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SUMMARY

This report presents a high-level view on sea ice and why it is important to develop observing and forecasting systems to support different user groups. Climate research users need long term data sets of sea ice parameters, especially ice area, ice thick ness and ice drift. Marine operators, including offshore industry, need daily high-reoslution maps and forecast of the ice conditions in the areas where they are working. Monitoring and protection of the environment in the polar regions need both large-scale, regional and local ice information for studies such as marine mammals. There are also other users groups who need sea ice information, such as fisheries, tourist operators, shipping companies, coast guards and various research groups working in Arctic and Antarctic areas.

1 Why is it important to monitor Arctic and Antarctic Oceans ?

The Arctic and Antactic is dominated by ice-covered oceans and coasts. The regions are exposed to climate change with significant impact on the cryosphere and the environment which depends on the presence of ice. In the Arctic the global warming is at roughly twice the global average rate, with a dramatic reduction in summer sea ice extent as one of the clearest indicators of this trend. Physical and biological processes are being transformed across the entire regions while climate feedback mechanisms in the Arctic's changing atmospheric and oceanic dynamics impact at global scales.

The Arctic regions offer vast areas of hydrocarbon resources that have just started to be exploited. The Arctic Ocean is surrounded by continental shelves, where in particular the huge Siberian shelf covering the eastern hemisphere, extending from the Barents Sea to the Chukchi Sea.

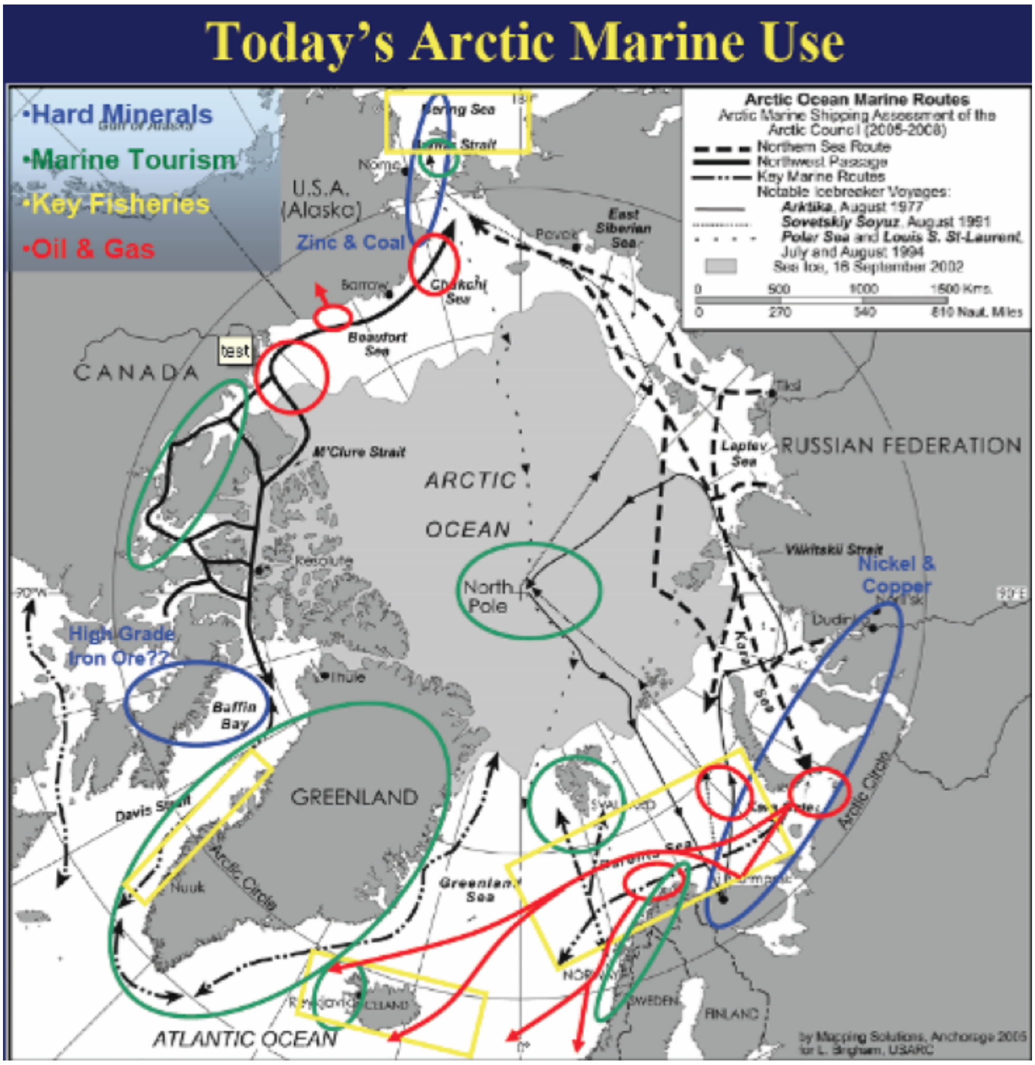

Figure 1. Map of the main areas where resource expoitation is a driver for shipping in the Arctic (Ref. L. Brigham).

There is growing political interest for the Arctic Ocean and several countries have started investigations of the continental shelves. Under the UN Convention on the Law of the Sea, a country can claim exclusive economic rights within 200 miles (Fig.2) If a country can prove that its continental shelf extends beyond the 200-mile economic zone, it can claim similar rights over a larger area. All States involved in the Arctic Ocean continental shelf have ratified the Convention except the USA.

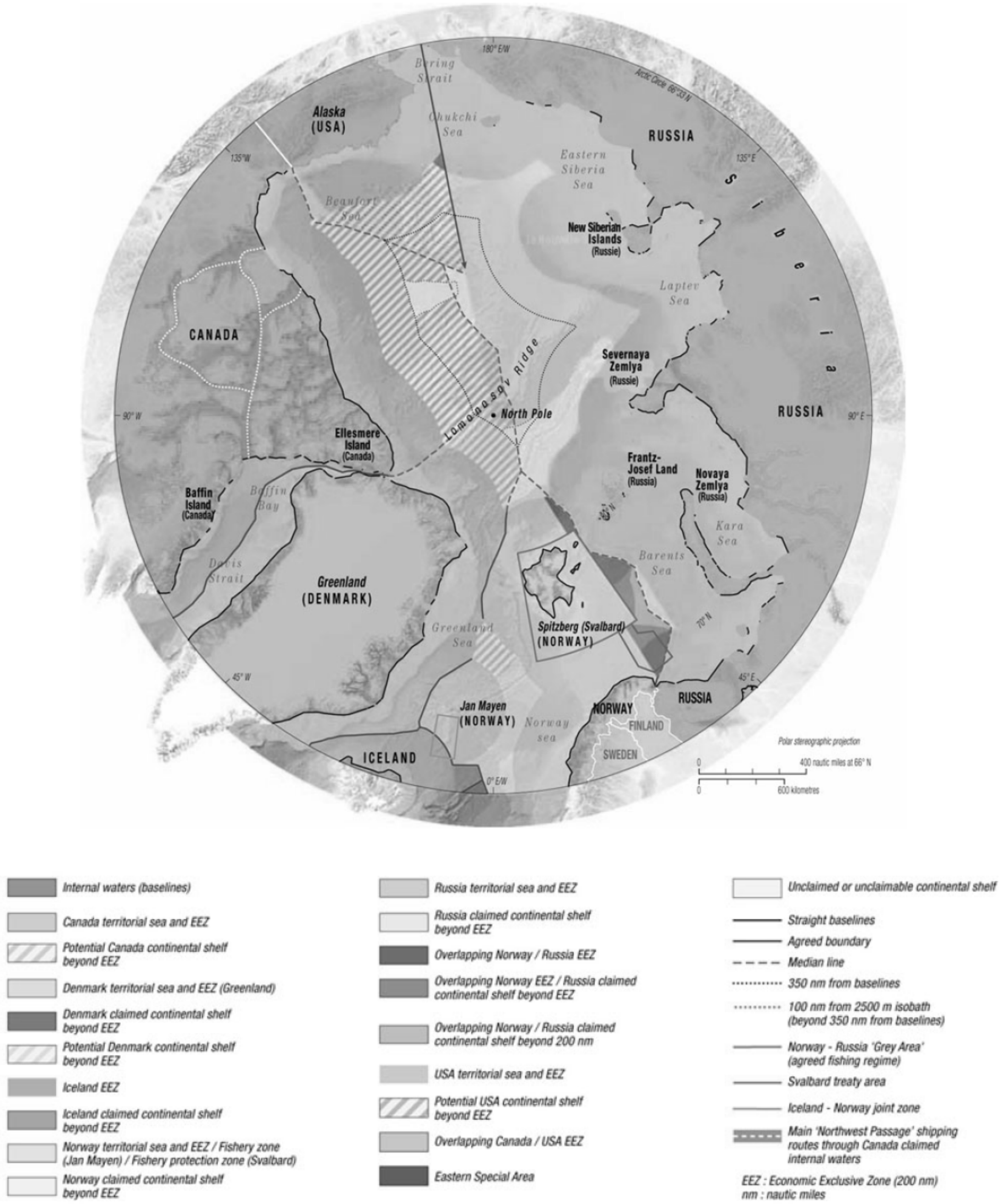

Figure 2. Legal situation in the Arctic (European Parliament, draft report on the sustainable EU policy for the High North, 2009).

The Russian expedition to the North Pole with planting of the Russian flag on the seafloor in summer 2007 was a politically staged event, triggering debates over claims for the Arctic Ocean seabed [1]. The Russian expedition was led by Arthur Chilingarov, the vice-president of the Russian Parliament, and also an Arctic explorer. The mission claimed that the Lomonosov Ridge, running across the North Pole, was an extension of the Eurasian continent. Russian scientists are, however, divided on this issue. Also Canada, USA, Denmark and Norway had expeditions to investigate the Arctic seabed in 2007. These expeditions refelct the growing interest and rivalry between Russia, the USA, Canada, Norway and Denmark for the resources of the Arctic Ocean.

The global warming, as expressed by the air temperature increase, has been most pronounced in the Arctic regions. In the last three decades, the temperature has increased by 2 -4 degrees, depending on the sector of the Arctic, which is more than twice the global mean temperature increase. Enhanced warming in the Arctic is predicted in the next decades according to the climate models, but strong decadal variability must be expected [4]. This may cause colder periods with more sea ice conditions in some winters compared to the present situation, even if there is a long-term trend of decreasing ice cover. It is difficult to predict the sea cover for the coming winters, because the forecasting models are not capable of providing reliable seasonal and multiyear forecasts of weather and sea ice conditions. This means that design of platforms and other installations for winter operations must take into account extreme values of ice conditions, low temperature, high wind speeds and wave heights and icing.

The ongoing changes in Arctic climate with increasing temperatures and decreasing sea ice cover have stimulated the interest for oil and gas exploration in several Arctic areas. A reduction of the sea ice area opens up the possibility to access new areas of the Arctic Ocean where hydrocarbon resources can be exploited and transported to the markets. The main Arctic areas where large-scale offshore exploration have started are: Sakhalin in Sea of Okhotsk, North Slope of Alaska, Cook Inlet, Grand Banks of Newfoundland, Barents Sea (Snøhvit field and the upcoming Shtokman field) and the Pechora Sea. All these areas have seasonal sea ice cover and some have icebergs that put severe constraints on design and operation of installations and on transport solutions. Even if the sea ice cover is decreasing and is expected to diminish further in the coming decades, the sea ice will still remain a dominant factor in most of the exploration areas in the winter season. In the summer months, however, less sea ice will provide access to offshore areas in Canada, Greenland and on the eastern Siberian shelf that were previously inaccessible due to sea ice.

2 The need for ice information services

Sea ice concentration, thickness, and pressure are the major direct factors influencing ice forcing on constructions and operations in ice areas. For offshore construction, the drift of ice as well as its thickness and mass are key parameters in calculation of ice loading. Maximum ice thickness is mainly determined by ridges and ice keels, formed when ice floes are pushed against the shore and can be piled on top of each other. In shallow waters, where depths are less than 20 m, ice keels can become grounded and ridges can build up to more than 10 m as a result of the drifting ice floes. For offshore operations, there are two main situations that require different management of the ice. The first situation is in shallow waters (5 – 20 m) where constructions are built on the seafloor and designed to withstand the forces of the drifting sea ice. The sea ice is often attached to the seafloor and can be stationary for a long time. But stationary ice can start to drift due to strong winds and pile up ice blocks forming stamukhas. The other situation is when operations take place in deeper water covered with ice that is freely drifting and also icebergs can occur. Floating constructions and ships can operate if they are designed to withstand the ice forcing. In case of extreme ice conditions, the platforms can be released and towed away.

Ice information products, such as charts and forecasts, are provided by the national meteorological or oceanographic services of countries with activities in ice-affected waters. Currently, shipping is the primary user of these products (Fig. 3). They are created by combining data from satellites, *in situ* sensors, and aerial and shipboard observations. Each source has strengths and weaknesses. *In situ* sensors, aerial surveys and ships provide specific but sparse information, and aerial surveys are expensive. Satellite data are not as detailed, but they are systematic, cost-effective and cover wide areas. A variety of satellite sensors provide data at varying resolutions, spatial scales and costs. Because ice can be highly dynamic, ice products must be synthesised quickly (in 1-6 hours) and regularly (every 6-24 hours, every day). Synthesis of data archives allows for statistical analysis and prediction.

Figure 3. Ice navigation of nuclear iceb.reaker in the Russian Arctic,where satellite SAR data can be used to map the optimal sailing routes

3 Future scenarios for the Arctic

The Intergovernmental Panel on Climate Change (IPCC) has provided several scenarios for future climate change in different parts of the world [5]. For the Arctic, the observed trend of reduced ice extent will continue and the summer ice extent may disappear towards the end of the century. The record low ice extent in September 2007 suggested that the summer ice may disappear much sooner (Fig.4). In the early 1980s the summer ice area was about 6.5 mill km^2, and it diminished by about 8 % per decade until 2006. In 2007 it the area shrunk to less than 4.5 mill km^2. The reduction of ice area of more than 2 mill km^2 corresponds to the size of Greenland. When the summer ice disappears, the thick multiyear ice will be absent, leaving the Arctic Ocean with a thinner ice cover in the winter season. The disappearance of multiyear ice combined with longer melt season will have important operational implications, leading to greater access and longer navigation season for shipping around the Arctic basin.

The IPCC scenarios suggest that there will be a substantial warming in Arctic and sub-Arctic areas compared to the present situation, which is closely linked to the reduction of the sea ice. The surface air temperature in many climate model projections shows a 6-8°C warming over the ocean during winter, with a less dramatic change in terrestrial regions. With higher temperature and reduction of the ice cover, the marginal ice zone will move poleward, leaving the coastal and shelf areas ice-free in the summer.

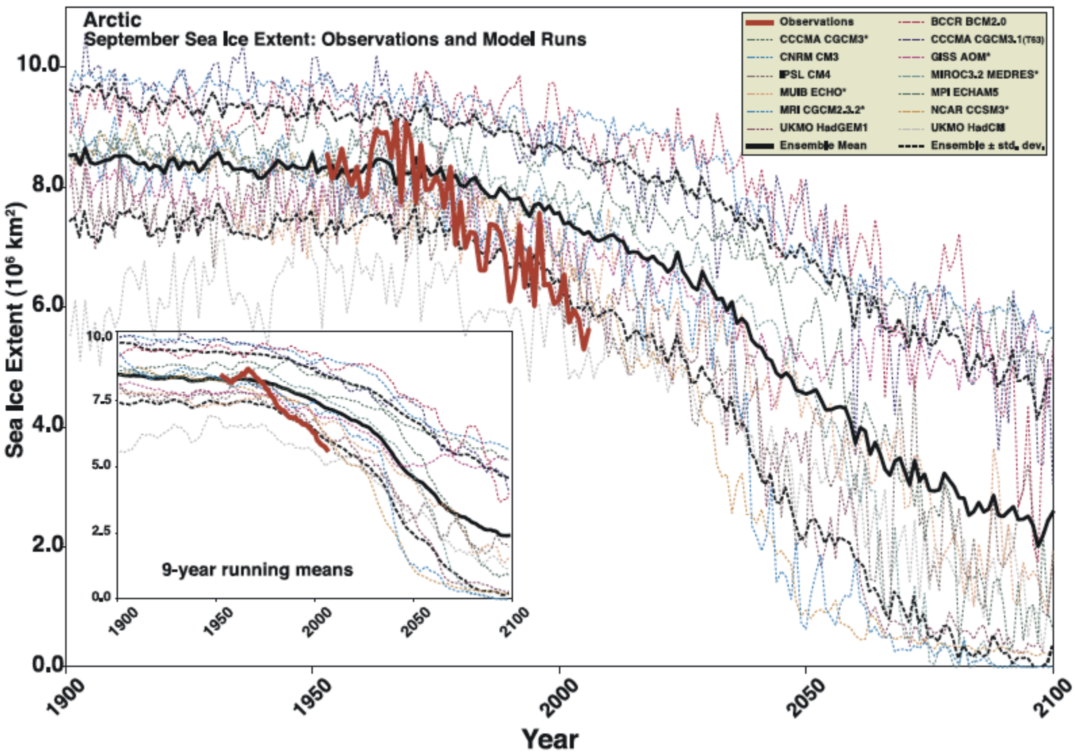

Figure 4. Arctic September sea ice extent (x10^6 km^2) from observations (thick red line) and 13 IPCC AR4 climate models, together with the multi-model ensemble mean (solid black line) and standard deviation (dotted black line). Models with more than one ensemble member are indicated with an asterisk. Inset shows 9-year running means (Stroeve et al., 2007).

With a smaller area covered by sea ice, more heat from solar radiation will be absorbed in the ocean, leading to increased ocean temperature. A warmer ocean will in turn reduce the amount of sea ice formed in the following winter. This is a so-called positive feedback mechanism, leading to enhanced warming in the Arctic. Another effect of a warmer Arctic is more clouds and precipitation. Increased fog will result sin in poorer surface visibility, which is an obstacle for many operations. More frequent and stronger storms can also be expected in the sub-Arctic areas. Vessel icing could also increase in these areas, especially during outbreak of cold Arctic continental air masses.

How can we assess the climate change impact in the various sub-Arctic regions where offshore operations are foreseen ? During winter, the central Arctic and all peripheral seas including the Greenland Sea, Bering Sea, and Gulf of St. Lawrence will continue to have significant ice cover. Ice extent and thickness will generally be reduced. The Sea of Okhotsk and Sea of Japan will be ice-free for the entire year. In late summer, the entire Russian coast will be ice free, allowing navigation through the Barents, Kara, Laptev and East Siberian Seas along the entire Northern Sea Route [6]. This situation has already been observed in the last couple of summers. The Northwest Passage through the Canadian Archipelago and along the coast of Alaska will in general be ice free and navigable in summer by non-icebreaking ships. Ice will be present all year along the eastern and northern coasts of Greenland. Ice will also remain throughout the summer within and adjacent to the northern Canadian Archipelago. However, severe winters with more ice than average may also be expected due to the natural variability of the climate system. The effect of more wind and waves in ice-covered areas will be increased ridging and stamukhas in near coastal regions. The iceberg situation in different parts of the Arctic is difficult to assess, but it is likely that more icebergs can occur in some years as a consequence of diminishing Arctic glaciers. Arctic shipping is expected to increase as a consequence of less sea ice and more offshore exploration [7].

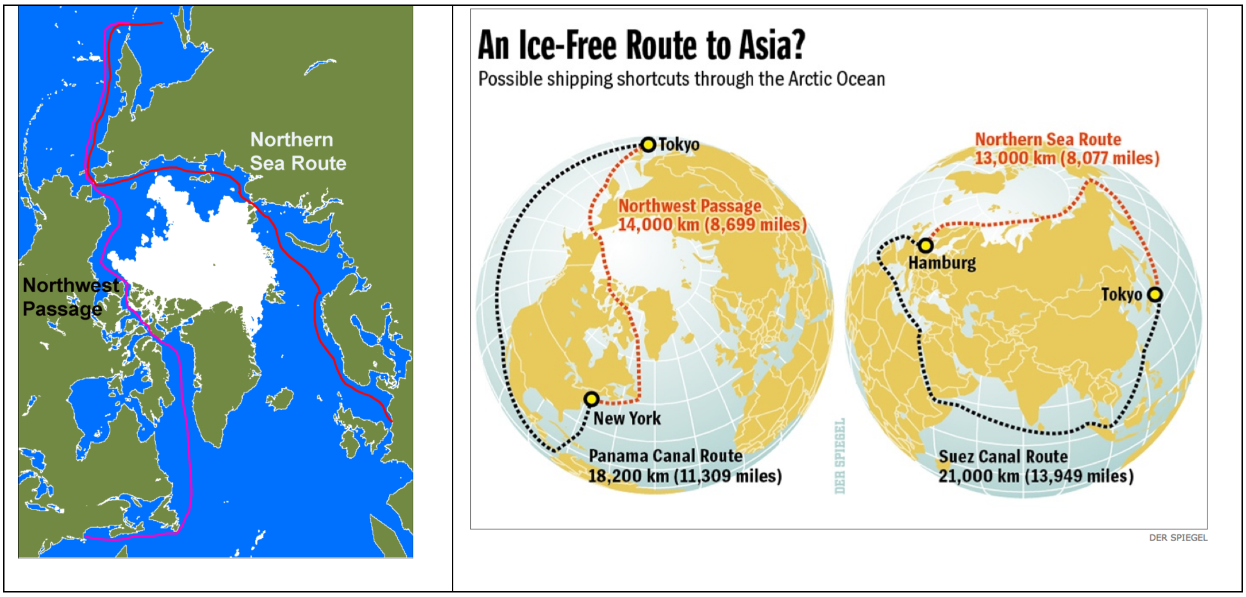

Figure 5. Map showing ice free sailing routes in both Northeast and Northwest passage in summer 2010. These sailing routes can become important for shipping in the future.

The possible consequences of increased oil and gas exploration in the vulnerable Arctic environment is a controversial issue. The Arctic ecosystems are already today exposed to severe treats due to the effects of a warmer climate. The climate effect comes in addition to the latent risk of radioactive contamination due to extensive nuclear bomb testing in the Russian Arctic in the previous decades. The storage of nuclear waste from scrapped reactors is also a severe risk factor, because it is not clear how safe this storage will be in the future. A growing oil and gas industry operation on land as well as at sea will increase the pressure on the environment with increased risk of accidents that can have severe and long-lasting negative effects on ecosystems. A worst-case scenario is an Exxon-Valdez type of accident that occurred in Alaska. The ecosystems in the area affected by this accident are still marked by this oil pollution disaster, almost 20 years after it happened [8]. The environmental impact of oil and gas exploration will be higher in the Arctic compared to other areas in the world. This calls for new technologies to ensure safe operations as well as legislative norms that regulate the activities. These factors are not in place yet and need to be developed.

In conclusion, offshore operations in the Arctic will be more feasible as a consequence of the climate change, leading to less sea ice and warmer temperatures, The costs of operations, however, will be high due to extreme ice and weather conditions and requirements to operate with minimum risks to harm the vulnerable Arctic environment.

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