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ACCESS NEWSLETTER

Arctic Climate Change
Economy and Society

Issue No. 8
April 2014

ACCESS Highlights

Killer whale (Orcinus orca) spyhoping in Northern Norway

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

For the current newsletter N°8 we selected contributions dealing with shipping along the Northern Sea Route (NSR) and potential pollution that could impact the atmosphere and ocean. Aiming at the increasing shipping traffic along the NSR, ACCESS partners are estimating the impacts from various pollutants and their significance on the pristine Arctic environment. These include air pollution from ship emissions, black carbon deposition on snow and sea-ice and ocean disturbances from ship noise, which impact the life of marine mammals. A major outcome from these analyses is that while emissions from shipping will be the highest in summer, maximum impact is expected to occur in spring. This is important since ACCESS has already revealed earlier sea-ice break up in recent years related to a decrease in winter atmospheric cooling (see ACCESS Newsletter 6). Another major topic is oil spills in an ice-covered ocean. Lab experiments and modeling are some of the main tools used by the ACCESS consortium to deal with these important issues as explained in this ACCESS newsletter. In addition, ACCESS has developed two policy briefs on oil spill under sea-ice and air pollution from ship emissions (*in preparation*), respectively. Both are available for download from the project website (www.access-eu.org).

The ACCESS project is beginning its last year. Three major workshops will be organized in the remainder of 2014. The first workshop will be held in Villefranche-sur-Mer, France, early June (2nd-3rd). The workshop will be dedicated to the integration of the climate change and environmental aspects in the Arctic into the synthesis of the project, dealing with the impacts on marine transportation, oil and gas extraction, fisheries and governance. The second workshop will be held in Paris, late June (23rd-25th) and will focus on indigenous people around the Arctic, as they are affected by climate change, the changes in commercial sectors and how they deal with the challenges that those changes bring. The third workshop will be held in Stockholm, September (22nd-26th) and back to back with a summer school dedicated to the ACCESS synthesis and scenarios. Each workshop will be the focus of one forthcoming ACCESS newsletter: Newsletter NL 9 in June 2014, NL 10 in October 2014 and NL 11 in January 2015.

ACCESS editorial board

Cross-sectoral results

Shipping and resources extraction in Arctic waters. Risks and impacts.

Climate impacts of global and arctic shipping

Center for International and Environmental Research (CICERO)

Within the scope of the ACCESS project, Dalsøren et al. (2013) estimated climate impacts of global and Arctic shipping in 2030, with a particular focus on different scenarios for soot (black carbon) emissions, of which maritime transportation is among the most important Arctic sources. Using global models, the focus was on short-lived climate forcers (SLCFs) (black carbon, ozone, sulphate, methane and organic aerosols) [1].

Depending on emissions distribution, the net impact of the SLCFs on the climate might be a warming or a cooling. The net impact of SLCFs emitted from present day shipping is a cooling both globally and in the Arctic (Figure 1: blue bars - Ødemark, et al. 2012). Large sulphur emissions result in net negative radiative forcing (cooling) from shipping. In contrast, higher black carbon (BC) emissions and small sulphur emissions result in net positive radiative forcing (warming) from Arctic petroleum field activities (Figure 1: red bars).

1- The three-dimensional chemistry transport *osloctm2 model* and a state of the art radiative forcing model are used, applying coherent datasets of current and future arctic emissions.

Two datasets for ship emissions into the atmosphere were used in Dalsøren et al. (2013) to study the climatic impacts of increasing shipping activities in2030:

1) a high growth scenario, and

2) a low growth scenario with maximum feasible reduction (MFR) of black carbon emissions.

Both scenarios result in moderate to substantial increases in pollutant concentrations both globally and in the Arctic. Exceptions are black carbon in the MFR scenario, and sulphur species and organic carbon in both scenarios due to the future phase-in of current regulation that reduces fuel sulphur content (International Maritime Organization (IMO) regulations effective in 2020).

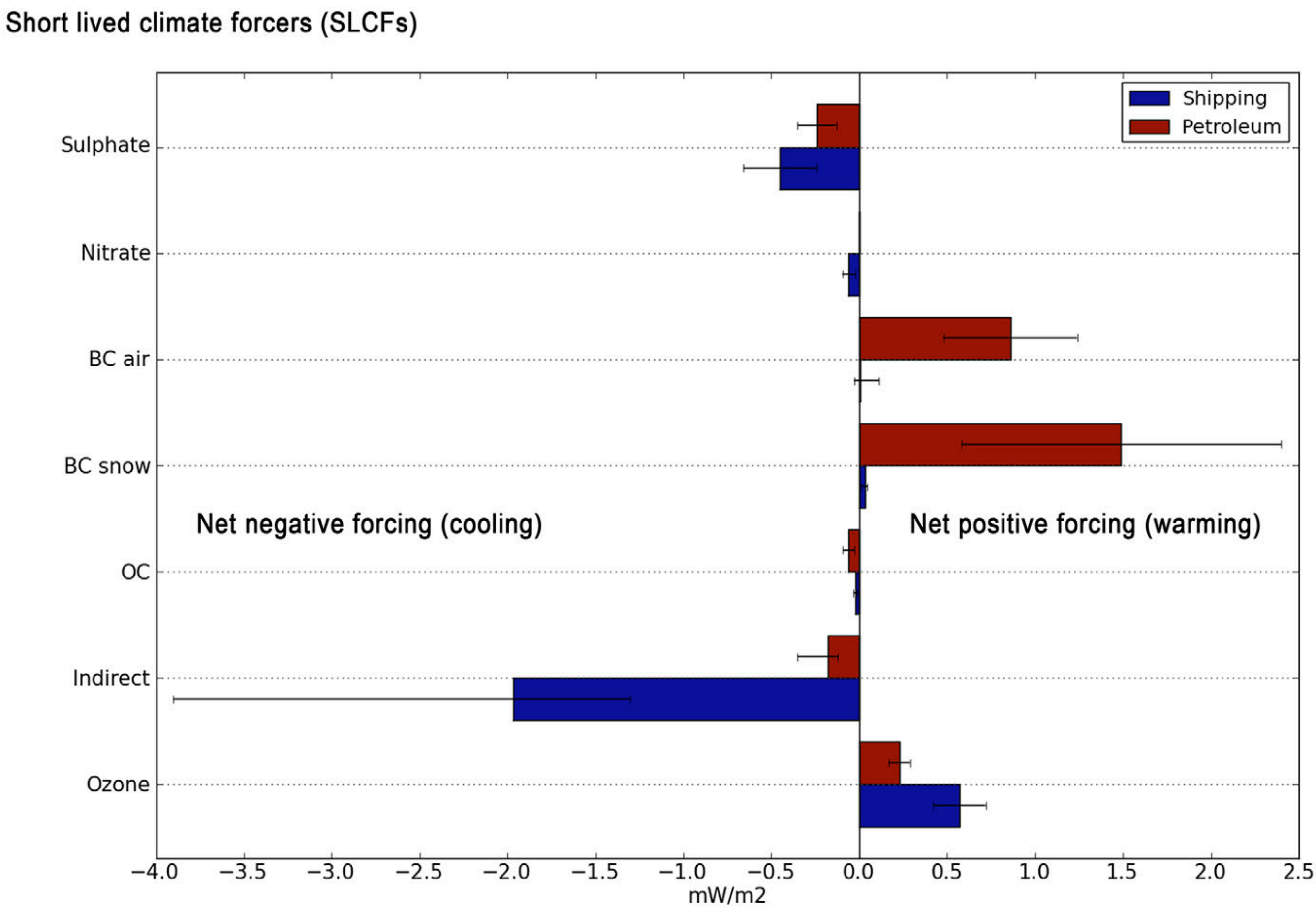


Figure 1 - Average global annual radiative forcing [mWm−2] for the different short-lived climate forcers (SLCFs) from present day Arctic shipping and petroleum activities (oil and gas production) emissions (Ødemark et al. 2012).

The analysis indicates that an increase in Arctic maritime transport activity between 2004 and 2030 combined with reduced sulphur emissions from ships will contribute to Arctic and global warming, mainly due to a reduced cooling effect of sulphate aerosols and clouds. While emissions from shipping will be the highest in summer and early autumn, maximum impact is expected to be observed in spring-early summer. This coincides with the melting season, thus making it essential to consider how shipping may accelerate future sea-ice and snow cover melt in the Arctic.

Implications

So far, shipping emissions primarily contributes to cooling. Large amounts of sulphur dioxide (SO_2) are released into the atmosphere, which contribute to the formation of sulphate particles and clouds and produce a cooling effect. However, these SO_2 emissions have a negative influence on air quality. Ports and shipping lanes with unregulated shipping fuel use are well known to have high air pollution levels. Consequently, new worldwide regulations are being implemented by the IMO to reduce the sulphur content of fuel used in shipping. These measures will come into force in 2020 (IMO Annex VI).

This study points out that the phasing-in of the IMO regulations on sulphur would be effective in reducing particle pollution in the Arctic as well as on a global level. The trade-off, however, is that reduction of sulphur emissions leads to warming. Though, in a global context, black carbon emissions from shipping are small, the study points out an important contribution from black carbon to Arctic ice reduction in 2030 : Black carbon deposition on snow and ice efficiently absorbs solar radiation and warms the surface, which accelerates the snow-melting process in spring. The climate impact of black carbon in the Arctic is approximately 60 % lower in the MFR scenario than in the high growth scenario.

Citations :

Dalsøren, Stig B., Bjørn Hallvard Samset, Gunnar Myhre, James J. Corbett, Ray Minjares, Daniel Lack and Jan S. Fuglestvedt, 2013. "*Environmental impacts of shipping in 2030 with a particular focus on the Arctic region.*" Atmospheric Chemistry And Physics, 13 (4): pp. 1941-1955.

Ødemark, Karianne, Stig B. Dalsøren, Bjørn Hallvard Samset, Terje Berntsen, Jan S. Fuglestvedt and Gunnar Myhre, 2012. "*Short-lived climate forcers from current shipping and petroleum activities in the Arctic.*" Atmospheric Chemistry And Physics, 12 (4): pp. 1979-1993.

Iceroute Programme

The Hamburgische Schiffbau-Versuchsanstalt GmbH (HSVA)

Within the EU ACCESS project [1], HSVA (Hamburgische Schiffbau-Versuchsanstalt GmbH, Hamburg Ship Model Basin Ltd.) has carried out travel time simulations in Arctic waters for various ice scenarios. These scenarios are based on ice data for the period 2000 to 2007, using the ICEROUTE program, which was developed in previous research projects. Originally, ICEROUTE was planned to simulate the travel time for different merchant ships along the Northern Sea Route (NSR) and the North West Passage (NWP) [1]. However, during the course of this project, due to the lack of reliable ice data for the North West Passage, the investigations were reoriented mostly towards transit simulation on the Northern Sea Route (read page 6).

1- Arctic main shipping routes are: The North East Passage (NEP) along the coasts of Norway, Russia and Alaska and the North West Passage (NWP) along the coast of Canada and Alaska. The Russian section of the NEP is called the Northern Sea Route (NSR). (Source: EU ARCTIC IMPACT ASSESSMENT, "Changes in Arctic Maritime Transport", Rovaniemi, 2013).

Description of HSVA Program Ice Route

General description

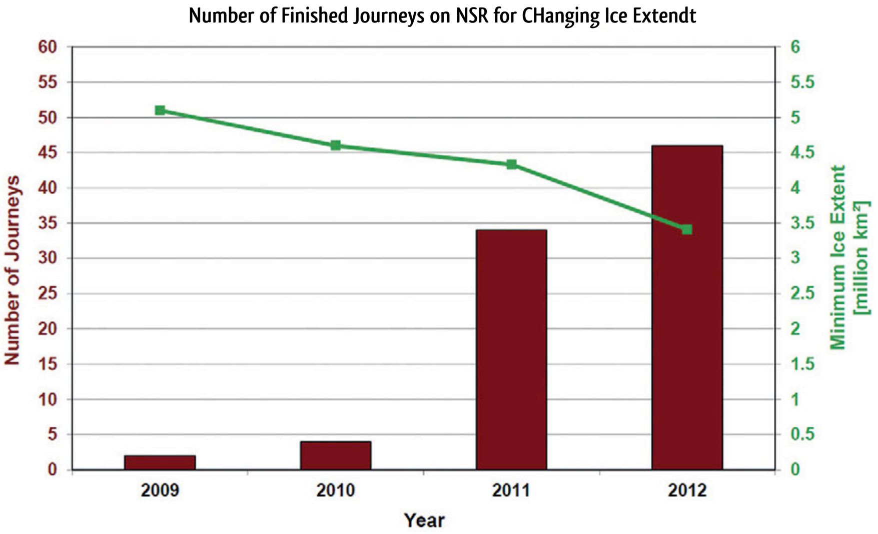
The Estimated Time of Arrival (ETA) program was developed at HSVA as part of the ARCDEV research project ARCDEV in 1998. [2] It aims to predict ship resistance in different environmental conditions including ice coverage. Additionally, data of the ships' specific means of propulsion are used to calculate required power and thereby estimate maximum speed under various ice conditions.

Shipping routes are subdivided into a number of legs chosen according to the required spatial resolution with regard to variations in environmental conditions. Consequently, the travel time for an entire route can be determined by the aggregate of travel time for each leg. The result is called a "module route".

Ice Resistance

The focus of the module route is the additional resistance in various ice conditions such as concentration and thickness. Additional single features like ridges are also taken into account. The resistance calculation is based on the well-established method of Lindqvist [3]: total resistance in level ice takes into account ice breaking resistance (including initial crushing), ice submersion resistance (including ice hull friction) and open water resistance.

Ice resistance components are calculated using input data for the ice thickness, strength and density as well as a friction coefficient. Furthermore, the ships' ice breaking ability is linked to its main dimensions and its hull characteristics. The ice resistance calculation includes a mathematical relation between ice crushing resistance, ice bending resistance and ice thickness. Resistance components due to calm water, wind and waves are also included. For these simulations, the thrust and power of the ship's propulsion motor were calculated using propeller open-water data from model tests at HSVA.



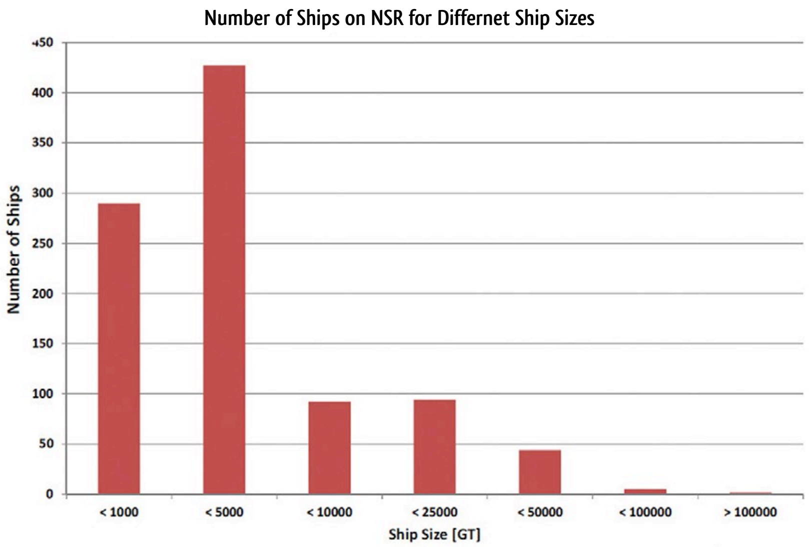


Figure 2 - Transit statistics for the Northern Sea Route in recent years.

Investigated Scenarios

Route Options

For the transit scenarios considered here, it was assumed that most ships would travel from Europe to East Asia via the Northern Sea Route. Therefore, the transit route started from Rotterdam (Netherlands) and registration at Murmansk port (on the shore of the Barents Sea, Russia) was taken into account before the ship may enter the NSR. Thereafter, four different options along the Northern Sea Route were considered before the ship reaches the Bering Strait and continues its journey in ice-free water to Yokohama (Figures 3 to 8).

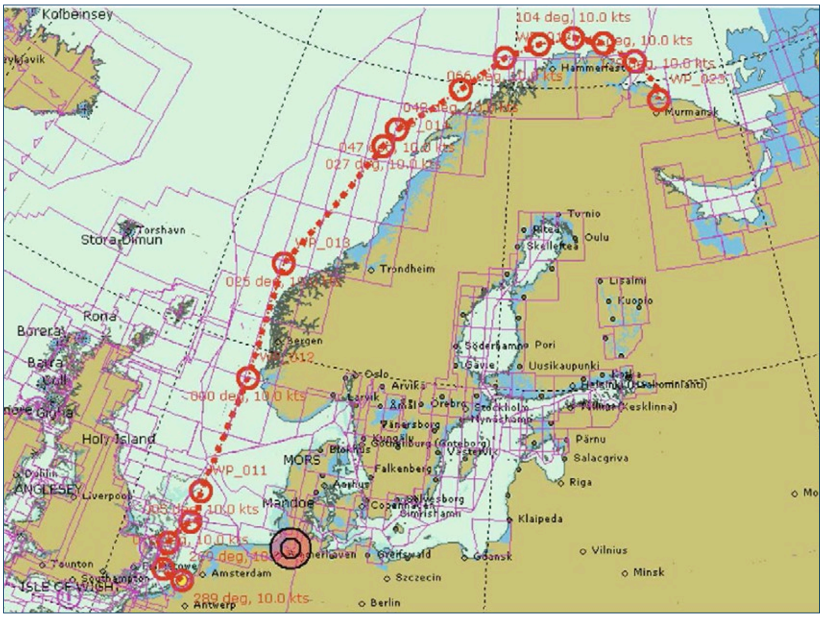


Figure 3 - Route from Rotterdam to Murmansk

Route Section	Length [nm]
Rotterdam to Murmansk	1672.1
NSR Route Option I	3017.8
NSR Route Option II	2976.9
NSR Route Option III	2842.6
NSR Route Option IV	2801.8
Bering Strait to Yokohama	2747.1
Average Total Route	7329
Alternative Suez Route	11500

Table 1 - Length of each route section and total length in nautical miles [nm]

Figure 4 - Route from Bering Strait to Yokohama

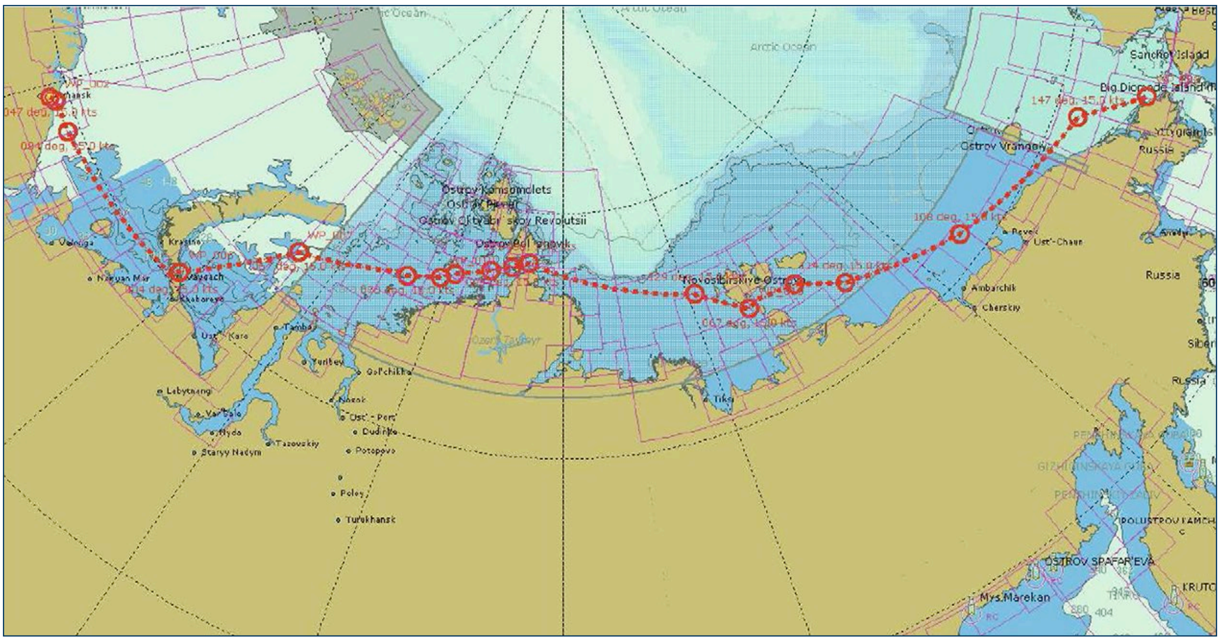


Figure 5 - Route Option I along the Northern Sea Route, south of Novaya Zemlya and south of Novo Siberian Islands

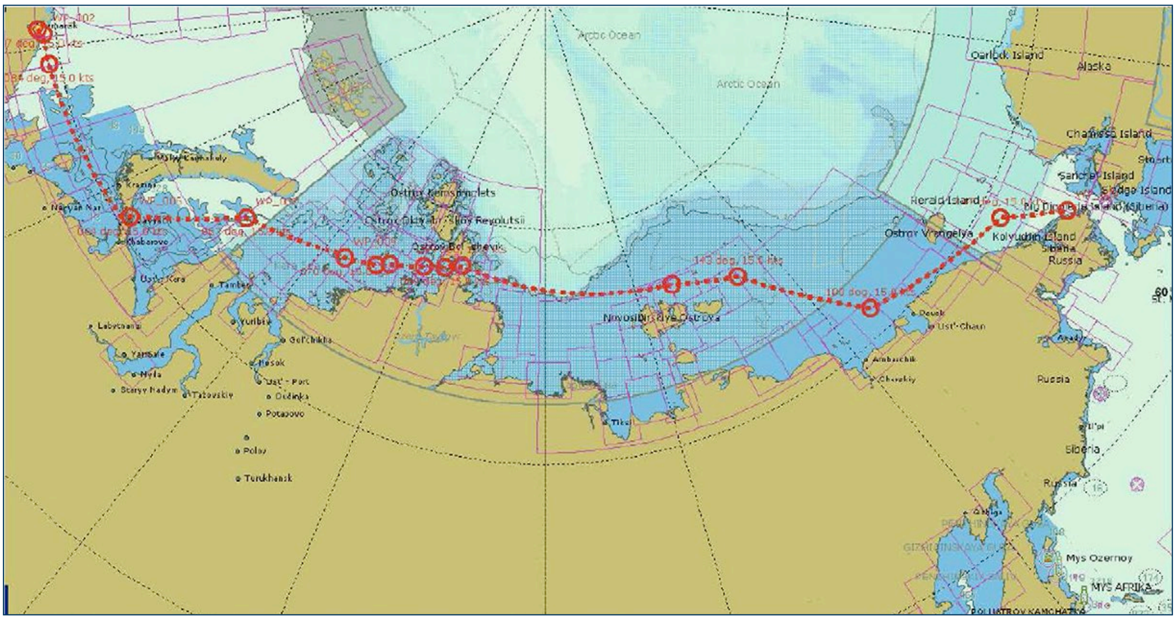


Figure 6 - Route Option II south of Novaya Zemlya and north of Novo Siberian Islands

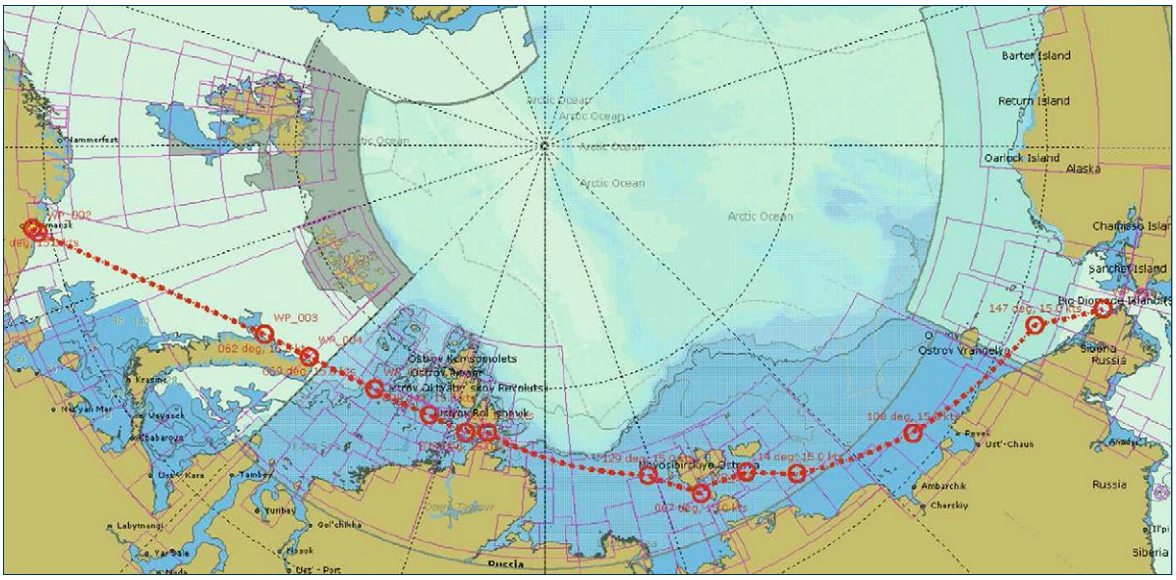


Figure 7 - Route Option III along the Northern Sea Route, north of Novaya Zemlya and south of Novo Siberian Island

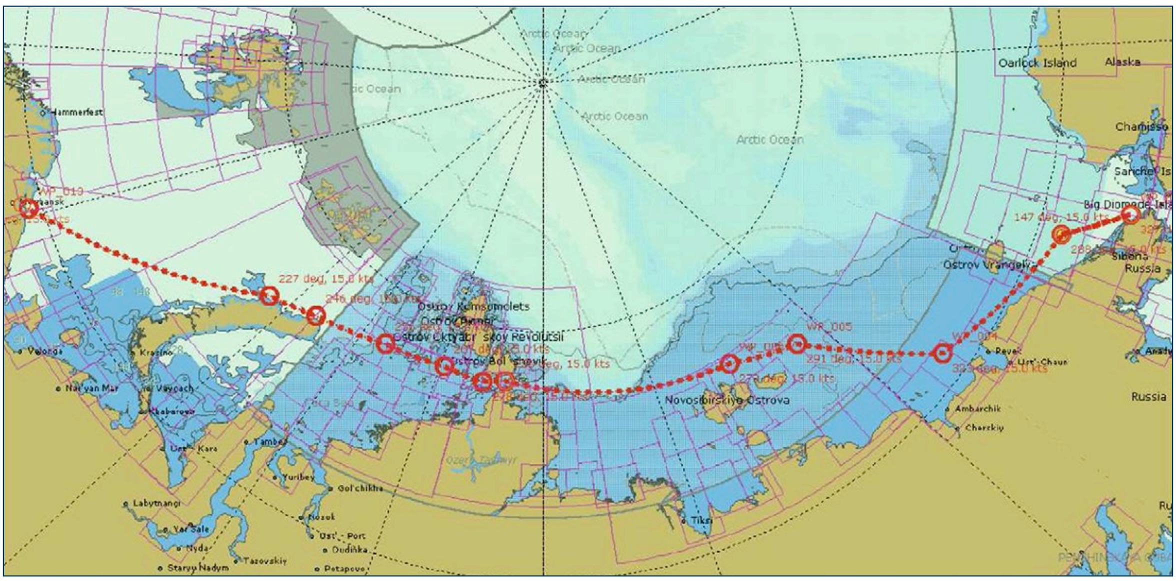


Figure 8 - Route Option IV north of Novaya Zemlya and north of Novo Siberian Islands

Environmental Input Data

In order to perform transit scenario investigations along the Northern Sea Route, ice data are required at a reasonable spatial and temporal resolution with regard to typical transit speed of cargo ships. Most of the available ice data are collected for climate research purposes and therefore are rather coarse. Local observation data are often restricted to special areas in coastal zones where they are used to assist frequent ship traffic.

For this investigation, ice concentration and thickness data should be available at an acceptable resolution with respect to the whole Northern Sea Route, with a travel distance of about 7 300 nautical miles (13 519.6 km). Since it was not possible to acquire this data from a single source, ice data for the whole Northern Sea Route were manually processed using data from different scientific publications. Most data were obtained from radarsat charts of the US National / Naval Ice Center and local data were transcripted into route files containing information for each leg.

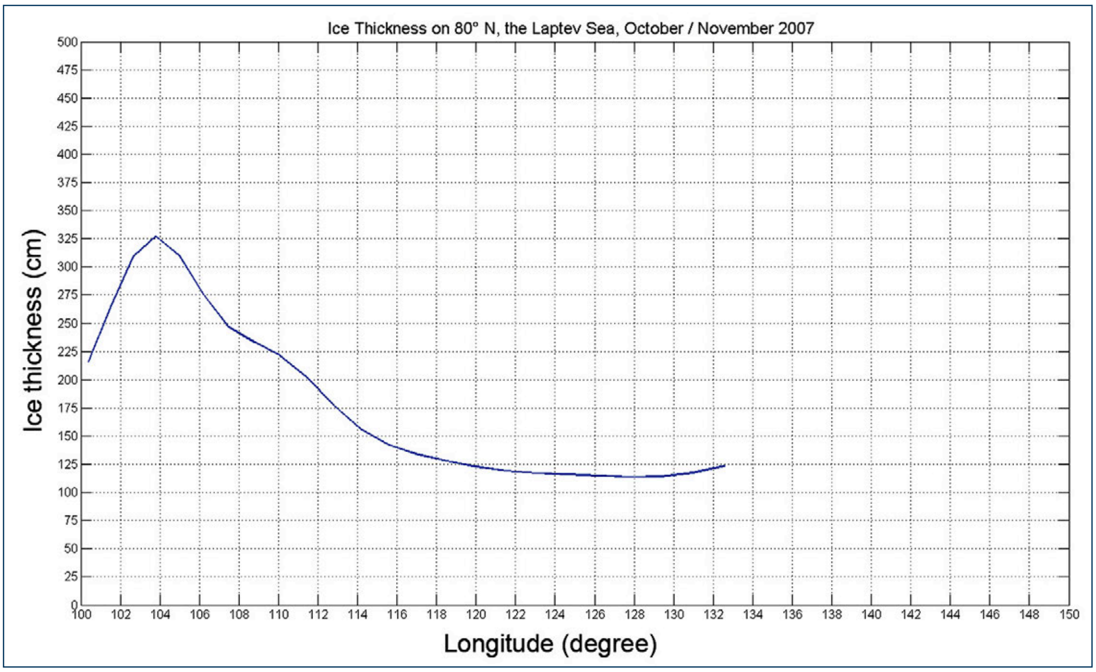


Figure 9 - Example of ice thickness (IceSat) at 80° N, Laptev Sea, October/ November 2007.[9]

Ship Types Example : Bulk Carrier

In order to perform transit scenario investigations along the In order to provide realistic predictions for ships adapted to Arctic operation, three different ship data models were generated using the HSVA database. These models differ with respect to the type of ship, main dimensions, hull shape and propulsion systems. Therefore, data were chosen so that different travel times could be expected and also so that the extent of required icebreaker assistance could vary.

In order to perform simulations, the maximum speed for each ship type in light ice conditions was limited to 8 knots (14.83 km/h), which represents a safe speed in case of ice floe collision events. In addition, it is assumed that ships would call for icebreaker assistance if their speed would drop to a value below 3 knots (5.55 km/h). In this case, the ICEROUTE program switches to speed calculation mode in a broken channel behind an icebreaker.

Results

When comparing 2000 and 2007 in Figure 10, it is obvious that in most cases, travel time is longer in 2000, especially in summer with an extreme value up to four times higher. Still for some route options, travel time in winter 2007 shows approximately the same time frame. This allows one to conclude that winter sea-ice extent and quality is comparable between 2000 and 2007. Whereas the change in quality and extent of the summer sea-ice between 2000 and 2007 is such that icebreaker assistance in 2007 is no longer required for most observed routes (Figure 11).

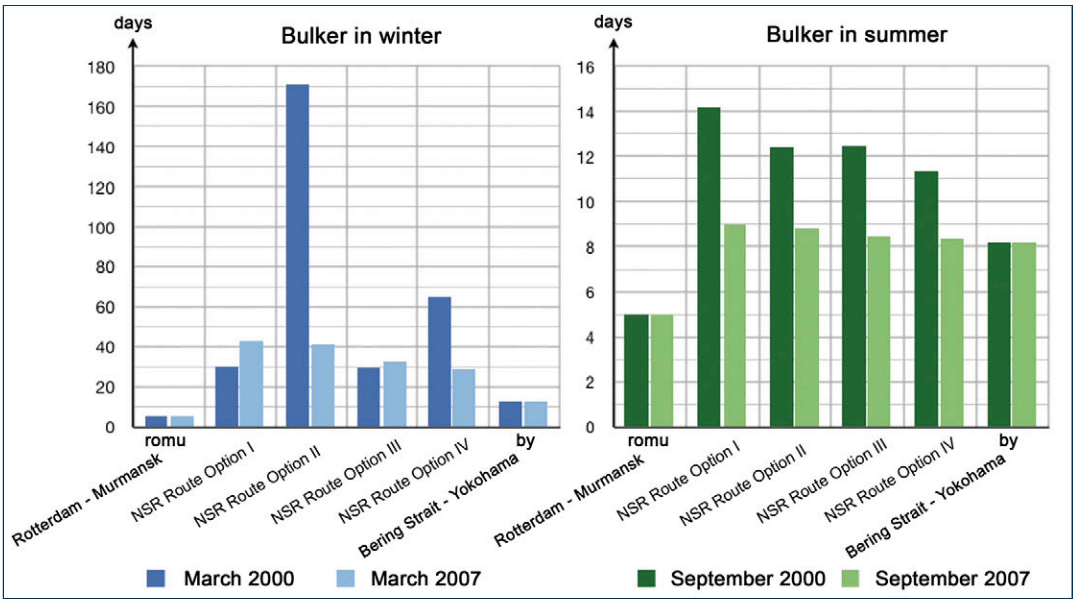


Figure 10 - Travel time of bulk carrier in March and September 2000 and 2007

The transit simulation results reveal a clear trend of decreased travel time for all ship types caused by a reduction in ice extent and volume over the last decade. Furthermore, it can be observed that in recent years (since 2007), the operation window for cargo transit shipping can be extended to the freeze-up period (October, November).

As data from the European Centre for Medium-Range Weather Forecasts (ECMWF) [13] was provided by our partner, the Alfred Wegener Institute (AWI) [14], the calculation could be extended to the period 1950-2040.Whereas data resolution is rather coarse and only monthly averages are available, this dataset could be useful to investigate possible long-term trends in Arctic shipping, with a special focus on the NSR. Hence, it is suggested that additional calculations for transit time be performed in order to show long-term trends and the potential for increased shipping along Arctic routes. Special focus shall be put on the length of possible transit period within each year for different decades.

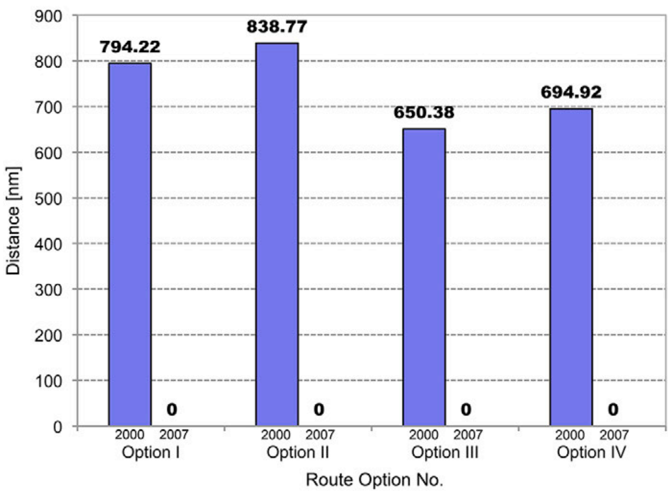


Figure 11 - Total distance in nautical miles with required icebreaker assistance for bulk carrier in November 2000 / 2007.
Note: 1 nautical mile (nm) = 1 852 m

Citations:

[1] ACCESS, (Arctic Climate Change, Economy and Society), EU Seventh Framework Program, Final Proposal, February 2011.
[2] HSVA, Final public report on the ARCDEV (Arctic Demonstration and Exploratory Voyage) project, EU funded Project ARCDEV, Hamburg, 1999.
[3] Lindqvist, G., A Straightforward *Method for Calculation of Ship Resistance in Ice*. POAC Proceedings, 1989.
[4] Holtrop Mennen, *An approximate power prediction method.* International Shipbuilding Progress 1982.
[5] Hollenbach, K.U., *Beitrag zur Abschätzung von Schiffswiderstand und Propulsion im Vorentwurf.* IfS-Bericht 588, 1997.
[6] Blume, P., *Berechnungen des Seeverhaltens für eine systematisch variierte Formfamilie.* HSVA Bericht 1505, 1977.
[7] Blendermann, W., *Wind Loading of Ships – collected data from wind tunnel test in uniform flow.* IfS-Bericht 574, 1996.
[8] Lackenby, H., *The Effect of Shallow Water on Ship Speed.* Shipbuilder, 70, No. 672, 1963.
[9] NSIDC, IceSat Products, 2011.
[10] NSIDC, http://www.natice.noaa.gov/products/weekly_products.html
[11] HSVA ship data base, Hamburg 2011.
[12] U.S. National/Naval Ice Center (NIC), http://www.natice.noaa.gov/index.html
[13] ECMWF (European Centre for Medium-Range Weather Forecasts), http://www.ecmwf.int/
[14] AWI(Alfred Wegener Institute), http://www.awi.de/en/home/Report
prepared by: Nils Reimer.

Marine pollution by oil spills

BAS/SAMS, HSVA, MET.NO, SINTEF, UCAM

Understanding the impact of an Arctic oil spill through modelling and experiments

Results from the ACCESS programme are particularly timely, especially in light of the accelerated changes that are occurring to Arctic systems. Since the start of the ACCESS project in 2011, the impacts of Arctic change have become apparent on local, regional and global scales. However, these are not the only shifts the Arctic is facing. Commercial investment in the Arctic is predicted to potentially reach $100 billion or more in the coming decade, with development of oil and gas, mining and the shipping industries being the biggest drivers. This "industrialisation of the Arctic" seems to be driven by a combination of climate change effects as well as the ever-increasing demand for hydrocarbons and minerals. ACCESS, with its broad remit, is one of the few programmes that cover the environmental, commercial, socio-economic and geopolitical consequences of Arctic evolution.

In this newsletter, the focus is on oil spill observational and modelling research in ice covered oceans. Modelling is used to gain a window into the future by making predictions and is a synthesis point for much laboratory bench, meso-scale [1] and field-scale work that is currently being done. Knowledge gained in this area would help estimate and compare potential biological and socio-economic impacts of oil spills caused by oil development, shipping and other human uses.

Modelling and observations of oil spills in sea ice

As the Arctic appears to be transitioning to seasonal ice cover, the latest Intergovernmental Panel on Climate Change (IPCC) report estimates that by 2050 navigable conditions in the Arctic will be 2-1/2 times longer than today, with 125 days available [2]. ACCESS provides an assessment and vision of the technological advancements that will allow the safe and sustainable use of Arctic resources.

Various characteristics of Arctic sea-ice

During the melt period, sea-ice in the Arctic is an evolving transition zone between the dense central ice pack [3] of the Arctic Ocean and open-water on the landward side of the ice edge. Between these two regimes exists a marginal ice zone (MIZ). Generally speaking, the size of the floes within the MIZ increases with distance from the ice edge, from a slurry of brash ice [4] to the larger floes further into the pack. However, due to the dynamic nature of sea ice, the MIZ can be found many hundreds of kilometres away from the main ice edge. As a result, moving platforms (i.e. ships) or fixed assets (such as drilling platforms) may come in contact with older ice types such as individual floes or fields of first-year and multi-year floes at any stage of the summer season. On the other hand, should operations continue towards the end of summer, or if freeze-up occurs particularly early, there is the possibility these operations may occur within a field of new ice, such as frazil [5], nilas [6] or pancake ice [7].

Both new and older ice types have very different characteristics and dynamics:

- Frazil ice is a soupy mixture of individual ice crystals.
- Nilas forms a thin, continuous ice layer on the ocean's surface.
- Pancake ice has rounded bottoms and upturned edges.
- Older ice floes come in all shapes (from a few metres to several kilometres in length) and thickness (ridged and level ice).
- Pack ice is a mass from other types of ice that have frozen together.

ACCESS Solutions

Given the complexity of sea-ice and its variability over time and space, a great deal of research is still required to better understand and model these ice types. The same is also true when it comes to understanding the movement (and weathering) of oil spilled within these ice types. Therefore, in order to better parameterise the dynamics of oil under different ice conditions, dedicated experiments are needed. From these experiments, new parameterisations can be included in oil spill models. Within the ACCESS programme, and with

1 - Meso-scale: "meso-scale" refers to weather systems comprised between large-scale systems (spanning from several hundred to several thousand kilometres) and smaller weather systems of less than 2km in diameter.

2 - The fifth IPCC Assessment Report (AR5) was released 30 March 2014. It "considers the vulnerability and exposure of human and natural systems, the observed impacts and future risks of climate change, and the potential for and limits to adaptation" www.ipcc.ch . The summary for policymakers is available at http://ipcc-wg2.gov/AR5/images/uploads/IPCC_WG2AR5_SPM_Approved.pdf.

3 - Pack ice : also known as ice pack or pack, any area of sea-ice (ice formed by freezing of seawater) that is not land fast; it is mobile by virtue of not being attached to the shoreline or something else. (Source: Encyclopaedia Britannica).

4 - Brash : Accumulated fragments of brokenseaicefloes (generally less than about 2 m in size).

5 - Frazil : Individualcrystals/platelets of icegenerallylessthan 1 cm in diameter.

6 - Nilas : Thin,continuouslayer of sea-ice which is produced by the freezing together of frazil crystals.

7 - Pancakeice : In the presence of waves, frazil does not freeze together to takes shape as continuous sheets of nilas, but will consolidate to form circular pans known as pancake ice. Pancake ice is generally less than 2 m in diameter.

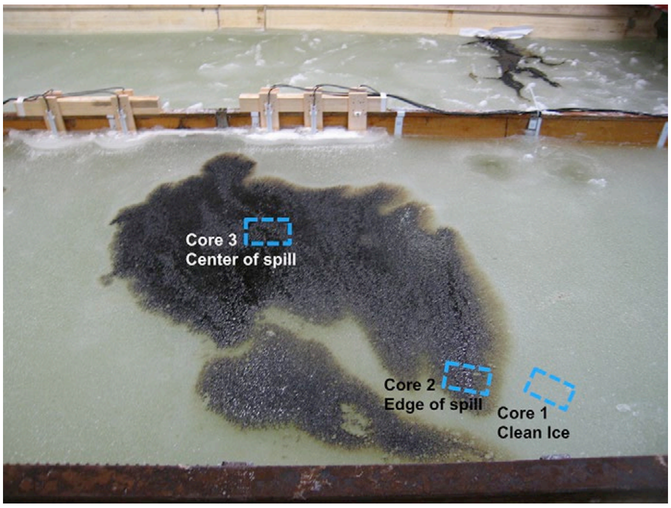
the support of other funding agencies[8], we have been able to perform observational and modelling experiments under various ice types in the laboratory.

Selected observations from ice tank experiments of oil and sea ice

A number of different "oil in ice" experiments have been performed in large-scale tanks. These tests covered a wide range of sea-ice types, from the initial formation of sea-ice through to thick ice sheets. Examples of experimental oil spills in frazil and nilas ice types are shown below.

1- Frazil ice: frazil ice is the first stage of ice formation, comprised of a collection of individual, randomly oriented disc and needle-shaped ice crystals. Under turbulent conditions like waves and winds, high concentrations and thickness of frazil ice can develop (Figure 12).

Figure 12 - Oil spill experiments in frazil ice



A - Results of the simulated spill. Most of the oil spread across the surface of the frazil. The blue boxes indicate where cores were taken and frozen for further analysis.

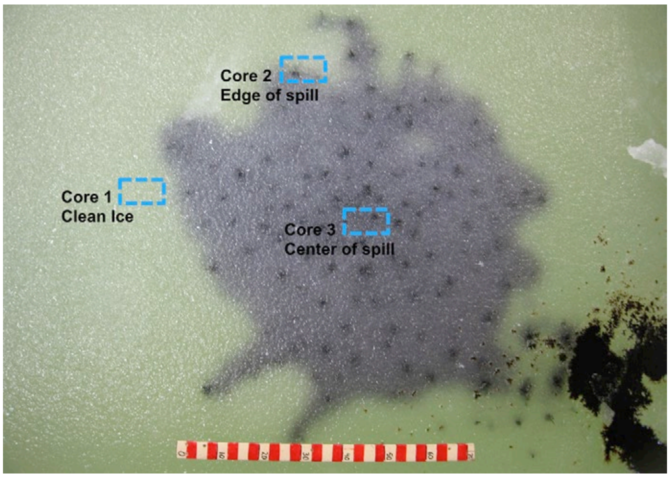
B - Example of Core 3 was taken from near the centre of the spill. Oil was still fluid at this core site and as such oil coated the sample when it was removed. Upon cleaning, only evidence of oil at the top of the icewasfound.

8 - Additional funding agencies include: EU funded Hydralab programme, Alaska Clean Seas (US), Oil Spill Recovery Institute (US).

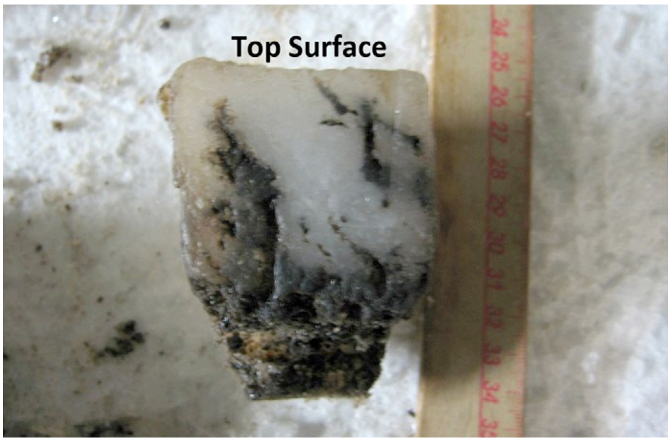
During this experiment, oil was spilled below an 8 cm thick frazil layer. Due to the buoyancy of the oil, it floated up towards the underside of the frazil layer. Once at the bottom of the layer, the oil did not spread laterally across the bottom of the ice as with other ice types, but penetrated the frazil layer until reaching the sea surface. Once the oil was at the surface, the oil continued to spread horizontally across the upper surface of the frazil ice in seawater. Oil penetration through the frazil layer is due to the cyclic compression and relaxation mechanisms of passing waves and the natural tendency of oil to break up into smaller forms.

2- Nilas Ice: Nilas was formed by removing the influence of the waves, and allowing the surface frazil crystals to freeze together. The resulting ice field was one whose upper surface was frozen together and lower surface was comprised of individual frazil crystals (Figure 13).

Figure 13 - Oil spill experiments in nilas ice



A - Aftermath of the spill in Nilas ice. All of the oil was contained below the ice surface. Some migration towards the surface atdiscrete points caused the spotty nature to the image. The blue boxes indicate where cores were taken and frozen for further analysis.



B - Example of Core 3 which was taken from near the centre of the spill. Oil was located at the bottom of the ice. Some vertical migration of oil through brine drainage channels is evident.

Even though the ice conditions were very similar to the frazil ice spill discussed above, results of this experiment were very different as the lack of wave energy inhibited the vertical migration of oil towards the surface. As a result, oil stayed at the bottom of the ice and spread latterly. There was some evidence of oil migrating upwards through brine channels.

Modelling oil spills in ice

Within ACCESS, we are integrating the SINTEF Oil Spill Contingency and Response (OSCAR) oil spill model with SINTEF SINMOD [9] model, an Arctic climate-scale coupled atmosphere-ice-ocean model. We are combining OSCAR with this climate model so that we can simulate oil spill scenarios and their consequences in the future as compared to now.

A coupled atmosphere-ice-ocean model simulates the movement of heat and water among three compartments on our planet: atmosphere (air), cryosphere (ice) and hydrosphere (ocean and freshwater). These compartments are simulated together, as they are intimately connected to the regulation of the planetary climate system. Furthermore, these fully coupled ocean-ice-atmosphere models are relevant both for large-scale and regional study (from global to the entire Arctic), and are designed to predict changes over decades into the future. As a result, coupled atmosphere-ice-ocean models simulate general quantities, such as average sea-ice thickness over a gridcell area and percentage of open water in a gridcell. Simulation of these quantities is important for the understanding of how the Arctic climate may change.

However, even the largest oil spills are smaller than the entire Arctic region, so we want to know more about oil spill dispersion in ice-covered waters at smaller scales than what the climate models simulate. Therefore, we need to reduce the scale for simulating individual oil spills. From knowledge gained through simulation of different scenarios and sources of oil spills at various locations, potential biological and socio-economic impacts can be estimated and compared. Whereas this process seems straightforward, this requires some exciting improvements in modelling to achieve our goal. Within ACCESS, we are scaling down the models to be more spill relevant.

9 - SINMOD is a 3D coupled atmosphere-ice-ocean model system that also couples physical and biological processes for natural resource information. The model has been developed and used at SINTEF since 1987.

Underwater Noise in the Arctic

Universitat Politecnica de Catalunya (UPC)
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Introduction

The ocean is full of natural sounds, but many anthropogenic sources (resulting from the influence of human beings) are increasingly adding to the general noise level (Figure 14). The extent to which sounds in the sea impact marine life is a current topic of considerable interest both for the scientific community and the general public. Scientific interest stems from a need to better understand the effect of sound production and reception on the behaviour, physiology, and ecology of marine organisms. Man-made sound, including that required for the study of the marine environment, can interfere with the natural use of sound by marine organisms. Public interest is primarily concerned with the potential effects of anthropogenic sound on marine mammals, given the public's broad recognition of the importance of sound in the lives of these species. For acoustical oceanographers, marine seismologists and minerals explorers, sound is the most powerful remote-sensing tool available to determine the geological structure of the seabed and to discover oil and gas reserves deep below the seafloor.

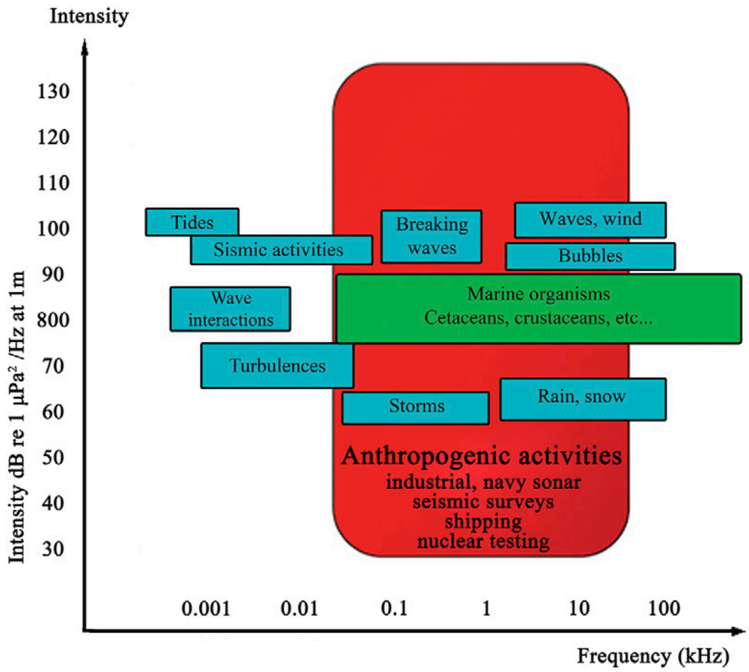


Figure 14 - Simplified diagram of noise budget in the ocean showing frequency ranges and intensities of sound components.

Both scientific and public interest in the impact of human-generated ocean noise on marine animals has greatly increased in recent years. Concerns include whether man-made sounds may interfere with the way in which marine animals use sound and that it may cause them physical harm. Therefore, a key issue is to study if artificial sounds affect the ability of marine organisms to practice their normal behaviour as well as to assess the long-term ability of these animals to survive, reproduce and maintain healthy populations.

Indicators for Underwater Noise in the EU Marine Strategy Framework Directive

Most studies lack information on the long-term effects of noise sources on specific populations. There are very few data on current ambient noise levels in most regions and even less historical data. Information on trends is not available neither in European or international waters. According to the Marine Mammal Commission (2007), underwater ambient sound levels will increase over time with more human activity in the marine environment (shipping, offshore industrial construction and exploitation). It should be noted that the potential increase in ambient sound levels will not affect all areas equally but specific regions where offshore activity is high, e.g., some of the Exclusive Economic Zones (OSPAR Commission 2009). Potential effects might not be proportionate to pollution levels due to variation in sound propagation and, most importantly, the distribution of marine life that is sensitive to sound.

Organisms that are exposed to sound can be adversely affected both on a short timescale (acute effect) and on a long timescale (permanent or chronic effects). These adverse effects can be widespread and the European Commission decided in September 2010, under the Marine Strategy Framework Directive that two indicators for underwater noise be used in describing ocean "Good Environmental Status".

The first indicator refers to impulsive sound sources and the impact that it addresses is "considerable displacement", meaning a displacement of a significant proportion of individuals for a relevant time period and spatial scale. The indicator addresses the cumulative impact of sound generating activities and possible associated displacement, rather than that of individual projects. This indicator is clearly a pressure indicator, and a possible future target would thus be in the form of a threshold of, or a trend in, the proportion of days when impulsive sounds occur and in their spatial distribution.

The second indicator concerns ambient noise, or continuous low frequency sounds. This mostly refers to shipping noise, that should be measured at representative locations backed up by noise models that would strengthen the analysis by overcoming bias introduced by changes in human activities or the by the natural variability of the environment and will extending the monitoring to poorly or un-covered areas.

These two indicators will enable European Union member states to get an overview of the overall pressure from these sources, which have not been achieved previously. A necessary follow-up in future years would be to evaluate effects on biota, set targets and potentially take measures.

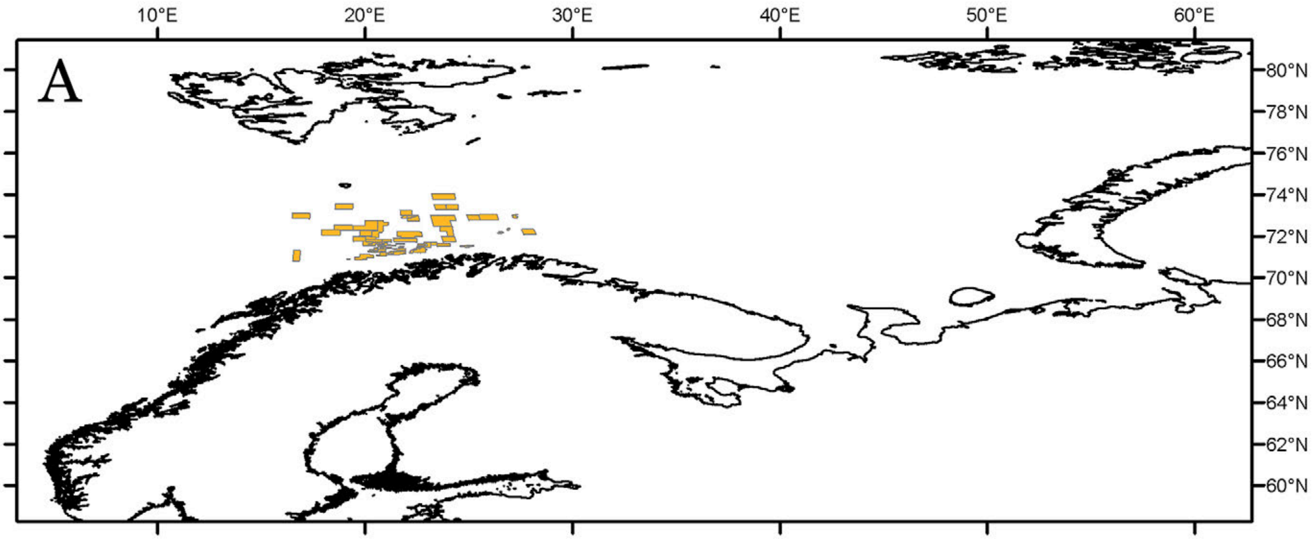
Shipping and seismic operations coincident with marine mammals

ACCESS partners have looked at how shipping, fisheries, and oil and gas operations could affect marine organisms in the Arctic, with a special focus on marine mammals, through tasks in Work Packages 2, 3 and 4.

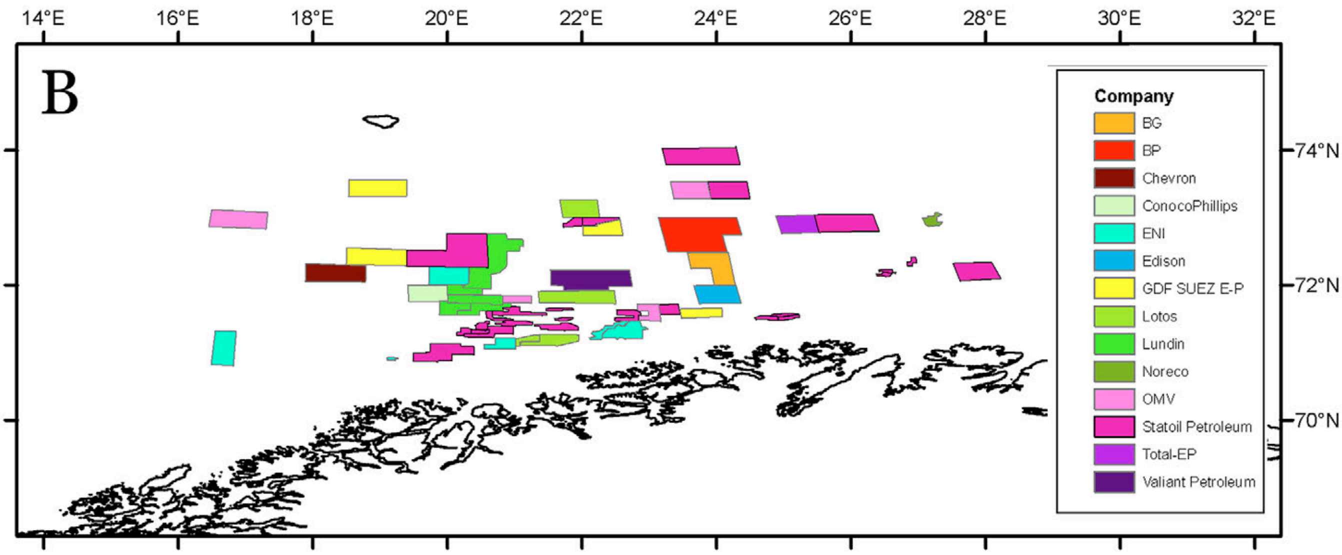
The maps in Figure 15 show the distribution of shipping density in the Barents Sea, coupled with the presence of marine mammal species and the projected oil and gas operations that were scheduled in 2012.

These maps allow the comparison of the number of passages each month in 2012 with areas of marine mammals distribution. December had the highest number of passages at1 835, while 1 671 passages were observed in April and 1 631 passages in May. The months with the least traffic were June with 631 and September with 816 passages. The areas with the most traffic were those near the coastline of Norway, Bjørnøya and the southern coast of Svalbard. These areas overlap with the distribution of shallow water baleen whales, such as minke whales and fin whales.

Figure 15 - Barents Sea shipping density, presence of marine mammal species and scheduled oil and gas operations, 2012.

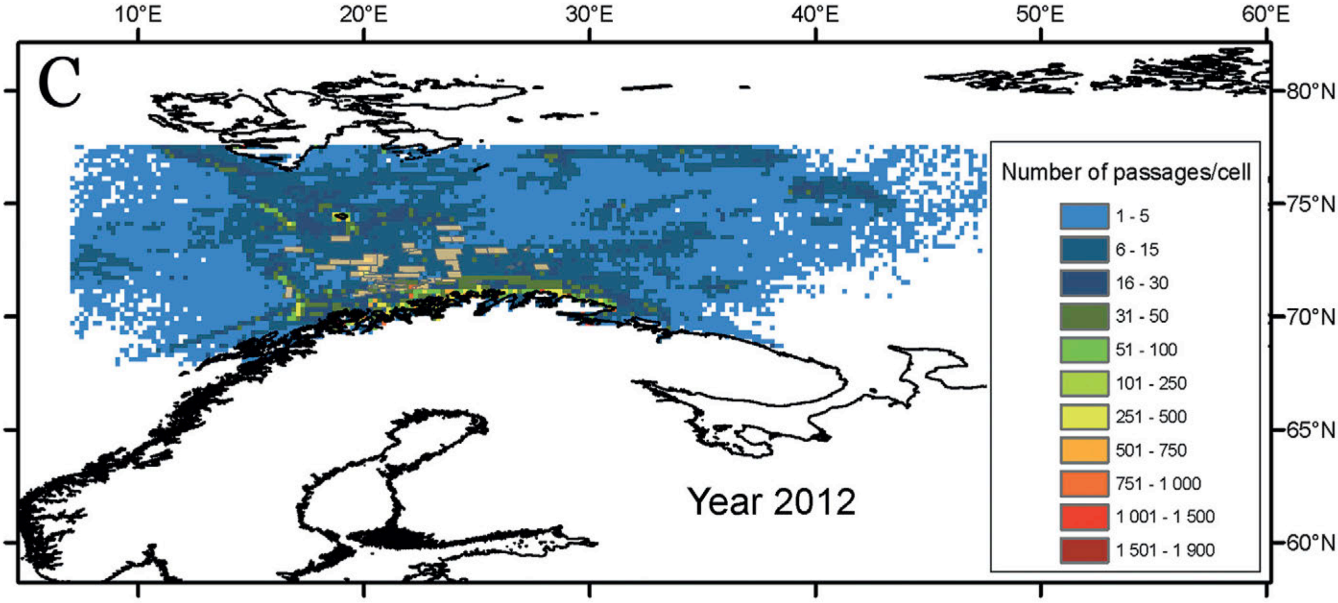


Map A - Oil prospecting areas covered 20 June 2012

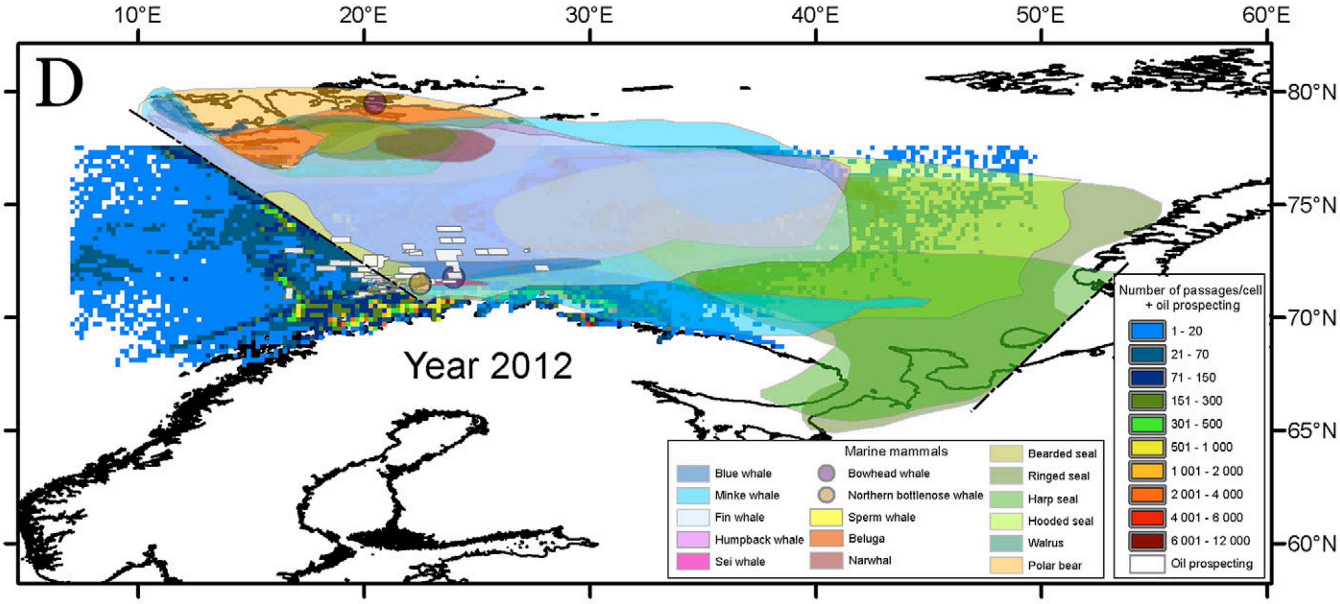


Map B - Detail of Map A showing oil companies in charge of the exploration. Data provided by the Norwegian Petroleum Directorate.

Figure 15 - (continued)



Map C - Ship traffic in the Barents Sea based on Automatic Identification System



Map D - Integrated ship traffic in the Barents Sea, oil & gas operations and marine mammal distribution, 2012

Acoustic impact zones for marine mammals during seismic surveys

According to existing mitigation and monitoring practices for seismic surveys, monitoring of two types of safety zones should be established to protect marine mammals such as cetaceans (whales) and pinnipeds (seals) from physical injury or undue disturbance during feeding. The parameters of the safety zones depend on specific tolerable levels of acoustic pressure by species.

- The Disturbance Safety Zone is defined as the zone within which the received acoustic pulse levels exceed 160decibels root mean square (dB rms) [1].
- The Injury Safety Zone for cetaceans has been set at 180dB rms and at 190dB rms for pinnipeds.

1 "Root-mean-square means that the (...) sound pressures (...) are squared, averaged and the square root of the average is taken." (Source: Fundamentals of acoustics, Professor Colin H. Hansen Department of Mechanical Engineering, University of Adelaide, Australia.)

In order to better understand how climate change in the Arctic has an impact on the size variations of Disturbance Safety Zones, a series of seismic surveys (measurements of an environment's properties in response to disturbances such as acoustic waves) were performed using a seismic airgun as the source of acoustic emissions. Tests were conducted using an accurate acoustic model and a forecast for warming in the upper layers of the sea. The acoustic model is based on environmental parameters of water layers in the Barents Sea from different seasons and years: May and September 1991, May and September 2010. The forecast used for environment warming in the upper layers of sea water for the next decades considers an increase of temperature up to 5° C. The survey parameters and results are summarised in the following sections.

Study area

The seismic source (where the seismic airgun impulse was emitted) was located in the Barents Sea (75°30'N 35°30'E), west from Novaya Zemlya Island (Figure 16).

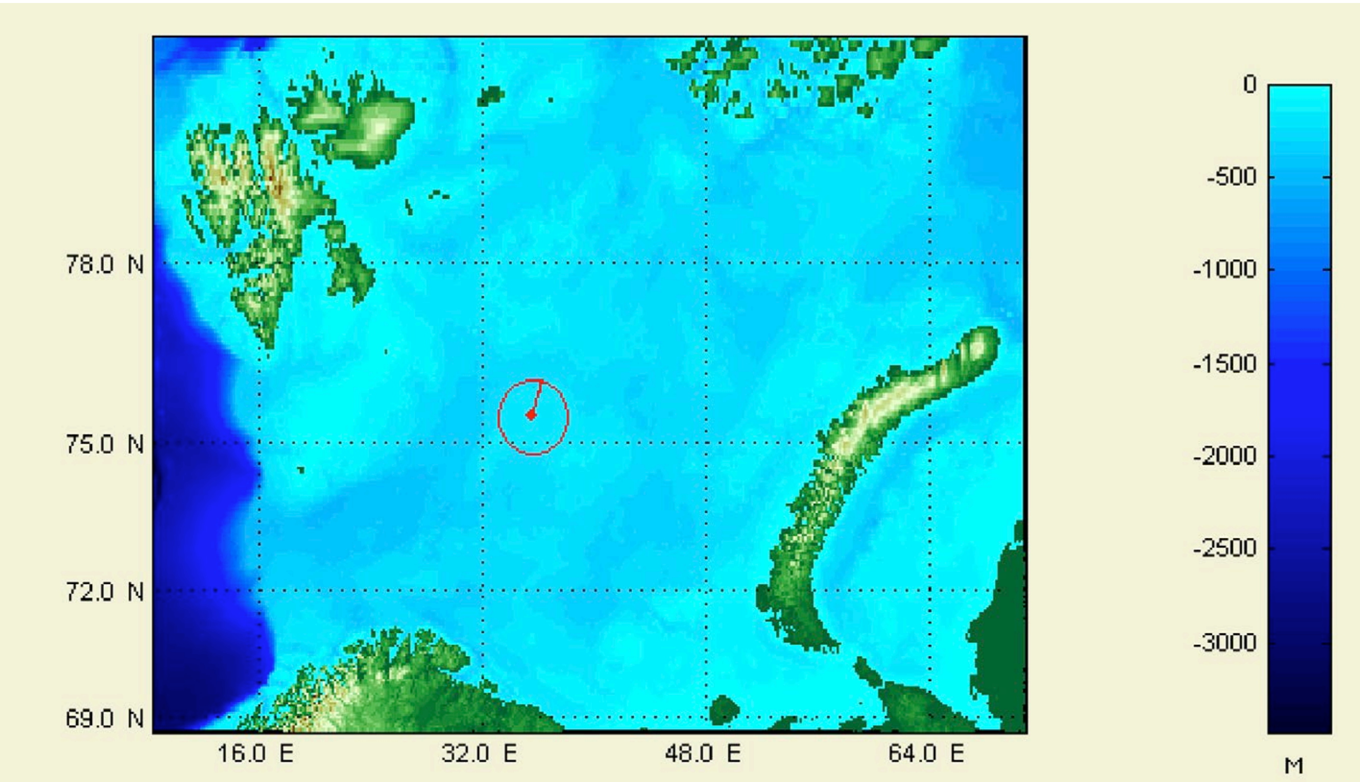


Figure 16 - Barents Sea study area. The red circle shows the area of modelling; the line inside the circle shows the track the transmission loss curves.

Geoacoustic parameters

Five distributions of sound speed in water were used as input data for sound propagation modelling. The distributions correspond to environmental parameters of water layers for May and September 1991, May and September 2010.Distribution of sound speed profile when thewaterreaches5o C was measured relative to the September 2010 forecast.

Historical data on salinity and water temperature were obtained from the Arctic Ocean Physics Reanalysis database and used to calculate sound speed profiles. Data on the sea floor acoustic properties were obtained from the ETOPO2 database.

Examples of two-dimensional distributions of sound speed in water and the sea floor along a track in May 1991 (Figure 17) and in May 2010 (Figure 18) are shown below.

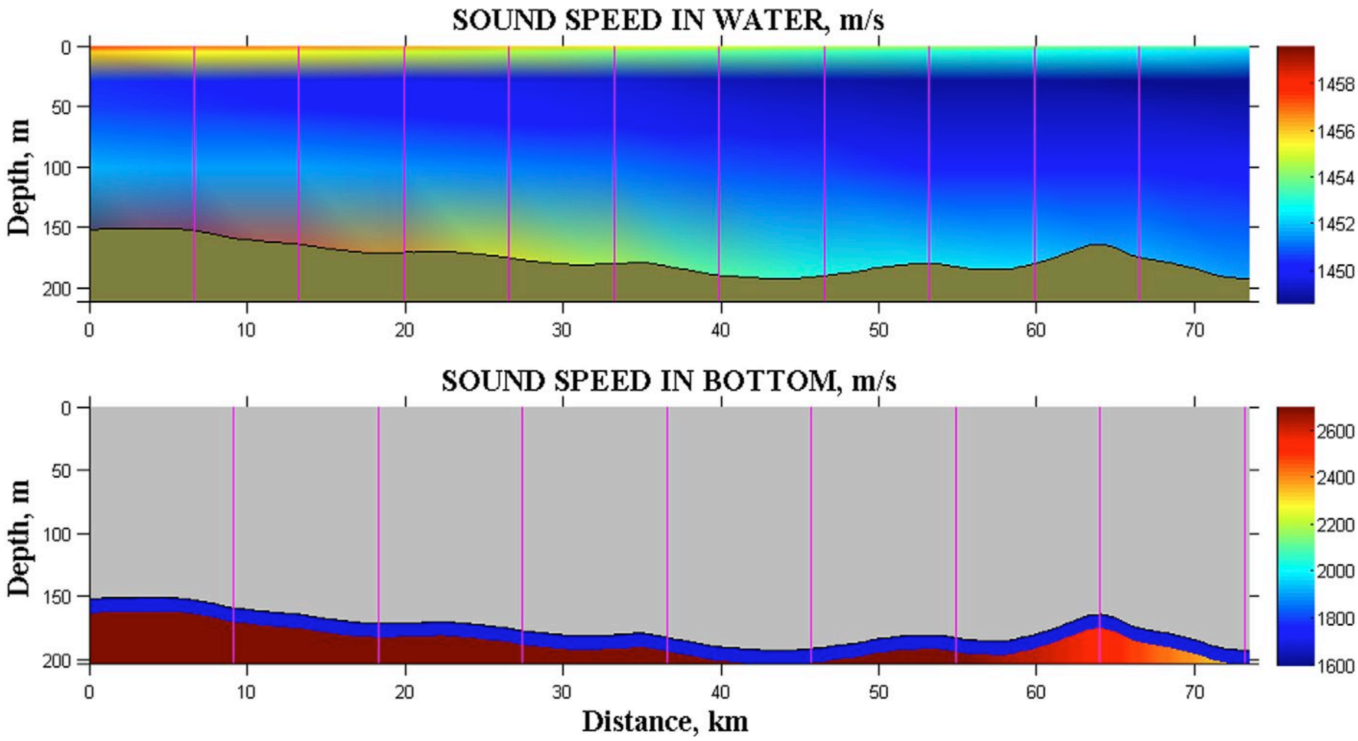


Figure 17 - Examples of 2-D distributions of sound speed in water (upper plot) and sea-floor (lower plot) in May 1991 along a track.

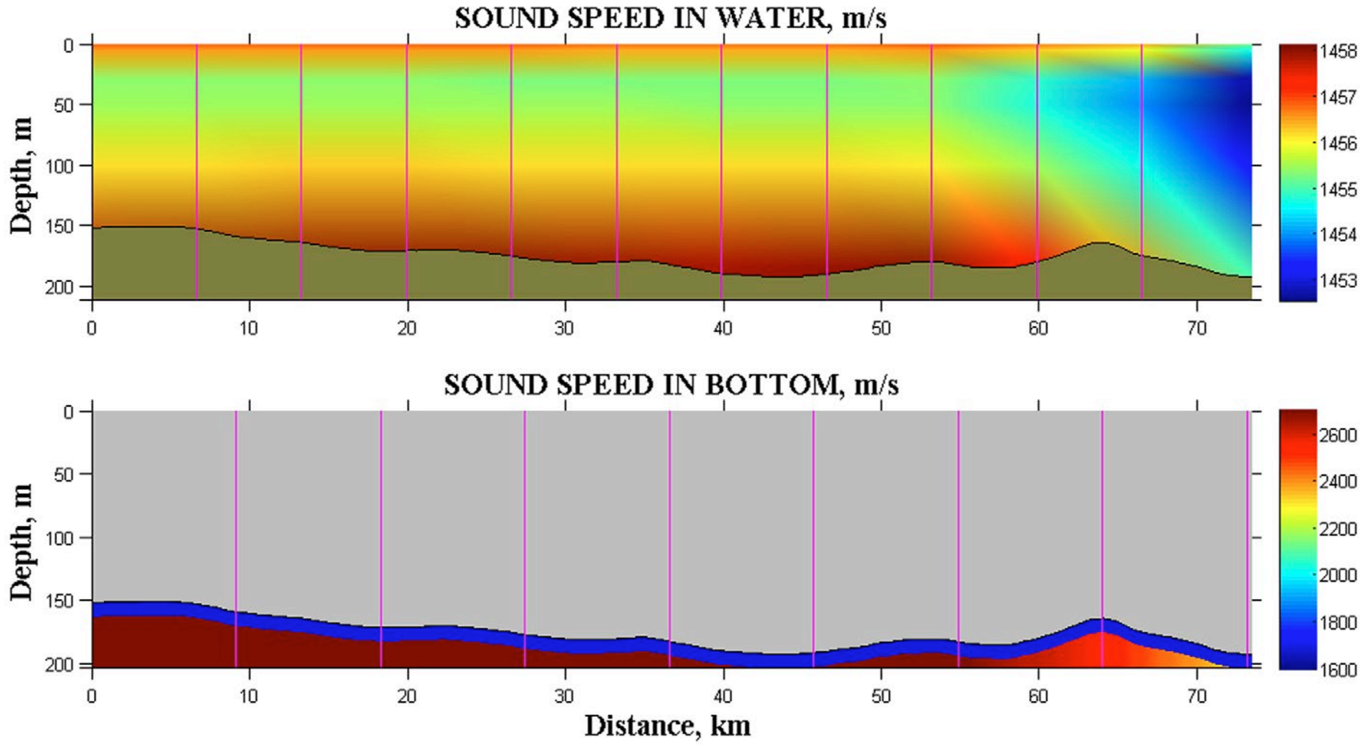


Figure 18 - Examples of 2-D distributions of sound speed in water (upper plot) and sea-floor (lower plot) in May 2010 along a track.

Modelling results

Modelling was carried done for seismic source approximated as point source. Examples of transmission loss (TL) modelling for 2010are shown in Figure 19. Decreasing sound pressure levels on TL curves along the track for a fixed 100 metre depth are shown in Figure 20 with a zoom in the range of +/- 180 dB level.

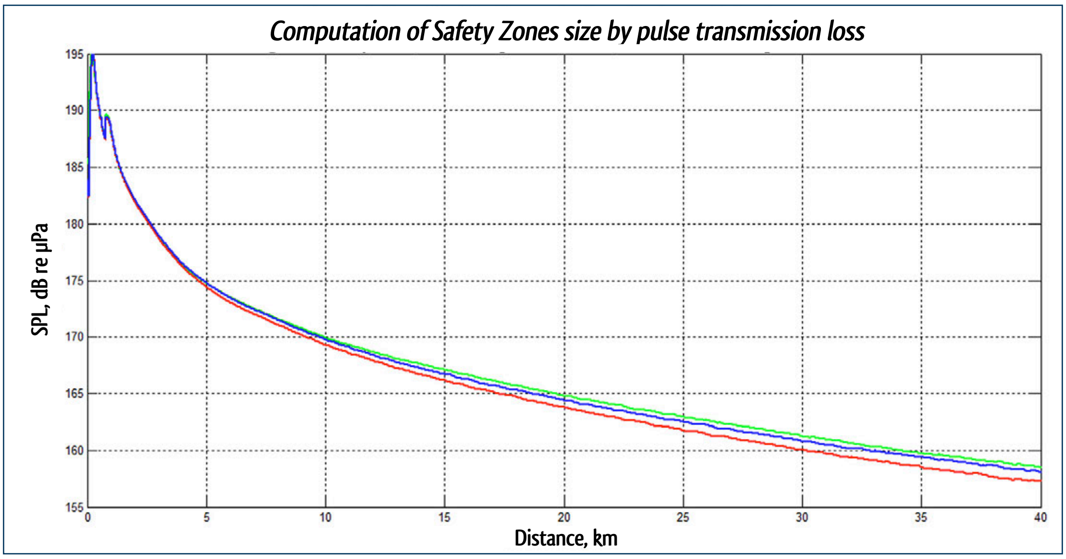


Figure 19 - Transmission loss curves for fixed depth (green = May 2010; blue = September 2010; red = forecast for September 2010).

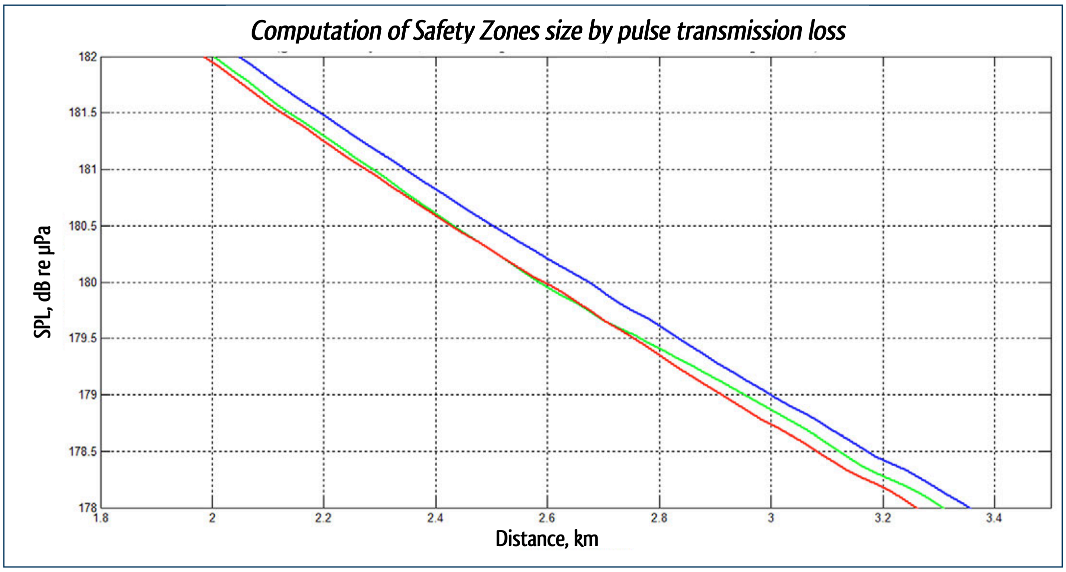


Figure 20 - Transmission loss curves zoom in the range of +/- 180 dB level (green = May 2010; blue = September 2010; red = forecast for September).

Preliminary conclusions

A preliminary analysis of the model results draws two conclusions.

- In most cases, the shift in boundaries of the Injury Safety Zones (at 180 dB level) is not significant while the shift in boundaries of the Disturbance Safety Zones (at 160 dB level) can increase up to several kilometres in the direction of the seismic source.
- A higher temperature in the upper water layer leads to a decrease in pressure levels of sound propagation due to ray paths bending towards the sea floor, thus enlarging the interaction between sound propagation and the seabed. As a consequence, the size of Disturbance Safety Zones will be smaller.

These results show that the change in the water column temperature in the Arctic region will have impacts on the way sounds propagate. This requires that the monitoring and mitigation policies and practices take account of these changes to properly address noise issues to ensure environmental quality in the region. This should include acoustic monitoring before, during and after the seismic operations take place as well as correspondent modelling so all the acoustic events in the area are taken into account. In terms of cetacean presence, the monitoring process should also count on an alert service able to warn the operators of the presence of species at risk, allowing adequate mitigation action to limit the effects of sound exposure.

Work Package 6 – Dissemination and Outreach

Important meetings of great interest for ACCESS
in chronological order

29 April, 2014

European Geosciences Union (EGU) General Assembly in Vienna, Austria.

On April 29, the EGU General Assembly will dedicate a special session to Polar Oceans in memoria of Eberhard Fahrbach, who passed away on April 23, 2013. Eberhard Fahrbach "was one of the pioneers of long-term high-latitude ocean observations. His devotion to promoting multi-year studies was equally strong in the seasonally ice-covered Southern Ocean and in the Arctic and Subarctic seas" (source: EGU).
More information: http://meetingorganizer.copernicus.org/EGU2014/session/15290

2 - 3 June, 2014

ACCESS WP1 workshop at the Laboratory of Oceanography in Villefranche (LOV), France.

The aim of this workshop organized by ACCESS work package 1 (WP1) dedicated to the Arctic Environment in the Context of Climate Change, is to sort out the internal synthesis of WP1 results so that they can be delivered in the most effective form to other work packages. Participation of other work package members is very much encouraged.

23 - 25 June 2014

ACCESS WP5 workshop on indigenous populations in Paris, France.

This ACCESS workshop will concentrate on the impacts of climate change on indigenous people's everyday life and their participation in the future Arctic governance. This meeting would also like to focus on the participation of indigenous peoples social sciences researchers.

15 - 16 September, 2014

6th International Workshop on Sea Ice Modelling and Data Assimilation in Toulouse, France.

The Organizing Committee of the workshop of the International Ice Charting Working Group Data Assimilation Working Group together with the EU FP7 ICE-ARC Project organize a workshop that will focus on research and development related to numerical sea ice analysis and prediction. Registration will be opened until 31 May 2014.

More information: http://www.ice-arc.eu/2014/04/16/toulouse-modelling-workshop/

22 - 26 September, 2014

ACCESS 2nd Summerchool at the Beijer Institute of Ecological Economics in Stockholm, Sweden.

ACCESS 2nd cross-sectoral workshop will be dedicated to the project's synthesis and scenarios. It will be also hosted at the Beijer Institute of Ecological Economics in Stockholm, Sweden, from September 22nd to 26th.

22 - 25 September, 2014

Arctic Sea Ice Reduction: the evidence, models, and global impacts

Two meetings will be organized:

22 - 23 September at The Royal Society in London, UK.

This meeting explores the recent, rapid Arctic sea ice reduction, the evidence for change, the inability of our climate models to predict these changes, the processes responsible for sea ice reduction and improved representation of these processes in climate models, and the impacts of sea ice change on local and global weather and climate.

More information and programme: http://royalsociety.org/events/2014/arctic-sea-ice/ and https://royalsociety.org/~/media/events/2014/DM0614%20Schedule.pdf

24 - 25 September at The Royal Society at Chicheley Hall, Buckinghamshire, UK.

The satellite meeting will host presentations and discussion of the latest scientific developments in sea ice observation, model simulations, theory, and impacts on weather and climate. This would also include the polar ocean and atmosphere as they are affected by sea ice. The purpose of this meeting is that it offers a more informal forum for discussion among scientists.

More information and programme: http://royalsociety.org/events/2014/sea-ice-reduction-satellite/ and https://royalsociety.org/~/media/events/2014/SM0614%20Schedule.pdf

31 October – 02 November, 2014

Second Arctic Circle Assembly in Reykjavik, Iceland

The Arctic Circle holds its second assembly at the Harpa Reykjavík Concert Hall and Conference Centre between October 31 and November 2. Issues of particular relevance for ACCESS that will be discussed during the assembly include: The science of ice: global research cooperation; shipping and transportation infrastructure; fisheries and ecosystem management; the prospects and risks of oil and gas drilling; Arctic resources; Arctic tourism and the role and rights of indigenous peoples. The Arctic Circle aims to support, complement and extend the reach of the work of the Arctic Council by facilitating a broad exchange of ideas and information.

More information: http://www.arcticcircle.org/