Improving sea ice predictions along the Arctic sea route using observation data

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Abstract

Sea ice extent in the Arctic ocean has been decreasing for the past three decades. This has led to increased transportation in the Arctic Sea Routes(ASRs)Accurately predicting sea ice conditions is essential to safely navigate along the Arctic sea routes. Accuracy of sea ice predictions in the Arctic Ocean is improved by assimilating sea ice variables in an ice-ocean coupled Ice-POM model. Sea ice concentration, sea ice thickness and sea ice velocity are assimilated in this study. Sea ice observations are obtained from AMSR2-data sets. The assimilation method that is used is an improved nudging method that minimizes the observation errors and model errors. As a result of assimilation, the ocean conditions have been greatly improved. This is evident in resulting ocean salinity. Sea ice extent and ice thickness are also improved by assimilation. The assimilation time interval is also altered in daily weekly, monthly and yearly intervals. Weekly assimilation can also produce reasonable results compared to the model only predictions.

Model description

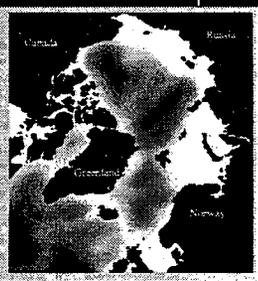


Fig 1: Model Domain

- Used ice ocean coupled model is Ice-POM.
- Ocean part of the model is based on Princeton ocean model (POM).
  - 3D, Primitive Eqs. and Continuum Eq. with a hydrostatic approximation
- Ice part of Ice-POM is based on Sagawa(2007), Fujisaki et al. (2010), and De Silva (2013).
  - 0-layer thermodynamics model (Semtner 1976)
  - Snow effects (Zhang and Zhang, 2001)
- ETOPO1 – 1arc minute topography data
  - Vertical 33 z-sigma layers
  - Spatial resolution = 25km
- Boundary conditions
  - Radiation and no-slip

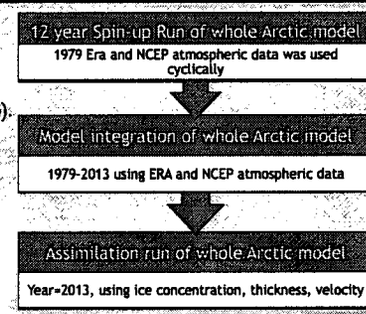


Fig 2: Overview of experiments

Assimilation method

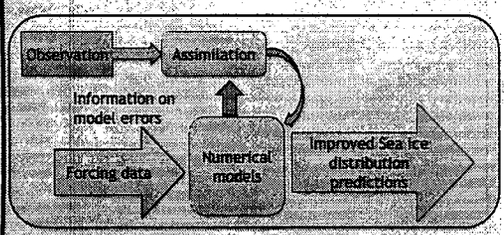


Fig 3: Data assimilation flowchart

$$C_{analysis} = C_{model} + K(C_{obs} - C_{model})$$

$$K = \frac{R^2_{model}}{R^2_{model} + R^2_{obs}}$$

$$K = \frac{|C_{obs} - C_{model}|^2}{|C_{obs} - C_{model}|^2 + R^2_{obs}}$$

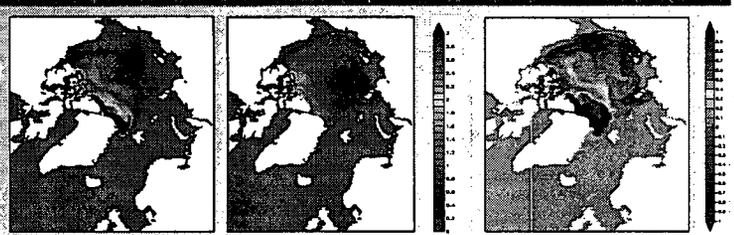
R^2_{obs} = was varied upon the season and location.

Observation data

Sea ice concentration	AMSR2 satellite gridded data set 10km resolution, Daily
Sea ice thickness	Tateyama (Krishfield et. al, 2014) gridded data set 10km resolution, daily
Sea ice	Kimura (Kimura et. al, 2013) gridded data set 10km resolution, daily

Results

Sea ice concentration assimilation comparison of sea ice thickness (Aug)

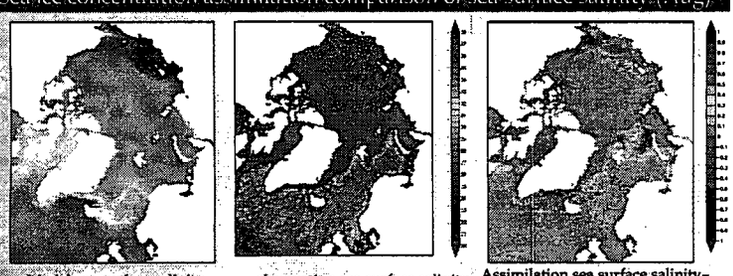


Assimilation sea ice thickness | Model sea ice thickness | Assimilation sea ice thickness – Model sea ice thickness

Sea ice concentration assimilation comparison of sea ice velocity

Assimilation sea ice velocity | Model sea ice velocity

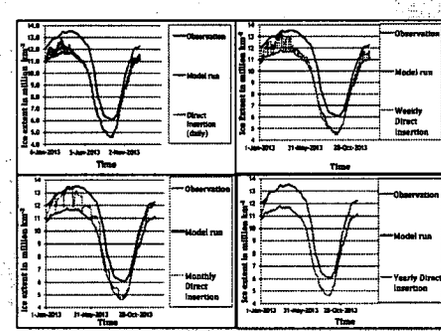
Sea ice concentration assimilation comparison of sea surface salinity (Aug)



Model sea surface salinity | observation sea surface salinity | Assimilation sea surface salinity – Model sea surface salinity

Sea ice thickness near the North pole is under-predicted in the model. Assimilation corrects this with improved sea ice velocity in the assimilation run. Decreased velocity near the North pole prevents sea ice getting advected away from the North pole. Sea ice salinity is improved with sea ice extent improvement.

Sea ice concentration assimilation assimilation time interval



Time evolution of total sea ice extent by assimilating sea ice concentration daily(top left), weekly(top right), monthly(bottom left), and yearly(bottom right)

While daily assimilation produced best results, weekly and monthly assimilation could also produce reasonable results in summer.