An assessment of short-term sea ice forecast skill of ice-POM model in the Northern Sea Route

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Introduction

Significant decline of Arctic summer sea ice has increased marine accessibility to Arctic areas, such as natural resource exploitation, fishing and commercial shipment through the Northern Sea route (abbreviated as NSR hereafter). Advantages of NSR are shorter distance; according to the surveys (Frank 2000) NSR can shorten the travel distance from Yokohama port to Rotterdam port by 35% from the existing southern sea route through Sues Canal. Instead of the one sole southern route, the existence of two routes will provide the tremendous boost for the security of international shipping. Therefore NSRs are considered to be efficient, economical, and safe passages for transportation industry. Sea ice predictions and observations are important to protect the ships and offshore/coastal structures in order to utilize NSR.

In our previous study, (De Silve, 2013) we have developed the hindcast ice-ocean coupled model to reproduce the short-term sea ice conditions in NSR. We used a mesoscale eddy resolving ice-ocean coupled model (ice-POM) with explicitly treating the ice floe collision in the marginal ice zones to reproduce the NSR sea ice conditions. In this study, we aim to extend our previous hindcast study into the short-term forecast study using a statistical based ensemble forecasting method.

Model description

A mesoscale eddy resolving ice-ocean coupled model is used to predict the sea ice in the NSR. The model configurations are almost the same as that of De Silva (2013). Model domain consists of Laptev Sea, part of Kara and East Siberian Seas. Zonal and meridional grid spacing are approximately 2.5 x 2.5 km for the high-resolution regional model. The vertical grid adopted sigma coordinate systems with 33 levels.

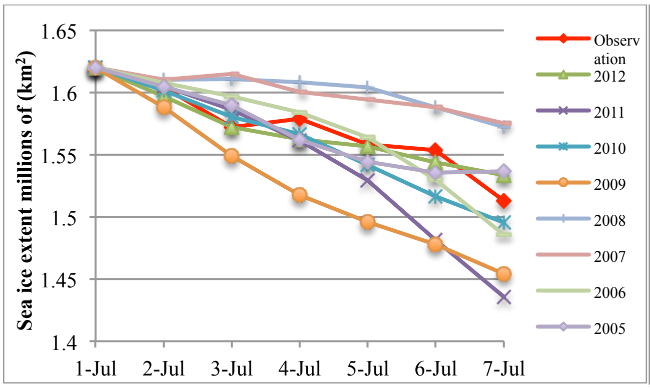
The ocean part of the ice-POM model is a parallel, free-surface, sigma-coordinate, primitive equations ocean modeling code based on the Princeton Ocean Model (POM). Thermodynamic part of this ice-ocean coupled model is based on (Parkinson & Washington 1979) and adopted the (Semtner 1976) zero-layer model. The radiation boundary condition is applied at the open lateral boundaries and no-slip boundary condition is used along the coastlines. To avoid the singularity at the North Pole, the whole Arctic model grid is rotated to place its North Pole over the equator. 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 (2007). Semi-Lagrangian advection scheme is used for the advection of sea ice variables.

Short-term forecast skill

Present version of the ice-POM model coupled interaction between the ocean/sea ice and atmosphere is not taken into account. Therefore we employed the ERA-interim atmospheric forcing for our hindcast computation. But in the present study, we aim to predict the 7 days ahead sea ice conditions in the summer 2013. Therefore the predictions, we planed to use the historical atmospheric forcing data by ERA-interim and forecasted atmospheric data by different ECMWF's operational forecasts listed in the website [http://apps.ecmwf.int/datasets/data/tigge/?levtype=sfc&type=cf] as an ensemble members. This historical ensemble method was first introduced by Zhang et al. (2008) for 1 year ensemble forecast for September 2008 sea ice. The initial (2013 July 1st) oceanic conditions and sea ice conditions are given from the 25km resolution whole Arctic ice-ocean model output by De Silva (2013). Please note that only for the sea ice concentration we used the AMSR-E sea ice concentration as an initial condition except the model results.

Discussion

We first examine the ice-POM prediction skill using historical ensemble members (Figure 1) form year 2005 to 2012. All the ensemble members show the decreasing trend during the computation. Year 2007 and 2008 results shows over predicted results compare to the AMSR-E observation while 2009 shows the worst under predicted result. When we compared the mean and standard deviation of historical ensemble member; we could see that mean value change almost linearly with time and standard deviation increased. On the other hand we examined the ice-POM prediction skill using 6 ECMWF's operational forecasts forcing data as an ensemble members (Figure 2). All the operational forecast ensemble members show the over predicted results.



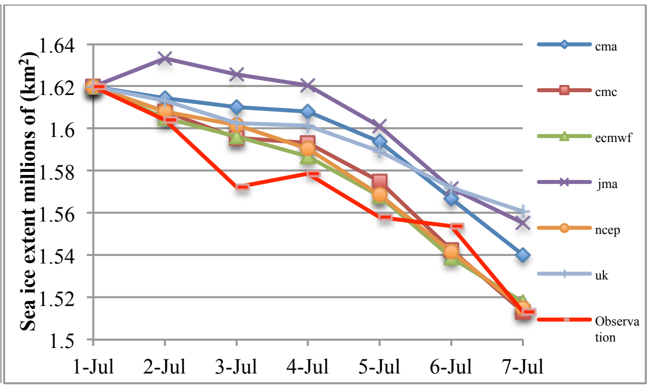


Figure 1. Time series of sea ice extent; AMSR-E observation and predicted by historical forcing data

Figure 2. Time series of sea ice extent; AMSR-E observation and predicted by ECMWF's operational forecasts forcing data

Conclusions

A difficulty in the sea ice prediction is the lack of prediction forcing data since ice-POM model does not include atmospheric component. Here we used the ERA-interim reanalysis forcing field data from 2005-2012 and ECMWF's operational forecast data for predict the sea ice in 2013 July. Mean value of both ensemble methods shows the similar reduction trend in short-term forecasting and does not significantly different from observations. In addition to that we have seen that ice-POM model is very sensitive to the precipitation data. In the future we are planning to extend our results to investigate the predictability of ice-POM model initial date of computation, duration of computation and influence of extreme weather events.

Acknowledgments
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