Numerical investigation of sea ice prediction to support ice navigation in the Northern Sea route

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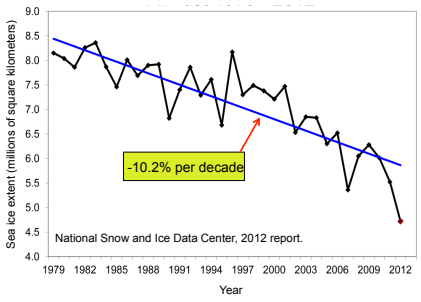
GRENE-Arctic

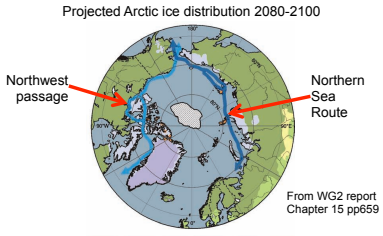
Introduction

Rapid decrease of summer sea ice in the Arctic Ocean has been extending the navigation period in the Northern Sea Route(NSR).



Monthly average Arctic sea ice extent August 1979-2012

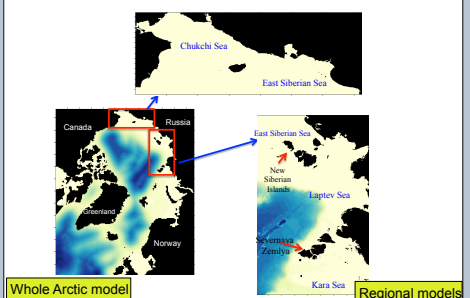
The passages through the Arctic Ocean are the shortest sea routes from North American and European harbors to Far East Asian harbors. In this regard, precise ice distribution prediction is one of the key issues to realize safe and efficient navigation in the Arctic Ocean.



In general, however, most of the available numerical models have shown high uncertainties in the short-term and narrow-area predictions, especially marginal ice zones like ASR.
In this study, therefore, we predicted the short-term sea ice conditions in Arctic sea routes using meso-scale eddy resolving ice-ocean coupled model (ice-POM) with explicitly treating the ice floe collision in the marginal ice zones.

Objectives and Model domains

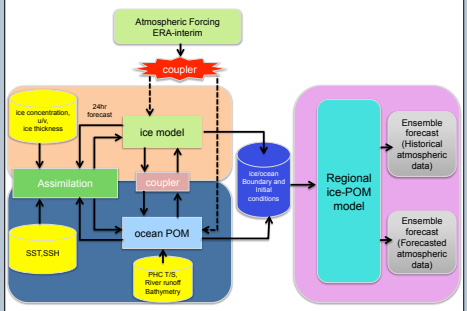
1. Predict ice edge zones up to 5 days ahead within errors of ±10 km, in regions of NSR
2. Investigate the mesoscale and large-scale sea ice behaviors in the NSR using high-resolution regional models



Ice-ocean coupled model description

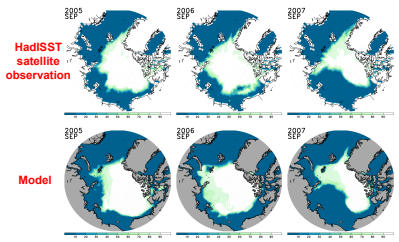
- Ocean model based on Princeton Ocean Model (POM)
  - 3D, Primitive Eqs. and Continuum Eq. with a hydrostatic approximation
  - Vertical 33 sigma layers
- Lateral boundary conditions
  - Radiation and no-slip
  - Volume, *T*, *S* at Bering Strait Woodgate et al. (2005a)
- Ice model based on Sagawa(2007), Fujisaki et al. (2010), and De Silva (2013)
- Two state variables (mean thickness and concentration)
- Semi Lagrangian advection scheme
- Ice collision rheology
- Thermodynamics model Based on 0-layer model proposed by (Semtner 1976)
- Snow effect (Zhang and Zhang, 2001)

Ice-POM Nowcast/Forecast System

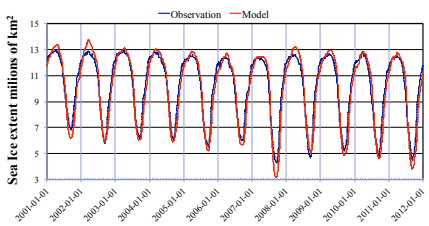


Model Results

HadISST observation and model September ice concentration

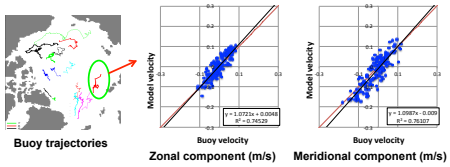


Time series of model and observational ice extent from 2001-2011

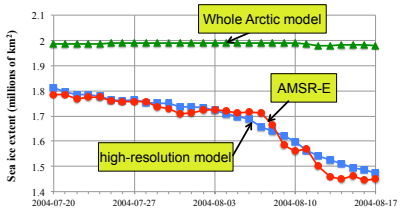


Model Results

Comparison of the observed and simulated sea-ice velocities

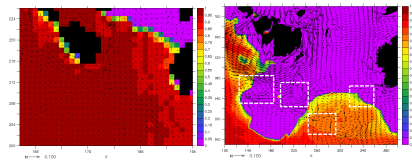


High-resolution regional model sea ice extent comparison (off Laptev Sea)

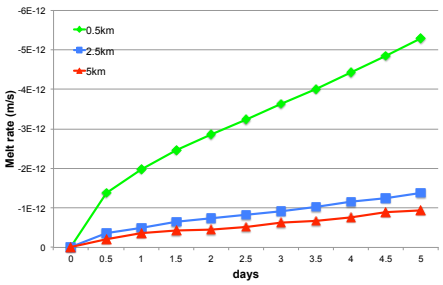


We believed, better results shows in high-resolution model is due to the mesoscale eddy resolving capability, which may not be resolved in many general circulation models.

Sea ice concentration and average top 100m ocean velocity on 2004-09-13



Grid size effect on sea ice melt due to the mesoscale dynamics



Idealized box model is used to investigate the grid size effect on sea ice melt due to the mesoscale ocean eddies.

Conclusion

- Successfully resolved numerical instability issues associated with collision rheology
- Whole Arctic model sea ice extent, thickness and velocity reproducibility are very reasonable.
- High-resolution model reproduced the sea ice extent and concentrations reasonably with observation
- Mesoscale eddies play an significant role in sea ice melting/freezing in Northern sea routes.
- mesoscale eddies and associated vertical mixing are not be resolved adequately in the global models in which grid size are larger than 5km