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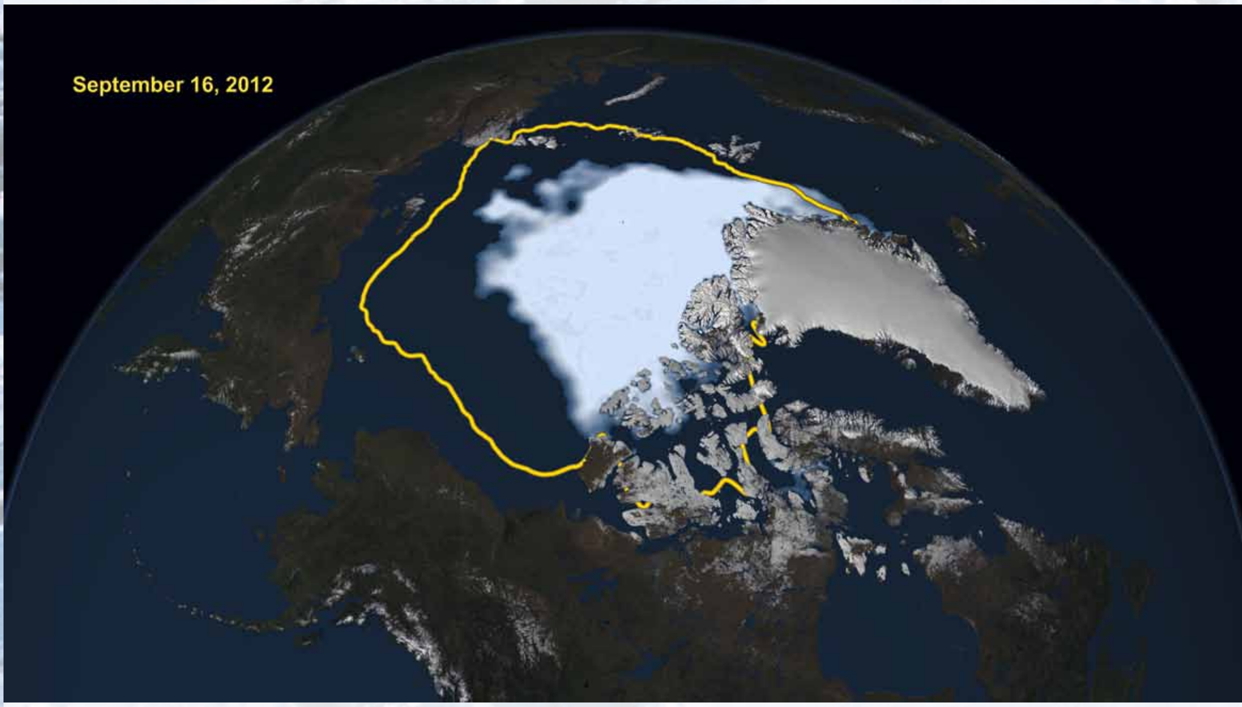
ACCESS NEWSLETTER

Arctic Climate Change
Economy and Society

Issue No. 4
October 2012

ACCESS Highlights



The image from 16 September 2012 shows the minimum extent of sea ice ever recorded in the Arctic Ocean from satellites, starting in 1979. The yellow outline shows the average sea-ice minimum from 1979 through 2010. Analysis of satellite data by the National Snow and Ice Data Center (www.nsidc.org) indicate that the 2012 sea-ice minimum covered only 3.41 million square kilometers, decreasing more than 750,000 square kilometers compared to the previous Arctic sea-ice minimum set in September 2007. Moreover, the 2012 sea-ice minimum was 11.83 million square kilometers less than the sea-ice maximum on 20 March 2012, reflecting the environmental state-change from a polar marine system dominated by old perennial sea ice to a new Arctic Ocean dominated by young first-year sea ice. Overall, the coverage of sea ice in the Arctic Ocean has been diminishing faster than 10% per decade. Sea-ice extent is derived from data captured by the Scanning Multichannel Microwave Radiometer aboard the Nimbus-7 satellite from NASA and the Special Sensor Microwave Imager aboard multiple satellites from the United States Defense Meteorological Satellite Program. This image is generously provided by the NASA Goddard Space Flight Center (GSFC) Scientific Visualization Studio with the Next Generation Blue Marble data courtesy of Reto Stockli (NASA/GSFC) through www.nasaimages.org.

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

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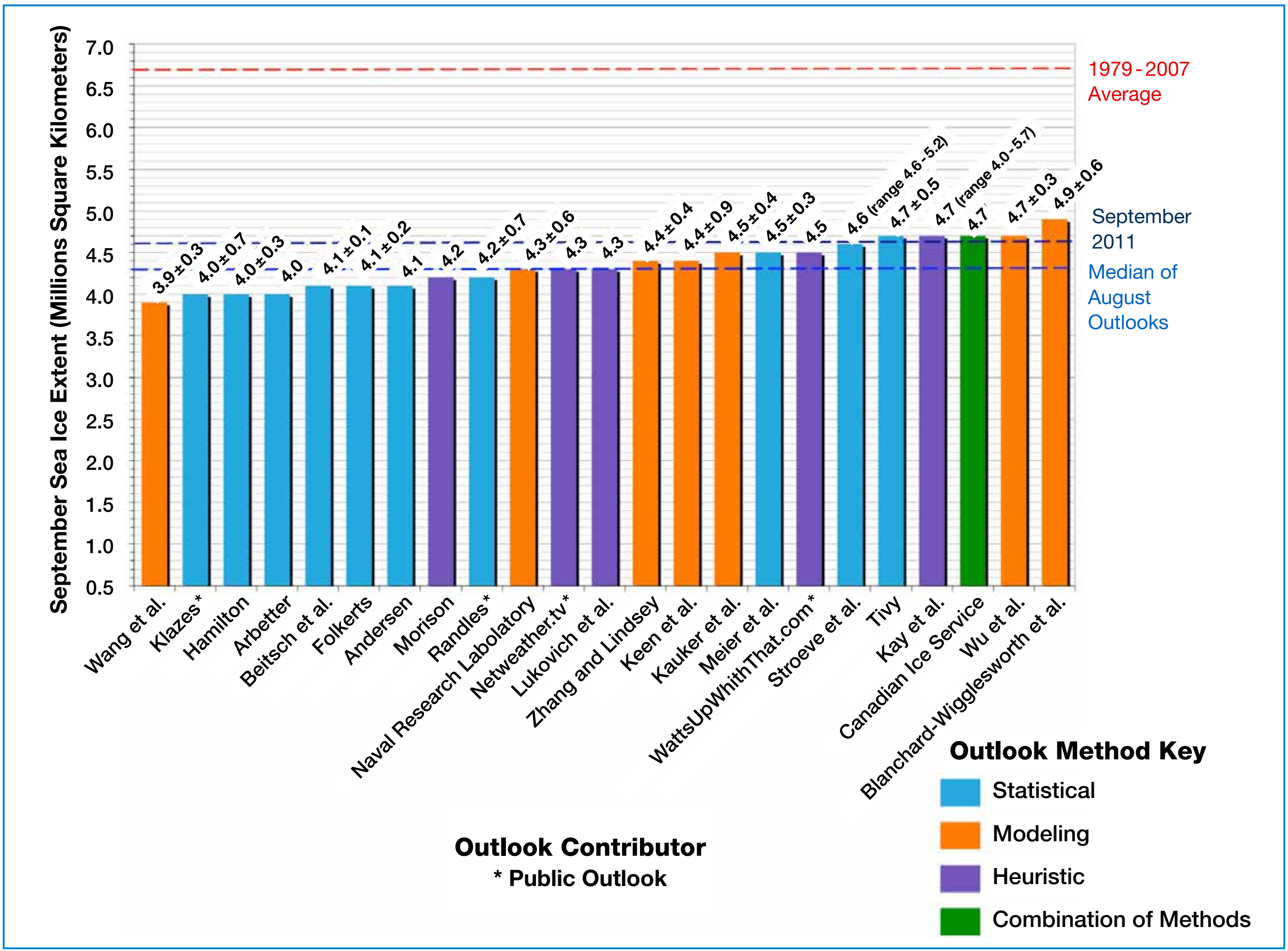
Editorial

Thematic Integration Across the ACCESS Project

This ACCESS newsletter focuses on "Modeling" in view of the interdisciplinary scope and spirit of the ACCESS project. Importantly, modeling activities cross all aspects of the ACCESS project to deliver practical policy and infrastructure options for responding to the rapidly changing Arctic Ocean.

This newsletter is very timely. On September 16, 2012 (cover figure), a new record minimum of Arctic sea-ice extent record was reached (3.4 millions km²), which was far below the previous minimum reported in September 2007 (4.1 millions km²). Attempts to predict the mean September sea-ice extent for 2012, even as late as July and August, underestimated the record minimum that was reached this year (figure below). The 2012 development and the attempts to predict the sea ice minimum highlight a number of important aspects with respect to modeling and field research (which will be the focus of the next ACCESS newsletter) very relevant for ACCESS.



2012 Sea Ice Outlook: August Report. *Bar chart showing results of the August 2012 Sea Ice Outlook (SIO), which is organized by the Study of Environmental Arctic Change (SEARCH) and the Arctic Research Consortium of the United States (ARCUS) with diverse international volunteer contributions (http://www.arcus.org/search/seaiceoutlook/2012/august). The SIO was initiated during the 2007-2009 International Polar Year between United States and European institutions through the SEARCH FOR DAMOCLES consortium. Since 2008, expert groups have been cooperating to provide estimates of the September sea ice minimum for the Arctic Ocean each month after the onset of the melting season. A variety of methods are applied, ranging from heuristic to statistical and to numerical modeling. For 2012, all of the SIO groups estimated the mean September extent to be greater than the observed extent. ACCESS partners AWI, OASys, and FastOpt contributed to the 2012 SIO (see 'Kauker et al.' in the figure), using ensemble integrations with the coupled sea ice-ocean model NAOSIM forced by spring to summer atmospheric conditions of preceding years to estimate a potential range of sea-ice extents. The September value of the ensemble mean in their simulations is 4.46 million km². The standard deviation of the ensemble is 0.38 million km². However, one of their ensemble realisations applying the August and September atmospheric conditions of 2007, actually provided a mean September minimum of 3.6 million km².close to the observed minimum. This is an indication that actually the Arctic sea ice cover has been ripe for a new record minimum, given that the 'favorable' atmospheric conditions prevail.*

Following the three decades of decline in ice extent and ice thickness, the Arctic sea ice cover today is much more vulnerable to external forcings as compared to earlier times. Atmospheric or oceanic conditions, which in the 1980s would not have significantly impacted the sea ice extent, now lead to large areas of open water. This holds even more for extreme weather events like the large Arctic storm that occurred during the first week in August 2012 and led to the new record ice minimum in September 2012.

As a consequence of the increased vulnerability of the thinner sea ice, the knowledge of the initial sea ice thickness at the end of the winter, plus a continuous monitoring of the sea ice thickness development during the summer season is essential. Regarding prediction timescales of several days, improvement of numerical weather prediction (NWP) by enhanced atmospheric observations in the Arctic and improved models are needed.

On timescales beyond weather (i.e., weeks to decades), the vulnerability of the sea ice in combination with the natural variability of the Arctic climate system, makes it impossible to come up with accurate predictions seasons in advance. However, with ongoing modeling and research, we will be better able to project a range of potential future states of Arctic sea-ice cover. Such future scenarios are necessary to identify infrastructure and policy options for addressing economic activities that include destinational and trans-Arctic shipping, oil and gas exploration, fisheries and tourism.

Modeling activities of the ACCESS project, which are represented in this newsletter, illustrate strategies to estimate and interpret the impacts of climate change as well as the expanding commercial activities in the Arctic Ocean. These impacts are being considered at local, regional and international levels with regard to socio-economic systems, cultures and governments. Reflecting the interdisciplinary and cross-sectoral approach of the ACCESS project, the organization of this newsletter is related to thematic topics such as:

1/ Climate, Weather and Environmental Changes in the Arctic Ocean and improving predictions and forecasts;

2/ Socio economic impacts in the changing Arctic Ocean such as marine transportation, fisheries and oil and gas extraction;

3/ Risk assessments in the changing Arctic Ocean related to oil spills, noise affecting marine mammals and air pollution due to increased activities in and around the Arctic Ocean;

4/ Integrated Policy Development in the changing Arctic Ocean with regard to the time scales of climate change and holistic perspectives under the framework of ecosystems based management.

Overall, the objective of ACCESS modeling activities is to provide a scientific foundation that will facilitate sustainable development in a changing Arctic Ocean with balance between environmental protection, economic prosperity and social equity.

Interdisciplinary Modeling in the ACCESS Project

Varying levels of details with the following model descriptions reflect different levels of progress with these ACCESS activities.

Climate, Weather and Environmental Changes in the Arctic Ocean

MODELLING THE ARCTIC SEA-ICE DISTRIBUTION AND ITS VARIABILITY

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The knowledge of the Arctic sea-ice property distributions and their variability is of great interest to various groups. For example, shipping companies might be interested in the current sea ice concentration along the North-East Passage and the likelihood of open water passage during coming August. Climate scientist would like to know the area of open water to calculate the heat stored in the upper ocean that would later be available to melt or prevent the formation of sea ice. A large number of field observations aimed at these problems are carried out. However, they are impossible to perform over the whole Arctic Ocean. Satellite observations are available for some sea ice properties, however, these measurements suffer from uncertainties especially during the summer months.

An alternative approach is the reconstruction of the sea ice state using numerical sea ice model hindcasts that have been optimized using the available observations. They can also be used for forecasts of sea ice properties given atmospheric and oceanic forcing fields. True predictions require well-initialized ocean-sea ice-atmosphere models. For long-term developments we rely on emission scenarios applied to coupled climate models. All above approaches are employed within WP1. Here, we focus on the analysis of coupled climate model results. We are especially interested in recent trends and variability in sea-ice concentration and thickness as well as their projected changes during the next decades.

Within the Coupled Model Intercomparison Project phase 5 (CMIP5) more than 30 global climate GCMs (general circulation models) provide sea-ice parameters for historical simulations (for the 20th century and the early years of this century) and possible future warming scenarios. A comparison of the historical simulations with satellite-derived sea ice fields is used to identify the range of GCM sea-ice distribution and variability. The winter sea-ice edge was situated in the southern Barents Sea during 1979-2005. For this time period, several CMIP5 models overestimate the ice coverage in the Barents Sea and thus overestimate the seasonal variability (Fig. 1).

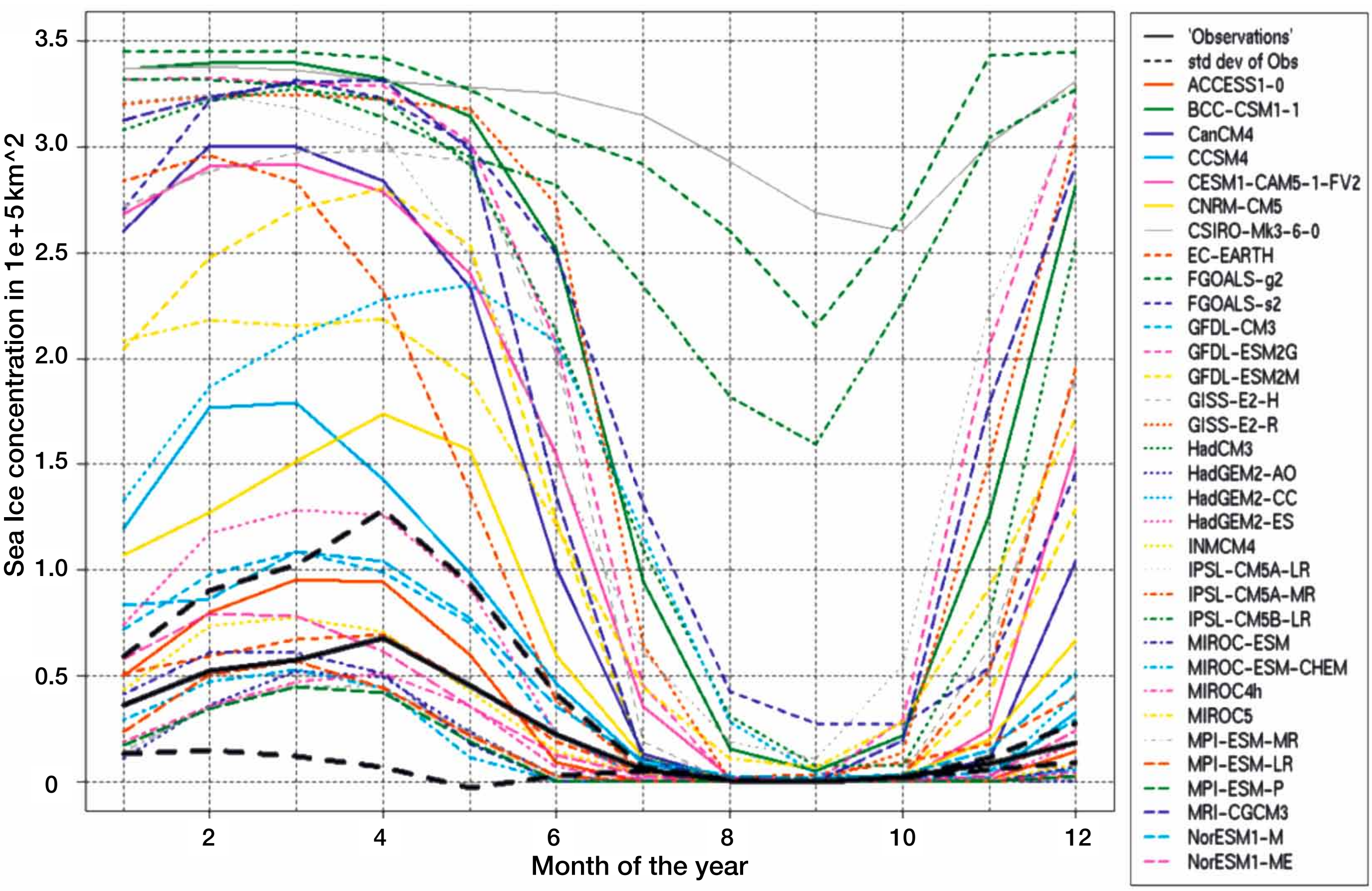

Figure 1 - The mean seasonal cycle of area integrated sea-ice concentration in km² for the years 1979-2005. CMIP5 models are compared to Satellite derived 'observations' in the southern Barents Sea.

We use a cost function approach to filter out the six best-performing GCMs in terms of sea-ice concentration focusing on the Barents Sea, the Kara Sea and off the western coast of Greenland. These regions are deemed to be especially important for oil and gas extraction over the next few decades. The variability between the so filtered GCMs is still large, especially for the Barents Sea, as seen in the monthly mean sea-ice concentration of April 2012 (Figs. 2-3).

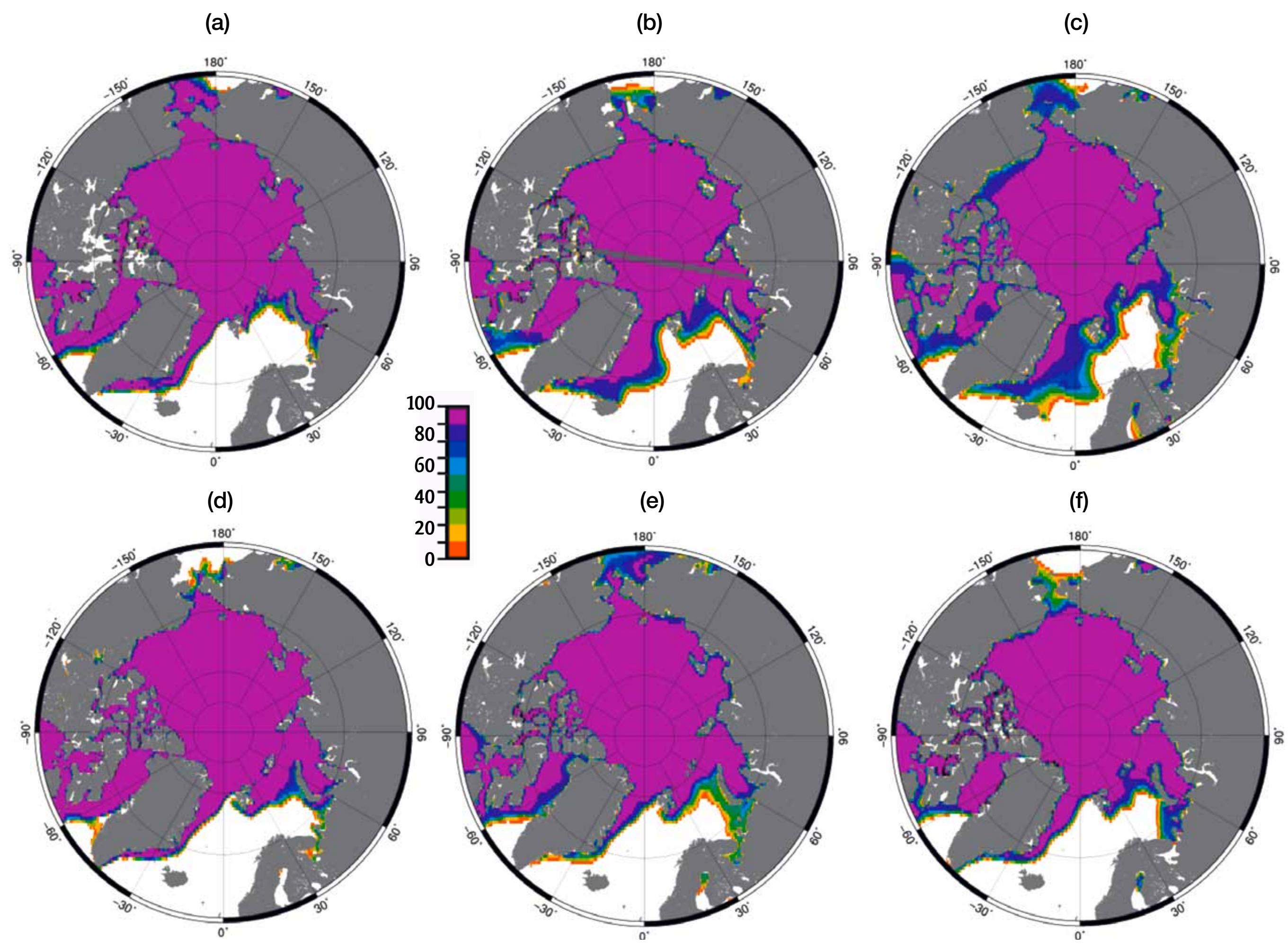

Figure 2 - Sea-ice concentration in % at April 2012. CMIP5 models (simulation RCP 4.5) : (a) ACCESS1.0 (b) GFDL-CM3 (c) INMCM4, (d) MIROC4h, (e) MPI-ESM-LR and (f) NorESM-ME.

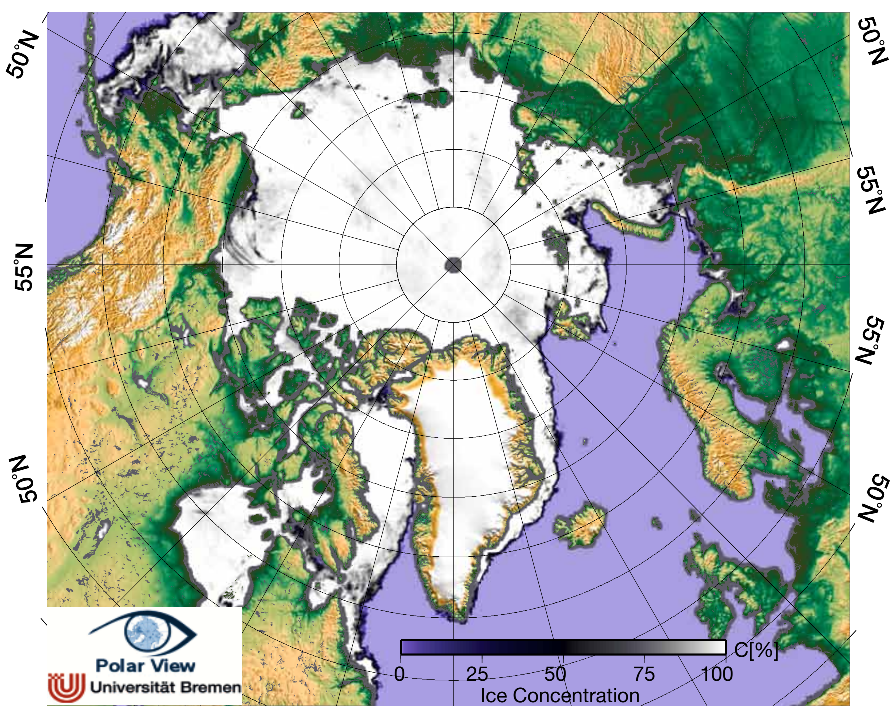

Figure 3 - Polar View of the University of Bremen, satellite-derived sea-ice concentration at 15 April 2012.

The sea-ice concentration varies between the models, a similar spread is visible in the mean sea-ice thickness (Fig. 4). Three things can be noted in Fig. 4 : (i) The model variability is expressed by the fact that all six models agree on decreasing mean sea-ice thickness until 2040. However, they do not agree on the strength of the decrease. (ii) A strong natural variability is indicated by the model INMCM4, which computes a maximum of 2.2 m in April 2018 exceeding the sea-ice thickness in all years prior by a minimum difference of 0.3 m. (iii) There is no clear distinction between the two future scenarios RCP 4.5 and RCP 8.5, which differ in the amount of greenhouse gas (GHG) emissions (Moss et al., 2010). The mean thickness seems to develop independently of this strength in the scenarios.

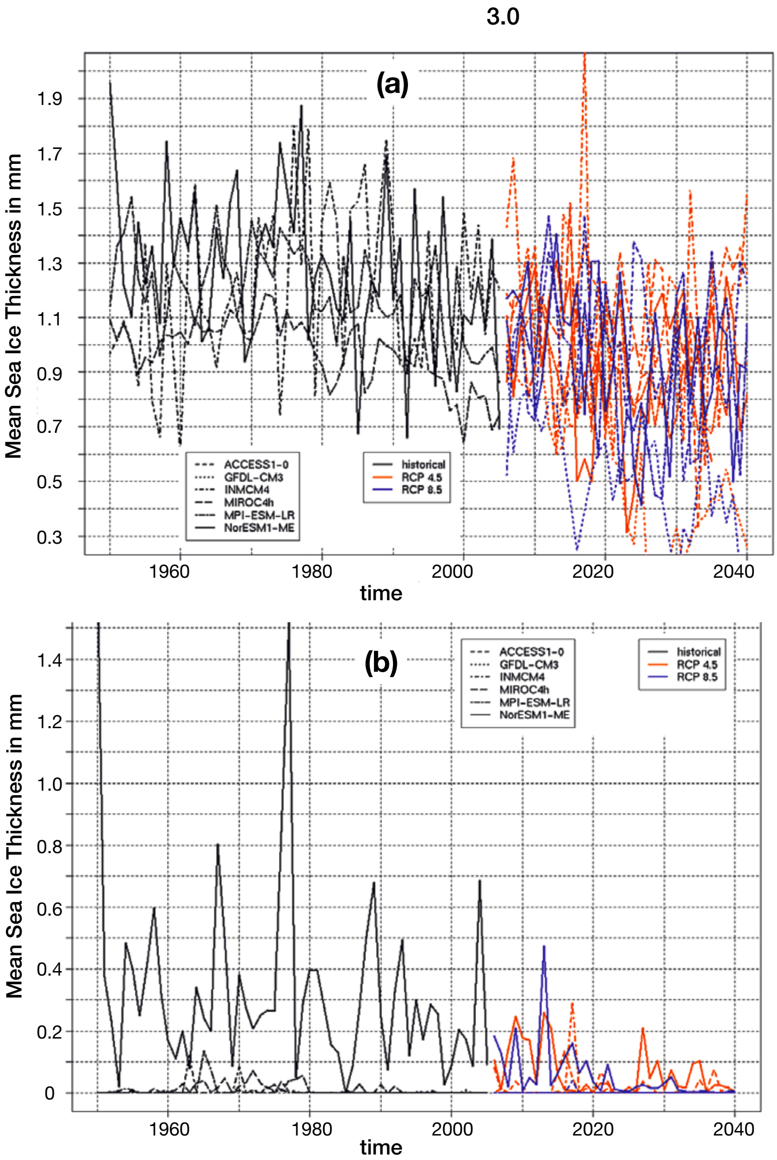

Figure 4 - Mean sea-ice thickness in m in the Kara Sea between 1950 and 2040 in April (upper panel) and September (lower panel). The line type indicates the CMIP5 model, the colour indicates the simulation. The GHG emissions are stronger in the future scenario RCP 8.5 than in RCP 4.5 (Moss et al., 2010).

Global climate models usually use a relatively coarse grid resolution due to computational costs. However, the sea-ice distribution depends strongly on ocean currents, which can only be simulated realistically in higher resolution models. Therefore, we will use a regional ocean-sea ice model with a higher resolution where the atmospheric fields will be taken from selected CMIP5 models. Using several CMIP5 models to provide atmospheric data to force our regional model takes into account the range of possible future developments and also considers the non-linear reaction of ocean and sea ice to atmospheric variability.

Citations

Moss, R.H., Edmonds, J.A., Hibbard, K.A., Manning, M.R., Rose, S.K., van Vuuren, D.P., Carter, T.R., Emori, S., Kainuma, M., Kram, T., Meehl, G.A., Mitchell, J.F.B., Nakicenovic, N., Riahi, K., Smith, S.J., Stouffer, R.J., Thomson, A.M., Weyant, J.P. and Wilbanks, T.J. 2010 : The next generation of scenarios for climate change research and assessment. *Nature* 463:747-756, doi :10.1038/nature08823.

PROSPECTS FOR DEVELOPMENTS OF ARCTIC NWP AND OBSERVING SYSTEM REQUIREMENTS

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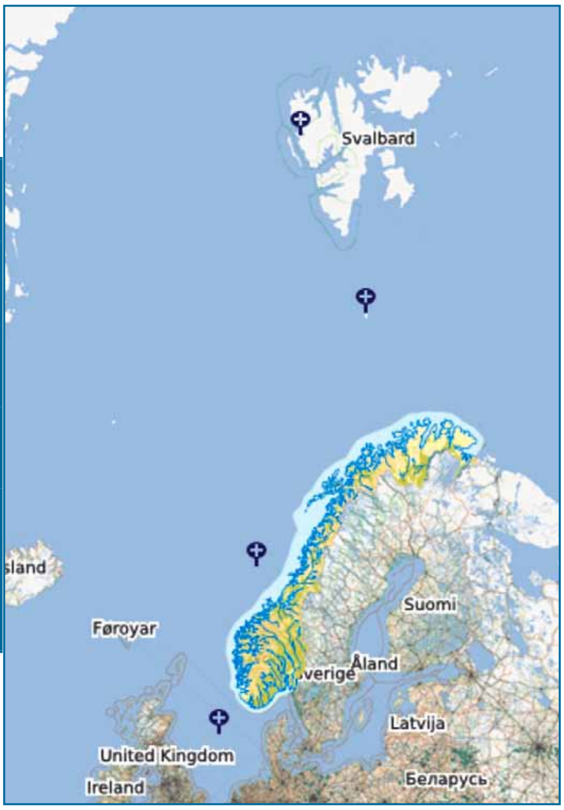
To ensure safety in the increased economic activities in the Arctic, forecasting capabilities are important for predicting the environment the operations will meet. Of particular importance is warning of risk of hazardous weather or ocean conditions. The present situation is that forecast errors from the operational Numerical Weather Prediction (NWP) models are increasing towards higher latitudes. The figure below shows the location of four meteorological observing stations and the verification statistics for the Norwegian operational limited area model HIRLAM for these stations (mean sea level pressure error statistics in hPa based on a composite of forecast lengths from 18 to 42 h for the period 1 January to 30 September 2010. Also, for instance the ECMWF global model used for longer range forecasting shows similar increased errors at high latitudes.

The basic reason for this situation is believed to be in the present operational observing system for meteorology, with scarcity of for instance radiosondes profiling the atmosphere and surface observations in the northern ocean and over the sea ice areas. Availability of satellite data is not sufficient for fully alleviating this situation. As a part of ACCESS, the Norwegian Meteorological Institute is doing an analysis towards what would be the best way of helping this situation in the future. Cost effectiveness and deploying observations at the right locations is seen as important for planning the future evolution of the observing system. The analysis will start with a more complete assessment of the NWP forecast quality in the Arctic, which will give a more complete picture than the figures presented below (Table 1). This will be complemented with an analysis of the various observations contributing to the present forecasting capabilities, and their relative importance. This will be done with so called "data denial" studies in the NWP system. Finally we will propose and analyse scenarios for how forecasting capabilities are likely to evolve in the future and give recommendations for key areas to improve the capabilities based on simulating the future observing system. This activity at the Norwegian Meteorological Institute is complementary to an activity in the project done by FastOpt and OASys to assess the observation requirements for longer time scale forecasting.

Table 1: Latitudinal Transect Of Stations
(See Insert)

Station	Latitude (°N)	Mean Error	STD	RMSE
Ny Ålesund	78.9	0.6	1.3	1.5
Bjøyrnøya	74.5	0.5	1.4	1.5
Heidrun	65.3	0.2	1.2	1.2
Efofisk	56.5	0.0	1.1	1.1



Testing The Impact Of Observations With Quantitative Network Design

TESTING THE IMPACT OF OBSERVATIONS WITH QUANTITATIVE NETWORK DESIGN

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For an offshore platform, information about the ice conditions expected for the next few days in its vicinity is crucial. Similarly, for shipping companies, a forecast of the ice conditions along, say, the Northern sea route is clearly desirable. If we replace 'ice conditions' by 'ice thickness', these are just two examples of physical quantities of interest, which are not observable. In this case, this is because these *target quantities* refer to a period in the future. In other cases, the target quantity may not be accessible through direct measurements. For example, we cannot directly measure the ice export through Fram Strait or the mean temperature of the Arctic ocean. We can, however, simulate all the above examples of target quantities with a numerical model of the Arctic Ocean sea-ice system such as NAOSIM (Kauker et al., 2003).

A drawback of such model simulations is that they are uncertain for a number of reasons. Among these reasons are uncertainties in input quantities to the simulation, such as the state at the beginning of the simulation (initial state) and the atmospheric boundary condition over the simulation period. Also, there are uncertain constants in the formulation of the model (process parameters). Observations of the ocean sea-ice system have the potential to reduce this uncertainty. Variational Data Assimilation systems systematically combine observational information with numerical models and prior information on a control vector that is composed by a combination of the above quantities (initial and boundary conditions and process parameters). For example, NAOSIMDAS, a variational assimilation system constructed around NAOSIM, which has been applied to prediction of the Arctic ice concentration on seasonal time scale (Kauker et al., 2010).

Advanced data assimilation systems are also capable of inferring posterior uncertainty ranges of the control vector (composed of initial and boundary conditions and process parameters) such that they are consistent with the data uncertainty, i.e. the uncertainty ranges associated with the observations. The data uncertainty is the combination of observational and model uncertainty, the latter reflecting residual imperfections in the model that cannot be resolved by optimising the control vector. In a second step these posterior uncertainty ranges can then be mapped forward onto uncertainty ranges in a target quantity. Doing this uncertainty propagation twice, with and without observations, quantifies the added value through the observations in terms of an uncertainty reduction in the target quantity. For an example expressing the added value of atmospheric carbon dioxide observations for constraining net and gross carbon fluxes simulated by a terrestrial biosphere model see Rayner et al., 2005.

Quantitative Network Design (QND) systems exploit this capability of uncertainty propagation. They are built around assimilation systems (Fig. 6) and calculate posterior uncertainty ranges in one or several target quantities that are consistent with data uncertainties in given observational networks. The methodology (see Kaminski and Rayner, 2008) can also be applied to hypothetical observations, provided that: (1) they can be simulated with the model and (2) the data uncertainty can be estimated.

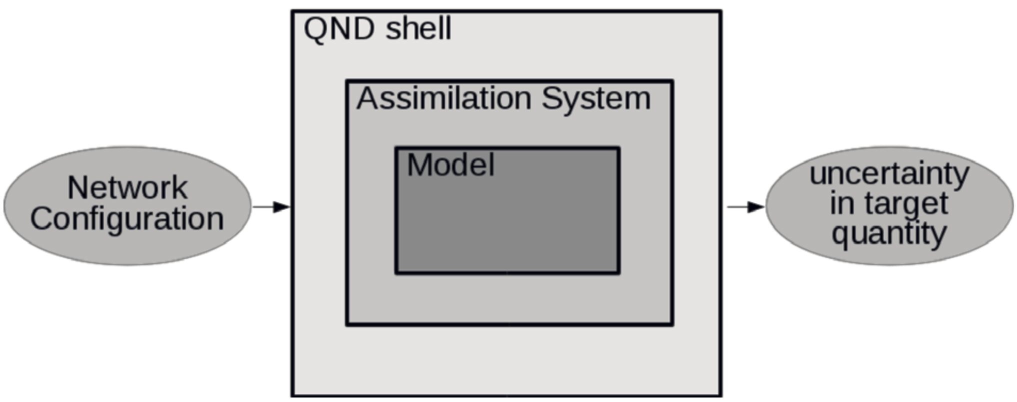

Figure 5 - Schematic Presentation of Quantitative Network Design Procedure. Network configuration includes samples quantities, sampling times and locations and data uncertainty.

A QND system is, hence, capable of assessing the performance of a set of candidate networks, as quantified by the uncertainty in a set of target quantities. This means we can use a QND system to construct network configurations that meet the requirements of stakeholders such as shipping companies or offshore platforms. The technique is successfully applied in other areas of environmental science, e.g. to networks observing the global carbon cycle: Kaminski et al. (2010) applied QND to evaluate a mission concept for observing atmospheric carbon dioxide from space. An interactive QND system (publicly available at http://imecc.ccdas.org) for atmospheric and terrestrial observations constraining the terrestrial biosphere was set up and applied by Kaminski et al. (2012).

Within ACCESS a QND system is being built around NAOSIM by FastOpt and OASys. In August 2012, a basic demonstrator around a coarse resolution version of the model was completed. The model is set up for a simulation period covering January 2007 and uses a seven dimensional control vector composed of scalar multipliers for the initial ocean temperature, the atmospheric temperature, and the zonal wind stress component as well as two parameters of the ocean component and two of the sea-ice component. As target quantities it offers Arctic-wide average values of the ocean kinetic energy, the ocean temperature and salinity as well as the total ice volume and area. The QND system allows to test networks composed of daily samples of up to three data streams. They are ice concentration and thickness as well as snow thickness are available over the entire model domain, which is north of 54 degree North.

The respective data uncertainties and the number of daily samples are flexible. As an example, Figure 6 displays an evaluation of three networks sampling ice concentration with ice volume and area as target quantities. All networks cover the entire model domain with a data uncertainty of 20%, but they differ in the number of daily samples. The first network (blue bars) samples every day in January, while the second (orange bars) samples only the first week and the third (yellow bars) only the first two days. The quantity displayed is uncertainty reduction in the target quantities, relative to the prior uncertainty (i.e. a case without any observations). A value of 0% means the observations do not reduce any uncertainty, while a value of 50% means the posterior uncertainty is half of the prior uncertainty. We can note at least two things: First, even though we are observing ice concentration, the uncertainty reduction for ice volume is higher than for ice area. This is because the volume is the product of area and thickness. Any uncertainty reduction in the area will, hence, also show up in the volume. On top, the volume is affected by uncertainty reduction in the thickness, which, through the dynamics of the model, is linked to ice concentration. Second, the shorter the observed period the higher the posterior uncertainty. Unfortunately our initial examples, forecasted ice thickness around a platform or a shipping route, are more similar to the 1 week or the 2 day case, where (most of) the target quantity extends into the future. By contrast, retrospective analyses of the Arctic system use a setup similar to the 1 month case.

We further note that this basic setup has only demonstrator character and the above numbers are only preliminary. In the course of the project, we will refine this setup to study networks addressing questions related to ACCESS Work Packages: 1 (Climate Change and the Arctic Environment), 2 (Marine Transportation and Tourism) and 4 (Resource Extraction).

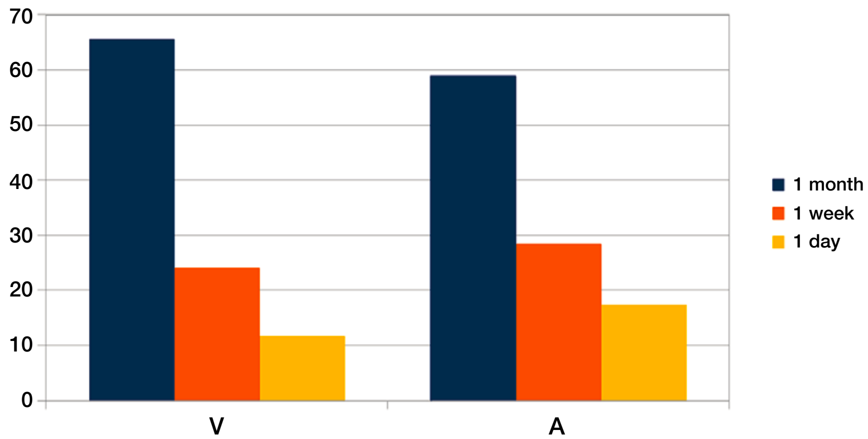

Figure 6 - Uncertainty Reduction in % for total ice volume (V) and total ice area (A) averaged over January 2007 and model domain for daily samples of ice concentration over every grid cell at every day (blue), the first seven days (red) and the first two days (yellow) in January.

Citations

Kaminski, T. and Rayner, P.J. 2008. Assimilation and network design. In H. Dolman, A. Freibauer, and R. Valentini, editors, Observing the continental scale Greenhouse Gas Balance of Europe, Ecological Studies, chapter 3, pages 33-52. Springer-Verlag, New York.

Kaminski, T., Scholze, M. and Houweling, S. 2010. Quantifying the Benefit of A-SCOPE Data for Reducing Uncertainties in Terrestrial Carbon Fluxes in CCDAS. *Tellus B*, 62(5):784-796.

Kaminski, T., Rayner, P.J., Voßbeck, M., Scholze, M., and Koffi. E. 2012. Observing the continental-scale carbon balance: assessment of sampling complementarity and redundancy in a terrestrial assimilation system by means of quantitative network design. *Atmospheric Chemistry and Physics*, 12(16):7867-7879.

Kauker, F., Gerdes, R., Karcher, M., Köberle, C., and Lieser, J.L. 2003. Variability of Arctic and North Atlantic sea ice: A combined analysis of model results and observations from 1978 to 2001. *J. Geophys. Res.*, 108(C6).

Kauker, F., Gerdes, R., Karcher, M., Kaminski, T., Giering, R., and Voßbeck, M. 2010. June 2010 Sea Ice Outlook - AWI/FastOpt/OASys. *Sea Ice Outlook web page*, June 2010.

Rayner, P., Scholze, M., Knorr, W., Kaminski, T., Giering, R., and Widmann, H. 2005. Two decades of terrestrial Carbon fluxes from a Carbon Cycle Data Assimilation System (CCDAS). *Global Biogeochemical Cycles*, 19(GB2026) :doi:10.1029/2004GB002254.

MODELLING SHIP TRAVELLING TIME ON THE NORTHERN SEA ROUTE

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Goals: Using an existing simulation tool developed by HSVA (Lübcke 1998), the average travelling time for three different ship types on the Northern Sea Route have been calculated. The investigation is carried out for different route options with regard to the passage either north or south of Novaya Zemlya and Novosibirskiye (Fig. 7). The average travelling time for different ships is mainly depending on the ice breaking capability and ice conditions on each route. Therefore the simulation may indicate future development and profitability of arctic traffic due to changes of ice conditions compared to the conventional Suez route.

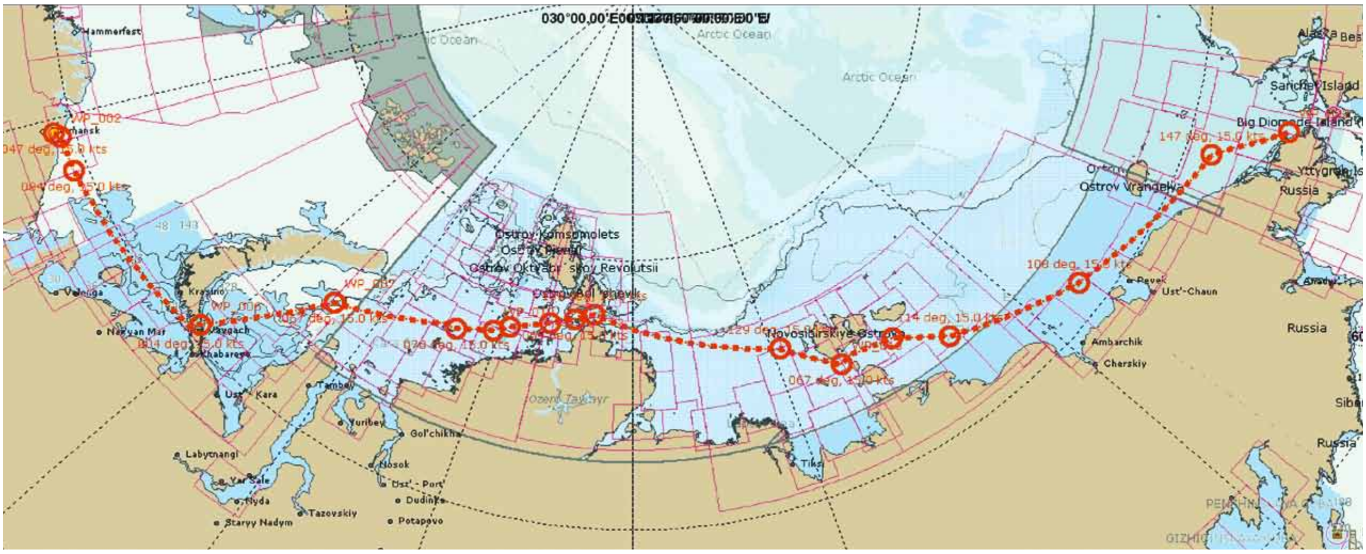

Figure 7 - Example for possible route from Murmansk to Bering Strait along the Northern Sea Route (Kaestener, 2012).

Model Parameters: For the current model three different months within the years 2000 and 2007 were chosen, namely March, September and November, to compare the arctic winter, summer and freeze up period. The simulation is based on different approaches for ship resistance in different sea conditions while the focus is put on navigation in ice. The complete route is divided into legs while the length of each leg is chosen differently between 40 nm and 200 nm with respect to the change of environmental conditions (ice, seaway, water depth etc.). These environmental factors are punched into an input file. Additionally for each representative ship type all relevant data like main dimensions of the ship, hull shape and propulsion arrangement (engine, propeller combination) are included. Finally some limiting boundary conditions are set in order to avoid unrealistic traffic conditions. Minimum and maximum values for the average speed are included as even in moderate ice conditions ships have to reduce their speed for safety reasons and in very severe ice conditions the ship will call for icebreaker assistance if the speed is too low.

Results: The comparison for travelling time on the NSR between the years 2000 and 2007 is shown in Figure 8. The triple-digit codes below columns in Figure 8 are labels for the different route options mentioned above. Comparing the data an obvious decrease of travelling time for the year 2007 may be stated for all arctic route options. In September the difference between two years is not as significant as in November as the summer ice conditions have already been moderate in 2000. For November the difference between both years is showing an extension of whole possible operating season by one month for 2007.

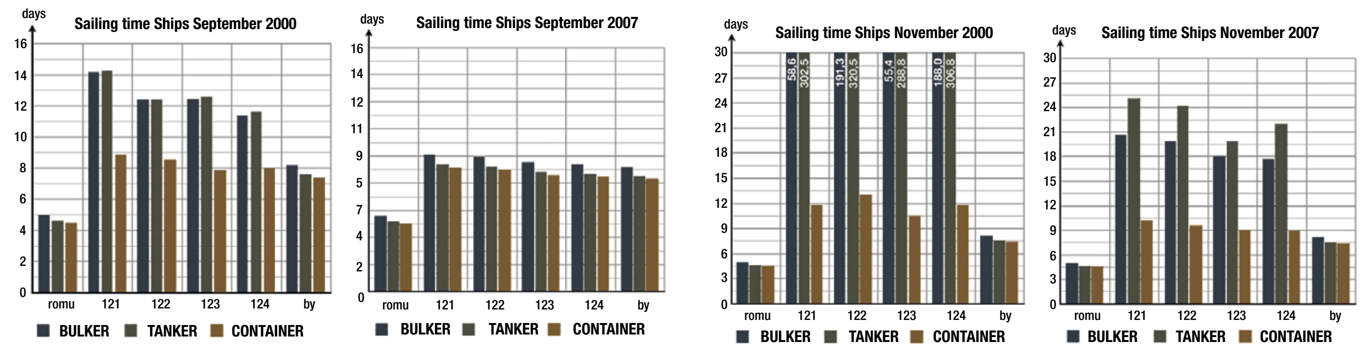

Figure 8 - Comparison of sailing time in days for the Northern Sea Route (from left to right) for September 2000, September 2007, November 2000 and November 2007 with regard to bulker, tanker and container ships.

Citations

Lübcke, L. 1998. 'Geschwindigkeitsprognose im Eis', Studienarbeit an IfS / HSVA.

Kaestener, J. 2012. Effects if ice reduction on Arctic Shipping and possible threats to the polar region by the increasing use of new routing – The Northeast Passage (NEP), *Bachelor Thesis,* University of Applied Sciences Technology, Business and Design Wismar.

MODELLING SHIP FUEL CONSUMPTION AND EXHAUST EMISSION ON THE NORTHERN SEA ROUTE

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Goals: Based on the results of the travelling time analysis, the fuel consumption and exhaust emission of typical merchant ships on transit using the Northern Sea Route is to be investigated. Therefore the existing simulation tool has to be further developed by including realistic approaches for fuel consumption of different propulsion concepts:

- conventional diesel driven single shaft line;
- diesel electric or pod drive; and
- LNG gas turbine.

Model Parameters: The actual fuel consumption is mainly determined by the specific fuel consumption (b) of the engine type with fuel mass flow (M) in kilograms per second and engine effective power (P) in kilowatts and the operating profile of the ship, which itself is related to the ice conditions.

$$b=M/P$$

The total amount of consumed fuel S for the route may then be calculated by summation for all n legs with travelling time (ti) for each leg.

$$S = \sum_{i=1}^{n} b_i \cdot P_i \cdot t_i$$

As in ice-infested waters, the propeller will operate in complete different conditions compared to open water (inflow speed, rotational speed, torque) the power demand will encounter strong variations. Therefore the final fuel consumption will be different for each propulsion concept. The operation condition and power consumption will also affect the exhaust gas amount and distribution. Therefore correlations between the load and speed of the engine and the amount of each exhaust component have to be implemented. Finally the calculation has to be carried out for different time periods using the same legs as described for the travelling time investigation.

Results: The calculated resistance, power and travelling time data are summarized and the modelled exhaust emission values resulting from these data are shown in Table 2.

a

Leg	Leg 1	Leg 2	Leg 3	Leg 4	Sum
Resistance (kN)	650.2	1247.39	545.19	1247.38	
Required power (kW)	3337.4	8274.3	2540.8	8274.3	
Time (h)	47	136	33	221	137
Fuel consumption kg/h)	584.05	1448.00	444.64	1448.00	
Total fuel (tons)	27.45	196.93	14.67	320.01	559.06

b

Leg	Leg 1	Leg 2	Leg 3	Leg 4	Sum
CO (kg)	203.13	12457.27	108.58	2368.06	1660.40
NOx (kg)	2141.11	15360.41	1144.50	24960.67	17501.52
SOx (kg)	1482.31	10631.13	792.35	17280.16	12116.11
HC (kg	38.98	279.64	20.84	454.41	318.62
PM (kg)	145.49	1043.72	77.77	1696.05	1189.21

Table 2 - Example for calculation of exhaust gas emission based on required power and travelling time (Duong 2012).

Connection to Work Packages: Simulations are highly sensitive to the ice input data. These data are provided by work Task No. 2.1.1 (*Analysis of Historical Sea Ice Data and Their Influence on the Navigation Along the Northern Sea Route in the 20th and the Beginning of the 21st Century*). The results of the travelling time investigation will be embedded into the work Task 2.4.1. (*Air Pollution and Surface Deposition Related to Today's and Future Arctic Shipping*). The results of the calculation of exhaust emissions will provide an independent validation data basis for the measurements of air pollution from ships conducted by DLR within work task 2.4.1.

Relevance of Models: The simulation of travelling time and fuel consumption based on realistic ship ice interaction in the arctic region may provide fundamental assistance for economic and political decisions for the future. The travelling time of ships for certain ice conditions besides safety and insurance is the main factor for the assessment of the profitability of the Northern Sea Route for purpose of transit. The accuracy of prediction of fuel consumption is highly sensitive to a realistic model for a power consumption profile of ships travelling in the arctic. Therefore the correlations between propulsion arrangement, ship speed and ice conditions need to be investigated carefully.

Citations

Duong, Q.T. 2012. Fuel Consumption of Ships in Ice Conditions. *Internal Presentation, HSVA.*

Socio-Economic Impacts in the Changing Arctic Ocean

FUEL PRICE SENSITIVITY ANALYSIS

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In Task 3.3 (*Climate Change Effects on Factor and Product Markets for Capture Fisheries*) we will undertake some not-so-sophisticated modeling, as described initially below.

Goals: The purpose of our modelling attempt is to illustrate how the fishing fleet behaviour might be altered/adjusted as a response to increased fuel prices. In a world facing climate changes one can expect national governments - or preferably international agreements - to tax carbon fuels in order to compensate for the externalities produced. In that respect it is important for authorities to know the effects on industry performance and adaptation from such measures. Through our modelling efforts we want to point out the likely response to such measures, regarding both adjustments made in the fishing activity and industry/fleet profitability.

Parameters: At hand for our analysis we have data from the annual profitability study in the Norwegian fishing fleet, together with detailed data on fleet fuel consumption (in National waters). The Norwegian fleet constitute a great share of the Arctic fish uptake and can be utilised to illustrate the effects in other national fleets as well (Russian, Icelandic, etc.) Data will be provided for the latest year available (2010 or 2011) and few restrictions apply (boundary conditions, forcing, resolution, etc,). However, the sensitivity analysis on different vessel groups (i.e. which fuel price increase is needed for a 'break-even' result) will be a static one, based on hindsight average cost and activity data, and will not consider the immediate and dynamic decisions in order to economise on fuel that vessel owners will do when confronted with higher inputs prices. Such adaptations will however be substantiated through interviews with industry actors.

Graphical Result: Figure 9 illustrates the heterogeneity of the Norwegian fleet with respect to fuel price increases. Despite the Norwegian fishing fleet's robustness to fuel price increases, some vessel groups will be affected harder than others.

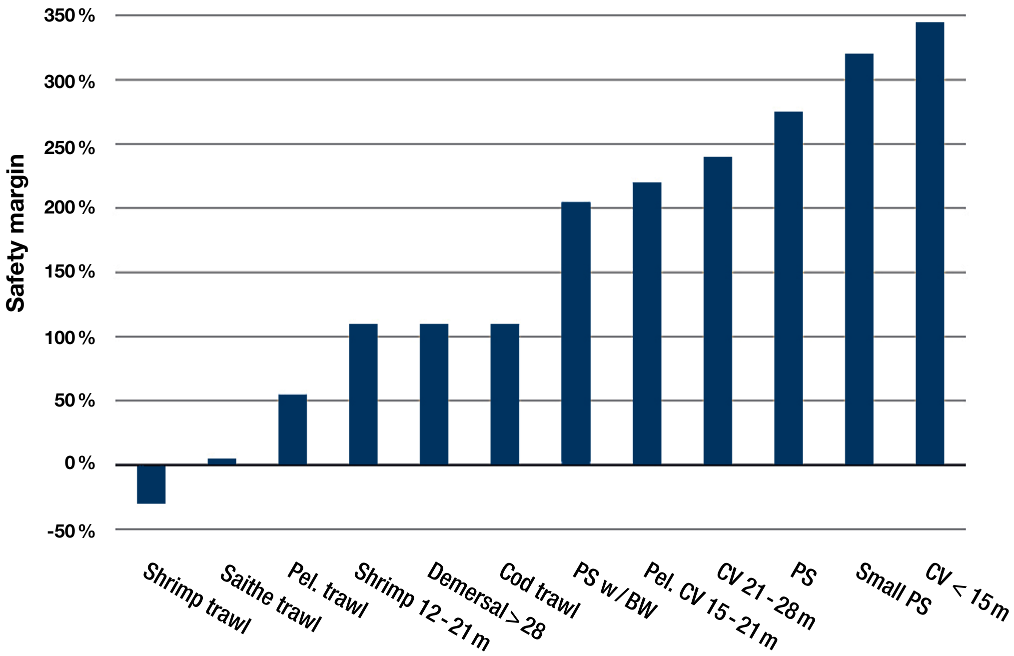

Figure 9 - "Safety margin" with respect to fuel price increase (increase needed for "break-even" result) for a sample of vessel groups in Norwegian fisheries. Average for 2004–2007. Abbrevations: Pel. = pelagic, PS = purse seine, BW = blue whiting trawl license, CV = coastal vessels (Isaksen et al. 2012).

Connection: The modeling results complement the goals of Work Package 3 (Fisheries): *"to estimate and quantify how climate changes impact Arctic fisheries... and how governance can support the fisheries industries under climate change influence."* As underlined earlier, the economic effects from, among other things input factor prices, might have more severe influence on industry performance than slowly accumulating climate changes that fishermen adopt to. Also, the interaction between climate changes in Arctic waters (fish population migration and abundance) and economic variables (input prices, distance to fishing fields) might play a more immense role for fisheries in the Arctic than climate changes alone, especially in the short and medium term.

Relevance: Results from our modeling will probably give valuable help to the authorities in providing ways to evaluate the effects from a tax on fuel in the fishing fleet. Until now, Norwegian consumers and most sectors of Norwegian industry have been subject to tax on fuels. Fishing vessels, however, have been exempted from this tax, or been reimbursed upon application. Now, politicians are questioning this exemption in their strive to make a more environmental friendly policy.

Citations

Isaksen, J. Hermansen, O. and Flaaten. 2012. Persistent subsidies in fishing: The case of fuel tax exemption in Norwegian fisheries. Paper presented at the bi-annual IIFET-conference, July 2012, Dar es Salaam, Tanzania.

MODELLING FISHERIES IN ACCESS

Arne Eide (arne.eide@maremacentre.com)

The SinMod model (see ACCESS Newsletter No. 3) provides a linkage between the physical environment and living aquatic organisms, including growth and distribution in time and space of phytoplankton and zooplankton species. This is possible because these species have strong and predictable linkages to changes in the physical environment. Taking this further to include higher trophic levels of aquatic ecosystems is however challenging, since it include species with more complex behavioural dynamics; targeting prey species of varying densities and behaviour, attempting to avoid predators with similar variability, and performing long distance annual migrations for spawning and feeding.

The spatial distributions of fish species therefore often are omitted in bioeconomic fishery models. While focusing the Barents Sea fisheries and the possible impact it may experience from climate change, the spatial distribution needs to be included (Fig. 10). It has become more and more clear that climate change first of all affects the spatial distribution of fish species.

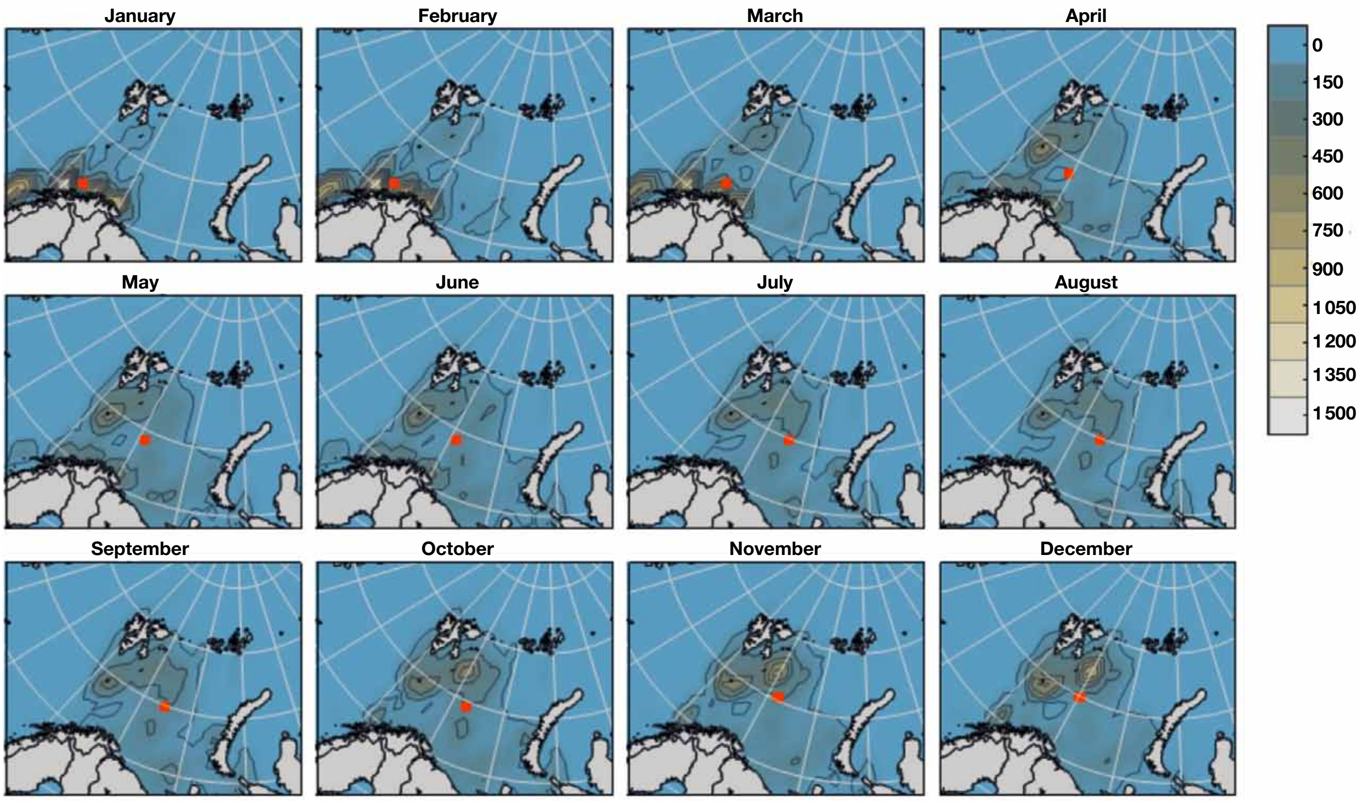

Figure 10 - Monthly distribution of cod based on catch and survey data for the period 2004-2010. The legend displays maximum values in thousand tonnes per grid cell (80 km x 80 km). The cell size is indicated by the red squares, representing biomass centres of gravity.

A spatial model with a simple structure is set up for the purpose of quantifying some effects climate change may have on the Barents Sea cod fishery. The model resolution is an aggregate of the SinMod grid. Biological growth and distribution is modeled by continuous cellular automata rules where biomass may diffuse into two neighbouring cells in all directions (range 2).

Fishing may take place in the whole area, but is constrained by economic and biological factors, in addition to fisheries management. The first also includes available fish finding technology, increasing the ability to target areas with high density of fish. Figures 11a,b display a given economic and technological performance of a fixed fishing effort associated with two different home ports. The model is parameterised on the basis of empirical data. Possible changes in spatial distribution caused by climate change will be investigated and compared with the zero scenario (current situation), assuming different management regimes. The combined effect of increasing fuel prices and changing distances to fishing grounds represent issues that may be studied within the framework of this model.

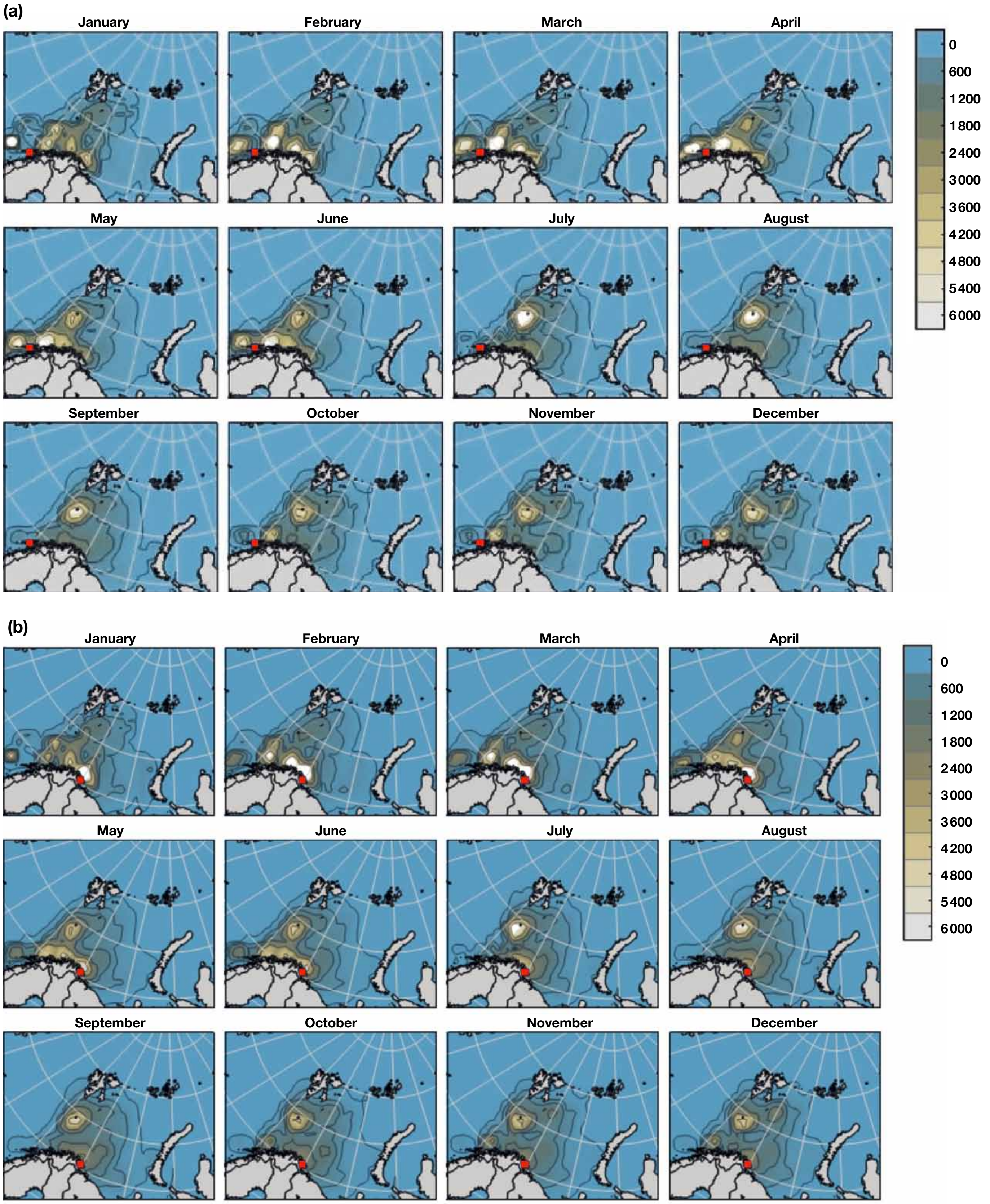

Figure 11 - Simulated monthly distribution of cod catches (in tonnes per cell) from ports in Norway: (a) southern port of Lofoten and (b) northern port of Finmark. The location of the fishing ports are marked with red squares corresponding to the resolution of the model.

SOCIO-ECONOMIC IMPACTS OF THE EXTRACTION OF ENERGY RESOURCES

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Modelling efforts of ACCESS Task 4.1 (*Socio-economic impacts of resource extraction*): Within ACCESS Task 4.1, the economics subgroup within WP 4 (IfW, EWI) will assess the socio-economic impacts of the extraction of energy resources in the Arctic. This includes the development of scenarios how, where and when Arctic energy resources will be produced and delivered to which markets. Apart from varying assumptions about the development of international oil and gas markets and economies, these scenarios will be based on information on sea ice from WP1, complemented by estimates of production costs and local employment effects depending on different technologies, as provided by IMPaC. The scenarios form the basis for our modeling efforts. These efforts aim at evaluating the consequences of resource extraction for import composition and import quotas of European economies and beyond as well as European and global transport routes and modes. We will also evaluate the consequences for substitute fuels and non-energy economic sectors including distributional implications within Europe and beyond, such as implications for welfare and trade.

The modeling work will be carried out using EWI's global gas markets model COLUMBUS (formerly MAGELAN) and IfW's global computable general equilibrium model (CGE) model DART. Furthermore, EWI is at the moment developing an oil market model as well, which might be used within ACCESS. The use of both models ensures a balance between sufficient detail and necessary scope. We attempt to iterate the models to cover and quantify repercussions between energy supply from the Arctic and according demand from European and other markets as well as between gas markets and the rest of the economy.

The COLUMBUS Gas Market Model (EWI): The COLUMBUS model (previously called MAGELAN) is a long-term optimization model to simulate possible developments on the natural gas market for the period from 2010 to 2050, while taking account of global interdependencies (Fig. 13). At the same time, COLUMBUS has been designed as a dynamic, spatial and intertemporal model.

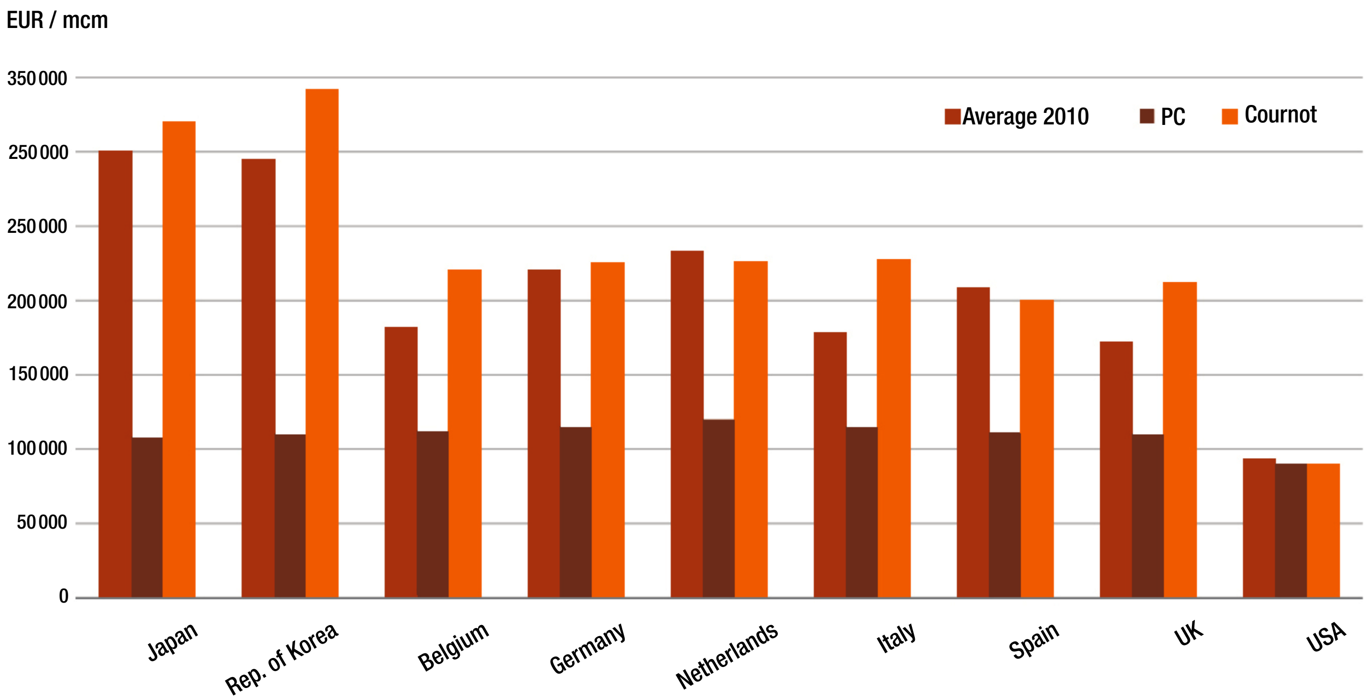

Figure 12 - Comparison of the annual average gas price in 2010 and gas prices modeled with COLUMUS using two different assumptions regarding competitiveness, Cournot and Perfect Competition (PC), of the global natural gas market. Modelled natural gas prices fit realised gas prices in 2010 better when players in the market are allowed to act strategically

The model is supply-based, and the aim of the basic version is to satisfy the demand for gas at the lowest possible cost. As a result, the existence of a fully competitive gas market is initially assumed. Due to the flexibility of mixed-complementary programming (MCP), COLUMBUS also has the option of showing the strategic behavior of individual players in the gas market.

On the supply side, the model includes all key gas-producing countries as well as their specific supply characteristics (production costs of various extraction sites, reserves, connection to infrastructure, non-conventional natural gas, such as 'shale gas'). COLUMBUS further permits investment decisions to be shown in terms of production sites, transport infrastructure and storage capacities.

The demand side is represented by the key demand countries, where there is the option to replace the specified fixed demand with a price-sensitive demand function. Instead of an annual resolution, the model can be calculated alternatively on a monthly basis, in order to account for the key seasonal fluctuations in demand for the natural gas market. (Fig. 13).

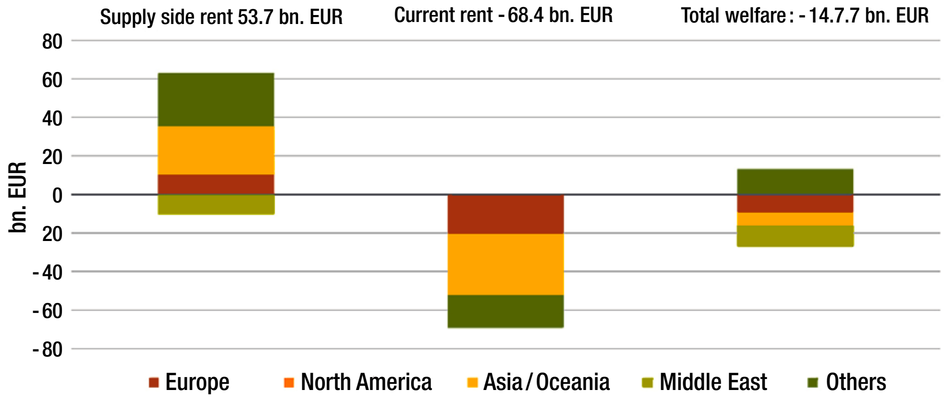

Figure 13 - Differences in welfare between a scenario with a six-months blockage / disruption of LNG supply via the Strait of Hormuz and a base-case scenario. Results from EWI's COLUMBUS model.

The model therefore permits a consistent, quantitative investigation of the future development paths of the natural gas market, taking account of the key fundamental data and market characteristics. In terms of results, the model provides trade flows (pipeline or LNG), marginal supply costs (price estimator assuming perfect competition) or prices determined by strategic behavior (assuming the exercise of market power), as well as the geographic distribution and level of investment in production sites and the transport and storage infrastructure. Furthermore, it is possible to examine the capacity utilisation of infrastructure (e.g. storage, pipelines, LNG terminals). [For a detailed list of publications, see www.ewi.uni-koeln.de/en/publications/working-paper/].

The DART Model (IfW) : The DART-Model of the Kiel Institute for World Economics (IfW) is a recursive-dynamic computable general equilibrium (CGE) model of the world economy that is designed for the analysis of international climate policies. The first version of DART was developed in the late 90's and used to analyze the implementation of the Kyoto Protocol by unilateral action but also to assess the effects of international capital mobility. In addition, DART was coupled to an ocean-atmosphere model, to estimate the economic costs of climate change. Today, new data allow e.g. to disaggregate the European Union into its individual member states. Besides, new topics require to continuously develop the original model, for example in order to analyze international climate and energy policies, technology transfer, or the impacts of the extended use of biofuel and increased competition for agricultural land.

DART stands for «Dynamic Applied Regional Trade». The static part of DART is a multi-regional, multi-sectoral computable general equilibrium model of the world economy. It is written in the mathematical programming language GAMS/MPSGE and is based on the GTAP7 data set of the Global Trade Project (GTAP). The 57 sectors and 113 regions of GTAP7 can be aggregated to address the question at hand. The economic structure of DART is fully specified for each region and covers production, investment and final demand. Primary factors are labor, capital and land. Details on the model setup can be found on the IfW's homepage (http://www.ifw-kiel.de/academy/data-bases/dart_e/a-short-description-of-dart/).

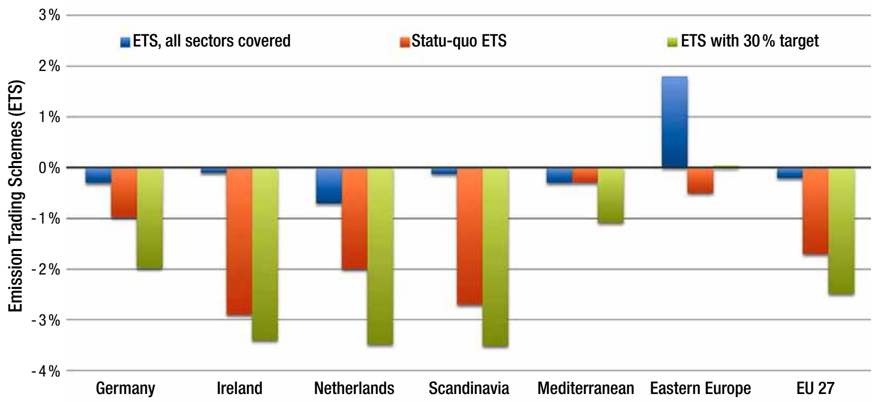

Figure 14 : Real income effects of various Emission Trading Schemes (ETS) compared to a business-as-usual scenario without climate policy. Results from IfW's DART model.

RISKS ANALYSIS OF OIL SPILLS IN THE ARCTIC OCEAN

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Task 4.4. (*Assessment of Environmental Risks Related to Resource Exploration, Extraction, and Transportation, and Contingency Planning for Mitigation of Risk*) focuses on the assessment of environmental risks of resource exploration, extraction and transportation in Arctic waters. An initial report on the status of oil spill response capabilities and technologies in ice-covered waters has been completed. The behaviour of different types of oil and gas products in cold environments will be investigated at laboratory scale, and the impact of potential oil spill scenarios for different climate change predictions will be elucidated. The task will provide recommendations for the design of an observing system tailored to safe resource extraction, and evaluate the accuracy of iceberg remote detection, trajectory forecasting, and tracking.

The oil spill modelling will produce information to support decision-making in regard to preparation for oil spill response as well as exploration planning with regard to potential environmental effects of accidental releases of oil. Operational short- to medium-range forecasting capability will be provided by coupling the OSCAR oil spill model to the outputs of the TOPAZ Arctic Ocean model provided by the EC GMES Marine Core Service project MyOcean (www.myocean.eu.org) run by Met.no. This will create the capability to assist oil spill contingency planning within an environmental information framework already being developed by the EC. Input data for the long range forecasts will be provided from WP1 (Task 1.3.1 - *Past Change*). An example output of the oil spill assessment model is shown in Figure 15.

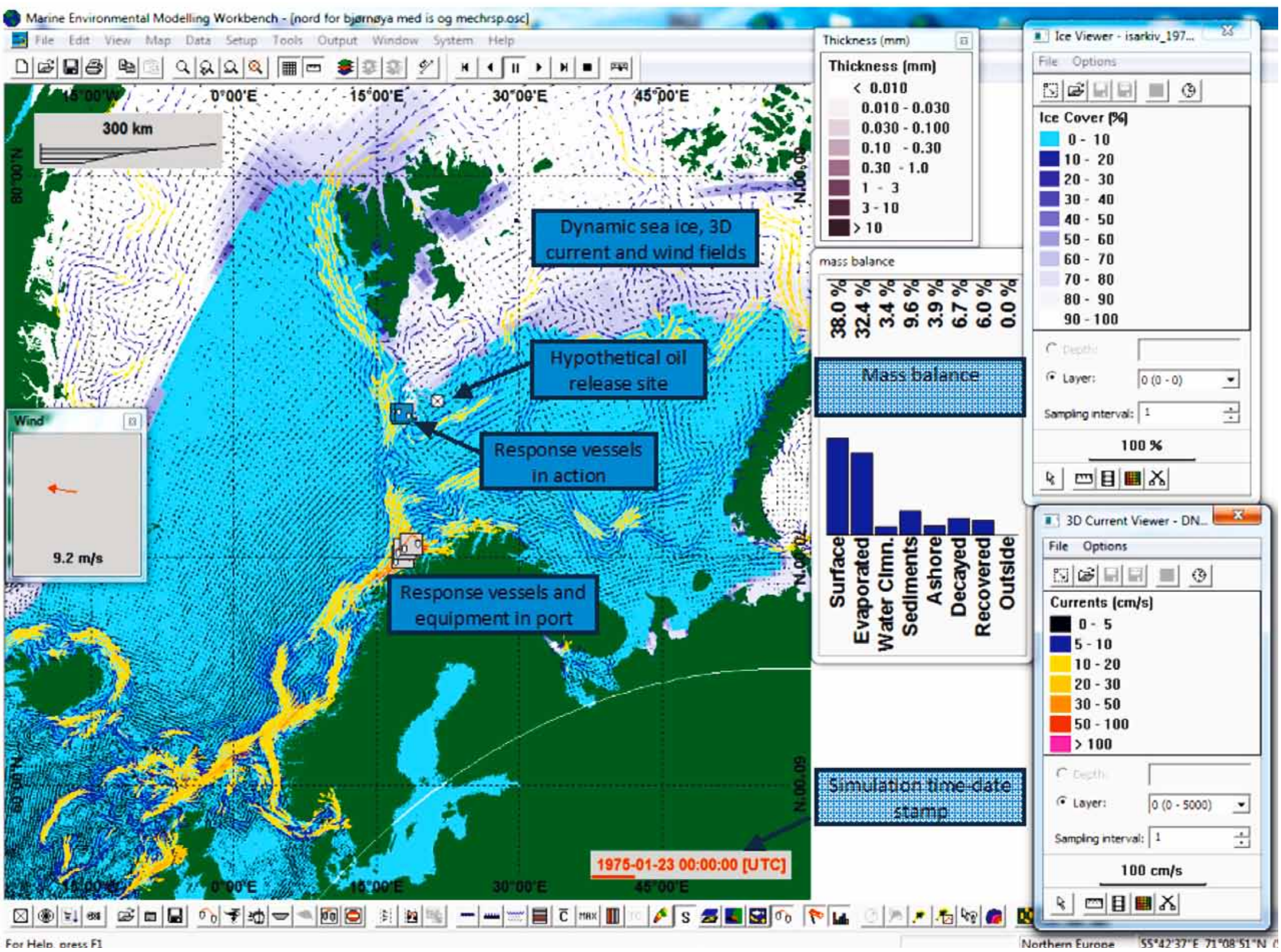

Figure 15 : Computing the transport and fate of oil spilled in the marginal ice zone using the SINTEF model OSCAR, and currents, winds, and ice cover provided by the climate change models in the project. The model linkages have not yet been fully established.

MODELING THE EFFECTS OF MAN-MADE NOISE ON MARINE MAMMALS

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In order to model and manage the relationship between artificial noise (shipping; oil and gas exploration and production) and marine mammals in the Arctic, the following process is being conducted:

1. Noise measurements coming from various sources (ships, exploration and production operations) in different environments are collected.

2. To estimate the noise contribution to an area, e.g. where a ship passes through, the source levels must be estimated. This is done through simulations using the software package ORCA, computing the propagation loss and subsequently the levels at the source. The focus here is on the frequencies that are defined to have a potential effect on marine mammal behaviour.

3. The noise sources, e.g. ships, are placed in a different environment (changing ocean characteristics, thus varying sound propagation). Their estimated source levels over the background noise are computed. For this task, different methods available in the ocean acoustic library are used.

4. Data is entered into SONS-3D, a 3D software simulator, developed by the LAB, to combine the artificial noise sources with marine mammal presence and to assess the influence of these sources on the nearby area.

The following images illustrate the masking effect on the signal of a dolphin at a frequency of 5 kHz by a merchant vessel (Figs. 16-18). The environment shown here uses a Summer deep-water sound speed profile using information from the NOAA World Ocean Database. The dolphin source level is set to 165 dB re 1 uPa @ 1 m. The ship source level and directivity pattern is based on measurements made from the Ships Oriented Innovative Solutions to Reduce Noise and Vibrations project supported by by the European Commission (www.silenv.eu/). Propagation was performed using the Ocean Acoustic Library; the simulation uses X3D with the H3D API and NumPy for computations. The grid has a 1-km spacing.

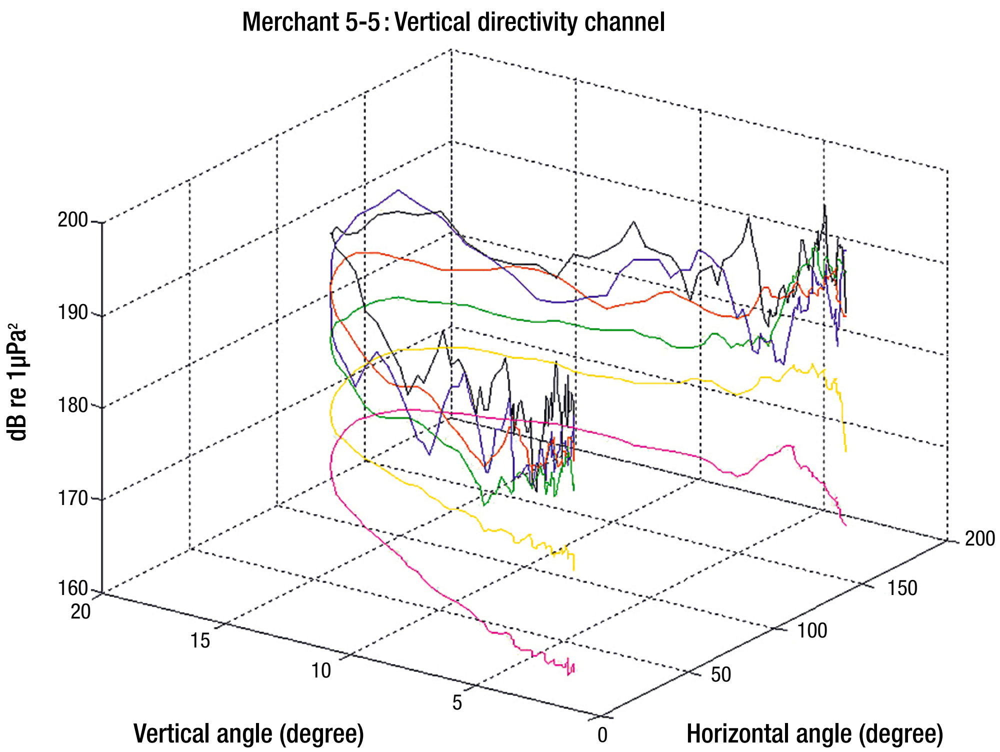

Figure 16 - Noise directivity diagram from a merchant vessel in vertical and horizontal degrees.

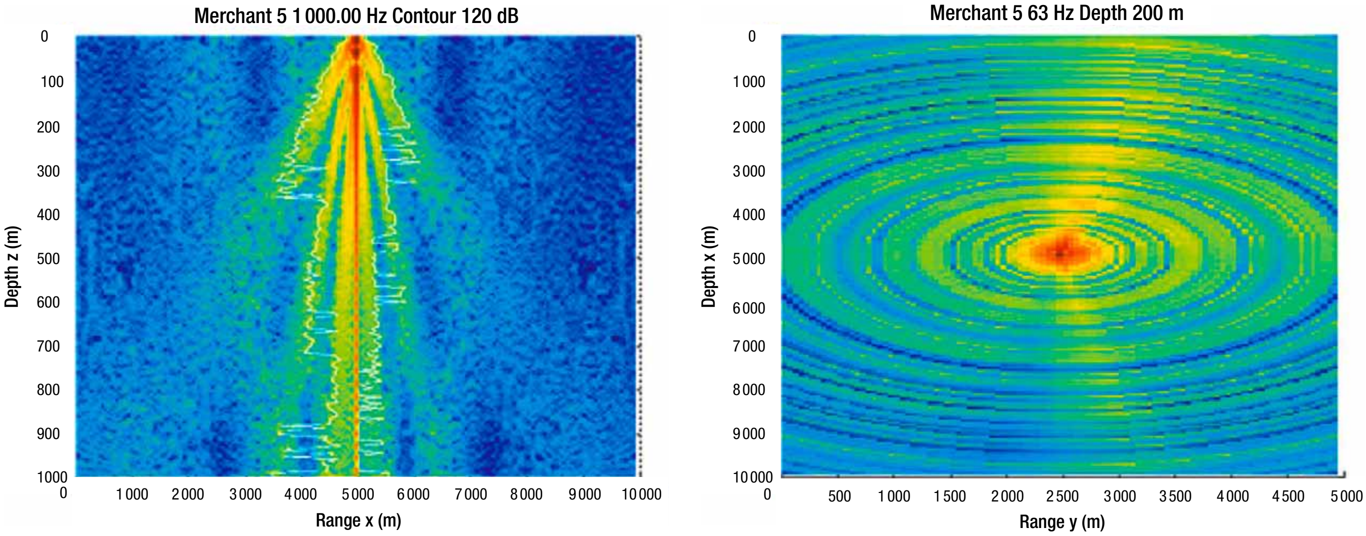

Figure 17 - Screen shots of the directivity noise pattern at different ranges from a merchant ship from the simulator at (left) 1000 Hz and (right) 63 Hz at a depth of 200 m.

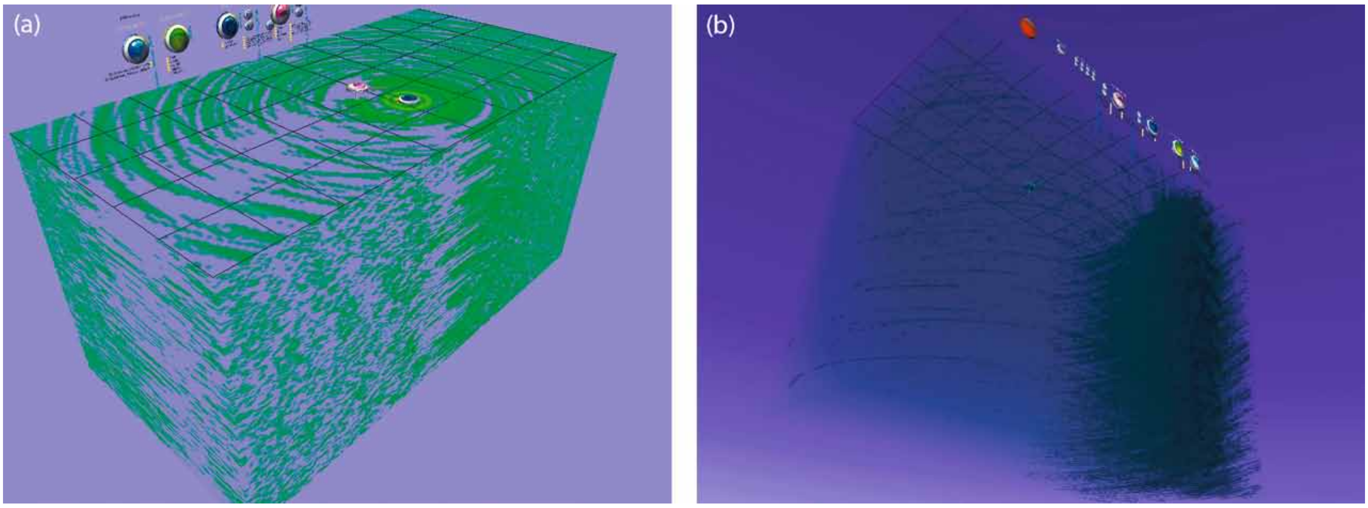

Figure 18 - STwo 3-D views of the masking effect of noise from a merchant ship (Figs. 17) on a dolphin acoustic signal, using the SONS-3D software package. The translucent areas in the clips are where the dolphin whistle may be masked by the background noise and where communication with other dolphins may not be possible.

MODELLING LOCAL AIR POLLUTION IMPACTS IN THE ARCTIC

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Within ACCESS the group at LATMOS-UPMC is examining the impacts of local sources of air pollution from shipping and oil/gas extraction on atmospheric composition (ozone, aerosols). These sources are likely to increase as a result of Arctic warming. A global chemical transport model, MOZART, is being used to quantify the relative contributions of local versus remote pollution transported from emissions located in northern mid-latitudes. At the same time, a regional chemical model, WRF-Chem is being used to quantify local impacts and to analyse data from the ACCESS (DLR) aircraft campaign (July 2012) which aims to produce improved emission estimates for Arctic shipping and oil/gas extraction.

The Model for Ozone and Related chemical Tracers version 4 (MOZART-4, Emmons et al., 2011) is an offline global chemical transport model particularly suited for studies of the composition of the troposphere and its evolution as a results of human activities. The MOZART-4 model is driven by meteorological fields from either climate models or assimilation of meteorological observations: in THE ACCESS simulations, we will use the meteorology fields provided by the from the National Center for Atmospheric Research (NCAR, USA) reanalysis of the National Centers for Environmental Prediction (NCEP, USA) forecasts. In ACCESS, the model with be run at with a T63 spatial resolution, i.e. approximately 1.8 x 1.8 degree in both latitude and longitude.

The standard MOZART-4 chemical mechanism includes 85 gas-phase species, 12 bulk aerosol compounds, 39 photolysis and 157 gas-phase reactions. The representation of tropospheric aerosols in MOZART-4 includes the calculation of sulfate, black carbon, primary organic, secondary organic (SOA), ammonium nitrate, and sea salt.

The simulations we will perform during the project will help to quantify the impact of ship emissions on the global distribution of chemical species. Simulations for future scenarios of shipping, which will include the opening of the Northern Passages to international shipping will also be considered.

A regional chemical transport model (WRF-Chem) will also be used during ACCESS to study the chemistry of pollution emitted in the Arctic. WRF-Chem (Grell et al., 2005, Fast et al., 2006) uses meteorological fields from global models to drive an online weather model that is run at the same time as chemistry. This model is advantageous because it can be run at multiple resolutions with different gas and aerosol schemes and adapted to the specific needs of the ACCESS project.

As part of ACCESS an aircraft campaign was conducted in summer 2012 to study ship and oil/gas platform emissions in and near the Arctic. WRF-Chem has been used to forecast the location of pollution plumes during the campaign, which was essential to plan flights that intersect plumes of interest (Fig. 19).

In order to understand the campaign measurements future work with WRF-Chem will include modeling the composition of the atmosphere during the campaign and comparison with the aircraft data. It's important to note that a high resolution model is needed because ship and oil/gas emissions occur on a spatial scale that cannot be included in current global chemical transport models (such as MOZART-4). The studies with WRF-Chem are an necessary step to understood the regional impact of emissions.

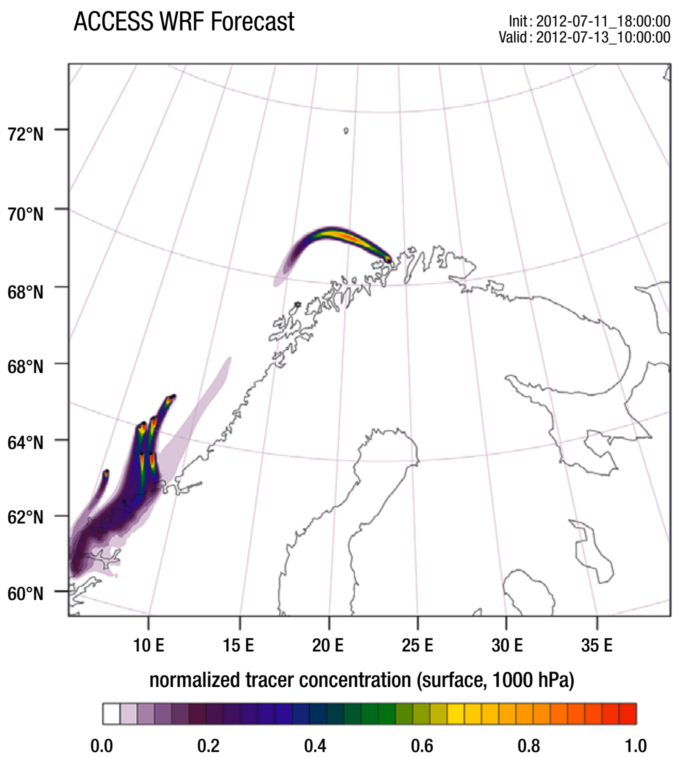

Figure 19 - An example forecast from 13 July 13 2012 at 10:00 UTC shows where oil/gas platform emissions were predicted during the campaign.

Citations

Emmons, L. K., Walters, S., Hess, P. G., Lamarque, J.-F., Pfister, G. G., Fillmore, D., Granier, C., Guenther, A., Kinnison, D., Laepple, T., Orlando, J., Tie, X., Tyndall, G., Wiedinmyer, C., Baughcum, S. L., and Kloster, S.: 2010. Description and evaluation of the Model for Ozone and Related chemical Tracers, version 4 (MOZART-4), *Geosci. Model Dev.,* 3:43-67, doi:10.5194/gmd-3-43-2010.

Grell G. A., et al., 2005. Fully coupled 'online' chemistry in the WRF model. *Atmos. Environ.,* 39:6957–6976,

Fast J. D., et al., 2006. Evolution of ozone, particulates, and aerosol direct forcing in an urban area using a new fully-coupled meteorology, chemistry, and aerosol model. *J. Geophys. Res,.* 111, D21305

ENERGY BALANCE CLIMATE MODELS, DAMAGE RESERVOIRS AND THE TIME PROFILE OF CLIMATE CHANGE POLICY

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This is an example of more detailed modeling activity that illustrate the particular linkages between sea ice melting, the global economy and policy responses to climate change. We explore optimal climate mitigation policies using a standard economic growth model, coupled to a latitude dependent energy balance climate model (EBCM). The latitude dependent EBCMs allows us to explore how model simulated melting of polar ice caps should shape optimal mitigation policies. We capture the positive feedback effect associated with decreasing albedo, as more polar ice starts to melt due to global warming as well as the idea that melting ice can only cause damage as long as there is ice melting. We link these ice dynamics with a simple economic growth model. The endogenous ice line characteristic of our energy balance climate model induces a non-linearity in the model, which generates multiple equilibria.

To see potential impacts on actual policy recommendations from integrated assessment models we introduce these concepts into the well-known DICE model (Nordhaus) and show that the model simulates optimal policies that call for high mitigation now as opposed to status quo. The simulation results further suggests that the policy ramp could be u-shaped instead of the usual monotonically increasing ramp. The results from these policy runs are displayed in Figure 20.

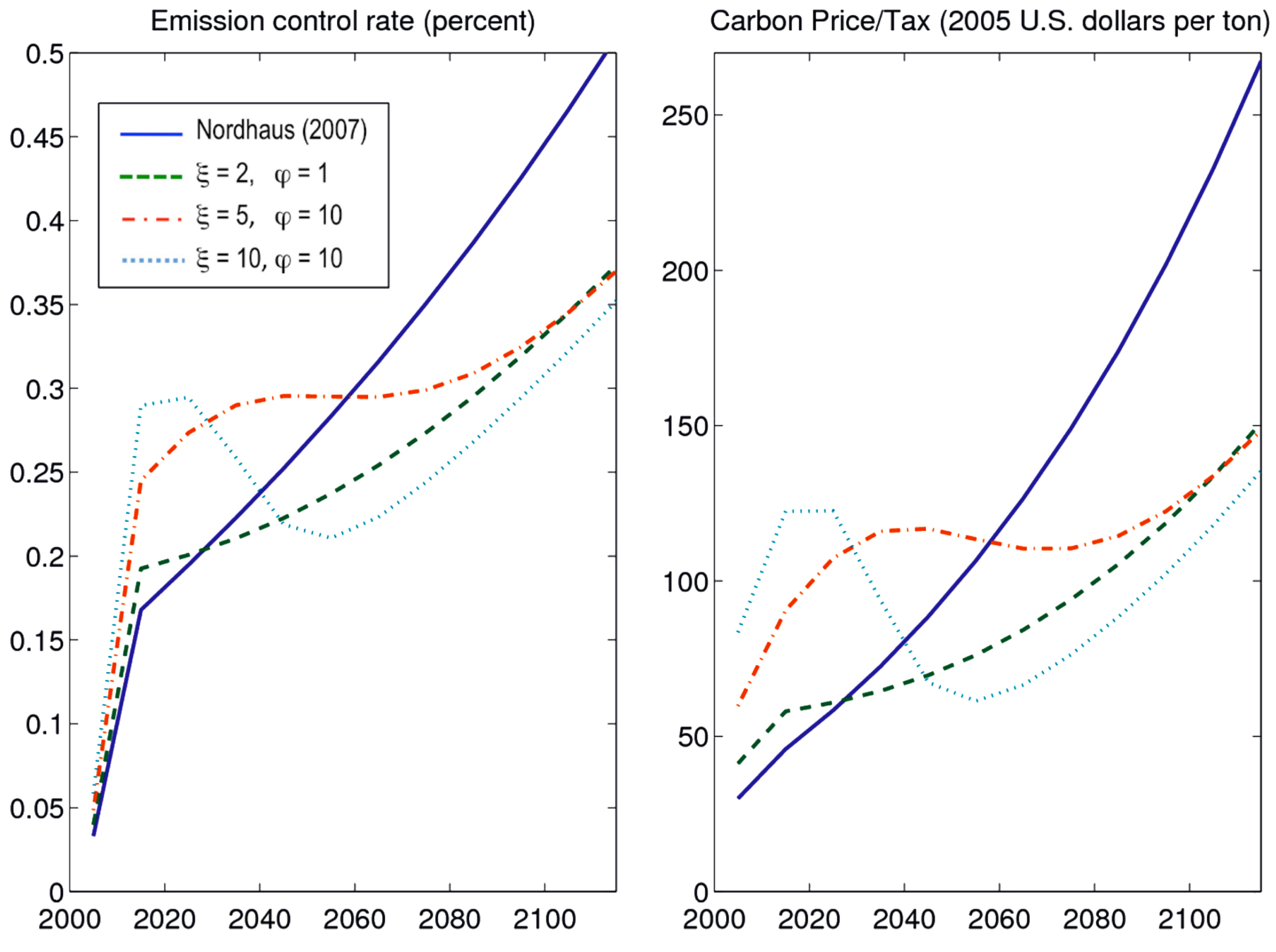

Figure 20 - Optimal emission control rates (left) and optimal tax rates (right) for different modeling runs from year 2000-2100. The solid blue lines represent the policy recommendations coming from the original DICE model. The other lines depict policy recommendations accounting for the shape of damages from melting polar ice caps. The alternative policy scenarios are performed for a varying set of damage parameters.

FRAMEWORK FOR INTEGRATED ECOSYSTEM BASED MANAGEMENT

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Resource use and other activities in the Arctic create more or less recognized side effects that may impact for example on other Arctic activities, on the Arctic ecosystem or on the economic system sometimes even outside the Arctic. For example the impacts of climate change on agriculture in Africa and Southern Europe may increase the need for fish to provide enough food for a growing global population. This could lead to substantial direct impacts on the Arctic Ocean by increasing the need for Arctic fisheries and indirect impacts by changing the prices at which Arctic fish can be sold on the world market.

Sustainable use of Arctic resources thus depends on the decision makers' ability to understand, recognize and properly incorporate the impacts of these connections in their decisions. The Beijer Institute of Ecological Economics (Beijer) proposes within Task 5.7 (*Ecosystems Services - Building a Framework for Integrated Ecosystem Based Management*) of ACCESS to build a framework for integrated ecosystem based management. We will build it as a flexible model that can be used to support policy advisors and help them give more accurate advice to policy makers, by highlighting elements essential to an integrated approach to management.

The integrated EBM approach we propose focuses on the Arctic Ocean as a social ecological system: a system where people and nature interact in multiple and sometimes unexpected ways. Hence it is more meaningful to view it as one complex adaptive system rather than separate ecological and social systems with week connections between them (Fig. 21). The model boundaries are quite broad as it focuses on the whole Arctic Ocean including economic activities and ecosystem dynamics. Ecosystem dynamics are critical as they produce essential ecosystem services, some of which have no substitute. They also form the base for essential economic activities like fisheries and are often impacted by these activities for example through release of harmful substances during transportation or natural resource extraction. Economic activities are important too as they form the base for the well being of people living in the Arctic.

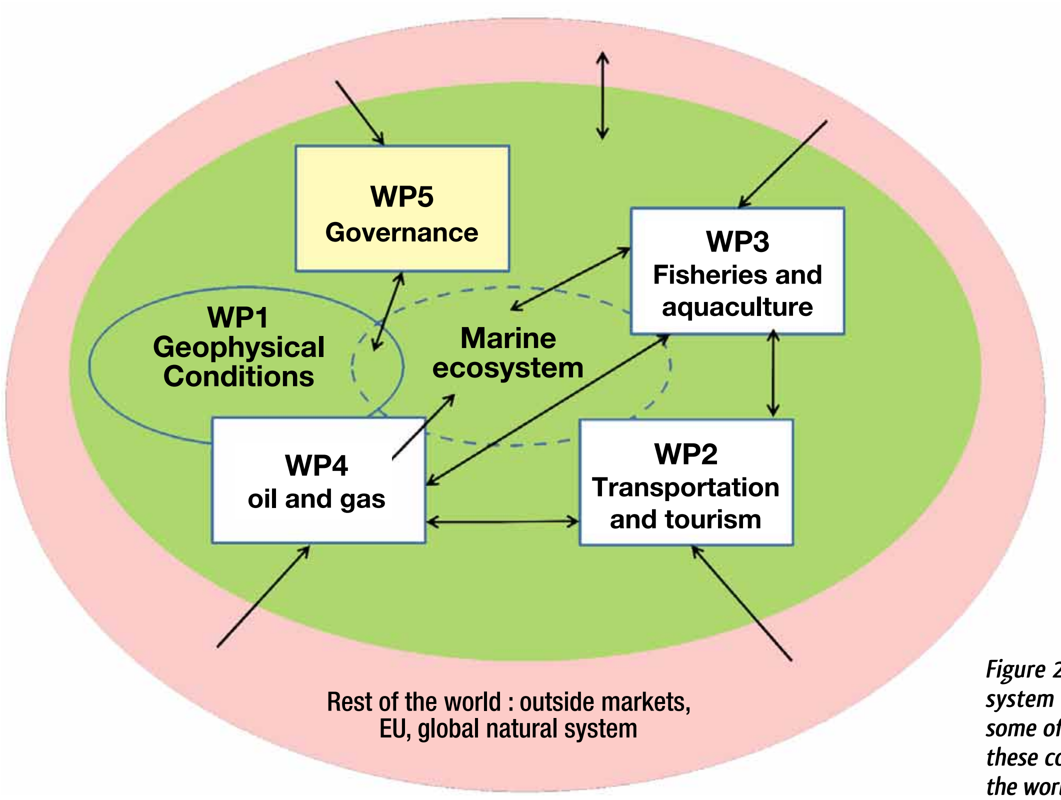
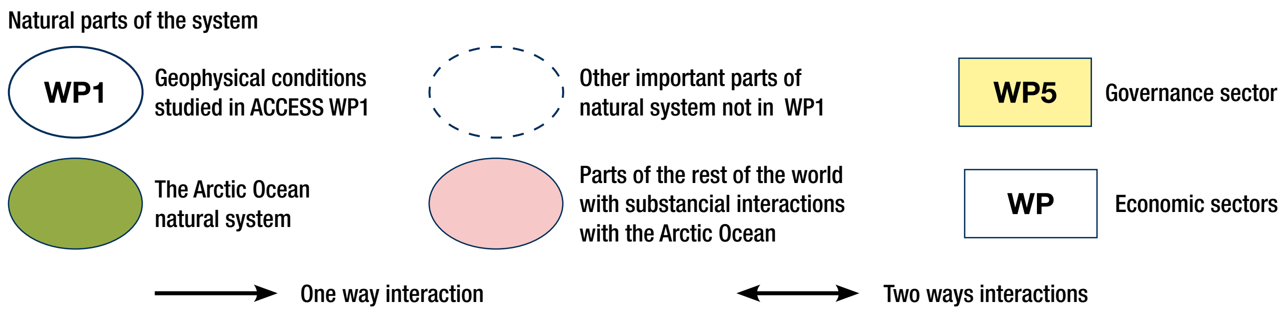


Figure 21 - The Arctic social ecological system with its main components and some of the essential linkages between these components and with the rest of the world



Besides economic and ecological dynamics, the model should also incorporate links towards elements outside the Arctic that are of essential character either because they could substantially impact future development in the Arctic or because future scenarios in the Arctic may cause substantial changes in the rest of the world through these links.

Such a model is by nature dynamic and can in principle stretch much farther than the scope of ACCESS even if the more detailed studies we envisage will remain within the time scope of this project. The trade off of such a broad approach covering large areas with potentially far away time horizon is of course a low model resolution at least for the whole Pan Arctic framework. We will remedy this by introducing the possibility to nest more detailed but also more specific models within this framework (see previous section on Energy Balance Climate Models, Damage Reservoirs and the Time Profile of Climate Change Policy). For example a more detailed study of the Barents Sea region or of the particular connections between marine transportation and fisheries activities should be possible because much of the data necessary to study these connections is already available.

Once the framework is set up, the main forcing will be of course climate change. Meanwhile as we will strive for a large amount of flexibility in the model we hope that it can also be useful in the future to study other kinds of forcing that may not necessarily be within the scope of ACCESS, like changing public perceptions.

The model built to serve as a framework for integrated ecosystem based management is an important tool for synthesis of activities within ACCESS. It helps picture the connections between different work packages and model them based on available information either from ACCESS results of from other sources. To build the framework requires only rather elementary data in the form of narratives stories telling how known interactions operate, which node they connect to each other and in which direction they work.

Populating the framework with more detailed nested models, typically small mathematical models, requires more information about the essential variables steering the connection (e.g. stock of fish, salinity of sea water) and the quality of the connection (e.g. whether the relationship is linear, sigmoid or maybe exponential).

With such information it becomes possible to explore the system's dynamics and identify possible bifurcations of the system, which could hint on possible interesting scenarios to study closer. It also becomes possible to make qualitative predictions.

If substantial data is available it may also be possible to run some more realistic model scenarios and make predictions for a selected range of scenarios. Figure 21 illustrates how the connections in a very simple framework representing the Arctic social ecological system could look like.

Glossary of Acronmys

ACCESS 1.0: a coupled climate model

AWI: Alfred Wegener Institute for Polar and Marine Research (ACCESS consortium partner)

CGE: Global Computable General Equilibrium model

CMIP5: Coupled Model Intercomparison Project phase 5

COLUMBUS: a global gas markets model

DART: Dynamic Applied Regional Trade model

DICE: Dynamic Integrated Climate-Economy model

DLR: German Aerospace Centre (ACCESS consortium partner)

EBCM: Energy Balance Climate Model

ECGMES: Global Monitoring for Environment and Security program of the European Commission

ECMWF: European Centre for Medium Range Weather Forecast

EWI: Scientific Institute of Energy Cologne (ACCESS consortium partner)

FastOpt: FastOpt GMBH (ACCESS consortium partner)

GCM: General Circulation Model

GFDF-CM3: a coupled climate model

GHG: Greenhouse Gas

GTAP: Global Trade Project

HIRLAM: High Resolution Limited Area Model

HSVA: The Hamburg Shipmodel Basin (ACCESS consortium partner)

iFW: Kiel Institute for the World Economy (ACCESS consortium partner)

IMPaC: Impac Offshore Engineering GMBH (ACCESS consortium partner)

INMCM4: an atmospheric climate model

LATMOS: Laboratoire Atmosphères, Milieux, Observations Spatiales (ACCESS consortium partner)

LNG: Liquified Natural Gas

MAGELAN: a global gas markets model

MCP: Mixed Complementary Programming

Met.No.: Meteorological Institute of Norway (ACCESS consortium partner)

MOZART-4: Model for Ozone and Related Chemical Tracers version 4

NCAR: National Center for Atmospheric Research

NCEP: National Center for Environmental Prediction

NOAA: National Oceanic and Atmospheric Administration

NAOSIM: North Atlantic/Arctic Ocean Sea Ice Model

NAOSIMDAS: NAOSIM based Data Assimilation System

NWP: Numerical Weather Prediction

OASyS: Ocean Atmosphere Systems GMBH (ACCESS consortium partner)

OSCAR: Oil Spill Contingency And Response model

QND: Quantitative Network Design

RCP 4.5: Representative Concentrations Pathways – 4.5 W/m^2 stabilization after 2100

RCP 8.5: Representative Concentrations Pathways – 8.5 W/m^2 stabilization after 2100

SOA: Secondary Organic

SONS-3D: a three-dimensional software simulator

TOPAZ: an Arctic Ocean sea-ice prediction model

UPMC: Université Pierre et Marie Curie (ACCESS consortium partner)

WRF-Chem: Weather Research and Forecast model coupled with Chemistry

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Comments and suggestions for the ACCESS Newsletter are most welcome

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