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Institutional Dimensions of Sustaining Arctic Observing Networks (SAON)

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ABSTRACT. Sustaining Arctic Observing Networks (SAON) implies a system of different sensors that are generating data to be preserved, interpreted, and applied in a continuous manner over a long period on a pan-Arctic scale. This note summarizes the current institutional framework that relates to data generation and use, as well as decision making and operational responses, around the Arctic Ocean. Sustainable solutions will necessarily involve those institutions that have the financial, logistic, policy, and legal capacity to support infrastructure in the Arctic Ocean region into the future. Three options are introduced for supporting SAON as a key element of the sustainable Arctic Ocean infrastructure that governments and Indigenous peoples hope to develop. Option 1 would be for the Arctic coastal states to mandate that a portion of leasehold payments from energy companies be earmarked for general-purpose infrastructure development in the Arctic Ocean region, with specific inclusion of SAON. Option 2 would be for the Arctic Council, as the high-level forum for international cooperation in the Arctic, to spread the burden of supporting SAON among the Arctic states, non-Arctic states, and Indigenous peoples. Option 3 would be to support SAON through coordinated public-private partnerships among diverse organizations and institutions with Arctic remits. Compelling justification for supporting SAON is that it is needed to inform decision making about both sustainable infrastructure development and maritime domain awareness for commercial operations in the Arctic Ocean.

Key words: holistic; infrastructure; institutions; options; pan-Arctic; sustainability

RÉSUMÉ. Les réseaux Sustaining Arctic Observing Networks (SAON, ou réseaux d'observation durables de l'Arctique) sont dotés d'un système de capteurs différents qui produisent des données à stocker, à interpréter et à appliquer de manière continue sur une longue période, à l'échelle panarctique. Cette communication résume le cadre institutionnel actuel faisant le lien entre la production des données et leur utilisation, et fait état de la prise de décisions et des interventions opérationnelles relatives à l'océan Arctique. Les solutions durables feront nécessairement appel aux établissements qui possèdent la capacité financière, logistique, politique et juridique de soutenir l'infrastructure dans la région de l'océan Arctique à l'avenir. Trois options sont présentées pour appuyer les réseaux SAON en tant qu'élément-clé de l'infrastructure durable de l'océan Arctique que les gouvernements et les peuples indigènes espèrent aménager. La première option ferait en sorte que les états côtiers de l'Arctique mandateraient qu'une partie des versements à bail de la part des sociétés du secteur de l'énergie soit affectée à l'aménagement de l'infrastructure générale dans la région de l'océan Arctique, ce qui comprendrait les réseaux SAON. La deuxième option viserait à ce que le Conseil de l'Arctique, cette tribune de collaboration internationale de premier plan dans l'Arctique, répartisse le fardeau de soutenir les réseaux SAON entre les états arctiques, les états non arctiques et les peuples indigènes. La troisième option consisterait à faire appuyer les réseaux SAON par des partenariats coordonnés entre divers organismes et établissements du secteur public et du secteur privé pour que des remises soient faites dans l'Arctique. La justification permettant de convaincre de la nécessité de soutenir les réseaux SAON est que l'existence des réseaux s'avère nécessaire pour informer la prise de décisions relatives aux aménagements d'infrastructures durables et à la sensibilisation au domaine maritime en vue de la réalisation d'activités commerciales dans l'océan Arctique.

Mots clés : holistique; infrastructure; établissements; options; panarctique; durabilité

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INTRODUCTION

Environmental State-Change in the Arctic Ocean

The Arctic Ocean had been characterized by sea ice accreting over many years and then persisting year-round as part of an environmental process repeated for millennia (Overpeck et al., 2005; Stickley et al., 2009). In fact, until the 21st century, the Arctic Ocean was covered mostly by multi-year sea ice, in contrast to the Southern Ocean around Antarctica, where first-year sea ice predominates. This situation has changed.

The Arctic Ocean is now dominated by open water during the summer and first-year sea ice during the winter

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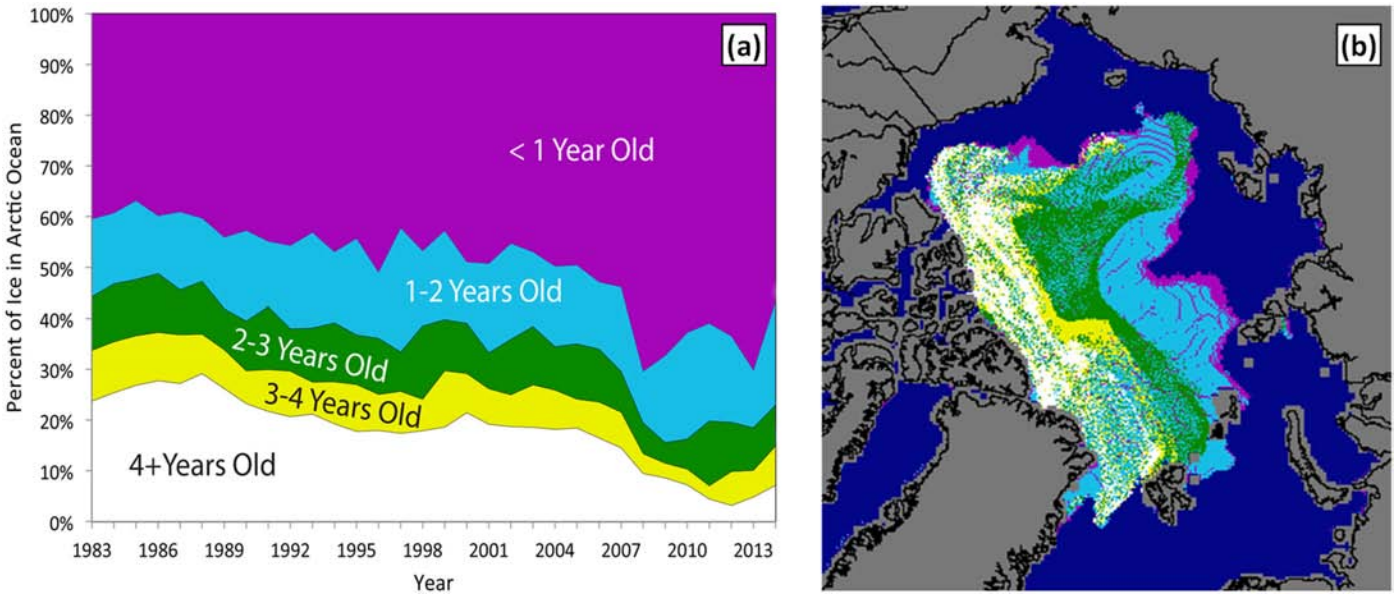

FIG. 1. Environmental state-change in the Arctic Ocean. (a) Arctic sea-ice composition changes in March (when sea-ice extent is maximal each year) from 1983 to 2014, revealing that multi-year sea ice has been replaced by first-year sea ice, which now dominates in the Arctic Ocean. (b) September 2014 distribution of sea-ice age classes (colors shown in Fig. 1a), revealing that most older sea ice remains next to North America with open water extending from the Bering Strait to the Barents Sea along the Northern Sea Route adjacent to Russia. Images from NSIDC (2014).

(Fig. 1a, b). Within the past three decades, the Arctic Ocean has been transformed from a sea with a permanent sea-ice cap to a seasonally ice-free sea with sea ice shrinking to its minimum extent in September and growing to its maximum extent in March (Berkman, 2012). Rather than projecting forward to the mid-21st century, when the Arctic Ocean may be open water across the North Pole, we can see that the system has already crossed a threshold, with more than 50% of the sea ice newly forming each year (Fig. 1a). Like a fertile land area becoming a desert, or a glacier becoming a mountain valley, the Arctic Ocean is experiencing an environmental state-change in which the boundary conditions and dynamics of the system are fundamentally replaced. Without its permanent sea-ice cap, the Arctic Ocean effectively is a new system.

Unparalleled access to the Arctic Ocean is awakening opportunities for trade routes, as well as exploitation of living and non-living resources. The environmental state-change is also introducing inherent risks of political, economic, and cultural instability, as well as ecosystem impacts beyond anything previously experienced by humans in the region. The fact that these opportunities and risks are occurring on the time scale of years rather than decades makes them matters of urgency (Berkman and Vylegzhanin, 2013).

Societal Need for Arctic Observing Networks

Historically, the boundaries of the Arctic Ocean system have been the seafloor, the surrounding land areas, and its permanent sea ice, with inflow and outflow from the North Pacific and North Atlantic. This marine system effectively turns on and off with seasonal solar forcing constrained by tilt of the Earth's axis, which is why the Arctic Circle is at 66.5º N. This astronomical boundary provides the only unambiguous, consistent, and objective delimitation of the Arctic Ocean with its surrounding states and Indigenous peoples (Fig. 2).

The resulting oceanography and meteorology of the Arctic Ocean directly influence natural ecosystems (Fig. 3a) and adjacent human populations in the surrounding coastal states of Canada, Denmark, Norway, the Russian Federation, and the United States, as well as in the non-coastal states of Finland and Sweden (Fig. 3b).

Dynamics of the Arctic Ocean system also influence institutions with diverse remits in this maritime region. Recently, stimulated by the environmental state-change in the Arctic Ocean (Fig. 1), the Arctic states have begun to adopt binding agreements in conjunction with their biennial ministerial meetings through the Arctic Council (Fig. 3c). These include the Agreement on Cooperation on Aeronautical and Maritime Search and Rescue in the Arctic (SAR; Arctic Council, 2011; Fig. 3c) and the Agreement on Cooperation on Marine Oil Pollution, Preparedness and Response in the Arctic (MOPP; Arctic Council, 2013). Through the International Maritime Organization, the international community has also adopted a binding polar code for shipping that applies specifically to the Arctic (Fig. 3d), as well as to the Antarctic (IMO, 2015).

In addition, activities in the Arctic Ocean are influenced by institutions with remits beyond the region, for example, the United Nations Convention on the Law of the Sea (UNCLOS, 1982; Fig. 4a, b). Navigational areas and meteorological areas (Fig. 4c), as well as environmental and fisheries conventions, also include the Arctic Ocean (Fig. 4d).

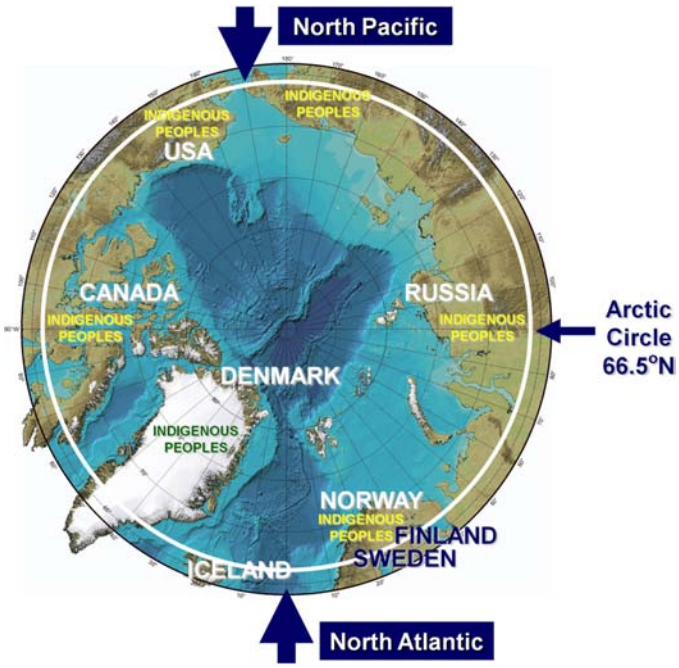

FIG. 2. Earth-system boundary configuration covering the Arctic Ocean in view of the astronomical position of the Arctic circle at 66.5˚ N latitude (white line), based on 23.5˚ tilt of the Earth's axis, with inflow and outflow from the North Pacific and North Atlantic. Also shown are the surrounding Arctic coastal states (Canada, Denmark, Iceland, Norway, Russian Federation and United States), non-coastal states (Finland and Sweden) and circumpolar presence of Indigenous peoples.

It is noteworthy that the SAR (Arctic Council, 2011) and MOPP (Arctic Council, 2013) agreements both represent unfunded mandates for the Arctic states that will require shared infrastructure that does not yet exist. For sustainable development purposes, infrastructure is herein defined as the combination of fixed, mobile, and other built assets (including communications, research, observing and information systems) and regulatory, policy, and other governance mechanisms (including insurance). Such infrastructure, which will be critical for operational decision making, relates directly to fixed, mobile, and remote observing systems in and around the Arctic Ocean. Moreover, a network of observing systems will provide real-time data and model predictions that will be essential for the Arctic states to allocate their response resources cost-effectively and efficiently to urgencies that require their shared stewardship.

Implications of the environmental state-change in the Arctic Ocean relate to all human activities and natural ecosystems in the region. To both understand and respond to the impacts of the environmental state-change in the Arctic Ocean, it is essential to have accurate, timely, and repeatable measurements of the geophysical, chemical, and biological dynamics of this pan-Arctic system. Such measurements will require a stable and continuously operating network of instruments across the entire Arctic Ocean region, which in turn will depend on logistics and financial support especially from the Arctic states.

This paper identifies the challenge to sustain Arctic observing networks as essential infrastructure elements that will facilitate informed decision making for "sustainable development and environmental protection," which are the "common Arctic issues" established by the Arctic states and Indigenous peoples (Ottawa Declaration, 1996). Sustainable development is herein defined in terms of balancing environmental protection, economic prosperity, social equity, and public welfare over time in view of the urgencies of present generations and the needs of future generations. Sustainable development further involves balance between national interests and common interests to maintain geopolitical stability for the Arctic region, without which the necessary international investment, coordination, and consistent application among nations will be inadequate for any shared infrastructure.

Objectives in this paper are to (1) provoke discussion about SAON among diverse Arctic stakeholders; (2) illustrate the international, interdisciplinary, and inclusive (i.e., holistic) relevance of SAON; and (3) briefly reveal examples of options that can be considered in greater depth to support the long-term implementation of SAON.

SUSTAINABLE DEVELOPMENT IN THE ARCTIC REGION

Background Considerations for SAON

The Arctic region entered into a sustainable development phase (Fig. 5) with the visionary speech by Soviet President Mikhail Gorbachev (1987), who proposed an "Arctic Research Council," as well as environmental protection and international cooperation in the Arctic. Building on these proposals at the end of the Cold War, the eight Arctic states initiated the International Arctic Science Committee (IASC) in 1990, the Arctic Environmental Protection Strategy (1991), and finally, the Arctic Council (Ottawa Declaration, 1996).

Whether the impacts are local or global, sustainable development of the Arctic will involve informed decision making, with sufficient details about the "pressures and drivers of change [and] the current state of the system, as well as identifying the key indicators that will mark systemic and potential detrimental changes, before the appropriate responses and actions are devised and implemented" (Bock, 2013:40). Understanding these drivers and indicators will require implementation of observational networks that are continuously and objectively collecting diverse data in a shared manner.

As a high-level forum, the Arctic Council has provided an umbrella framework for its six working groups to observe, assess, and synthesize data into a wide variety of targeted research reports (Arctic Council, 2015). With SAON, the Arctic Council already has recognized that a necessary component of sustainable development is the built infrastructure for observing and interpreting the

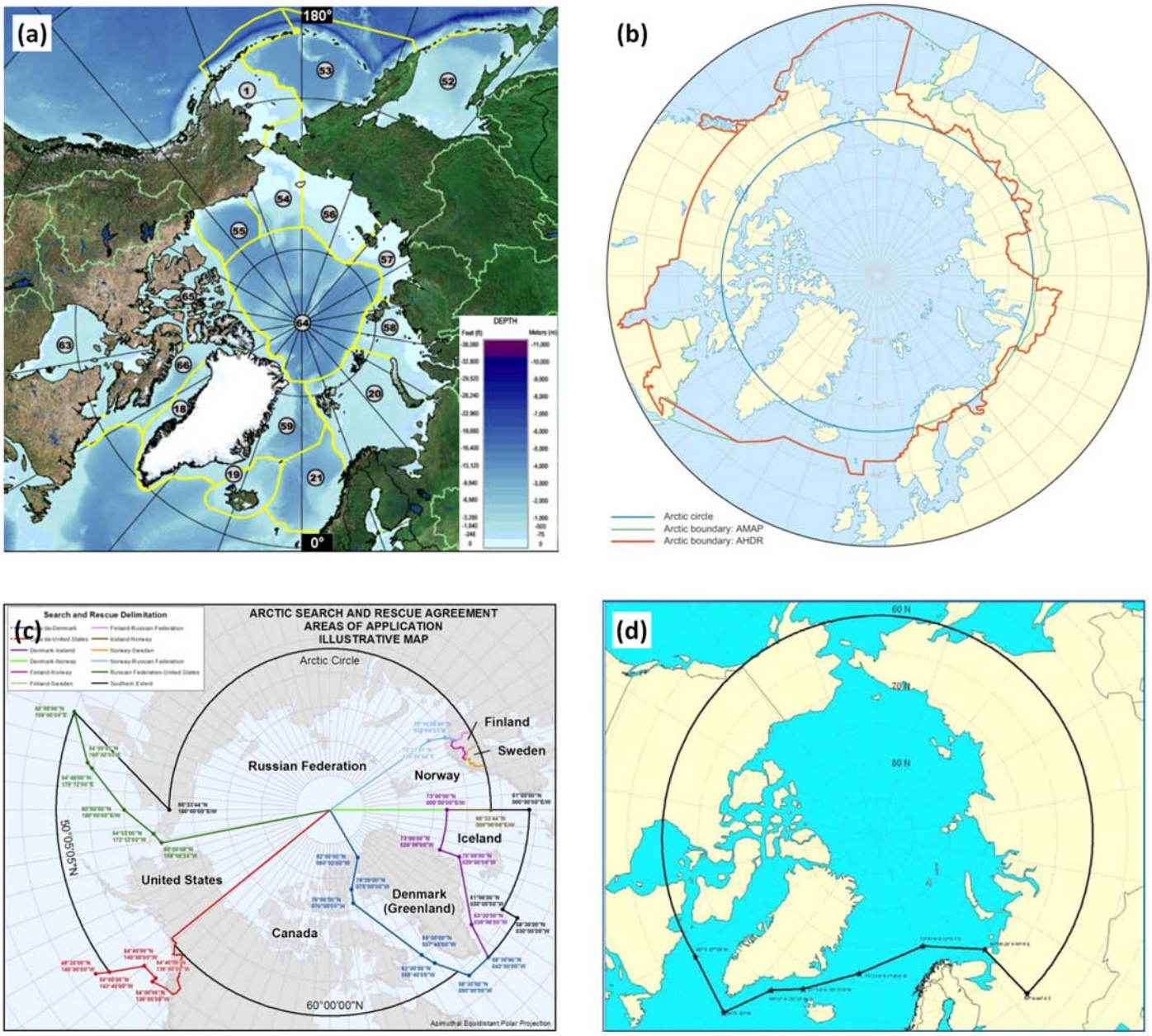

FIG. 3. Arctic biophysical, socio-economic and institutional boundary configurations covering the Arctic Ocean. (a) Large Marine Ecosystems with boundaries in yellow (AMSA, 2009); (b) Human development boundary for the Arctic region in red (AHDR, 2004); (c) Search and rescue areas of the Arctic states (Arctic Council, 2011); and (d) Arctic boundary for the binding International Code for Ships Operating in Polar Waters (Polar Code), showing the map from earlier guidelines (IMO, 2009). Modified from Berkman and Vylegzhanin (2013).

dynamics of Arctic systems on a pan-Arctic scale (Arctic Council, 2009; SAON, 2011).

Holistic Relevance of SAON

Objective observational data underlying the risks and opportunities in the Arctic region are relevant to the Arctic states and Indigenous peoples, as well as to non-Arctic states, international government institutions, non-governmental organizations, and corporations (Fig. 6). While the Arctic states and Indigenous peoples are at the core, in reality, all of these stakeholder-types are already involved in decision making about the Arctic region.

Today, more than a dozen organizations have remits specifically in the Arctic region, involving more than 50 nations (Table 1). Among the organizations, the Arctic Council (Ottawa Declaration, 1996) has a pivotal role as the high-level forum for the Arctic region; it includes all eight Arctic states and six Indigenous peoples' organizations. All Arctic states are also included in the following institutions, listed by the year of their formation: Treaty Concerning the Archipelago of Spitsbergen, 1920; International Arctic Science Committee, 1990; the Barents Euro-Arctic Council, 1993; Conference of Parliamentarians of the Arctic Region, 1993; Forum of Arctic Research Operators, 1998; North Atlantic Coast Guard Forum, 2007;

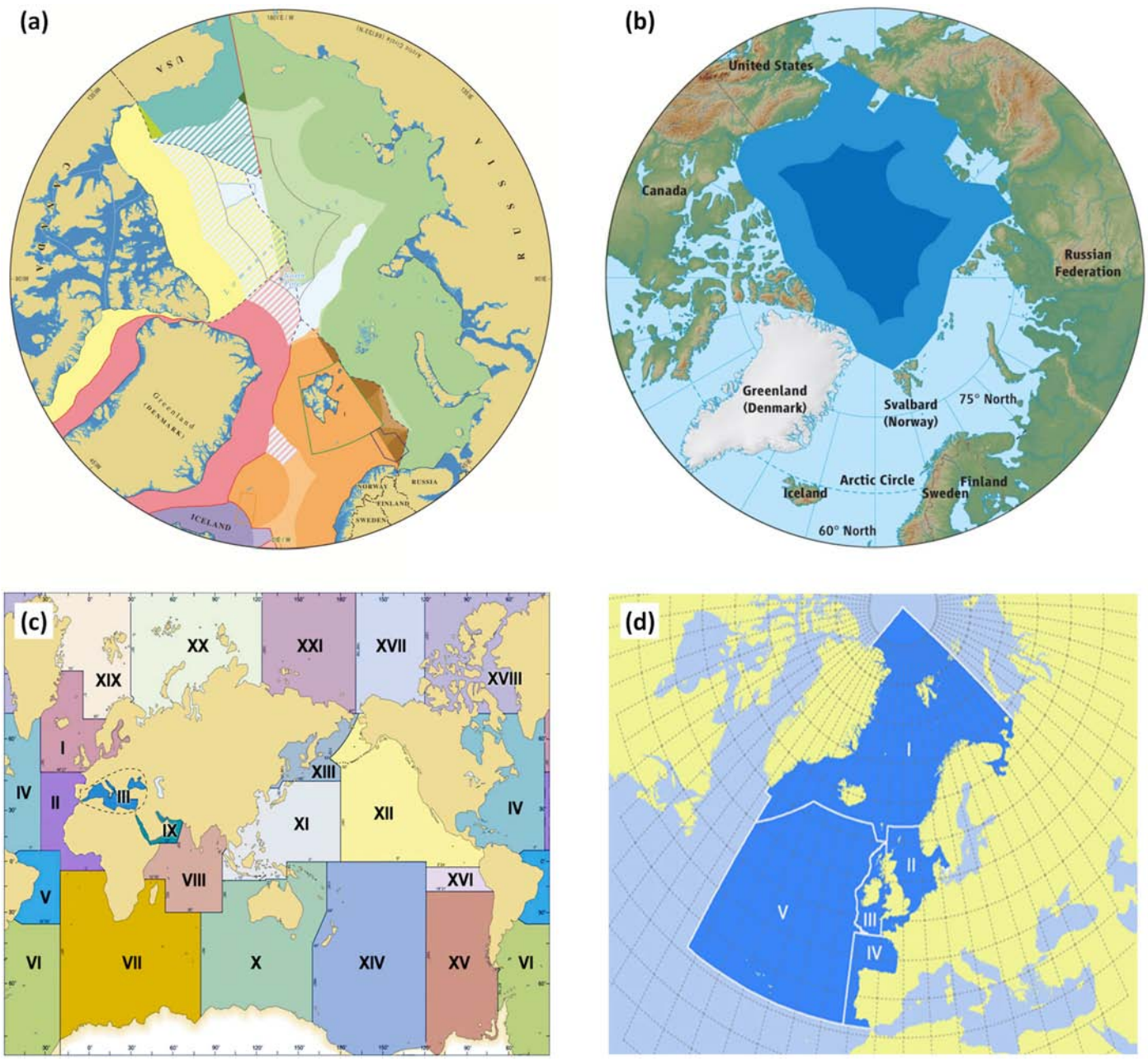

FIG. 4. Boundary configurations covering the Arctic Ocean from institutions with remits beyond the region. (a) Law of the Sea (UNCLOS, 1982) boundaries based on the seafloor with sovereign areas and outer continental shelf claims of the surrounding coastal states (different colors) from IBRU (2008); (b) Law of the Sea (UNCLOS, 1982) boundaries based on the overlying water column, emphasizing the high seas (dark blue), which is an inviolate international space that exists unambiguously in the central Arctic Ocean surrounded by exclusive economic zones (light blue) from Berkman and Young (2009). (c) Meteorological and navigational areas throughout the world ocean, including the Arctic Ocean (IHO, 2009; IMO, 2011); (d) Boundaries of the OSPAR (1992) and NEAF (1980) conventions in the northeast Atlantic sector of the Arctic Ocean to the North Pole. Modified from Berkman and Vylegzhanin (2013).

Agreement on Cooperation on Aeronautical and Maritime Search and Rescue in the Arctic, 2011; and Agreement on Cooperation on Marine Oil Pollution, Preparedness and Response in the Arctic, 2013. Each Arctic organization (Table 1) has its own history of decision making, reflecting an evolving "ecosystem" of international policies, which has been interpreted partially in a pan-Arctic context (e.g., Koivurova and Molenaar, 2009).

Since the Arctic region entered into a sustainable development phase (Fig. 5), a consistent thread of international policy development has been the ministerial declarations from the Arctic Council, all of which have relied on analyses of observational data. Most poignantly, observational data about the environmental state-change (Fig. 1) and its diverse implications (e.g., PAME, 2013) have awakened global interest in the Arctic Ocean.

Since observations of the sea-ice minimum in 2007 (NSIDC, 2007), policy development for the Arctic region has been accelerating at national and international levels (Fig. 5). This acceleration of policies also coincided with

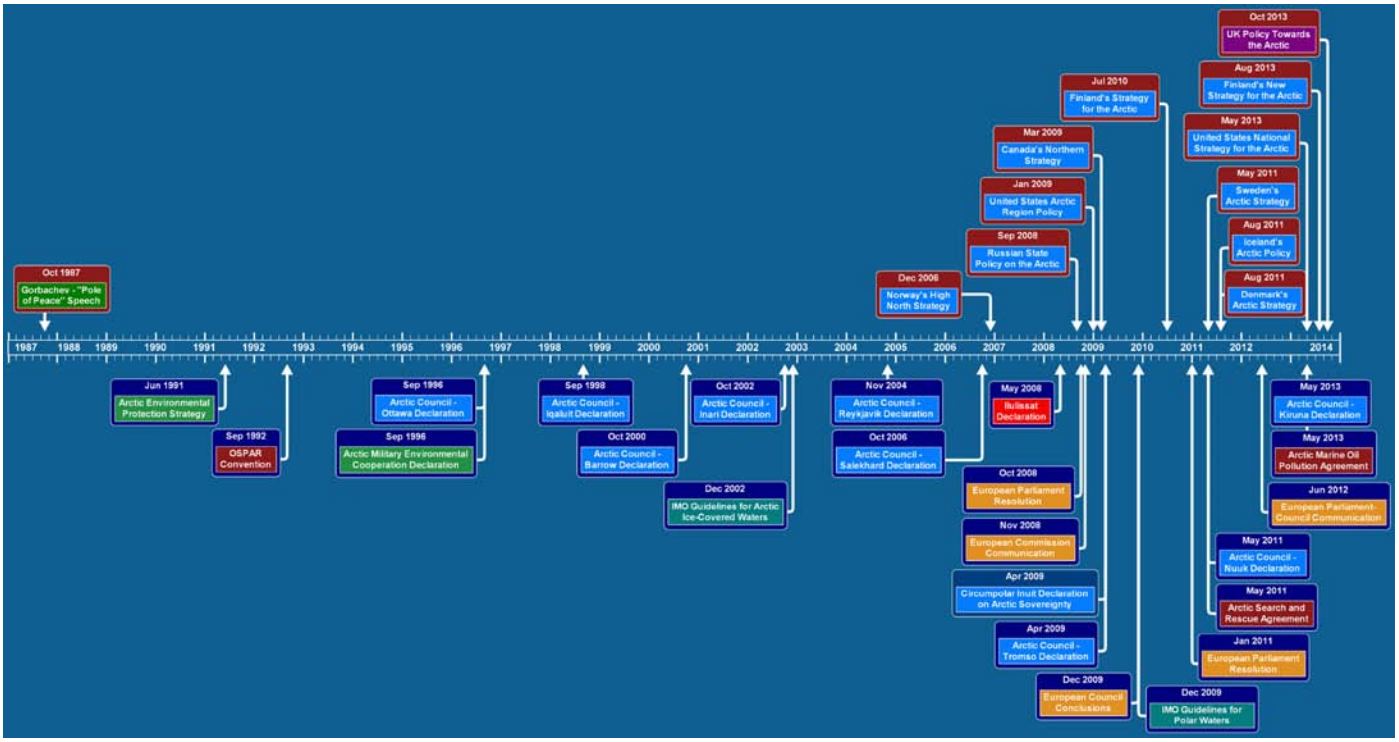

FIG. 5. Sustainable development phase of the Arctic. Shown is a timeline of Arctic-relevant policy documents that have emerged since the visionary speech of Soviet President Mikhail Gorbachev (1987). Color schemes of international (below the timeline) and national (above the timeline) Arctic policies simply represent documents that are similar in jurisdiction, scope or concept, including: national Arctic strategies; Arctic Council declarations among the Arctic states and Indigenous peoples; guidelines from the International Maritime Organization (IMO); or policies from the European Union. Production of policy documents has been accelerating at national and international levels since the Ilulissat Declaration (2008).

FIG. 6. Concentric levels of responsibilities to manage human activities in the Arctic Ocean. The Arctic coastal states, Arctic non-coastal states and six Indigenous peoples organizations (Fig. 2) were original signatories to the Ottawa Declaration (1996) that established the Arctic Council. Interactions with non-Arctic states and non-state actors, especially industry, reflect the interplay of global civil society in the Arctic Ocean. Adapted from Berkman (2010).

the Russian flag planting on the seabed at the North Pole (Chivers, 2007) and the subsequent declaration by five Arctic coastal states about their "sovereignty, sovereign rights and jurisdiction" in the Arctic Ocean (Ilulissat Declaration, 2008).

However, the overriding stimulus for policy development and accelerating interest in the Arctic Ocean (Fig. 5) is economic opportunity. In the short term, over the next 3–5 decades, there may be billions of barrels of oil and trillions of cubic feet of natural gas to exploit north of the Arctic Circle (Gautier et al., 2009). Over the longer term, Arctic trade routes may become significant on a global scale, even in relation to traffic through the Panama and Suez Canals (AMSA, 2009). Urgency to promote sustainable development of energy and shipping activities in the Arctic Ocean is reflected in the binding agreements that are emerging through the Arctic Council (Arctic Council, 2011, 2013).

The challenge is to balance national interests and common interests (Fig. 7) and respond effectively to the opportunities, as well as the risks, generated by the environmental state-change in the Arctic Ocean (Figs. 1a, b). A key to achieving this international and interdisciplinary balance will be to involve the diverse stakeholders (Figs. 2–7, Table 1) in sustainable infrastructure development, as well as maritime domain awareness (IMO, 2010).

The common infrastructure component for all involved could be the pan-Arctic implementation of SAON. Compared to port facilities and ships, SAON would be among

TABLE 1. International participation in Arctic organizations and information networks (updated from Berkman and Vylegzhanin, 2013). Among the 52 states in the table, the eight Arctic states are shaded. The organizations in bold include all of the Arctic states.

	Arctic organization[1]																
States	**AC**[2]	AMEC	**BEAC**[3]	**FARO**	**IASC**	**MOPP**	**NACG**	NAFO[4]	NC	NEAF[4]	NF	OSPAR	PB	**SAR**	**SCAP**[4]	**SPIT**	NATO[5]
Afghanistan																X	
Albania																X	X
Argentina																X	
Australia																X	
Austria				X												X	
Belgium[6]							X					X				X	X
Bulgaria[6]																X	X
Canada	X		X	X	X	X	X	X		X	X		X	X	X	X	X
Chile																X	
China	X			X	X											X	
Croatia																	X
Cuba								X									
Czech Republic[6]				X	X											X	X
Denmark[6,7]	X		X	X	X	X	X	X	X	X		X	X	X	X	X	X
Dominican Republic																X	
Egypt																X	
Estonia[6]							X									X	X
Finland[6]	X		X	X	X	X	X		X			X		X	X	X	
France[6]	X		X	X	X		X	X				X				X	X
Germany[6]	X		X	X	X		X					X				X	X
Greece[6]																X	X
Hungary[6]																X	X
Iceland	X		X	X	X	X	X	X	X	X	X	X		X	X	X	X
India	X				X											X	
Ireland[6]							X					X					
Italy[6]	X		X	X	X											X	X
Japan	X		X	X	X			X			X					X	
Latvia[6]							X										X
Lithuania							X										X
Luxembourg[6]												X					X
Monaco																X	
Netherlands[6]	X		X	X	X		X					X				X	X
New Zealand										X						X	
Norway	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X
Poland[6]	X		X	X	X		X									X	X
Portugal[6]							X					X				X	X
Republic of Korea	X			X	X			X			X						
Romania																X	X
Russian Federation	X	X	X	X	X	X	X	X		X	X		X	X	X	X	
Saudi Arabia																X	
Singapore	X																
Slovakia																	X
Slovenia																	X
South Africa																X	
Spain[6]	X				X		X					X	X	X			
St. Kitt and Nevis										X							
Sweden[6]	X		X	X	X	X	X		X			X		X	X	X	
Switzerland					X							X				X	
Turkey																	X
Ukraine								X									
United Kingdom[6]	X	X	X	X	X		X					X				X	X
United States	X	X	X	X	X	X	X	X					X	X	X	X	X
Venezuela																X	
Number of states	20	4	15	19	21	8	20	12	5	7	5	15	5	8	8	40	28

[1] AC = Arctic Council (1996); AMEC = Arctic Military Environmental Cooperation Programme (1996); BEAC = Barents Euro-Arctic Council (1993); FARO = Forum of Arctic Research Operators (1998); IASC = International Arctic Science Committee (1990); MOPP = Agreement on Cooperation on Marine Oil Pollution, Preparedness and Response in the Arctic (2013); NACG = North Atlantic Coast Guard Forum (2007); NAFO = Convention on Future Multilateral Cooperation in the Northwest Atlantic Fisheries (1978); NATO = North Atlantic Treaty Organization (1949); NC = Nordic Council (1952); NEAF = Convention on Future Multilateral Cooperation in North-East Atlantic Fisheries (1980); NF = Northern Forum (1991); OSPAR = Convention for the Protection of the Marine Environment of the North-East Atlantic (1992); PB = Agreement on the Conservation of Polar Bears (1973); SAR = Agreement on Cooperation on Aeronautical and Maritime Search and Rescue in the Arctic (2011); SCAP = Standing Committee of the Conference of Arctic Parliamentarians (1994), SPIT = Treaty Concerning the Archipelago of Spitsbergen, and Protocol (1920).

[2] In addition to the eight Arctic Member States of the Arctic Council and the 12 non-Arctic Observer states listed in the table, there are six permanent participants from Arctic Indigenous peoples' organizations (Arctic Athabaskan Council, Aleut International Association, Gwich'in Council International, Inuit Circumpolar Council, Russian Arctic Indigenous Peoples of the North, and Saami Council). The Arctic Council also involves nine intergovernmental and inter-parliamentary organizations (International Federation of Red Cross & Red Crescent Societies, International Union for the Conservation of Nature, Nordic Council of Ministers, Nordic Environment Finance Corporation, North Atlantic Marine Mammal Commission, Standing Committee of the Parliamentarians of the Arctic Region, United Nations Economic Commission for Europe, United Nations Development Program, United Nations Environment Program) as well as eleven non-governmental organizations (Advisory Committee on Protection of the Seas, Arctic Circumpolar Gateway, Association of World Reindeer Herders, Circumpolar Conservation Union, International Arctic Science Committee, International Arctic Social Sciences Association, International Union for Circumpolar Health, International Work Group for Indigenous Affairs, Northern Forum, University of the Arctic, World Wide Fund for Nature-Global Arctic Program). The European Union has applied to the Arctic Council for Permanent Observer status. In addition, the Arctic Council involves expert groups and task forces along with its six working groups: Arctic Contaminant Action Program (ACAP), Arctic Monitoring and Assessment Programme (AMAP), Conservation of Arctic Fauna and Flora (CAFF), Emergency Prevention, Preparedness and Response (EPPR), Protection of the Arctic Marine Environment (PAME), and Sustainable Development Working Group (SDWG).

[3] The Barents Euro-Arctic Council has seven permanent members, Denmark, Finland, Iceland, Norway, Sweden, the Russian Federation, and the European Commission, and other states participate as observers.

[4] Includes European Economic Community or European Union.

[5] It is a question whether NATO, like other North Atlantic organizations (e.g., NACG, NAFO, NEAF, OSPAR) has an Arctic remit.

[6] Member of European Union.

[7] Includes Greenland (which is not a member of the European Union) and the Faroe Islands as autonomous areas.

the least expensive infrastructure elements to sustain. Moreover, SAON would build on current research activities and funding, enabling governments to readily contribute to sustainable development of the Arctic, particularly in the Arctic Ocean (UNESCO, 2009).

Law of the Sea for Sustainability in the Arctic Ocean

In their central role (Fig. 6), the Arctic coastal states "remain committed" to the Law of the Sea (Ilulissat Declaration, 2008), which is a universal jurisdictional framework that is accepted by Arctic and non-Arctic states alike. Law of the Sea zones (Figs. 4a, 4b, 7), which are defined by the United Nations Convention on the Law of the Sea (UNCLOS, 1982), are accepted because nations have either ratified this convention or accepted the zones under customary international law, as is the case with the United States.

Law of the Sea zones apply throughout the world ocean without geographic or thematic emphasis, revealing a national-international gradient of jurisdictions (Fig. 7). National jurisdictions range from the coastal boundary to the edge of the exclusive economic zone in the water column and across the continental shelf on the seafloor. Beyond the exclusive economic zone and continental shelf are the international spaces of the high seas and the deep sea, respectively (Berkman et al., 2011).

With regard to the Arctic Ocean (Berkman and Young, 2009), beyond any sovereign rights that coastal states may have on the seafloor, even to the North Pole, there always will be high seas where the international community has rights and responsibilities (Figs. 4b, 7). Consequently, the Law of the Sea provides the justification and framework for Arctic and non-Arctic states to coordinate, support, and share infrastructure for sustainable development in the Arctic Ocean. Such an infrastructure will require capacity to respond to impacts and resources that either cross or extend beyond the boundaries of the coastal states. Marine scientific research (UNCLOS, 1982) such as the research that would be implemented by SAON provides the inclusive pathway to address these transboundary issues.

CONCLUSIONS

> The Arctic is now experiencing some of the most rapid and severe climate change on earth. Over the next 100 years, climate change is expected to accelerate, contributing to major physical, ecological, social, and economic changes, many of which have already begun.
>
> (ACIA, 2004:10)

SAON represents an opportunity to initiate sustainable infrastructure development in the Arctic Ocean, as a practical and cost-effective first step that can be inclusive on an international scale. The reality is, however, that SAON will require funding as well as technical expertise, as described in the plan for the implementation phase of SAON (2011:6): "Other than the Secretariat functions, which are provided by AMAP and by IASC, all other SAON activities are to be funded by the participants or by financial sponsors in response to proposals from the participants."

The above scope for funding SAON is vague and impractical at an integrated international and pan-Arctic scale. To provoke discussion about how to sustain SAON, three options for effective funding are introduced here:

Option 1: Arctic coastal states, as part of their leasehold agreements with major energy companies that seek to

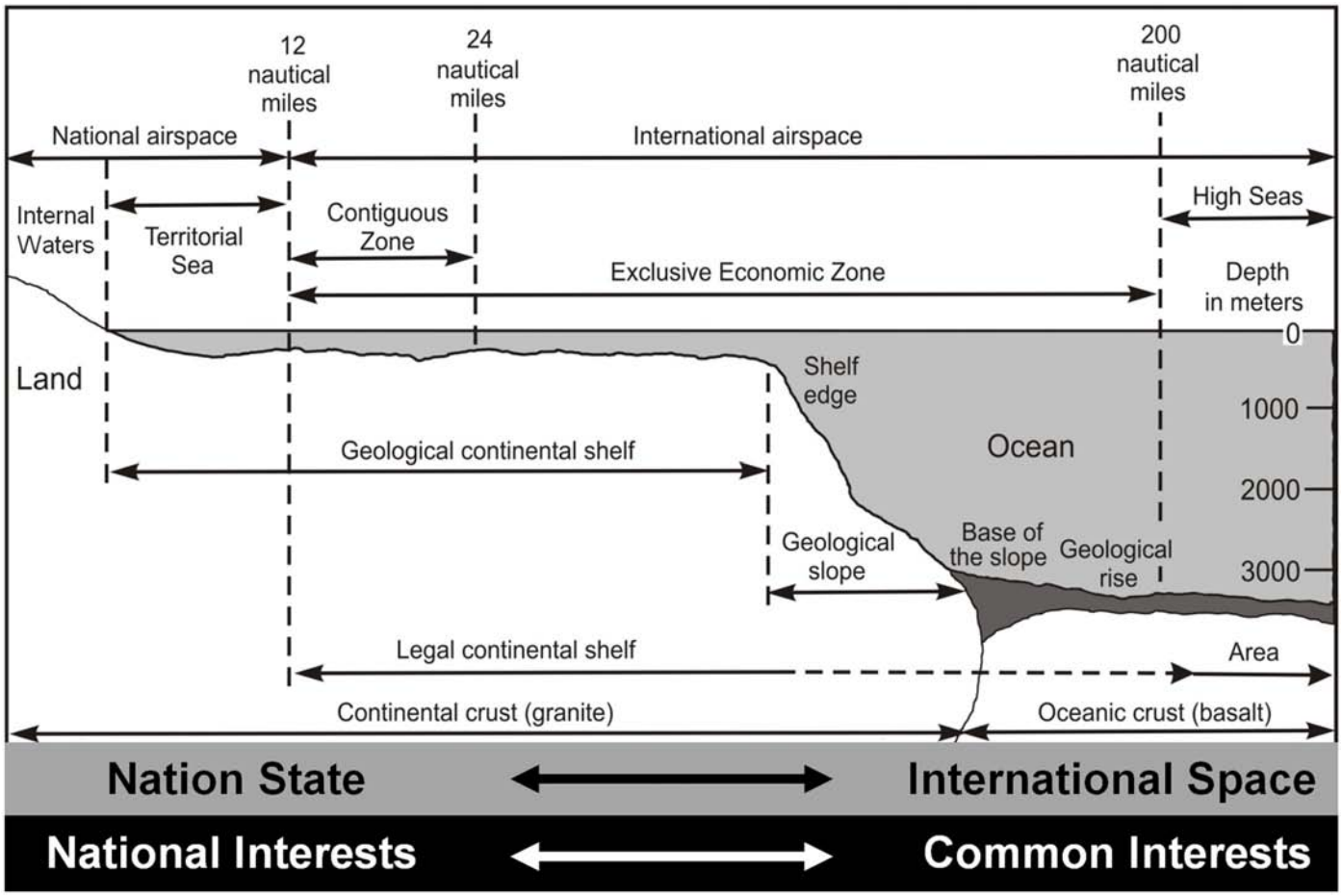

FIG. 7. Zones throughout the world ocean, from the baselines of coastal states into the international spaces beyond sovereign jurisdictions (i.e., the high seas and deep sea), reflecting the gradient from national interests into common interests. The zones (see Fig. 4a, b) are defined by customary international law and the United Nations Convention on the Law of the Sea (UNCLOS, 1982) with provisions that "will contribute to the strengthening of peace, security, co-operation and friendly relations among all nations." Adapted from United States (1985) with inclusion of zones that are in force for the area and internal waters.

extract hydrocarbons from the seafloor within sovereign jurisdictions, should require energy companies to support sustainable infrastructure development in the Arctic Ocean as a cost of business, with funding earmarked for SAON.

Option 2: In addition to the Arctic states with their "stewardship" roles in the Arctic Ocean (Ilulissat Declaration, 2008), non-Arctic states that are admitted as observers to the Arctic Council should commit funding to SAON.

Option 3: Some level of public-private coordination could be developed among the diverse institutions and organizations with Arctic interests (Figs. 3 and 4, Table 1) to support SAON for informed decision making about their activities in the Arctic Ocean.

In addition to geospatial data to support decisions about positioning built infrastructure in and around the Arctic Ocean, SAON will be necessary for operational decision making about responses to commercial impacts and activities in the Arctic Ocean. Such response capacity is a requirement for the Arctic states in binding agreements (e.g., Arctic Council, 2011, 2013), for point emergencies (e.g., rescue of persons from a sinking ship), and transitory impacts (e.g., clean-up of an oil or gas spill).

There are many uncertainties about how to balance the diverse interests (Figs. 2–7, Table 1) and capabilities for responding to the emerging risks and opportunities in the Arctic. "What is clear, however, is that changes in the region's physical environment are likely to present policy planners and political decision-makers with a wide array of challenges that will require extraordinary measures at the national as well as at the regional and international levels" (Åtland 2013:213). Among the challenges is planning an integrated pan-Arctic infrastructure to accommodate global activities in the Arctic Ocean, not just for the Arctic states and Indigenous peoples, but for the whole world.

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