Professor, Arctic Research Centre, Hokkaido University, Japan.
Alexey Shtrek, Development Manager, Consulting, Aker Arctic Technology, St. Petersburg, Russia.

Discussion Highlights:

There are many new marine technologies on the drawing board or in various stages of development affecting shipping, ice-breaking, communications, and, although distant, even the possibility of deep-sea mining in the Arctic. All tend to be expensive. For some, there are likely markets; for others, no markets are yet on the horizon.

In shipping, the main drivers are reduced costs and environmental sustainability. The pace of international regulation, with the exception of the Polar Code, has lagged. The biggest promise for transformational change may lie in new fuels, replacing heavy fuel oil and eventually even LNG with renewably made methanol, ammonia, and hydrogen fuel-cells. Although there are solutions to some of the technological problems associated with energy supply innovations, these fuels remain largely unavailable on Arctic routes.

The use of LNG as a fuel in icebreaking ships operating along the Northern Sea Route is driven by economic factors, including the fuel's availability. Associated releases of methane, however, make LNG an unattractive alternative fuel from a long-term environmental perspective.

There have been significant developments in fuel use, design, and connectivity of icebreakers, providing more capacity on Arctic routes. Some argue that the rapid loss of sea ice north of Russia means that heavy icebreakers will be less essential in the future.

The Polar Code, 25 years in the making and still evolving, is a significant development in ensuring safe and environmentally responsible shipping in the Arctic. But its real impact will depend on effective implementation, enforcement, and cooperation among Arctic nations. For monitoring and safety reasons, there are critical data needs, especially in areas of the Arctic that so far have seen little shipping, including the transpolar route.

Although submarine cables have limited environmental costs, they seem unlikely to power significant economic development in the region, with the possible exception of international data storage centers depending on firm-level calculations of costs and benefits. Most of the plans for new cables have few landing places, and most of these will be in larger communities or where industrial infrastructure already exists, so they may be of limited use to more remote Arctic communities.

The Arctic stands to benefit from technologies under development in non-Arctic countries, especially those in Asia. Korea, for example, has relevant technologies in shipping, port facilities, and internet infrastructure. The Arctic Council, the Arctic Economic Council, and other venues are helpful for connecting technology developers and users in governmental, business, and community circles.

Once final boundaries are delimited, extended continental shelf jurisdiction may mean that most or all seabed minerals in the Arctic will come under national control. Some governments, Norway for example, have moved ahead with planning a regulatory framework, for exploration if not exploitation of the seabed. But current technological limitations, environmental issues, costs, and market trends make any early initiatives relating to deep-sea mining in the Arctic unlikely.

There are potential conflicts between the governance structures for the seabed being developed under national management schemes and the Central Arctic Ocean Fisheries Agreement (Agreement to Prevent Unregulated High-Seas Fisheries in the Central Arctic Ocean) that came into force earlier in 2021.

11. Operating Ships Safely and Confidently while Protecting the Arctic Environment

James Bond

Changes in international shipping regulations have recently come into force with the dual intent of increasing safety of life at sea and providing stricter environmental protection in polar waters. The changing extent of Arctic ice cover coupled with the drive to measure and reduce global shipping emissions may encourage use of shorter northern routes through the Arctic.

The IMO Polar Code lists sea ice as one of the critical hazards and risks to shipping that must be assessed. The Polar Code requires that risks be understood and mitigated if necessary. Ship strengthening to achieve ice-class designation may be an appropriate mitigation step but is not always necessary given the temporal and spatial variation in sea ice cover. Operating within understood capabilities and limitations of individual ships, fitted equipment and crew are required to match those capabilities with existing conditions. With a focus on ship operations in sea ice, developments to advance the state of the art in ice load structural monitoring systems are underway. These include shifting from purely reporting ship/ice interaction events as they occur to a predictive and communicative system about near future events. This shift, driven by changing conditions, evolving regulation, and new technologies, has the potential to enhance Arctic shipping safety and pollution prevention.

Drivers for Arctic Transit Shipping

The promise of shorter sea routes across the north, potential fuel savings, associated reduction in greenhouse gas emissions, and even reduced piracy risks are attractive to ship owners in the always competitive shipping markets. Several different Arctic routes have been considered as potential transit options, as shown in Figure IV.1. Distance savings compared with traditional blue-water trading routes, which make use of the Suez or Panama canals, can be as high as 35%.

- Northern Sea Route (NSR): The NSR stretches across the Russian Arctic, linking Asian and Northern European markets. It is typically the first Arctic route to be ice free in the summer and has in recent years been characterized by an absence of multi-year ice.

- Northwest Passage (NWP): The NWP is not a single route, but rather multiple path options through the Canadian Archipelago. Some recent transits of dry bulk cargo and cruise operations have been successfully undertaken. Projections from several years ago had the NWP becoming usable on a regular basis by 2020-2025. However, a reduction in the amounts of first-year ice has freed the multi-year ice to enter these waters in unprecedented ways, making year-to-year variability greater and planning more difficult.
- Arctic Bridge: The Arctic Bridge is a potential route that links the Port of Churchill in northern Manitoba, Canada with western parts of Russia, Scandinavia and Europe. The Port of Churchill is ice free in the summer months and is served by a rail line extending to the Canadian national railway system.
- Transpolar Sea Route: The Transpolar Sea Route extends directly across the Arctic Ocean to link the Bering Strait with the North Atlantic. This route, as drawn in Figure IV.1, remains hypothetical as it

Figure IV.1 *Arctic shipping routes (courtesy of Dr. Jean-Paul Rodriguez, Hofstra University)*

> requires an essentially ice-free Arctic Ocean for most ships. However, as the ice continues to retreat on the Russian side of the Arctic, a route closer to Russia appears more and more attractive.

The shipping efficiencies to be gained using these Arctic routes in terms of distance travelled are obvious. Variability of the Arctic environment, however, makes voyage planning a challenge in a "just in time" delivery environment, particularly for container ships. Other sensitivities must be recognized, both environmental and societal. Specific route demarcations that emphasize the shortest possible routes, minimize Arctic resident impacts (to humans and other animals), and reduce environmental footprints are being examined on several fronts.

IMO Polar Code: Landmark Regulation for Polar Shipping Safety and Pollution Prevention

On 21 November 2014 and 15 May 2015, the International Maritime Organization (IMO) formally adopted the safety and environmental parts of the Polar Code at its Maritime Safety Committee (MSC) and Marine Environmental Protection Committee (MEPC) meetings in London, UK. This milestone and truly seminal regulatory Code, the result of a 20-plus year international effort led by the IMO, promotes safety and reduces the potential for environmental pollution from the increasing number of vessels operating in Arctic and Antarctic waters. The Polar Code introduced a broad spectrum of new binding regulations covering elements of ship design, construction, onboard equipment and machinery, operational procedures, training standards, and pollution prevention. New ships with keel lay dates after 1 January 2017 need to comply with the Polar Code and existing ships need to comply at the first renewal of their IMO SOLAS Safety Construction (SLC) certificate or SOLAS Passenger vessel (SLP) certificate, after 1 January 2018. Given the approximate 2.5-year cycle on the SCC, any ship now entering defined polar waters is required to be Polar Code compliant. Compliance is indicated by the presence of a valid Polar Ship Certificate (PSC) onboard when the ship sails in Polar waters.

The Polar Code is a simple, yet far reaching goal-based standard (GBS). As such, there are typically multiple means to meet the requirements after establishing the severity of the relevant Polar shipping hazards, operational risks, and appropriate mitigation measures. Understanding the hazards (related to the presence of sea ice, low air temperature, extended periods of darkness or daylight, remoteness, high latitude communications difficulties, poor hydrography, etc.) as they change by location and throughout the year is key. Through an Operational Assessment process, hazards are identified and the risk to the ship is established. This is achieved by looking at the severity of the hazards and other sensitivities, including the presence of marine mammals or Indigenous People's activities in the area of operation. The capability of the ship and its crew must always be considered for all hazards.

Information to characterize the environment across the Arctic is needed to properly prepare for anticipated increases in polar shipping. The long-term effort to develop the Polar Code fostered ties amongst multiple organizations, created working groups, and established reporting commonality for data sharing, all leading to excellent results. For example, the Arctic countries have improved search-and-rescue (SAR) coordination in recognition of the Polar Code requirement to establish minimum time to rescue in the event of a SAR need.

In the broadest sense, the IMO Polar Code has successfully fostered cooperation among ship owners and operators, Arctic States, Flag Administrations, International Association of Classification Society (IACS) members, the World Meteorological Organization, Indigenous groups, environmental non-government organization (NGOs), SAR organizations, high-latitude communications providers, and technology developers.

Operational Limitations

A Polar Ship Certificate (PSC) signals compliance with the Polar Code. Importantly the PSC lists operational limitations, specifically with respect to high latitudes, air temperature (low), and operations in sea ice that must be followed. High latitude affects communications, specifically the ability to send and receive information in real time. Ships with a typical navigational and communications suite are normally limited to 80° North or as specified on the Cargo Ship Safety Radio Certificate (or Passenger Ship Safety Certificate) or any limitations of the system used to acquire ice conditions or other environmental information. Similarly, a ship could be limited with respect to low air temperatures if the steel grades used in its hull construction (above the waterline) do not have appropriate toughness. Typically, IACS steel grades intended for non-low air temperature operations are restricted to areas with a Mean Daily Low Temperature (MDLT) above -13°C.

Sea ice presents the largest challenge with respect to imposing and operating within stated limitations. This is due to the extreme variability in sea ice coverage and characteristics in any polar area at different times of any given year. To establish limitations and guidelines, the IMO developed the Polar Operational Limit Assessment Risk Indexing System (POLARIS). The description of this system is provided in IMO Circular—MSC.1—Circ.1519. The system incorporates experience and best practices from the Canadian Arctic Ice Regime Shipping System (AIRSS) and the Russian Ice Certificate concept, with additional input provided by other coastal administrations with experience regulating marine traffic in ice conditions, as well as select members of IACS, including the American Bureau of Shipping (ABS). A PSC stating that POLARIS will be used as a means to establish operational limitations in sea ice is appropriate and recommended.

POLARIS provides a means to quantify the risk posed to the ship by ice conditions as described by the World Meteorological Organization (WMO) nomenclature and the ship's assigned ice class (or lack thereof). POLARIS can be used for voyage planning or importantly on-board decisionmaking in real time on the bridge. As with any maritime risk methodology, it is not intended to replace the judgement of an experienced Master. POLARIS assesses ice condition risk and quantifies it as a Risk Index Outcome (RIO) value determined by the following simple calculation:

$$RIO = (C1 \times RV1) + (C2 \times RV2) + (C3 \times RV3) + (C4 \times RV4)$$

Where;

- C1…C4 : Concentrations of ice types within ice regime
- RV1…RV4 : Corresponding risk values for a given Ice Class

The Risk Values (RVs) are a function of ice type, the vessel's ice class, and season of operation. The winter season RVs is shown in Table IV.1. Risk levels are higher with increasing ice thickness and decreasing ice class. POLARIS provides RVs for the seven (7) IACS Polar Classes, four (4) Finnish-Swedish Ice Classes, and non-ice strengthened ships. For example, for a non-ice strengthened, Polar Code Category C ship, only the bottom

Table IV.1 *POLARIS risk values (RVs)*

Increasing ice thickness(severity) →

Winter risk values (RVs)

Decreasing ice class ↓ ; Increased risk ↘

Polar ship category	Ice class	Ice free	New ice	Grey ice	Grey white ice	Thin first year 1st stage	Thin first year 2nd stage	Medium first year 1st stage	Medium first year 2nd stage	Thick first year	Second year	Light multi year	Heavy multi year
		-	0-10 cm	10-15 cm	15-30 cm	30-50 cm	50-70 cm	70-95 cm	95-120 cm	120-200 cm	200-250 cm	250-300 cm	300+ cm
A	PC 1	3	3	3	3	2	2	2	2	2	2	1	1
	PC 2	3	3	3	3	2	2	2	2	2	1	1	0
	PC 3	3	3	3	3	2	2	2	2	2	1	0	-1
	PC 4	3	3	3	3	2	2	2	2	1	0	-1	-2
	PC 5	3	3	3	3	2	2	1	1	0	-1	-2	-2
B	PC 6	3	2	2	2	2	1	1	0	-1	-2	-3	-3
	PC 7	3	2	2	2	1	1	0	-1	-2	-3	-3	-3
C	IA super	3	2	2	2	2	1	0	-1	-2	-3	-4	-4
	IA	3	2	2	2	1	0	-1	-2	-3	-4	-5	-5
	IB	3	2	2	1	0	-1	-2	-3	-4	-5	-6	-6
	IC	3	2	1	0	-1	-2	-3	-4	-5	-6	-7	-8
	No ice class	3	1	0	-1	-2	-3	-4	-5	-6	-7	-8	-8

Table IV.2 *POLARIS risk index outcome (RIO) criteria*

RIO_{SHIP}	Ice classes RCI-PC7	Ice classes below PC7	Color Code
20 ≤ RIO	Normal operation	Normal operation	
10 ≤ RIO < 20			
0 ≤ RIO < 10			
-10 ≤ RIO < 0	Elevated operational risk	Operation subject to special consideration	
-20 ≤ RIO < -10	Operation subject to special consideration	Operation subject to special consideration	
-30 ≤ RIO < -20			

row of risk values needs to be considered. It is important to note that when it was being developed, the non-ice strengthened RV line in POLARIS was intended for cargo vessels designed and built to rules such as the ABS Marine Vessel Rules. Its application to lighter-structured vessels (eg. yachts) needs special consideration.

A positive RIO indicates an acceptable level of risk where operations may proceed normally. A negative RIO indicates an increased risk level, potentially to unacceptable levels. Established criteria, grouped by Polar Ship Category and Ice Class, is listed in Table IV.2. For negative RIOs, the IMO suggests that operations should both be stopped and reassessed or proceed cautiously with reduced speeds (IMO terminology is "subject to special consideration"). Note that for Category C ships, only positive RIO values are considered normal operations and therefore elevated risk (reduced speed) operations should not occur.

ABS uses available digital ice data and the IMO POLARIS methodology to produce ABS POLARIS RIO charts. The process scans through ice data looking for ice regimes and turning "egg codes" into an RIO for a ship of specified Ice Class. The right side of Figure IV.2 shows the results of the ABS process as it transforms the data from ice regime definition to POLARIS RIO.

Using archived datasets, mathematical or statistical analyses can be performed to give estimated ice conditions for an area of operation. This analysis is incredibly useful when planning a polar voyage, conducting a Polar Code Operational Assessment, or selecting an appropriate ice class

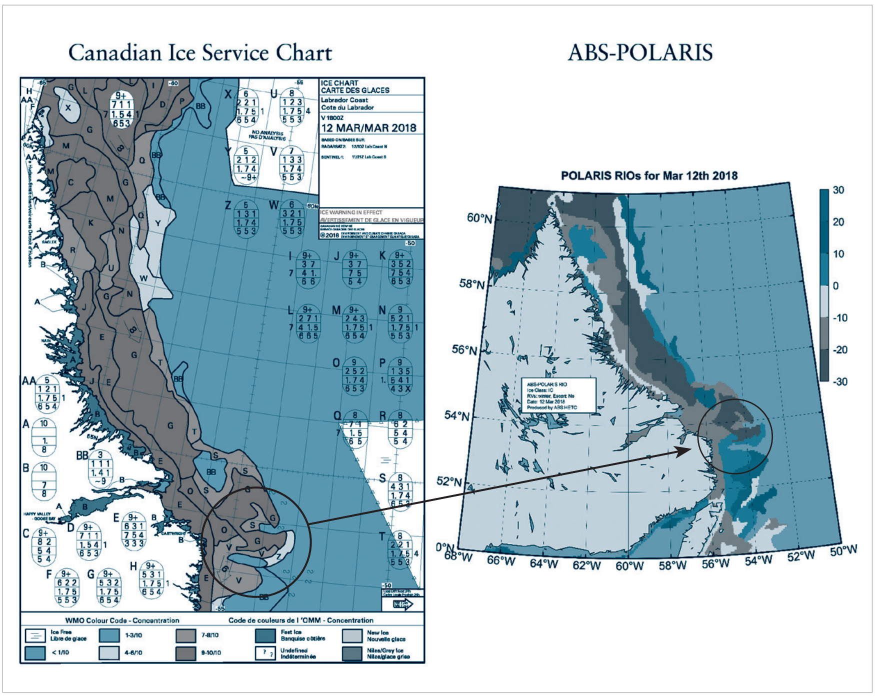


Figure IV.2 *Canadian Ice Service chart to ABS-POLARIS RIO plot* for an intended area and time of operation.

When POLARIS is used for bridge decisionmaking, the crew must be able to recognize, characterize, and understand the sea-ice regime in which they are operating. Experienced Ice Navigators and Ice Pilots continue to be challenged in some circumstances. The IMO, under the Polar Code, has mandated training levels for certain crew members on ships expected to encounter sea ice to increase safety of ice operations. Yet with increasing polar ship traffic, the overall level of experience in operating in ice is dropping worldwide.

Ice load monitoring systems (ILMS) have been available for decades. ILMS that use strain gauges to measure the structural response from a ship-ice interaction event were developed in the 1970s and 1980s. The ILMS informs a bridge navigation team about the structural response to an ice load (usually as a percentage of yield or design force) while operating in ice. The recorded sensor array data can be analyzed after impact events to gain insights into load magnitudes and patterns. The current state of the art is remarkably similar to the 1980s' systems in design, while benefiting from increased robustness in gauges (fiber optic strain gauges now the norm) and significant increases in onboard data processing and data storage. Commercially available ice-load monitoring systems continue to be load event reporters and recorders. The primary shortcoming of these systems is that they can only predict near-term future load events based on trends from recently recorded impact history.

New Technologies Can Change Ice-load Monitoring from a Historical Record to Insightful Actionable Data

The ABS-envisaged Ice Operations Monitoring System (IOMS) can change from offering historical record displays to providing insightful actionable data about future events. The system, intended to augment experience, will:

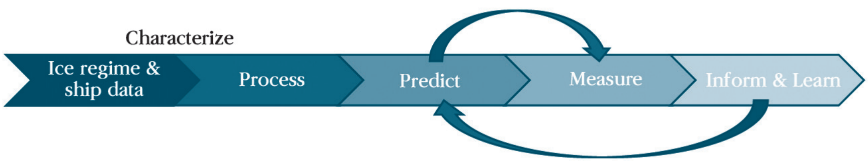
- Characterize the ice regime in front of the ship
- Predict the ramification of the foreseeable ship ice interactions (loads and ship response)
- Measure the loads experienced by the ship and convert to actionable information
- Inform with actionable data via dashboard(s) to the personnel on the bridge (report data against threshold load limits, provide route

guidance through an ice regime)
- Refine predictions using advanced learning algorithms
- Store data for future analysis (understand damage events, and validate / improve rule and regulatory regimes)

This system does far more than report and record loads. It predicts ice-load events that will likely occur, measures what has occurred, and uses this event data to refine predictions.

An Ice Operations Monitoring System can (1) increase operational safety because it alleviates some of the risk associated with the unknowns and variability of an ice regime; and (2) increase operational efficiency by offering recommendations for the least resistance path through an ice regime.

The system comprises a series of four subsystems that characterize, predict, measure, and inform. A learning feedback loop that improves the prediction based on the difference between predicted and measured structural response provides refinement and improvement of the system. This refinement, via manual calculation or through artificial intelligence (AI) and machine learning (ML) algorithms, is a key advancement of the state of the art.



Characterize:

The characterization of the ice regime that is likely to be encountered by the ship is the critical step in moving from ILMS to IOMS.

- Forward-looking detection sensors (visual, thermal, radar, LIDAR, etc.). System takes sensor outputs and:
  - rectifies to a "birds eye view," stitches multiple images together and creates the local ice regime off the bow (or stern)
  - tags and tracks individual floes
  - calculates the thickness of ice floes based on apparent freeboard
- Prediction accuracy is refined as the ship moves into an ice regime, updating the near field and adding new far field characterization

- Downward-looking cameras on bridge wings capture images as the ice breaks and turns up
  - measures ice thickness and snow cover
  - estimates age of ice and strength based on the colour of the ice
- Air temperature data (past five days and current) used to refine ice strength estimate
- ML and AI systems to identify individual ice floes ahead of the ship and label each with type, size (area, thickness, and mass), and location

Predict:

Based on the ice regime in front of the ship, the information that is being captured by the ship's Voyage Data Recorder and an assumed ship-ice interaction model, the forces imparted to the hull are predicted. Multiple hyper-real time simulations are envisaged around the near field ice regime (likely less than 100m off the bow and would be confirmed with the maneuverability of the ship). Checks for "least resistance path" through the ice (within maneuverability and structural capacity constraints) are performed. In addition, the path into the far field ice regime would be checked against constraints. The "least resistance path" is a means to reduce ice loads on the ship, which in turn reduces the propulsion power. This requires less fuel to be burned and produces lower emissions.

Measure:

A scaled down, current state-of-the-art strain gauge system would be used to measure the ship ice interaction forces on hull structural framing members. Given the benefits gained from this predict/measure /learn approach, a simplified strain gauge arrangement is achievable. Strain gauges are to be supplemented with bow accelerometers (vertical motion) and bow shoulder (aft quarter possible also) accelerometers to capture sway motions.

Inform:

Predictions and measured outcomes are to be displayed in forms that are useful to the navigation crew while allowing a more thorough investigation and analysis if desired.

Learn and refine predictions:

Predictions and measured data are to be compared. Refinement of predictions will be made through machine-learning algorithms.

Data storage:

Appropriate data is to be stored for future analysis and for use in future system development and refinement. Data can be further shared among different users with the aim of informing ship design rule refinement.

Summary

The IMO Polar Code has created a step change in polar shipping safety and pollution prevention. It requires a methodical process of hazard identification, understanding of risks, and their mitigation. Documentation to demonstrate compliance is enforceable and training is being augmented. Operational uncertainty remains due to the highly variable and challenging environment that is the Arctic. Increased shipping utilizing the shorter northern routes will bring less experienced crews and operating companies into the Arctic. Updating of ship operation monitoring systems that can provide predictive insights into ship ice interaction can further increase safety, enhance pollution prevention, and provide operational efficiencies, allowing ships to be operated safely and confidently while protecting the Arctic marine environment.

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12. Developments in Icebreaking Technologies

Alexey Shtrek

Introduction

Extreme navigation conditions in the Arctic and highly sophisticated requirements for safety and reliability force ship designers to constantly look for more advanced engineering solutions in icebreaking technologies. At the same time, most icebreaking technologies originated from traditional and proven solutions. New inventions must always go through numerous model testing and experimental full-scale trials before achieving widespread acceptance.

Icebreaking technologies are steadily developing, with the occasional appearance of breakthrough solutions that have a significant impact on further progress and improve engineering approaches.

The first such historical example is the polar icebreaker *Yermak*, which was built in 1899 and afterwards served as a prototype for other Arctic icebreakers for the next half century[1]. Another indicative example is the development of Soviet nuclear icebreakers in the second half of the 20th century. The drivers that helped create this unique nuclear fleet included the need to provide long-term endurance at high power consumption and constant operation of a propulsion plant in variable modes. The organization of the accompanying industry and the supporting infrastructure became possible within the framework of the centralized state management of the Soviet Arctic[2]. Nowhere else in the maritime world would nuclear ships have become an economically feasible solution. But it was not surprising that with the collapse of the USSR and a sharp reduction in the volume of cargo transportation along the Northern Sea Route (NSR), the maintenance of the nuclear fleet became unprofitable. In turn, the burden of operational expenses for the nuclear fleet fell on the remaining NSR users.

Considering all the challenges and associated risks, when we look back 60 years to the first nuclear-powered icebreaker Lenin, we can conclude that the operation of this icebreaker has been a success overall. At the same time, it should be noted that *Lenin* and the subsequent "old *Arktika*" nuclear-powered icebreaker series were, apart from a more powerful nuclear plant, in other aspects quite traditional and not especially innovative[3]. Some technical innovations (such as an air-bubbling system, which at that time was in common use on diesel icebreakers) were introduced on the third icebreaker of the series (*Rossiya*), but serous modifications to more advanced bow hull form were only incorporated on the sixth icebreaker of the series (*50 let Pobedy*).

In other countries, such as Canada, Germany, Finland, and Sweden, Arctic engineers took a different path. Throughout the 1970s and 1980s, many efforts were made in the domain of experimental research and development of new, more efficient hull shapes that require less energy consumption to break ice. In particular, the "Thyssen-Waas" concept of an icebreaking bow was proposed in Germany, and the so-called "conical" ("spoon-shaped") bow was developed by Wärtsilä Marine in Finland[4]. The main machinery and propulsion plants have been constantly improved, and the most common became diesel-electric and, to a lesser extent, direct diesel and turbines. These innovations were among the reasons prompted the Soviet Ministry of Merchant Marine to order diesel-electric icebreakers from abroad. Almost all diesel-electric icebreakers for the former USSR were built in Finland, among them powerful linear icebreakers of the "new *Yermak*" type and shallow-draft icebreakers of *Kapitan* Sorokin type[5].

The shallow-draft nuclear icebreakers *Taimyr* and *Vaygach* have combined the advantages of nuclear power with other technical innovations. Very strict functional requirements to ensure the possibility of operations in the shallow waters of the mouth of the Yenisei River demanded the most modern expertise in optimizing of hull shape. Therefore, their hulls were designed by Finnish specialists who used their experience of creating river icebreakers for use in Siberian rivers.

At the same time, companies involved in the development of Arctic projects in Canada and the United States paid much more attention to studying the independent navigation of cargo vessels in ice conditions. The issue of using large-tonnage cargo vessels for ice navigation was initially raised with the discovery in the 1950-60s of oil and gas fields in the Canadian Arctic and Alaska. Already at that time, the feasibility of creating large tankers for active ice navigation without icebreaker assistance had been considered.

Based on the results of experimental voyages of the specially refitted tanker *SS Manhattan* in 1969-70, the technical possibility of using large-capacity icebreaking vessels in the Arctic has been demonstrated, while also showing that this would require more ice-capable and reliable designs[6]. A lot of conceptual design studies of large Arctic tankers and innovative icebreaking LNG carriers were carried out in 1970-80s, but none of these projects were implemented during that time. The first icebreaking vessel capable of independent Arctic operations was the Canadian ore-bulk-oil carrier *MV Arctic*, built in 1978. After eight years of operation in the Arctic, *MV Arctic* was refitted. By replacing the forward part with a new form called Melville Bow, the renovation increased the icebreaking capability of the bulker from 1 m to 1.5 m.

Recent Developments

At the turn of the century, a breakthrough in the creation of dedicated icebreaking cargo vessels designed for independent navigation in ice was the development of "Double Acting Ship" concept. This concept, which allows a vessel equipped with azimuthing propeller pod units to move astern in heavy ice with much less resistance than ahead, leads to a significant reduction in energy consumption and therefore cuts emissions. In addition, the vessel maintains efficiency when operating in open water[7].

The aforementioned sharp increase in fees needed for the maintenance of nuclear icebreaker fleet led to a new development trend: companies engaged in the export of minerals, oil, and gas in the Russian Arctic began to create their own icebreaking cargo fleet that was only minimally dependent on icebreaker support.

These new generation cargo vessels appeared in the Arctic after the Norilsk Nickel mining company decided in the early 2000s to create its own cargo fleet to replace the chartered SA-15 (Norilsk-type) vessels that had been built in the 1980s.

The first prototype diesel-electric Arctic container vessel *Norilskiy Nickel* was designed according to the "Double Acting Ship" concept. It was built in Finland and successfully passed delivery ice trials in 2006. Then another four sister ships of this type were built in Germany, as well as the product tanker *Enisey* with the same dimensions, hull form, and propulsion system.

Further development of new projects for the export of hydrocarbons from the Russian Arctic has led to the creation of new types of icebreaking cargo vessels capable of providing reliable, cost-effective, and safe shipping.

Almost at the same time, three shuttle tankers of the *Vasily Dinkov* type were built in Korea for the purpose of exporting crude oil from the Varandey offshore terminal in the Pechora Sea. Two shuttle tankers of the *Mikhail Ulyanov* type were also delivered from Admiralty Shipyards in St. Petersburg for exporting oil produced by the offshore stationary platform Prirazlomnaya in the same sea area. Both types of tankers have a deadweight of 70,000 tons, ice class Arc6, and diesel-electric propulsion, including two azimithing pods with shaft power of 20 MW on tankers of the *Vasily Dinkov* type and 17 MW on tankers of the *Mikhail Ulyanov* type.

The next important step in the development of Arctic cargo vessels was the Yamal LNG project. To export LNG from the new port of Sabetta, a design concept for an Arc7 ice class LNG carrier with a 172,000 cubic meter capacity and with three azimuthing propulsion pod units with a total power of 45 MW was created. From this concept, the Korean shipyard Daewoo has built 15 LNG carriers known as the Yamalmax (*Christophe de Margerie*) type. Two gas condensate carriers for the Novatek company's same project, as well as seven shuttle tankers for the other project of Gazpromneft—a single-point oil export terminal in the Gulf of Ob—are based on the same design principles as the aforementioned shuttle tankers for the Pechora Sea.

In addition to these icebreaking cargo ships, which have played a key role in the development of the latest Arctic transportation projects, it is worth mentioning other new solutions in icebreaking technologies, such as the oblique icebreaker *Baltika* (with an asymmetric hull form and three propulsion pod units); the Finnish icebreaker Polaris and its Arctic followers. These include icebreaking supply vessels of the *Aleksandr Sannikov* type (with two propulsion pod units in the stern and one unit in the bow), as well as the unique port icebreaker *Ob* with four azimuthing propulsion pods (two in the stern and two in the bow), powered by the world's most efficient four-stroke diesel engine and featuring a DC grid to further improve efficiency and reduce fuel consumption. The icebreaker *Polaris* is also the first icebreaker that uses LNG as fuel.

How Will New Technologies Contribute to More Environmentally Sustainable Arctic Business?

It is important to note that every Arctic transportation project is unique and is usually preceded by a detailed feasibility study. Thus, it is possible to choose optimal technical solutions that will also meet up-to-date environmental standards. Nowadays the Arctic region is affected dramatically by global warming with tangible changes in sea ice conditions already visible, with effects that have been more pronounced than in the southern latitudes. These effects have profound implications for Arctic shipping—and shipbuilding.

The main modern trends in the development of icebreaking technologies listed in article[8] are analyzed below in terms of their impacts on more environmentally sustainable Arctic business.

Use of LNG and other alternative fuels on new Arctic cargo vessels and icebreakers

One of the most effective methods for reducing emissions into the atmosphere is the use of natural gas fuel on ships. This fuel eliminates the emission of sulfur oxides and solid particles, reduces nitrogen oxide emissions by 90%, and reduces CO_2 emissions by 30%. This is evidenced by the rapid increase in the number of ships in the worldwide fleet using LNG as fuel. A complete ban on the use of heavy oil fuel in the Arctic has already been agreed upon and approved by the International Maritime Organization to come into effect in mid 2029.

It should be noted that Yamalmax-type LNG carriers, thanks to studies made during concept design and implemented engineering solutions, were the first such vessels to be able to use LNG as a main fuel in all modes of operation. All previous conventional LNG carriers were forced to switch to diesel fuel in maneuvering (with variable power) mode of navigation. An important economic benefit for more advanced use of LNG was the fact that these vessels use their own cargo, loaded right there in the Arctic, as a fuel. One of the main arguments against independently operating in ice vessels has always been that they consume a lot of fuel and constantly carry a large amount of additional diesel oil in case of extreme conditions. Thus, in terms of power and autonomy, icebreaking LNG carriers are becoming comparable to nuclear icebreakers in terms of their operational performance in remote Arctic areas.

In addition, Novatek emphasizes that due to the cold climate, the productivity of the Sabetta LNG plant, and the efficiency of the shipping terminal have significantly exceeded design parameters.

Some of these benefits are applicable to icebreakers and other cargo vessels (not LNG carriers). When working in areas close to LNG production, for example, the task of bunkering the ships is much easier. The use of diesel electric power plants, which is a standard solution, with dual-fuel medium-speed diesel engines on ships of high ice classes, allows avoiding sharp fluctuations of engine load. On tankers and bulk carriers, LNG fuel tanks can be installed on an open deck, which does not entail the use of additional space; on container ships, LNG tanks can be placed only in the ship's hull, resulting in slightly reduced container capacity.

But today, the possibility of using LNG as fuel on icebreakers and cargo vessels is limited by the lack of a bunkering system in the Arctic region. One possible design and logistics solution may be the creation and placement along the Northern Sea Route of several floating LNG storage facilities, which can be used both for supplying gas to Arctic settlements and for bunkering ships navigating along NSR routes. The issue of autonomy is also especially challenging to icebreakers, as LNG requires more space than diesel fuel.

Regarding other alternative fuels, the possibility of their use on icebreaking ships will depend on the possibility of organizing their local production and bunkering in the Arctic region, as well as on progress in creating reliable engines that can operate using such fuels.

It is also clear that the use of nuclear power on large powerful Arctic icebreakers will continue in the near future. At the end of 2020, after three-year delay, the first 60 MW icebreaker *Arktika* has been commissioned, second icebreaker of project 22220—*Sibir*—delivered to Atomflot at the end of 2021. Three more icebreakers of the series are at different stages of construction. Also, construction of a nuclear icebreaker-leader of 120 MW power also started at the new Zvezda shipyard at Russian Far East, with an option to prolong the series for two more such giant icebreakers. At the same time, as noted by some experts[9], certain design faults remain, often associated with hesitance to introduce new solutions. Along with other factors, this may lead to the fact that the maintenance of the nuclear icebreaker fleet of this new generation will be very expensive.

Use of Arctic cargo vessels with larger capacity

The use of larger vessels in projects for the export of natural resources from the Arctic region can reduce the intensity of shipping and thereby reduce the impact on the environment and total emissions by the whole fleet.

For example, the cargo capacity of Yamalmax LNG carriers corresponds to the most common capacity of modern conventional LNG carriers, which is also a significant cost-saving and better logistic solution than a shuttle scheme. This confirms that now there are no technical obstacles to designing icebreaking cargo vessels of any required size to be optimal for the selected routes and logistic schemes.

At the same time, it should be noted that Arctic ports and terminals are very often located in shallow water areas, which requires extensive dredging to allow the entry of such large vessels as Yamalmax LNG carriers.

Transportation schemes with transshipment of cargo from high ice-class shuttle vessels to vessels without ice class

This logistics scheme is used in many Arctic projects, as when transporting oil from the Gulf of Ob by shuttle tankers with a deadweight of 40,000 tons to an oil storage vessel near Murmansk. Additional dredging in the Gulf of Ob near Cape Kamenny was not required in this case.

For its new projects for LNG export from the Arctic, Novatek also decided to use a scheme involving LNG transshipment via specialized floating barges to be located near Murmansk and Petropavlovsk-Kamchatsky. This approach can also contribute to the further development and implementation of LNG as fuel for Arctic ships and icebreakers.

Optimization of joint operations of icebreakers and cargo vessels

Despite the recent great progress in the development of icebreaking cargo ships, transportation solutions without the assistance of icebreakers may not always be optimal and safe enough.

In any case, the main declared purpose of the new nuclear-powered icebreakers is to provide year-round navigation along the whole NSR water area.

However, as had been predicted earlier and was confirmed by recent experimental voyages of Yamalmax LNG carriers along the NSR during extended periods of navigation, the escort by a powerful nuclear icebreaker is not the only condition necessary to increase the average speed and safety of the convoy. In addition, other parameters (including bow and shoulder hull form and reinforcements of this areas, as well as performance in the channel behind the icebreaker) of the escorted cargo vessel should also be optimized for efficient convoy movement.

In order for convoys of an icebreaker and an escorted vessel to proceed with optimal speed and minimum total energy consumption, the ice performance characteristics of both vessels would need to be correlated to each other in the best possible ratio.

This means that, for example, new Arctic LNG carriers to be built for the Arctic LNG 2 project will differ in design concept from the *Christophe de Margerie*-type LNG carriers already in operation.

Possible Risks for Coastal Communities and Marine Resources

It is evident that shipping activity in the polar regions will increase in the coming decades, but the magnitude of those increases is still difficult to estimate. Uncontrolled rapid growth of shipping in the Arctic could increase the risks to marine biological resources and the impacts on the lives of Indigenous People in the region.

These impacts will be different depending on the type of cargo and the location of the transit. For example, a possible oil spill in a more remote area would have more catastrophic consequences compared to an accident involving a bulk carrier, a general cargo vessel, or even an LNG carrier closer to established port facilities. Risk mitigation measures include regulatory restrictions of shipping activity, a ban on navigation in certain areas and months, and other possible measures.

In the Russian Federation, the Indigenous population and environmental organizations have little influence on Arctic project decision-making. For example, the Yamal LNG project required a significant amount of dredging at the sand bar of the Gulf of Ob in order for large LNG carriers with a draft of about 12 meters to be able to enter the port of Sabetta. It is obvious that such a noticeable anthropogenic impact on the environment should have required a serious study of the possible consequences. However, Novatek met almost no opposition from the public and environmental authorities. All expenses for the creation of this fairway channel were covered from the budget via the state-owned company Rosmorport.

However, private shipowners and operators of Arctic vessels are not always careful and attentive to environmental issues. From a technical point of view, the biggest risks arise from the use of outdated equipment, in particular old cargo ships and icebreakers. For example, big concerns arise with the recent practice of purchasing of second-hand vessels originally designed for operation in freezing non-Arctic seas, mainly in the Baltic, and then operated during wintertime in the Kara Sea. As mentioned above, these vessels are not optimal for operation under icebreaker assistance in specific areas of the Arctic.

Conclusion

It is evident that shipping activity in the polar regions will increase in the coming decades, but it is still difficult to estimate the level of future traffic. Nevertheless, there are already technologies available that correspond to the global trend towards greener technology and lower emissions. For example, ongoing studies regarding the selection of energy sources for Arctic-going ships are highly interesting and important.

During the feasibility study and ship design phases, the expected operational profile and corresponding fuel consumption values can be used in the life cycle assessment (LCA), which shows the amount of emissions generated during a vessel's lifetime.

Taking into account the unique character of each icebreaker or icebreaking vessel project, it is recommended that ship design takes into consideration ways to make it as easy as possible to upgrade ships to a new type of fuel or to introduce more efficient technologies in the future as soon as they become available.

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13. New Marine Communication Cables in the Arctic

Juha Saunavaara

The past year has witnessed rapid changes in the development of trans-Arctic submarine fiber-optic cable projects. The new Russian Polar Express project was announced and the international Arctic Connect project was suddenly terminated at the end of May 2021, due to a decision made by the Russian project partner. Today, detailed plans concerning the Polar Express are publicly available. The first kilometers of the cable are apparently already installed, and the cable system is visible at TeleGeography's famous Submarine Cable Map.[1] However, it seems that this quick start will only take place in a limited section of the western end of the system and the main section may not be installed until 2025-2026. Furthermore, it is still unclear whether this project will develop as a Russian government domestic initiative or whether there are international players interested in joining the project under strong state control. In the meantime, news concerning the future course of the Arctic Connect and the project led by Quintillion Subsea Holdings is expected to be released soon. The latter plans to connect East Asia and Europe with a submarine fiber-optic cable through the Northwest Passage. While Quintillion has recently been silent concerning its trans-Arctic grand plan, it has established a satellite landing station in northern Alaska that is connected to its fiber-optic network, and openly emphasized its infrastructures' importance to U.S. national security.[2]

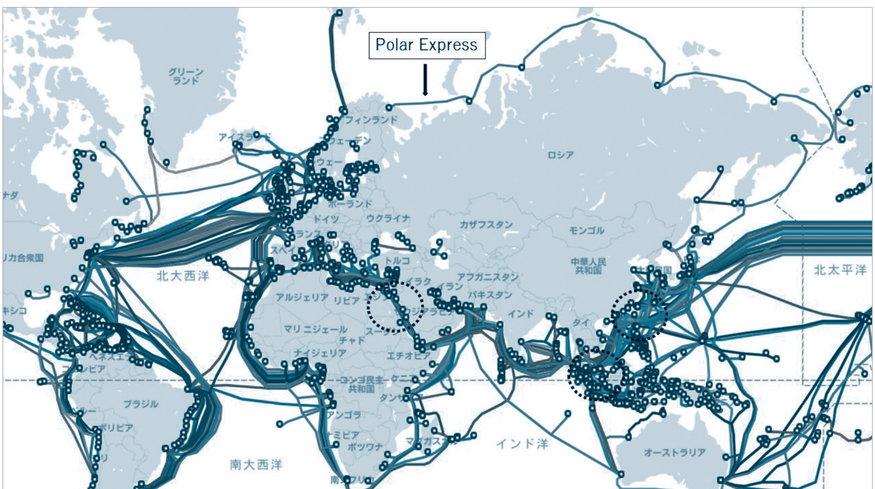
This paper explains the basic logic and reasons behind the growing interest in improved connectivity in and through the Arctic, introduces the development of various submarine fiber-optic cable projects, discusses the (possible) role of Arctic cable initiatives in the global submarine cable network, analyses communication cables' contribution to environmentally sustainable Arctic business, and elaborates the risks for coastal communities and conflicts with other uses of marine resources. Although there are many ongoing regional submarine fiber-optic cable projects in different parts of the Arctic, this paper will focus on large-scale trans-Arctic projects.

Why Submarine Fiber-optic Cables Matter in the Arctic

Submarine fiber-optic cables are laid on the seabed to carry telecommunications signals between land-based stations. These cables have a capacity to transmit large amounts of data and current internet and international digital communications systems require them. The global cable network consists of more than 1.2 million kilometers of submarine cable and handles 99 percent of international data traffic. While this infrastructure plays a critical role to societies dependent on its flawless functioning, it also has some problems that are easy to identify but difficult to correct. One of the problems identified already years ago is related to overconcentration that makes the submarine fiber-optic cable infrastructure vulnerable to natural and man-made hazards. This is especially true in areas (choke points) where various cables are in close proximity with each other.[3]

Although the planned route and structure of different trans-Arctic projects vary, they are based, more or less, on the same logic and they try to fulfill similar kinds of needs:

- New data transmission capacity.
- Faster connections. This includes the need for shorter routes, and the Arctic is a shortcut that links Europe, North America, and East Asia.



Source: https://creativecommons.org/licenses/by-nc-sa/3.0/). Modified from TeleGeography Submarine Cable Map (https://www.submarinecablemap.com/#/

Figure IV.3 *Global submarine fiber-optic cable map with landing stations*

- Network diversity/robustness in the global submarine cable network.

In addition to these needs and requirements deriving from and reflecting the development of global telecommunications markets, there are also national and local reasons that explain a special interest in the Arctic. The needs of the local people (and the improvements these projects could bring to sparsely populated areas) are often mentioned when talking about the possibilities and the positive outcomes of the trans-Arctic cables. However, these kinds of projects' concrete effects on local communication infrastructure and connectivity (in areas that are not close to the landing stations) will depend on local telecommunication companies and public authorities who are responsible for developing the terrestrial networks.[4] Until the emergence of the Polar Express, trans-Arctic projects were also considered as international partnerships where customers and investors would be commercial actors with diverse backgrounds.

The historical development of telecommunication infrastructure in the Arctic has been tightly connected with the development of industries such as mining or forestry. Therefore, the telecommunication infrastructure that has to date had relatively limited direct environmental impact may have large indirect effects as it enables the development of different types of industrial activities.[5] While some businesses have not necessarily been green or sustainable, many if not all modern environmentally friendly and energy-efficient solutions depend on broadband connections. Submarine fiber-optic cables are armored and buried in shallow waters. However, this process impacts only a small area, happens only once during the entire lifespan of 25 years, and thus differs from activities such as bottom-contact fishing that causes repeated pressures on the seafloor ecosystem. The Arctic environment has posed unique challenges for terrestrial telecommunication infrastructure development since the mid-19th century, but experience in installing submarine cables at the bottom of the Arctic Sea areas is still limited. Therefore, further studies concerning submarine cable burial and the melting of subsea permafrost, for example, may be needed.

The Arctic has also attracted attention as a place where the materialization of the concept of dual-purpose undersea cable would be extremely beneficial. The basic idea of dual-purpose (Sensor Enabled Scientific Monitoring and Reliable Telecommunications SMART) cables is to integrate different types of environmental sensors into commercial submarine telecommunications cables. Cooperation between the industry and academia could be mutually beneficial, as the latter could cover part of the costs in order to create a unique monitoring system. While these kinds of possibilities have been discussed, large-scale implementation has not yet been carried out.

A Short Introduction to Trans-Arctic Cable Projects

The idea of connecting East Asia and Europe with a communication cable through the Arctic is not new. The Russian Optical Trans-Arctic Submarine Cable System (ROTACS) project, which envisioned a connection between Japan and the UK through the Northeast Passage, was launched in 2000. Despite the permissions and funding received from the Russian national authorities, this project never materialized – at least partly due to political and financing problems related to the annexation of Crimea by the Russian Federation. After ROTACS, new Russian initiatives emerged in the spring of 2018 and 2019. These initiatives originated from the Ministry of Defense and other military authorities. The basic idea seems to have been to install a trans-Arctic fiber-optic cable serving the needs of the military and to support a plan to build a new closed internet fully isolated from the World Wide Web.[6]

The North American discussion concerning trans-Arctic communication cables has focused on a project led by the Alaska-based Quintillion Subsea Holdings. This project was originally called Arctic Fibre and it was run by a Canadian company with the same name. However, Arctic Fibre merged with Quintillion in 2016, which then completed and implemented the first phase, which included the regional system in Alaska consisting of submarine and terrestrial cables and new landing stations. While Quintillion has not announced anything new concerning the planned connections from Alaska to Japan and to the UK (Phases 2 and 3) recently, they have built a ground station for polar orbiting satellites and announced that they will cooperate with Equinix data center, located in Seattle. Furthermore, the company has hired former military officers to key positions and emphasized that their infrastructure can help fulfill U.S. national security needs in the Arctic.

Although international by nature, the Arctic Connect project originates from Finland. The project has been led by the mainly Finnish state-owned company Cinia as the leading party of the international Cinia Alliance, in collaboration with their Russian partner Megafon. This project is planning to build a cable system that ranges from Kirkenes, Norway to Japan and consists of both fiber pairs landing in the Russian Far North and fiber pairs connecting Europe and East Asia without any linkage to Russia. Besides planning to connect the new Arctic cable to the existing European cable networks through Finland and international cables landing in Japan, landings in North America have been planned as well. The development of the Arctic Connect gained speed when Megafon joined the project and various steps forward were taken in a relatively short period of time: the seabed surveys between Kirkeness/Teriberka and Vladivostok were launched in August-November 2020; a group of new companies, including from Japan, joined the Cinia Alliance in September 2020. Subsequently, NORDUnet (research and education networks of the Nordic countries) completed a MOU with Cinia concerning one fiber pair in January 2021. At that time, the Arctic Connect was described as a valuable asset to Nordic and even to the global telecom infrastructure supporting research and education. However, Megafon announced at the end of May 2021 that it had frozen the Arctic Connect project in order to revise the structure and economics of the project, and to study whether they will continue the project later.[7]

Approximately a month earlier, in mid-April 2021, the Russian deputy minister of transport announced that construction permits had been granted for a communication cable from Teriberka near Murmansk to Vladivostok and to several landings in the Russian Arctic and Far East. This was followed by the announcement that the Federal State Unitary Enterprise Morsviazsputnik was appointed as the operator of the planned trans-Arctic cable. This company was in charge of the interaction with potential partners and consumers and soon signed

Figure IV.4 Trans-Arctic communication cable projects cooperation agreements with other Russian companies. According to information available in the early summer of 2021, the cable was to cost a little less than 900 million USD and be exclusively financed by the state. The manufacturing of the cable was to take place in Murmansk using Chinese optical fiber and Russian components. Furthermore, it was announced that a ship had departed Murmansk at the beginning of August to begin installation near Teriberka. According to the CEO of Morsviazsputnik, the system required additional cable interconnections in order to link to existing cable systems and negotiations to attract foreign investments were under way. While the cable from Murmansk to Vladivostok is to be state-funded, the extension of the project to Europe and Asia was described as a separate commercial project.

A more detailed description of the Polar Express has recently been added to the homepage of Morsviazsputnik. Besides listing technical characteristics and project participants (state customers include the Ministry of Transport of the Russian Federation and Federal Agency for Sea and River transport (Rosmorrechflot), and contractor-developer FSUE Rosmoport), the homepage dates the beginning of the project back to 2020. The objectives of the project and the description of the advantages the trans-Arctic route can offer have a great resemblance with the descriptions provided by actors behind the other Arctic projects.

One obvious question that has come up is the possible connection between the termination of Arctic Connect and the emergence of the Polar Express. While no official statements have been made, there has been speculation that Megafon may have stepped back because it did not want to compete with the state-run project. While this is only speculation, the early explanation originating from the Russian media and spreading in the English language media concerning the freezing of the Arctic Connect only makes a little sense. In other words, the logic behind the claim that Megafon's decision was based on the inactivity of the Japanese partner Sojitz Corporation is difficult to follow. Sojitz Corporation led the group of Japanese companies who joined the Cinia Alliance and were interested in the international part of the Arctic Connect, not in the Megafon's fiber pairs landing in Russia. Furthermore, they were not expected to fund the whole project, but only to join as one of many international partners. When these rumors appeared, Cinia was quick to refute them.

Besides the cable routes through the Northeast and Northwest Passages, there has also been a project called Borealis that envisioned the shortest possible submarine fiber-optic cable crossing the North Pole. Although desktop studies were made already some years ago; it is unclear whether this project is still being actively developed.

Trans-Arctic Communication Cables and the Global Networks

Formerly, large-scale submarine fiber-optic cable projects were designed and implemented by international consortia involving telecommunication companies from different countries. However, recent years have witnessed the changing dynamic in ownership, notably a partial shift from the consortium model toward single ownership. In practice, companies such as Facebook, Google, Microsoft, and Amazon (so-called Big Tech) that used to buy a significant part of the carrying capacity of the cables owned by others began to join international partnerships as co-owners and eventually to develop their own submarine cable systems. At the same time, the global market is shifting from connecting population centers (city-to-city model) to improving connectivity between hyperscale data centers (data center-to-data center model).[8] This shift may eventually cause changes in the existing network topology as new routes and landing stations may gain greater importance. The connection between the improved fiber-optic connectivity and the possibility of attracting new data center investments in the Arctic has been discussed in recent years. The data centers consume a huge amount of energy but the cold climate could help in the cooling process and open new possibilities to re-use data center waste heat based on principles of circular economies. Although the new trans-Arctic cables can shorten the network latency and thus improve different Arctic regions' competitiveness, questions concerning the availability of a skilled workforce and risks related to the development of new sites outside of traditional data center markets, among other concerns, may remain obstacles hindering further development.

As the history of submarine cables is replete with conflicts between cable developers and other interest groups, telecommunication companies have traditionally been conservative when developing new routes. There are numerous technical reasons that favor the old routes, ranging from the need to connect new cable systems into older ones to the fact that data about the environmental conditions, seabed topography, sediment types, and natural hazards is already available when an old route is used. Furthermore, questions concerning no-anchor zones, other fishery-related issues such as bottom trawling (conflicting interests between cable developers and fishermen are quite common) and the environmental impacts on shorelines may already have been solved when landing in a place where somebody has landed before. The maintenance of new routes may also be more expensive, cable ships capable of correcting damages may be located far from the new routes, and uncertainties concerning market demand are higher in the case of new connections.[9]

These issues at least partly explain why different Arctic projects have faced difficulties in finding investors (Quintillion's Phase 1 was funded but the process through which investments were gathered has later been found to be illegal and the previous CEO has been imprisoned) and anchor customers, although the benefits of the new route are easy to explain. It is noteworthy that the most direct Arctic communication cables routes differ from the most direct Arctic shipping routes. While environmental conditions in the Arctic affect the speed of ships, the speed of the data transmission is the same everywhere and the shortening of the distance correlates directly with savings in transmission delay. Although the implementation of projects involving new cable landings might bring along new types of conflicts between cable developers and coastal communities, examples from Alaska speak well to the possibility to cooperate and find solutions acceptable for everyone.

As mentioned above, Polar Express is challenging the basic assumptions that the trans-Arctic projects would be commercial and multinational. However, it remains to be seen whether the Russian actors behind the project need technical support from foreign actors and how much there is capacity demand for Russian domestic data transfer through the Arctic. Although the plan to build the first Russian data center in the Arctic has recently been announced, the great majority of data centers and data traffic seems likely to take place in areas around Moscow and Saint Petersburg in the foreseeable future. The idea of connecting the new cable system into the global network is obviously attractive from the perspective of the Russian cable developers. However, many well-informed experts with whom the author has consulted seem to be rather skeptical about international actors' interest in the planned system. Finally, the fact that the Ready for Service (RFS) date of the Polar Express cable is still far away (the only ongoing submarine fiber-optic cable project with RFS date past 2024) may increase uncertainties around the initiative.

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14. Deep Sea Mining in the Arctic

Steinar L. Ellefmo

Introduction

Although the ocean covers more than 70 percent of our planet's surface, large parts of the deep ocean are still unexplored. Little is known about its inhabitants and how these hidden ecosystems function. With the need to reduce geopolitical supply risks and an increasing demand for mineral resources that are by many considered to be keys for the transition towards an increased share of renewable energy production and increased e-mobility, deep-sea mining has moved into the focus of international interest. The seabed and ocean floor within and beyond the limits of national jurisdiction and the subsoil thereof is estimated to contain vast amounts of essential metals such as zinc, nickel, and copper, as well as critical minerals such as cobalt and rare earth elements (Cathles, 2011; Ellefmo *et al.*, 2019; Hannington *et al.*, 2011; Hein *et al.*, 2020; Singer, 2014; Yeo *et al.*, 2018). These metals are found in seafloor massive sulphide (SMS) deposits along the mid-ocean ridges, in manganese nodules of the Indian and the Pacific Ocean, and in cobalt-rich ferromanganese crusts on underwater mountain ranges and on seamounts at great water depths with largely unknown ecosystems.

While Mineral Resource Management (MRM) is well established in the conventional, land-based mining and agriculture industries, strategies and plans for the management of deep-sea mineral resources still need to be developed in parallel with ongoing exploration and technology development activities. The aim should be to ensure an environmentally responsible, resource- and cost-efficient (economic) use of these limited and unique minerals for the benefit of mankind and a green energy future. Such strategies need to consider uncertainties and lessons learnt regarding the environmental impact of deep-sea mining, including measures and thresholds necessary to maintain a healthy ecosystem. This chapter aims to shed light on the question about whether deep sea mining can be executed in a responsible way. It gives a broad overview over potential mining technologies available in the public domain, outlines some of the resource potential, and briefly highlights some of the environmental aspects related to deep sea mining. This is discussed from an MRM perspective and an attempt is made to link this concept to deep-sea mining in the Arctic Ocean. No decisive conclusions are drawn as to whether or when mining can or should commence in this enigmatic area.

Arctic Characteristics Influencing Technology Selection

No formal definition of the Arctic exists. The region has been defined, however, based on various characteristics of the region: latitude (north of the Arctic Circle at 66° 33'N); temperature (warmest month with an average temperature lower than 10°C); forest line; the presence of permafrost; and culturally defined based on areas where northern Indigenous Peoples live. These varying definitions result in slightly different boundaries for the region in both geopolitical and ecological terms. Canada, Denmark (including Greenland and the Faroe Islands), Finland, Iceland, Norway, Sweden, Russia, and the United States are said to be "Arctic nations." Another definition of the Arctic can be based on the five countries that have economic zones and continental shelves in the Arctic Ocean. These are Norway, Denmark (Greenland), Russia, the United States, and Canada (Grønnestad, 2016). This latter definition is the center of attention in this contribution.

The region is characterized by long cold winters and short cool summers, with high temperature variations. The relatively warm ocean keeps the Arctic from being among the absolute coldest regions on the Earth. Average winter temperatures are in the range of -30°C to -35°C, with temperatures down to -45°C far from the ocean. Average summer temperatures are as stated above: below +10°C. Ice-free sections of the Arctic are warmer due to the relatively warm ocean that never drops below -2°C.

The amount of precipitation varies highly across the Arctic, with lows of about 150 mm of precipitation annually and highs of more than 1000 mm annually (Boisvert *et al.*, 2018). 500 mm precipitation annually is a representative number for most areas (Serreze and Hurst, 2000). Precipitation is expected to increase in the future (Bintanja *et al.*, 2020).

The design and selection of mining systems will be highly influenced by icing, wind, and wave characteristics at the site of interest. Marine operations in the Arctic will be exposed to icing through sea spray. The amount of icing is temporal and may vary between 0.7 and 4 cm per hour (Guest, 2005), dependent on wind speed, air temperature, water temperature, freezing temperature of water, wind direction relative to the surface structure, swell and wave characteristics, wave size, wavelength, and wave propagation direction (Guest, 2001). Icing may seriously affect stability, loading capacity, and other factors relating to any infrastructure on the surface.

Sea ice occurs naturally in the Arctic and its interaction with vessels will vary depending on the characteristics of the ice. Ice thickness, age, and extent will influence the vessels' ability to hold position and keep course. Sea ice status in the Arctic is published on a regular basis by the National Snow and Ice Data Center (NSIDC, 2021). Similarly, icebergs occur in the North Atlantic and may affect and influence any marine operation in the Arctic.

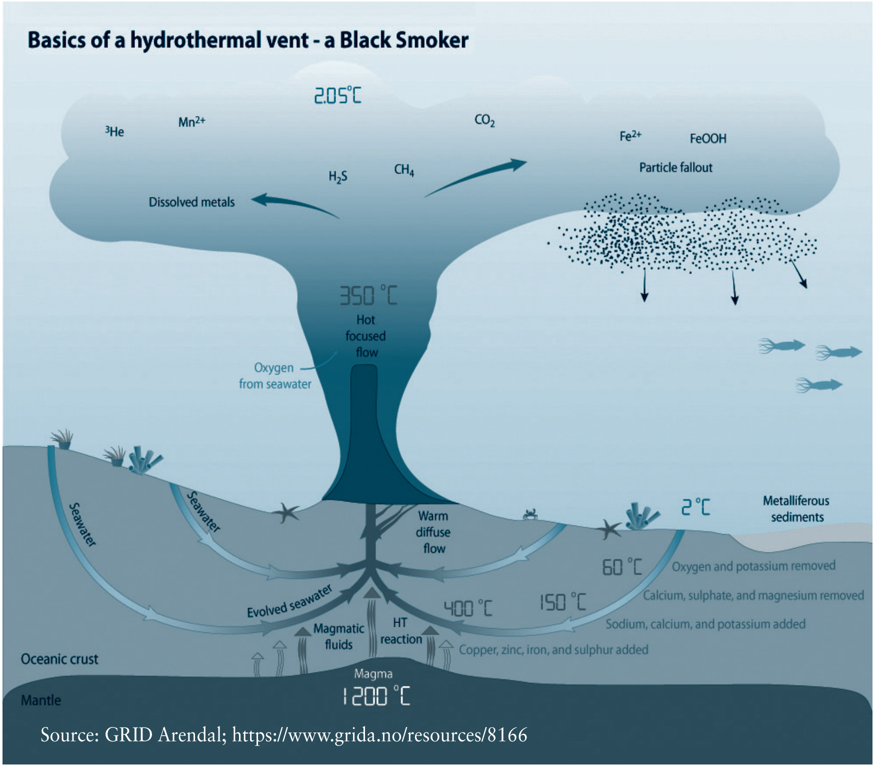
Data from the NORA10-database (Reistad *et al.*, 2011) can be used to gain some insight into wave characteristics in the Arctic. Along the Arctic Mid-Ocean Ridge, the data show a most probable Hs between 0.75 og 1.5 meter and a Tp between 7.6 og 9.5. During polar lows, large diameter Arctic hurricanes may appear with average speeds of about 50 miles per hour (NSIDC, 2021).

Resource Potential: A Focus on SMS

Figure IV.5 shows the basics of a hydrothermal vent. Driven by a heat source (magma), the seawater circulates into the crust and is heated to temperatures up to 400°C. The vent's physical characteristics are thereby changed, and hydrothermal fluids will leach metals from the crust as the fluids migrate towards the ocean floor through fractures and faults that can facilitate the flow. When the mineral-laden fluids reach the ocean floor, the metals are precipitated in and on the ocean floor. Where they are precipitated is a function of temperature, pressure, and fluid characteristics. Metals of economic interest may accumulate and form deposits with sulphide minerals, so-called seafloor massive sulphides (SMS) (Robb, 2005).

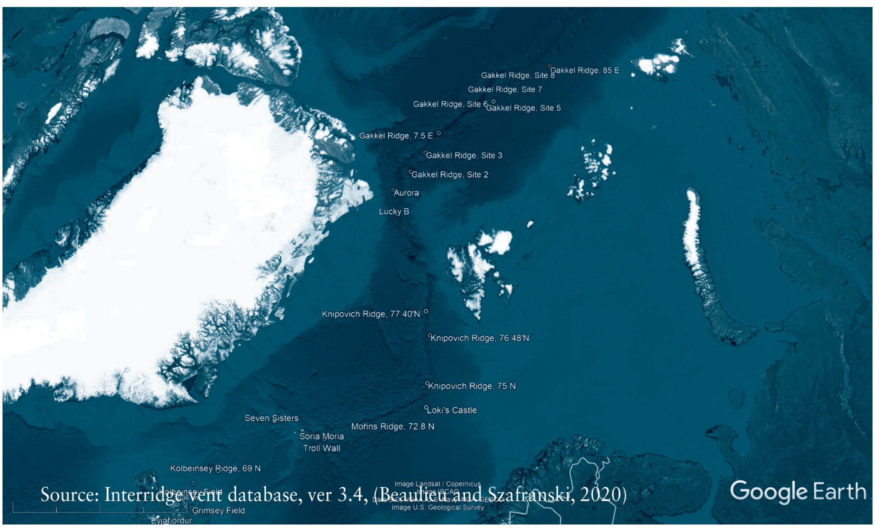
There is a highly uncertain but potentially large potential of these SMS deposits (Ellefmo *et al.*, 2019) along the Mohn's and the Knipovich ridges. There are also a number of indications of hydrothermal activity along the Gakkel Ridge (Edmonds *et al.*, 2003; Jean-Baptiste and Fourré, 2004; Snow *et al.*, 2001). Figure IV.6 shows sites of interest along the ridge system in the Arctic Ocean and along the Arctic Mid-Ocean ridge from the Interridge database (Beaulieu and Szafranski, 2020). These sites of interest include both confirmed sites (active and inactive) and indications in the water column.

The Arctic also contains a potential for crust and nodules (Ingri, 1985;



Source: GRID Arendal; https://www.grida.no/resources/8166

Figure IV.5 *Basics of a black smoker vent*



Source: Interridge vent database, ver 3.4, (Beaulieu and Szafrański, 2020)

Figure IV.6 *Sites of interest in the Arctic*

Jokat, 2000), but their amount and characteristics are unknown.

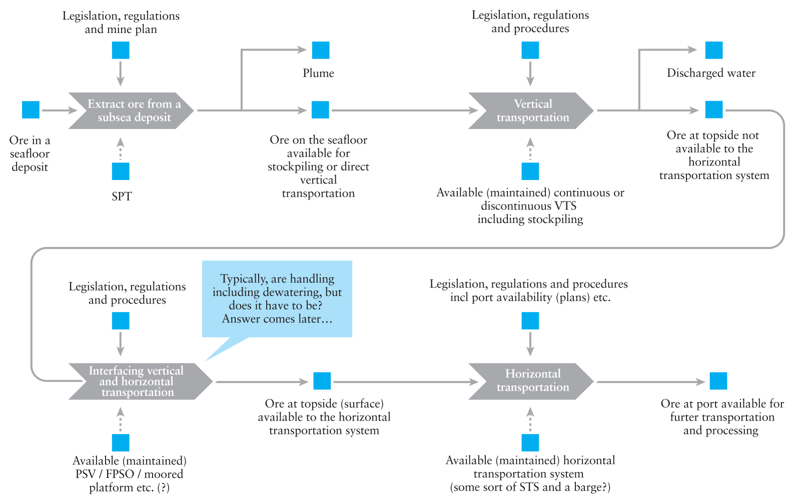
Deep-sea Mining

Figure IV.7 gives an overview over the deep-sea mining value chain. The model is made up of five types of components: input, process, output, the controlling elements (top down into the process) and supporting elements (bottom up into the process). The input is consumed or changed by the process. The process transforms the input into an output. The process can have multiple inputs and outputs which are the products and can act as inputs into the next process or functional structure. Supporting elements are used, but not consumed or changed, although wear and tear on equipment will occur during the mining process. The supporting element is normally an output from a secondary and not directly value adding process such as "Maintenance." The controlling elements dictate when and how the process or functional structure must be executed. These elements can for example be outputs from supporting processes like "Mine plan development" or "Development of Regional Environmental Management Plans."

Having a deposit on the ocean floor, this would be fragmented and mined through some crushing- or collection-production tool. This tool could be connected to a stockpile for temporarily storage or be directly connected to the vertical transportation system that transports the mined ore to the surface. On a type of production support vessel (a PSV), the ore would be dewatered, potentially further processed and stored before some means of horizontal transportation arrives to offload and load the ore for shipment onshore for further processing and beneficiation.

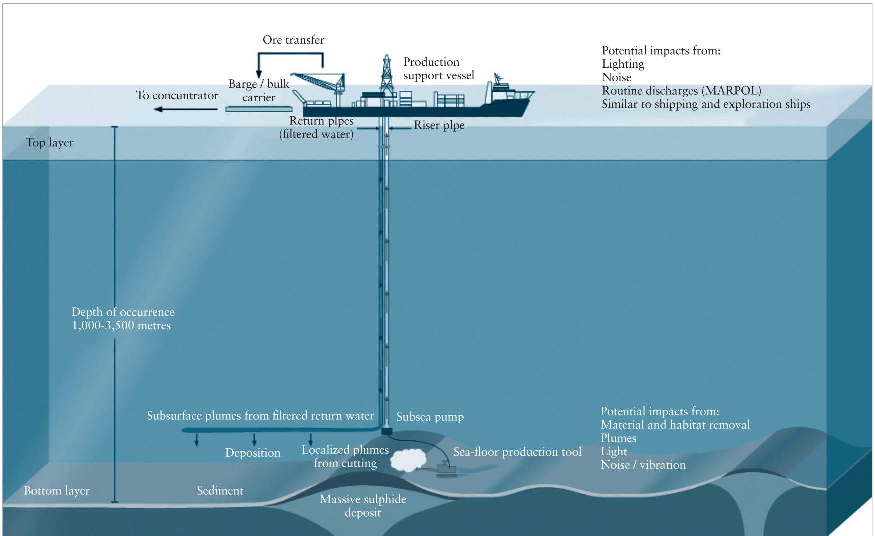
How any given deep-sea mineral deposit would be mined is a function of ecosystem characteristics, ore geometry and quality variations, water depths, and distance to shore, among other factors.

It is useful to consider both vertical and horizontal mining methods. Horizontal mining methods would be used on laterally extensive deposits, such as the large fields of manganese nodules in the Pacific and the Indian Ocean (and potentially crust if the inclination of the seamount surface is not too steep). Although the crusts can be up to +/- 20 cm thick, these deposits show a 2D extension. Vertical mining methods (Spagnoli *et al.*, 2016) that are based on drilling, trenching, or cutting technologies, would instinctively have been used on deposits that show a vertical extension, like the TAG site



Note: SPT = Seafloor Production Tools. IDEF0-model made based on function structures modelled in (Lesage, 2020).

Figure IV.7 Deep-sea mining value chain overview build using the IDEF0-methodology to model functions



Note: Seafloor production tools on the ocean floor fragment the ore. A vertical transportation system transports the ore to the surface, where the ore is dewatered and stored.
Source: GRID Arendal; https://www.grida.no/resources/8156

Figure IV.8 A conceptual mining system

(Grant *et al.*, 2018). Figure IV.8 shows a conceptual mining system setup for mining a SMS. It consists as illustrated in Figure IV.7 of the seafloor mining tools, the riser and lifting system, and the topside, the PSV.

A technology overview is given in Laugesen *et al.* (2021). A vertical transport system (VTS) could consist of a lift system or pumps, a riser, a flexible jumper, infrastructure for communication, and return pipes for transporting the return water back to the ocean floor. Various concepts for vertical transport systems have been developed for deep sea mining. Concepts of VTS for nodules or SMS show similarities, but there are differences driven by differences in the water depth and how these two deposit types would require a moving and a fixed mining system, respectively. Different VTS concepts can be classified as hydraulic systems, where the ore is moved as a slurry through the riser system using centrifugal pumps, an airlift system, or a combination of both, incorporating continuous line bucket lifting systems where buckets are attached to a line that lifts these buckets to the waiting PSV or in a modular or shuttle lifting system where the ore is lifted in batch, potentially using a buoyancy reserve. Hydraulic systems have so far been the suggested and the preferred solution.

Technologies for operating the vessel and deploying equipment envisioned for deep sea mining have been proven by ultra-deep water drilling as well as in the installation of subsea production systems in the offshore oil and gas industry. For deep-sea mining research projects in the 1980s, drilling vessels such as the SECO445 were adapted to nodules mining. Now, the former ultra-deep-water drillship Vitoria 10000 is in for reconstruction as a nodule collection vessel. The now-bankrupt Nautilus Minerals planned to build a custom-made vessel to support their hoped for operations in the Bismarck Sea. Their assets have been transferred to Deep Sea Mining Finance Ltd. Debmarine Namibia has built vessels especially suited for offshore diamond mining.

Environmental Aspects

Potential impacts from mining on the ocean floor and on the surface are illustrated in Figure IV.8. These impacts are dependent on the selection of the mining system, the deposit type (crust, nodules, active / inactive SMS), and include but are not limited to removal of habitats during mining, lighting, noise, vibration, sediment plumes from the mining operation itself (the cutting) and from the return water, and routine discharges during the operations (Danovaro *et al.*, 2020; Van Dover, 2012, 2019, 2011; Washburn *et al.*, 2019). The mining method selection process and the mine plan must aim to consider all environmental factors to reduce these to the minimum. For example, the generation of the plume is dependent on the detailed setup of the seafloor production tool and on whether vertical or horizontal mining is the preferred solution. To minimize environmental impacts, ESGs considerations (Environmental, Social and Governance) must be integrated into the whole-mine planning and design processes.

Marine Mineral Resource Management

Mineral Resource Management (MRM) was arguably first mentioned by (Blaauw and Trevarthen, 1987) and developed further by (Macfarlane, 2006). These authors defined it as the identification, optimization, and realization of the value of a mineral deposit. This is done by converting an inferred deposit into indicated and measured resources, to probable and proved reserves (JORC, 2012), and subsequently by developing the deposit and transforming the ore into a saleable product. The goal of MRM is to develop and implement the mine plan, where the mine plan is an overview specifying when the operation will extract what qualities and tonnages from where (Camus, 2002), taking all framework conditions into account. Haugen (2015) states that this includes mine planning, the organization and management of mining activities, and the communication of mine plans. In (public) governance, MRM is linked to issuing exploration and exploitation permits, reviewing and approving periodic mine plans, producting, environmental follow-up, and monitoring and processing of concession applications along with the definition of standards and guidelines. Core principles in MRM as it is applied to terrestrial mining are linked to environmental, economic, technological, geological, social, and legal factors. These factors are and will be equally important in deep-sea mining operations. An adaptive management system for deep sea mining application is given in Hyman *et al.* (2021) and a comparison between the Norwegian management system for petroleum resources and ISA's management system for marine minerals are made in Moses and Brigham. (2021). Durden *et al.* (2017) and Jones *et al.* (2019) review existing regulatory and management frameworks for deep-sea mining and contribute important input to future developments.

Norwegian Management of petroleum resources (Overland, 2018) on the Norwegian continental shelf (NCS) has received global attention and is one of the management models that is studied by the International Seabed Authority (Brekke, 2019). However, the work to finalize the international management system is ongoing (Brekke, 2021).

Discussion and Closing Remarks

Can we today do responsible mining from the deep ocean floor? We do not know. Available information about mining technologies in the public domain is sparse. Nautilus Minerals failed to commence mining in the Bismarck Sea. Their mining setup would not work in the Arctic (Lesage, 2020), with its rough sea and challenges with sea ice, icebergs, and icing. Components of the needed mining system, such as pumps, are available and proven technology, but crucial components have not been combined and tested into a system. Global technology and service providers delivering systems and solutions to offshore industry globally are naturally in a very good position to supply a future deep-sea mining industry with services and technologies. Offshore mining of diamonds and aggregates is taking place off the coast of Namibia and in the southern North Sea, with documented impacts (Robinson *et al.*, 2005). The water depths there are shallower and the rock that is mined is significantly easier to fragment than crust and SMS, which suffers from the hyperbaric effect (Kuiper *et al.*, 2016; Spagnoli *et al.*, 2016). Today, known deposits that are in the public domain with sufficient metal grades and ore tonnages to potentially justify mining are very few and the environmental challenges and consequences are to a large extent unknown. Data and information are crucial to reduce this uncertainty. These data can and will be collected during exploration and pilot studies and are necessary for responsible deep-sea mining and deep-sea minerals to be a part of the solution towards achieving sustainable development goals. The green transition requires minerals and metals. These can and will in the future still come from onshore mining but will benefit if backed by responsible and environmentally sound extraction from the ocean floor and urban mining (Kakkos *et al.*, 2020). A challenge today is that components of many ubiquitous modern technologies are not made to last, and it is not simple to separate metals in alloys in a cost-efficient manner. Are consumers willing to pay for this extra cost? In the future, components must be designed to last, be repairable and be recyclable when they are beyond repair. Given minerals' and metals' residence time in our society and the expected increase in demand for global living standard minerals, ongoing efforts to expand sourcing of these materials will be necessary. The simple fact remains that metals require mining, and mining, like every human activity, has impacts. We just must minimize the impacts through a holistic mineral resource management where environmental, economic, technological, geological, social, and legal factors, among others, are considered.

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15. New Korean Technological Developments for the Arctic

Sung Jin Kim

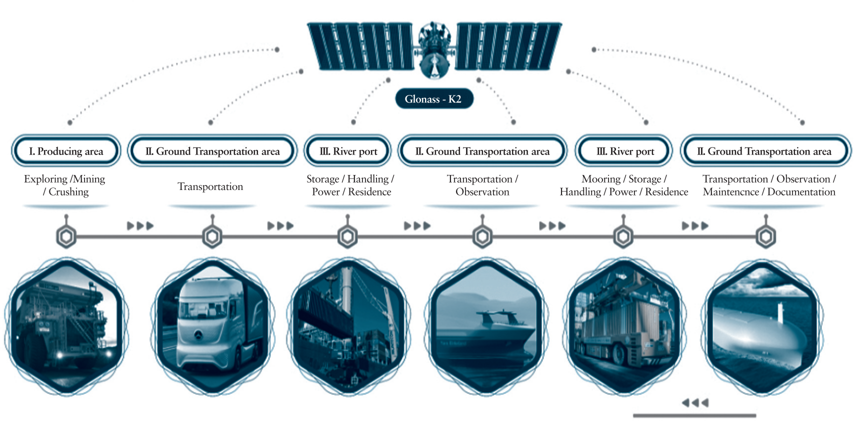
Marine Science and Technology Development in the Arctic

The ocean is considered the last frontier for addressing major challenges faced by humanity concerning food, resources, the environment, and undeveloped space. Therefore, we need to find the most effective way to use and preserve this valuable asset that humanity holds in common. Science and technology as well as close international cooperation are considered some of the most essential factors that could help us balance the use of the benefits of the ocean while addressing its challenges. Throughout human history we have witnessed continuous attempts and achievements in marine science and technology striving towards a more harmonious relationship between conservation of the marine environment and its utilization for human endeavor.

The oceans have been recklessly developed and exploited and are suffering from the effects of climate change, overfishing, and pollution. Recently, new technologies such as so-called Fourth Industrial Revolution technologies are being applied to the ocean, with expectations that they will be a "transformative force" in helping to address marine issues.[1] For example, those technologies can be applied in many ways to solve marine concerns, such as preventing illegal fishing, protecting marine habitats and species, monitoring marine pollution, managing the ocean, and exploring the ocean.

The World Economic Forum has selected the following 12 Fourth Industrial Revolution technologies that could potentially bring about great change when applied to the oceans: autonomous ships, SCUBA droids, underwater augmented reality glasses, underwater farming, undersea cloud computing, wave and tidal energy, ocean thermal energy conversion, deep sea mining, ocean big data, coastal sensors, biomimetic robots, and medicines from the seas.[2]

Today, challenges and opportunities coexist in the Arctic. The Arctic features unique environmental constraints, such as extreme weather conditions, a harsh marine environment, specific safety risks, and geographic isolation that make it difficult to build communications facilities and infrastructure. Nonetheless, with the acceleration of thawing as a result of a warming Earth, development of Arctic sea routes and resources is now in full swing, along with considerable changes to the economy, society, and culture. Breakthrough technologies, including Fourth Industrial Revolution technologies, present practical solutions to address this twofold situation in the region. These technologies will have greater economic value all over the world and are regarded as solutions to respond to challenges and expand opportunities in the Arctic.[3] For example, demands for convergence technologies are expected to grow, such as building the state-of-the-art eco-friendly vessels with ice-breaking functions, monitoring the seas and Arctic Ocean using big data, exploration and investigation into the marine environment using unmanned drones, reducing marine garbage in the Arctic Ocean, and prediction and prevention of plastic and oil pollution in the Arctic Ocean. Notably, the Arctic Council is actively engaged in developing solutions whereby scientific knowledge and innovative technologies are applied through six working groups in the areas of managing marine waste and micro-plastics, monitoring climate change and the ecosystem, protecting biodiversity, preventing and responding to marine contamination accidents, building a data network of the Arctic Ocean, and supporting a



Source: Sung-woo Lee, "Cooperation Ways for Commercializing NSR based on IRT4.0,'2021, p.13.

Figure IV.9 Examples of applying technologies of 4th Industrial Revolution to commercialize Arctic shipping routes marine blue economy.

Meanwhile, the arena of port operations and logistics related to the Northern Sea Route is being regarded as the most promising area where innovative technologies can be applied in the Arctic in a commercial manner. The Arctic sea ice is continuing to melt, generating opportunities to develop resources in the Arctic. Along with the development of infrastructure, new demands for marine transport and logistics will lead to building a comprehensive industrial network. One result is that demands for cutting-edge innovative technologies that take into account the unique conditions of the Arctic Ocean will also increase.

A Korean Case Study: Application of New Technologies that Contribute to Sustainable Development in the Arctic

The Korean[4] government is currently implementing a Korean Green New Deal (2020-2025) that includes adopting eco-friendly (green transformation) and new technologies (digital transformation) by 2025. Under the scheme, a total of 160 trillion KRW (~USD 133.5 billion) will be invested to create 1.9 million jobs. This policy is expected to upgrade eco-friendly new technologies in all industrial areas and to increase demands for cutting-edge new technologies that contribute to a sustainable development of the Arctic in the mid- and long term.

Korea's "Third Master Plan for Oceans and Fisheries Development (2021-2030)" suggests policies based on eco-friendly, smart, and digital innovative technologies. The "Policy Framework for the Promotion of Arctic Activities of the Republic of Korea (2018-2022)" also encourages development of new technologies that can contribute to sustainable development in the Arctic through application of technologies adapted to cold regions to shipbuilding, conducting research into a possible application of ICT and other technologies of the Fourth Industrial Revolution to the Arctic region, building a comprehensive monitoring system for environmental change in the Arctic Ocean, and establishing a comprehensive monitoring network for the atmosphere, land, and space. Key technologies that are currently being applied in the Arctic or are likely to be developed based on the above-mentioned Korean policies will be discussed below.

Icebreaking LNG carriers and eco-friendly vessels

Korea is making contributions in the area of shipbuilding and innovative marine technology. In particular, the nation's technology was highly recognized when it received orders for all of the 15 ice-breaking LNG carriers needed for Russia's Yamal LNG project. The country has satisfied all technical conditions, including: all functions of vessels need to operate normally under extreme weather conditions (at air temperatures of -50°C or below); meeting Arc7 standards at the level of Russian vessels, which break the ice by themselves and maintain intensity of the body enough for propulsion; ice-breaking needs to be done both in the forward and backward directions; and the vessel needs to maintain a certain speed (five nautical miles per hour) while breaking the ice and also the maintain the same speed as a general LNG carrier in waters with no ice.

Furthermore, Korea is taking the lead in building eco-friendly ships using fuels such as methanol and ammonia. Korea Shipbuilding & Offshore Engineering has recently signed a contract with Denmark's A.P. Moller-Maersk to build eight methanol-powered containerships (16,000 twenty-foot equivalent unit ships) for the first time in the world. Samsung Heavy Industries is conducting research and development to convert LNG- and diesel-powered ships into ammonia-powered ones in the future. In addition, the company is active in developing vessels powered by hydrogen fuel cells. These vessels using eco-friendly fuels are expected to be the main type of ships to navigate in the Arctic Ocean. At the same time, Korea's technologies to build eco-friendly ships will create an eco-friendly business ecosystem and contribute to sustainable development in the polar area. In December 2020, the Society of Naval Architects of Korea selected the Korean version of technology to provide cryosphere information of the North Pole Route, technology to predict ice performance of the vessel based on AI deep learning, simulators to evaluate economic and safe sailing in the Arctic based on AI deep learning, technology for vessels to respond to accidents in polar areas based on real-time simulation, and technology development for sailing control and test drives in ice fields.

Building an eco-friendly, energy self-sufficient village in the Arctic

In 2021, Korea began officially participating in the "Snowflake" project being carried out by the Sustainable Development Working Group (SDWG) of the Arctic Council, which is a pilot project to build a hydrogen station that emits zero carbon. This project aims to build a remote village that is energy self-sufficient and emits zero carbon by using renewable energy, hydrogen, or other eco-friendly energy fuels. Russia, which is taking the lead now, is planning to expand this project to include Indigenous villages within the Arctic region. Cooperation is being made to provide technical advice for infrastructure and micro-grid projects using hydrogen.

Next-generation icebreaker: innovative technology contributions to Arctic science

In the first half of 2021, it was decided to build a second ice-breaking research vessel, scheduled to begin operation in 2027. The icebreaker Araon, which is currently in operation, was designed to break one meter-thick ice and operate at a minimum temperature of –35°C. However, the specifications for the second vessel will be upgraded to 1.5 meters and –45°C, respectively. Besides, it being made more environmentally friendly by applying a double fuel system using both LNG and low sulfur oil. When put into operation, the vessel will be mainly used for Arctic Ocean research. By utilizing this next generation icebreaker, Korea is planning to respond to current challenges caused by climate change and ice-melting in the Arctic and to work with the Arctic nations on scientific cooperation and international scientific joint research.

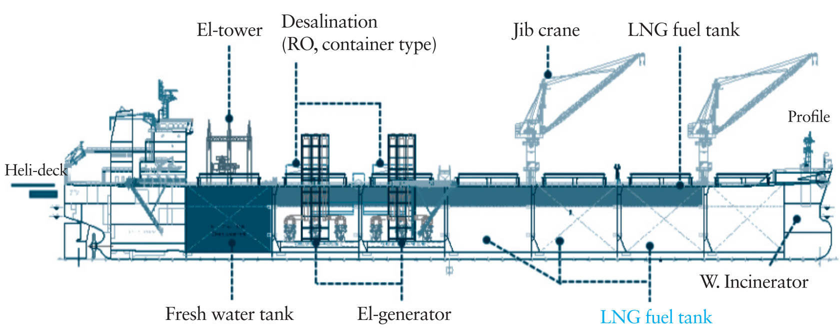
Korea is a non-Arctic state party to the Agreement to Prevent Unregulated High Seas Fisheries in the Central Arctic Ocean (CAOFA), along with China and Japan, and will host the first Conference of the Parties in 2022. Korea is also planning to adopt measures for joint scientific research and monitoring, information sharing and pilot operation management within three years. When the next-generation icebreaker is put into operation in 2027, research will be carried out on marine resources in regions at 80 degrees latitude or higher. In 2018, the Korea Polar Research Institute came in second place among research organizations working in polar areas in the world, showcasing the nation's world-class scientific technology related to polar areas.

Utilizing remote medical technology to respond to COVID-19

The Arctic Circle is characterized by extreme weather conditions, isolation, and low population density. The recent COVID-19 pandemic has exacerbated the isolation of the region. However, innovative technologies to respond to COVID-19 in the Arctic are emerging to provide new solutions to mitigate its isolation. This is due to the accelerated development of new technologies for remote and virtual services, and their commercialization is also being advanced. In the past, innovative technologies were not efficient due to high prices and investment costs, despite their utility. However, demands for those technologies increased significantly due to the COVID-19, making them the most realistic and efficient solutions. For example, if high-tech remote healthcare systems based on the successful "K-quarantine" standards are commercialized in the Arctic, they will contribute to solving problems in the region, such as remoteness and lack of healthcare infrastructure.

Prompt Port Facility (PPF)

Korea had suggested the idea of a "Prompt Port Facility (PPF)" as a project for cooperation with the Arctic region at times when the cost of second-hand ships was low. A PPF can be used to improve settlement environments for residents, as well as for disaster preparedness. A PPF will be made by remodeling a second-hand vessel and anchoring in adjacent waters to be used as a port. They are designed to perform main functions as a port facility as well as others, such as power generation, desalination, storage of key resources (drinking water, oil, grains), port control, small-sized education and healthcare facilities, habitation, and gardening.



Source: KangKi LEE, "Multi-Prompt Port Facility," NeLT-ITLS Seminar, April 2017.

Figure IV.10 *PPF "ALL IN ONE" solution model*

Notably, since a PPF is designed to adapt to extreme weather conditions by applying innovative technologies in each sector, these facilities are expected to be used in remote regions such as the Arctic, where infrastructure is underdeveloped and population density is low.

Communications technology to enhance connectivity in the Arctic

The Arctic Economic Council (AEC) is working on developing technology to connect remote areas in the Arctic by building a communications network through the Connectivity Working Group. In particular, Arctic nations are building underwater cables to create the most direct communications network connecting Europe and Asia through the Arctic Ocean. As a world-class ICT powerhouse, Korea has great potential to construct a communication network connecting Indigenous communities in the Arctic Circle and connecting the Arctic and non-Arctic regions through underwater cables by utilizing these new technologies.

Other applicable technologies

Korea is planning to develop innovative technologies in the maritime sector based on the "Third Master Plan for Oceans and Fisheries Development" until 2030. First of all, it will try to apply smart technologies to marine transport and port management. It will conduct a phased development of autonomous vessel technologies and build port infrastructure for safe navigation. In addition, it will develop intelligent smart ports where the loading/unloading and transferring systems are automatized and optimized. Connectivity will be enhanced through digitalization throughout all stages of fisheries operations, and virtual distribution systems for fishery products, such as online auctions and transaction platforms. These innovative technologies will be applied in parallel with zero-carbon, eco-friendly technologies and ecosystems. Technologies to build the next generation of eco-friendly vessels and ports are being developed, as well as those to monitor and reduce air pollutants coming from marine transport and ports. Technologies to manage digital-based marine spaces in a comprehensive and optimized manner are also under development. Korea is planning to build infrastructure for innovative technologies in the marine and fisheries area by 2030, which is expected to promote utilization of the infrastructure and businesses in the Arctic Circle surrounding the Arctic Ocean in the mid- and long-term time frames.

Possible Cooperation in the Arctic and Challenges Ahead

Avenues for cooperation

Innovative technologies are influencing the entire globe without being confined to certain industries or sectors. Given its environmental restrictions and limited human resources, the Arctic Circle will be one of those places where innovative technologies are needed the most. Consequently, Arctic nations will actively adopt policies to introduce innovative technologies and expand cooperation with countries that have those technologies.

Exploring innovative technologies where both Korea and Arctic nations are competitive can be a key area where Korea can contribute to the development of Arctic-related industries. Korea, even as a non-Arctic nation, can make a huge contribution to applying Fourth Industrial Revolution technologies to Arctic industries. In its role as an observer country in the Arctic Council, Korea can assist in the sustainable development of the Arctic as a responsible partner for cooperation and create future business opportunities in the Arctic. This cooperation will be carried out in the form of: 1) "top-down" cooperation, such as developing agendas for technology exchanges and cooperation through high-level consultations on the Arctic that are held regularly between Korea and Arctic nations; 2) cooperation, joint research, and technology exchange between businesses to promote new industries based on innovative technologies in the Arctic Circle and; 3) "bottom-up" cooperation through regular consultations between research institutes of Korea and Arctic countries to share technologies and research achievements in areas where each party has a competitive edge, to conduct mid- and long term R&D projects, and to make policies based on achievements, among other possibilities.

Challenges

However, there are some prerequisites to be met before proceeding with such cooperation.

First of all, since companies with proprietary technologies want to use their information and technologies for profit, an institutional strategy is needed to utilize or share intellectual property for public purposes. For example, it is necessary to build an information platform to collect and provide information that can be made public among member companies of the AEC. It may be useful to introduce institutional incentives so that companies can regard such technical cooperation as part of a win-win strategy.

Second, infrastructure to ensure connectivity, such as broadband infrastructure, needs to be built in order to utilize innovative technologies in the Arctic region. To this end, when the ongoing project to install underwater cables is successfully completed, a network of underwater cables for optical communications that connects the Arctic and Asia also needs to be constructed.

Third, the extreme weather of the region should also be taken into account when introducing and using innovative technologies in the Arctic. It is not certain whether innovative technologies designed to be applied in normal weather conditions will also work well in the Arctic extreme weather, which brings us another challenge. Across the board, we need "winterization" to make it possible to use existing innovative technologies in the Arctic. To do so, facilities need to be constructed that can provide research and development capacity to test technologies in the polar region.

Fourth, to appropriately utilize technologies of the Fourth Industrial Revolution, education is also needed for concerned parties in the region that includes Indigenous populations. Furthermore, there is a need to train experts how to apply these technologies in different areas in the mid- and long term.

Conclusion

The development of Arctic science and technology is a prerequisite for the sustainable development of the Arctic region, and scientific and technological cooperation between Arctic and non-Arctic states is at its core. Creating synergies utilizing the technological capacity and potentials of respective states through cooperation and utilizing this to respond to challenges in the Arctic while creating the impetus for further development is needed. As a platform for discussing Arctic issues for the past 10 years, the North Pacific Arctic Conference (NPAC) has examined various issues and offered suggestions. At a point where NPAC is looking at the next decade ahead, it is hoped that NPAC will seek to strengthen its role in leading the discourse in Arctic science and technology. Perhaps a scientific and technology taskforce or a working group under NPAC auspices could be created, where experts can discuss topics concerning Arctic science and technology and present summaries of their work at the annual NPAC conference. This could help promote multidisciplinary and convergent perspectives to science and technology-industry-policy issues being discussed at NPAC and also provide forward-thinking solutions.

Notes

1. World Economic Forum, *A New vision for the Ocean: Ocean systems Leadership and the Fourth Industrial Revolution*, June 2017.
2. World Economic Forum, searched on September 10, 2021. https://www.weforum.org/agenda/2016/09/12-cutting-edge-technologies-that-could-save-our-oceans/.
3. McKinsey has forecast that twelve technologies of the fourth industrial revolution will create an economic ripple effect worth $16.7 trillion minimum and $40.4 trillion maximum by 2025. McKinsey Global Institute, “Disruptive technologies: Advances that will transform life, business, and the global economy,” 2013, p.12.
4. In this paper, ‘Korea’ refers to the Republic of Korea.
5. According to the 2018 Nature Index, Korea Polar Research Institute was ranked second after the British Antarctic Survey.

PART V

TECHNOLOGICAL DIMENSIONS OF ARCTIC GOVERNANCE

Highlights from Session 5, North Pacific Arctic Conference 2021

Technological Dimensions of Arctic Governance

Session 5 consisted of a structured discussion between participants knowledgeable about specific governance challenges in the Arctic and those with expertise relating to advanced technologies. The goal was to explore how technological applications might help address an array of governance needs and how to best facilitate the development of these options. This session gave special emphasis to issues of protecting biodiversity and managing Arctic shipping.

Chairs and Organizers:

Jian Yang, Vice President, Shanghai Institute of International Studies
Oran R. Young, Professor Emeritus, Bren School of Environmental Science and Management, University of California, Santa Barbara

Panelists:

Jian Yang and Guijie Shi, Shanghai Jiao Tong University.
Xiao-Shan Yap, Department of Environmental Social Sciences, Swiss Federal Institute of Aquatic Science and Technology (EAWAG)
Tom Barry, Executive Secretary, Working Group, Conservation of Arctic Flora and Fauna (CAFF).
Paul A. Berkman, Director, Science Diplomacy Center, EvREsearch.
Misako Kachi, Senior Researcher, and Naoko Sugita, Advisor to the Director, Japan Aerospace Exploration Agency (JAXA).
Karen Pletnikoff, Environment & Safety Program Administrator, Aleutian Pribilof Islands Association.
Walker Mills, United States Marine Corps (NPAC Fellow)

Discussion Highlights:

An established forum for dialogue between technology developers and users is needed, since there are many advanced technologies, each with its own distinctive features, and also needs for improved governance that vary depending on the particular challenge and stakeholders involved. Whether formal or informal, a forum in which developers and users could explore options for adopting existing technologies or tailoring them for Arctic applications would be useful. Case studies of successes could inform this effort.

Combinations of advanced technologies can address some specific needs for governance. For example, data on Arctic shipping derived from satellite-based automatic information systems (AISs) using computer algorithms capable of integrating big data can identify trends and patterns relevant to best practices and enforcement of regulations.

A balance should be struck between advanced technology developers, who are often motivated to come up with new and more powerful applications, and technology users, who want to address current needs for governance in a timely, cost-effective fashion. Responding to the practical needs of users need not discourage exploration of new frontiers in advanced technologies.

Stages in the governance process should be distinguished. Responses may range from identifying emerging issues giving rise to new governance needs through creating and administering governance systems, monitoring progress toward fulfilling treaty obligations, and adapting monitoring systems to meet changing circumstances. Applications of advanced technologies may depend on the stage in the governance process considered. For example, whereas transmitters attached to migratory birds may help in identifying where additional protection is needed to maintain biodiversity, satellite observations can also help determine compliance of ships operating in the Arctic under the existing provisions of the Polar Code, perhaps triggering enforcement actions.

It is one thing to identify possible governance applications and another actually to apply them. It is important to understand how the dynamics of innovation systems determine success or failure of specific technologies. This requires considering the building of new market segments, the creation of technological legitimacy among users, the fostering of entrepreneurial experimentation, and the shaping of regulations and standardization to facilitate adoption of the new technologies. For successful technological diffusion, these different processes must align with each other. Without clear demand, companies are less interested in investing in technological improvements or adaptations. Arctic shipping suggests that public-private partnerships in the Arctic can be a core strategy in connecting technological tools with governmental users.

While the range of potential applications is broad, there are also actual or potential downsides that need to be taken seriously. These may range from restrictions on access to relevant data arising from privacy concerns to sensitivities associated with dual use technologies. For example, data from observation systems critical for the administration of regulatory arrangements may also entail risk of endangering privacy.

16. Innovations in Marine Technology and the Needs of Arctic Governance

Jian Yang and Guijie Shi

Introduction

Human activities in the most populated parts of our planet have environmental, societal, and economic impacts that extend to its less populated regions. Human-induced planetary warming is leading to climate changes occurring faster in the Arctic than anywhere else on our planet. In turn, due to the Arctic's outsized role in the earth's climate system, the growth of human activities in the Arctic also has impacts that extend around the planet.

A recent increase in human activities across the Arctic has been made possible by advances in marine technology, with shipbuilding as the core. Innovations in marine technology can and do also play an important role as tools in the governance of the Arctic. Based on the Polar Code, ISO 19906 (an International Standard for Arctic Offshore Structures)[1] and other governance mechanisms for the Arctic, this chapter explores the main innovations in marine technology and equipment in the context of a growing need for more robust Arctic governance, and explores ways to enhance international cooperation in the development of Arctic marine technology and equipment innovation.

By linking the development of ocean technology with the needs of Arctic economic development and Arctic governance, we can see that Arctic Ocean technology and equipment innovation has four categories: Innovations driven by traditional thinking; innovations for environmental protection; innovations for practical application; and innovations for observing information systems.

Innovations driven by traditional thinking

In this category of innovation, the equipment and materials are generally new but the ideas and purposes of the innovation still remain traditional ones. In traditional thinking about innovations in marine technology and equipment, people have sought, for example, new types of steel to increase the strength of the hull, new technology to improve icebreaking ability, new engines to improve the ship's sailing ability, and new energy supplies to increase ships' range, among other improvements in vessel design and operation.

This concept of innovation driven by traditional thinking seems to be a contradiction in terms, since change by its nature does not easily mix with tradition. However, change can also be incremental and build on existing designs without completely abandoning traditional approaches. At present, many of the innovative resources used for marine equipment in the Arctic Ocean are still concentrated in this area of incremental advances. These innovations can increase the reliability of equipment and the safety of personnel. They are called traditional innovations because the purposes and the driving forces of these innovations or improvements are almost identical to those of people who built marine equipment 200 years ago: 1) to upgrade the capability of human to go further, be stronger, be more powerful and to work more in harsh, cold, conditions; 2) to liberate humans from the hardships of manual work; 3) to upgrade safety of the marine equipment; and 4) to find natural resources and to utilize them for human benefit.

We can still see in the Polar Code and ISO 19906 and other regulations for offshore oil and gas drilling platforms that many design changes are focused on improving the level of reliability with respect to personal safety. These are traditional innovations, and these innovations are welcomed by ship owners and crews. In the context of this traditional model, any damage or deterioration to the environment by the equipment and machines is likely to be negligible or treated as a secondary consideration.

Innovations for environmental protection

The second group of innovations are innovations for the purpose of environmental protection. In the two documents Polar Code and ISO 19906 an International Standard for Arctic Offshore Structures, rulemakers put forward more stringent requirements for environmental protection and ecological protection in response to the fragility of the Arctic biological system and the difficulty of cleanup operations should any spill or pollution discharge occur. At the same time, in response to the global trend to accelerate emission reductions, more stringent requirements for designing and manufacturing marine equipment have been put forward to decrease exhaust and carbon emissions of polar ships and other offshore engineering equipment. This type of innovation aimed primarily at environmental protection looks to reduce and limit negative externalities. These innovations seek alternative materials and ways to adopt new technologies to reduce dumping and emissions. For example, the use of heavy oil is being phased out in favor of less polluting fuels, and no toxic or harmful liquid substances are allowed by law to leak into the Arctic Ocean and frozen soil. On the one hand, this type of innovation must meet the requirements of Arctic governance, especially environmental protection, and on the other hand it strives to reduce costs so that purchasers and users of this new equipment are also commercially profitable.

Polar waters are highly sensitive to environmental contaminants and the effects of warming on sea ice cover duration and extent. Global efforts to reduce emissions and slow the rate of warming are important to prevent the accelerated melting of ice, but so are efforts to reduce impacts on marine life in polar waters, which exist in an intricate web connecting invertebrates to mammals. Therefore, pollution prevention requirements for ships, in addition to meeting the existing MARPOL requirements, must consider carbon emissions and gray water emissions, and even a proposed ban on the use of heavy oil, as well as the ability to recover pollutants, and institute underwater noise controls. These goals pose a challenge to ship design. Meeting the requirements of pollution prevention will increase costs, which in turn will affect the shipping economy and the willingness of shipowners to operate in the Arctic. The focus of innovation is to discover new materials and technologies to meet the requirements of the Polar Code without greatly increasing shipbuilding costs and affecting the original capabilities and functions of the ship. The Polar Code already prohibits any discharge of oil or oily mixtures, noxious liquid substances, or mixtures containing such substances from any ship into Arctic waters, and the shipping has slowly been responding to these requirements.

At the 60th meeting of the Marine Environmental Protection Committee (MEPC), significant progress was made in creating technical measures to reduce exhaust emissions and air pollution. These include developing relevant mandatory texts for the Energy Efficiency Design Index (EEDI) of new ships using MARPOL Annex VI as the legal framework. From the perspective of environmental protection, this is a very big improvement. However, compared to improvements aimed at upgrading the safety of people and ships navigating in ice regions, the problem of reducing exhaust emissions and air pollution is a more difficult task. Ships built in accordance with the Energy Efficiency Design Index (EEDI) can lack sufficient power to operate in the special navigation environment of the Arctic. In some cases, ships are not able to maintain normal speeds or move forward in turbulent winds and waves. If a ship in the ice zone does not have sufficient power, it is likely to become stuck. Therefore, any innovations in ship design must strike a balance between power and efficiency in order to meet the requirements of EEDI and properly function in cold Arctic regions.

The Arctic environment can be more sensitive and vulnerable to pollution than more temperate regions. Structures intended for such environments should be designed to minimize the potential for polluting the environment as far as is reasonably practicable. For example, scientists have developed bacteria-resistant paints that could help prevent biofilms from forming on ship hulls, helping to reduce the introduction of invasive species in Arctic waters.

According to ISO 19906, some structures should be designed to contain spills that can result in the case of any inadvertent release of contaminants into the environment. Structural systems requiring active operations to avoid pollution should be kept to a minimum. Harmful environmental impacts should also be minimized in the construction, transportation, installation, and decommissioning phases. Special attention should be given to containing fluids and materials used for commissioning in order to avoid potential harmful releases to the environment. Fluids and materials that, if released, can pollute the environment should be contained in tanks having double barriers. Structures should be designed to facilitate environmental monitoring, which is addressed in ISO 35103. A protocol should be established for the inspection, maintenance, and repair of any tanks containing fluids or materials that can possibly pollute. Higher dissolved oxygen content can be encountered in cold water regions. Since higher oxygen levels can enhance corrosion, local data should be collected to assess this hazard, when relevant, for choosing structural materials.

Innovations for practical applications

The third category is application innovation. Application innovation refers to newly developed marine equipment technology in other parts of the world that need targeted design modifications to meet the needs of the extreme conditions of the Arctic and unique application needs. With the development of technology, the discovery of Arctic resources, and changes in Arctic natural conditions, the types of human activities in the Arctic have begun to increase. Some activities carried out in low-latitude oceans have also begun to appear in the Arctic. Therefore, people hope to design new tools to develop new production and social activities in the Arctic Ocean. This provides an opportunity for marine engineers to create new or adapted technology for the need of Arctic marine activities.

For example, in open water in low-latitude regions, offshore oil and gas extraction activities are commonplace, wind power generation devices are regularly installed offshore, submarine cables are laid, and aquaculture cages are installed in the ocean. But in order for these activities to take place in polar waters, technological innovations for application must adapt these technologies to the Arctic.

American ExxonMobil and Norwegian Kvaerner have submitted patent applications for ice-resistant drilling rigs that can be left in place over the winter season. Some robotic IT equipment, such as nimble robotic hands, immersive vision systems, and humanoid walking robots, are also reducing the need for people to be on site at all times. Several subsea cables are under development to bring high-speed communications to remote Arctic locations. The Arctic Fibre and Arctic Link broadband projects will span more than 15,000 km from Japan to Europe, running through the Northwest Passage.

The "innovations for practical application" focusses on taking into consideration and adapting to conditions in polar waters (such as low temperatures, high latitudes, dark polar nights, and remoteness) that may affect hull structure, stability characteristics, machinery systems, communication systems, navigation, equipment functionality and efficiency, maintenance and emergency preparedness tasks, and performance of safety equipment and systems. "Winterization" is one main approach to realize these innovations for application. This involves the process of ensuring that a structure is suitably prepared for and capable of operation in the extreme winter conditions in polar waters. The objective is to design operations with appropriate materials that will perform in extreme conditions and create reliable functionality of systems and equipment, as well as a safe working environment for personnel.

These innovations for practical application in Arctic Ocean focus on the following four areas: Transport and communication equipment, resource development equipment, equipment for scientific research and monitoring, and rescue equipment.

Polar transport equipment includes multi-purpose ships, semi-submersible ships, oil tankers, LNG ships, container ships, bulk carriers, ore carriers, cruise ships, and other vessels. Polar resource development equipment includes seismic ships, drilling ship/platforms, fixed production platforms, floating production ships, subsea production systems, offshore support ships, and other related infrastructure. Polar rescue equipment includes icebreakers and lifeboats. Polar equipment for scientific research and monitoring will be discussed in the next section.

Innovations for observing information systems

The fourth category is innovation aimed at data integration of observation systems. This innovation category involves new missions and activities of mankind in the Arctic to strengthen the understanding of changing ecological conditions of both the Arctic system and the Earth system. In order to understand the dynamic changes taking place in the Arctic system, comprehensive scientific observation data is needed. Today, most Arctic data are handled in a fragmented manner. Humans began studying the Arctic to help with weather forecasts, and later carried out surveys that included measuring ocean currents, seabed locations, ice conditions, and biodiversity. Early data about the Arctic Ocean, weather, and ice conditions are mostly scattered around a variety of shore-based and ship-based measurements. This has led to data that is spatially and temporally fragmented due to regionally different approaches, measurement standards, and different sources of data from different periods in time.

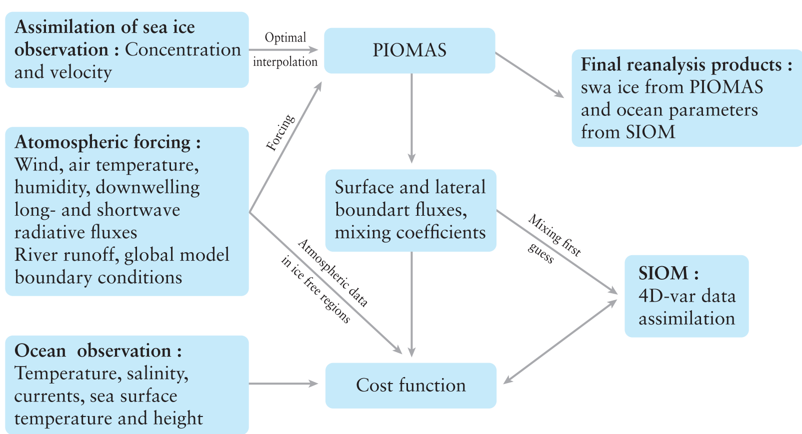
Data collection is now multi-dimensional. In addition to increasing the amount of shore-based and ship-based data, today's observational platforms include space-based, outer-space-based, ice-based, and underwater measurements that also obtain data. With the increase of different kinds of measuring devices, including aircraft-borne equipment, the number and kind of sensors used to obtain data is rapidly growing.

Another important effort underway is assimilating and integrating data of different scales, sources, and time periods with the help of information technology. These efforts aim to improve data assimilation and improve the accuracy and completeness of assessing trends of change in the earth system, ocean system, and polar system. This data integration helps in making more comprehensive analyses of these complex systems, and therefore, it is of special significance. Regarding technological innovation in this area, we can get inspiration from the field of data assimilation.

Data assimilation is an approach to combining dynamic models and observations to obtain an estimate of the true state of a system and model parameters (Wikle and Berliner, 2007). Data assimilation is a powerful technique which has been widely applied in investigations of the atmosphere, ocean, and land surface. It combines observational data and the underlying dynamical principles governing a system to provide an estimate of the state of the system that is better than could be obtained using just the data or the model alone. Much of the Arctic Ocean is covered by year-round sea ice. Ideally, any data assimilation procedure should take into account dynamic ice-ocean interactions and data assimilation algorithms should be designed for a sea-ice–ocean coupled model system.

Observations from the International Arctic Buoy Programme (IABP) were designed to monitor Arctic and global climate change and aid in forecasting weather and sea ice conditions while assimilating and validating global weather and climate models and validating satellite data.

The Integrative Data Assimilation for the Arctic System (IDAAS) has

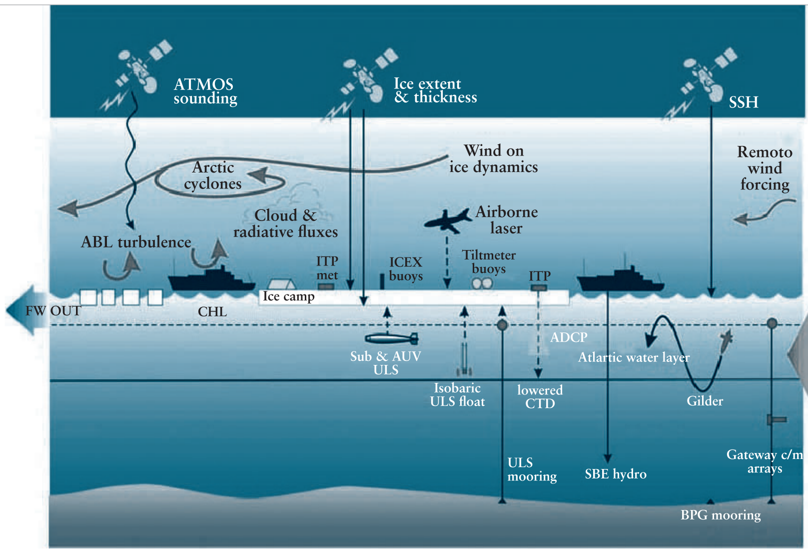


Source: Andrey Proshutinsky,Dmitri Nechaev, Jinlun Zhang and Ron Lindsay, Toward reanalysis of the Arctic Climate System–sea ice and ocean reconstruction with data assimilation. https://www.whoi.edu/science/PO/arcticgroup/projects/andrey_project2/indexAP.html.

Figure V.1 Data flow chart for the data assimilation procedure been recommended for development by a special interagency research program, "A Study of Environmental Arctic Change." IDAAS activity would include non-atmospheric components: Oceanic, terrestrial geophysical and biogeochemical parameters, sea ice measurements, and human dimensions data.

The Pan-Arctic Ice Ocean Modeling and Assimilation System (PIOMAS) is one model to understand data assimilation and information integration. The original version of SIOM (Semi-Implicit Ocean Model) does not model sea ice, but now it is able to assimilate the momentum, heat, and salt fluxes between ice and ocean. It includes a coupled ice–ocean model. Arctic Climate System Reanalysis uses modern four-dimensional variational (4D-Var, adjoint) data assimilation methods to integrate the coupled information.

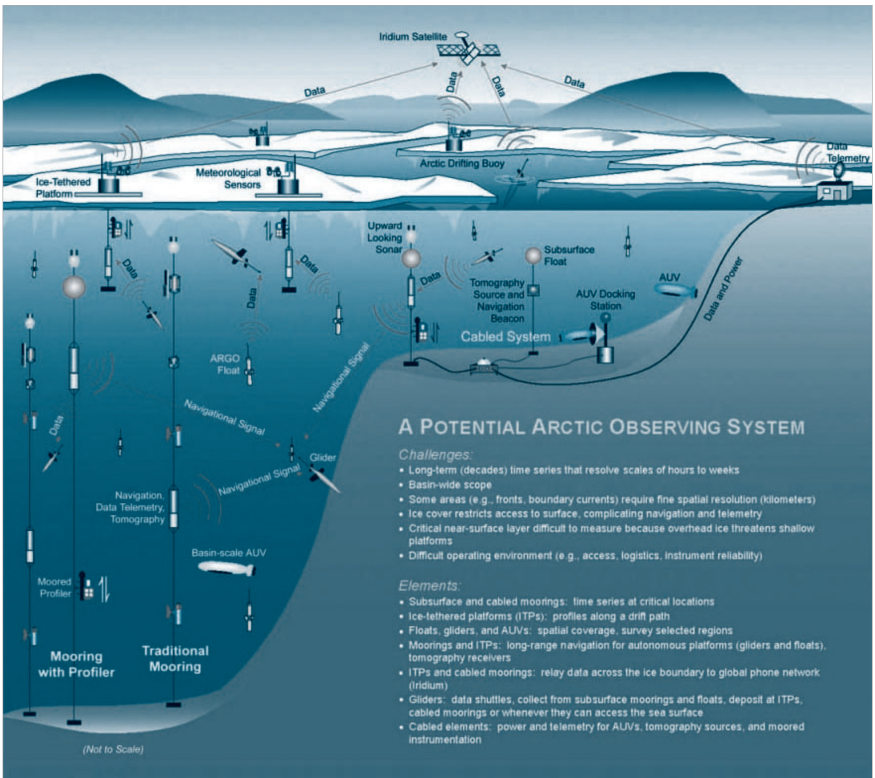
In order to record and describe the changes that are taking place in the Arctic more clearly and accurately and to predict the trends of future changes, technology needs to solve two major problems: One is to increase the number of monitoring devices as well as the spatial reach and measurement capabilities of various measuring equipment. It is important



Source: http://www.iopan.gda.pl/oceanologia/481dicks.pdf

Figure V.2 Schematic of the vertical stack of observations from satellites to seabed in the integrated Arctic Ocean Observing System (iAOOS) to maximize access to various data that are useful for governance decisions from different parts of the Arctic system. Another problem to be solved is the isolation of ocean technology (the relatively isolated location of different ships) and the fragmentation of data (including spatial and temporal data fragmentation), which are the main reasons for the low degree of information integration in the Arctic Observation System.

Out of this need for data assimilation and information integration, marine equipment innovations must incorporate designs that include navigation equipment that can accurately chart sea surface area, the seabed, as well as a certain subsurface areas at specific depths required for key scientific observations. These must be coupled with cruising and data collection methods that are optimized to obtain data and information. At



Source: "Arctic Sea Ice and Ocean Observations" G. Rigor, of the Applied Physics Laboratory (APL), University of Washington, Seattle;
https://www.nsf.gov/pubs/2005/nsf0539/nsf0539_4.pdf

Figure V.3 Components of the Arctic Ocean Observing System (AOOS) the same time, it is necessary to design ways for this special navigation equipment to transmit information and data in a timely, safe, and reliable manner.

Marine equipment innovations in this category include directly designing small equipment that can operate in seabeds, underwater, on the sea surface, and on ice. These innovations can also ensure information transmission and networking instead of simply allowing monitoring equipment to be carried on ships. There is a need to place monitoring and observation devices on submarines, such as specially designed underwater and surface unmanned and remote-control devices. In the realm of data collection, compatible data standards must be established for the next step of information processing (data assimilation, integration, simulation, calculation, and modeling).

These marine equipment innovations must be systemic, compatible, and connected with shore-based equipment, aircraft onboard equipment, and existing space-based equipment. Marine equipment acts as a hub and platform for equipment release, machine installation, data collection, and safety assurance. These hubs can be connected to the connection, installation, and data transmission of various space-based, aircraft, surface, underwater, seabed, and ice equipment. For example, marine equipment can become a receiving station for GPS satellites and other satellites on the sea and ice. Innovations in marine equipment must also consider ways to function as connecting hubs in multi-dimensional observations of the Arctic, and must take into account the technical requirements of various data collection and processing centers that receive information from shore-based, airborne, and satellite observations.

From this perspective, marine equipment used for measurement and observation is also based on Arctic governance requirements. From the design or modification of related marine equipment, it is necessary to consider the need for data assimilation and data integration into the system of systems.

From the above picture we can see a range of marine equipment that is needed for Arctic observing system. This includes Basin-scale AUV[2], ROV[3], CTD[4], Mooring with profiler, gliders with water lasers, ARGO float, cabled seabed systems, AUV docking station, subsurface float, upward looking sonar, drifting buoy, Ice-Tethered Platform (IPTs), cabled mooring, data shuttles, tomography receivers under the water, and others.

International Cooperation for Arctic Marine Innovation

Marine technological innovation in the Arctic requires new knowledge, new technologies, and extensive international cooperation. The international cooperation process for the development of the Polar Code is one of the most successful efforts to date regarding Arctic governance.

Under the guidance of the concept of goal-based governance led by IMO Secretary-General Koji Sekimizu (Japan) and his successor, Kitack Lim (Korea), representatives from East Asian maritime countries cooperated with their counterparts from Arctic countries and other important shipping countries using the platform of the International Maritime Organization (IMO) to promote the adoption and implementation of the Polar Code.

This chapter introduces ISO 19906 as an International Standard for Arctic Offshore Structures. The following table provides a list of countries represented in WG8 during work activities, as well as the main representatives and their affiliations. This illustrates that the Standard has combined the knowledge and experience of both Arctic and non-Arctic countries. As can be noted, the Arctic countries (Canada, Denmark/Greenland, Finland, Norway, Russia, United States) and non-Arctic countries (China, France, Germany, Italy, Japan, Kazakhstan, Netherlands, and the United Kingdom) were represented. Significant experience had been gained with measuring ice loading from offshore exploration structures deployed in the Beaufort Sea during the 1980s. Newer research projects, such as the European Lolief and Strice projects and measurement of ice loads in Bohai Sea in China and on the Confederation Bridge in Canada and in Japan (JOIA), provided new insights into ice loads and ice behavior, which have been incorporated into the new standard. The Polar Code and ISO 19906 documents partially meet the needs of Arctic governance and play an important role in regulating marine and non-ship engineering and technology projects. These two documents also point to a direction for future marine technological innovation. The final formulation of these documents is a good example of international cooperation. It also shows that the experience, knowledge, and technology of countries outside the Arctic can be well applied to Arctic governance.

China, South Korea, and Japan are all advanced countries in technological innovation and can cooperate with Arctic countries on Arctic marine equipment based on governance goals. China, South Korea, and Japan's advantages in information technology (Internet of Things),

Table V.1 List of WG8 country members and their representatives during the development of ISO 19906

Country	Representatives	Affiliation
Canada	Blanchet / Croasdale	BP / K.R. Croasdale and associates
China	W. Dong / X. Yang	Chinese national offshore oil company
Denmark / Greenland	O. Pedersen	Department of petroleum bureau of mines and energy
Finland	M. Määttänen	HelsinkUniv. of Technology
France	M. Vaché	Doris engineering
Germany	J. Schwarz / J. Berger	Consultant / Impac engineering
Italy	A. Baryshnikov	AgipKCO
Japan	K. Izumiyama / N. Nakazawa	NMRI / SEA system engineering
Kazakhstan	K. Kaipiyev / T. Svetlana / Y. smagulov	JSC board of oil and gas industy / AgipKCO
Norway	O. Gudmestad / M. Morland	Statoil / Norsk hydro
Russia	D. Mirzoev / M. Mansurov	VNIIGAZ
The Netherlands	F. Sliggers	Shell
United Kingdom	G. Thomas / D. Clare	BP / Arup
United States	W. Spring / D. Hinnah / J Hamilton	Bear ice technology / MMS / ExxonMobil

Source: Blanchet, D., Spring, W., McKenna, R.F., and G.A.N. Thomas. "ISO 19906: An International Standard for Arctic Offshore Structures." Paper presented at the OTC Arctic Technology Conference, Houston, Texas, USA, February 2011. doi: https://doi.org/10.4043/22068-MS

shipbuilding technology, port construction in cold regions, and smart port construction can contribute to improve governance in the Arctic. According to a KMI survey led by Jong Deog Kim on technological innovations for a sustainable Arctic, the priority areas for the application of these technologies to Arctic include: Ocean energy development and utilization; predicting and managing ocean environmental change and mitigating marine pollution; fundamental marine bioengineering; oceanographic observation and monitoring systems; ocean equipment and exploration; port operation information systems; advanced automated maritime traffic and safety; fishery resources surveys, and aquaculture production management. Most of the listed priority areas are related to marine technology, where East Asian countries can continue to make more contributions into the future.

Notes

1. The objective of ISO 19906 an International Standard for Arctic Offshore Structures is to ensure that complete structures, including substructures, topsides structures, floating production vessel hulls, foundations and mooring systems, in Arctic and cold regions provide an appropriate level of reliability with respect to personnel safety, environmental protection and asset value.
2. AUV stands for autonomous underwater vehicle and is commonly known as an un-crewed underwater vehicle. AUVs can be used for underwater survey missions such as detecting and mapping submerged wrecks, rocks, and obstructions. An AUV conducts its survey mission without operator intervention. When a mission is complete, the AUV will return to a pre-programmed location where the data can be downloaded and processed.
3. ROV refers to remotely operated underwater vehicle. It is an underwater vehicle that is unmanned and usually tethered to the operator. The unmanned vehicle is similar to a robot, which is fitted out with sensors and sampling tools to collect various types of data. A network of cables is utilized to establish a connection between the operator and the remotely operated vehicle, which would enable the proper movement of the ROV.
4. CTD stands for an acronym for Conductivity, Temperature, and Depth—is the primary tool for determining essential physical properties of sea water. It gives scientists a precise and comprehensive charting of the distribution and variation of water temperature, salinity, and density that helps to understand how the oceans affect life. It has the advantages like remote sensing, is very accurate, light weight and can be used at depths up to several thousand meters. Its disadvantages are, The small, low-powered CTD sensors that are used on autonomous instruments are more complex to operate, the chief limitation is the need to calibrate the individual sensors.

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17. Opportunities and Challenges of Space-based Infrastructures for Arctic Governance: Assessment from an Innovation System Perspective

Xiao-Shan Yap

Introduction

The satellite sector has experienced dramatic developments over the last decade, mainly driven by improved technological innovations and increasing privatization of the sector. Miniaturized components for satellites and lower costs for satellite manufacturing and launching, coupled with improvements in large data management, have allowed satellite systems to advance rapidly. In recent years, space-based infrastructures such as Earth-observation and communication satellites are increasingly used for remote areas with extreme conditions. These technologies can help improve Arctic governance in a number of ways. This trend is expected to grow quickly in the coming decade as satellite technologies get more integrated with different Arctic- related applications and as different satellite-based infrastructures become increasingly aligned, such as among observation, communication, and navigation systems, as well as with technological progress in cloud computing and deep learning.

Space-based infrastructures are therefore expected to shape Arctic governance in the coming years, ranging from new problem identification to new regime design. This chapter uses an "innovation system" perspective to assess the development of the rising satellite sector in general and how that may influence opportunities and challenges for Arctic governance in particular. The Technological Innovation System (TIS) perspective has been usefully applied in many sectoral fields to analyze success and failure conditions of newly emerging technologies and industries (Bergek, Jacobsson, Carlsson, Lindmark, & Rickne, 2008; Binz & Truffer, 2017; Suurs & Hekkert, 2009). Following the TIS perspective, several innovation processes are critical to facilitate successful development and diffusion of space-based infrastructures in the Arctic, including transforming innovation policy of the space sector, knowledge or technological development, entrepreneurial experimentation, guidance and standardization, technology legitimation, industry formation, and downstream market integration. This chapter will outline different potentials offered by advanced space-based infrastructures in governing different Arctic related issues. Subsequently, the chapter discusses the most salient innovation processes taking place in the space sector in general, but also assesses how that may influence opportunities and challenges in shaping Arctic governance in particular.

How Space-based Technologies May Reshape Arctic Governance

Conservation of Arctic biodiversity

One promising area is in the potential of using satellite images to assist in tracking and counting cetaceans such as whales. These efforts can be substantially enhanced when combined with open satellite data and deep learning (Guirado *et al*., 2019). Scientists are increasingly working on these data and developing models that contribute to the assessment of whale populations to guide conservation activities generally, and which can also be used in the Arctic. The conventional way of identifying or estimating the population of cetaceans is in situ, involving ships, planes, or ground stations. With satellite observation systems, remote sensing, and appropriate scientific modelling, whale tracking could now become more convenient, more efficient in terms of time, and less costly – especially in remote places like the Arctic. Besides spotting whales that are trapped inside sea ice (Williams *et al*., 2015), the ability to track movements of whales in real-time also helps guide the operation of ships, potentially minimizing the likelihood of ship strikes on whales. This in turn could enhance the scope of the Polar Code.

Satellite technologies can also be used for tracking migratory animals, which will be useful to inform the design of existing regimes concerning the area of protection coverage for those animals. In particular, the use of satellite telemetry combined with satellite navigation systems such as GPS can help track the movement of animals over long distances and a relatively long timeframe (Perras & Nebel, 2012). For instance, scientists recently studied the journey of an arctic fox over 76 days using the Argos Data Collection System, which is a long-term international program that connects to sensors and transmitters on over 21,000 satellites that are orbiting the

Earth pole-to-pole.[1] The scientists were able to track the westward journey of an Arctic fox from northeast Svalbard across that island onto sea ice, the open ocean, and finally to northern Greenland and then to Ellesmere Island in the northernmost Canada. These satellite systems can also be used for tracking polar bears, which could be informative to the formulation or revision of conservation policies.[2] The ability to track the movements of wildlife could therefore be helpful in determining suitable boundaries for the establishment of protected areas relevant to the Arctic, such as the Ecologically or Biologically Significant Marine Areas (EBSAS) as envisioned in the Convention on Biological Diversity.

Governing Arctic fisheries

Companies offering satellite-enabled Automatic Identification System (AIS) services can work with government agencies, especially in the detection of illegal fisheries or in investigations of causes and impacts of fishing activities. AIS has been used to help review or verify spatial distribution patterns of main fishing operations used in the Arctic Sea (FAO Area 18) as estimated by the Global Fishing Watch (GFW). In particular, AIS-generated datasets can be used to characterize fishing activities by fishing style, such as in detailing the presence or absence of fishing activity, its intensity, and hot spots (FAO., 2019, p. 117). For instance, AIS data could identify that most of the fishing activity in FAO Area 18 is by trawlers, taking place in the far northwestern corner of the Russian Federation that is less covered by sea ice, as well as in the eastern edge of the Hudson Straight in Canadian waters (FAO., 2019, p. 118). Overall, AIS based information on fishing activities can be useful for monitoring purposes in the short run but may also provide insights to new regime design in the long run. However, it will also be important to address the issue of fishing activities via smaller vessels in the future, such as those close to land, as these vessels are not required to be equipped with AIS.

Governing marine litter/ debris

Scientists are also increasingly combining satellite systems with artificial intelligence/ deep learning to detect marine plastic pollution or to identify the extent of marine debris distribution (Biermann *et al.*, 2020). This indicates that it will be easier in the near future to detect debris littering in the Arctic seas, but also to identify sources of marine debris coming into and leaving the Arctic seas. This might therefore lead to the identification of new governance needs for the Arctic with regard to marine debris mitigation.

Governing Arctic shipping

AIS can also substantially improve day-to-day administration in the Arctic. An important example is through enriching geospatial analysis with AIS data for the purpose of ship and vessel tracking. Advanced AIS can record positions, routes, destinations, and estimated time arrivals for daily logistics issues. These data can furthermore be augmented to derive historical vessel positions or voyage data. This can enhance ship detection, port monitoring, vessel route optimization, etc. With these tools, maritime traffic in the Arctic can be better managed, including identifying ships stranded in sea ice.

Combining satellite systems with AIS can also aid processes related to monitoring, reporting and verification. In particular, this can help track seafaring vessels equipped with AIS devices beyond coastal areas. Satellite-based AIS allows more comprehensive terrestrial coverage, potentially covering any given area on Earth, including the Arctic. An example of an ongoing project is the European Space Agency's (ESA) effort to build a European-based satellite-AIS system in collaboration with the European Maritime Safety Agency, which aims to complement the SafeSeaNet (SSN) system. This can help with monitoring vessels in different maritime areas in terms of their routes, activities, etc.

In addition, satellite-based AIS can also help monitor the emission compliance of ships or vessels. The emissions from ship or vessel navigation are expected to increase in the future as a result of the decline in Arctic sea ice coverage and accompanying rise in ship traffic. Satellite-based AIS data can be useful in this regard. The increasing availability of satellite-based data for ship tracking allows the formulation of detailed fleet specific emission inventories that provides high temporal and spatial resolutions for the Arctic (Winther *et al*., 2014). This will encourage seafaring ships or vessels to be more compliant. As scientists continue to conduct different modelling scenarios, it is expected that these methods can also help assess the emission consequences of future diversion shipping routes—which contributes also to new regime designs.

Table V.2 *Potential satellite applications for Arctic governance*

Governance potentials	Application details	Examples of relevant projects
Tracking and counting of cetaceans	Combining satellite imagery data with deep learning/ modelling can help with tracking and counting of cetaceans in the Arctic, such as whales that are trapped in sea ice. This was not easily done before.	Mostly done by scientific researchers in universities/ institutes at the moment
Tracking of migratory animals	The use of satellite telemetry (in combination with satellite navigation systems) can help track migratory animals such as arctic foxes and also help protect animals such as polar bears.	Migratory animals by Argos Data Collection System; WWF- supported research teams for polar bears
Sustainable fisheries and preservation	AIS can help identify spatial distribution patterns of main fishing gear used in the FAO Area 18. AIS data can also be used to verify estimates of fishing activities provided by Global Fishing Watch.	SAT-AIS by ESA in collaboration with European Maritime Safety Agency
Identifying the distribution of marine debris	Combining satellite systems with artificial intelligence can help detect marine plastic pollution or to identify the extent of marine debris distribution.	NASA is active in this regard, as well as university scientists
Shipping and vessel tracking/ logistics	SAT-AIS can help track seafaring vessels equipped with AIS devices beyond coastal areas with comprehensive coverage, including the Arctic. Subscribing to improved AIS can help determine route efficiency, plan emission compliance, etc. Advanced AIS can also be a solution to the High Traffic Zones data gap issue.	Partnership between UP42 and exactEarth; Spire Maritime
Reduce risks related to maritime traffic such as beset	Satellite images can help predictions for ice conditions for each point along the Northern Sea Route. Ships of different Polar Ship Categories can become stranded in ice along the Northern Sea Route. Ships of a lower category are most at risk to become stranded. This can help inform legislation planning.	Aalto University, University of Helsinki
Safety for ship navigation	This Arctic waterway monitoring/imaging satellite has the capability to improve the safety of ship navigation in the icy waters along Russia's Northern Sea Route.	China Synthetic Aperture Radar (SAR) satellite (expected to launch in 2022)
Emissions from ships or vessels	Satellite-based data for ship tracking allows to set up more detailed fleet-specific emission inventories that provide a high temporal and spatial resolutions for the Arctic.	Mostly done by scientific researchers in universities/ institutes at the moment
Internet broadband to aid Arctic shipping	There has been a boost in connectivity speed in the passage through northern shipping routes and Arctic waters (the Northern Sea Route), as a result of Iridium CertusTM network. This service is connected to a compatible network management solution 'OneGate', which allows their customers better visibility over their remote satellite assets.	Iridium CertusTM network
Distress management/ search and rescue	To retransmit distress signals from ships, aircraft, or people in remote areas as part of the international Cospas-Sarsat satellite-based search and rescue programme.	Arktika-M in February 2021

Source: Author's compilation.

The increasing number of Internet satellites and their applications can also help boost connectivity in the Arctic, allowing shipping in the region to have more seamless communications. Combining different satellite systems (communication, navigation and observation) can furthermore aid the transmission of distress signals and search and rescue activities, ensuring a safer Arctic in the near future. Table V.2 summarizes how different satellite technologies may contribute to Arctic governance in the near future, along with some ongoing examples.

Assessing Innovation Processes of Space-based Infrastructures for Arctic Governance

Different space-related innovation activities are emerging across different places in the world, which are rapidly shaping the development and diffusion of the abovementioned technological opportunities. In the following, we first discuss the fundamental developments that are rapidly shaping the emergence of space-based infrastructures, i.e. recent shifts in innovation policy of the space sector and increasing integrated technologies enabled by the current Information and Communication Technology (ICT) revolution. Against this background, we subsequently assess the TIS of different space-based infrastructures (i.e. satellite navigation, Internet satellite constellation, and Earth observation) in general but also their specific potential for shaping new Arctic governance.

Recent fundamental shifts in the space sector

Scientists argue that the globe is progressing into a new techno-economic paradigm, driven by rapid ICT advancement, along with the Fourth Industrial Revolution, as well as increasing globalization and new sustainability challenges (Mathews, 2013; Perez, 2013; Schot & Kanger, 2018; Young, 2021). This rising techno-economic paradigm may bring new windows of opportunity to reconfigure the ways technologies are used and diffused, including new business models and new market creation. Human capital with increasing computer literacy, industry opportunities following the so-called green economy, and advanced ICT allow integrating different technological systems to be more feasible than before.

The space sector is a critical component to the abovementioned new techno-economic paradigm (Yap & Truffer, 2021). The space sector has been increasingly privatized over the last decade, following renewed innovation policies of leading space agencies such as the U.S. National Aeronautics and Space Administration (NASA) and the European Space Agency (ESA) that foster space commercialization. This led to the so-called "New Space" era in which the multiplication of private spacefaring actors emerges across the world. In particular, there has been a shift in space innovation policy, moving from a top-down framework towards a more bottom-up orientation. While the former can be understood as the conventional "moonshot" model in the last space race, the latter focuses on diffusing space-based technologies through bottom-up participation of actors, with downstream application and commercialization the center of policy attention (Mazzucato & Robinson, 2018; Robinson & Mazzucato, 2019).

As a result, the space sector is drawing increasing numbers of public-private partnerships (PPPs). Many space missions today are led by private actors with support from governments. Large technological enterprises tend to receive favoritism from national space agencies in a number of areas. Among others, billionaire-owned enterprises leading satellite constellation projects (for high-speed broadband) received various forms of state support, such as receiving licenses for satellite launching. SpaceX also received funding support from NASA through their joint space missions, which facilitated the company's rocket-related innovations and cost reductions. Other private enterprises focusing on Earth monitoring (or telecommunication purposes) are also expected to receive continuous support from their national governments, since governments tend to perceive these missions as valuable to national technological supremacy or national security.

Under the conditions of this new techno-economic paradigm, integrating different space-based systems or combining these systems with other technology fields become more feasible than before. For instance, data scientists today make major leaps in combining Earth monitoring technology with big data and deep learning. Successful integration and diffusion of these technologies can substantially reconfigure the infrastructures in place for the Arctic, as new modelling can help design governance (e.g. fisheries regimes) and contribute to day-to-day operating regimes (e.g. regimes for the conservation of migratory wildlife).

Transformative potentials for Arctic governance

Realizing the potentials of space-based infrastructures for Arctic governance as outlined above will require well-aligned technological innovation system (TIS) processes, including technology development, entrepreneurial experimentation, guidance of search, market formation, and technology legitimation (Bergek *et al.*, 2008; Hekkert *et al.*, 2007). Table V.3 presents a brief assessment on the performance of these innovation processes so far in the three major space-based infrastructure fields and their potential for Arctic governance. In general, the three space fields experienced rapid expansion of knowledge and technological development in recent years. Some of the opportunities discussed above, such as the combined use of satellite telemetry and navigation for tracking migratory animals, have attracted increased research and development (R&D) activities in the Arctic by universities, but diffusion will still require entrepreneurial experimentation by industry actors. Otherwise, these technologies will remain as scientific experiments and too expensive to be diffused.

To ensure successful development and diffusion of different space-based infrastructures, the Arctic will require access to stable, high-speed 5G Internet in the region. Without comprehensive Internet coverage, data generated from Earth monitoring and satellite navigation will not be able to be transmitted effectively and communication will not be efficient. In other words, enhanced Internet and broadband services is a critical enabler to the successful diffusion of other new space-based technologies in the Arctic. Service installations of Internet satellite constellations are therefore critical. At the moment, there is substantial entrepreneurial experimentation in this area, given intense industry competition among large technological companies like SpaceX and OneWeb, which are also actively exploring new services for the Arctic region. This field is also favored by their respective state policies, given geopolitical interests in the 5G race. Following this trend, Internet satellites might increasingly diffuse in the Arctic in the near future, although initially with limited coverage in the region.

However, there is still a lack of market formation among the three fields of space-based infrastructures. Market formation here requires integrating the space-based technologies with downstream applications, most of the time by translating raw satellite data into usable information and through the delivery of new services. Combining big data and deep learning could bring manifold opportunities in this regard. Private actors are core to lead these activities, from the translation of raw data to identifying new market segments and shaping different use contexts, as well as developing relevant software or apps which can then be diffused as services to specific industry areas or local contexts.

Over the last few years, an increasing number of data service companies have emerged in the global satellite sector (Haarler, 2020). However, the number of private actors active in developing downstream market integration of space technologies in the Arctic is low at the moment. This will be critical for the successful diffusion of satellite technologies and AIS- generated data for Arctic governance. More entries of these data service companies focusing on applications in the Arctic is needed, by engaging with needs and preferences of users, operators, or governance officials in the Arctic. The core challenge lies in incentivizing more entries of application service companies and creating a business case for these companies. In other words, who will be the users that pay for these services and for what applications?

Since the Arctic has a relatively lower number of commercial activities as compared to other parts of the world, policy, regulations and standardization—also known as guidance of search in TIS—are key elements that will shape initial market segments for these data application services. More specifically, guidance of search activities defines the set of criteria to be included in a "selection environment" with the aim to facilitate rapid diffusion of specific technologies (Yap & Truffer, 2019). More stringent governance or expanded regulations such as through new additions to the Polar Code as discussed above will create demand for actors in the Arctic to sign up for those space-based systems or data application services, including shipping companies, fishermen, and specific governing agencies. Therefore, these actors/ agencies are ideally among the first to pay for these services, attract entries of application service companies, and subsequently set in motion market competition that leads to lower costs in long run.

Successful guidance of search helps shape technology legitimacy for deploying these space-based infrastructures, which is critical given that users might find resistance to subscribe to these new technology services, at least in the beginning. There might be operational users who are locked-in to existing practices and hence refuse to adopt new ways of doing things. For instance, the daily jobs of actors in the "old regime" might

Table V.3 Assessing the TIS processes of different space-based infrastructures and their potentials for Arctic governance

TIS processes	Internet satellite constellation	Satellite navigation	Earth monitoring
Knowledge/ technology development	Well developed, R&D by high-profile technological companies.	Well developed, R&D by states (the United States, Russia, EU, and China). R&D specifically for Arctic is unclear.	Well developed, by space agencies, universities, research institutes, smaller companies
Entrepreneurial experimentation	Progressing quite rapidly, driven by competition among high- profile companies.	More experimentation by companies for use contexts are needed.	Still weak in the Arctic. More bottom-up participation by small and local companies will be critical.
Guidance of search/ standardization	Progressing quite steadily. The installation of services is currently weakly governed. Technology standards are driven by competing companies and the quality of services differs.	Standards are shaped by national system operators. In general, new standards shaped by Chinese BeiDou and EU's Galileo are emerging. But this is still quite disconnected from Arctic purposes.	Still weak. Due to low business participation for Arctic purposes, the lack of standardization also leads to weak progress in data translation/ interpretation.
Market formation (downstream integration)	Still weak. Shaping markets for Arctic governance purposes will require identifying potential customers. This should start with industry or governmental users.	This will require the subscription of industry and governmental users, e.g. shipping companies. Countries that have built up their own ports in the Arctic e.g. Russia most likely use their own national systems. These systems can also be combined with monitoring data and deep learning.	Weak. Market formation here will require more data application service companies translating raw satellite data of the Arctic into real application services. These companies will have the incentive to combine satellite data with modelling and deep learning.
Technology legitimation	Strong. It is expected that users in remote regions (in this case the Arctic) tend to favor the access to stable and high-speed connection.	User acceptance could be higher among the shipping community, as navigation can substantially improve shipping efficiency and safety.	Different actors in the Arctic in general will have to accept that they (or their natural environments) are increasingly monitored.

Note: Information in this table is drawn from broader research that is still in progress.
Source: Author.

have to integrate new application services based on navigation or Earth monitoring data. These old-regime actors, however, might still prefer on-the-ground field inspections and so refuse to switch to new and arguably more advanced methods. Meanwhile, there might also be users or actors exposed to increasing satellite monitoring or surveillance therefore leading to resistance, controversies, or even backlash. To gain legitimacy among these users, the introduction of new policies or regulations will be critical. There could also be other means of legitimizing these new technologies, such as shaping the media narrative concerning the benefits of new Arctic governance as enabled by the new space-based infrastructure.

Overall, innovation processes for the global satellite sector will increasingly align in the coming years, rapidly shaping next-generation space-based infrastructure. More feasible applications for Arctic governance, however, seem to lack demand for rapid diffusion. The potential of space-based infrastructure for Arctic governance is still limited to scientific projects led by universities using research funding granted by governments, public agencies, or international organizations. Given that the Arctic is furthermore attracting new arrays of geopolitical interests in recent years (Young, 2020), the abovementioned innovation processes for diffusing space-based infrastructure in the Arctic will need to take into consideration the different value orientations or conflicting interests among different actors, including nation states, agencies and the private sector. In view of that, PPPs might be key in the beginning in order to diffuse those technologies in the Arctic, through the provision of market incentives and supportive contexts (such as protected licenses, dedicated standardization, and revision of regulatory criteria) driven by states with vested interests in their respective national technological companies. In addition, strengthening governance requirements in the Arctic such as through enhancing the Polar Code accordingly will attract smaller downstream application service companies. These strategies may help establish a business case for the Arctic, create demand for space-based services, and incentivize private actors to work with public actors to facilitate activities related to Arctic governance. This may overall expedite entrepreneurial experimentation in the Arctic, followed by industry competition that can substantially reduce costs, allowing a quicker uptake of application services in that region.

Notes

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18. The Role of Remote Sensing in Addressing Issues of Environmental Protection

Misako Kachi and Naoko Sugita

This chapter addresses issues of governance regarding the role that remote sensing can play as an example of innovative science and technology in creating and implementing effective governance systems to address Arctic issues. Acknowledging the necessity for "governance systems that are both robust in the sense that they have the capacity to steer the actions of a variety of actors,"[1] this chapter focuses on the advantages of remote sensing and the contributions it can make under conditions often characterized as nonlinear developments in complex systems. It addresses how and what kind of observations remote sensing can provide, which may provide scientific knowledge and evidence that could affect the actions of actors involved in Arctic issues.

Arctic and Governance Issues

The characteristics of the Arctic region, which mainly consists of seasonally ice-covered ocean with minimal terrestrial area, makes continuous in-situ observations in these high latitudes very difficult. Satellite remote sensing is the only tool available to measure the status and changes of the Arctic region in a spatially and temporally homogeneous manner. Adding to the strength of remote sensing is synthetic aperture radar (SAR) satellite, which allows both night-time observation as well as when there is cloud cover, which is often the case in the Arctic.

A geostationary satellite cannot cover polar regions due to limitations of satellite elevation angles that can be used effectively in observations. For Japanese geostationary satellites, observation areas for cloud analysis are limited to those with satellite elevation angles greater than 10-20 degrees (Japan Meteological Agency, 2002, in Japanese, https://www.data.jma.go.jp/mscweb/ja/prod/pdf/book/2-chapter1.pdf), and areas that cannot be observed are almost equivalent to high latitudes of 60 degrees and greater. Thus, low-altitude polar orbital satellites have become the primary tool for Arctic monitoring. Instruments with high spatial resolution capability have a narrow swath and provide observations less frequently; those with coarse spatial resolution have a broader swath and provide more frequent observations, up to several times per day in high latitudes. While the former are used to determine the detailed status of a specific event or phenomenon, the latter are essential for day-to-day monitoring of the whole area.

This chapter examines the strength and characteristics of satellite remote sensing and approaches to Arctic and governance, categorized into two aspects.

Value of Research and Monitoring of the Arctic

Monitoring the Arctic is essential to accurately project global warming rates and trends because the region is warming much faster than lower latitudes, a phenomenon known as Arctic warming amplification. With continuous observations of the record summer minimum of Arctic sea-ice recession, satellites charting the effects of climate change have "revolutionize[d] the understanding of the cryosphere and the critical role it plays in shaping Earth's climate system."[2] "Governance" in this context refers to regulating human activities in response to global warming, not limited to the Arctic. Scientific evidence, including contributions from satellite observations, will be the basis for deriving such a global governance scheme. It is this scientific evidence that may also contribute to conserving the Arctic environment.

Maintaining the Status Quo of the Arctic Environment

Another approach regarding the contribution of remote sensing to Arctic governance is whether such leading technologies could be used to monitor the implementation of existing international arrangements. It is an intriguing argument that there would be no need for new formal agreements, such as diplomatically difficult Arctic treaties, if it became possible for new technologies to monitor whether state and private actors are complying with existing agreements.

Having distinguished two aspects of governance for the Arctic, it is worth noting that the accumulation of scientific evidence contributing to global governance schemes to address global warming would likely also provide the rationale to conserve the region's environment. Thus, the role of remote sensing is examined at two levels: First, emphasizing the role it can play in the governance responding to global warming; second, the state of remote sensing for the possible monitoring of existing arrangements is explored. “Stakeholders” refers collectively to the actors involved, both having direct interest (such as Arctic Council members and Indigenous Peoples of the Arctic region) and those indirectly affected by the Arctic issues. Objectivity and availability of remote sensing technologies are addressed in both cases.

Scientific Knowledge for Global Governance of Global Warming

The Arctic is one of the regions on Earth where the influence of climate change is most evident. These rapid changes may in turn impact the environment and ecosystems of the entire planet. The recent sixth IPCC Assessment Report (AR6) noted that “it is unequivocal that human influence has warmed the atmosphere, ocean, and land. Widespread and rapid changes in the atmosphere, ocean, cryosphere, and biosphere have occurred.” For example, the decrease in Arctic sea ice area between 1979–1988 and 2010–2019 has been about 40% in September and about 10% in March.[3]

A decrease in the Arctic sea ice extent is expected to expand economic opportunities in this region, such as shipping and resource extraction. However, this expansion may also bring risks to the severely vulnerable environment, and consequently increase environmental changes in other regions. Therefore, the importance of increasing the scientific knowledge of the region’s current status, as well as documenting environmental changes and improving meteorological and climate prediction in the region has increased. Also, there is an increasing demand to assess the impacts of these changes on society. Even areas physically distant from the Arctic are affected by changes there and at high latitudes. Because of its location, Japan is climatologically and environmentally affected by these changes.

State of Satellite Technologies for Arctic Governance

Monitoring the Arctic environment

Satellite observations provide several indicators of global warming to monitor Earth’s environmental changes. The Global Climate Observing

Table V.4 *List of Essential Climate Variables (ECVs)**

Atmosphere			Land		Oceanic	
Surface	**Upper-air**	**Atmospheric Composition**	**Hydrosphere**	**Biosphere**	**Physical**	**Biochemical**
Precipitation	Earth radiation budget	Aerosols	Groundwater	Above-ground biomass	Ocean surface heat flux	Inorganic carbon
Pressure	Lightning	Carbon dioxide, methane and other greenhouse gases	Lakes	Albedo	Sea ice	Nitrous oxide
Radiation budget	Temperature		River discharge	Evaporation from land	Sea level	Nutrients
Temperature	Water vapour	Clouds	Cryosphere	Fire	Sea state	Ocean colour
Water vapour	Wind speed & direction	Ozone	Glaciers	Fraction of absorbed photosynthetically active radiation (FAPAR)	Sea surface currents	Oxygen
Wind speed & direction		Precursors for aerosols and ozone	Ice sheets and ice shelves	Land cover	Sea surface salinity	Ocean acidity
			Permafrost	Land surface temperature	Sea surface stress	Transient tracers
			Snow	Leaf area index	Sea surface temperature	Biological/ ecosystem
			Anthroposphere	Soil carbon	Subsurface currents	Marine habitats
			Anthropogenic Greenhouse gas fluxes	Soil moisture	Subsurface salinity	Plankton
			Anthropogenic water use		Subsurface temperature	

* As of October 2021. The latest ECV list is available from https://gcos.wmo.int/en/essential-climate-variables/table

System (GCOS) has defined a number of Essential Climate Variables (ECVs), which are a set of variables that are critical to contributing to the characterization of Earth's changing climate (Table V.4) and are updated periodically. Observation requirements of ECVs, including temporospatial resolutions and accuracy, are defined by consensus among the scientific and operational communities for climate change studies and activities. Currently, 54 ECVs have been identified, and more than half of them are compiled mainly by satellite observation data. The Inventory of Climate Data Records of space-based ECVs is available at http://climatemonitoring.

info/ecvinventory/. Examples of space-based Arctic ECVs include sea surface temperature (SST), sea ice, snow, glaciers, ice sheets, and ice shelves.

Observations of SST and sea ice cover from space is essential to monitor the state of the atmosphere and ocean. Passive microwave imaging with cloud-penetrating capability is an especially powerful way to provide continuous daily observation of SST and sea ice, regardless of cloud cover, and monitor their global distribution and trends.

Melting of snow and ice over land, including land snow, glaciers, and ice sheets, is another critical issue that must be monitored. Several satellite sensors, including the optical imager, passive microwave imager, Synthetic Aperture Radar (SAR), and optical lidar, are operated by various space agencies and utilized to monitor changes under various time scales.

Impacts on ecosystems

Changes in the physical environment, such as an increase of SST and decline of sea ice cover, will affect the habitat of many species and, in turn, ecosystems. Although present satellite technologies cannot directly capture changes in specific marine species' distribution except phytoplankton, information about environmental changes is used to estimate changes in habitat that in turn create cascading ecological effects.

In addition, changes in the biological environment also impact the ocean ecosystem, including ocean biomass. Satellite remote sensing can monitor limited but essential parameters related to ocean ecosystems. For example, phytoplankton are the base of the ocean's food chain. The chlorophyll-a concentration and productivity of organic matter (ocean net primary productivity) over the ocean surface influence the distribution of marine life across the Arctic ecosystem.

Support for ship navigation

Ships in the polar region use satellite data for navigation in and near sea ice areas. High-resolution images from microwave radar, such as SAR, support decisions about optimal paths along shipping routes. These images are fine spatial resolution but only cover narrow areas. Images from passive microwave imagers help capture sea ice distributions in broad areas with 10-km resolution several times per day. They are also used for summer forecasts of the Arctic sea ice extent.

Recent expectations that Arctic shipping will increase due to the decline of seasonal sea ice cover also create a need to monitor navigation activities in the area. Information on ships from the Automatic Identification System (AIS), including dynamic (such as ship position, time, track, and speed) and static (ship number, name, size, and category) information, and have been collected by the satellites' monitoring status and change of navigation activities across a wide area. AIS information in the Arctic has been suitable to date since there have been few ships and frequent satellite observations. Statistical reports of navigational activities in high latitudes are public, such as those from the Center for High North Logistics at Nord University (https://chnl.galschjodtdesign.no/). The Hokkaido and Aomori (northern) Prefectures provide a navigation activity report every year (https://www.hkd.mlit.go.jp/ky/kk/kou_kei/ud49g70000000slz-att/slo5pa0000004kv3.pdf).

Observing marine contamination

Monitoring marine contamination is critical to the environment and ecosystem health, more so for the Arctic region due to its geographical location, weather/ocean conditions, and vulnerability. Satellite observation is an essential tool to capture marine contamination, including oil spills. Recently, SAR sensors with high-resolution cloud-penetrating capability have been utilized in this field, but their observation frequency must be improved for practical use.

Plastic marine pollution in the Arctic and its ecological impacts are increasingly acknowledged as significant policy issues.[4] However, observations of plastics and other artificial materials, including their sources, composition, pathways and distributions, temporal trends, degradation processes, vertical fluxes, and time scales, are largely unknown.[5] Several studies to detect marine plastics accumulated along coastal areas or currents using high-resolution optical sensors are underway. Still, it is difficult to reliably determine whether they are plastic materials. To detect marine plastics, efforts to utilize other satellite capabilities, such as lidar and Synthetic Aperture Radar (SAR), are also being investigated, but they need further improvement for practical application. A numerical model is needed to improve monitoring to compare satellite remote sensing with in-situ observations by buoys, ships, and aircraft.

Conclusion and the Way Forward

Meta-governance affecting micro-governance of the Arctic

It is essential to understand that creating and implementing effective governance systems to address Arctic issues depends on more significant governance issues, such as international efforts to address global warming. Considering the nature of the Arctic environment, satellite remote sensing is a promising tool to collect scientific observations of the region. There is a concerted effort by scientists worldwide to monitor the region by contributing to the observation of ECVs. Although direct remote sensing observation of habitat and marine life is theoretically possible, it has not been widely developed or applied.

Besides ECVs observations, AIS is also close to being ready for use in day-to-day administration, with various technical demonstrations in progress. There is a need from different users to observe shipping routes. The potential economic opportunities opening in the Arctic passage resulting from global warming and ensuring adverse impacts on the environment must be controlled to compensate for the increased shipping volume.

The state of current technologies suggest that, when thinking of governance as "a social function centered on the development and operation of mechanisms to steer human societies toward outcomes deemed desirable in collective terms and away from undesirable outcomes"[6], the value of satellite remote sensing is clear. It is used to understand global warming's impacts better. However, regarding direct observation of the targets to conserve the region's environment, there are still gaps in technology, a motivation to develop such technology, and important decisions to be made about the most important variables to observe in order to achieve these important goals.

Filling the gaps to utilize remote sensing

We need considerable effort to fill the gaps between the promise of satellite technology and its practical applications (societal benefits). There are considerable discrepancies between what satellites can observe and what stakeholders want to know. Closing this gap cannot be achieved by a single application of remote sensing or by a single user.

One solution is to better identify observational needs. With regard to climate change, the definition of ECVs provides a clear reference basis for observation targets. However, these needs are not limited to satellite data no matter how accurate they are, considering the complicated array of information that users need to know to achieve their purposes. Establishing a process for definition, consensus, and periodic updates (refinement) of requirements from the community should be beneficial for mutual understanding, future improvement, and possible breakthrough technologies.

Additional effort, dialogues, and close cooperation among different communities regarding the optimal ways to achieve the above needs should be pursued. Satellite remote sensing is not an almighty tool, yet provides critical information that other methods of observation do not. In many cases, indirect information can be provided from remote sensing technology corresponding to requirements from stakeholders. For example, in fisheries management, end users want to know where and when a school of target fish comes to their fields, yet satellite remote sensing cannot observe the movements of individual fish species. Alternatively, satellite data provides environmental information that can inform fisheries management, such as SST and the concentration of phytoplankton that the fish eat. To utilize such information in an operational application, considerable research efforts by the fishery community have been conducted and are ongoing to find the preferred SST of each target fish and to detail relationships between distribution of phytoplankton and the abundance and range of target fish species. User conferencing is one solution to establish a mechanism to connect user needs and remote sensing technology.

This is not an easily achievable goal, but we can accomplish this if researchers and engineers in the remote sensing and application communities have regular communication and persistently collaborate in their research.

We should note that most governmental space agencies have difficulties choosing the time scales for advancing remote sensing technology and application. In considering the technology, we should develop optimal technologies that can adapt to dynamic conditions and address new possibilities rapidly. Appropriate technology is usually requested from the application side to sustain its utilization over the long term. Research-to-operation is a significant issue that R&D entities also face when promoting their technology for society. Therefore, we should also consider this discrepancy between remote sensing technology and application through communications and collaborative research.

The overarching issue of governance in regard to global warming may advance governance across the Arctic. By looking at two types of governance and their relations, it may be possible to obtain clues for a rational way forward. Bearing in mind the nature of most space agencies destined to develop "the best" technologies, establishing a collaborative working process and methods to reflect user requirements would also be a key goal.

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Notes

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19. Satellite Observations of Maritime Ship Traffic to Enhance Implementation of Binding Agreements in the Arctic Ocean

Paul A. Berkman

This chapter addresses practical elements of satellite observations, especially regarding maritime ship traffic, to enhance binding agreements that apply to the Arctic Ocean. These include the five binding Arctic agreements that have entered into force since 2009 when there were substantive changes in the operation of the Arctic Council. In particular, this paper will focus on the 2018 Agreement to Prevent Unregulated High Seas Fisheries in the Central Arctic Ocean that entered into force on 25 June 2021, requiring the integration of biogeophysical and socio-economic assessments to implement its "precautionary approach" in this area beyond national jurisdictions. In addition to the big-data analyses utilizing the oldest and longest continuous satellite record of maritime ship traffic north of the Arctic Circle, this chapter involves KnoHow™ (https://knohow.co) for the purposes of knowledge discovery with "unstructured data" to reveal objective relationships within and between the binding agreements. These analyses highlight observing systems as core features of built infrastructure, involving technology plus capitalization, that are coupled with governance mechanisms to achieve progress with sustainable development in the Arctic.

Case-study with Binding Arctic Agreements

The binding agreements in Table V.5 provide the basis for case studies to interpret how their implementation can be enhanced with satellite observations of maritime ship traffic in the Arctic Ocean. These binding agreements were chosen objectively in view of their origin after the 2009 Arctic Council Ministerial Meeting in Tromsø, Norway, when there were substantive changes in the operation of the Arctic Council with the creation of task forces and the engagement of Foreign Ministers from all eight Arctic states in the Arctic Council Ministerial Meetings (Vylegzhanin *et al.*, 2021). The Tromsø Declaration (2009) also was the first declaration of "peace"

Table V.5 *Complex of Arctic governance mechanisms emerging after 2009*

Binding Agreement			
Number	**Name**	**Done At**	**Entry into Force**
1	Agreement on Cooperation on Aeronautical and Maritime Search and Rescue in the Arctic (https://oaarchive.arctic-council.org/handle/11374/531)	Nuuk May 12, 2011	January 19, 2013
2	Agreement on Cooperation on Marine Oil Pollution Preparedness and Response in the Arctic (https://oaarchive.arctic-council.org/handle/11374/529)	Kiruna May 15, 2013	March 25, 2016
3	Agreement on Enhancing International Arctic Scientific Cooperation https://oaarchive.arctic-council.org/handle/11374/1916	Fairbanks May 11, 2017	May 23, 2018
4	International Code for Ships Operating in Polar Waters (Polar Code) (http://www.imo.org/en/MediaCentre/HotTopics/polar/Pages/default.aspx)	appending IMO Conventions	January 1, 2017
5	Agreement to Prevent Unregulated High Seas Fisheries in the Central Arctic Ocean (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2018:453:FIN)	Ilulissat October 3, 2018	25 June, 2021

from the Arctic Council, reiterated as a common interest in all subsequent Arctic Council Ministerial Declarations, as revealed with KnoHow™ (Arctic Council Knowledge Bank, 2021). With satellite observing systems as elements of built infrastructure (involving technology plus capitalization) and related governance mechanisms (e.g., Table V.5), the objective of this chapter is to raise questions of common concern that will influence sustainable development in the Arctic Ocean.

Scalability of the Satellite Record with Arctic Maritime Ship Traffic

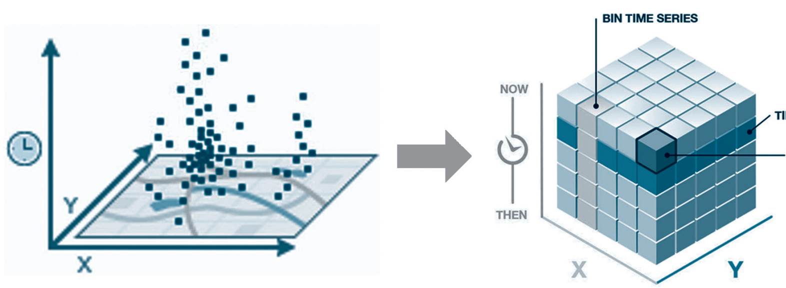
Maritime ship traffic is a fundamental socio-economic indicator of change that can be interpreted with synoptic coverage and integrated objectively with biogeophysical system changes in the Arctic Ocean (Table V.6). Moreover, the satellite record of maritime ship traffic can be analyzed across all time and space scales that are relevant to sustainable development in the Arctic Ocean.

Big-data analysis utilizing the satellite record of Arctic maritime ship traffic can be dissected with user-defined granularity by applying the space-time cube (ESRI, 2021) in the cloud with Google® Big Query (2017), as illustrated in Figure V.5. These time-dependent geospatial analyses are both

Table V.6 Next-generation Arctic marine shipping assessments[1]

Attribute	Arctic Marine Shipping Assessments (AMSA)	
	AMSA (2009)	**Next-Generation**
Sampling Period	2004	2009-present
Data Sources	Arctic States Individually and with the Arctic Council	Diverse Government and Commercial Automatic Identification System (AIS) Sources
Observation Coverage	Point, Regional	Point, Regional and Pan-Arctic
Observation Scope	Ground-Based	Ground-Based and Satellite
Observation Frequency	Inconsistent over Space and Time	Synoptic and Continuous (from minutes to decades)
Ship-Type Designations	Variable National Designations	Standardized International Designations
Individual Ship Attributes	Inconsistent and Incomplete	Consistent and Comprehensive
Analytical Capacity	Limited Granularity and Questions	Open-Ended Granularity and Questions
Science-Diplomacy Contributions	Scenarios and Negotiated Recommendations	Holistic Evidence and Options (without advocacy)
Informed Decisionmaking[2]	Governance Mechanisms	Operations, Built Infrastructure and Governance Mechanisms

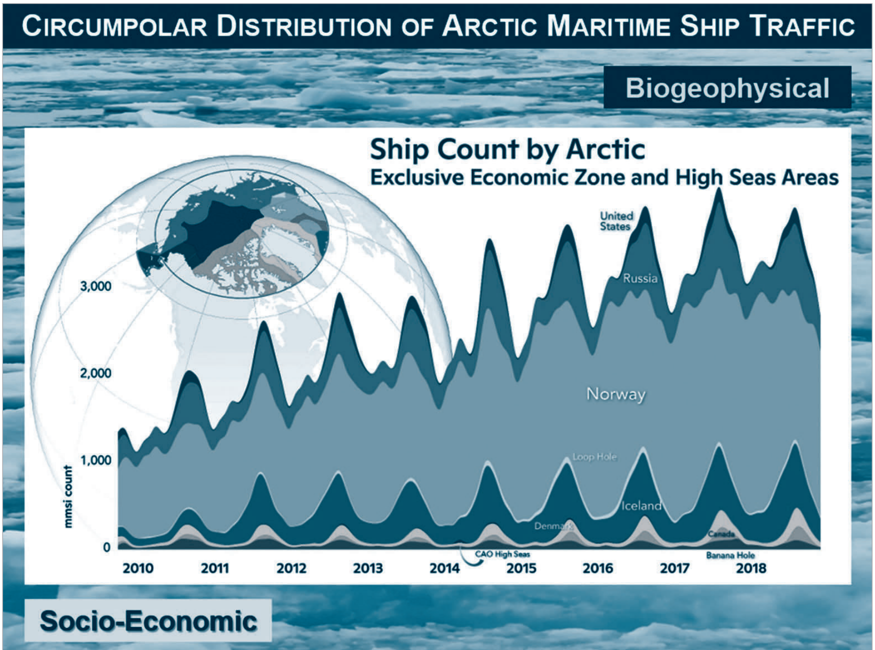
1 Updated from Berkman *et al*., (2020), involving Automatic Identification System (AIS) data collected by polar-orbiting satellites.
2 Informed decisions operate across a 'continuum of urgencies' short-to-long term (Berkman *et al.,* 2017), as elaborated subsequently (Berkman *et al*., 2020; Berkman 2020a,b).



Note: (Left) Threedimensional system to analyze change in issues, impacts or resources that are measured over space (x-y, latitude-longitude) and time (past to future). (Right) The 'space-time cube' from ESRI (2017) is a geospatial approach that can be applied to 'big data' questions with vector-based analyses (points, lines and polygons) within and between 'bins.' From Berkman et al. (2020a).

Figure V.4 Knowledge discovery over space and time cost-effective and highly efficient (Berkman *et al.*, 2022a), generating results within seconds at $5 USD per terabyte processing costs and $0.02 USD per gigabyte storage costs (Google, 2020). Importantly, the space-time cube is open, enabling the integration of any numeric data (i.e., biogeophysical and socio-economic) that can be situated within the space and time boundaries of the information system that is being analyzed.

Building on earlier regional analyses with the space-time cube in the Arctic Ocean (Berkman *et al.*, 2020a), the scalability of the satellite



Note: Derived from satellite Automatic Identification System (AIS) big-data with synoptic circumpolar coverage within the Exclusive Economic Zones (EEZ) of Arctic coastal states as well as High Seas areas beyond national jurisdictions from 1 September 2009 through 31 December 2018 north of the Arctic Circle, including the Bering Strait Region as analyzed previously (Berkman et al. 2020a). These socio-economic data represent more than 173,000,000 AIS records with 21,005 unique ships during the 2009-2018 observation period with seasonality reflected in view of the biogeophysical system. Longitudes range from 0°EW in the Barents Sea with surrounding Norwegian and Russian EEZ to 180°EW through the Bering Strait with surrounding United States and Russian EEZ. Additional mapping of High Seas areas north of the Arctic Circle is shown in Harrison et al. (2020) for the Banana Hole in the Norwegian Sea and Loop Hole in the Barents Sea as well as the Central Arctic Ocean. Adapted from Berkman et al. (2022a).

Figure V.5 Pan-Arctic ecosystem of maritime ship traffic among Law of the Sea Zones in the Arctic Ocean record of maritime ship traffic is illustrated best in relation to governance mechanisms within the "framework of the Law of the Sea" (Figure V.5), to which all Arctic states and Indigenous Peoples' Organizations "remain committed" for the purposes of "informed decisionmaking in the Arctic" (Arctic Council, 2013). The Pan-Arctic ecosystem of maritime ship traffic north of the Arctic Circle is shown comprehensively with Figure V.5 in relation to Exclusive Economic Zones of Arctic coastal states surrounding High Seas areas beyond national jurisdictions, as defined under international law of the sea (UNCLOS, 1982).

The ecosystem of maritime ship traffic in the Arctic Ocean (Figure V.5) includes information about the numbers and types of ships based on their flag states, types and sizes among other features in the metadata of each Automatic Identification System (AIS) record. Together, the aggregated data from the movements of each individual ship over time reflect the socio-economic dynamics of human activities that can be integrated objectively with biogeophysical data to assess impacts, issues, and resources in the Arctic Ocean as elsewhere in the world ocean. Such integration is reflected simply by the seasonal dynamics of the socio-economic and biogeophysical systems (Figure V.5), underlying suites of more complex interactions that will be revealed and addressed in view questions framed by diverse stakeholders, rightsholders, and actors.

Common-interest Building with Questions to Produce Informed Decisions

In the context of institutions, characterized inclusively with the two coupled arenas of governance (mechanisms and built infrastructure) (Berkman *et al*., 2020b), socio-economic and biogeophysical data (Figure V.5) serve as the precursors of evidence for decisions that will influence sustainable development in the Arctic Ocean. With diplomacy as an option (without advocacy) that can be used or ignored explicitly, the path to produce informed decisions (Table V.5) for sustainable development is founded on questions that create the opportunity to reveal questions of common concern among allies and adversaries alike (Figure V.6).

This chapter has the objective to reveal such questions of common concern as options for further consideration. Characterizing the scope of an informed decision (Table V.6), as the apex goal with governance mechanisms and built infrastructure as well their coupling for sustainable development, the informed decisionmaking pyramid (Figure V.6) provides a methodology to reveal as well as apply questions of common concern in view of satellites and the socio-economic data associated Arctic maritime ship traffic.

With holistic (international, interdisciplinary and inclusive) integration, questions of common concern reveal the methods of science to study change (Figure V.6) and generate the necessary data to produce answers in a transdisciplinary manner (Zeekhorst *et al*., 2001, Hadorn *et al*., 2008). These stages of research are transformed into action with evidence for decisions, involving institutions and their decisionmakers. Across the data-evidence interface, the importance of including science in diplomacy is first and foremost to reveal options (without advocacy) that can be used or ignored explicitly, respecting the institutions. Starting with questions among allies and adversaries underlies the skill to build common interests. The engine of informed decisionmaking (Berkman 2020a) operates with common-interest building, enhancing research capacities as a positive feedback with individuals contributing as observers and participants inclusively.

Note: Pyramid of Informed Decisionmaking as a holistic (international, interdisciplinary and inclusive) methodology with science diplomacy to apply, train, and refine across a 'continuum of urgencies' (Table V.5). From Berkman et al. (2022b).

Figure V.6 Pyramid of informed decisionmaking

Operating across the data-evidence interface, transforming research into action (Gluckman *et al.,* 2018) to produce informed decisions (Berkman *et al.,* 2017) is the essence of science diplomacy (Berkman, 2020a). In this transdisciplinary field, science diplomats serve as a brokers (Gluckman *et al.,* 2021), enabling dialogues among allies and adversaries alike to build common interests that are fundamental to informed decisionmaking (Berkman *et al.,* 2017, 2020b, 2022b).

Discovering Institutional Interplay with Cross-cutting Questions

To operate across the research-action interface requires an understanding of the relevant institutions to transform data into evidence for decisions, emerging from questions of common concern (Figure V.6). In this chapter, the questions originate with satellite observing systems as elements of built infrastructure that are necessary to effectively implement governance mechanisms associated with the Arctic Ocean, reflecting the rational for next-generation Arctic marine shipping assessments (Table V.5). With the binding agreements in Table V.5:

Question 1. How are satellite observing systems referenced explicitly or implicitly?

Question 2. How can satellite data be applied as evidence for decisions?

Question 3. Does the satellite record of maritime ship traffic uniquely introduce options (without advocacy) that contribute to informed decisionmaking for sustainable development in the Arctic Ocean?

Question 1 requires a literal understanding of the governance mechanisms in Table V.5, individually as well as collectively, recognizing their institutional interplay (Young, 2002, Berkman *et al.*, 2020b) in the Arctic Ocean. Despite the notion of Portable Data Format (PDF) files as a classic form of "unstructured data" (Feldman and Sanger, 2007), relationships within and between digital documents can be discovered objectively with automated granularity (Berkman *et al.*, 2006) using KnoHow™ (https://knohow.co). Herein, this easy-to-use knowledge discovery tool comprehensively integrates the five binding agreements represented in Table V.5, enabling quantitative relationships to be extracted in view of cross-cutting themes, based on questions framed with “satellite” and other search terms (Table V.7).

As a baseline search term, “Arctic” is prominent across all five binding agreements with jurisdiction as a cross-cutting theme (Table V.7). Similarly, providing another baseline test of KnoHow™, the term “ship” occurs most prominently in the Polar Code as would be expected, in view of its impact as a cross-cutting theme.

It also is discovered herein that “satellite” only occurs in the Polar Code, considering contributions to research and action as cross-cutting themes that contribute to informed decisions (Figure V.6) that are characterized across a ‘continuum of urgencies’ short-to-long term (Table V.6). Applying this cross-cutting theme of time, “months,” “seasons” and “years” are shown to exist among the five documents, but the term “decades” is missing, despite the 16-year period specified in the “precautionary approach” delineated in the Agreement to Prevent Unregulated High Seas Fisheries in the Central Arctic Ocean (CAO High Seas Fisheries Agreement). As reflected by various search terms, KnoHow™ also reveals there is inconsistent consideration of the elements of research and action that underlie capacities of these binding agreement (Table V.5) to deliver informed decisions.

Moreover, despite the cross-cutting relevance of sustainable development as a common Arctic issue, terms associated with sustainability have limited usage in these binding agreements, except for the CAO High Seas Fisheries Agreement. It also is surprising to discover the term “Indigenous” occurs most frequently in the CAO High Seas Fisheries Agreement, even though the other agreements touch the coastal areas and emphasize opportunities for common-interest building with global inclusion (Berkman *et al.*, 2022c) in this area beyond national jurisdictions.

These analyses introduce a quantitative platform to assess the institutional interplay among agreements that entered into force after 2009 with application in the Arctic Ocean (Table V.5). In view of Question 1 above, there is limited specification of satellites, even though these remote observing systems serve as a keystone source of data for open science (United Nations 2021) and informed decisionmaking. The frequencies of other search terms and cross-cutting themes (Table V.7) can be interpreted further with individual design to identify gaps as well as synergies among the binding agreements included in Table V.5.

Table V.7 Institutional interplay among Arctic governance mechanisms (Table V.5) discovered with knohow™ (https://knohow.co) to enhance informed decisionmaking (Figure V.6) for sustainable development in the Arctic Ocean

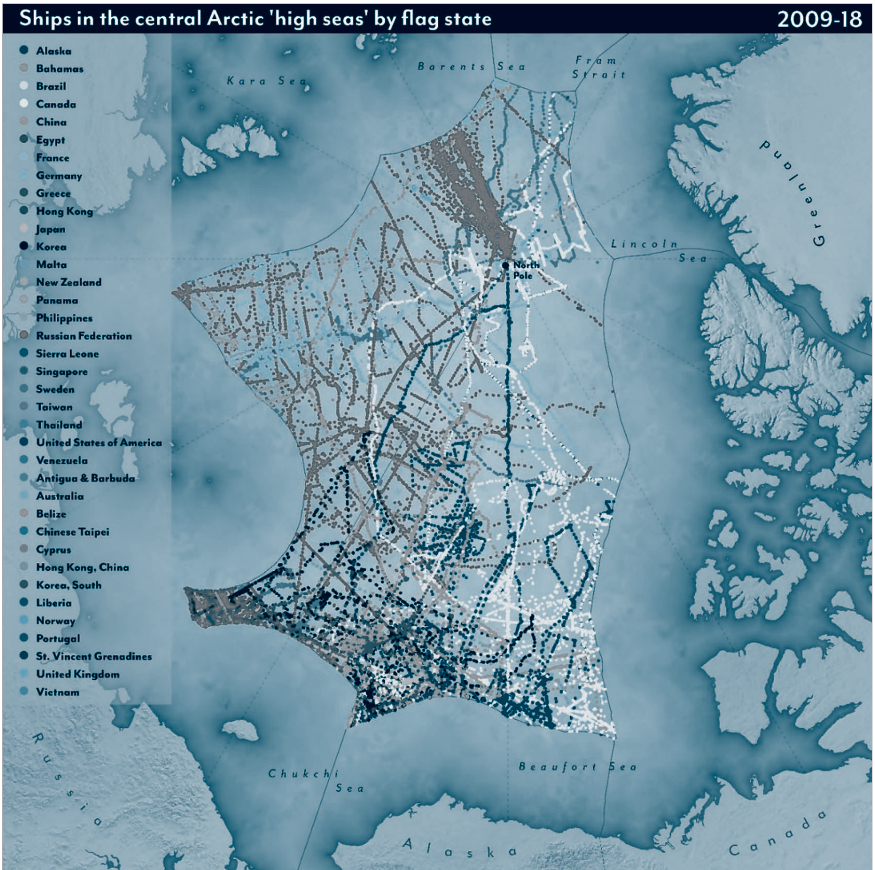
Exact Search Term (highlighted by cross-cutting theme)	Search-Term Occurrences Among Binding Arctic Agreements (Agreement Number Referenced in Table V.5)				
	1	2	3	4	5
Arctic	22	18	25	15	25
Analysis	0	0	1	2	0
Border	26	1	0	0	0
Borders	8	2	1	0	0
Compliance	0	0	0	11	1
Data	0	1	7	11	4
Decades	0	0	0	0	0
Decision	0	0	0	2	1
Decision-making	0	0	0	1	1
Ecological	0	1	0	0	0
Economic	0	4	3	0	0
Ecosystems	0	0	0	1	13
Evidence	0	0	0	0	0
Impact	0	0	0	3	0
Indigenous	0	2	1	0	6
Integration	0	0	0	0	0
International	6	15	17	20	11
Jurisdiction	1	5	2	0	3
Land	31	0	2	10	0
Monitor	0	1	0	3	1
Monitored	0	0	0	2	0
Monitoring	0	3	4	3	0
Months	1	1	2	0	4
National	3	12	6	1	5
Observation	0	0	1	0	0
Observations	1	0	1	1	0
Ocean	0	0	3	0	23
Options	0	0	3	0	0
Protection	0	0	3	10	0
Question	0	0	0	0	1
Reporting	1	0	1	0	0
Remote	0	1	0	4	0
Research	1	1	17	0	16
Rights	2	3	4	0	5
Satelite	0	0	0	2	0

Exact Search Term (highlighted by cross-cutting theme)	Search-Term Occurrences Among Binding Arctic Agreements (Agreement Number Referenced in Table V.5)				
	1	2	3	4	5
Science	0	0	4	0	0
Sea Ice	0	0	0	5	0
Season	0	0	0	3	0
Seasonal	0	0	0	3	0
Ships	0	3	0	123	0
Sustain	0	0	0	1	0
Sustaining	0	0	1	0	0
Sustainable	1	0	0	0	8
Sustainability	0	0	0	0	2
Synoptic	0	0	0	0	0
Systems	3	1	0	41	0
Technology	0	0	1	1	0
Tracking	0	0	0	0	0
Verification	0	0	0	2	0
Years	0	0	1	4	8
Cross-Cutting Theme	Time	Research	Action	Impact	Jurisdiction

Satellite Infrastructure for the CAO High Seas Fisheries Agreement

Satellite data about maritime ship traffic in the Arctic Ocean contribute substantively to the objective of this chapter, as reflected by regional analyses with the CAO High Seas (Figure V.7) that can be used to address Questions 2 and 3 above. Stimulated by the consideration of strategies to effectively implement a "precautionary approach" under international law with the binding agreement that entered into force in June 2021 (Table V.5), the CAO High Seas also provides a framework to test the "ship-ice hypothesis" that Arctic ship traffic is increasing as sea-ice is diminishing (Berkman *et al.*, 2020a, 2022a). With sea ice and shipping as key considerations for Arctic sustainable development, the "ship-ice hypothesis" further illustrates the application of questions of common concern to integrate research into action across the data-evidence interface, introducing options (without advocacy) that lead to informed decisions (Figure V.6).

The ecosystem of maritime ship traffic in the CAO High Seas is shown in Figure V.7 in relation to the flag states of the ships comprehensively from 2009-2018, further illustrating application of the space-time cube (Figure 1)



Note: Based on the diversity of vessel flag states with distinct ship tracks from 1 September 2009 to 31 December 2018 (see legend). From Berkman et al. (2022a).

Figure V.7 Ecosystem of maritime ship traffic in the CAO High Seas

with user-defined boundaries considered in the context of international law of the sea (Figure V.5). Moreover, as a region, the CAO High Seas offers a unique test of the "ship-ice hypothesis" because diminished sea-ice and open-water predominate only the Beaufort Sea and Chukchi Sea sectors (Thompson *et al*., 2015, Armitage *et al*., 2020), adjacent to the 180o EW meridian. Consequently, it is predicted that maritime ship traffic (i.e., socioeconomic activity) in the CAO High Seas will primarily come from the Pacific Ocean rather than from the Atlantic Ocean (Berkman *et al*., 2022a), even though vessel traffic north of the Arctic Circle predominates in the

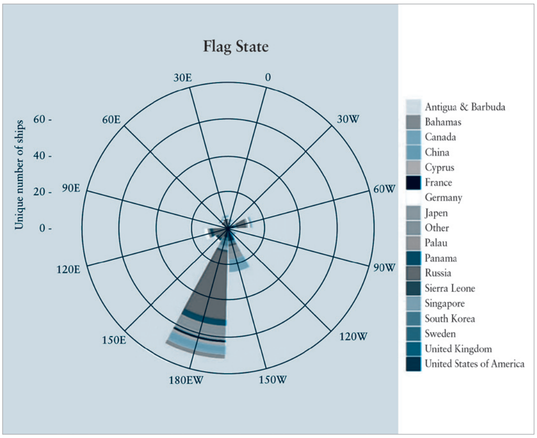


Figure V.8 *'Ship-Ice Hypothesis' test with maritime ship traffic populations in the CAO High Seas (Figure V.5) based on the distribution of ship flag states (Figures. V.6-V.7)*

Note: From MMSI records (Table V.7) across 30° meridional sectors surrounding the North Pole. See Figure V.4 for East-West orientation around Arctic Ocean longitudes with 0°EW in the Barents Sea to 180°EW through the Bering Strait. From Berkman et al. (2022a).

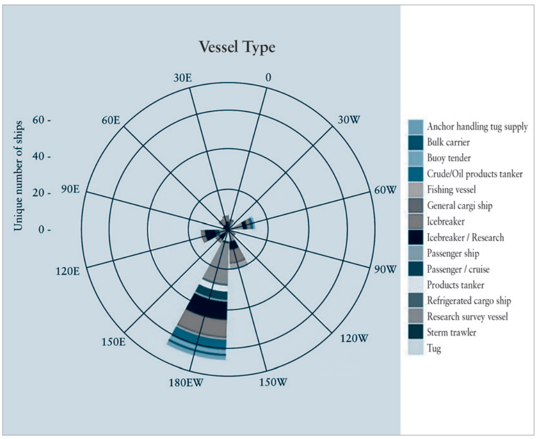


Figure V.9 *'Ship-Ice Hypothesis' test with maritime ship traffic populations in the CAO High Seas (Figure V.5) based on the distribution of ship types (Figures V.8-V.9)*

Note: From MMSI records (Table V.7) across 30° meridional sectors surrounding the North Pole. See Figure V.4 for East-West orientation around Arctic Ocean longitudes with 0°EW in the Barents Sea to 180°EW through the Bering Strait. From Berkman et al. (2022a).

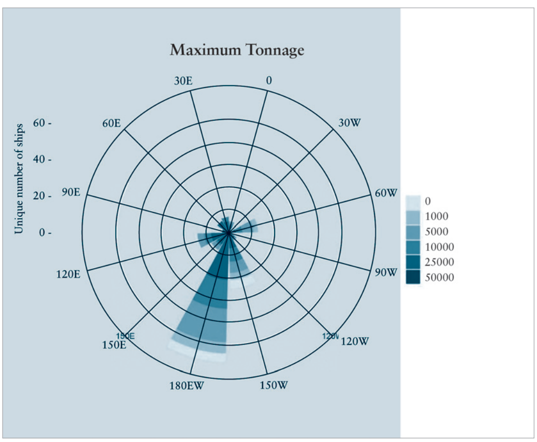


Figure V.10 *'Ship-Ice Hypothesis' test with maritime ship traffic populations in the CAO High Seas (Figure V.5) based on the distribution of ship size-classes*

Note: From MMSI records (Table V.7) across 30° meridional sectors surrounding the North Pole. See Figure V.4 for East-West orientation around Arctic Ocean longitudes with 0°EW in the Barents Sea to 180°EW through the Bering Strait. From Berkman et al. (2022a).

EEZ connected to the North Atlantic (Figure V.5).

Test of the "ship-ice hypothesis" can be characterized by vessel numbers and diversities in view of the origins within adjacent 30° sectors to identify any directional trends during the 2009-2016 period (Berkman *et al.*, 2022a). Within the CAO High Seas, international presence predominately comes from the Pacific Arctic sectors (Figure V.5) along the 180° EW meridian, adjacent to the Bering Strait. This same directionality is seen with ship types (Figure V.9), noting that icebreakers are the only types of ship that are entering the CAO High Seas independent of direction. Additionally, the predominant Pacific Ocean origin of ships into the CAO High Seas is revealed in view of diverse ship sizes, with small tonnage ships only appearing in the Beaufort Sea region (Figure V.10).

Utilizing the satellite AIS data, it has been discovered that most of the ships arriving into the CAO High Seas originate from the Pacific Ocean (Figures V.8, V.9 and V.10) through the Bering Strait, which is the choke point of maritime ship traffic into and out of the Arctic Ocean (Berkman *et al.*, 2016, Rothwell, 2017, WWF, 2020). This maritime ship-traffic directionality is 180° offset from the majority of shipping north of the Arctic Circle, which predominates in the Barents Sea (Figure V.5) where there is open water, as reflected by the Polar Code boundaries of ice-covered areas in the Arctic Ocean. Revealed by the satellite record of maritime ship-traffic to test the "ship-ice hypothesis" in the CAO High Sea, these analyses:

- Underscore the importance of framing questions to address with empirical methods;
- Emphasize the importance of observing systems with decisionmaking;
- Illustrate data that can be integrated into evidence for decisions (Figure V.6); and
- Highlight synoptic data that can be acquired only from satellites (Table V.6).

Bullet points (b) and (c) directly touch Question 2 above, both in view of the CAO High Seas Fisheries Agreement and its "precautionary approach" as well as the other binding agreements that have entered into force since 2009 (Table V.5). Similarly, bullet point (d) affirmatively answers Question 3, as it would have been impossible to discover the directionality of maritime ship traffic into the CAO High Seas without synoptic data from satellite observing systems. Collectively, the bullet points above and the underlying satellite analyses (Figures V.5, V.7, V.8, V.9 and

V.10) introduce options (without advocacy) to enhance the implementation of binding agreement in the Arctic Ocean.

Options (without advocacy) to Enhance Binding Arctic Agreements

To reiterate, the options herein are without advocacy and can be used or ignored explicitly in view of the governance mechanisms in Table V.5, respecting the institutions and those with responsibilities for their implementation. These options (without advocacy) are simply listed, noting their elaboration is beyond the scope of this discussion:

Option 1. The lack of specificity about "satellite" observations and observing systems is a shortcoming to address with the binding Arctic agreements that have entered into force since 2009 (Tables V.5, V.6 and V.7), appreciating the Arctic Marine Shipping Assessment (AMSA, 2009) and its influence with these governance mechanisms emerged before the satellite AIS record (Figures V.5, V.7, V.8, V.9, and V.10).

Option 2. Application of the "precautionary approach" with the CAO High Seas Fisheries Agreement ("as part of a long-term strategy to safeguard healthy marine ecosystems and to ensure the conservation and sustainable use of fish stocks") is a demonstration of informed decisionmaking (Table V.6, Figure V.6) under international law, complementing the Vision for the Arctic of the eight Arctic states and six Indigenous Peoples' Organizations (Arctic Council, 2013);

Option 3. Discovery that maritime ship traffic directionality predominates from the Pacific Ocean into the CAO High Seas (Figures V.8, V.9, and V.10) represents growing risks for Arctic Indigenous communities from the Aleutian Islands northward to address with all emergency response agreements in force for the Arctic Ocean (Table V.5);

Option 4. The satellite record of maritime ship traffic in and around the CAO High Seas (Figures V.5, V.7, V.8, V.9, and V.10) represents socio-economic data to integrate with biogeophysical data for effective implementation of all binding agreement that have entered into force since 2009 (Table V.5);

Option 5. Satellites and other observing systems (Table V.6) are vital elements of built infrastructure (involving technology plus capitalization) to support for both research and action with informed decisionmaking short-to-long term (Figure V.6) in all binding agreements that have entered into force since 2009 (Table V.5);

The above options are introduced specifically to provoke discussions, recognizing that sustainable development requires strategies across a "continuum of urgencies" with informed decisionmaking and effective coupling of built infrastructure plus governance mechanisms (Table V.6, Figure V.6).

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20. An Indigenous Perspective on Integrating Advanced Technologies and Indigenous Knowledge to Address Issues of Arctic Governance

Karen Pletnikoff

While there are many more ways that the contributions of Indigenous Knowledge can be used to inform issues of technology and governance in the Arctic, three will be the focus here:

- How active partnerships and deployment of appropriate technologies support Indigenous communities and their living knowledge;
- Why these arrangements serve a greater purpose than data alone and also provide good governance, cultivate equity, and align with trust responsibilities; and
- How these enterprises efficiently assemble information in novel ways, available nowhere else, and improve responsiveness in these important governance efforts.

Common definitions of technology and governance are intended here. However, in the context of Alaskan experts' current dialogs about Indigenous Knowledge, defining Indigenous Knowledge (IK) as distinct from Traditional Ecological Knowledge (TEK) and Local Knowledge (LK) is necessary to provide a common framing. These definitions are the author's and are for the purpose of this chapter and do not dispute any others' definitions. IK is a term applied to specific Indigenous cultures' living systems of knowing, which have been developed and refined over thousands of years and over the generations, ever evolving to incorporate constant environmental, ecological and social changes. TEK is a subset of IK, applied to the natural world and frequently viewed from the outside as past or looking backwards. The common western use of TEK is separated from the spiritual and cultural beliefs and practices that are integral to the specific people's worldview and needs, and so will not be used. LK is mentioned only to specifically designate it as not IK or TEK, but a term to acknowledge that anyone living anywhere will have some specialized knowledge about their surroundings. While LK can have valuable relevance in specific situations, it is not interchangeable or an acceptable substitute for IK or even TEK, nor is it required to be considered outside of regular public input to satisfy trust responsibilities.

A couple other concepts about Indigenous Knowledge should be noted. IK is not free for science or governance applications upon request, nor permitted to be shared publicly when provided, without specific terms and conditions supportive of the IK holders' goals. While many Indigenous Peoples want IK included in environmental and natural resource management and other governance actions, there is both inherent and market value to the information and the IK holders' time and efforts to document and share it. The IK holders may share data for only a singular purpose and allow no other use. Individuals may not consider themselves IK holders, but others in their communities may and apply willingly shared information as IK. Navigating how and what IK to collect and apply is a partnership between the IK holders and the decision-makers, not a third-party data broker.

For this discussion, the Aleut region can be defined as the entire 1,200-mile-long Aleutian Islands Archipelago, the lower end of the Alaska Peninsula, and the northern extent of the Pribilof Islands, encompassing the Bering Sea. The Unangax (Aleut) people have lived off these land and ocean resources for at least 10,000 years. Even older dating could be expected, as has been documented recently across the American continents. Archeological evidence demonstrates that all the islands and lands throughout the region were repeatedly inhabited over the millennia, with communities relocating as needed, often intentionally on top of previous village sites, to accommodate constantly changing environmental conditions, including regular volcanic activity and fluctuating natural resource availability.

These ancient Unangan people were not impoverished or disadvantaged. Nor is our region today, with some of the planet's richest fisheries providing sustained highly profitable exploitation and abundant renewable energy resources, including record-class wind, wave, tidal, and wide-spread geothermal. Maritime transportation and support industries, tourism, specialty livestock, mineral extraction, and cultural arts are other economic opportunities in the region. Improving local socio-economic conditions requires revisiting the governance of resource access and distribution, alongside investments in technologies and actions that work with our changing situations.

Alaska was purchased by the United States from Russia in 1867 for Alaska's exploitable natural resources, largely for the northern fur seal that were harvested and initially processed on the Pribilof Islands with Unangan labor. This purchase did not include concurrent negotiations or compensation for Indigenous Peoples' losses and personal and cultural trauma. Those continuing economic interests and arrears, the territorial legacy of land ownership, and the U.S. federal trust responsibility for Alaska Native individuals and their communities perpetuate significant remote federal governance, with all its inherent challenges and deficiencies. Conservation refuges and federally owned land dominate the majority of land ownership and management in the region, while offshore resources that were the livelihood of our ancestors are managed primarily for exclusive non-resident access rights. Improved local Indigenous participation in the numerous governance structures at all levels will improve our representative democracy and improve the governance itself, as needs are better understood and solutions customized to the consumer and better suited to work with the changing environment.

Technological advancements are not new to the Unangax people or our region; from advanced mummification in a damp climate to the Unangax iqyax, or kayak. As example, the iqyax has been considered one of the most technologically advanced vessels on the seas for thousands of years, due to numerous tested and improved features including: the flexible frame, inlaid ivory joints, customized proportions built for the user, wave-cutting bows, and wave-catching sterns. In the American period, we have seen these technologies deployed for World War II battles, Cold War-era military outposts, atomic testing on Amchitka Island, over-the-horizon radar systems, ports for advanced naval equipment, and currently on one of the U.S. military's more access-restricted air stations. WWII clean up necessitates new remediation and detection technologies be brought to bear, as these sites are frequently on top of protected ancient and historical sites. Evolving maritime technologies are vital to transitioning fisheries under changing species and distributions and continue to propel our seascape's fishing economy. The Aleut region's strategic location between increasingly tense international posturing brings the Unangan and the nation higher stakes and the need for greater involvement.

The northern arc of the Great Circle maritime shipping route cuts through the Aleutian archipelago with thousands of innocent passage transits annually. Risk assessments have shown, and we also witness, the need for increased capacity to respond to greater vessel casualty, search-and-rescue needs, and spill response; all of which require technological advancements and investments. Reduced Arctic Ocean ice has opened the Northern Sea Route and increased Bering Sea and Bering Strait traffic. This has also introduced new vessel types and participants, continually changing marine¸ safety and security issues that that this increased traffic creates. One encouraging example of effective governance is the self-governance found in the maritime industry, where industry's internal processes, such as underwriting and insurance requirements, can enact widely and quickly adopted changes to vessel behavior as preventative measures. A straightforward example of this idea can be seen in best practices, including Areas To Be Avoided (ATBA). Indigenous Knowledge is indispensable in designating important resource locations, timing, and behaviors, as well as acceptable and appropriate vessel management. When paired with observational data capturing technologies, continual feedback refines effectiveness and defines future needs.

Historic and recent maritime border incursions and fishing treaty violations drive the need to expand the tactics used for vessel tracking and response to protect Indigenous, local and national interests. The United States Coast Guard's Captain of the Port of Anchorage oversees a scope of activities and a scale of area of responsibility in the Arctic and Western Alaska that is exceedingly disproportional compared to the assets and infrastructure allocated to all the smaller sectors with narrower missions in the lower 48 states. Parity in investments between the Arctic and lower latitudes would greatly benefit current governance and enforcement, as well as help to gain ground on the ever-increasing regional environmental change and security threats. By including Indigenous communities' participation in these investments, decision-makers would create a pathway to incorporate both IK and real time observations and capitalize on the resulting cost and resource effectiveness.

Local interests have been involved in multiple efforts to improve governance for vessel traffic lanes and behavior through continual participation in regional response planning, best practices committees, sponsoring ATBA's, and investigating how geo-fencing and other local water-use planning can improve activities to protect our natural resources and environment. The reoccurring effort of updating the local Geographic Response Strategies (GRS) maps and spill response maps with local features and resources is a policy-based way to apply IK. It is also a strong example of the intersection of technology, IK and good governance. The GRS system is being transferred to a digital format, with the intent to improve active use and detail in a spill response, but the application in remote Alaska will be a real test and drive inevitable improvements. The long-term result could increase the use, and hopefully access to, digital mapping technologies that can be continuously updated as conditions require.

Amchitka Island is a prime example of a place where technological advancements can improve governance in the relative near term. Our Indigenous Knowledge tells us that we are the perpetual stewards of our lands and waters, providing no exceptions for current Western management schemes. This responsibility has been shouldered with significant apprehension for the future of our traditional foods and natural resources. The Atomic Energy Commission's Amchitka Island Nuclear Tests left large fractures under the island. Here, seawater infiltration and its eventual migration will release radionuclides into the environment, which can accumulate in our foods and impact fisheries. Understanding how this process's timeframe will be accelerated by the island's geological torsion and pulling apart, local earthquakes, regional volcanic activity, landslides and submarine landslides, is where technological investments could provide annual or near real-time monitoring. The subsequent governance options that early detection would offer could preserve fisheries, subsistence foods access, and, perhaps most importantly, public perception, a known casualty of these types of releases.

Beyond detecting any releases from Amchitka Island, there is no plan to address this contamination. Undeniably, there a need for a multinational "moon-shot" level of investment in the science and technology to clean up, contain and perpetually store radionuclides and their wastes. An imperative for slow and stationary sites like Amchitka, it is also an urgent requisite for new floating atomic power plants like the Akademik Lomonosov and the ongoing nuclear disaster at the Fukushima Daiichi Nuclear Power Plant. Planned releases of millions of gallons of radioactive water from Fukushima Daiichi storage tanks into the North Pacific can predictably ride the Kuroshio Current and North Pacific Gyre into the North Pacific and Bering Sea and impact and accumulate in the biota that we Unangax depend on. As we have seen from the market demand and rebound failures for Gulf of Mexico shrimp and oysters following the BP Deepwater Horizon Oil Spill disaster, contaminants do not need to reach levels of measurable dietary concern to impact human health through stress and diminish and even destroy economies. Many IK traditions require us to pay attention to the subtle and constant changes in our natural resources and environment and further demand we take action before those resources are irreparably damaged by our actions. Of course, the precautionary principle is not only found in IK, and Indigenous Peoples are not solely responsible – or alone – in calling for these needed efforts.

One of the most important ways technology identifies needs and priorities for governance is in the timely measurement of the rate and direction of changes. There are significant anticipated changes in natural resources. These include the current rapid and unpredictable changes in species populations, distributions and conditions, the potential for widespread population collapses of species that Indigenous, regional and national people and economies depend upon, and the introduction of new species, some of which may compete with currently preferred species. In the ocean, fundamental changes in habitat conditions and states are being driven by increased temperatures, such as loss of sea ice and protective ice benching, ocean acidification, oxygen capacity decreases, and other ocean chemistry impacts, all of which can alter primary productivity and cascade through the food chain. On land, changing environmental conditions force infrastructure and community protection, mitigation and even relocation, driving the need for new technologies and infrastructure designs that account for local economic priorities, local built environment use, and unpredictability brought about by changing conditions. Measuring and monitoring these indicators would take considerable effort applying our best technology, but even then, requires investment and the local expertise to apply the technologies effectively to withstand the local conditions and capture the desired data.

The Indigenous Sentinels Network and other environmental and resource stewardship programs embody this concept. Indigenous Knowledge holders, and those who do not yet self-classify that way, provide both observations and collect data determined to be needed and appropriate by their Tribe and/or community leadership. These efforts have direct impacts on the regular governance conducted in partnership with mission agencies when objectives align. However, these Indigenous groups are not merely technicians for these other agencies, as the overall goal is maintaining and increasing local understanding for local planning and decision making. This decision-making can be part of a co-management regime, and traditional natural resource management benefits greatly by incorporating these distributed and expanded data sources when rapid change destabilizes western data collection and management effectiveness. It is important to note that local management options are not limited to co-management. Tribal communities have many other uses for these efforts that may not align with agency interests or be intended for outside distribution.

Current technologies play important and growing roles in these efforts, including digital observation portals and databases, satellite-supported communication, GPS and digital mapping, and unmanned aerial and underwater vehicles, among other data collection tools. Technology improvements in high-speed, high-throughput communications that include fiber optic cable, renewable energy, and energy management are all anticipated to increase the types of data collection and management, and importantly, data analyses and application as they become available.

There are other areas where the application of technologies will have direct, measurable and desired local impacts. Marine debris sullies our beaches, entangles our marine mammals and poisons our seabirds, with the burden left to our communities and federal assistance requiring a full match. Advances in monitoring, identifying, labeling, tracking, and capturing marine debris are needed to improve overall health of our communities and our oceans, while enabling regulators to work on prevention and enforcement. There is special regional interest in value-added seafood processing, using renewable energy, and energy management technologies. Finally, our built environment is where significant technological advancement is needed to support good governance in a changing Arctic. Incorporating historic practices and methods found in IK such as portable infrastructure and multiple-sited communities can reinstate the resilience and adaptability that we require to effectively and efficiently meet our challenges. After all, an uninhabited Arctic would be the real battle lost.

The complex and evolving interdependence between Unangax and marine mammals is demonstrated by northern fur seal co-management on the Pribilof Islands. UAV and other remote sensing technologies are playing a growing role in this co-management and are likely to become an important way to reduce disturbance and improve population statistics for any threatened species. After 40 years of decline, there is urgency to take the next significant steps to return the northern fur seal to ecologically sound standing, requiring greater governance. This should include co-management led by Indigenous values at increased scope and scale, new monitoring and management methods that leverage new technologies, and involvement of supported partnerships to implement these innovations.

For us, there is one best measure of the performance of our governance systems: that we Unangax are one and remain on our lands and waters for another 10,000 years. This measure accounts for all our needs at once in one place: health, food security, economy, quality of life, and perpetuating our Indigenous Knowledge that has built us for our unique and ever-changing environment. Between then and now, incremental measures include subsistence resource access, natural resource and environmental protection, preserving and diversifying a continuous fisheries economy, regional security and safety, and increased Indigenous leadership in the structures that safeguard these important activities. Fundamentally, with every regulation enacted and resource allocated, our society actively chooses to perpetuate archaic perspectives or advance equality. In the case of rapid Arctic change, advancing equity is essential to America's Indigenous Peoples' continued success.

21. Roles that Advanced Technologies Play in the Work of the Arctic Council's Working Group on the Conservation of Arctic Flora and Fauna

Tom Barry

The 2030 vision outlined in the Strategic Plan for the Arctic Council 2021-2030 notes that the Council will develop working methods in response to the new realities being faced in the Arctic. Goal 1 highlights the desire to improve the exchange of knowledge and innovative technologies to help strengthen circumpolar cooperation in support of climate science and observations, reduction of emissions, climate change mitigation, adaptation, and resilience (Arctic Council, 2021). Focusing on the Conservation of Arctic Flora and Fauna (CAFF), the biodiversity working group of the Council, this chapter considers examples of how the Council is acting upon this vision and strategic goal through the use of advanced technologies to produce results that have the potential to make a difference from a governance perspective.

Sitting on the border between science and policy, CAFF seeks to benefit from advanced technologies through its focus on monitoring Arctic biodiversity and ecosystems, conducting assessments, implementing conservation strategies, delivering key findings, providing advice, and making recommendations to the Arctic Council. Central to this process is the application of an ecosystem-based approach to monitoring, whereby user needs and questions are informed by new knowledge and new technologies (methods and analysis) to inform the work of CAFF, guiding the evolution of its programmes such as the Circumpolar Biodiversity Monitoring Programme (CBMP) and the Arctic Migratory Birds Initiative (AMBI), and informing advice delivered to decision-makers (Figure V.11; Christensen *et al.*, 2021). This framework provides the base from which advanced technologies and approaches are applied within CAFFs activities through:

- Applying advanced technologies to ensure improved access to and archiving of biodiversity data;
- Using advanced technologies to help broaden the sources of

knowledge generation;

- Improving how information is reported upon to decision-makers in more relevant and useful formats; and
- Providing guidance on how advanced technologies and approaches might inform responses to issues such as conservation of migratory birds, invasive alien species, and plastic pollution.

Improving Access to and Archiving of Biodiversity Data

A fundamental step towards informed policy- and decision-making is reliable access to comprehensive data. While many such data already exist, the challenge in the context of the Arctic lies in finding, accessing, and making sense of existing but dispersed data. Data are not always encoded in accordance with international data standards and best practices and often lack the necessary contextual metadata required to correctly apply and interpret them. Accessing Arctic data from a range of sources and in variable formats can require a lot of effort to gather and assemble information that is useful to stakeholders and policymakers.

The Arctic Council does not have a common data policy to guide approaches to data management and access across its subsidiary bodies. For example, CAFF has an open access data policy (Barry *et al.*, 2021) that strives to be in accordance with the Conservation Commons and International Polar Year (IPY) data policies. In contrast, the Protection of the Arctic Marine Environment (PAME) Working Group places cost and

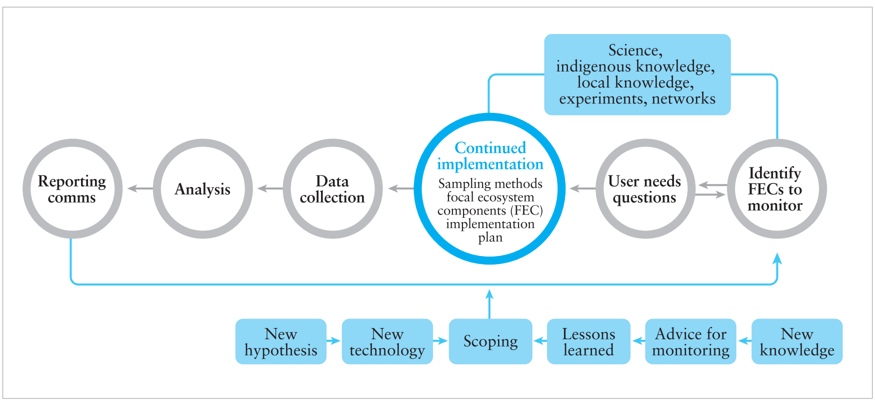

Figure V.11 Adaptive, ecosystem-based approach to monitoring—CBMP usage restrictions on access to the Council's Arctic Ship Tracking Database (Arctic STD). The Council also has no common data framework to ensure that the huge amount of information it generates is captured and archived so that it can be used to more easily inform future assessments and policy initiatives. In response, CAFF is implementing a data management framework for biodiversity data and supporting the development of common data policies for the Council. Both processes build upon the adoption and application of advanced data management technologies and approaches to lay the groundwork to help facilitate improved data management, integration, and access.

To develop a data management framework for biodiversity data, CAFF turned to the world of open-source data management and sharing technologies to develop the Arctic Biodiversity Data Service (ABDS). The data management system for biodiversity data was generated via the Council and uses open-source solutions: GeoServer, GeoNetwork, an Integrated Publishing Toolkit and a Postgre SQL PostGIS database combined to facilitate sharing of information, searching geospatial data, combining distributed map services, publishing geospatial data, and scheduling metadata harvesting from other catalogues (Barry *et al.*, 2019). Reflecting a growing awareness of its potential to enhance access to Arctic biodiversity data and helping ensure that reliable data can be channelled to inform decision-making (Barry *et al.*, 2021), the ABDS is embedded within regional data frameworks (e.g., the Arctic SDI and global frameworks,

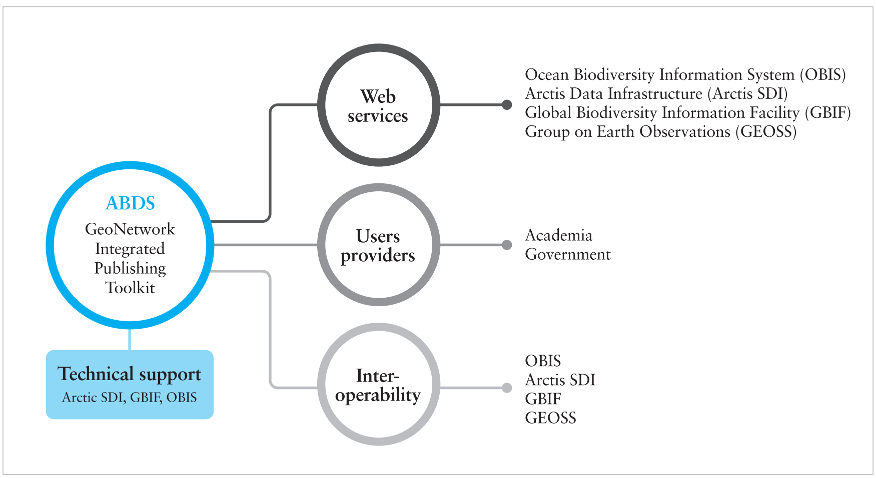

Figure V.12 *ABDS structure*

UNESCOs Ocean Biodiversity Information System (OBIS), and as a node within the Global Biodiversity Information Facility (GBIF)) (Figure V.12).

The impacts of this approach to monitoring (CBMP), coupled with the ABDS, is leading to the development of more integrated, easily accessible, and therefore more policy relevant and useful data. This is reflected in the steady increase in the extent of data ABDS data holdings. Currently ABDS holds 315 datasets and more than 370,000 individual data records, with a significant increase in records as of 2015 reflecting when ABDS became an Arctic node within GBIF and OBIS (Figure V.14). This increasing integration of and access to data is reflected in the increase in the number of papers citing ABDS data holdings, reflecting a growing awareness of the ABDS (Figure V.15). Similarly, this increasingly coordinated focus on improving how Arctic Council initiatives deliver information is leading to more integrated approaches to reporting, as in the State of the Arctic Biodiversity Reports. One example is the release in 2019 of the State of the Arctic Freshwater Biodiversity Report (Lento *et al.,* 2019) where, for the first time, a fully integrated database accompanied an Arctic Council assessment. The Arctic Freshwater Biodiversity database contains data from more than 9,000 stations with multiple samples across multiple years (Figure V.14) – and has significant potential to transform the manner and speed at which status and trends of freshwater biodiversity can be reported on into decision-making processes in the future. Other examples can be seen in the development of the Circumpolar Seabird database, which is being designed to collect data on the

Figure V.13 *ABDS data coverage in GBIF*

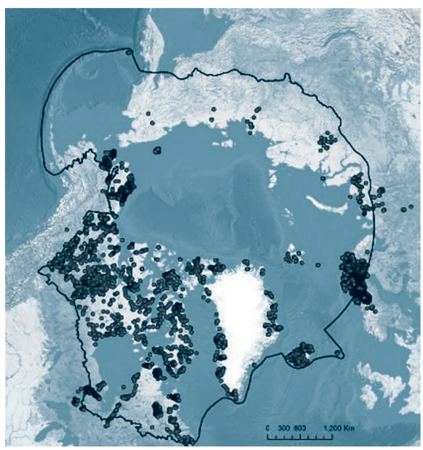

Figure V.14 *Arctic freshwater monitoring stations*

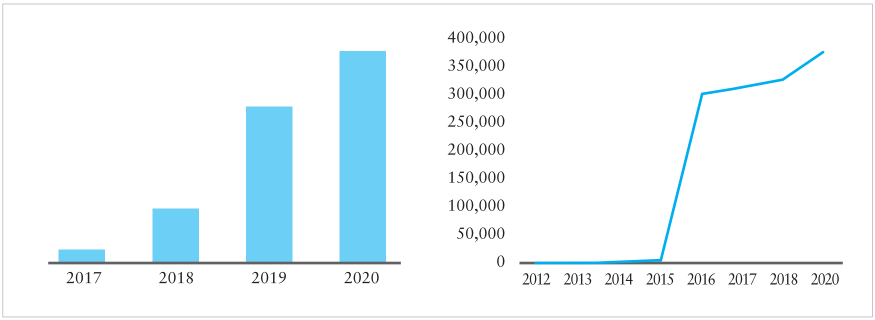

Figure V.15 *Growth in GBIF citations and ABDS data holdings in GBIF*

health of seabird colonies (Barry *et al.*, 2021).

To help encourage a common approach to data across the Council and the Arctic, CAFF has been instrumental in supporting an initiative among the mapping agencies of the eight Arctic States to support development of an Arctic Spatial Data Infrastructure (SDI) (Barry 2008; Skedsmo *et al.*, 2011, Arctic SDI, 2011). This led to the signing of a Memorandum of Understanding (MOU) among the mapping agencies of the Arctic states (2014) to develop an Arctic SDI and provide tools for data distributors to ensure that their geospatial data is easier for users to access, validate, and combine with other data. When complete, the Arctic SDI will allow access to interoperable data and tools supporting monitoring and decision making for politicians, governments, policy makers, scientists, and industry across the Arctic (Arctic SDI, 2020).

Broadening the Sources of Knowledge Generation

Data collection in the Arctic is challenging and resource intensive, and as a result, data are sparse and disparate (Jenkins *et al.*, 2020). Recognizing this challenge and the need for a more comprehensive understanding of change across the Arctic, the *Action Plan for Biodiversity: 2013-2023* (CAFF, 2015) has a focus on developing tools for data sharing in order that data collected can be used by a wide range of people engaged in Arctic biodiversity science, policy, and management. One example is the five-year strategic plan guiding the implementation of CAFFs monitoring programme, the CBMP, which has a focus (Objective 2.2) on evaluating the effectiveness of existing and new methods and technologies to support biodiversity monitoring and assessment.

One area where this is being explored is through remote sensing. While remote sensing data have frequently been used for specific studies at focused locations across the Arctic, few large-scale studies, at the landscape or pan-Arctic scale, have been conducted. In response, CAFFs Land Cover Change index explores how remote sensing technologies might be harnessed for use in Arctic biodiversity monitoring and assessment activities (Shuchman *et al.*, 2015; Barry and Jenkins, 2021). Using a standard remote sensing platform (MODIS), a series of satellite-based remote sensing products focusing on the circumpolar Arctic, parameters were developed that represent key drivers dictating seasonal processes in Arctic ecosystems. These were analysed between 2001 and 2020 to help understand changes occurring and evaluate remote sensing for use in Arctic biodiversity monitoring and assessment. A key challenge is to translate what these mean on the ground for Arctic

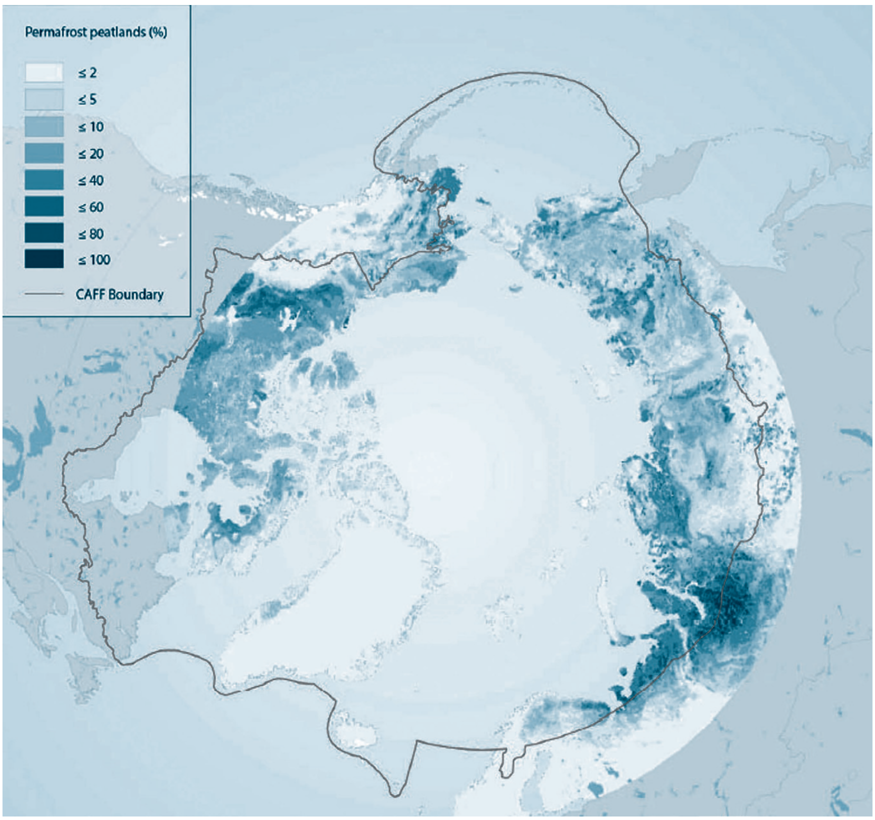

Figure V.16 Extent of peatlands with near surface permafrost (Hugelius and Barry 2021) biodiversity and how this assessment coupled with the CBMP Biodiversity Monitoring Plans (Gill *et al.,* 2011; Culp *et al.,* 2012; Christensen *et al.,* 2013; Jones *et al.,* 2019) can help improve our understanding of biotic responses to these broad-scale drivers; and provide more targeted and effective advice to decision makers.

Further work is also underway in cooperation with the Arctic SDI to develop a Pan-Arctic Wetlands Inventory Map at higher spatial resolutions to classify wetlands from satellite imagery (Figure V.16). This will generate a wetland baseline dataset that includes the latest wetland data from each Arctic state and help support longer-term efforts to monitor changes and measure the impacts of climate change. Other examples include: planning to cooperate on a satellite tracking program for key migratory waterbird species within the Central East-Asian Flyway to identify still undiscovered sites; analysing the results of satellite tracking data and other sources of information to identify important breeding and staging areas; conducting surveys and assessments there; identifying threats and working with national/regional governments; research institutions and NGOs to develop monitoring techniques and implement conservation plans.

An important challenge facing the Council is also how to adopt a co-production of knowledge approach to generating information to inform decision-making. CAFF, through the CBMP Coastal Biodiversity Monitoring Plan (Jones *et al.,* 2019), has developed the Council's first approved platform to develop and communicate information on the status of selected Arctic coastal species and ecosystems based on Indigenous Knowledge, science, and local knowledge. This plan identifies seven "coastscapes" around which to build this knowledge, with each defined by the natural and human environments within them. To implement this monitoring plan spatial technologies are being used to map the distribution of these coastscapes and apply metadata structures and standards.

Improving How information is Reported

CAFF sits on the divide between the worlds of science and policy. A key challenge is how to improve the ways in which the outcomes of its monitoring and assessment activities are communicated in a manner that makes them easier for decision-makers to understand, in a format that makes these outcomes easier to apply in a governance context. One of the five themes of the *Action Plan for Biodiversity: 2013-2023* is improving public awareness and is reflected in Goal 1 of the CBMP Strategic plan to ensure that it remains relevant by providing high quality information to support decision making at global, national, regional, and local levels. One example of how CAFF is taking advantage of advanced technologies to achieve this is through creation of a regional reporting tool (the *Arctic Biodiversity Dashboard* (Gill *et al.*, 2021)), a policy-friendly interactive platform that visualizes datasets for regional target tracking and reporting (Figure V.17). Helping to determine if the Arctic is moving towards or away from key post-2020 CBD and SDG targets, using local, regional, or global data accessible through Arctic organizations (e.g., CAFF) or international institutions (e.g., GBIF). This effort is utilizing Application Programming Interfaces (API) to allow for automated updates to indicators on the Dashboard to ensure sustainability and efficiency. This will help track biodiversity trends while allowing users to select or de-select various features, functions, and indicators. It will also streamline access to indicators in customizable scales to facilitate more effective and relevant national, regional, and global biodiversity assessments.

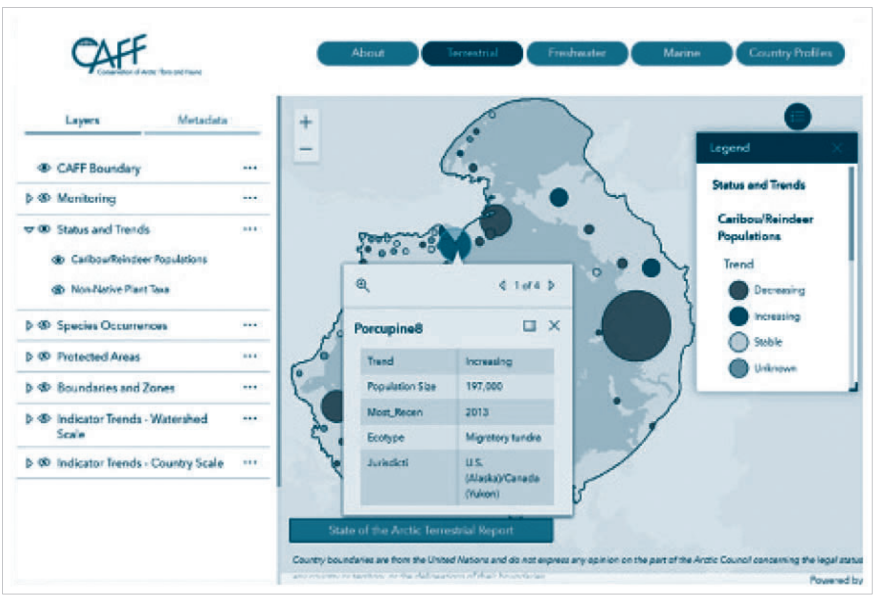

Figure V.17 *Arctic biodiversity dashboard: Example of a pan-Arctic visualization of caribou/reindeer herd population trends, size, and distribution*

Guidance on Advanced Technologies and Approaches

The CBMP ecosystem monitoring plans (coastal, freshwater, terrestrial, and marine) identify a suite of key elements, called Focal Ecosystem Components (FECs) for each ecosystem; where changes in FECs status likely indicate changes in the overall environment and are therefore monitored. Each plan identifies recommended approaches to collecting data on FECs. For example, the CBMP Freshwater group is currently preparing a handbook to provide authorities, research station managers and researchers with recommended, standardized monitoring protocols to promote consistent and harmonized monitoring protocols including for the application of emerging technologies.

Conclusion

The 2021 Declaration by the Foreign Ministers of the Arctic States (Arctic Council 2021) contained for the first time clear statements recognising that effective governance relies upon reliable data. The Declaration also welcomed progress towards implementing guiding principles on data management and access to ensure that information generated by the Council is findable, accessible, interoperable, reusable, and widely shared. The above examples illustrate how the Council is exploring how to make use of advanced technologies to improve the knowledge it generates, ensure it is more comprehensive, and that the systems it has established (such as the CBMP) can inform decision-making and lead to improved governance. The Arctic SDI is helping the Council to develop common data management principles as a first step towards a more coordinated approach to how it manages information. However, the current absence of a common approach means that data initiatives across the Council's subsidiary bodies at present remain largely uncoordinated. There are exceptions, such as some biodiversity data generated through PAME and cross-Working Group initiatives that have been archived within the ABDS, making these data accessible and subject to the data policy and standards applied to the ABDS.

In many ways data derived from advanced technologies is already being used to inform Arctic Council monitoring and assessment activities. A more cohesive approach/framework is gradually evolving, helping to facilitate and encourage more integrated biodiversity monitoring and assessment. This is likely to ultimately lead to more reliable key findings and more informed advice and recommendations. By building upon more integrated data and using advanced technologies, these efforts can support more informed decision making. Examples can be seen in how the Council is:

- Providing best practices and guidelines e.g., *Guidelines for implementing Scientific Data Collection across the Arctic Oceanic Region Utilizing Unmanned Aircraft Systems* (AMAP, 2015);
- Developing more cohesive frameworks to ensure more integrated, accessible, and maintainable structures e.g., ABDS, Arctic SDI, Arctic STD;
- Applying new technologies to complement more traditional approaches to knowledge gathering and conservation actions e.g., satellite tagging, remote sensing indicators of change e.g., wetlands;
- Taking first steps towards common data principles and policies; and
- Improving how information is reported e.g., the Artic Biodiversity Dashboard and the Arctic STD.

A challenge to all these activities is the speed at which it is happening and its cumulative nature. A question remains: do the efforts of the Council to improve how it collects and manages data reflect this urgency?

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Highlights from Session 6 of the North Pacific Arctic Conference 2021

Arctic Futures and the Pathway toward NPAC 2022

Session 6, the final session of the NPAC 2021 virtual conference, provided an opportunity to reflect on this year's conference and to discuss priorities for future years, especially 2022. While NPAC veterans were featured in the first part of this session chaired by Jong Deog Kim, the second half was devoted to perspectives from NPAC Fellows and chaired by Nancy D. Lewis. No formal papers were prepared for this informal dialogue but Fellows were asked to reflect on new perspectives that they were taking away from the conference and on governance components of key challenges facing the Arctic which might be included in the NPAC 2022 agenda.

Chairs and Organizers:

Nancy D. Lewis
Jong Deog Kim

Discussion Highlights:

Throughout NPAC 2021, many governance issues "hovered over" the agenda, in some sessions more explicitly than others, making governance a logical thematic choice for NPAC 2022. There were numerous suggestions regarding important topics to be considered, including climate change, biodiversity, fisheries, black carbon, data sharing, securitization, and energy and mineral exploitation and regulation, as well as questions about how complex governance or quasi-governance structures might be more efficiently coordinated and managed.

Arctic peoples need to be brought into this discussion in an integral way, not only because of their inherent right to self-determination, but because they experience and view contemporary Arctic realities very differently. It was noted, for example, that ideas for addressing climate change arising from non-Arctic perspectives, including non-Arctic parts of Arctic states, often appear to Indigenous Peoples to be a new form of "green colonialism" in which traditional impositions on their homelands and resources are reframed as part of the effort to address global climate change.

There is broad recognition that businesses are important stakeholders in regional development and governance. The recurring question of whether the Arctic Economic Council is an adequate venue for businesspeople to interact with governments and Arctic peoples arose as a key consideration.

There was considerable interest in addressing "securitization" from at least two perspectives. One involves showing how exaggerating security challenges arising in the Arctic inhibits cooperation in other areas. The other is to recognize that rapid climate change and related impacts are themselves security challenges of common interest to Arctic Indigenous Peoples and other residents as well as to national governments. There was the recognition that while traditional geopolitical tensions pose challenges, there are also opportunities in areas such as data sharing, communications, environmental protection, hazard mitigation, and search and rescue.

Twenty-one NPAC Fellows have participated in recent NPAC conferences with dedicated funding streams from the Korea Maritime Institute, the U.S. National Science Foundation, and the East-West Center. The input from NPAC Fellows introduces new perspectives that enrich the conference, and the Fellows both value and contribute to the interdisciplinarity and diversity of the conference participants. Involving the next generation of individuals who will become the policymakers, researchers, scientists, and practitioners of the future is one of the specific goals of NPAC.

The Korea Maritime Institute (KMI) is a government-affiliated research organization under the umbrella of the National Research Council for Economics, Humanities and Social Science (NRC) in the Republic of Korea. Since its establishment in 1984, the KMI has been a major think tank in the development of national maritime and fisheries policies including shipping and logistics, port development, coastal and ocean management, maritime safety and security, and fisheries affairs.

The East-West Center (EWC) promotes better relations and understanding among the people and nations of the United States, Asia, and the Pacific through cooperative study, research, and dialogue. Established by the U.S. Congress in 1960, the Center serves as a resource for information and analysis on critical issues of common concern, bringing people together to exchange views, build expertise, and develop policy options.

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