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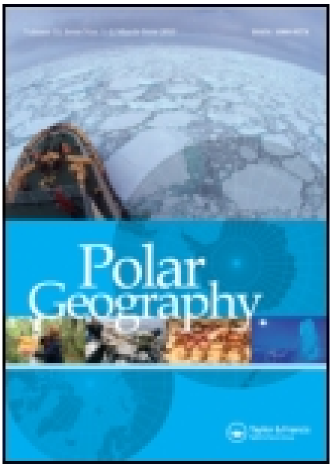

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Commercial Arctic shipping through the Northeast Passage: routes, resources, governance, technology, and infrastructure

Albert Buixadé Farré[a], Scott R. Stephenson[b], Linling Chen[c], Michael Czub[d], Ying Dai[e], Denis Demchev[c], Yaroslav Efimov[f], Piotr Graczyk[g], Henrik Grythe[h], Kathrin Keil[i], Niku Kivekäs[j], Naresh Kumar[k], Nengye Liu[l], Igor Matelenok[m], Mari Myksvoll[n], Derek O'Leary[o], Julia Olsen[p], Sachin Pavithran.A.P.[q], Edward Petersen[a], Andreas Raspotnik[r], Ivan Ryzhov[s], Jan Solski[t], Lingling Suo[c], Caroline Troein[a], Vilena Valeeva[u], Jaap van Rijckevorsel[g] & Jonathan Wighting[v]

[a] The Fletcher School of Law and Diplomacy, Tufts University, 160 Packard Ave, Medford, MA 02155, USA

[b] Department of Geography, University of Connecticut, 215 Glenbrook Road, U-4148, Storrs, CT 06269-4148, USA

[c] Nansen Environmental and Remote Sensing Center, Bergen, Norway

[d] The Institute of Oceanology Polish Academy of Sciences, Sopot, Poland

[e] Department of Atmospheric and Oceanic Sciences, School of Physics, Peking University, Beijing, China

[f] Gazprom, Moscow, Russia

[g] UiT - The Arctic University of Norway, Tromsø, Norway

[h] Atmospheric Science Unit, Stockholm University, Stockholm, Sweden

[i] Institute for Advanced Sustainability Studies, The Arctic Institute, Potsdam, Germany

[j] Sweden and Finnish Meteorological Institute, Lund University, Helsinki, Finland

[k] Centre for the Study of Geopolitics, Panjab University, Chandigarh, India

[l] School of Law, University of Dundee, Dundee, UK

[m] State University of Aerospace Instrumentation, St. Petersburg, Russia

[n] Institute of Marine Research, Bergen, Norway
[o] Department of History, University of California, Berkeley, CA, USA
[p] Nordland Research Institute, Bodø, Norway
[q] Nansen Environmental Research Centre India, Cochin University of Science and Technology, Cochin, India
[r] The Arctic Institute, Washington, DC, USA
[s] Arctic and Antarctic Research Institute, Russian Federal Service for Hydrometeorology and Environmental Monitoring, St. Petersburg, Russia
[t] K.G. Jebsen Centre for the Law of the Sea, UiT - The Arctic University of Norway, Tromsø, Norway
[u] The Global Climate Forum, Berlin, Germany
[v] StormGeo, Aberdeen, UK
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ALBERT BUIXADÉ FARRÉ[a]*, SCOTT R. STEPHENSON[b], LINLING CHEN[c], MICHAEL CZUB[d], YING DAI[e], DENIS DEMCHEV[c], YAROSLAV EFIMOV[f], PIOTR GRACZYK[g], HENRIK GRYTHE[h], KATHRIN KEIL[i], NIKU KIVEKÄS[j], NARESH KUMAR[k], NENGYE LIU[l], IGOR MATELENOK[m], MARI MYKSVOLL[n], DEREK O'LEARY[o], JULIA OLSEN[p], SACHIN PAVITHRAN.A.P.[q], EDWARD PETERSEN[a], ANDREAS RASPOTNIK[r], IVAN RYZHOV[s], JAN SOLSKI[t], LINGLING SUO[c], CAROLINE TROEIN[a], VILENA VALEEVA[u], JAAP VAN RIJCKEVORSEL[g] and JONATHAN WIGHTING[v]

[a]*The Fletcher School of Law and Diplomacy, Tufts University, 160 Packard Ave, Medford, MA 02155, USA;*
[b]*Department of Geography, University of Connecticut, 215 Glenbrook Road, U-4148, Storrs, CT 06269-4148, USA;*
[c]*Nansen Environmental and Remote Sensing Center, Bergen, Norway;*
[d]*The Institute of Oceanology Polish Academy of Sciences, Sopot, Poland;*
[e]*Department of Atmospheric and Oceanic Sciences, School of Physics, Peking University, Beijing, China;*
[f]*Gazprom, Moscow, Russia;*
[g]*UiT – The Arctic University of Norway, Tromsø, Norway;*
[h]*Atmospheric Science Unit, Stockholm University, Stockholm, Sweden;*
[i]*Institute for Advanced Sustainability Studies, The Arctic Institute, Potsdam, Germany;*
[j]*Sweden and Finnish Meteorological Institute, Lund University, Helsinki, Finland;*
[k]*Centre for the Study of Geopolitics, Panjab University, Chandigarh, India;*
[l]*School of Law, University of Dundee, Dundee, UK;*
[m]*State University of Aerospace Instrumentation, St. Petersburg, Russia;*
[n]*Institute of Marine Research, Bergen, Norway;*
[o]*Department of History, University of California, Berkeley, CA, USA;*
[p]*Nordland Research Institute, Bodø, Norway;*
[q]*Nansen Environmental Research Centre India, Cochin University of Science and Technology, Cochin, India;*
[r]*The Arctic Institute, Washington, DC, USA;*
[s]*Arctic and Antarctic Research Institute, Russian Federal Service for Hydrometeorology and Environmental Monitoring, St. Petersburg, Russia;*
[t]*K.G. Jebsen Centre for the Law of the Sea, UiT – The Arctic University of Norway, Tromsø, Norway;*

*Corresponding author. Email: albertbuixade@gmail.com
Besides the first and second authors, all other co-authors are listed in alphabetical order.

[u]*The Global Climate Forum, Berlin, Germany;*
[v]*StormGeo, Aberdeen, UK*

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The Russian and Norwegian Arctic are gaining notoriety as an alternative maritime route connecting the Atlantic and Pacific Oceans and as sources of natural resources. The renewed interest in the Northeast Passage or the Northern Sea Route is fueled by a recession of Arctic sea ice coupled with the discovery of new natural resources at a time when emerging and global markets are in growing demand for them. Driven by the expectation of potential future economic importance of the region, political interest and governance has been rapidly developing, mostly within the Arctic Council. However, this paper argues that optimism regarding the potential of Arctic routes as an alternative to the Suez Canal is overstated. The route involves many challenges: jurisdictional disputes create political uncertainties; shallow waters limit ship size; lack of modern deepwater ports and search and rescue (SAR) capabilities requires ships to have higher standards of autonomy and safety; harsh weather conditions and free-floating ice make navigation more difficult and schedules more variable; and more expensive ship construction and operation costs lessen the economic viability of the route. Technological advances and infrastructure investments may ameliorate navigational challenges, enabling increased shipping of natural resources from the Arctic to global markets.

Introduction

As sea ice recedes in the Arctic, expectations for a commercially feasible Arctic shipping route are rising. Increased access to natural resources and longer navigation seasons are making the Arctic more appealing as a source of new energy and mineral supplies and as an avenue for maritime transport. The economic lure is also appealing to states, leading them to work toward developing a governance framework in anticipation of an economic boom.

Analysis of Arctic shipping has focused predominantly on two routes: the Northeast Passage (NEP) encompassing the route along the Norwegian and Russian Arctic coasts, and the Northwest Passage (NWP) through the Canadian Archipelago and North of Alaska (Figure 1). While the NEP is at times called the Northern Sea Route (NSR), the NSR is formally defined in Russian law as extending from the Novaya Zhelaniya straits (at the Novaya Zemlya archipelago, connecting the Barents Sea to the West and the Kara Sea to the East), to Cape Dezhnev by the Bering Strait (Solski 2013). The main difference between the NSR and the NEP is that the latter comprises the Barents Sea (Østreng *et al.* 2013) and provides access to the port of Murmansk, the largest Russian Arctic port. Given that the NSR constitutes the majority of the NEP, many sources use the terms NSR and NEP interchangeably. Thick multiyear ice, complex straits, and pingos (underwater ice formations protruding from the seabed) make navigation especially arduous in the NWP (Østreng *et al.* 2013, p. 25, Yoshikawa *et al.* 2006). While mainly limited to summer, navigation along the NEP is relatively easier owing to lower overall ice extent and open water in the Barents Sea (Østreng *et al.* 2013). Unlike similar latitudes in Alaska or in Canada, this area remains ice-free due to currents of warm water from the Gulf Stream, feeding into the North Atlantic

Figure 1. The NSR, The NEP, and Trans-Polar Route (adapted from Stephenson *et al.* 2013b).

Current, flowing toward the Northeast Atlantic (Rasmussen and Turner 2003, p. 68). A third option, the Transpolar Route traversing the North Pole, encounters thick and persistent ice. Even aggressive climate model scenarios project extensive sea ice in winter in the central Arctic for decades to come (Østreng *et al.* 2013).

Despite its economic potential, significant environmental and infrastructural challenges constrain resource and transport activities in the Arctic. This paper critiques the claim that melting sea ice alone will attract large-scale shipping between Atlantic and Pacific and evaluates the variables for potential future success. We first determine that the NEP is the most practicable route in the Arctic, both as a corridor for the transport of natural resources and as a shorter avenue for transit shipping. We then examine how economic potential is driving international efforts to develop stronger governance in the region and assess the potential impacts on shipping from Russia's controversial interpretation of maritime law. We then evaluate the technical feasibility of Arctic shipping by first surveying the evolution of Arctic ice in recent decades, followed by an evaluation of shipping technology, needs for broadband communications, and the promising emerging field of ice forecasting. Then we examine the necessity for support infrastructure such as seaports and search and rescue (SAR) capabilities, which are currently lacking in Russia, but progressively developing. Finally, we evaluate the potential of the Arctic as a shipping space in comparison to the Suez Canal Route. We conclude by distinguishing between the large-scale climate impacts and medium-term policy-driven factors like infrastructure and technology in developing an economically feasible Arctic route.

The economic lure

The substantial reduction of ice thickness, age, and extent since the early 2000s has spurred interest in future economic development. Of the three Arctic shipping routes, the NEP, along the Eurasian northern coast, has the highest potential to enable economic activity in the Arctic. This promise is two-pronged: transit shipping, for transporting cargo between non-Arctic ports, and destinational shipping, for activities with an origin or destination in the Arctic. These include fishing, tourist cruises, scientific expeditions, and resource extraction. Of these, resource extraction is the sector with the most immediate potential for expansion of shipping activities as a means of transporting resources out of the region, either westward to Europe or eastward to Asia.

For shipping between Northeast Asia and Europe (for example, from Shanghai to Rotterdam) the oldest, pre-Suez route spans about 14,000 nautical miles around the Cape of Good Hope. The opening of the Suez Canal in 1869 shortened the trip by 23%, and the NEP has the potential to shrink the distance by a further 24%, when little or no sea ice is present. The NEP is most enticing for trade with Northeast Asia (Japan, Korea, and China), gradually losing appeal as one moves south toward Ho Chi Minh City where the NEP and Suez routes are virtually equidistant (see Table 1).

Therefore, the NEP is only one of several avenues for Eurasian trade, with the main competitor being the Suez Canal Route. Shipping activity along the NEP has

Table 1. Sailing distances between Asia and Europe.

	To Rotterdam, via (in nautical miles)			
From	Cape of Good Hope	Suez Canal	NEP	Difference between Suez and NEP (%)
Yokohama	14,448	11,133	7010	37
Busan	14,084	10,744	7667	29
Shanghai	13,796	10,557	8046	24
Hong Kong	13,014	9701	8594	11
Ho Chi Minh City	12,258	8887	9428	–6

Note: Sailing distances between major East Asian ports and Rotterdam are calculated by taking the distance between Yokohama and Hamburg via the NEP and Suez Canal routes (as provided by Østreng et al 2013, p. 49) and approximating the additional distances originating before Yokohama and beyond Hamburg, using an online voyage calculator (http://sea-distances.com/). Distances assume no route diversions owing to ice conditions.

occurred for centuries. Before the twentieth century it was sporadic, with many failures, and mostly driven by scientific and exploration expeditions. In the 1900s, during Soviet Union times, the NSR greatly developed as a heavily subsidized and entirely domestic route, with traffic peaking in 1987 with 6.58 million tons of cargo carried by 331 ships over 1306 voyages. Arctic traffic collapsed to 1.5–2 M tons once the subsidies vanished with the demise of the USSR and has yet to return to those levels (Ragner 2008, Stephenson *et al.* 2013a). The question is whether the recent rapid loss of sea ice in combination with new governance and new technical developments will substantially increase the potential for Arctic shipping. The increase of actual shipping has so far been minimal in a broader global context. While voyages from or through the NEP grew from almost 0 in 2008 to 44 in 2013 (NSR Information Office 2014), 17,225 ships passed through the Suez Canal in 2012 (Suez Canal Authority 2013). The NSR reported a total of 71 voyages in 2013, of which 27 had both their origin and destination within the NEP; 25 of them were destinational, having either their origin or their destination within the NEP; and 19 of them were full trans-Arctic voyages traversing completely the Arctic, connecting the Atlantic and Pacific Oceans.[1]

Numerous scholars have noted the challenges of using the NEP for container shipping. Container ships operate under a just-in-time system, which relies on precise schedules for loading, shipping, and unloading to maximize the efficiency of logistics and push costs down (Humpert and Raspotnik 2012b, Lasserre and Pelletier 2011, Liu and Kronbak 2010, Stephenson *et al.* 2013a, Verny and Grigentin 2009). Therefore, predictability is highly sought-after, and the Suez Canal Route offers the most stable option, bar piracy in the Indian Ocean. In contrast, the NEP may be highly unpredictable owing to seasonal variability in ice extent and local ice drift (Smith 2009). Unlike container ships, bulk cargo ships do not require such precise schedules and can better cope with variability of the NEP. In addition, it must also be noted that since bulk cargo shipping is less sensitive to timing, it also has the potential to adopt super-slow sailing. This means using the shorter distance of the NEP to sail at slower speeds and still arrive within the same time frame as if using the Suez route but achieving greater fuel efficiency, lowering fuel costs and emissions (Humpert and Raspotnik 2012b). These, coupled with the large energy and mineral potential of the Eurasian Arctic and the availability of Russian icebreaker support, have made destinational resource shipping the most economically viable sea trade activity in the NEP. These resources consist of oil, gas, and minerals such as phosphates, nickel, and copper.

Russia's undiscovered petroleum is estimated between 66 billion tons of oil equivalent (BTOE) according to the United States Geological Survey (USGS) (Bird *et al.* 2008, Gautier *et al.* 2009) and 142 BTOE according to the Russian Academy of Science (Efimov *et al.* 2014, Kontorovich 2009)[2]. To put this in perspective, in 2011, the world consumed 13 BTOE of energy, 31% from oil and 21% from natural gas (International Energy Agency 2013). Russia's vast energy resources account for 52% of the Arctic totals and Norway's for 12% (Bird *et al.* 2008). Norway, which has been extracting petroleum in the North Sea for 40 years, now expects new discoveries in the Barents Sea (NPD 2011). Russia is currently exporting 88% of crude oil via pipelines, with a large majority of the natural gas also transported in that manner. Seventy-six percent of natural gas and 79% of oil are exported to Europe, with the second largest customer for oil being China and for natural gas being Japan. Russia continues to expand both its pipeline networks and its seaborne capacity, with absolute maritime transportation of petroleum growing but remaining a small portion of the overall exports (EIA 2013).

The Arctic also holds large quantities of minerals, including phosphate, bauxite, iron ore, copper, and nickel. These are of pervasive use in industrialized economies. Russia produces an average of 11 M tons of phosphates, 8% of the global output (Bambulyak *et al*. 2012). Phosphates are used as fertilizers in agriculture, with other uses including water treatment, flame-retardant materials, and corrosion protection. In 2010, Russia also extracted and processed bauxite into 3.85 M tons of aluminum, constituting 9.3% of the global production and making it the second-largest producer in the world after China. It also mined 100 M tons of iron ore, 6.25% of the global production (Bambulyak *et al*. 2012).

Nickel is an important metal used in the production of steel and other industrial, commercial, and consumer goods. The largest Russian mining company Norilsk Nickel MMC leads the world's production of nickel and palladium as a by-product. The company has its own fleet of vessels to ship out the minerals and also owns port terminals. Worldwide production of nickel was of 1.5 M tons in 2011, out of which 297,000 tons was mined by the Russian giant, holding 5.8 M more in proven reserves (2010 figures). Palladium is mostly used in engines as a catalyst converting 90% of highly harmful exhaust gasses into less harmful ones. The company is also a major producer of copper (mining 389,000 tons out of 8.7 M tons worldwide), platinum, rhodium, and cobalt (Bambulyak *et al*. 2012). In anticipation of a growth in demand for government icebreaker services, Norilsk Nickel started in 2006 to order the construction of its own fleet of five icebreaking cargo vessels, now in operation. These vessels are capable of breaking through 1.5 m (5 ft) of ice at a rate of 1–2 knots, without the support of an icebreaker, while transporting 14,500 tons of cargo (Litovkin 2012, Ragner 2008).

As an energy source, the Eurasian Arctic may have the greatest short-term potential. The continued development of the large economies like those of China and India will require massive supplies of raw materials and energy (Mouawad and Werdigier 2007), both of which Russia and Norway can offer. For example, China's energy demand is projected to double by 2040 (EIA 2013). Most electricity in the country is generated from plants burning coal, a plentiful domestic resource. However, air pollution in the cities from coal emissions has thrust people to unusually high levels of popular discontent and riots (Duggan 2013, EIA 2014, Watts 2009). In response, the Chinese Government is increasingly turning to gas to reduce city air pollution, and it can choose from three sources: domestic shale gas, conversion of coal to synthetic natural gas, or imported natural gas. While China is developing all the three options, the first two encounter severe drawbacks including the use of large amounts of water, which is scarce in China (EIA 2014, Guilford 2014, Larson 2013, Perkowski 2013).

Furthermore, China ails from an overdependency on oil imports coming by tanker from Africa and the Middle East (EIA 2014). These shipments must transit through the Malacca Strait, stoking in China a sense of vulnerability and overreliance on unstable sources and potentially unfriendly maritime neighbors as the tankers traverse the South China Sea. China's strategy to diversify its sources of energy makes it a prime candidate to exploit the NEP (Humpert and Raspotnik 2012b). This interest is already materializing with the fact that China, a non-Arctic country, has acquired its own icebreaking research vessel and is scheduled to build another by 2016 (Associated Press 2012, NDTV 2014). Furthermore, China is seeking to obtain new oil and gas supplies from Russia (including from the Arctic), to be transported overland by train and pipelines, and some by ship (Dyomkin 2013, Snow 2014). Furthermore, as Russia's relations with Western countries become more problematic, its interest in diversifying its markets also increases. To fulfill its strategic diversification, Russia looks to China as a key partner. The two countries have signed multiple petroleum development projects in the Arctic. Recent examples are the agreement reached on May 2014, where Gazprom entered into a 30-year $400 bn agreement with China to supply Siberian natural gas, most of it to be transported via pipeline (Watt and Isachenkov 2014), and a July agreement on a smaller Siberian Liquefied Natural Gas project (LNG, the method used for the maritime transportation of gas) on the Yamal Peninsula (Reuters 2014).

Despite the potential for bulk resource transport, significant physical and logistical limitations persist. The coastal route of the NEP (which has been ice-free in summer in recent years) has shallow bathymetry, with drafts of 13 and 6.7 m in the Sannikov and Dmitry Laptev Straits, and with much of the Laptev Sea with depths of < 20 m (Figure 2). This bathymetry is limiting cargo size to approximately 50,000 deadweight tons (the total weight a ship can carry including cargo and fuel), or 2500–4500 of twenty-foot equivalent unit containers (TEU). This severely undermines the economies of scale achieved by much larger vessels (Ragner 2008, Stephenson *et al.* 2013a). These limitations carry a trade-off for shipping companies: smaller vessels can sail through coastal waters, enjoying longer navigation seasons at a cost of lower economies of scale; conversely, bigger ships enable greater economies of scale but are forced to sail through deeper Arctic waters farther from the coast with fewer days a year of ice-free conditions, unless companies invest in ice-class vessels or pay for icebreaker escort (Stephenson *et al.* 2013a).

A new generation of ultra large container ships (ULCS), such as Maersk Triple E-class that has a capacity exceeding 18,000 TEU, greatly surpass the current standard of 6000–8000 TEU. While these ships offer much greater economies of scale, their size (> 15 m draft; > 49 m beam) limits their potential in the Arctic. The widths of these ULCS exceed that of icebreakers today (~30 m; Humpert and Raspotnik 2012b) and are unable to escort them.

To keep up with this growth in vessel's carrying capacity, the Suez Canal Authority has made numerous expansions to the canal over the years. The last improvement was made in 2010, increasing the prior maximum ship draft of 62 ft (19 m) to 66 ft (20 m), accommodating ships carrying up to 220,000 tons of cargo (Reuters 2010). This allows passage of most container vessels (most have a draft of 15 m or less) but restricts some large dry bulk cargo and ULCS vessels. A new phase for deepening the canal is under study to accommodate drafts of up to 72 ft (22 m), making it navigable for ULCS, all dry bulk cargo vessels, and 80% of oil tankers (Suez Canal Authority 2009).

Compared to the NEP, the Suez Canal Route offers larger vessel capacity, greater predictability, and opportunities to stop at multiple ports along the way for maintenance and support. Most importantly, it provides access to multiple markets along highly populated coastal areas, as container ships rarely unload all cargo at a single destination. Therefore, container shipping will continue to heavily concentrate along the Suez Canal Route, while bulk carriage of resources from the Eurasian Arctic offers greater opportunities for shipping along the NEP.

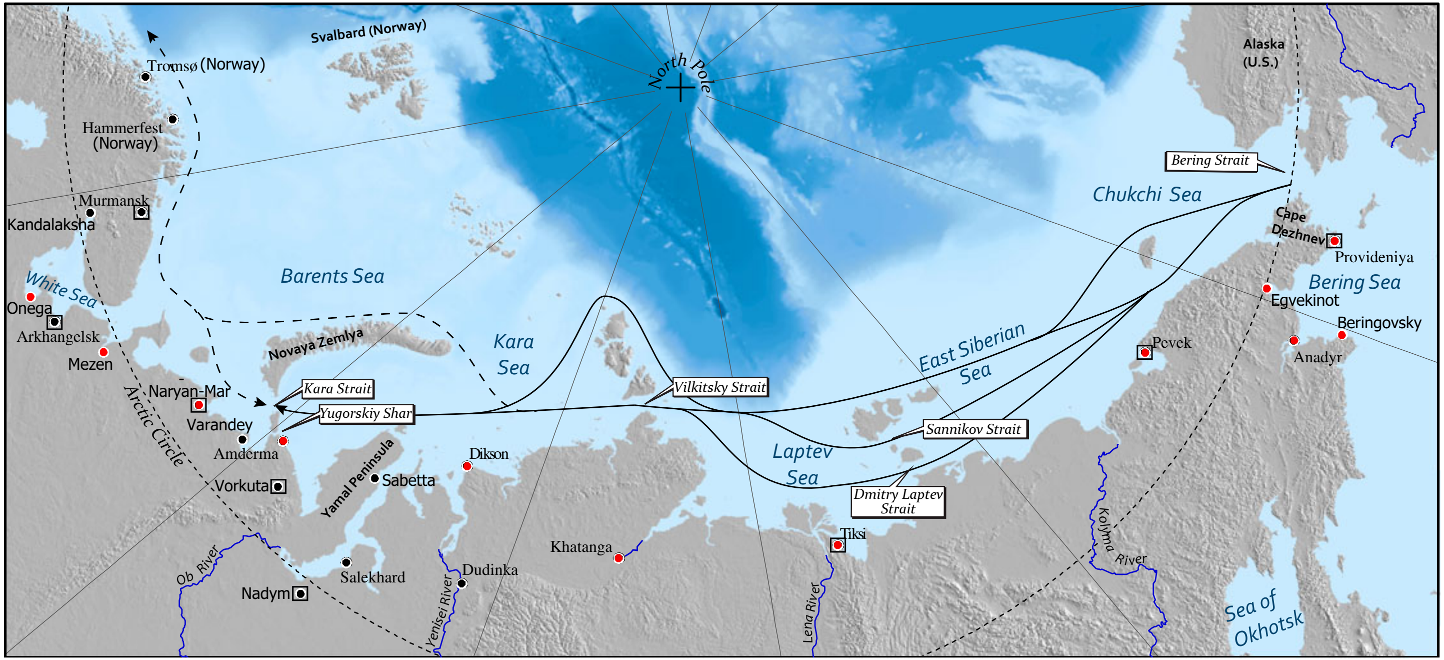

Figure 2. Map of the Russian and Norwegian Arctic coasts, showing the NSR (solid line) and its extension to the NEP (dotted line). Settlements in red have been identified by the Russian Government (FSUE 2013) as having port facilities in a state of disrepair. Planned SAR stations are also identified with a square (adapted from Stephenson *et al.* 2013a).

The maturing institutional framework

Commercial shipping and sustainable economic growth require a supportive, stable, and predictable governance system. Unlike previous chapters in history when expansion of human activity to new frontiers encountered political uncertainty and lawlessness, the development of the Arctic is occurring alongside a maturing international community and an increasingly robust legal and institutional framework. As in other oceans around the world, human activity in the Arctic is well regulated by a set of treaties and international organizations.

The main elements of governance along the NEP are the United Nations Convention on the Law of the Sea (UNCLOS), the Arctic Council (AC), the International Maritime Organization (IMO), and the domestic legislation of the Russian Federation. In combination, albeit with significant gaps, they cover territorial claims, economic exploitation, technical shipping requirements, environmental protection, and SAR responsibilities. The gaps lie with disputed interpretations, inadequate regulations, and insufficient infrastructure. The foremost international legal framework was provided in 1982 by UNCLOS, which codified and expanded on the existing customary law that regulated human use of the sea, by enshrining freedom of navigation, specifying rules to territorial claims, and determining economic rights and broad environmental responsibilities.

Then, pursuant to stronger cooperation, the Arctic states created the AC in 1996 with the Ottawa Declaration. It was formed by the five states with large Arctic Ocean coasts (U.S., Russia, Canada, Norway, and Denmark) and the three other states within the Arctic Circle (Finland, Sweden, and Iceland). The AC also provides Arctic native communities with a forum for addressing their interdependence in cross-boundary issues through the permanent member status of six groups representing indigenous peoples: the Arctic Athabaskan Council, Aleut International Association, Gwich'in Council International, Inuit Circumpolar Council, Russian Association of Indigenous Peoples of the North, and Saami Council (AC 2011, Koivurova *et al.* 2008). Finland described the AC as a forum 'to strengthen trust and mutual understanding between Arctic neighbors on the political platform as well as among the people. Scientific cooperation has been promoted and is ever growing as is the policy-shaping discussion on Arctic issues' (MFA Finland 2013). The organization has no regulatory authority of its own and serves instead as an intergovernmental forum within which governments reach consensus-based decisions.

The AC members are asserting their preeminence in the stewardship and governance of the Arctic. They advocate for the multiple emerging challenges to be addressed regionally, and with multiple tailored policies, in contrast to developing a new UNCLOS-like all-encompassing single treaty, thus limiting involvement by non-Arctic states (Rayfuse 2008, Young 2009). The five coastal Arctic states affirmed this position in the 2008 Ilulissat declaration. Later in 2011, the AC in clarifying its criteria for admission of observers, most notably included a requirement of applicants to 'recognize Arctic States' sovereignty, sovereign rights and jurisdiction in the Arctic' (Graczyk and Koivurova 2013, SAO 2011) and 'recognize that an extensive legal framework applies to the Arctic Ocean including, notably, the Law of the Sea, and that this framework provides a solid foundation for responsible management of this ocean' (Graczyk and Koivurova 2013, SAO 2011). Reinforcing the validity of UNCLOS meant reinforcing the treaty as the existing overarching international law, which included reinforcing the application of Article 234, extending the usual coastal state jurisdiction to broader ice-covered areas.

The AC has expressed its intent to pursue a model of sustainable development (AC Secretariat 2013) and has created six working groups (covering the issues of contamination, wildlife and marine environment conservation, emergency prevention and response, and sustainability) to inform the policy-making of the council and its member states. It has also highlighted its intent to further increase cooperation with the private sector on corporate social responsibility and to protect the indigenous and local communities. With that spirit, the Arctic Marine Shipping Assessment's (AMSA) recommendations included the creation of the Arctic Indigenous Marine Use Survey (AIMUS) to better inform policy-makers on how to protect the traditional livelihoods of local communities' interests. This survey is still underway.

While it started as a forum with low-level ministerial contacts, the AC has been rising to become an increasingly active regional organization, reflecting the growing importance of the Arctic as perceived by governments within and without the Arctic Circle. Pursuant to its policy development objectives, the AC issued in 2009 the policy-oriented comprehensive AMSA. Its recommendations led to the first two binding circumpolar treaties, of *Cooperation on Aeronautical and Maritime Search and Rescue in the Arctic* in 2011 and on the *Agreement on Cooperation on Marine Oil Pollution Preparedness and Response* in 2013. Also for the 2011 biannual meeting, the U.S. sent for first time its Secretary of State (Myers 2011), and again in 2013. In 2012, the conference of the parties established a permanent secretariat in Norway.

In parallel to AC members becoming increasingly involved and at higher levels, outside parties are also paying closer attention. Probably seeing the AC as the only option for substantive political involvement in circumpolar cooperation, in 2013, six non-Arctic states were granted observer status: China, India, Japan, Singapore, South Korea, and Italy (Myers 2013). These joined the ranks of the other existing observers: the UK, Germany, Netherlands, Poland, Spain, and France. Others including the European Union (EU) have their application pending. The EU observer status is awaiting an understanding with Canada over the EU's ban of sealskin imports (Boyd 2013). The inclusion of the most important Asian economies as observers to the AC signals the importance the Arctic and its council may hold for the wider world (Humpert and Raspotnik 2012a). Other examples of the AC's centrality are the European countries' involvement in shipping governance (Liu 2013), and the French involvement in SAR agreements (Graczyk 2011).

The third element of governance is the IMO, which since 1959 has taken charge of commercial shipping by setting worldwide uniform regulations and facilitating cooperation toward safety, security, efficiency, and environmental responsibility. The IMO has produced numerous international treaties subscribed by a majority of states, including the International Convention on the Prevention of Pollution from Vessels (MARPOL), International Convention on the Safety of Life at Sea (SOLAS), International Convention on the Control of Harmful Anti-Fouling Systems on Ships (Anti-fouling Convention), International Convention for the Control and Management of Ships' Ballast Water and Sediments (Ballast Water Management), International Convention on Oil Pollution Preparedness, Response and Co-operation (OPRC).

However, the international legal regime regulating shipping was established at a time when the unique conditions of the Arctic were not a primary concern. Since 1991, the IMO has been deliberating the adoption of the mandatory International Code of Safety for Ships operating in Polar Waters (in short, the Polar Code; Brigham 2000, p. 248). So far only voluntary guidelines for vessels operating in Arctic waters were adopted in 2002 (IMO 2002) and updated to include all Polar Waters in 2009 (IMO 2009). More recently, IMO has postponed the adoption of the mandatory Polar Code from 2012 to 2014, potentially entering into force in 2017 at the earliest (Lloyd's List 2014).

Drafting negotiations revolve around new standards on construction, design, equipment, and manning (CDEM), as well as other operational concerns as the management of ballast water to curtail invasive species, and measures to prevent hull eco-fouling. Especially salient are disagreements on ice-strengthening standards for ships and the inclusion of an environmental chapter that could exclude the use of heavy fuel oil similar to current regulations in Antarctica (IMO 2011a). A question also lingers on the potential regulatory overlap between the Polar Code and the extended jurisdiction conferred to Arctic states in UNCLOS Article 234.

Finally, a fourth major element of governance involves Russia. While Russian extended jurisdiction remains contested by the U.S., Russia has produced the majority of enforced Arctic-specific regulations for commercial shipping. Understandably, Russia, having the vast majority of the coastline along the NEP, holds the biggest stake in it. The *Russian Arctic Strategy* highlights the Russian Arctic as the key future resource reservoir and points to the necessity of infrastructural and administrative development of the NSR. Russia sees the utilization of the NSR as a national integrated transport and communication system, being instrumental in safeguarding vital interests of the country in its Arctic sphere (Russian Federation 2008).

Prior to the end of the USSR, the NSR had a considerable amount of traffic, but mostly for servicing domestic locations. With the collapse of the USSR came the political opening of the NEP by Russia legislating international ship traffic in 1990 (Solski 2013). Russia has now refurbished the law with a new set of rules enacted in 2012 and 2013 (*Federal Law on the NSR, July 28, 2012*; *Rules of navigation on the Water Area of the NSR, the order of the Ministry of Transport of Russia, January 17, 2013*).

Russia has set up a new NSR administration allowing for centralization of responsibilities; it has simplified the rules for a more streamlined application process and amended some of its most contentious elements to bring the legislation into compliance with international law. Going forward, prior inspection in a Russian port is no longer a requirement, icebreaker assistance is not always mandatory, and assessment of fees based on paying potential (which was contested under UNCLOS Article 26) is scrapped. The payment is now to correspond with the scope of service rendered. These services are limited to icebreaker assistance and the hiring of a specialized Arctic pilot. To determine the need for either of those services, new 2013 rules take into consideration vessel's ice-capability, area and period of navigation, and current ice conditions (Ministry of Transport 2013b). In 2014, more specific mechanisms for icebreaker tariff calculation were also adopted, taking one more step toward fee transparency (FTSR 2014).

Even if increasing shipping along the NSR has already had an impact on the local economic activities and traditional nature management (Davydov and Mikhailova

2011), overall, governance in the Arctic is becoming highly developed, balancing environmental protection and the security of indigenous peoples and local communities with support for economic growth and shipping. It will also be important to understand how shipping and port development will affect urban development, demography, transport routes, and the environment. UNCLOS sets the tone of protecting freedom of navigation by any country, while also conferring economic rights, sovereignty limits, and environmental stewardship responsibilities to the coastal states. These principles are taken further and developed by the AC, IMO, and Russia's domestic legislation. The result is a system open to international shipping within a framework of significant safety and environmental regulations, supported both by the Arctic states and by multilateral institutions such as the AC and IMO.

Jurisdictional disputes

Despite the potential for a constructive shared governance, a political challenge to Arctic shipping stems from potential jurisdictional disputes over large areas of Arctic waters. Russia (and Canada along the NWP) has challenged the traditional notion of freedom of navigation as applied to the NEP by granting itself jurisdiction to apply domestic legislation, prompting opposition from the U.S. and other countries. While Russia has recently begun changing course toward a more orthodox application of international norms in the Arctic, questions remain as to how far Russia will take its reforms.

Both Russia and supporters of traditional freedom of navigation heavily rely on UNCLOS to justify their positions. Following what was already customary law, UNCLOS codified in Article 87 the freedom of navigation in the high seas. It further guaranteed the right of 'innocent passage through the territorial sea' (Article 17; which extends 12 nm off the coast) and also the 'right of archipelagic sea lanes passage' (Article 52). It recognized the 'right of transit passage' through 'straits which are used for international navigation' and freedom of transit through exclusive economic zones (EEZ; Articles 37, 38, 58). Only internal waters (Article 8) were excluded from the international principle of freedom of navigation and, in particular, from the right of innocent passage, remaining instead under the unrestricted sovereignty of the state.

Under the terms of UNCLOS, Russia has invoked Article 234 to regulate the passage of ships sailing in ice-covered waters beyond its territorial seas. This article is central to determining the extent of rights of Arctic coastal states, conferring extended powers to regulate shipping for the purpose of environmental protection in areas where ice poses a shipping hazard. For that purpose, it grants coastal states regulatory powers over 'ice-covered' waters beyond their territorial waters and within their EEZ. However, no international political consensus exists on the definition of 'ice-covered,' as nominally ice-free waters may contain ice in low concentrations. Article 234 also introduces ambiguity in its ending clause: 'with due regard to navigation and the protection and preservation of the marine environment.' While possibly meant to strike a balance between the power of a coastal state to protect the environment and the rights of other states to freedom of navigation, the language is broad and open to multiple interpretations. Currently, the few ships traveling through the NEP are following Russia's terms. However, the U.S. contests the Russian interpretation, reasoning that Russia may use Article 234 as a pretext to impinge upon freedom of navigation (Flake 2013, Østreng *et al.* 2013, pp. 13–18, Ragner 2000, pp. 80–83).

While the true motives of the Russian Government remain somewhat unclear, scholars have speculated that Russia has intentionally maintained a degree of strategic ambiguity, allowing for the coexistence of divergent scholarly arguments that altogether support its claim of extended authority in Arctic waters, without being clear enough as to elicit stronger protests by other countries (Solski 2013). The application of this jurisdiction has led to the imposition of a system of expansive control involving mandatory navigation permits and transit fees. While the latter is allowed in some limited circumstances (Article 26), the first is very unusual. To support its policy, Russia interpreted the definition of internal waters (Articles 7 and 8) in such way as to controversially enclose major groups of islands with a system of baselines defining waters in straits as internal waters (Østreng *et al.* 2013, pp. 13–18, Ragner 2000, pp. 80–83). Russia had also enacted a doctrine by which it would claim authority over ships temporarily leaving the NSR to venture into the high seas, in addition to claiming state governance over the NSR on the grounds that it was historically a domestic transport route (Ragner 2000, Solski 2013).

Russia's disputed jurisdictional claims are cause for concern for two reasons. First, because even if the few ships sailing today through the NSR are granted permission to navigate, Russia has set a framework that obligates all ships to request permission to access the NSR. In the future Russia could choose to exercise its self-granted authority to deny passage for political reasons. In 2013, Russia denied three times the requests made by Greenpeace's icebreaker *Arctic Sunrise* to enter the NSR. While Russia cited technical deficiencies in the ship, making it unfit for Arctic waters, it is likely the decision was politically motivated (Ritter 2013). Another reason for concern is that ongoing, intensified disputes could lead to an uncertain climate for investment in infrastructure (Simmons 2005) needed to support growth in shipping (AMSA 2009). Furthermore, continued sea ice reductions could introduce further uncertainty over which areas remain 'ice-covered' under Article 234.

Despite these disagreements, there are signs that Russia is moving toward a more international interpretation of maritime jurisdiction. In 2012, Russia began enacting a series of legislative reforms to modernize their management and regulation of the NSR. Notably, Russia no longer claims extended jurisdiction by virtue of a ship leaving the NSR in its law of 2012 (Russian Federation 2012). In addition, the permit application has been streamlined and calls for compliance with international law (Solski 2013). The rules and tariffs of 2013 and 2014 are some more small steps in implementing a streamlined, fair, and transparent process.

However, while these reforms appear to set a new course in Russian policy that is more welcoming to international shipping in the Arctic, the terms of the reforms need to be developed in more detailed subsequent legislations and implementations (Solski 2013). Most important, it is necessary to better define the boundaries of the NSR upon which Russia claims jurisdiction and the extent to which Russia will exercise its authority. Since Russia has a track record of dissonance between legislation and its implementation, there remains uncertainty over how the reforms will be carried out in practice. In addition, the Ukrainian crisis of 2014 has affected the relations between Russia and the West, raising further uncertainty about the potential for future Arctic cooperation. Whether Russia will deliver on its stated reforms will depend in part on the resolution of political debates between domestic nationalist and 'progressive' factions (Solski 2013), as well as the evolving geopolitical landscape.

Changing Arctic sea ice

The disputes over how to apply freedom of navigation in the Arctic, what new treaties to negotiate, what new regulations to enact, and what relevance emerging regional governance bodies depend in large part on the expectations and actual evolution of ice conditions in the Arctic. While predicting long-term ice conditions is difficult owing to numerous spatial and temporal uncertainties (Stephenson *et al.* 2013a, 2013b, Stroeve *et al.* 2012), examining recent trends may offer a glimpse of what could be expected in the future.

Ice extent and thickness are critically important for navigation. Extent, or the area covered by at least 15% ice, grows and shrinks seasonally revealing open water in summer throughout much of the eastern Arctic.[3] Ice thickness and age are closely related, as multiyear ice (having survived one or more summers) is generally thicker and harder than first-year ice and poses a significant danger to ships. Overall, extent, thickness, and age of ice have experienced reductions in the past decades, with accelerated loss beginning around the year 2000.

The 1979–2000 average summer minimum ice extent was 6.71 million km^2 (Perovich *et al.* 2012). In contrast, the September 2007 ice extent declined to low-record levels of 4.17 million km^2, and in September 2012 to 3.41 million km^2. In September 2013, the minimum yearly extent was recorded at 5.10 million km^2 (NSIDC 2013). The seven lowest recorded minimum extents since satellite observations began in 1979 have occurred in the last 7 years. The largest reduction between the March maximum and September minimum extents occurred in 2012. The winter average extent from 1981 to 2010 was 15.51 million km^2, with a record low in 2011 of 14.63 million km^2. March 2014 had the fifth lowest maximum winter extent on record (NSIDC 2014a, 2014b).

Submarine sonar measurements of ice thickness for portions of the Arctic Ocean began in 1958. These data indicate that overall mean winter thickness declined from 3.64 m in 1980 to 1.89 m in 2008. Prior to 1997, summer ice extent was 90% of the winter maximum, but by 2007, this percentage had declined to 55% (Kwok and Rothrock 2009). Satellite data from 1980 to 2011 indicate a steep reduction of multiyear ice with a record low in 2008. The fraction of total multiyear ice in March decreased from about 75% in the mid-1980s to 45% in 2011, while the proportion of the oldest ice declined from 50% of the multiyear ice pack to 10%. Since 2008, multiyear ice levels have recovered somewhat (Comiso 2012, Maslanik *et al.* 2011).

Research points to both natural and human feedback mechanisms that may contribute to greater ice reductions. The loss of summer sea ice exposes more ocean water to incoming shortwave solar radiation. The absorption of shortwave solar radiation by an increasingly ice-free ocean leads to increased heating of surface waters, which reinforces the summer melting of sea ice (Deser *et al.* 2000), and increases heat and moisture flux from the Arctic Ocean to the atmosphere during autumn and winter (Overland and Wang 2010). In the same way, particulate emissions lower the albedo of ice, enhancing melting further. While receding ice enables Arctic shipping, shipping itself may also contribute to sea ice retreat through greenhouse gas and particulate emissions. The Intergovernmental Panel on

Climate Change (IPCC) estimates that the current net climate impact of shipping is negative (IPCC 2013, Solomon *et al.* 2007), and diverting traffic from lower latitudes to the NEP may reduce global shipping emissions by up to 20% (Winther *et al*. 2014). However, short-lived climate warming agents from exhaust such as soot have an enhanced effect at high latitudes (Berntsen *et al*. 2006, Curry *et al*. 1996, Garrett and Zhao 2006). Also, unlike stationary activities, moving ships create a diffuse source spreading the emissions over a larger area. This leads to a stronger climate effect per emission unit of black carbon deposited on ice (Berntsen *et al.* 2006, Hadley and Kirchstetter 2012). Nevertheless, emissions from shipping are likely to be minor in comparison to those from the petroleum extraction industry (Ødemark *et al*. 2012).

While predictions vary, recent historical data reveal a marked downward trend in ice extent, hinting at the possibility of continued decline throughout the century. Younger and thinner ice is already enabling more frequent voyages by icebreaking vessels and by common cargo vessels along ice-free coastal areas during summer. Local emissions from shipping and onshore activities may create a positive feedback loop, reducing ice further. While it may take decades, a progressive reduction of this physical barrier would be an enticing prospect for commercial shipping along the NEP. However, free-floating ice in summer will remain a serious threat to navigation, and widespread ice in winter will continue to obstruct passage by most ships.

Technology and infrastructure

Even as the ice-covered area shrinks, harsh weather conditions, low visibility due to darkness in winter, and intermittent fog in all seasons remain important technical obstacles to navigation in the Arctic. This is especially salient as remoteness places further demands on a ship's independence and its ability to operate in these conditions. Robust technical standards are determined and enforced by both public and private entities. These factors also heighten the need for land-based supporting infrastructure like SAR and repair facilities.

Innovation in Arctic shipping technology began over 100 years ago and has developed considerably since the 1960s. For example, the azimuth thruster is a major innovation in ship propulsion and maneuverability, which allows for rudderless movement in any horizontal direction. The azimuth thruster is typically included in double acting ships, which are vessels that sail forward in open waters, but turn around and proceed astern (backward) in heavy ice conditions. These advancements increase both the safety and the operational capabilities of Arctic shipping (Wilkman and Mattsson 2014).

The adoption of these types of technologies is driven by the standards set by the IMO, which in turn are further detailed and verified in ships by classification societies. The IMO sets minimum standards for ships that may be adopted by member states as mandatory through domestic legislation (IMO 2011b). In addition, individual states may impose more demanding regulations on their own. Noncompliant ships may be detained in a member state port, or denied entry. As mentioned above, the IMO is in a process of developing a mandatory Polar Code, which for now is only advisory.

In addition to international standards, classification societies have developed their own set of rules for the design and construction of vessels. The main purpose of these rules is to ensure the structural strength and integrity of the ship's hull as well as the reliability and operability of all systems on board required for maintaining the ship's essential services, such as the propulsion, steering, and power generation systems (IACS 2011a). Many classification societies have also developed specific rules for vessels intended for operations in ice-covered waters. These rules are often based on the Finnish-Swedish ice class rules (Trafi 2010) and the Unified Requirements concerning Polar Class (IACS 2011b) published by the International Association of Classification Societies (IACS). While the exact rules may differ between classification societies, it is common for all ships with Ice or Polar Class that they have to fulfill additional requirements, including ice strengthening of the hull, a higher propulsion power, and other winterizing features.

Given the frigid weather conditions, ships operating in the Arctic require winterization, a process of adapting safety, navigation and cargo handling equipment for cold climate to ensure operability. Winterization addresses challenges unique to sub-zero environments, including icing, the accumulation of ice on the structure of a ship from sea spray, snow, rain and fog. Icing creates hazards for sailors, impairs equipment, and makes ships top-heavy, undermining vessel stability (Guest and Luke 2005). Winterization solutions include building structures and equipment from materials resistant to low temperatures, to avoid breakage, or inoperability when frozen (e.g. pipes and plastic hoses). Winterization also involves anti-freezing measures, such as constant heating of pipes, valves, instruments, antennae, doors, and stairways, pathways that need to be kept unfrozen and operable at all times, and attendant increases in power-generating capacity. It also requires the procurement of freezing-resistant supplies, like lubricants and fire-fighting equipment that remains immune to low temperatures. Other winterization needs include preventing the freezing of ballast tanks, deicing capabilities like having hoses for steam blowing and having advanced life support lifeboats that provide sheltering and heating systems (DNV 2013).

Ships also rely on third-party support services, which include repairs and maintenance, traffic control, communications, SAR, and weather forecasts, particularly for predicting the hazardous polar lows (atmospheric depressions). Most Russian ports are in disrepair, neglected since Soviet times. While modern large vessels have enough autonomy to traverse the NEP without refueling, in case of damage the current availability of ports for repairs and maintenance is scarce, which in turn increases insurance premiums. According to the register of the seaports of the Russian Federation, there are 18 marine ports in the Russian Arctic, divided into three groups. Murmansk, Arkhangelsk, Vitino and Kandalaksha are in fairly good condition with rail connections. The ports of Varandey and Dudinka are active but serve a single company, exporting oil and nickel for Lukoil and Norilsk Nickel, respectively. Finally, 11 ports are located in regions with sparse land transportation infrastructure.[4] These ports are in poor condition and are used mainly for local resupply for nearby cities and settlements (5–50% of their capacities are currently utilized; FSUE 2013, Ministry of Transport 2013a). In addition, a new Arctic port in Sabetta is currently under construction, with the first phase scheduled to conclude in 2014 and the second in 2016. It is expected to become a major harbor in the Russian Arctic and to boost Arctic shipping. Sabetta is part of the Yamal LNG project (joint venture of Novatek, Total, and China National Petroleum Corporation) and is cofunded by the Russian Government (Ship-Technology 2013, Staalesen 2012).

Voice and data transfer capability is necessary for transmission of weather forecasts, ice charts, and distress signals between ships and for the emergency response services to coordinate operations. The available communication systems along the NSR are the Iridium satellites providing telephone and low-speed Internet. Radio transmissions along the Very High Frequency (VHF), High Frequency (HF) and Medium Frequency (MF) bands are also available. These services are adequate for voice communication. However, digital and broadband applications like the reception of modern weather and ice forecasts, global positioning system- (GPS) augmentation signals, or upcoming e-Navigation applications (Bronk 2013) are not reliably available. While a Vessel Traffic Management and Information System (VTMIS) has been in place along the NSR for decades, its capacity is inadequate for current shipping demand. These systems gather, evaluate, and distribute information about waterborne traffic to improve safety and efficiency. VTMIS capacity is scheduled to be upgraded by 2020, but it is unclear whether funding is available (Østreng *et al*. 2013, p. 200).

Broadband at sea requires line of sight access to a geostationary satellite for the main data intensive technologies to work. Due to the curvature of the earth, geostationary satellites cannot be used above 70–75 degrees of latitude. While these satellites transmit data at speeds of 2–4 Mbit/second, the Iridium Polar orbiting satellite array provides Kbits of speed, analogous to the Global System for Mobile Communications (GSM) cellular Internet coverage on land. These satellites orbit the globe at lower altitudes, and many satellites are required to be operating simultaneously to ensure coverage of the Arctic region. To offset this cost, connection speeds are much slower than satellites in geostationary orbits. To provide better service, the Norwegian companies Telenor and Kongsberg are working on launching new satellites that would provide better Arctic coverage in a project called Arctic Satellite Communication (ASK). This project is currently under study (Benjaminsen 2013, INTSOK 2012, Norwegian Space Center ca 2013).

The challenges with stable and high bandwidth data-communication in high latitudes also cause satellite positioning systems (e.g. GPS) to have insufficient accuracy for some offshore marine operations. During loading, construction, or maintenance operations, ships operate in very close vicinity to facilities which require dynamic positioning with decimeter accuracy. This accuracy can be provided by 'augmenting' the standard GPS signal (accuracy ~3 to 5 m; USDOD 2007) with a reference signal from a shore-based station (differential GPS, or DGPS). At lower latitudes, this signal is provided to vessels through a geostationary satellite service. Iridium is currently being considered as an alternative to provide the DGPS augmentation signal in the Arctic (de Jong *et al*. 2014).

Responses to maritime accidents include SAR and oil spill containment and recovery. In line with the aforementioned AC's agreement on SAR of 2011, responsibility for coordination of these activities along the NSR is governed by Russia. However, this agreement does not allocate any responsibility for the specific physical implementation of responses. The Russian plans involve extensive development of shore-based infrastructure (depots, crewing, and resupply logistics). Russian authorities are expecting cargo transported through the NSR to grow significantly (Pettersen 2014) and have invested 910M rubles ($30.1M) into the creation of 10 SAR centers along the NSR (Murmansk, Arkhangelsk, Naryan-Mar, Vorkuta, Nadym, Tiksi, Pevek, Provideniya, and Anadyr) to be completed by 2015 (Pettersen 2011). While these investments are a positive step toward infrastructural development in the Arctic, many experts believe that much more investments will be necessary (AMSA 2009).

Substantial parts of the NSR lie outside the coverage of these bases, making Russian icebreakers the only potential respondents to a SAR request (NSR Information Office 2013, USCG 2013). Even though an icebreaker convoy is no longer obligatory for certain classes of vessels under certain conditions (Ministry of Transport 2013b), ships will still be dependent on one of these icebreakers to be in range for adequate response assurance. The availability of these icebreakers may dwindle by the future development of the Yamal LNG project, as well as increased demand along extended parts of the NSR. Russia owns the largest icebreaking fleet in the world, including the largest nuclear-powered icebreakers. Five icebreakers are currently operational. One icebreaker is currently undergoing construction, and three more are planned to become operational this decade. However, at least three of these icebreakers will likely replace aging icebreakers built during the Soviet era (USCG 2013).

Under the implementation of the Russian federal target program *Development of transport system of Russia (2010–2015),* the construction of six modern response vessels is planned (NSR Information Office 2013). Until these vessels and a potential increase of shore-based resources are in place, the availability of response infrastructure along the NSR is lower than along other shipping areas in the world and will most likely be unable to handle all potential response scenarios (AMSA 2009).

To cope with the hazards of free-floating ice, a nascent field of ice forecasting is quickly developing. Monitoring of sea ice conditions is critical for understanding both climate changes and navigation. The scientific community has used many instruments and algorithms for sea ice analysis. Remotely sensed sea ice data are available from several instruments operating in the visible, infrared, and microwave bands. The most suitable instrument for sea ice monitoring for operational purposes is Synthetic Aperture Radar (SAR)[5] because it performs independent of weather conditions and has a high spatial resolution (1–100 m; Johannessen *et al.* 2007). It is widely used for tactical planning of optimal sailing routes for icebreakers and other vessels. Sea ice charts from national ice services in Europe and in North America are mainly based on passive microwave and SAR data. Passive microwave data have played a primary role in monitoring long-term inter-annual sea ice climatology since 1972 when the electrically scanning microwave radiometer aboard National Oceanic and Atmospheric Administration (NOAA)' s Nimbus-5 satellite was launched.

Sea ice retrieval algorithms using satellite data provide information on sea ice edge, type, concentration, and drift, as well as other dynamic characteristics such as zones of convergence and divergence that are critical for shipping (Karvonen *et al.* 2003, Martin and Augstein 2000, Zakhvatkina *et al.* 2013). Algorithm development is ongoing, and new SAR missions will be launched in the near future. Sea ice thickness remains difficult to retrieve using satellite data. New satellite altimeters provide improved sea ice freeboard for retrieval of ice thickness (ICESat and CryoSat-2). The methods of sea ice thickness retrieval are improving and results appear promising (Alexandrov *et al.* 2010, Sandven *et al.* 2011).

The harsh conditions of the Arctic require additional investment in materials and technology to develop stronger and highly equipped ships. Currently, the lack of widespread advanced communications and navigation technology poses significant operational risks. Land-based infrastructure in aging Russian seaports is mostly lacking as well, and minimal SAR capabilities exist currently along the NSR. Looking forward, new promising technologies like ice forecasting continue their development. These combined with possible but uncertain investment in satellites and coastal supporting services may serve to mitigate some environmental hazards. However, the high costs of such technologies and their relative developmental infancy suggest that it will be some time before their implementation will favor mainstream commercial shipping through the Arctic.

Conclusions

The NEP now bears more favorable ice conditions and a more stable and inclusive governance framework than ever before in its history. These changes are happening at a time of growing international trade driven by the rise of Asian economies, which require increasing imports of energy and raw materials. However, these conditions will only enable the NEP to become a seasonal complement, rather than replacement, to the Suez Canal (Reuters 2013).

Two major developments have facilitated growth in Arctic shipping in recent years. The first is the widespread climate-driven loss of sea ice, unprecedented in the 35 years of observed record. Projected future reductions have the potential to make the Arctic dramatically more navigable. More investments in infrastructure, navigation, communications, and the nascent field of ice forecasting offer potential for long-term growth in Arctic shipping. The second is the political opening of Arctic waters to international shipping within a stable institutional framework. This is a direct product of policy choices, with the AC continuously developing and adapting policies to the Arctic, and Russia reforming and streamlining its NSR regime, while also starting to invest in infrastructure. However, the possibility for future jurisdictional disagreements owing to differences of interpretations of international law could discourage development of international shipping.

The advantage of connecting Atlantic with Pacific with a 24% distance reduction (for Shanghai–Rotterdam) is offset by many factors including harsher weather and free-floating sea ice, requiring more expensive ship construction, and winterization investments. Remoteness, lack of broadband communications, and limited SAR capabilities increase the risk of Arctic operations. Shallow waters limit vessel size, and ice movements lead to unpredictability of the ships' arrival time. Lack of a dense coastal population lessens the value of the NEP as a trading route. For these reasons, the NEP is a less reliable seasonal alternative to the Suez Canal, especially for container transport. On the other hand, as a source of minerals and energy, the Eurasian Arctic holds greater short-term potential, evidenced by extensive mining in the region today. Emerging as well as mature markets in Asia are likely to drive Arctic resource development, leading to a growth of destinational shipping traffic along the NEP.

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Notes

1. Note that these statistics can become inflated when equating trans-Arctic voyages to voyages traversing the entirety of NSR, but not the entirety of the NEP. In that case, trips connecting Murmansk and Arkhangelsk (which lie outside the NSR but still within the Arctic) with a non-Arctic port become trans-Arctic voyages, increasing total transit shipping to 39 voyages.
2. The discrepancy between USGS and the Russian Academy of Science stems in part from the use of different definitions of the area extent of the Arctic. Furthermore, even though the data is several years old, they are the latest comprehensive studies available to date. New upcoming drilling in the summer of 2014 by Rosneft and ExxonMobil in the Kara Sea may yield new data (Efimov *et al.* 2014).
3. A good illustration of the recent year cycle of ice expansion and shrinkage can be found in a time-lapse video published by the NSR Information Office, which shows the relationship between 'Sea ice concentration and ship traffic during a yearly cycle' (2011; http://www.arctic-lio.com/nsr_transits).
4. These ports are, from East to West: Beringovsky, Anadyr, Egvekinot, Provideniya, Pevek, Tiksi, Khatanga, Dikson, Naryan-Mar, Mezen, and Onega.
5. The SAR acronym for Synthetic Aperture Radar is not to be confused with the same acronym for Search and Rescue and needs to be interpreted within the context where it is written.

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