Coupling of ice-ocean biogeochemical cycles in the Arctic with POP-CICE-ecosystem model

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Progress of ecosystem model in POP-CICE

• Ice algal ecosystem model in CICE stand-alone was set up in 2009 and a research paper was written.
• DMS modeling in sea ice was on the way and a paper is in preparation.
• We started to couple the sea ice and ocean ecosystem in CICE and POP from 2009 and get reasonable results in Jan 2010. Further analysis of the results and refinement may keep going on this year and a paper is in preparation.
• Here we introduce some results from the coupled POP-CICE-ecosystem model.
Configuration of global ice-ocean-ecosystem model
Ocean model – POP; Sea ice model- CICE4.0; 0.5 to 1-Degree, displace pole grid
Initial condition: T, S, nutrients from WOA2005, sea ice from and other ecosystem model components from previous model results.
Computational cost: 80CPU, 15 hours for one year integration
Ice core measurements reveal very productive bottom ice communities

- Additional source of primary production
  : 1 ~ 60 %, regionally in the Arctic Ocean
Ice algae model
Jin et al. (2006b)

pelagic ecosystem model plus ice algae.
2.1 The coupling of 3-D ice-ocean model and biological model

We have ecosystem model based on two sets of 3-D physical models:

1. Global model POP coupled with CICE for global biogeochemical cycle study

2. POM coupled with sea ice model (IARC-CIOM) for regional high-resolution applications.

**Coupling with ocean model**

\[
\Phi = \frac{\partial}{\partial x} (A_H \frac{\partial}{\partial x}) + \frac{\partial}{\partial y} (A_H \frac{\partial}{\partial y}) + \frac{\partial}{\partial z} (K_H \frac{\partial}{\partial z}) - u \frac{\partial}{\partial x} - v \frac{\partial}{\partial y} - w \frac{\partial}{\partial z}
\]

**Coupling with ice model**

\[
\frac{\partial g}{\partial t} = - \frac{\partial g_{y_i}}{\partial x} - \frac{\partial g_{v_i}}{\partial y} - \frac{\partial f_i g}{\partial h} + \Psi
\]

*Ice thickness distribution function g*

\[
\bar{h} = \sum_{n=2}^{NC} g(h_n) h_n \quad A = 1 - g(h = 0)
\]

*Mean biological variable b in sea ice*

\[
\frac{\partial b}{\partial t} = - \frac{\partial b u_i}{\partial x} - \frac{\partial b v_i}{\partial y}
\]

*Horizontal advection*
Model results from global POP-CICE-ecosystem model

Algae Chl a at ice bottom

Sea surface Chl a

Ice Algal (mg Chl m⁻³) 1992 04 15

Sea surface Chl a

Chl (mg m⁻³) 1992 04 16
Model estimate of annual primary production in sea ice and ocean
Comparison of model vs. monthly satellite remote sensing data

Satellite remote sensing sea surface Chl and ice edge

Modeled sea surface Chl and ice edge

Chl (mg m⁻³)  2000 03 22
Comparison of model vs. monthly satellite remote sensing data

Satellite remote sensing
sea surface Chl and ice edge

Modeled sea surface Chl and ice edge

Satellite remote sensing sea surface Chl and ice edge

Chl (mg m$^{-3}$) 2000 04 16
Comparison of model vs. monthly satellite remote sensing data

Satellite remote sensing
sea surface Chl and ice edge

Modeled sea surface Chl and ice edge

Satellite remote sensing vs. Modeled sea surface Chl and ice edge
Comparison of model vs. monthly satellite remote sensing data

Satellite remote sensing
sea surface Chl and ice edge

Modeled sea surface Chl and ice edge

Chl (mg m\(^{-3}\)) 2000 06 15
Comparison of model vs. monthly satellite remote sensing data

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Chl (mg m\(^{-3}\))

2000 08 14

50 cm/s
Our future research focus with this global POP-CICE-ecosystem model: model validation of the following processes:

• Primary production in ocean upper mixed layer and sea ice.
• Seasonal to inter-annual nutrient cycles and limitations on production in different regions and different times of a year.
• Carbon exchange with air and export to deep ocean.
• Ocean production-DMS-aerosol-atmospheric radiation feedback.

***There are more than 20 biochemical variables in the model output, we welcome anyone interested in collaborative research on analyzing those model results.
iComments and iQuesions?