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RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

ACCESS NEWSLETTER

Arctic Climate Change
Economy and Society

Issue No. 11
February 2015

ACCESS Highlights

Linking knowledge, research and responsibilities about the past, present and future of the Arctic between ACCESS scientists and graduate students participating in the 2nd ACCESS Summer School at the Royal Swedish Academy of Sciences in Stockholm on 22 -26 September 2014. Photo: courtesy of Aliaksei Patonia.

This newsletter is produced three times each year by a consortium of 27 partner organizations from 10 European countries in the 4-year Arctic Climate Change, Economy and Society (ACCESS) project. ACCESS is supported within the Ocean of Tomorrow call of the Seventh Framework Programme. Objectives of the ACCESS Newsletter are to facilitate international, interdisciplinary and inclusive information sharing of our research highlights about natural and human impact associated with sustainable development in the Arctic Ocean in the context of climate change.

SEVENTH FRAMEWORK PROGRAMME

www.access-eu.org

Editorial

Linking the past, present and future of Arctic research between senior and young scientists

ACCESS is now finishing and this is the final newsletter (number 11) of the project. During the fall of 2014 the project team entered the rather busy phase of finalising and summarising its results. An important stepping stone in that respect was a significant working meeting of the consortium held 22 - 26 September at the Royal Swedish Academy of Sciences in Stockholm, back-to-back with the Second Summer School, an important dissemination event of ACCESS. Beside internal work package meetings, one and a half days were devoted to a cross-sectoral synthesis meeting during which the researchers discussed synthesis issues, in particular interactions between different sectors of ACCESS activities. Two sessions were also dedicated to interaction between the researchers and the students from the summer school. The students presented their results as posters and oral presentations, and discussed them with the research teams. The student reports from their case studies in the Stockholm Summer School are highlighted in this newsletter.

ACCESS researchers at Stockholm synthesis workshop and 2nd ACCESS Summer School at the Royal Swedish Academy of Sciences in Stockholm on 22 - 26 September 2014. Photo: Agneta Sundin, The Beijer Institute.

Editorial

In addition to traditional research activities, ACCESS has provided a golden opportunity to experiment with different ways of linking research activities and results between researchers from different disciplinary backgrounds ranging from climatology and ice sciences to economics and social anthropology. During the general assemblies in Villanova (Spain, March 2013) and Cambridge (United Kingdom, March 2014), the research teams participated in several focus group activities dedicated to cross-sectoral and synthesis issues. Such activities were also organised at the ACCESS meetings held in parallel with the two summer schools (Bremen, Germany, September 2013 and the 2014 one in Stockholm). The results from these activities are a substantial contribution to the synthesis of ACCESS.

This newsletter provides a smörgasbord of issues related to Arctic transportation and oil and gas extraction. One article explains how climate change is likely to impact on the footprint of a possible Arctic oil spill because oil spreads more in a warmer climate with less ice and different weather conditions. However, while climate warming may favour increased oil and gas extraction in the Arctic, another article shows that this will probably not be substantial during the coming 30 years due to the technological challenges still posed by the harsh climate and the remoteness of the fields. Hence the impact on economies and markets in Europe and beyond is likely to be quite small. With increased marine activities it becomes particularly important to monitor changing environmental conditions in the Arctic. The successful mission of a Seaexplorer Glider, reported in this newsletter, gives an example of how this can be achieved.

To estimate the impacts of increased marine transportation it is important to be able to calculate the ships fuel consumption and emissions. Another article in this newsletter illustrates how to do this. In addition, industrial activities in Arctic and sub-Arctic regions increase demand for comprehensive international rules covering, among others, safety at sea, environmental protection and accident prevention.

The final meeting of ACCESS will be held at the end of February 2015 in Villanova (Spain) and we all look forward to putting together all the interesting results obtained during these four years of intensive work.

Anne-Sophie Crépin

Beijer Institute at the Royal Swedish Academy of Science, *for the ACCESS Editorial Board*

Climate Change and the Footprint of Arctic Oil Spills

Tor Nordam, CJ Beegle-Krause and Mark Reed / SINTEF Materials and Chemistry, Environmental Technology

Background

The fate of oil released in a spill is greatly influenced by environmental factors such as currents, winds, ice cover and temperature. The purpose of this ACCESS task (#4) is to compare the behaviour and fate of potential oil spills under present and future, probably warmer, climate conditions. High concentrations of ice control and limit the spreading of oil, which means that oil spills in the Arctic could on average have larger footprints in the future.

For this study, we use the OSCAR oil spill model developed at SINTEF Environmental Technology to perform numerical simulations. Two sets of environmental input data were used, one covering the years 2009 to 2013, and one from 2050 to 2054. Each dataset covers about half the Arctic (Figure 1), at 4 km resolution with 2 hour time-steps, in total about 4 terabytes of data.

The input data used for the simulations include currents, ice cover, ocean temperature and salinity data from SINMOD, an ocean model developed at SINTEF Fisheries and Aquaculture. Wind and air temperature for the present scenario were taken from ERA Interim, while the future atmospheric data was obtained from a regional model run at the Max Planck institute and based on the IPCC Spres2 scenario (A1B).

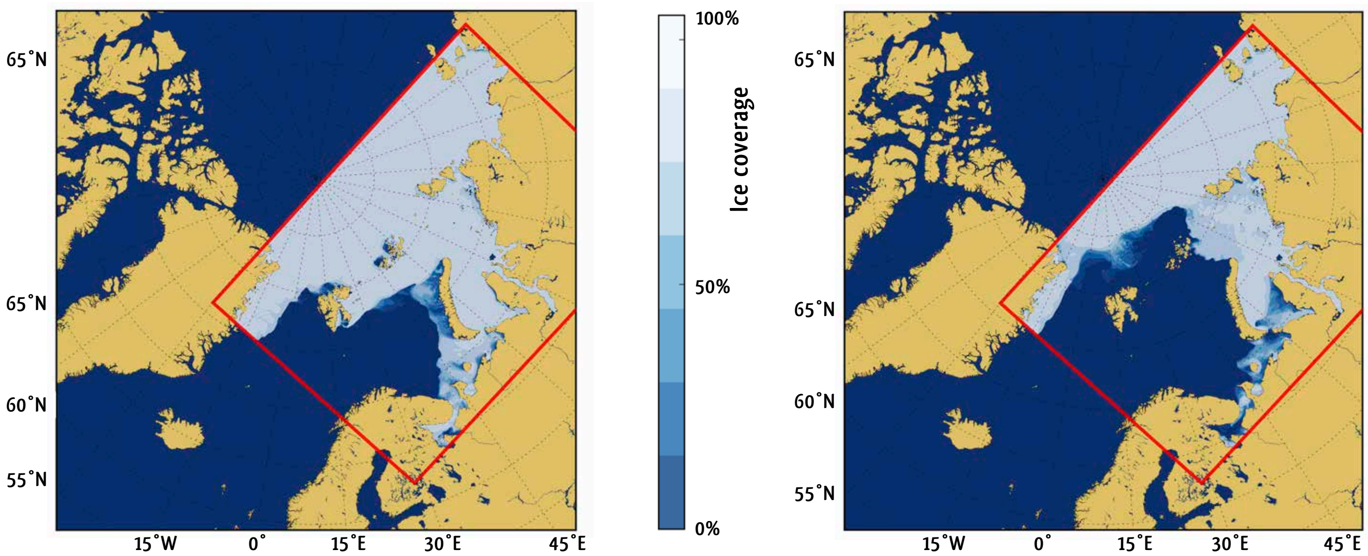


Figure 1 - Modelled ice thickness, on the left in March 2010, on the right in March 2050. The area for which environmental data are available is indicated by the red rectangle.

Case Studies

The study focuses on three scenarios: a well blowout, a pipeline rupture and a tanker accident. The data presented here are for a well blowout, similar in amount and rate of release to the Deepwater Horizon spill, but under Arctic conditions. The hypothetical blowout situation is at about 100 metres depth, off the northeast coast of Greenland in the Fram strait. Significant hydrocarbon deposits are believed to be found in this area and development is in an early phase.

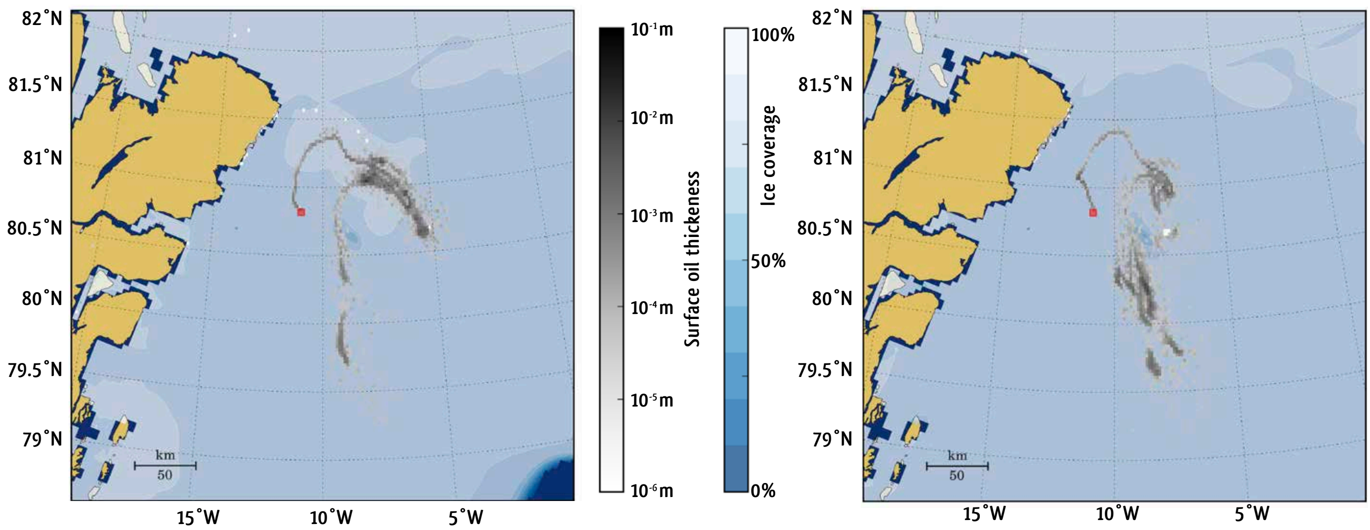


Figure 2 - Modelled distribution of surface oil, showing the thickness of the surface slick at the end of a 50-day simulation. Ice coverage is also shown. On the left, 15 March 2010 was used as the start date; on the right 30 March 2010 was used as the start date. The two results are somewhat different because of the partially different environmental forcing that was used in the simulations.

Simulation Results

In order to obtain statistical information about the fate of released oil, a form of Monte Carlo averaging is used. A continuous well blowout is simulated for a 50-day duration, running the same scenario repeatedly with all parameters kept constant except the start date. By starting a simulation for example every fifth day throughout the period covered by the available datasets, we sample from the underlying distribution of environmental conditions (Figure 2). This enables us to obtain statistical information about how the fate of the released oil depends on the time of year, as well as to compare present conditions to predicted future conditions.

In general, ice cover has the effect of reducing evaporation, as well as shielding the water from the wind. Wind causes both transport of surface oil, as well as mixing of the upper layer of water, which means that in simulations with less ice coverage, we see more spreading of the surface oil, as well as more evaporation. Figure 3 shows an example of results from a simulation with partially open water. Statistical data on the extent of the surface oil slick is presented in Figure 4.

The results show what we expected: spills in areas with a longer open water season, i.e. climate change impacts, will have more likelihood of a spill covering more area. Earlier research by SINTEF shows that oil co-located with ice also weathers more slowly, providing more time to respond. So planning for spills and spill response needs to consider how an Arctic area may change over the life of the development of oil in an area, e.g., exploration, development, production and decommissioning.

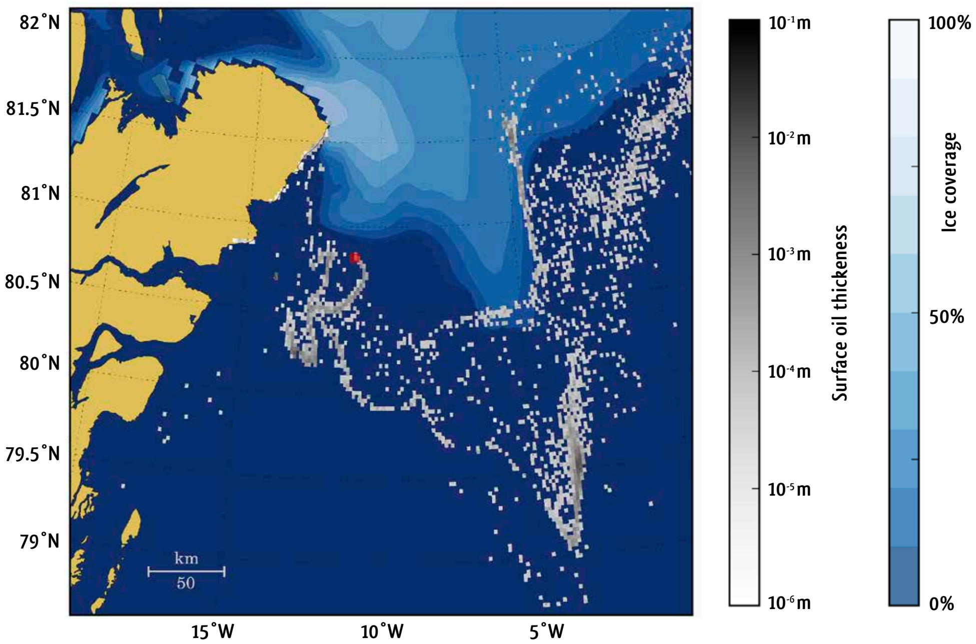


Figure 3 - Modelled distribution of surface oil, showing the thickness of the surface slick at the end of a 50-day simulation. Ice coverage is also shown. July 7, 2009 was used as a start date. Note the greater extent of the surface slick, which is caused by there being open water for parts of the simulation duration.

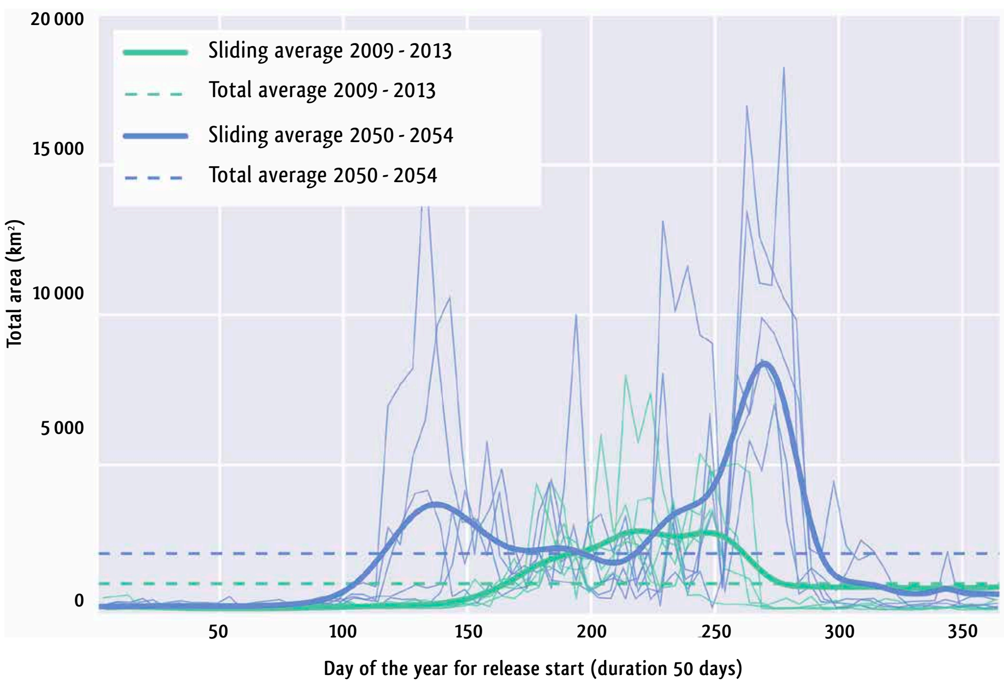


Figure 4 - Modelled results for area covered by surface oil, at the end of a 50-day simulation, shown as a function of the start date of that simulation. 700 simulations were performed, starting every fifth day during the two periods covered. The thick lines are averages over the years 2009-2013 and 2050-2054, while the thin lines show the individual years. The extent of the surface slick is on average larger in the summer, and the summer season has a longer duration in the future.

The Economic Effects of Offshore Production of Hydrocarbons in the European Arctic

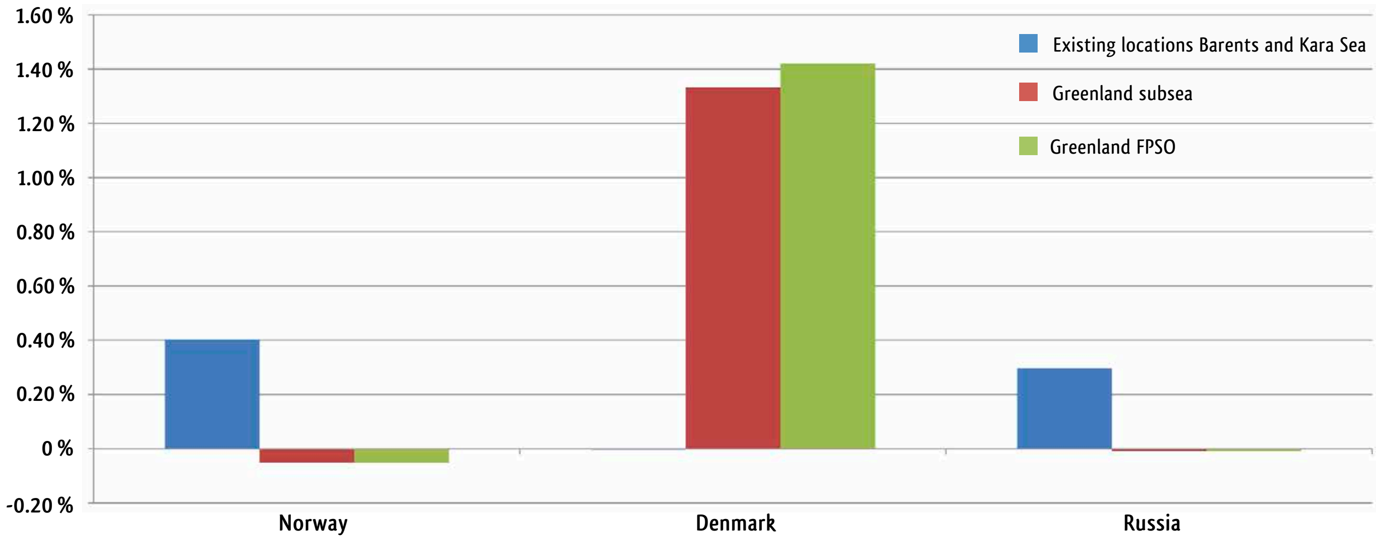
Sebastian Petrick / Kiel Institute for the World Economy (former) and German Institute for Economic Research

A significant share of the world's undiscovered oil and natural gas resources are assumed to lie under the seabed of the Arctic Ocean. Due to the technological challenges posed by the harsh climate and the remoteness of the fields, hydrocarbon exploitation in the Arctic is relatively expensive. As well, it must compete with less expensive supply options in other parts of the world. In light of these conditions, this ACCESS research assesses the future competitiveness of Arctic offshore gas and oil and effects on economies and markets in Europe and beyond. We use scenario-based analysis and economic modelling techniques for projections to 2040. A brief summary of key results are presented here.

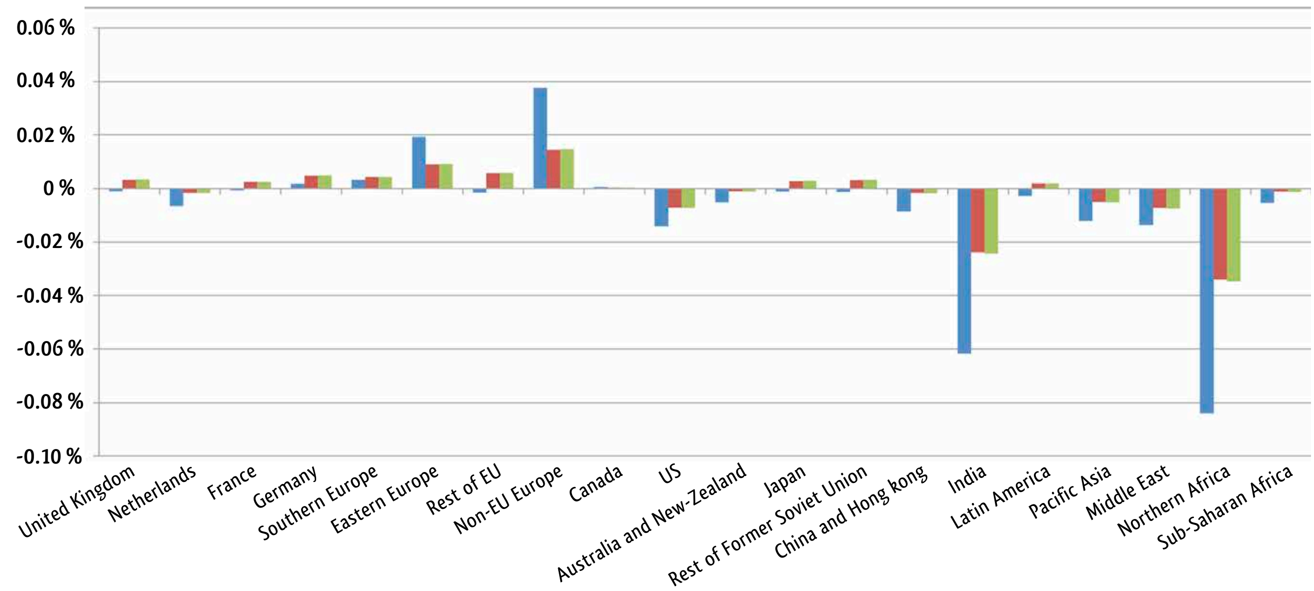
Natural Gas

In general, the effects of additional natural gas production are very moderate. This is due not only to the small existing production capacities which, taken together, will account for only 28.6 billion cubic metres in 2018. It is also due to the fact that only a few locations in the European Arctic are economically viable in the current gas market conditions. The analysis considers additional production in the Norwegian and Russian Barents Sea, existing Kara Sea facilities and off of the west coast of Greenland. Of these locations, only production in Greenland and the expansion of existing production facilities in Norway (Snøhvit) and Russia (Yamal) are

Panel A



Panel B



Notes: Southern Europe = Cyprus, Greece, Italy, Malta, Portugal and Spain. Eastern Europe includes Czech Republic, Estonia, Latvia, Lithuania and Poland. Rest of EU = Austria, Belgium, Finland, Ireland, Luxembourg, Sweden.

Figure 5 - GDP in 2040, difference in model runs for scenarios relative to reference scenario without additional Arctic natural gas production (beyond existing capacity in Snøhvit and Yamal), using the DART model. Existing locations Barents and Kara Sea = expansion of the Snøhvit and Yamal plants; Greenland subsea and Greenland FPSO = additional production units off west Greenland, using autonomous subsea technology or floating production, storage and offloading (FPSO) units.

economically viable. More challenging environments in the Barents Sea, e.g. offshore locations with higher step-out distances, are not economic in the current environment. This highlights the importance of existing infrastructure for economic development in the High North, which serves as a catalyst for future development.

Arctic natural gas production will be shipped in the form of liquefied natural gas (LNG) to Asia to meet steadily growing demand. Hence, the European supply portfolio is not going to be significantly altered by Arctic production from existing facilities, even if production volumes increase significantly. Only in the hypothetical case that LNG is produced in Greenland, this gas would be shipped to Europe where it partly replaces LNG from the United States.

We also find that accelerating climate change in the Arctic does not have a significant effect on deliveries via the Northern Sea Route. Even in the case of limited availability of the route in the reference scenario (NSR availability assumed from June to September), almost all gas is shipped to Asia.

Additional Arctic gas production has some small indirect impacts on Europe and beyond. Producing countries are most affected, particularly Greenland/Denmark (DNK) with an increase in gross domestic product (GDP) of 1.3 - 1.4 % and spill-overs to some manufacturing sectors in 2040 (Figure 5, Panel A). Overall economic impacts in Norway and Russia are smaller, although we find significant impacts in downstream sectors in both countries. In Norway the downstream economy is mostly negatively affected, with output decreasing especially in the chemical and energy-intensive industry sectors. These sectors are hit from additional production due to increased competition for qualified labour and disadvantageous appreciation of the real exchange rate. The Russian downstream economy, especially the chemical and electricity sectors, partly profits from lower prices for natural gas and increases production. Nevertheless, increased competition for qualified labour also can be seen in Denmark and Russia, and to a smaller effect also in other natural gas producing economies, including Netherlands and countries in North Africa.

While the overall effects outside the Arctic may be small, we do find some effects in non-Arctic countries (Figure 5, Panel B). Most affected are Eastern Europe (Eastern European Union, European Economic Union and parts of non-EU Europe) and other states of the Former Soviet Union (FSU). GDP increases in the gas- importing countries of Eastern Europe, thanks to lower gas prices, but decreases in gas-producing FSU countries. The chemical and energy-intensive industry sectors profit most from lower natural gas prices.

On global goods and services markets, we project that reactions are mostly limited to the producing countries. Terms of trade are decreased by around 1 % in 2040 for Denmark and Norway, as are exports in the Norwegian manufacturing sectors. Potential reasons for these losses are exchange rate effects as well as increased competition on factor markets, including labour. Despite reduced terms of trade, some Danish manufacturing sectors increase their exports as they profit from lower natural gas prices, as do the Russian chemical and electricity sectors.

The projections indicate that the production of other fuels is not significantly affected, apart from some special cases, such as Russian electricity and non-Arctic natural gas. Production of Arctic natural gas, however, is detrimental to reaching European and global climate change goals. The hope that natural gas might replace more carbon-intensive fuels such as coal or oil is not realised in the scenarios.

As a general conclusion, the production of natural gas in the Arctic, while having some modest regional effects, is certainly not a game-changer for Europe. The effects on import diversification are miniscule as economic possibilities on competing markets, especially Asia, are more tempting for natural gas producers. Also the impulse for economic development is small and confined to the producing countries or energy-intensive sectors.

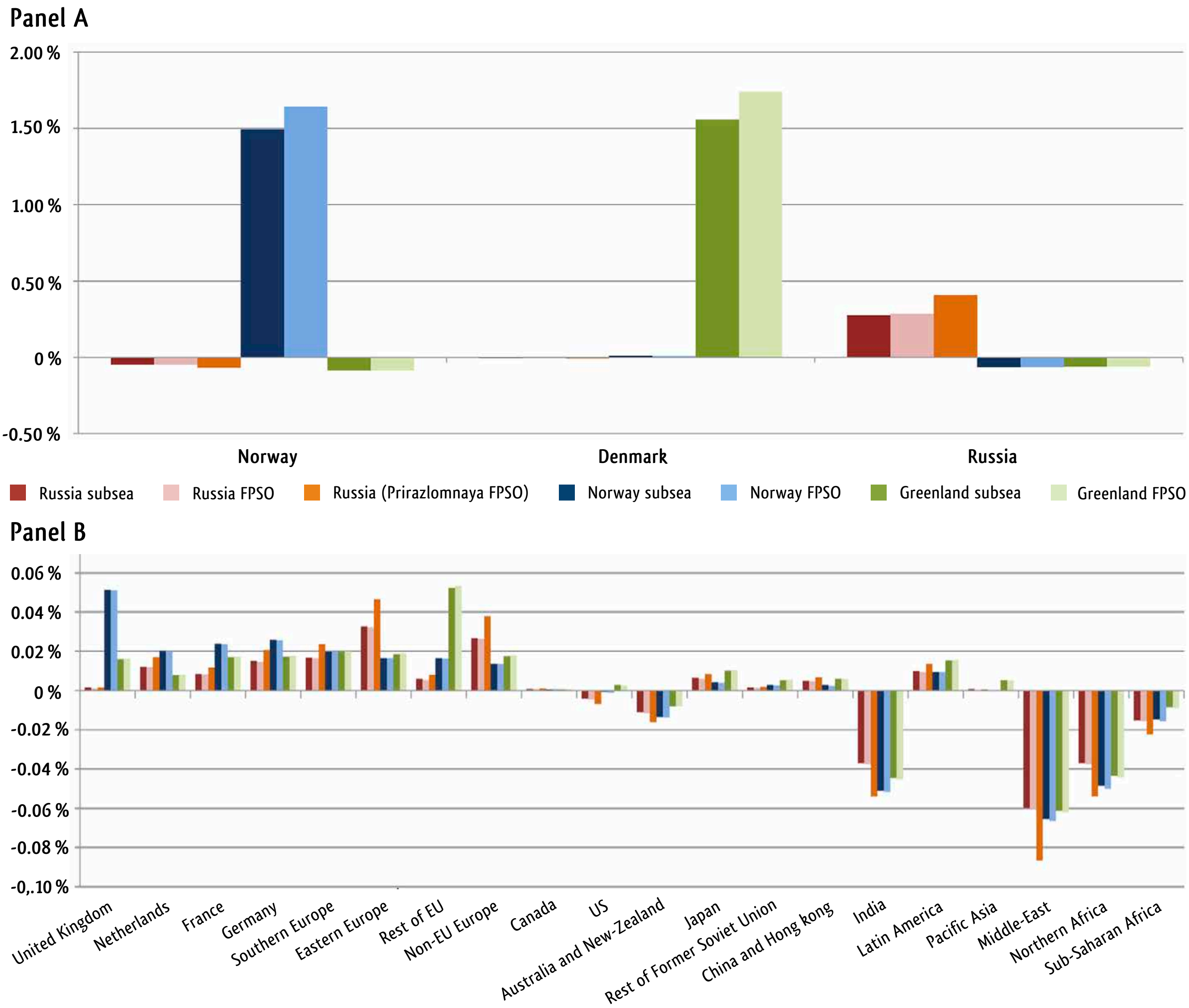
Crude Oil

The analysis indicates that additional Arctic offshore oil production has a number of consequences for European economies, not all of which are in line with policy goals. The most significant effect of Arctic oil – and presumably any additional oil production for that matter – would be a decrease in oil prices, both in producing and importing countries. As oil is a key input factor for any economy, the lower oil prices can stimulate economies. GDP increases significantly in producing countries, especially in comparably small Norway (NOR) and Greenland/Denmark where we see an increase of up to 1.7 % (Figure 6, Panel A). GDP increases are not restricted to the producing country; the findings show an expansion of economic activity for all European countries. Only competing oil exporters are negatively impacted, such as the Middle East countries, North and Sub-Saharan Africa and FSU states (Figure 6, Panel B).

The price changes and the economic expansion in many parts of the world have important implications for world trade. The terms of trade, i.e. the ratio of export prices in terms of import prices, decrease substantially for Arctic producers, even though each individual non-Arctic region is not much affected. Consequently, exports especially in manufacturing decrease in the producing countries. As an example, overall Danish exports decrease with oil production in Greenland, while in Russia exports remain constant, though with significant inter-sectoral shifts among exporting sectors in both countries. Appreciation of the exchange rate and increased competition on domestic input markets are among the reasons. Only Norway profits overall in terms of exporting activity. The rest of the world increases exporting activity as the overall economic expansion spurs global demand. Nevertheless, this economic expansion is not enough to produce significant changes on the labour markets outside the producing countries. In the producing countries, however, we find significant labour market effects, including shifts from manufacturing sectors towards the oil industry. The findings do not indicate significant shifts on the markets for primary fuels, however, they show a significant increase of carbon dioxide (CO_2) emissions as a consequence of additional oil production, more than 10 million tonnes (0.02 % of global emissions) even for the smallest production unit in this analysis.

As in the case for natural gas, the analysis indicates that European Arctic offshore oil would have some modest regional economic effects but is not a game changer for Europe. Even though oil production and an accompanying price decrease act as a small stimulus for European economies, this effect is not confined to Arctic oil, where, nevertheless, it is connected with detrimental environmental risks.

The Economic Effects of Offshore Production of Hydrocarbons in the European Arctic



Notes: Southern Europe = Cyprus, Greece, Italy, Malta, Portugal and Spain. Eastern Europe includes Czech Republic, Estonia, Latvia, Lithuania and Poland. Rest of EU = Austria, Belgium, Finland, Ireland, Luxembourg, Sweden.

Figure 6 - GDP in 2040, difference in model runs for scenarios relative to reference scenario without Arctic crude oil production, using the DART model. Subsea and FPSO indicate additional Arctic production units in the respective countries, using autonomous subsea technology or floating production, storage and offloading (FPSO) units.

General Conclusion

Both oil and natural gas production in the Arctic Ocean are discussed as a solution to diminishing fossil fuel supply and energy security worries in Europe. We conclude that neither European Arctic offshore natural gas nor offshore oil production is a game changer for Europe. While production in the European Arctic might in the long term alleviate some effects of severe supply disruptions, robust markets in Asia are the likely destination for what small realistic production we might witness in Greenland, the Norwegian Barents Sea, or even the Russian Arctic.

Nevertheless, we do project some effects of increased offshore production of hydrocarbons in the European Arctic: under certain conditions, oil and gas projects are viable in existing natural gas locations in Norway and Russia, and in Greenland. Also oil production in the Arctic would be economic, should the necessary discoveries be made. Nevertheless, most natural gas would be shipped to Asian markets. The economic non-viability of new production sites with large step-out distances in Norway and Russia highlights the importance of existing infrastructure for economic development in the High North, which serves as a catalyst for future development.

With additional Arctic gas or oil production, we project a positive effect on GDP in the producing countries, even larger in the case of oil compared to gas in Norway and about the same for Greenland / Denmark and Russia, with some modest second-round effects for downstream sectors. Regarding countries outside the Arctic, we find by comparing regions that are active on both the gas and oil markets, such as the Middle East or North Africa, using similar scenarios, that the effects of oil production in the Arctic are considerably larger than those of natural gas production. This reflects the higher integration of the corresponding global or regional markets. The same integration also leads to smaller price decreases in Russia and Denmark / Greenland for oil compared to natural gas. Expectations that additional natural gas production might lead to reductions in CO_2 emissions are not realised and emissions rise for both fuels in all the scenarios.

Barents Sea Monitoring with a Seaexplorer Glider

Michael Field, Laurent Oziel and Jean-Claude Gascard / Université Pierre et Marie Curie, LOCEAN, Laurent Beguery – ACSA

A SeaExplorer glider successfully completed a 388 km mission in the east Barents Sea in August and September 2014 as part of the ACCESS Work Package 4 (Figure 7). The purpose of this glider mission was to monitor the physical and biological features of the Barents Sea over a north-south transect along a longitude of 32°0' E between 72°0' N and 74°30' N latitude. The Barents Sea is one of the most biologically productive areas in the world. During the last decade, which has been the warmest ever observed in the Arctic, climate change in the Barents Sea has been illustrated by an unprecedented sea-ice decline.

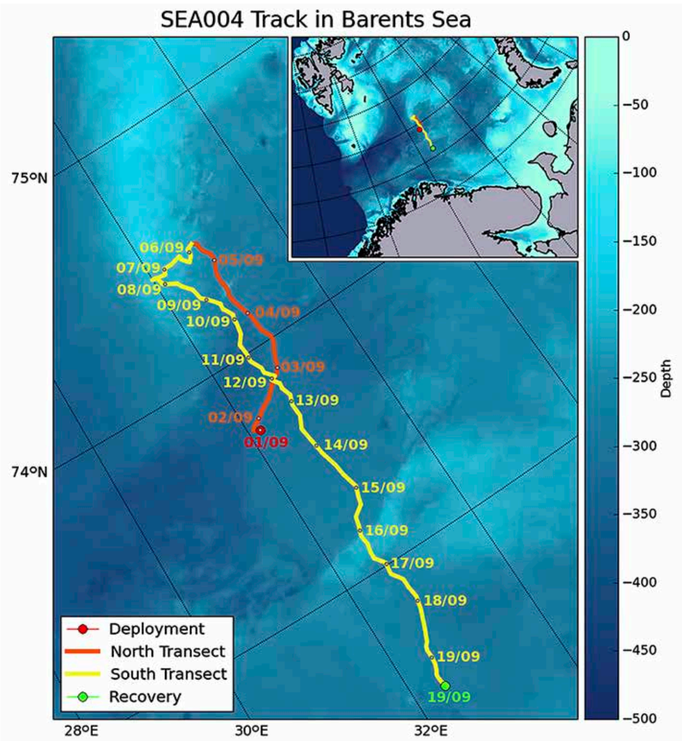


Figure 7 - SEA004 track in the Barents Sea.

SeaExplorer

The SeaExplorer is an underwater glider developed by ACSA-ALCEN, a French company. It is a wingless, low power design that travels through the water at speeds of up to 1 knot and allows up to several months at sea on a single charge of its rechargeable batteries. Every several hours the glider will surface and communicate its position and data via the Iridium satellite constellation, before diving again and continuing the transect. The SeaExplorer has a modular design with interchangeable wet and dry sections, allowing many different sensor configurations.

The SeaExplorer used by the ACCESS project – "SEA004" – was fitted with a sensor payload for measuring physical and biological parameters of the water column, and an altimeter for seafloor detection to allow full-depth profiling. These profiles will be used to study the impact of the changing environmental factors on the phytoplankton in the Barents Sea.

Testing in Tromsø

The SeaExplorer was shipped to Tromsø, Norway, with a technical team (Michael Field and Laurent Oziel, LOCEAN and Laurent Begeury, ACSA) to conduct field testing in preparation for the Barents Sea mission (Figure 8). The SeaExplorer is a reliable and proven vehicle in the Mediterranean Sea, however it had not yet experienced the colder Arctic waters or operation in close proximity to the magnetic north pole.

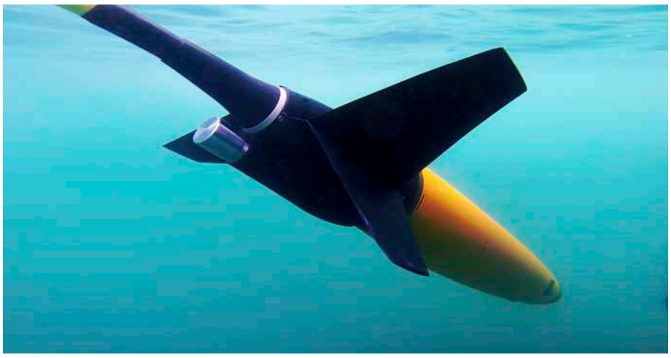


Figure 8 - SEA004 during testing in a fjord near Tromsø. Photo: Laurent Oziel.

The performance of the SeaExplorer was thoroughly tested on land and in fjords for a full range of headings and pitch angles (alignment in the magnetic field) using several different types of magnetic calibrations. The SeaExplorer magnetic compass was accurately calibrated and validated for the magnetic field at Tromsø, but was also tested using less accurate magnetic calibrations, including 24 hours unaided in a 100 metre deep fjord. This 24-hour test served to prove the reliability and robustness of the SeaExplorer performance in conditions where the magnetic compass accuracy is compromised, as well as providing an important dataset showing the best way to fly the SeaExplorer in these conditions.

Mission in the Barents Sea

The SeaExplorer "SEA004" was successfully deployed in the Barents Sea on 1 September 2014 in good sea conditions at a position of 73°43' N, 32°10' E (Figure 9). This was made possible thanks to the help of the Institute of Marine Research, Norway, providing the opportunity to participate in the Mareano 3 expedition on board the RV GO SARS. The deployment was co-ordinated with the ACSA piloting team in France, taking over control from the deployment team once the preliminary test dives were completed and SEA004 was ready for its mission.

SEA004 began the mission with a trajectory due north for the north transect and experienced significant water currents, generally in the northeast direction, which were gradually compensated for. SEA004 was profiling to a fixed depth of 200m with the altimeter initially disabled to conserve battery power. On 4 September, the SeaExplorer unexpectedly surfaced at 74°14.673' N, 32°50.411' E with an alarm resulting from making contact with the sea floor at 140 m depth. There is a known sea floor ridge at this position; however there is no documented point shallower than 190m on available bathymetry or sea charts. This bottom contact resulted in a temporary offset in dissolved oxygen measurements, likely due to sediment in the sensor tubing, which cleared within the following ten profiles. After this point the altimeter was enabled for safety.

Barents Sea Monitoring with a Seaexplorer Glider

Figure 9 - Deploying SEA004 in the Barents Sea from a rescue boat of the RV GO SARS. Photo: Anne Helene Tandberg.

Figure 10 - The crew of the RV Johan Hjort preparing to recover SEA004. Photo: Espen Strand.

On 5 September, SEA004 reached a northern-most position of 74˚30' N, 32˚45' E, which is the southwest corner of the central bank (centralbanken) of the Barents Sea. SEA004 then briefly travelled west to a longitude of 32˚0' E before turning due south for the south transect. The depths of the Barents Sea along this transect range between 165 m and 340 m, so the maximum depth of SEA004 was increased to allow profiling to within 20 m of the sea floor.

The south transect was successfully completed without any major problems. SEA004 continued to experience significant water currents, generally in the northeast direction, slowing the average speed of the glider by about 20%. The cold Arctic waters in the northern latitudes of the mission reduced the normal capacity of the rechargeable battery pack compared to similar missions in the Mediterranean Sea.

On 19 September, SEA004 was recovered by the RV Johan Hjort at 72˚30' N, 32˚25' E in rough sea conditions (26 knot winds, 4 metre swell), completing the 388 km mission (Figure 10). The sea conditions restricted the use of a rescue boat for the recovery; instead the ship positioned itself alongside the glider and completed the recovery via the CTD door.

Conclusion

This successful mission in the Barents Sea has proven the ability of the SeaExplorer glider to operate in the cold northern waters within the Arctic Circle (Figure 11). This opens the door to future opportunities to conduct autonomous monitoring in the Barents Sea, such as repeat observational missions of the north-south Vardø transect along 31˚ E longitude.

The mission in the Barents Sea also identified some possible improvements of the SeaExplorer for operating in the Arctic environment, such as economising the use of the largest power consumers (altimeter, fluorometer) without compromising their data or effectiveness. These operating improvements are expected to be released in early 2015.

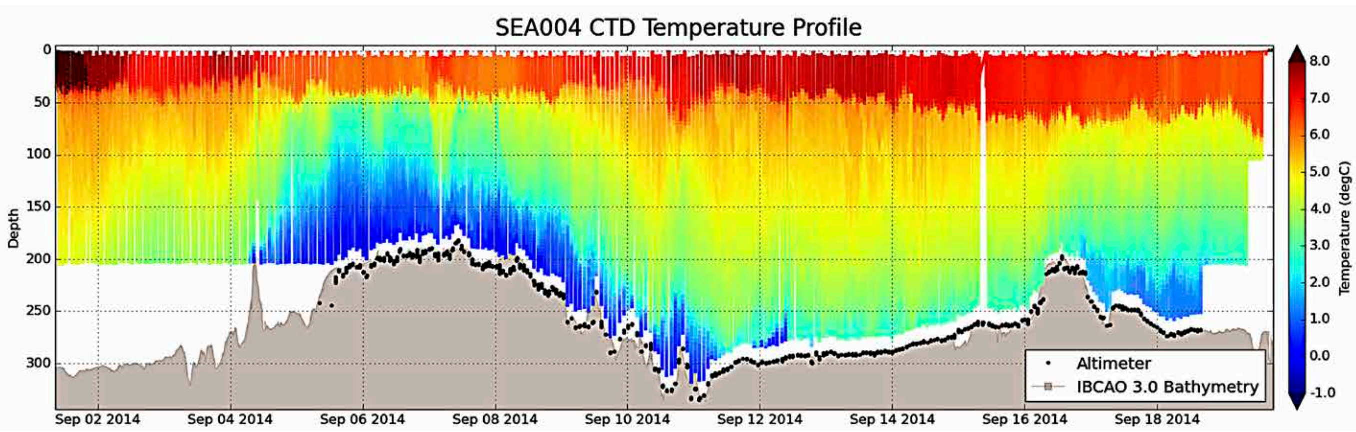


Figure 11 - SEA004 temperature profile from the Barents Sea mission.

Calculation of Fuel Consumption and Emissions for Various Ship Types

Christian Schröder / HSVA

Arctic sea-ice level has shown a dramatic decline in the past few decades, with a record minimum ice extent in 2011. These circumstances have generated high interest in establishing new trade routes, especially in economically viable shipping in Arctic regions. Ensuring exploration, access and extraction of resources in the Arctic will be of great value concerning the prospective trend of offshore engineering and economy.

Calculation Process

The ICEROUTE programme developed at HSVA is based on semi empirical - analytical formulations for predicting ship resistance in different environmental conditions including ice coverage. Additionally the data of the specific propulsion system is used to calculate the required power and thereby obtain the maximum attainable speed. The routes are subdivided into legs while the number of legs is chosen according to the required spatial resolution with regard to variations in environmental conditions. In a second step, the travel time for the entire route can be determined by summation of travel time for each leg (HSVA, 2011). In a third step with the information of specific engine data the Brake Specific Fuel Consumption fuel consumption (BSFC) can be determined and then the exhaust emissions are calculated by defining emission factors for the consumed fuel. The calculation steps and required input data are shown in Figure 12.

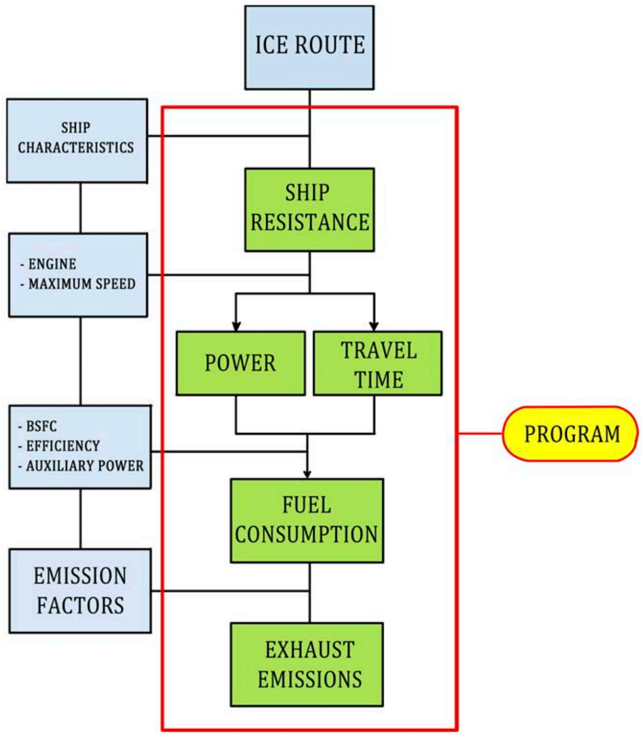


Figure 12 - Flow Chart of the calculation process. Source: Duong,Q., (2013).

Fuel Consumption of Ships in Ice Conditions

The increase in resistance resulting from navigation in ice-covered waters leads to higher fuel consumption. In addition, delays due to severe ice conditions lead to a longer duration of the voyage which results in increased total fuel consumption. The fuel consumption rate of a vessel depends on a variety of factors, such as its type and hull form, the environmental conditions it faces and its operating profile. Vessels are designed based on estimated resistance values and built with engines having specific fuel consumption values.

Assessment of Emissions

One possibility to calculate emissions of a ship is to use specific emission factors related to the consumed fuel. These can be described by the following formula.

$$E_{ijk} = EF_{ij} \,.\, LF_{jk} \,.\, (KW_j / \eta_j) \,.\, T_{jk}$$

- E_{ijk} are emissions of type *i* from vessel *j* on route k in grams (g)
- EF_{ij} is the emissions factor for emissions of type *i* on vessel *j* in (g/kWh)
- LF_{jk} is the average engine load factor for vessel *j* on route *k* and takes into account periods of manoeuvring, slow cruise, and full cruise operations
- KW_j is the rated main engine power in kilowatts (kW) for vessel *j*, is the engine efficiency
- T_{jk} is the duration of the trip for vessel *j* on route *k* in hours.

Emission factors can be found in Borkowski, 2011 and Corbett, 2010. Emission factors are based on different types of engines and fuel types used.

Surveyed Routes

The Northern Sea Route (NSR) passes through the Kara, Laptev, East Siberian and Chukchi seas. Entering the NSR is possible starting from Murmansk in western directions by passing south or north of Novaya Zemlya. In this direction, the NSR ends at the Bering Strait. Regardless of explicit routing, the NSR extends about 3 000 nautical miles. The factual length of the route in each case depends on ice conditions and on the choice of variants of passage resulting in individual leg-lengths. Different routes are surveyed beginning with a route near the coast, classic NSR and a route crossing the North Pole — the Polar route — which may be usable in the future. The surveyed routes as part of this ACCESS research are shown in Figure 13.

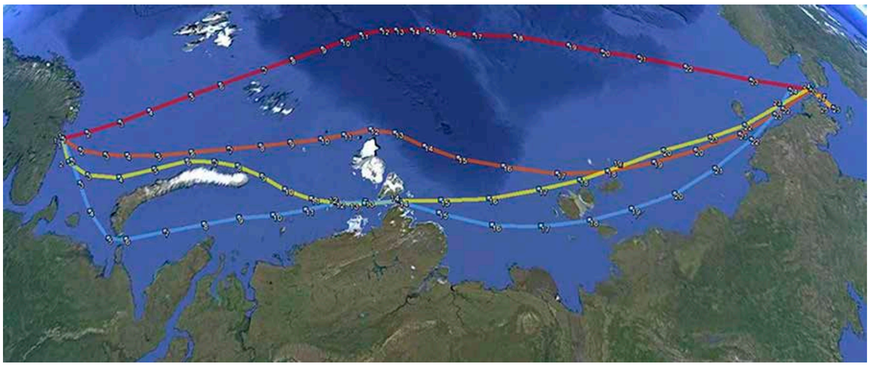


Figure 13 - Different transit routes along the NSR: 1 (blue), 2 (yellow), 3 (orange) and 4 (red).

Calculation of Fuel Consumption and Emissions for Various Ship Types

Environmental Conditions

The main factor influencing navigation through the NSR is the presence of ice. The navigation season for transit passages on the NSR starts approximately at the beginning of July and lasts to the second- half of November. The data set used in the following figures is provided by the World Climate Research Programme (WCRP) working group. For the case study, ice data were used from the coupled global climate model MPI-ESM-LR (Notz, 2013), part of the WCRP Inter-comparison Phase 5 (CMIP 5) (Taylor, et al., 2012. (These data were reviewed and provided by partners in ACCESS work package 1).[1] The data are based on historical scenarios and different emission scenarios for the future defined by emitted greenhouse gases in 2100. The data, including sea-ice coverage and sea-ice thickness, are available for the timeframe 1960 to 2040.

Analysed Scenarios

Calculations were performed within a period from 1960 to 2040, including the months April (04), July (07), September (09) and November (11) and evaluated for the four routes shown in Figure 13. The results clearly show the consequences concerning time and fuel consumption using the NSR in months other than September. In addition it was shown, that routes 3 and 4 are hard to pass in present conditions and the calculations show the first likely completed transits in 2040.

1 - See ACCESS Newsletter No. 4, www.access-eu.org.

An example of travel time, consumed fuel and emissions is presented in Figure 14. This calculation was performed for route 1 in September 1980 for various types of ships.

Conclusions and Future Prospects

- A clear trend of decreased travel time and coupled reduction of emission is obvious due to the decline of the Arctic sea-ice coverage and thickness.
- The new opportunities may raise the total emissions along the NSR due to increased shipping activities.
- Ships operate at a safe speed even in small ice coverage conditions to avoid damaging the vessel which leads to lower fuel consumption and correspondingly to reduced emissions.
- The simulations show that the travel time and resulting exhaust emissions are significantly lower at the end of the summer.
- The newly developed programme allows pollution scenario calculations of all types of ships at given environmental conditions.
- The most relevant input for the calculations is the environmental conditions.

To summarise, it must be stated that there is no unambiguous relation between the ice situation (extent, thickness, coverage) and fuel consumption and exhaust emissions. The reason is that if the ice extent increases towards the winter period fewer ships are able to travel the northern routes in a reasonable time. Additionally in the intermediate periods (freeze-up and melting) ships will be restricted in speed for safety reasons. In order to estimate future exhaust emissions for the Arctic region, the number of ships, which may operate under reasonable safe and economic conditions, has to be determined. The number of ships will depend on the development of the region and its infrastructure (socio-economic factors). Additionally the travel time and operating conditions of the different ship types is important as the speed profile will not only depend on technical ability but also on freight rates and type of goods to be transported along the Northern Sea Route.

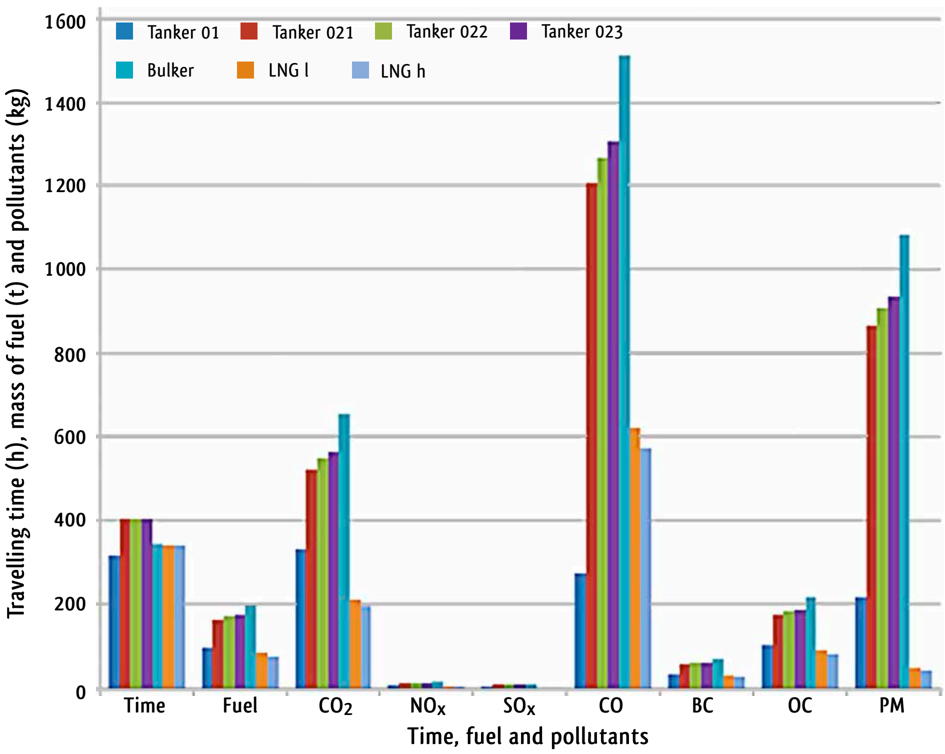


Figure 14 - Exhaust gas emissions from various types of ships - route 1 September 1980. Note: LNG l and LNG h refer to different power values provided to the propeller (l = 27 300 kW; h= 41 000 kW).

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Review of Maritime Transport Rules and Guidelines

Nils Reimer / HSVA

Introduction

Increased industrial activities in Arctic and sub-Arctic regions for purposes of transport and resource exploration lead to the demand for comprehensive international rules. The regulations have to cover the following aspects:

- Safety of life at sea
- Environmental protection, pollution prevention
- Casualty prevention
- Structural integrity and manoeuvrability of ships
- Functionality of on-board systems (winterisation).

Today a lot of basic rules with different objectives are defined by various authorities. The rules are mandatory within specific territories in Arctic and sub-Arctic regions. Additionally broad international rules are applied for all sea areas including those in ice-covered regions.

When discussing rules and guidelines which are covered by national law in Arctic waters an important fact is the actual territory of application for the laws. As the official process of territory definition is not yet finalised, national rules and guidelines can only be defined for coastal areas within the three-mile zone (Figure 15). This includes, for example, obligations for icebreaker assistance and special environmental protection rules for sensitive sea areas.

For remote places, like many areas in the Arctic, a crucial point is the time required for emergency response vessels to reach a disabled vessel from their station (Figure 16). A common scenario is a defect of a manoeuvring mechanism that leads to uncontrolled drift of a vessel in heavy seas or ice.

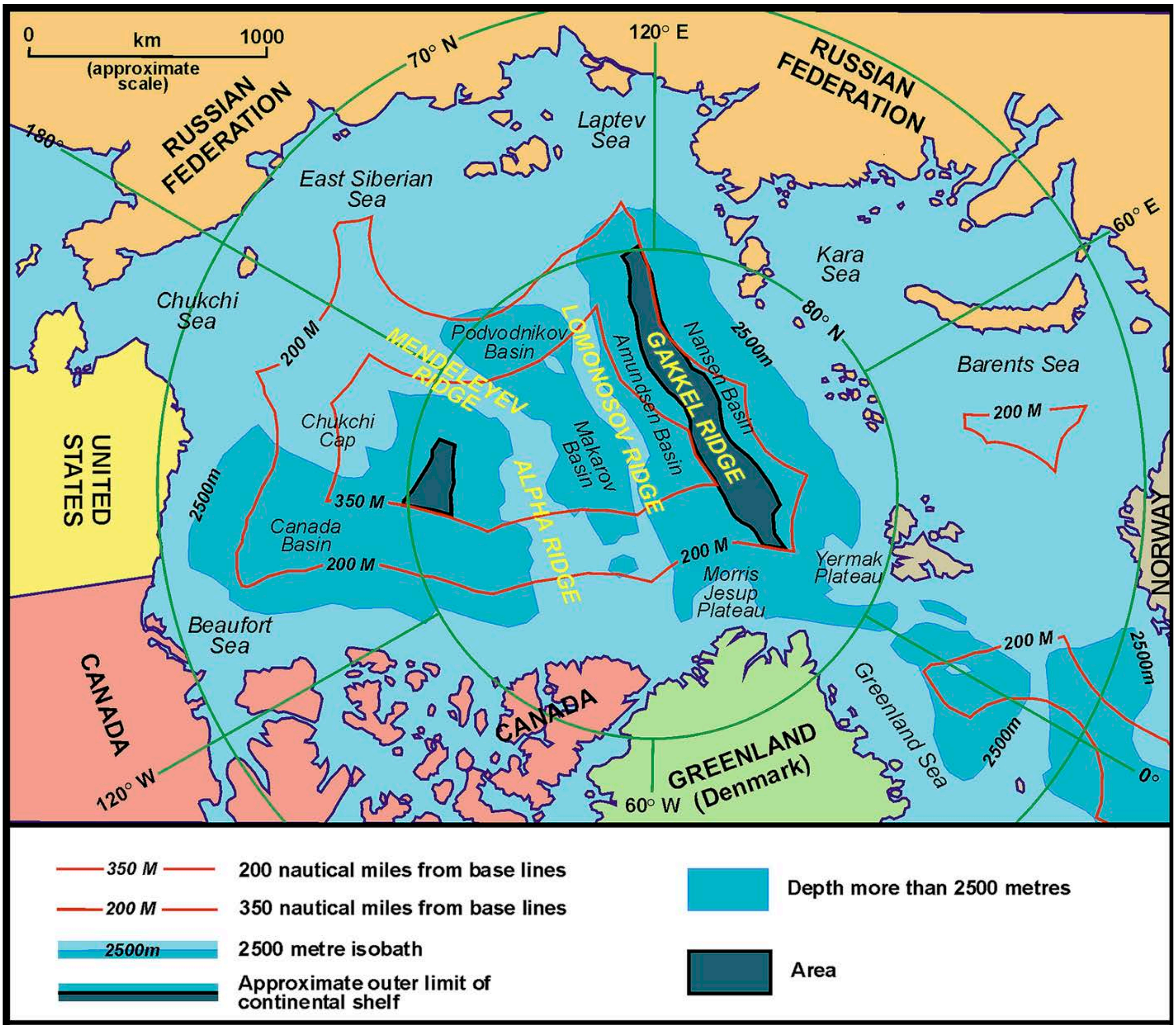

Figure 15 - Territorial claims in the Arctic Ocean. Source: Canada's Offshore: Jurisdiction, Rights and Management 3rd Edition, Association of Canada Lands Surveyors and the Canadian Hydrographic Association.

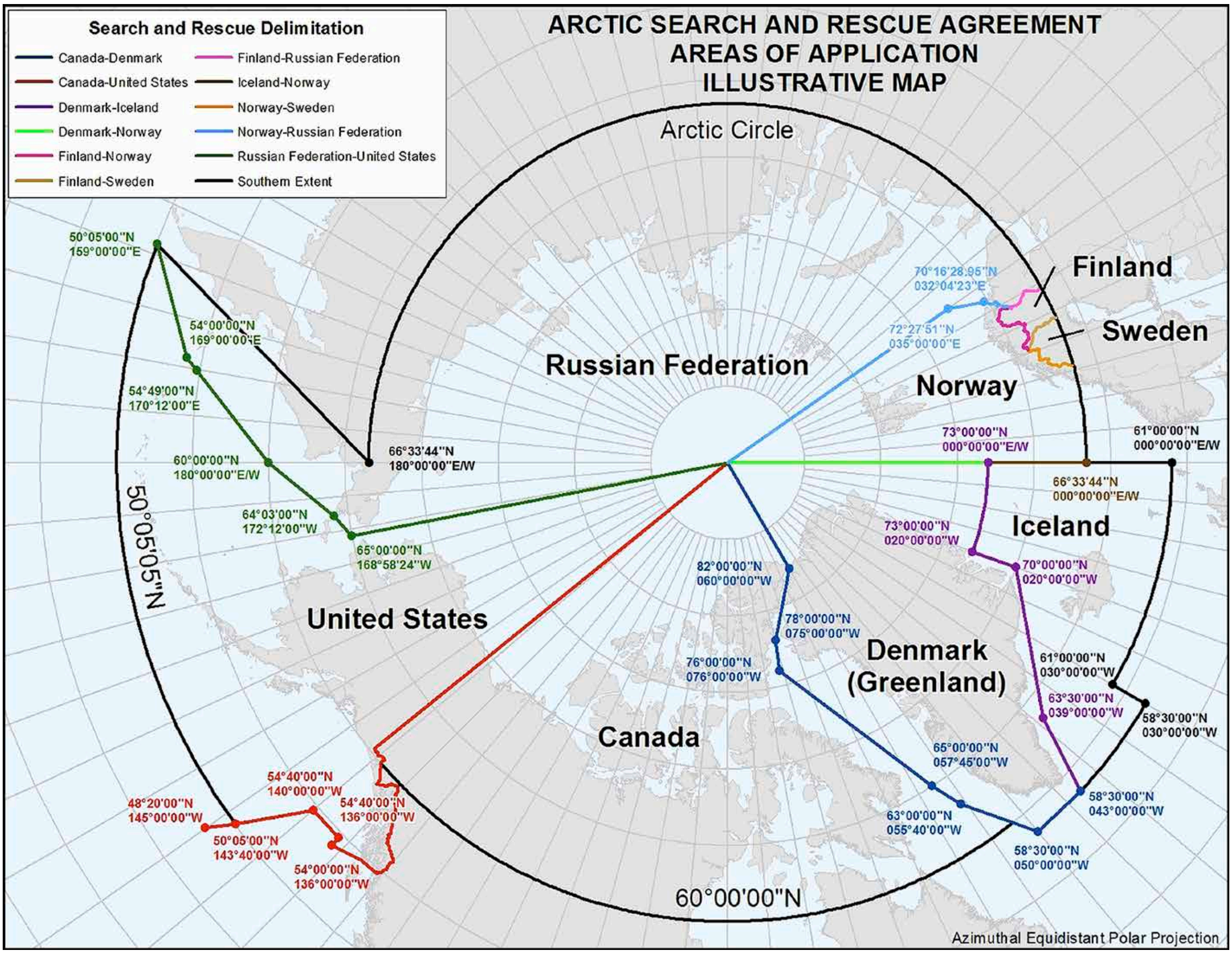

Figure 16 - Search and Rescue Delimitation in the Arctic. Source: Arctic Logistic Information Office.

Recent Accidents on the Northern Sea Route

"*More than 30 vessels damaged in ice compression in 1983; 19 Ships of Far Eastern Shipping Company damaged*" (Marchenko, 2012).

"*The 138 metre long, 6 403 dwt tanker Nordvik was struck by ice while sailing in the Matisen Strait to the north of the Taimyr Peninsula on 4 September 2013. The vessel, which was loaded with diesel fuel, struck an ice floe and started taking on water. Nordvik was built in Bulgaria in 1985.The vessel is sailing towards Murmansk at 4 knots. There is no information on any oil leaks or other damages to the environment*" (Petterson, 2013).

Figure 17 - Nuclear powered icebreaker "Taimyr" escorting the tanker "Nordvik" after an accident. Source: Maritime Executive, 2013. Photo: Timur V. Voronkov.

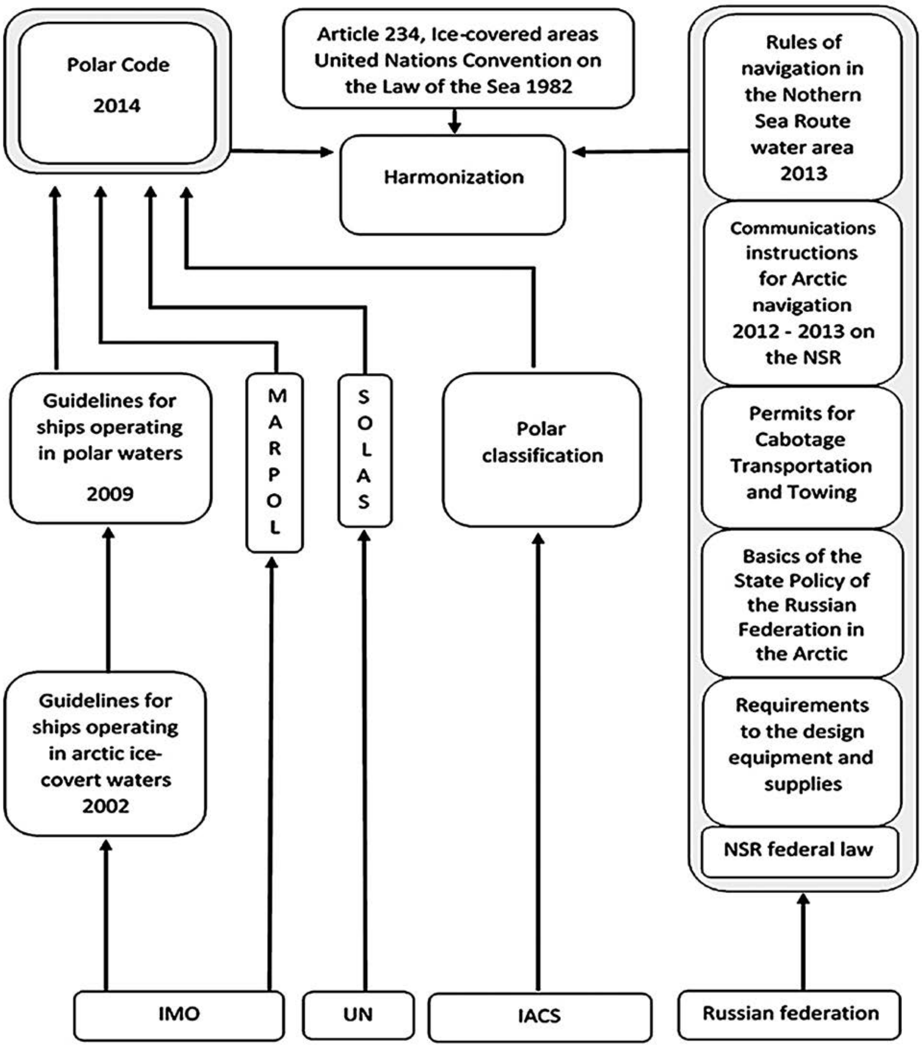

Figure 18 - Overview of existing rules specified and monitored by different authorities. Source: Heinke, 2013.

Review of Existing Rules

Presently many rules and guidelines that are defined and enforced by various institutions in different sea areas coexist (Figure 18). Namely the institutions involved in the rules development are the International Maritime Organization (IMO), the major classification societies and the local administrations of the states.

The classification societies are specifying the technical requirements for the additional strength of the hull and outfitting necessary for operation in ice.

The additional provisions for ice-going ships are specified in ice classes. The International Association of Classification Societies (IACS) has agreed on common polar ice classes. For the polar classes, equivalent classes in different registers are shown in Table 1.

	ICE Class				
RS (Rules 2003)	LU8	LU7	LU6	LU5	LU4
RS (Rules 1995)	-	ULA	-	UL	L1
IACS POLAR	PC2	PC3	PC4	PC5,6	PC7
ASPR, 1995	CAC2	CAC3	CAC4	A	B
ABS	A4	A3	A2	A1	AB
DNV	POLAR-20	POLAR-15	POLAR-10 ICE-15	ICE-10 ICE-1A*	ICE-05 ICE-1A
LR	AC2	AC1.5	AC1	1AS	1A
GL	Arc3	Arc2	Arc1	E4	E3
FSICR	-	-	-	IA Super	IA
BV	-	-	-	IA Super	IA
ClassNK	-	-	-	IA Super	IA
KR	-	-	-	ISS	IS1
CCS	-	-	-	B1*	B1
RINA Italian	-	-	-	1AS	IA

Table 1 - Approximate correspondence table by Central Marine Research and Design Institute.

Review of Maritime Transport Rules and Guidelines

Shortcomings of Existing Rules and Guidelines

Currently a lot of different rules coexist which makes it more complex for shipping companies and also for governing bodies to prepare for future scenarios with increased shipping traffic in the Arctic. The Polar Code is in an introductory process and there are still some open points with respect to solutions for oil spill protection and life-saving appliances for ice-covered areas.

To be applicable, rules and guidelines are often defined for a large number of different ship types and sea areas, and therefore are typically expressed in general terms. Most of the class rules focus on the structural reliability while the manoeuvring capability in ice is not specified to the same extent. Reviewing the accidents on the Northern Sea Route it can be seen that in many cases insufficient propulsion power to manoeuvring capability led to severe accidents. This particularly accounts for potential collision hazards during convoy operation with several ships of different strength and power.

Additional main hazards for future Arctic ship operations include:

- collision with strong ice floes (multi-year ice inclusions)
- navigating into compressed ice zones
- wrong decision navigation, navigation in convoys, damage due to wrong use of propulsion systems
- getting stuck in thick or compressive ice
- collision during convoy operation, grounding in coastal areas
- prolonged emergency response time
- difficult co-ordination of search and rescue operations due to lack of communication capabilities
- deterioration of relevant systems (communication), decrease of ship stability, fuel spills, exhaust emissions and noise , ballast water discharge, local disturbance of ice and ocean conditions
- insufficient manoeuvrability in waves, wave loads, ship motion, capsizing and grounding.

Conclusions

Presuming a further decrease of the average ice extent in the upcoming decades, increasing transit along the northeast and northwest passages can be expected. For the shipping companies, the trend of keeping their fleet flexible for different operation services leads to a scenario of ships with moderate ice classes operating in sub-Arctic regions (e.g. Baltic Sea) in winter periods and in Arctic waters in summer periods. In order to improve and enhance the existing rules for the demands of increased sea traffic in Arctic waters, the main threads and potential hazards are defined.

As some predictions of ice distribution in future decades show more open areas on the upper northern routes (close to the North Pole), it is assumed that ship traffic will tend to increase on these routes. As ships travelling on these routes will be further away from any search and rescue stations, the ships have to be outfitted to provide safe accommodation for a sufficient time in case of an emergency such as a ship getting stuck and drifting in ice-covered waters.

Citations:

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CNIIMF, ABS Technical Papers\Ice Course Materials, Part C.

ACCESS 2nd Summer School

The Royal Swedish Academy of Sciences, Stockholm

The 2014 Summer school was jointly organised by the ACCESS partner, The Beijer Institute of Ecological Economics, and the Arctic Resilience Report (ARR) partner, the Stockholm Resilience Centre. It was hosted at the Royal Swedish Academy of Sciences in Stockholm, Sweden, 22-26 September 2014. It brought together 15 participants from a variety of academic backgrounds and nationalities, mainly Masters' and Doctoral candidates. Its main purpose was to provide a learning opportunity concerning the various aspects of ongoing changes in the Arctic and its resilience. The focus was on climate change in the Arctic, the economic sectors of shipping, tourism, fisheries and aquaculture, oil and gas exploitation, as well as governance. The summer school also provided an important dissemination mechanism for the results and insights from ACCESS research.

The lecture series and the group assignments were designed to maximise the interaction between the students and the researchers. Seven experts from ACCESS and four experts from ARR provided participants with insights into recent developments and presented their views on the emerging opportunities and risks. Lectures started by providing an introduction to the wide context of the rapidly changing Arctic, and the multitude of views and interests at play. Subsequently they focused on specific economic sectors and their interactions, building on the most recent research insights regarding the direct and indirect impacts of climate change in the Arctic Ocean, as well as ongoing efforts to develop syntheses and systemic overviews using tools like marine spatial planning and resilience assessments.

Figure 19 - Student participants in ACCESS 2nd Summer School. Photo courtesy of Aliaksei Patonia.

Building on supplemental work prepared in advance of the summer school, participants worked in thematic groups to interpret and discuss three social-ecological cases studies. These selected case studies are specific examples of changing Arctic conditions, linking the climate, ecologic, economic and other social dimensions. The case studies are: the Shtokman Natural Gas Development; Metal Mining in Northern Finland; and Arctic Shipping in the Bering Strait and the Resilience of Local Hunting Communities. The students presented their insights from this work. Discussions with the experts taking part in the ACCESS synthesis workshop provided additional opportunities for understanding cross-sectoral interactions in the Arctic. As tangible products from these activities, the summer school participants generated contributions for the ARR case studies database, and the brief reports presented here.

Shtokman Natural Gas Development – Drivers and Potential Consequences

Aliaksei Patonia, MSc. student - International Management at University of Liverpool, United Kingdom; Dries Stevens, MSc. student - Globalization, Environment, and Social at University of Stockholm, Sweden; Christopher Cosgrove, MSc. student - Physical Geography at University of Uppsala, Sweden

The Shtokman field is one of the world's largest deposits of natural gas and condensates. Discovered in 1981 and named after the Russian geo-physicist who first identified the field, its estimated 4 trillion cubic metres of resources are on the Arctic shelf in the Barents Sea, 550 km north of the coast (Figure 20). The giant energy companies, Gazprom, Total and Statoil, signed an agreement in 2007 to co-operatively develop the field as advances in offshore production technology and high gas prices made it viable for the first time. However in 2008, the first year of the initial project phase, the shale gas revolution in North America led the investors to defer development. The plan for Shtokman field exploitation and the continued postponement due to suppressed gas prices formed the subject of our ACCESS and ARR Summer School case study.

Focusing on the implications of as yet unrealised potential development, and using a regime shift lens, we examined the effects of the planning phases, subsequent withdrawal of investment and likely future impacts, and/or regime shifts should the Shtokman project start in earnest again. We considered both local and regional dimensions, including onshore gas liquefaction plants, and an extension to the Nordstream gas pipeline from St. Petersburg to Murmansk and onto Teriberka, the small village where the project's onshore facilities are planned to be located.

Since its establishment in the 1600s, Teriberka has shown previous adaptive capacity, changing economically in response to external market pressures. Traditionally a reindeer herding and coastal fishing community, during the Soviet Union era Teriberka was transformed by the collectivisation and nationalisation efforts of the government. First, it became a main hub for the fishing industry in the Barents Sea, and later, an important location for the Russian Navy following the construction of a shipyard. After the dissolution of the Soviet Union, Teriberka had been in persistent decline, victim of increasing net emigration, unemployment, transport isolation, infrastructure degradation and decayed conditions. The initial agreement to develop the Shtokman field promised a new surge of investment and the villagers of Teriberka could be forgiven for believing that they were on the cusp of a regime shift to better economic times. However, visible social responsibility projects, such as a new school, which were started by the energy companies, now lie incomplete and the air of a ghost-town pervades.

We consider the environment of uncertainty surrounding whether or when the Shtokman project will go ahead as an example of psychological stress upon a system and its inhabitants - a concept we believe is little explored in resilience studies. The proposed job opportunities and industrial development of Teriberka would re-orientate large parts of its social and ecological fabric. So how do villagers and local indigenous people, who had believed in such a change, now feel about the precarity of their existence? Despite the biggest physical disturbance not yet being realised, does the resumption of a slow social erosion show that a regime shift has already occurred in expectations? Can you legislate to give people protection against such scenarios?

The Shtokman project and its effect on Teriberka has parallels throughout the Arctic, and we believe its detailed study would reveal rich insight into how even early stage resource exploration can disturb existing socio-economic systems. Its current aftermath, from a more regional perspective, could be an enlightening example of resilience planning too.

As even the Russian government now confirms that the Shtokman project has ceased to be of primary importance for the energy sector, regional authorities in the wider Murmansk area have begun to consider alternative investments that could enliven the local economy. Tapping what is believed to be a rich wind resource area, offshore wind power developments would imply a switch to renewable energy which might well be lauded for its green credentials. But could also be seen as providing a temporary infrastructure base until the time comes when the economics of gas extraction are more viable. Should wind power development be realised, the area's adaptive capacity would undoubtedly increase, and although investments will not match the level of the Shtokman project, economic opportunities would probably improve for many of the local people. However for the fauna of sensitive Arctic ecosystems and the few people that still practice traditional livelihoods, wind power developments would also bring high-voltage power lines that fragment their landscape in much the same way as a pipeline would.

Figure 20 - Projected gas pipelines and liquefied natural gas supplies for Russian domestic use and Atlantic basin markets. Source: Gazprom, www.gazprom.com/about/production/projects/deposits/shp.

Metal Mining in Northern Finland

Adrian Braun, PhD candidate - Sustainable Development Research Group, Arctic Centre, University of Lapland, Finland ; Melanie Flynn, MSc student - Environment and Human Security at United Nations University and University of Bonn, Germany ; Enoil de Souza Júnior, MSc student - Centro Polar e Climático, Instituto de Geociências, Universidade Federal do Rio Grande do Sul, Brazil

There are rich deposits of precious and base metals in northern Finland, including gold, nickel, chrome, iron, zinc and copper. Mining corporations have set up operations to extract these valuable raw materials to sell them on global markets. The focus of this report is on mining in the Finnish part of the Barents Region, namely the Finnish Lapland, Northern Ostrobothnia and Kainuu areas.

Metal mining can impact social and ecological systems at local, regional and even global scales. These impacts affect the resilience of sensitive Arctic systems. Adequate evaluation of these impacts and identification of feedback loops is essential to ensure that ecosystems do not reach adverse tipping points.

The ecosystems in northern Finland are comprised of vulnerable boreal forests and wetlands which can be easily affected by metal mines. There is a clear link between mining operations and potential environmental impacts. Possible negative environmental impacts due to mining operations span a wide range; some of the most significant include: water and soil pollution; destruction of landscapes; increased greenhouse gas (GHG) emissions; loss of biodiversity and deforestation; and negative effects on habitats through noise and vibrations. Open-pit mines, in particular, have severe and long-term impacts on the environment, which are often irreversible.

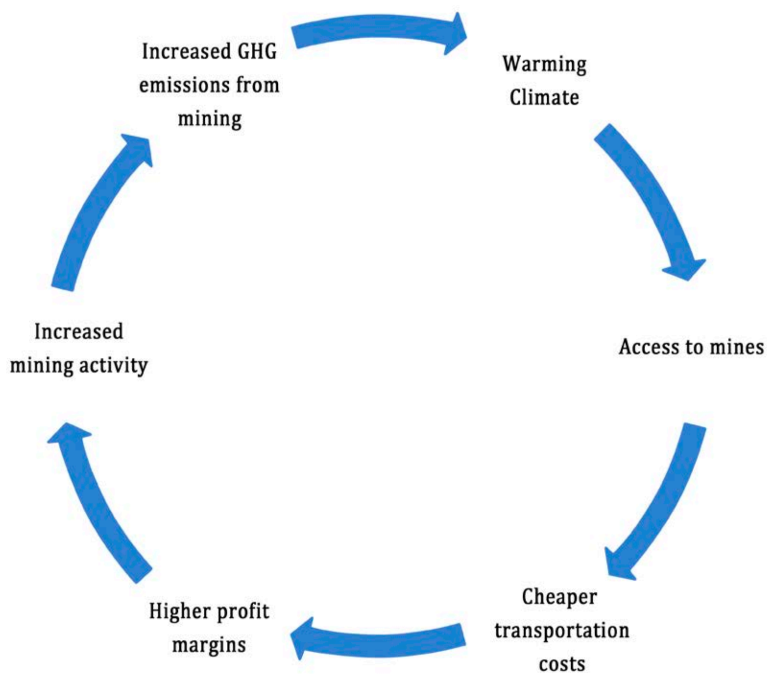

Figure 21 - Positive feedback loop between mining activities and warming climate through increased GHG emissions.

The primary geophysical driver with respect to increased mining in northern Finland is climate change, which may cause a number of positive feedback loops. A warming climate may result in shorter winter periods, subsequently to lowering the costs for metals extraction. Simarily, a considerable amount of the metal production will be transported via Norwegian ports on the Barents Sea. Climate change may open new sea routes in the Arctic Ocean, while existing routes may be accessible for longer periods due to sea-ice reduction. Such shifts would allow the mining companies to get metals production to markets with lower costs and in a more time-efficient manner, resulting in higher profit margins. Consequently, GHG emissions could increase due to increasing mining and transportation activities, thereby reinforcing climate change effects (Figure 21).

A variety of direct and indirect actors are involved with mining activities in northern Finland including: mining corporations, public authorities, employees, local communities, indigenous people (Saami people in Finnish Lapland), investors, NGOs, tourists and scientists. The livelihoods of indigenous people and local communities in this region strongly depend on reindeer herding and tourism, which can be enormously affected by environmental disturbances caused by mining operations. Many tourists want to visit the Finnish Arctic to enjoy the natural environment and remoteness of the region. Tourists expect to experience a natural and healthy ecosystem. Mining does not often fit into this picture. Importantly, reindeer herding requires large areas of pasture, which are being increasingly fragmented through mining and other economic activities. Yet, metal mining has a long tradition in northern Finland and plays a key role in the economic well-being of many local communities by providing employment opportunities and increasing prosperity.

In the coming years, it will be interesting to see to what extent mining corporations will build adaptive capacities linked to technological advances in equipment and practices. This might allow for more eco-friendly extraction of raw materials and better safety with automation of dangerous tasks by robotic systems. On the other hand, such automation may cause job losses that can disrupt economic and social dimensions in the towns and villages in the area of a mine.

Today metal mining remains a significant pillar of Finland's economy. Global demand for metals is high and the ore output of Finnish mines has quadrupled since 2008 (Geological Survey of Finland). The effects of climate change may favour increased mining of the resources in northern Finland and the Arctic. Mining in Finland, as well as globally, is often a controversial issue. There are positive aspects, such as the economic benefits, that need to be weighed with the potential negative impacts for ecosystems and possibly for local communities; and the possibility that this delicate balance is disrupted, for example, if an accident can irreversibly alter the state of local systems, such as drinking water contamination, further complicates assessments.

Arctic Shipping in the Bering Strait and the Resilience of Local Hunting Communities

Elin Högström, PhD candidate - Vienna University of Technology, Austria; Katrin Lindback, PhD candidate - Uppsala University, Sweden; Shealagh Pope, Acting Director at the Arctic Science Policy Integration Directorate, Canada

The Bering Strait is recognised for its globally significant marine, avian and coastal biological diversity. It has been designated as one of the most sensitive biological areas in the Arctic by the International Union for the Conservation of Nature. This narrow strait is an essential part of the migration route for the bowhead whale, when moving between its summer and winter habitats. It is also the home of indigenous communities that depend on the marine life through hunting and fishing.

The Arctic sea-ice has been observed to diminish in extent and thickness in response to climate change, notably so for multi-year ice (Niebauer, 1998). This has implications for animals and micro-organisms through effects on their habitat and on the migration routes of mammals, such as whales. In addition, shipping activity in the Arctic is increasing. There is a transition in shipping activity from experimental to more routine use of the Northern Sea Route (Brigham, 2010; Humpert and Raspotnik, 2012). The three main shipping routes (Northwest Passage, Northern Sea Route, and Transpolar Sea Route) across the Arctic Ocean all pass through the Bering Strait. In 2014, 275 ships passed through the Bering Strait during the six ice-free months. The sea-ice decrease, in combination with technological developments, makes it likely that vessel traffic through the Bering and Anadyr Straits will increase in the future linked to economic activities related to natural resource developments in the Arctic.

Studies from comparable situations in Alaska show that whales seem to aggregate in the shipping lanes, which in turn leads to increased ship strikes and injuries or death of whales (Silber, et al., 2012). These biophysical (sea-ice) and socio-economic (shipping) changes and developments are drivers that may cause damage to the ecosystem. This in turn may have negative effects on the local indigenous communities which depend on hunting and fishing. Figure 22, part A, illustrates these cause and effect in the form of a socio-ecological system. Drivers of change to the system in this case include: climate change (sea-ice decrease), habitat changes (whale migration), cultural changes (hunting techniques), industrial interests (offshore developments), technological advances (shipping, engineering structures for oil and gas), economic interests (fuel price), politics and globalisation.

For successful adaptation a system and holistic view is necessary to address the multiple inter-acting factors so that the system can absorb disturbances and adjust to new equilibriums. Partial solutions, for example changes in shipping policy, require action and agreements at global as well as local scales. Figure 23 lists the main actors identified for this case and the level on which they act. Figure 22, part C, illustrates the interaction / role of policy in this case.

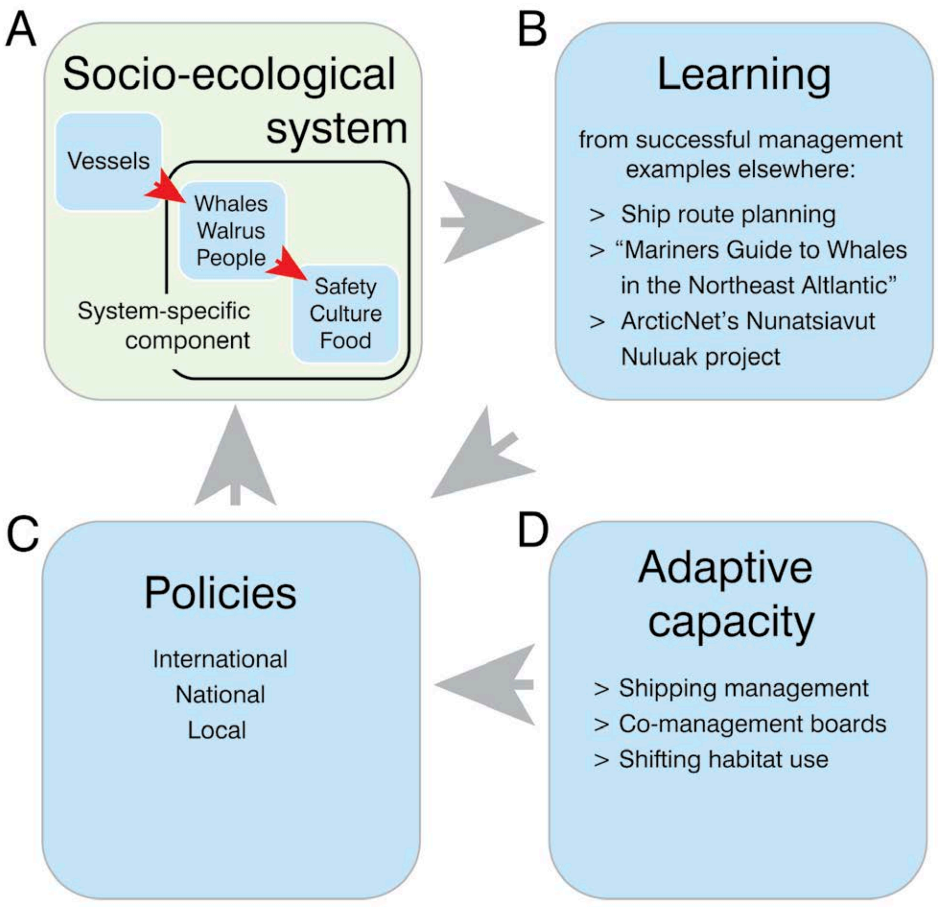

Figure 22 - Conceptual framework for the Shipping in the Bering Strait case study in the context of adaptation and resilience. Adapted from the Arctic Resilience Interim Report, Arctic Council 2013.

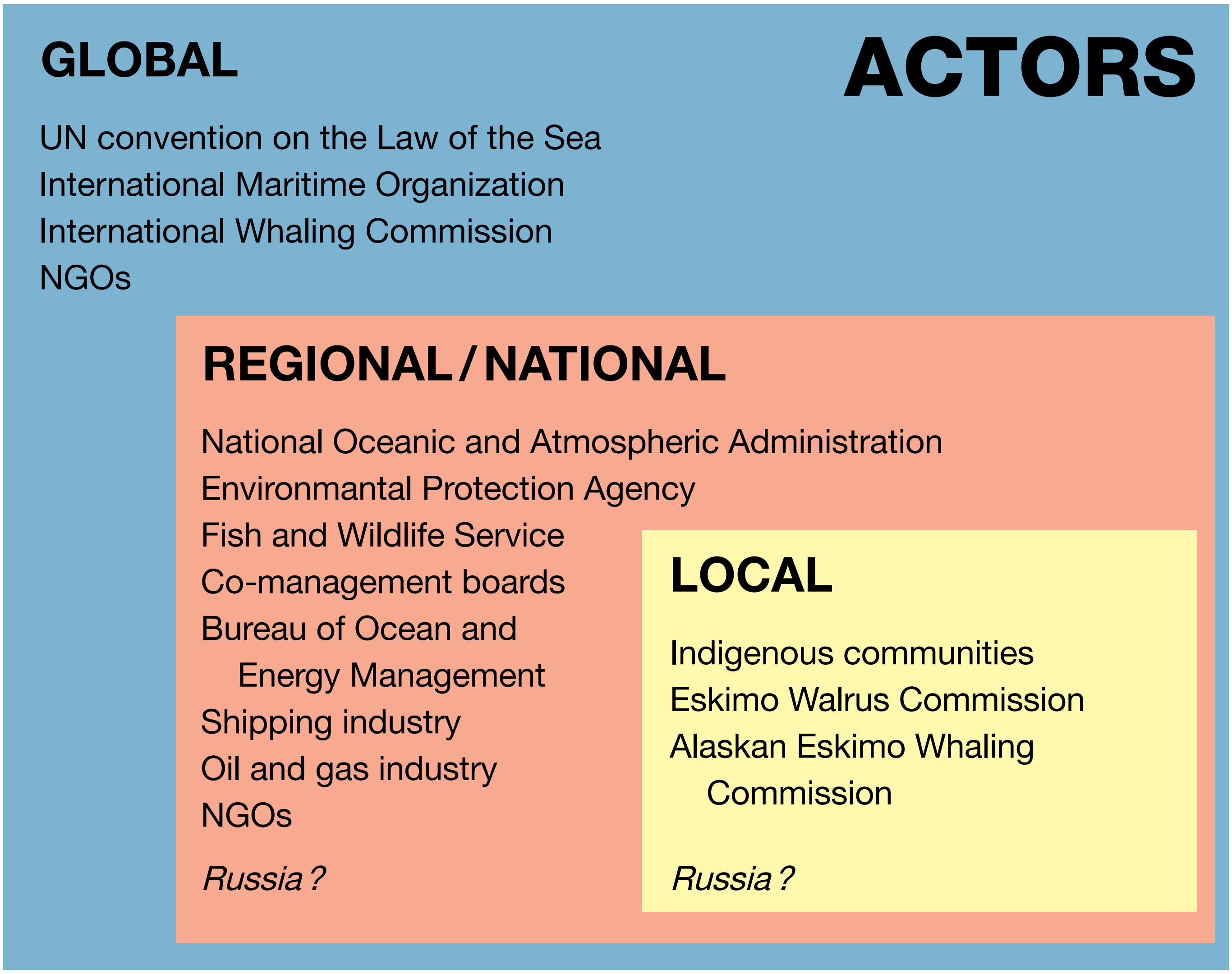

Figure 23 - Main actors relevant for the Shipping in the Bering Strait case study and the levels they act upon. (Note that the corresponding information about national actors in Russia was not investigated, mainly due to the limited time of this exercise in the summer school and language limitations.)

It is not unusual that adaptive and restoration actions are taken in response to a crisis. In the case of shipping in the biologically sensitive Bering Strait, it is possible to also take a preventative approach besides reacting to observed problems. Lessons learned from other area and applying that knowledge and experience in the Bering Strait can be beneficial. Actions to be implemented to protect whales from impacts with ships have been defined and could be applied, for example the "Mariner's Guide to Whales in the Northwest Atlantic".[2] There are successful management examples regarding ship routing from other areas. In the Roseway Basin – an important socialisation and feeding area for right whales about 30 nautical miles south of Nova Scotia – was designated an "Area To Be Avoided", which substantially diminished shipping in the area (Silber, et al., 2012). Building on traditional knowledge in innovative ways which work to actively integrate the local population with research projects where the outcome can be equally useful for both parties. The ArcticNet's Nunatsiavut Nuluak project and the development of the Smart-ICE (Sea-ice Monitoring and Real-Time Information for Coastal Environments) adaptation tool is an example, which addresses Inuit concerns about the impacts of climate change and modernisation on communities and ecosystems in Northern Labrador. In such projects, the scientific and indigenous communities seem to have found an approach to work together in mutually beneficial and respectful way.

2 - *www.romm.ca/documents/MarinersGuide9782981373946.pdf*

Citations:

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Humpert, M. and Raspotnik, A., 2012, The Future of Arctic Shipping, Port Technology International (55), October, 10–11, *www.porttechnology.org*.

Common Impacts of Mining, Natural Gas Extraction and Shipping Activities in the Arctic

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The Arctic region is currently transforming under the influence of climate change. Higher temperatures and decreasing sea-ice cover lead to new opportunities for commercial activities, but it also affects the indigenous way of living. In this context, three cases of new commercial activities in the Arctic were analysed at the ACCESS and ARR Summer School in Stockholm in September 2014. Three groups discussed "Mineral mining in Finland", "International shipping in the Bering Strait" and "Gas extraction in the South Barents Sea". The purpose of the fourth group was to find the links, which exist between these case studies, to enable a broader discussion of potential common solutions to the emerging problems. The synthesis of this effort is presented in Figure 24.

We started the analysis by identifying one common driver, which explains the presence of these activities in the Arctic despite the difficult working conditions and the missing infrastructure. This common driver is economic development and global growth. The fast economic growth of the last century is closely related to the emissions of greenhouse gases and to an increasing demand for natural resources. Emissions of greenhouse gases has led, through an increase of global mean temperature, to a partial retreat of the sea-ice cover, enabling natural gas extraction and shipping activities in the Arctic Ocean, and to an increasing demand for renewable energies, for which some of the minerals mined in Finland are used. Increasing demand for natural resources has led to depleting sources and therefore has increased the demand for new extraction sites. Large reserves of hydrocarbons are expected to be found beneath the Arctic Ocean floor.

Similarly, and as the Finland mining case exemplifies, the increasing demand for natural resources has driven the search for new extraction sites. The increase in demand for minerals and rare earth elements led to the establishment of an open mine in Finnish Lapland, despite the difficult climatic conditions.

Once the main common drivers had been defined, we looked in more detail at the common consequences. We defined six domains of consequences which are common to at least two of the three cases:

Disturbance in animal habitat and migration paths

The building of infrastructure through less populated areas does not necessarily mean that it has no impact. Reindeer herding is an important sector in north Scandinavia and north Russia. The farmers migrate every year with their reindeer over large distances. Pipelines coming from the gas extraction sites or mining facilities can be an obstacle to that essential yearly movement. In the Bering Strait, the marine animal population can be disturbed by an increase in ship traffic. Particularly, whales can be disturbed by the increased noise, changing their usual behaviour and altering their migration paths.

Changes in fishing grounds

Shipping and natural gas extraction also affect the behaviour of fish. Dispersion of fish stocks is a probable consequence. This would have a significant impact on local human populations as well as on commercial fishing.

Pollution risk

Ships also release high amounts of waste and pollutants during their travel, threatening the unique Arctic ecosystem. Moreover, the risk of an accident, leading to an oil spill should be taken into account. Gas extraction also leads to a potential risk as gas leakage can result in explosions. Mineral extraction can contaminate surrounding water threatening the quality of living of the local population and the biosphere.

Change in climatic conditions

Another common point to these cases is the change in climatic conditions that made them possible in the first place. Natural gas extraction in the Barents Sea and shipping through the Bering Strait would not be possible if the sea-ice had not retreated from those areas. Also, warming temperatures make working conditions easier in north Finland, providing the opportunity to start mining there.

Social impacts on indigenous livelihoods

Starting commercial activities that need huge infrastructure in areas with low population levels has impacted local livelihoods through changes in the landscape, as well as population size and composition. Mining in Finland seems to have more positive impacts, as it provides working opportunities and better infrastructure in a region where reindeer herding dominates. The two other cases are rather disturbing for the local population. In north Russia, pipelines limit movements and land is used by the gas extracting firms to build onshore platforms, in addition to the offshore platforms. Ships, by disturbing the behaviour of marine animals, force indigenous people to devote longer periods searching for their prey, to change their hunting habits and increase the risk of accidents between small umiaks (open boat made of stretched skins) and commercial ships.

Influence of the global market

Another common influence also describes one of the reason those projects started in the first place. If the minerals were not in a context of low competitive prices, their extraction would not be lucrative. Also the price for natural gas increases demand and therefore makes the gas extraction in the Arctic profitable.

As a conclusion, there are several common factors influencing the formation of these commercial activities in the Arctic region, as well as several common consequences. Most of these consequences should be taken into account and solved prior to further development of similar activities in the region. Local indigenous population and the local biosphere are most affected from those impacts.

Common Impacts of Mining, Natural Gas Extraction and Shipping Activities in the Arctic

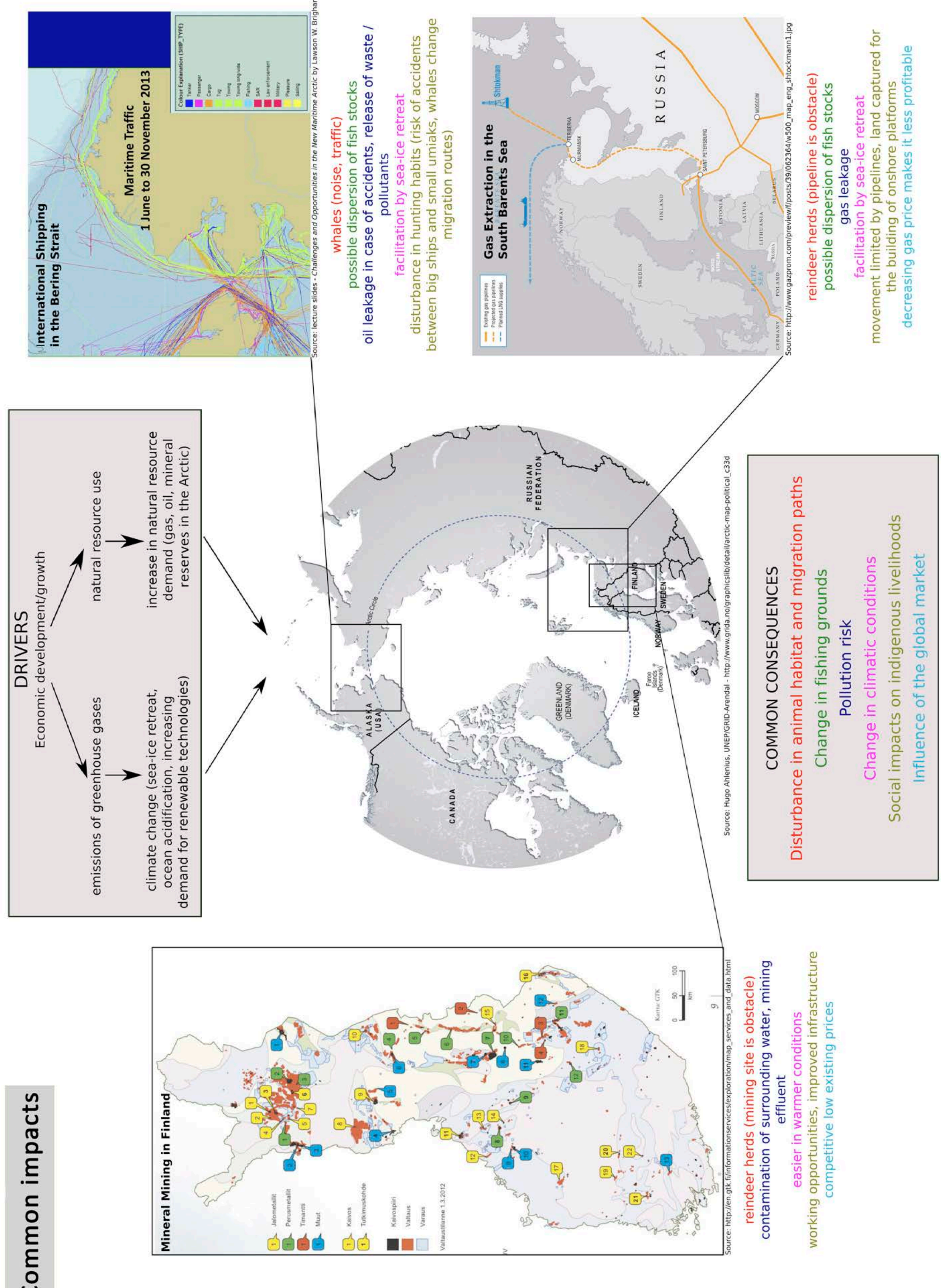

Figure 24 - Common Impacts

Upcoming Meetings of Note

24 – 26 February, 2015

ACCESS General Assembly. Universitat Politècnica de Catalunya in Vilanova, Spain

More information: *http://www.access-eu.org*

15 - 20 March 2015

2015 Polar Marine Science Gordon Research Conference. Lucca, Italy

The 2015 Polar Marine Science Gordon Research Conference (GRC) entitled "*Polar Shelves and Shelf Break Exchange in Times of Rapid Climate Warming*" will be held in Lucca, Italy. The GRCs provide an international forum for the presentation and discussion of frontier research in the biological, chemical, and physical sciences, and their related technologies.

More information: *http://www.grc.org/programs.aspx?id=12641*

23 – 27 March 2015

Dynamics of Atmosphere-Ice-Ocean Interactions in the High-Latitudes. Rosendal, Norway

The goal of the workshop is to summarise fundamental understanding and description of small-scale processes in the coupled atmosphere-ocean-ice climate system at high latitudes in order to assess and reduce bias and uncertainties in weather prediction and climate models.More information: *http://highlatdynamics.b.uib.no/*

23 – 30 April 2015

Arctic Science Summit Week (ASSW) 2015. Toyama International Conference Center, Toyama, Japan

The ASSW will include the final International Conference on Arctic Research Planning (ICARP III Conference and 4th International Symposium on Arctic Research (ISAR-4). The ICARP III aims to: identify Arctic science priorities for the next decade; co-ordinate various Arctic research agendas; inform policy makers, people who live in or near the Arctic and the global community; and to build constructive relationships between producers and users of knowledge.

More information:
http://icarp.iasc.info/images/articles/downloads/IASC_ProgressSpring_2014

29 - 30 May 2015

EU-Arctic Conference. University of Dundee, Scotland.

This conference will bring together academics and practitioners from disciplines such as international law, international relations, political science and marine biology, NGOs, representatives from EU institutions and international organisations to discuss the EU's potential contribution to enhance Arctic governance.

More information: *www.dundee.ac.uk/law/events/details/call-for-papers--the-european-union-and-the-arctic-2015-eu-arctic-conference.php*

2 - 5 June 2015

Ilulissat Climate Days. Ilullisat, Greenland.

The Ilulissat Climate Days will address recent, ongoing and future changes in the ice in and around Greenland, with a special focus on the effects for the Greenland society.

More information: *www.polar.dtu.dk/english/Ilulissat-Climate-Days*

10 June 2015

Ocean and Climate Platform. UNESCO, Paris, France.

The Ocean and Climate Platform will be launched at a press conference at the United Nations Educational, Scientific and Cultural Organization (UNESCO) in Paris. The platform aims to bring together the scientific community and civil society to place the ocean at the centre of the international climate change debate. This event is linked to the 8 June 2015 celebration of World Ocean Day.

More information: *www.unesco.org/Ocean and Climate Platform; http://worldoceansday.org/; http://www.theoceanproject.org/*

7 - 10 July 2015

Our Common Future under Climate Change conference. UNESCO, Paris, France.

Building on the results of the Intergovernmental Panel on Climate Change 5th Assessment Report, the conference will address key climate change issues and offer an opportunity for the scientific community to discuss solutions for both mitigation and adaptation issues. The conference will also welcome side-events organised by stakeholders.

More information: *http://www.commonfuture-paris2015.org/*

30 November – 11 December 2015

United Nations Framework Convention on Climate Change (UNFCCC). Conference of the Parties 21st Session. Le Bourget, France.

The aim of the 2015 conference is to adopt an international agreement on climate applicable to all parties of the UNFCCC that will set the framework for a transition towards resilient, low-carbon societies and economies.

More information: *www.cop21.gouv.fr/fr*

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