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Prediction of Arctic Sea Ice for Ship Routing: Forecast Experiment and Ship Cruise

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Abstract

Results are presented from a sea ice forecasting experiment combined with a field campaign undertaken in the Barents Sea in March 2014. The simulations were performed with the regional coupled atmosphere-sea ice-ocean model HAMMER, recently developed within the project IRO-2 dealing with ice forecast and route optimization. The model HAMMER is driven by the high-resolution forecasts provided by the ECMWF and by results of the Arctic wide ice ocean data assimilation system ICEDAS, ran by project partners. For initial conditions of sea ice thickness and concentration remote sensing information from SMOS and AMSR2 are used. Project partners used the model output to run a ship route optimization system. The experiment took place during a two-week period in March 2014 onboard RV Lance, to test the sea ice prediction system under operational conditions. The model results are compared to ice observations as well as to hydrographic measurements conducted during this cruise. By this means, it was possible to analyze the skill of the model system, and hence, its potential for a customized ship routing under ice conditions.

Introduction

Observations demonstrate that the Arctic sea ice coverage has declined substantially over the past decades. The sea ice dynamics is changing following variations in the atmospheric and ocean circulation, increase of global temperature and sea level rise. Mild ice conditions during the winter time and extension of “ice-free” time window in summer, offers more possibilities for navigation in the Arctic Ocean without the icebreaker service. Therefore, the ship navigation need to be adjusted to new ice conditions in terms of finding an optimal way through the sea ice. In March 2014 in the framework of IRO-2 project (IRO-2, 2014), a combined numerical forecast and research cruise experiment was conducted in the Barents Sea. The main goal of this experiment was to demonstrate the possibility of optimization of a ship track using satellite data and short-term (up to 5 days) numerical weather forecast of the sea ice conditions. We developed a coupled regional Atmosphere-Ice-Ocean forecast system HAMMER, which was used for weather forecast and route optimization in real time onboard of the RV Lance.

Hamburger System for Ice forecast: HAMMER

The regional coupled model system HAMMER (Hamburger System for Ice forecast HAMMER (Fock et al., 2013)) has three main components: (i) the mesoscale atmospheric model METRAS; (ii) the mesoscale sea ice model MESIM (Schlunzen et al., 2012); and (iii) the ocean circulation model HAMSOM (e.g. Pohlmann, 2006). In this study, HAMMER used a downscaling approach from a global to a regional model and was forced by the global weather forecast provided by the European Centre for Medium-Range Weather Forecasts (ECMWF) and the Arctic wide ice-ocean forecast ICEDAS (Kauker et al., 2003).

New advantages in the HAMMER system include: (i) daily assimilation of sea-ice satellite data and model initialization and (ii) providing forecast directly into a route optimization system (Fig. 1). Remote sensing data are used to initialize the sea ice model of HAMMER. Ice concentration is retrieved from the Advanced Microwave Scanning Radiometer 2 (AMSR2; Beitsch et al., 2014), and its daily averages are used for the initialization of both forecasts that start on the successive day. Ice thickness is observed by SMOS, and the processing of the daily averages (Tian-Kunze et al., 2014) is finilized about 1.5 days afterwards. Thus, these data are used to initialize the 12-UTC simulation of the successive day and the 00-UTC simulation of the day thereafter. Because the ice thickness is underestimated if the ice concentration is low, a correction method (Gierisch, 2015) is applied to the SMOS data. In order to reduce the influence of the late provision of the SMOS data, these data are combined with the latest forecast of the coarser ICEDAS model to generate an up-to-date and high-resolution product.

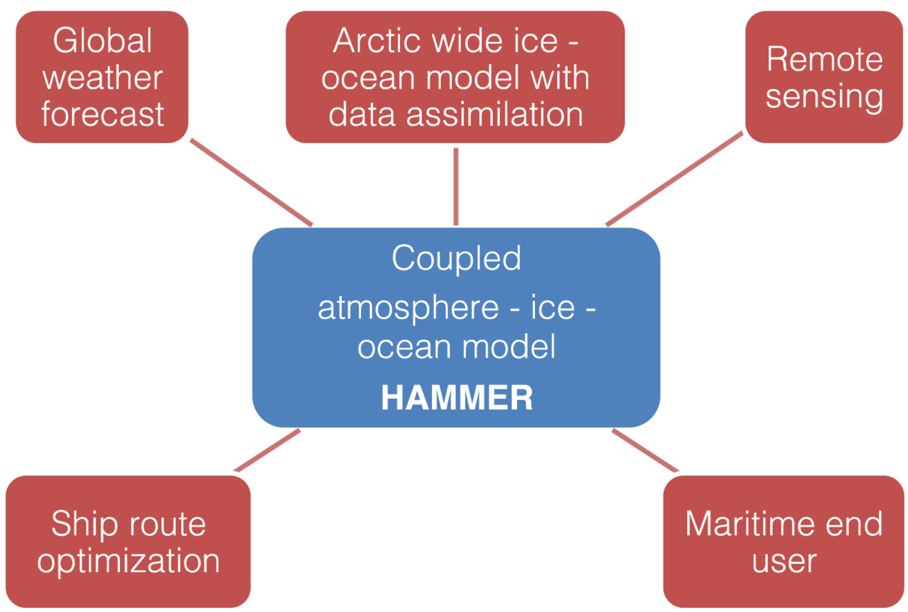

Figure 1—Schematic overview of the regional ice forecast system HAMMER.

Forecast experiment and model evaluation

RV Lance cruise in the western Barents Sea in March 2014 was conducted in the area covered by the HAMMER. The forecast during the cruise was performed by the IRO-2 project team using computer facilities of the German Climate Computing Center (DKRZ). The weather and ice forecast was available twice per day for 00 and 12 over 6 days. The time resolution of the main output parameters of weather, ocean and ice conditions in the HAM-MER forecast was 3 hours. Taking into account a limited data transmission rate onboard a vessel in high latitudes, only ice data (e.g. ice charts, Fig. 2) and optimized routes (Fig. 3) were available in real time. The optimization of ice routes was conducted by the support team based in the Hamburg Ship Model Basin (NSVA).

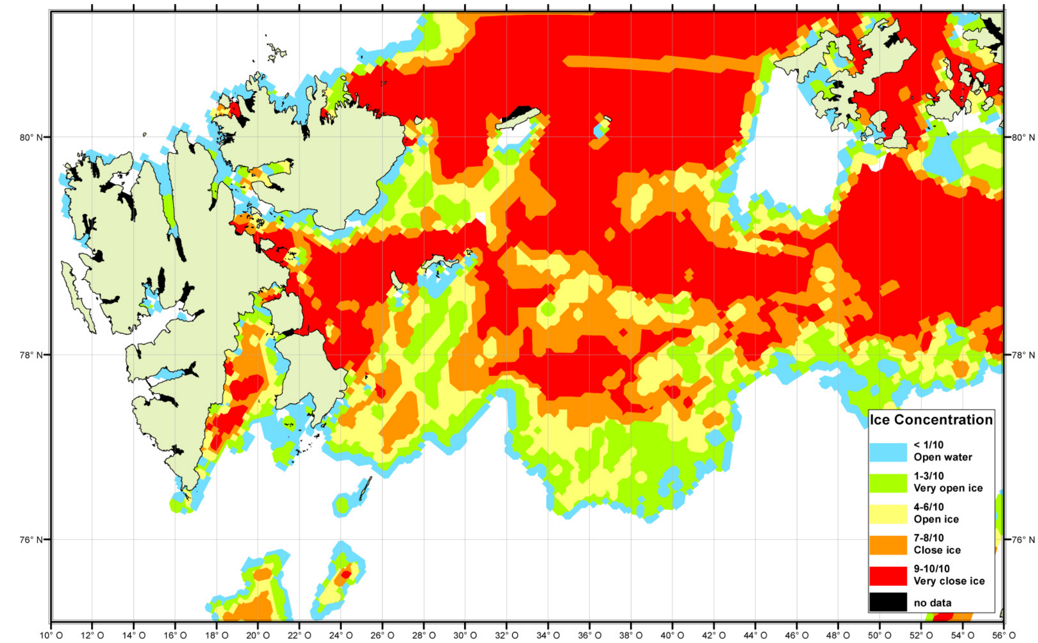

Figure 2—An example of ice chart for 2014-03-18 00, generated onboard using HAMMER forecast data and methods provided by the German Maritime and Hydrographic Agency (BSH).

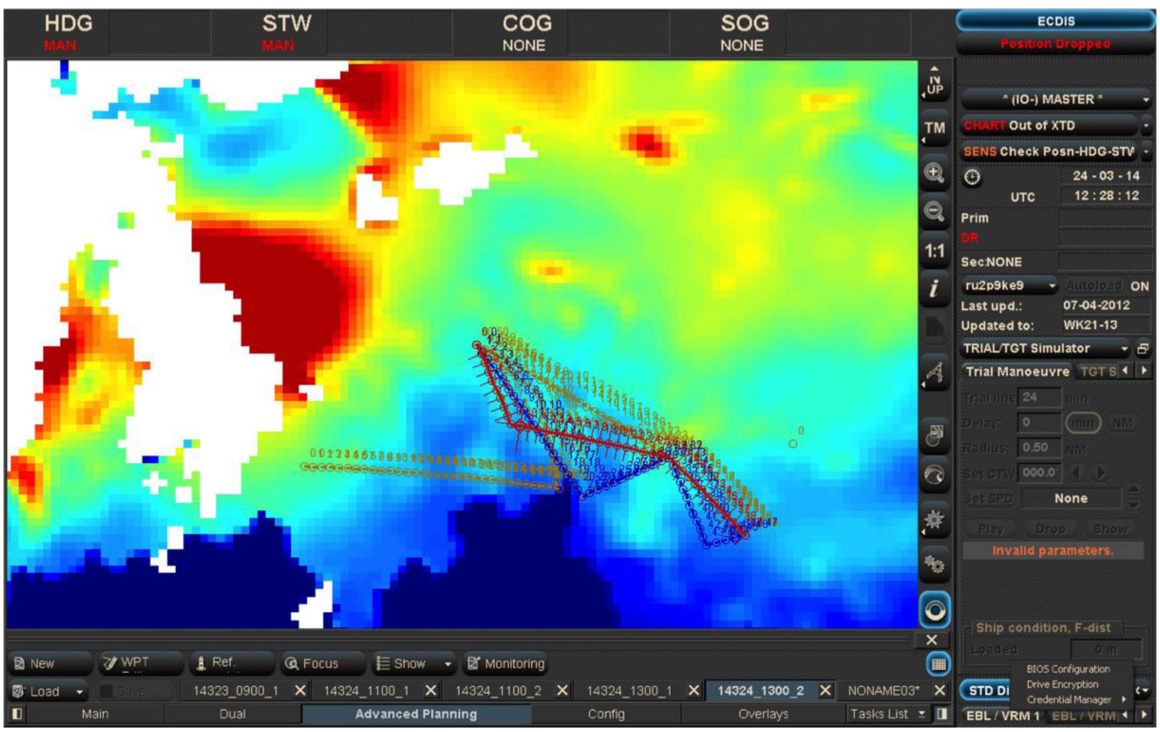

Figure 3—Sea ice thickness forecasted by HAMMER incorporated into the TRANSAS ECDIS navigation information system. Optimized routes are shown.

Satellite data of ice concentration vs. HAMMER forecast

The forecasts of HAMMER in March 2014 were evaluated with satellite observations as well as with in situ observations.

The AMSR2 satellite observations are used to evaluate the forecasted ice concentration field. For this, the same AMSR2 data are applied as were used for model initialization, i.e. daily average values. These are compared to daily averaged model results utilizing hit rates. For this, the allowed deviation between model and observation is set to the uncertainty of the satellite data as given in Spreen et al. (2008). Grid cells containing land are excluded from the analysis as well as grid cells which contain only open water without sea ice during the whole forecast.

The hit rate values in % are shown in Figure 4 (top) for all 00-UTC simulations from 13.03.2014 until 30.03.2014 (y-axis). For each of them, the ice concentration hit rate is given for each of the five forecast days (x-axis). For the first forecast day, the hit rate is between 63% and 75%. Higher values cannot be reached because the model is initialized with ”old” satellite data of the previous day. Thereafter, the hit rate decreases drastically, especially for simulations between 18.03.2014 and 20.03.2014. In this period, HAMMER has difficulties to predict the increase of ice concentration. It performs better between 26.03.2014 and 28.03.2014, when the number of cells with high ice concentration decreased. In average over all simulations (Fig. 4, bottom), the hit rate decreases to a mean value of less than 40%, with the minimum of 26% and the maximum of 47%.

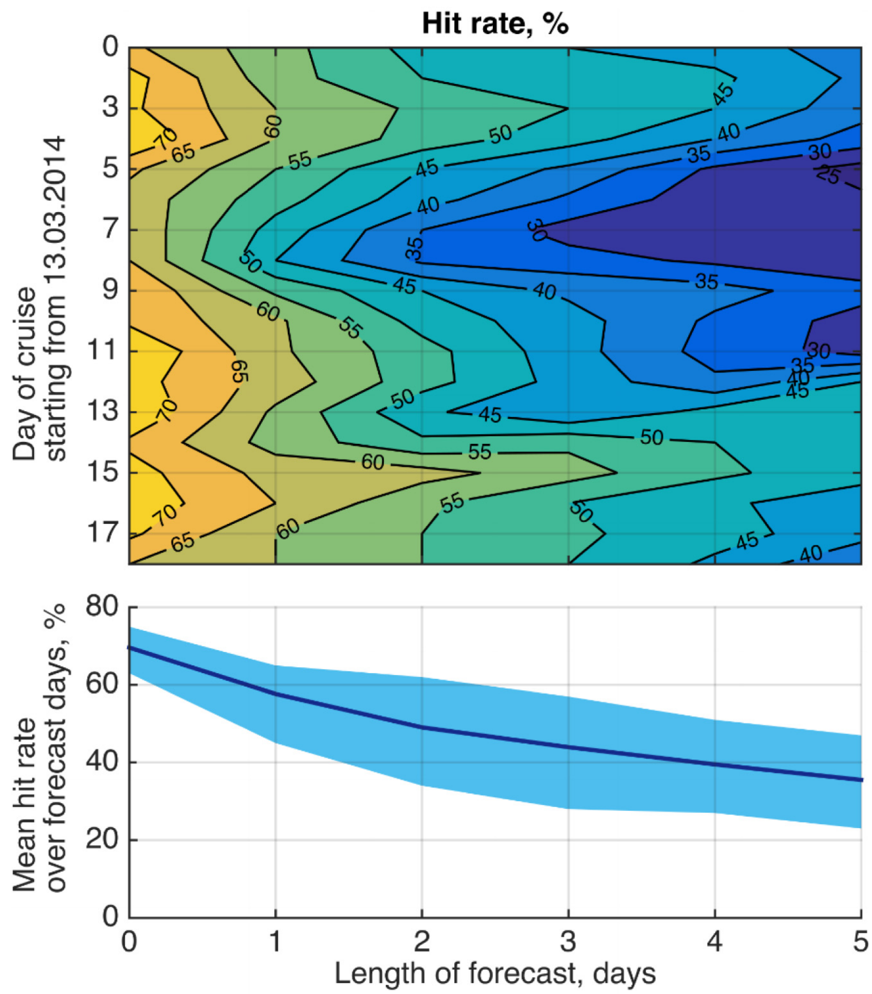

Figure 4—Hit rate of modelled sea-ice concentration in comparison to satellite observations.

Lance observations vs. HAMMER results

RV Lance has a number of sensors running in real time and collection data about atmospheric and ocean conditions. We used measurements of wind speed, air temperature and sea level pressure for first evaluation of HAMMER results. The model results of air temperature and sea level pressure have very good agreement with observations in terms of mean values and variations. However, the wind speed is underestimated by the model both in mean value and variation. Overall, HAMMER results are in good agreement with Lance observation (Table 1 and Fig. 5).

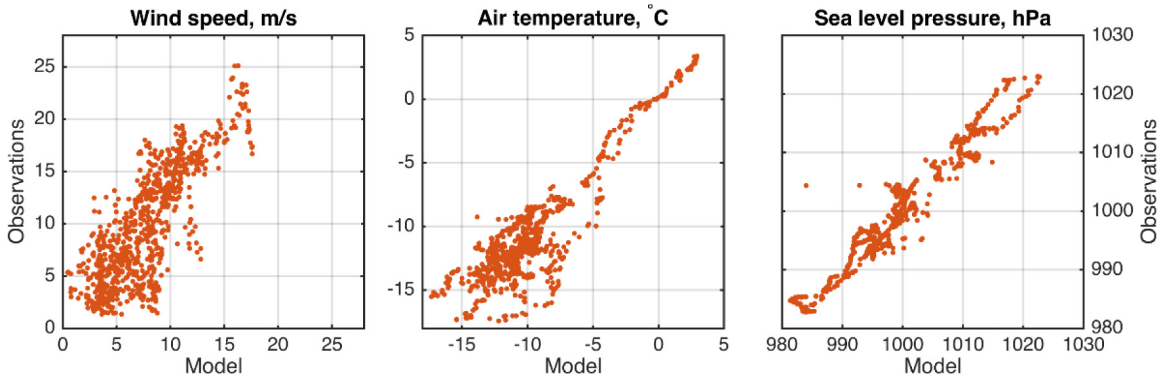

Figure 5—Comparison of the wind speed, air temperature and sea level pressure as calculated by HAMMER to the observations over the entire period of research cruise.

Summary

First prototype of a coupled atmosphere-ocean-ice HAMMER has been tested under realistic operational conditions providing weather and sea ice forecast in real-time during a research cruise in the Barents Sea for ship routes optimization. HAMMER demonstrated the advantages of using detailed, focused on actual ship position real-time sea-ice forecast for optimization of ship routes in the Arctic Ocean. This opens new perspectives for ship navigation in the Arctic Ocean under rapidly changing sea-ice conditions.

Acknowledgments

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