Short-term sea ice prediction for ice navigation in the Arctic sea routes using TIGGE data

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Introduction

Recent rapid decrease in the summer Arctic sea ice extent, together with climate model predictions of additional ice reduction in the future, have attract the interest of Arctic shipping routes. However, the precise prediction of ice distribution is crucial for safe and efficient navigation in the Arctic Ocean. In general, however, most of the available numerical models have exhibited significant uncertainties in short-term and narrow-area predictions. Ensemble predictions of short-term sea-ice conditions along the ASR have been carried out using a high-resolution (2.5km) ice–ocean coupled model that explicitly treats ice floe collisions in marginal ice zones. In this study, the ensembles are constructed by using forecasted atmospheric forcing data sets from THORPEX Interactive Grand Global Ensemble (TIGGE)) project in 2015 and the ice and ocean conditions estimated by the model (De Silva et al., 2015). The correlation score of ice edge error and sea ice concentration distribution quantifies forecast skill. Skill scores are computed from 5-days ensemble forecasts initialized in each month between May 2015 to October 2015. Comparison of different ensemble atmospheric forecasts, using different months initial data sets, revealed that our ice-POM numerical model skillfully predicts the ice distribution during the NSR operational period and NSR opening and closing dates.

Model description

A high-resolution (about 2.5km) ice–ocean coupled model used in this study is based on the model developed by De Silva et al. (2015). The ocean model is based on generalized coordinates, the Message Passing Interface version of the Princeton Ocean Model (POM; Mellor et al. 2002). The ice thermodynamics model is based on the zero-layer thermodynamic model proposed by Semtner (1976). The ice rheological model is based on the elastic–viscous–plastic (EVP) rheology proposed by Hunke (2001) and is modified to take ice floe collisions into account, following Sagawa & Yamaguchi (2006). Model domain is constructed using Earth Topography one-minute Gridded Elevation Dataset (ETOPO1). High-resolution computations are initialized using interpolated whole-Arctic model results and AMSR2 sea-ice concentration as described in De Silva et al., (2015). The atmospheric forcing are given by the TIGGE (Bougeault et al. 2010) dataset, which has been developed as part of THORPEX. TIGGE provides operational medium-range ensemble forecast data for non-commercial research purposes through its data portals. The seven operational ensemble prediction systems used here include the China Meteorological Administration (CMA), the Canadian Meteorological Center (CMC), the European Centre for Medium-range Weather Forecasts (ECMWF), the Japan Meteorological Agency (JMA), the France Metrological Office (FMO), the United Kingdom Meteorological Office (UKMO), and the US National Centers for Environmental Prediction (NCEP), as of July 2015.

Discussion

To evaluate the different atmospheric datasets we used the correlation score of ice edge error and sea ice concentration distribution. The ice edge error is defined as follows. First, the difference in the ice areas between the models predictions and AMSR2 satellite observations are calculated. Note that area covered with ice concentration more than 15% is taken into comparison. Next, dividing the length of the model predicted contour of the ice concentration of 15%, we obtain the ice edge error with the dimension of length. The results of the 5days (20 to 25 July 2015) forecasted ice edge error and the hindcast (ERA) using ERA-Interim data is shown in Fig. 1.

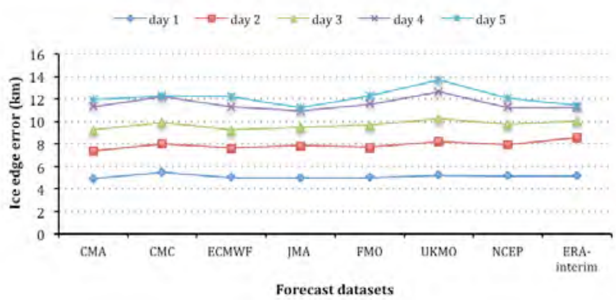

Figure 1. Ice edge error between different forecasted datasets and AMSR2

There were no significant differences of ice edge error between different forecasted datasets and ERA-interim hindcast data. Within 5 days average ice edge among seven-forecasted dataset is 9.28±2.44 km. During the computation period the JMA showed best ice edge error prediction of 8.89±2.57km and the UKMO shows worst ice edge error prediction of 10±3.41 km. In addition to the quantitative comparisons of ice edge error, we compared the sea-ice concentration distribution qualitatively. Fig. 2 shows the difference between the model and AMSR2 sea-ice concentrations after the 5^{th} day of computation (25 July 2015).

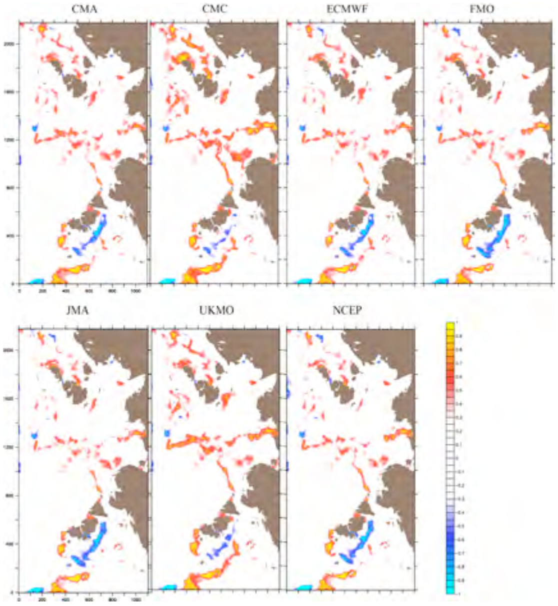

Figure 2. Difference between model-predicted ice concentration and AMSR2 (model - AMSR2)

Southern part of the domain, difference in sea ice concentration is higher compared to the other regions. This discrepancy could be due to the under estimation of heat transfer process between ice and ocean. However, sea ice spatial distribution between different datasets has no significant difference.

Conclusion

Sea ice forecasted skill of different dataset (TIGGE) is evaluated in the study. Average forecast skill of ice-POM model is 9.28±2.44 km that is in good agreement with the requirement of operational ice navigation system (10 km). The current study partly includes the preliminary results of the melting season. To improve the model forecast accuracy, the further studies would be necessary in freezing season.

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