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On the future navigability of Arctic sea routes: High-resolution projections of the Arctic Ocean and sea ice

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ABSTRACT

The rapid Arctic summer sea ice reduction in the last decade has lead to debates in the maritime industries on the possibility of an increase in cargo transportation in the region. Average sailing times on the North Sea Route along the Siberian Coast have fallen from 20 days in the 1990s to 11 days in 2012–2013, attributed to easing sea ice conditions along the Siberian coast. However, the economic risk of exploiting the Arctic shipping routes is substantial. Here a detailed high-resolution projection of ocean and sea ice to the end of the 21st century forced with the RCP8.5 IPCC emission scenario is used to examine navigability of the Arctic sea routes. In summer, opening of large areas of the Arctic Ocean previously covered by pack ice to the wind and surface waves leads to Arctic pack ice cover evolving into the Marginal Ice Zone. The emerging state of the Arctic Ocean features more fragmented thinner sea ice, stronger winds, ocean currents and waves. By the mid 21st century, summer season sailing times along the route via the North Pole are estimated to be 13–17 days, which could make this route as fast as the North Sea Route.

1. Introduction

The United Nations Framework Convention on Climate Change (UNFCC) held in Copenhagen in December 2009 agreed that global greenhouse emissions, including shipping, must be capped to prevent global temperature rising by more than 2 °C. This places heavy challenges on the industry. The estimated share of CO_2 emissions from shipping in the total global anthropogenic CO_2 emissions was about 3.3% in the 2000s [1]. Taking into account the projected increase in the volume of shipping, the emissions from global shipping operations will rise by 20–60% by 2050. To achieve the target global CO_2 concentration level of 450 ppm by 2050, global shipping is targeted to reduce its emissions at the rate of 2.6% per year from 2020 to 2050 [2–4]. The measures put in place by the International Maritime Organization (IMO) [5,6], including the recently adopted Energy Efficiency Design Index (EEDI), do not guarantee reaching the required reduction. Additional solutions must be sought, like switching to low-emission fuels, such as Liquid Natural Gas (LNG), hydrogen, biofuels, or non-emissive propulsion, solar- and wind-powered [7], reducing the water drag of ship's hulls and reducing the speed of sailing for cargo vessels (slow steaming). These measures will require several years to implement, and will require refitting the existing fleet at a very large expense for industry [8,9].

The exploitation of shipping routes in the Arctic Ocean can, in principle, reduce the navigational distances between Europe and Asia by about 40%, saving fuel and reducing CO_2 emissions [10]. Schøyen and Bråthen analyzed a potential reduction in sailing time, fuel and CO_2 emission savings for two types of bulk cargo vessels sailing along the Northern Sea Route (NSR) instead of via the Suez Canal [10]. They concluded that the main advantage of shipping operations using an ice-free NSR would be the reduction of sailing time, more than doubling the fuel efficiency and reducing CO_2 emissions by 49–78%. They however asserted that this would not necessary be the case for liner shipping due to uncertainty in the schedule reliability for the NSR so, in the short term, this route would first be of interest for bulk shipping. Overall, the saving in fuel might not necessarily translate to cost savings because of other factors, such as higher building costs for ice-classed ships, service irregularity and slower speeds, navigation difficulties, greater safety risks, etc., and, probably the most important factor, fees for icebreaker services. [10,11].

Here it is important to distinguish between trans-Arctic navigation, i.e., transporting cargo between Europe and Asia (and vice

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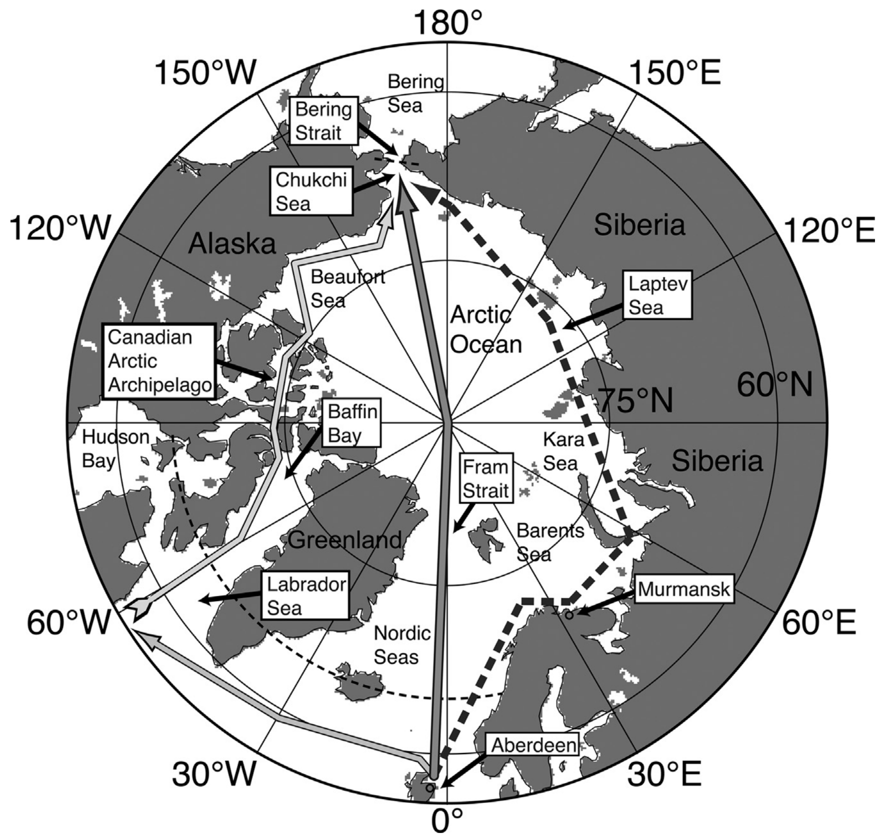

Fig. 1. Schematic showing the region of the study. The dashed arrow shows the Northern Sea Route (NSR) along the Siberian Coast from Murmansk (Russia) to Cape Dezhnev in Bering Strait; the light-gray arrow marks the Northwest Passage (NWP) through the Canadian Arctic Archipelago and the Arctic Bridge (AB) from Canada (St. John's, Newfoundland, Canada) to Europe (Aberdeen, UK); the dark-gray arrow shows the North Pole Route (NPR) from Europe (Aberdeen, UK) via Fram Strait across the North Pole to Bering Strait. Thin gray dashed line marks the 65°N boundary of the area used for sea ice analysis.

versa), which is driven by reducing navigational distances, and the regional Arctic shipping of commodities to Arctic settlements and natural resources from the Arctic. The present study addresses the former, whereas the latter has somewhat different economic controls (such as the quantity and type of cargo, commodity prices, vessels draft and accessibility of the few existing ports along the Arctic routes) and as well as social motivation (some of the Arctic settlements are not accessible by roads and can be supplied only by sea [12]. This regional Arctic shipping is beyond the scope of this study. The next section discusses the current state of Arctic shipping and formulates the aims of the present study.

1.1. Current state of shipping on the Northern Sea Route

Sailing routes between Europe and East Asian ports through the Arctic Ocean along the Northern Sea Route (NSR) are about 6000 nautical miles (1 nm = 1852 m) shorter (43% shorter) than the routes around the Cape of Good Hope and are about 2700 nm shorter (25% shorter) than the Europe to East Asia routes via Suez Canal (Table 1 in [13]). The NSR route is also shorter than the Panama Canal route by about 5380 nm (e.g., [10]). The use of the shipping route across the Arctic to bring cargo from Europe to Asia and vice versa has been explored in the 1990s in a series of international projects [14]. Based on Arctic sea ice and other environmental conditions characteristic of the pre-2000s, the International Northern Sea Route Program (INSROP) estimated that the Arctic shipping route along the NSR could save about 10 days of sailing (a reduction of about 50%) for general cargo type vessels, compared to the shipping route from Asia to Europe via the Suez Canal. The project concluded that savings in sailing time could be achieved if low ice or ice-free conditions were present along the NSR, although no comprehensive comparison between these two routes was made by the INSROP at that time [15–18]. Schøyen and Bråthen estimated that the NSR reduces the sailing time between Yokohama and London by 44%, as compared to the route via the Suez Canal, if the same average speed is maintained on these two routes [10]. These estimates were later put to the test by practice. For instance, in 2012 a Hong-Kong registered general cargo ship "Yong Sheng" of 14,357 tones of gross register tonnage (GRT) sailed between Dalian (China) and Rotterdam (Netherlands) along the NSR [19]. The ship spent 7.4 days on the NSR, at an average speed of 14.1 knots (1 knot = 1 nm per hour) (NSR Information Office, 2015), saving 27% of the sailing time by using the NSR, instead of the route via the Suez Canal (35 days vs. 48 days respectively).

The volume of cargo shipping along the NSR reached its peak in 1987 at 6.6 million tons (331 vessels, 1306 voyages), and then declined in the 1990s and 2000s almost to zero [20,21] Since the 2000s, the number of cargo-carrying vessels sailing along the NSR has increased again to 71 in 2013, with shipped cargo reaching 1.4 million tons. In 2014 there was a drop in the number of vessels sailing along the NSR to 53. Amongst these, 31 vessels transited on the NSR and 22 vessels were involved in regional supply operations [22]. Data on the volume of cargo in 2014 are not yet available [22].

The shipping data shows a reduction of sailing time along the NSR from 20 days in the 1990s to 11 days on average in 2012–2013. For this calculation the sailing time data is selected from the NSR Information Office database only for transit voyages between the Pacific ports and Europe [22]. The sailing time reduction is attributed to the easier summer ice conditions (ice extent and thickness) in the last decade [12,23].