High-resolution modeling of the Arctic Ocean with a nested-grid ice-ocean model forced by JRA55-do

○Yoshiki Komuro, Masao Kurogi（JAMSTEC）, Takao Kawasaki, Ryu Saiki, and Hiroyasu Hasumi（AORI, U. Tokyo）

Backgrounds

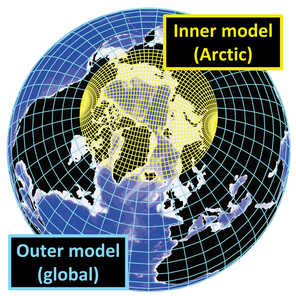
- Local changes in the Arctic region can affect the global climate
  - Relationship between Arctic sea ice and climate in mid-latitudes in winter (e.g., Inoue et al., 2012; Nakamura et al., 2016)
  - Better reproducibility of the Arctic climate is desirable for discussing global climate variability.
- Poor representation of Arctic climate in coarse-resolution global climate model (e.g., Ilicak et al., 2016)

→ We are performing a high-resolution modeling of the Arctic Ocean in the framework of global ice-ocean coupled modeling.
- Here, we show the model settings and some preliminary results.

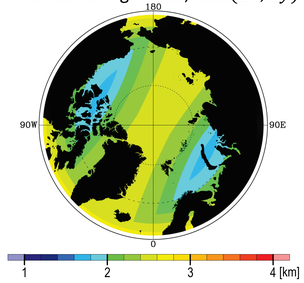
Model description, settings, and computational resources

Model description

- 2-way nested grid version of ice-ocean model COCO (Kurogi et al., 2013, 2016)
- Coordinate system:
  Tri-polar grid (Murray, 1996)
  - latitude-longitude grid to the south of 63.3N, and another bi-polar grid to the north of it
  - Outer model domain: global, nominal 0.25 degree
  - Inner model domain: to the north of 61.1N, approx. 2.5 km over the domain
  - 5x5 inner grids corresponds to a single outer grid



Inner-domain grid size, max($\Delta x, \Delta y$)



- Schemes and parameterizations
  - Ocean: UTOPIA-QUICKEST advection (Leonard, 1979; Leonard et al. 1993, 1994), bi-harmonic Smagorinsky viscosity (Griffies and Hallberg, 2000) , Noh and Kim ML param. (Noh and Kim, 1999).
  - Sea ice: Thickness distribution (Bitz et al., 2001), EVP rheology (Hunke and Dukowicz, 1997)
- Tuning sea-ice parameters
  - Smaller C (20 → 10) in ice strength formulation of Hibler (1979): $P = P_0 V_I \exp[-C(1-A)]$
  - Larger ice-ocean drag coefficient（0.005 → 0.02）

Experimental settings

- Surface boundary condition: JRA55-do v1.3 (Tsujino et al., 2018), a dataset for driving ice-ocean model based on JRA-55. No surface salinity restoring is applied.
- Spin-up procedure: using only the outer model, temperature/salinity below 50 m is restored to PHCv3 climatology（Steele et al., 2001）.
- Period of integration: 1990–1999 (10 years)

Computational resources

- The results shown here has been calculated by using a supercomputer system, Oakforest-PACS (8208 nodes, 25 Pflops, jointly operated by U. Tokyo and U. Tsukuba)
- 43 hours for calculating 1 model year, using 108 nodes of Oakforest-PACS
- The model can also be executed on the Earth Simulator at JAMSTEC

For future study…

- Further analysis in Atlantic/Pacific water flowing into the Arctic Ocean (spatial distribution, flux, …)
- Improvement in reproducibility, in particular the low salinity in the surface/subsurface Beaufort Sea.
- Downscaling experiment of global climate projections by using results of coupled GCM.
- Long-term hindcast from 1958, which is the first year of JRA55-do dataset, to the present.

Acknowledgements

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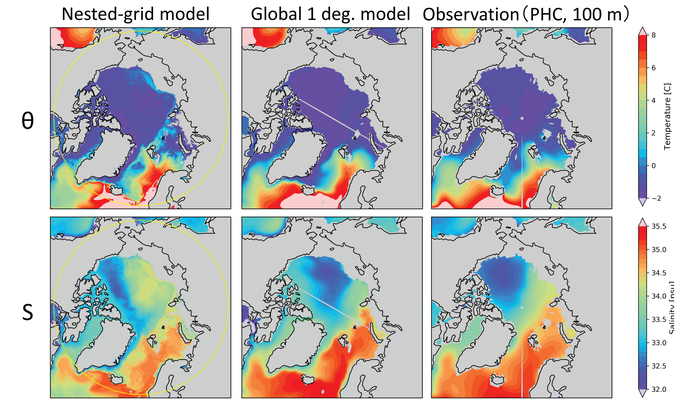
Results

Temperature/salinity/sea ice in year 1999 (10th year)

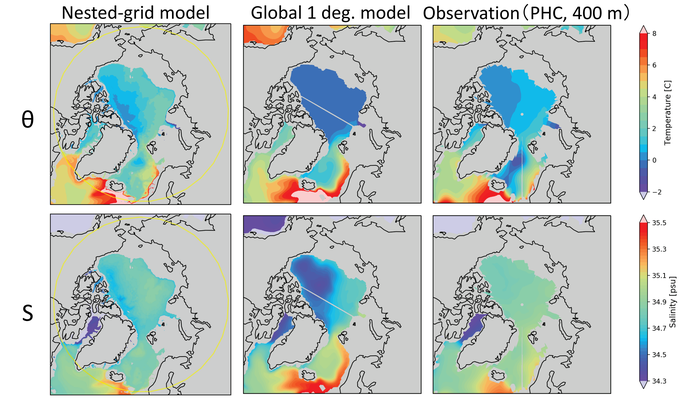
- For comparison, results of coarse-resolution (nominal 1 degree) model forced by JRA55-do are also shown (following CMIP6/OMIP protocol; Griffies et al., 2016)

Potential temperature θ/Salinity S at 97 m depth (annual mean)

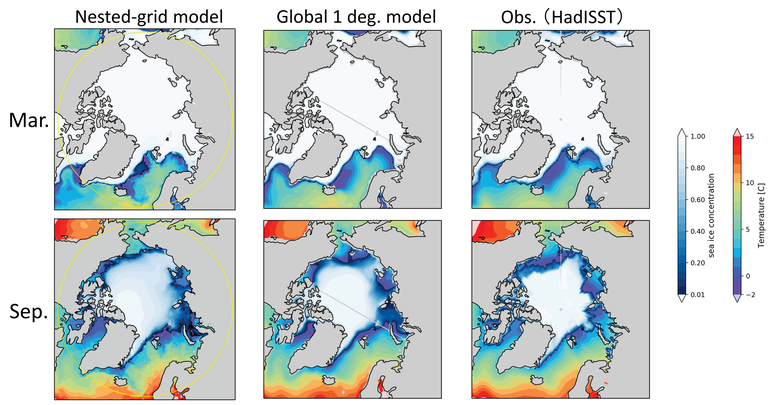


↑ Yellow circle indicates the outer/inner domain boundary

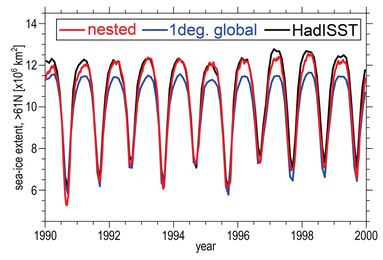
Potential temperature θ/Salinity S at 388 m depth (annual mean)



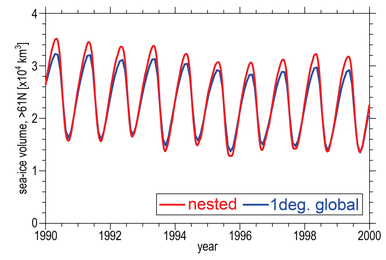
Sea-ice concentration/Sea surface temperature (monthly mean)



Time series of sea-ice extent (>61N)



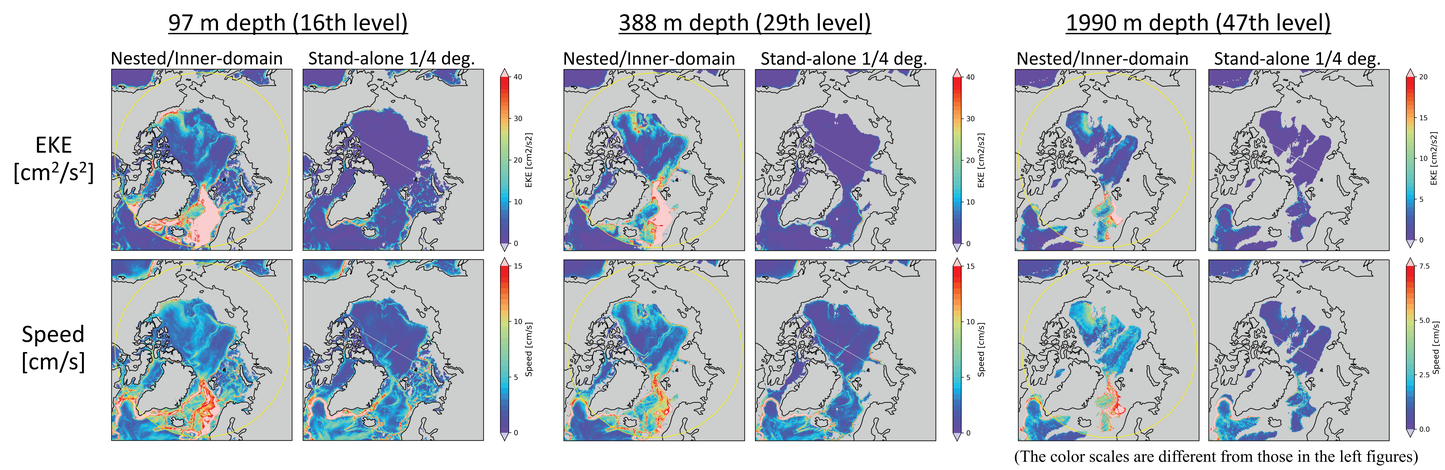
Time series of sea-ice volume (>61N)



- More warm water flows into the Arctic basin in the nested-grid model, in particular at 388 m depth (near the core depth of Atlantic water).
- Low salinity water in the Beaufort Sea diminishes in the nested-grid model.
- Spatial sea-ice distribution is well reproduced in both the models. The time series of sea-ice extent and volume are close to those in the coarse-resolution model and observational estimation.

Eddy kinetic energy (EKE) and current speed averaged over 10 years

- EKE is defined as $0.5[(u-\bar{u})^2 + (v-\bar{v})^2]$, where $\bar{u}$ and $\bar{v}$ are 10-year mean velocity. EKE is calculated from 5-daily mean output.
- For comparison, the outer (1/4 deg.) model was ran as a stand-alone global model for 10 years.
- Inner-domain of the nested model (inside the yellow circle) shows large EKE and high speed in the Arctic Basin, even in the deep layer.



(The color scales are different from those in the left figures)