Modeling of the coupled sea ice-ocean ecosystem in the pan-Arctic Ocean

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Motivations

- Declining sea ice and rising temperature in the Arctic
- The strong influences of climate changes on the integrated ice algal and pelagic ecosystem in the subarctic and arctic are still less known.
- Our goal is to establish 1) a 3-D ecosystem model including both ice algal and pelagic habitats; 2) the model is capable to model biogeological cycles across diverse eco-regimes; 3) the model is integrated with a climate model to investigate the climate impacts.

The working progress of ecosystem model in POP-CICE

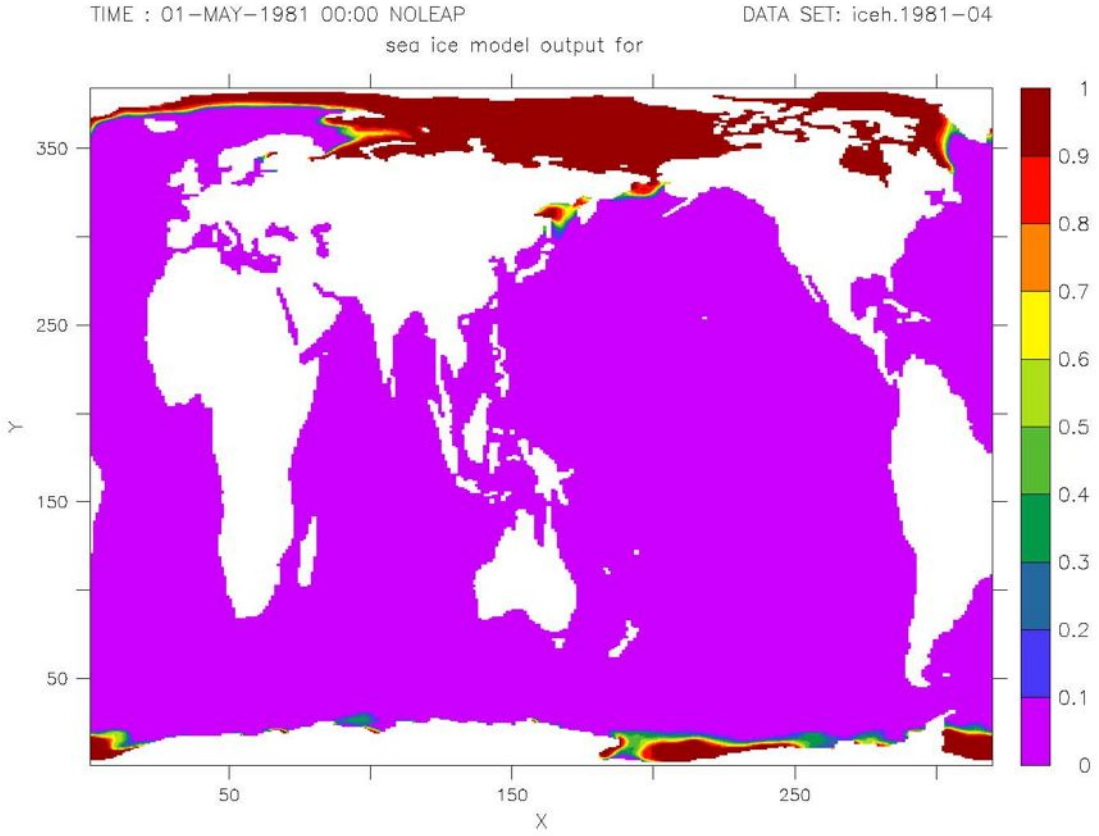
- Ice algal ecosystem model in CICE stand-alone was set up in 2009 and a research paper was written.
- DMS modeling in sea ice was on the way and a paper is in preparation.
- We started to couple the sea ice and ocean ecosystem in CICE and POP from 2009 and get reasonable results in Jan 2010. Further 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

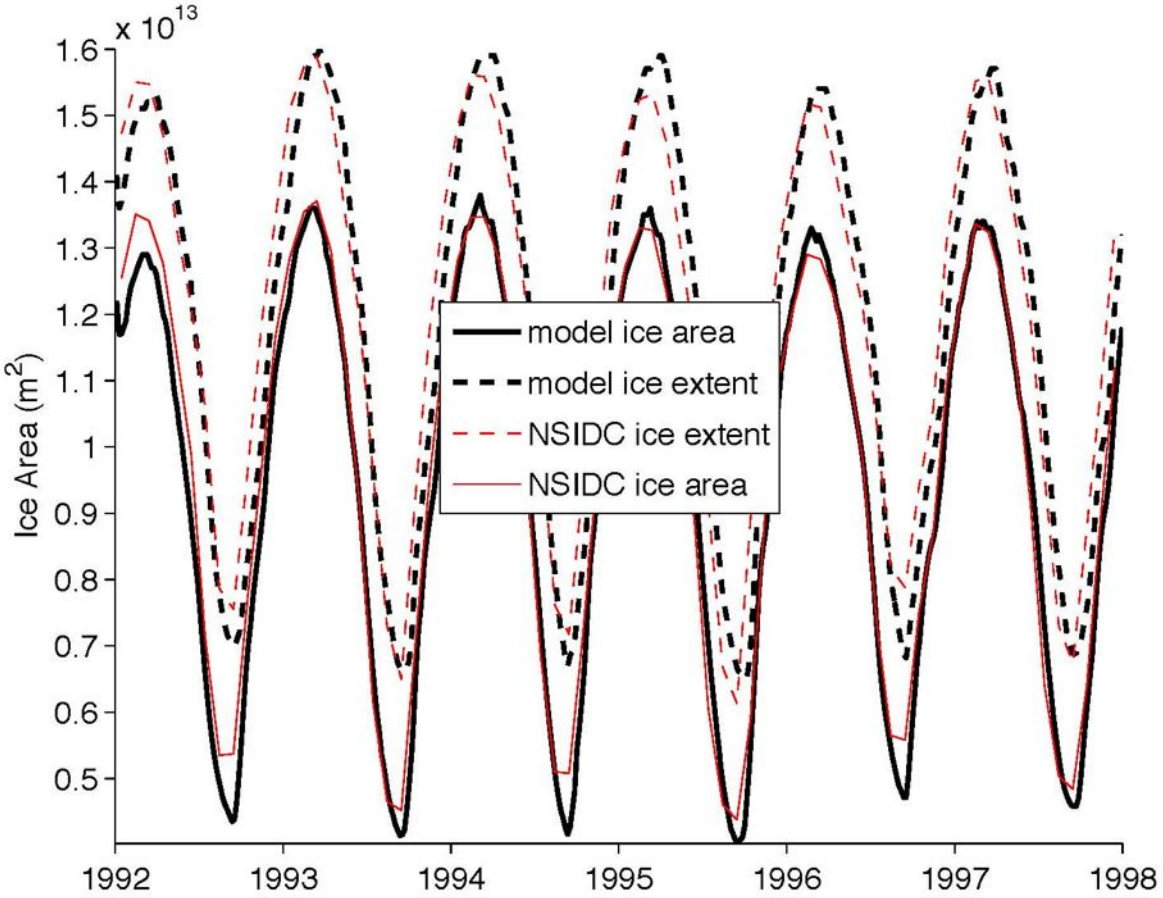
Ocean model – POP; Sea ice model- CICE4.0; 0.5 to 1-Degree, displace pole grid

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



Comparison of modeled Arctic ice area and extent with NSIDC remote sensing data

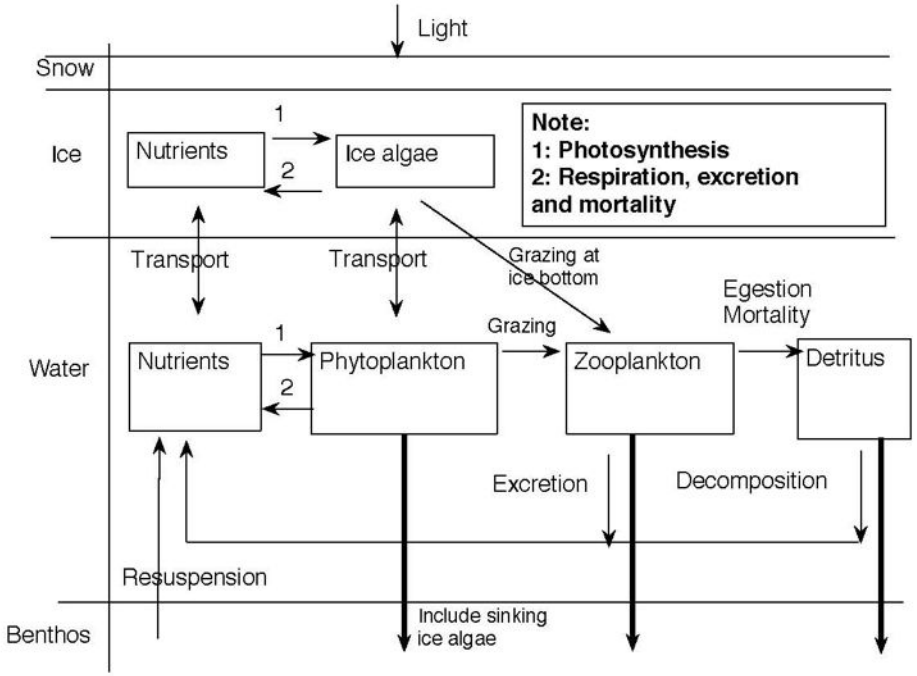


Ice core measurements reveal very productive bottom ice communities

- Additional source of primary production

: 1 ~ 60 %, regionally in the Arctic Ocean

2 Flowchart of the IARC- Physical-Ecosystem Model (PhEecoM)



Ice algae model

Jin et al. (2006b)

pelagic ecosystem model plus ice algae.

Jin et al. (2006a, 2007, 2008, 2009)

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

$$\frac{\partial g}{\partial t} = -\frac{\partial g u_i}{\partial x} - \frac{\partial g v_i}{\partial y} - \frac{\partial f_i g}{\partial h} + \Psi$$

Ice thickness distribution function g

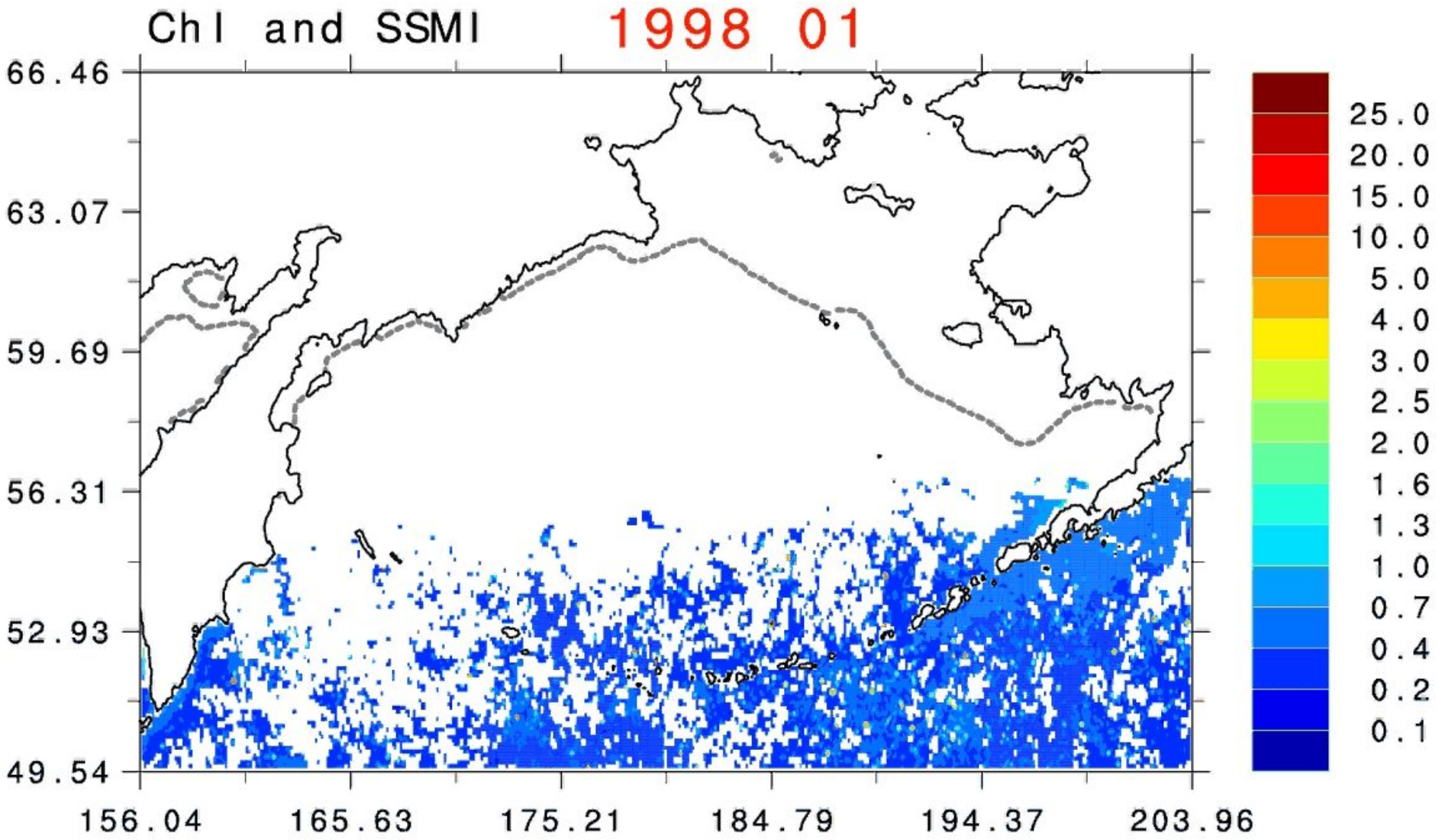
$$\overline{h} = \sum_{n=2}^{NC} g(h_n) h_n \qquad A = 1 - g(h=0)$$

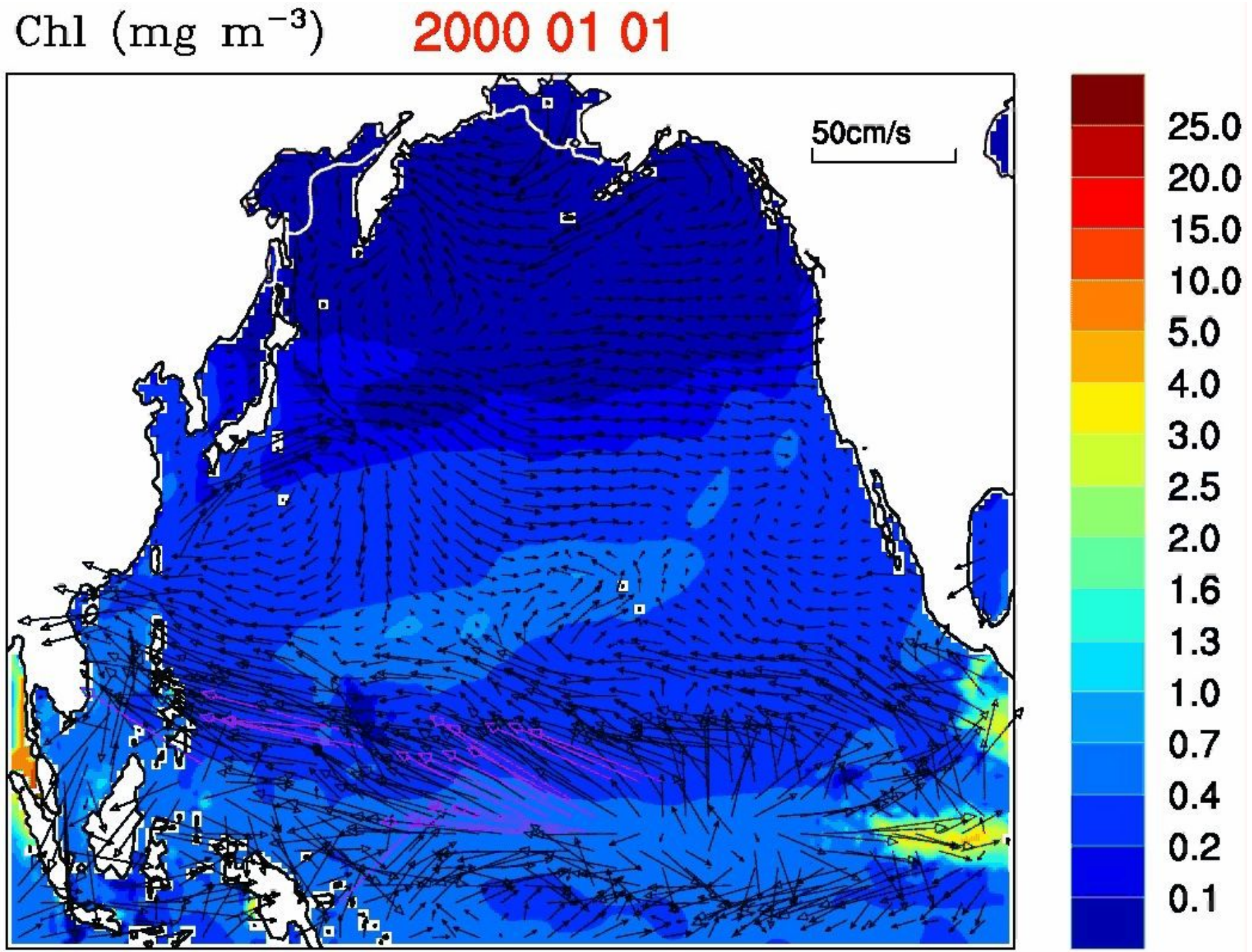
$$\overline{b} = \sum_{n=2}^{NC} g(h_n) b_n$$

Mean biological variable *b* in sea ice

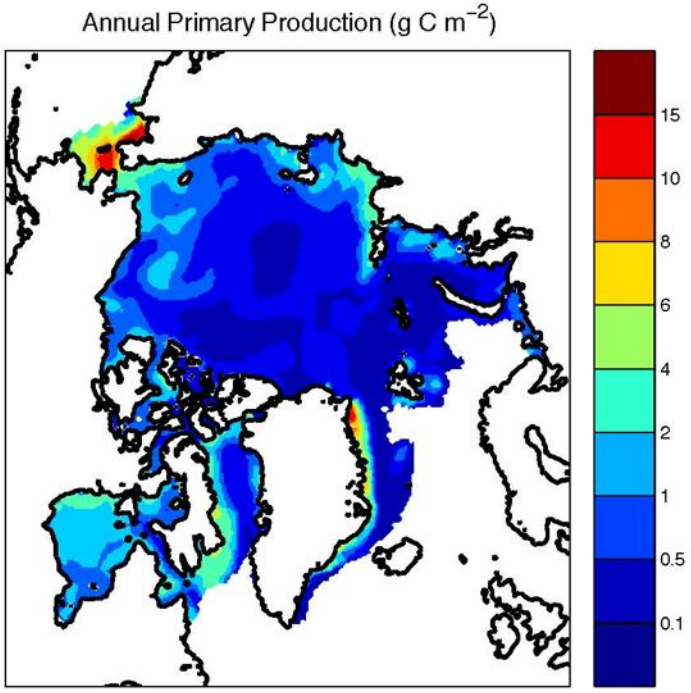
$$\frac{\partial b}{\partial t} = -\frac{\partial b u_i}{\partial x} - \frac{\partial b v_i}{\partial y}$$

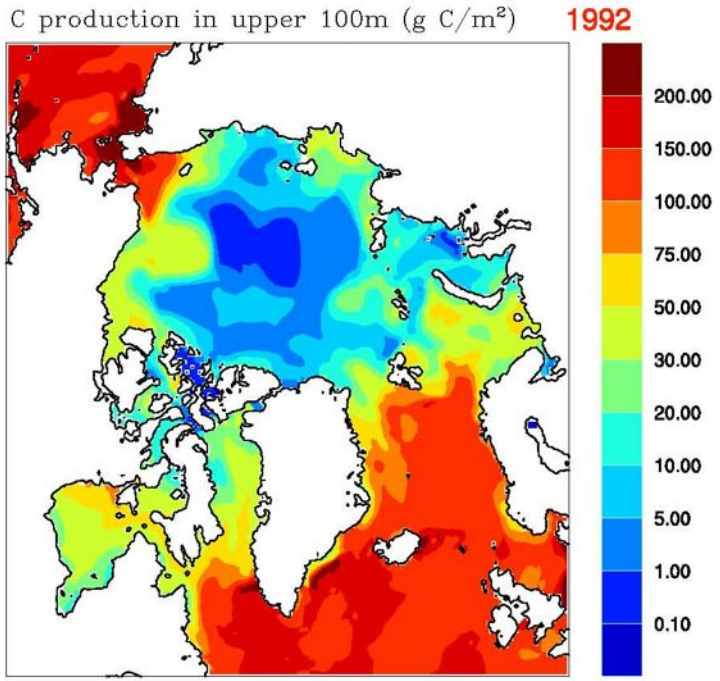
Horizontal advection


Chl and SSMI
1998 01
66.46
63.07
59.69
56.31
52.93
49.54
156.04
165.63
175.21
184.79
194.37
203.96
25.0
20.0
15.0
10.0
5.0
4.0
3.0
2.5
2.0
1.6
1.3
1.0
0.7
0.4
0.2
0.1


Chl (mg m^{-3})
2000 01 01
50cm/s
25.0
20.0
15.0
10.0
5.0
4.0
3.0
2.5
2.0
1.6
1.3
1.0
0.7
0.4
0.2
0.1

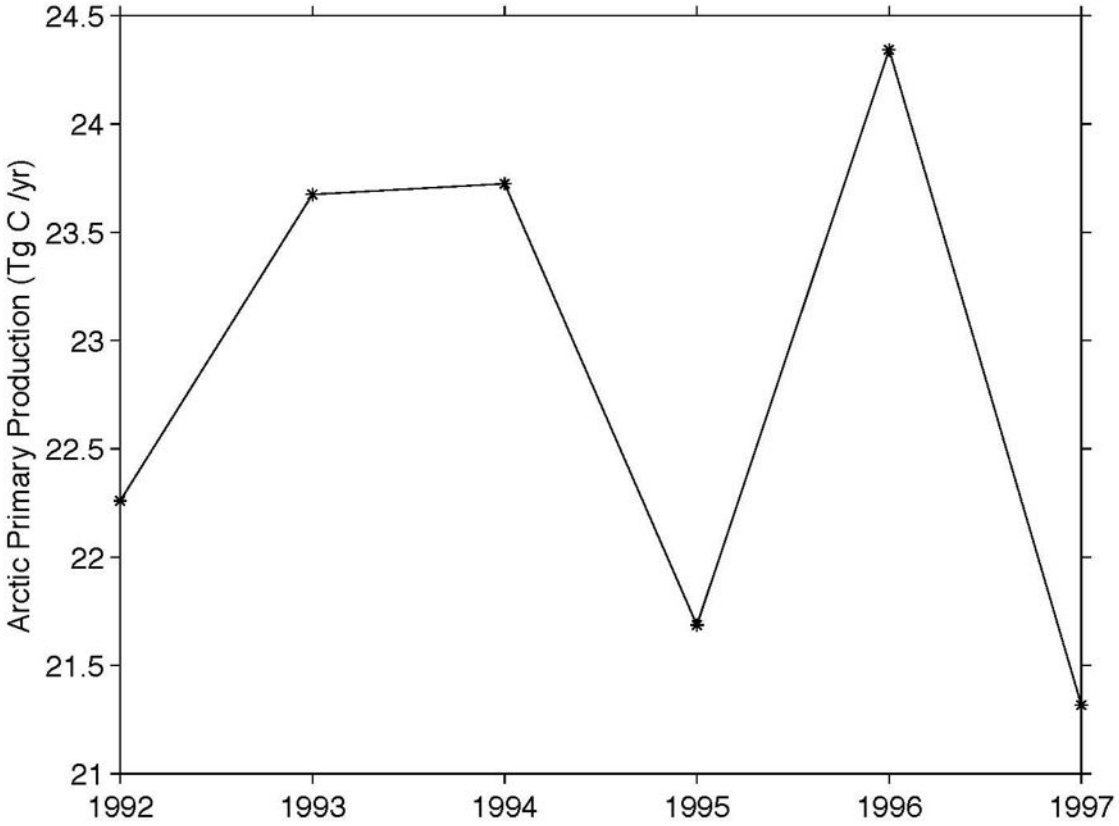
Model estimate of annual primary production in sea ice and ocean



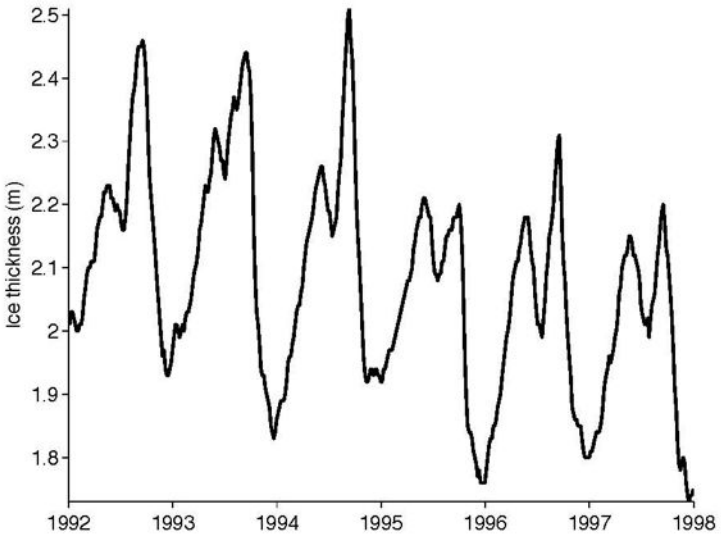


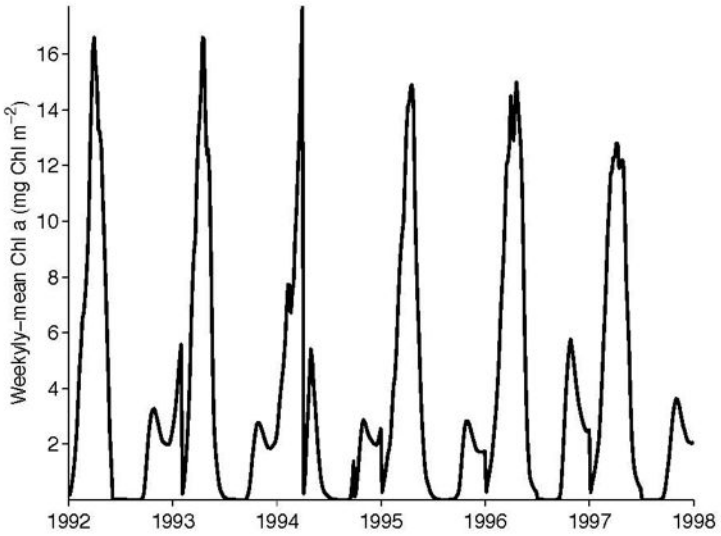
Model estimate of annual ice algal production within the observed range of 9 ~70 Tg C /yr

The production level are regulated by light, the nutrients flux related to ice growth rate, and ice melting flushing.



Less sea ice (1995-1997) --- Less sea ice algal biomass.

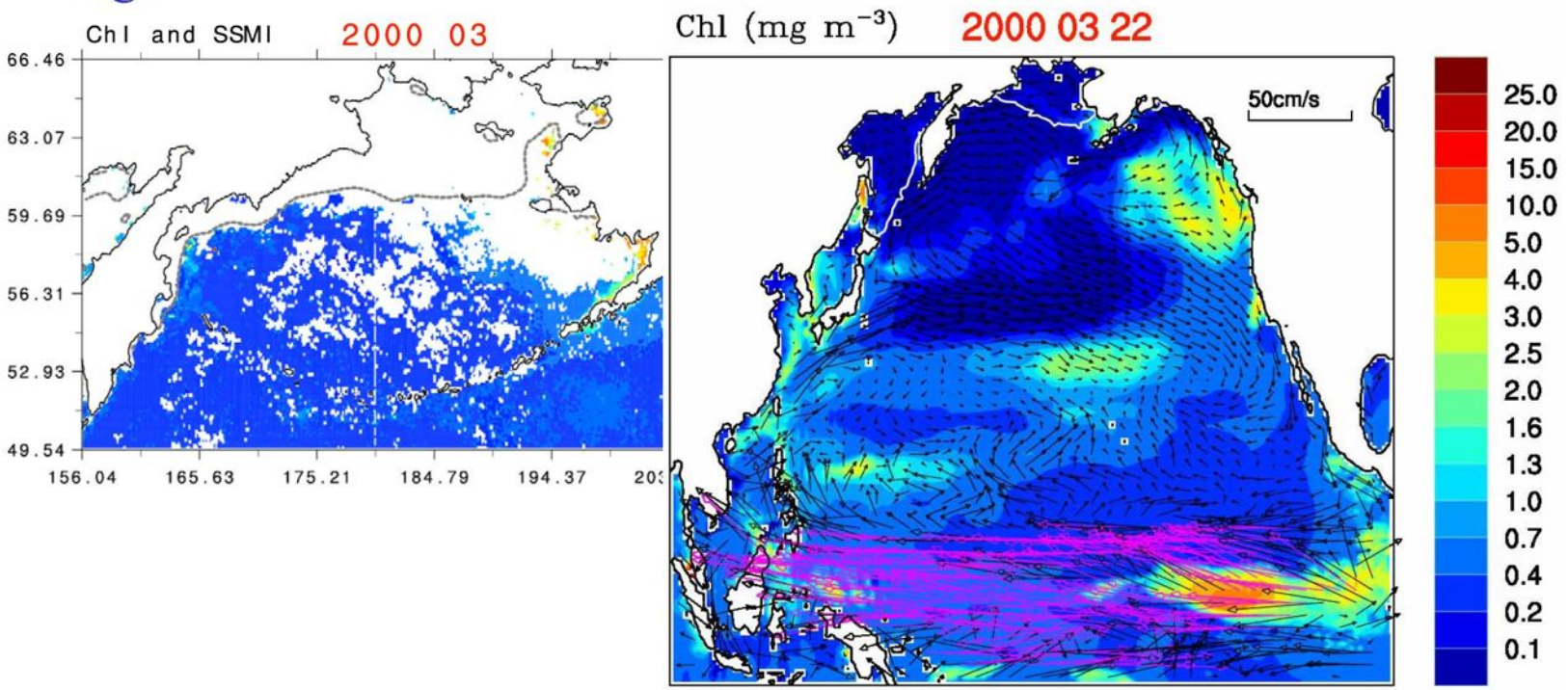




Comparison of model vs. monthly satellite remote sensing data

Satellite remote sensing sea surface Chl and ice edge

Modeled sea surface Chl and ice edge



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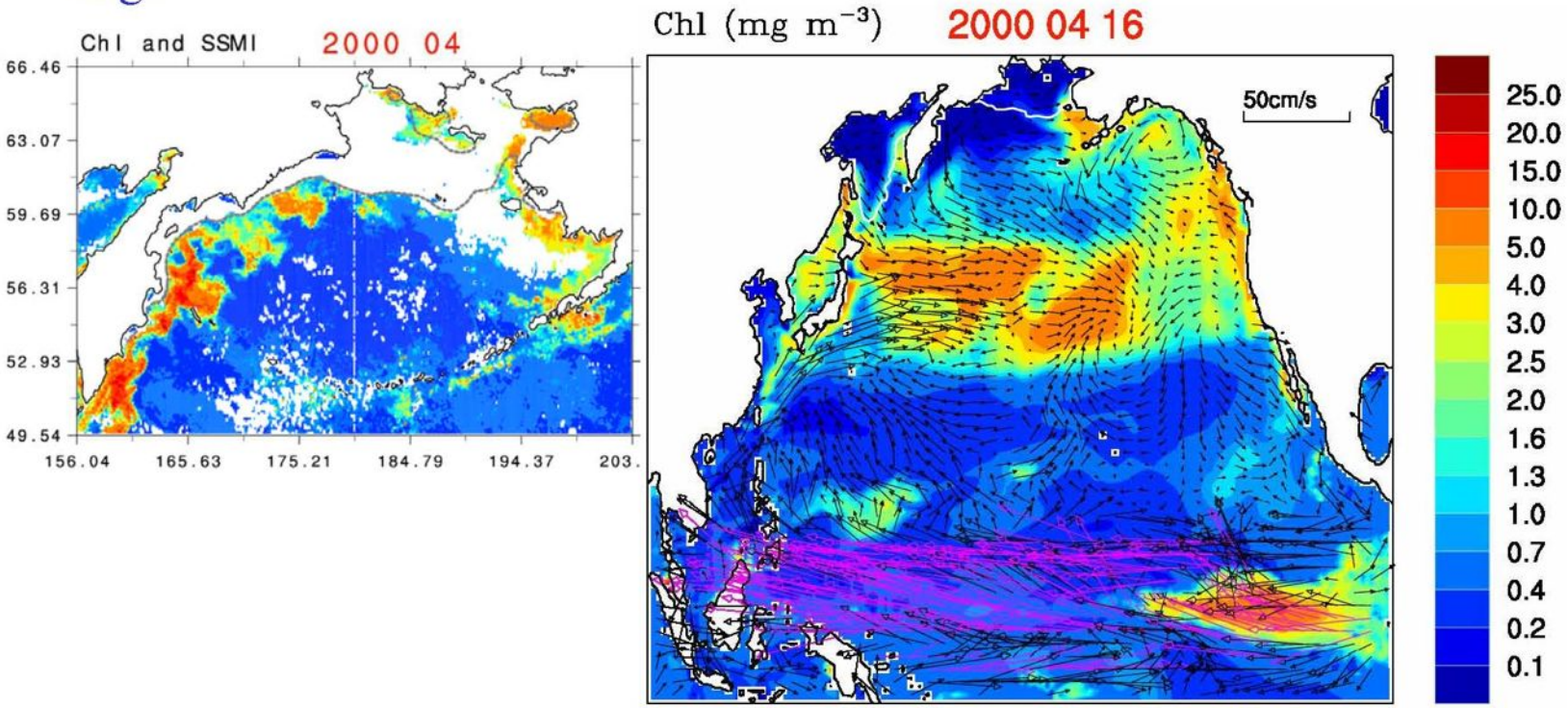

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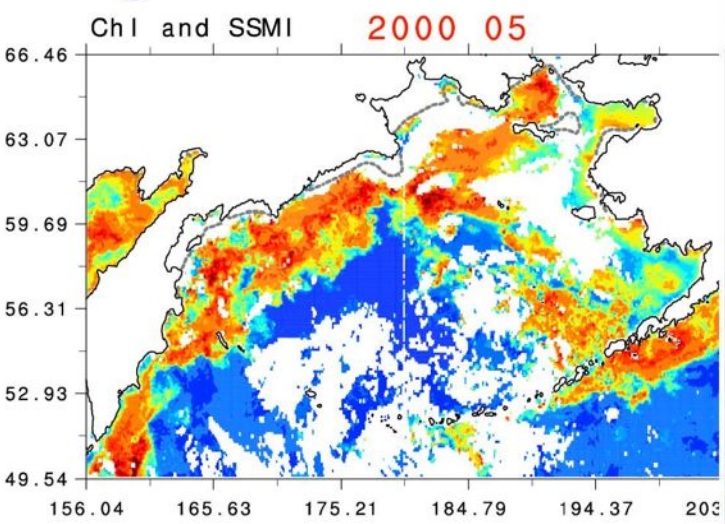

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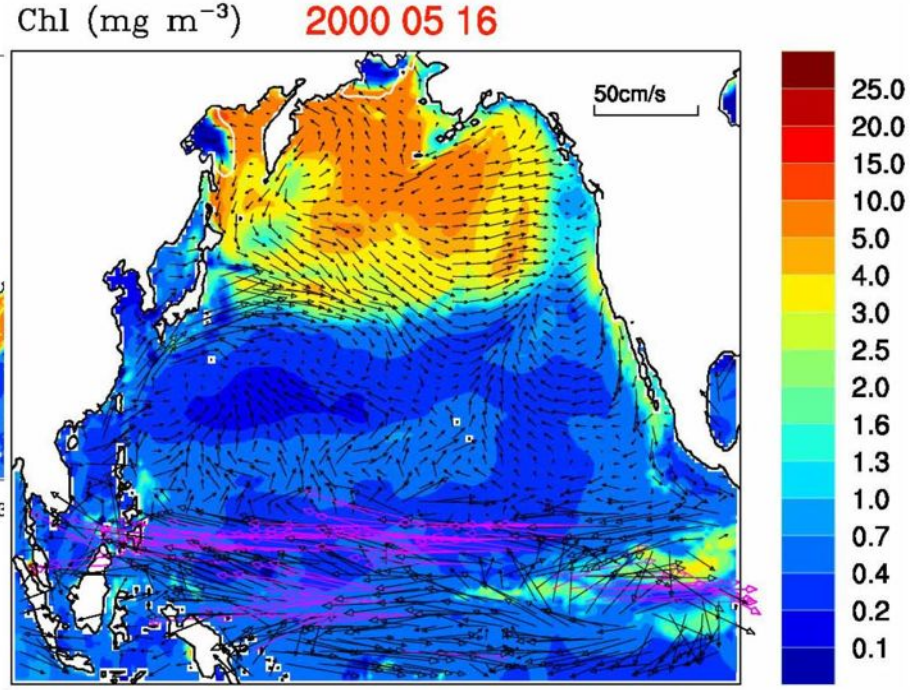

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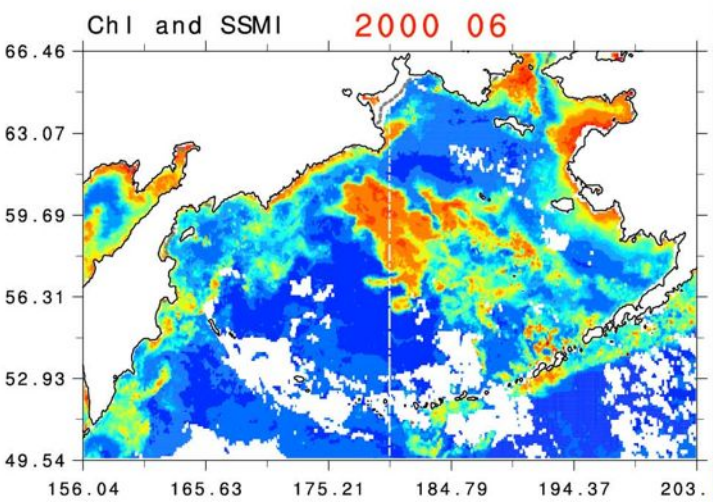

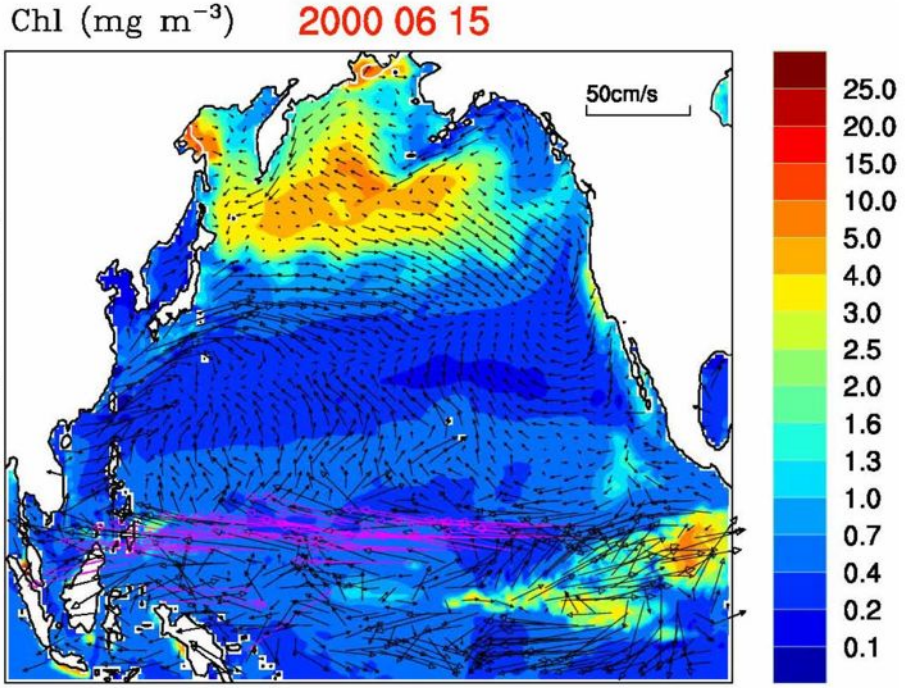

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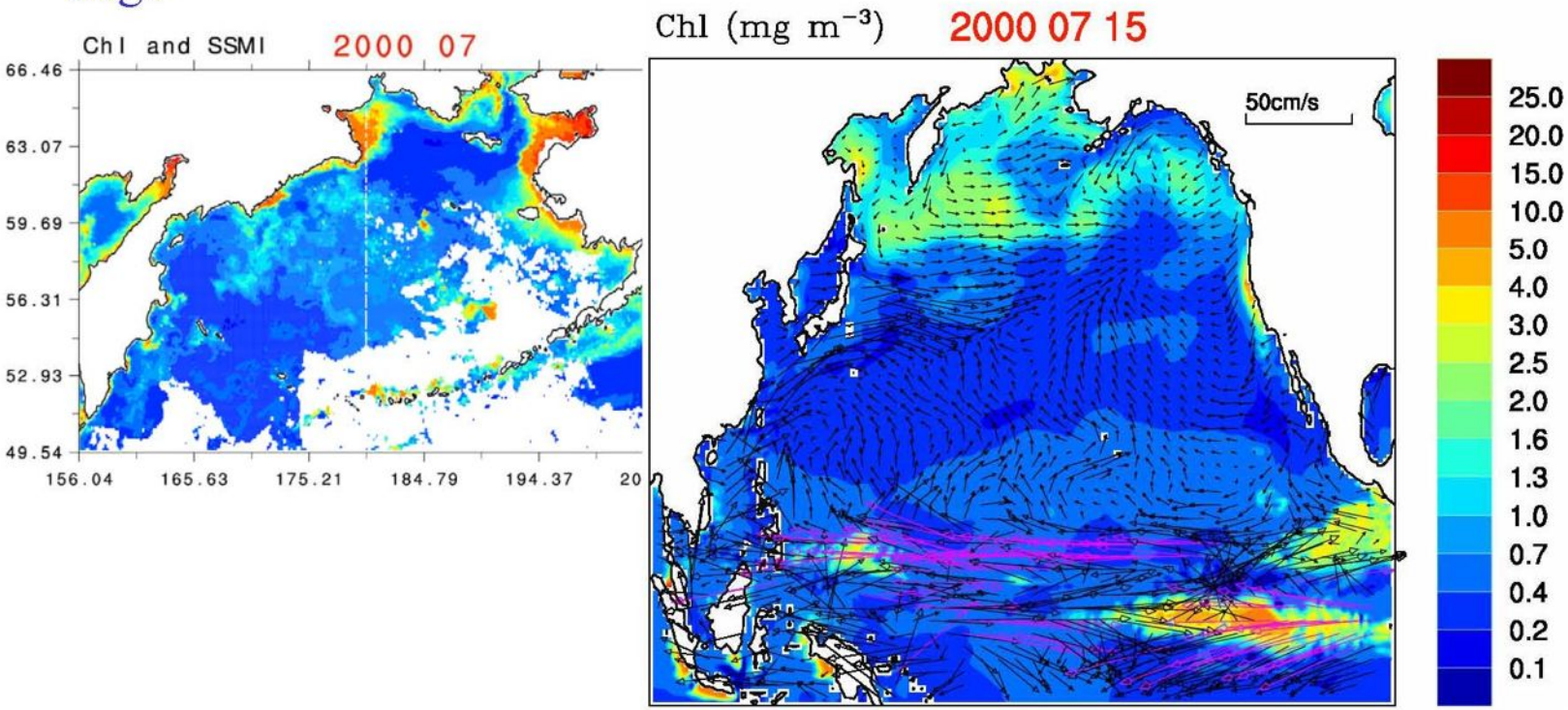

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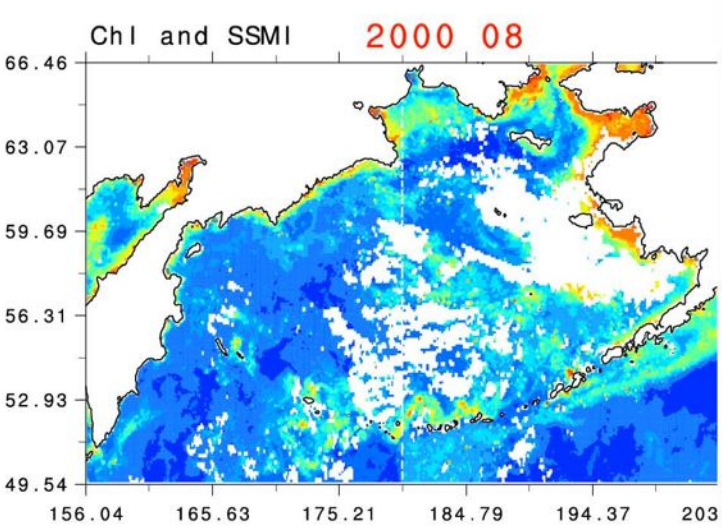

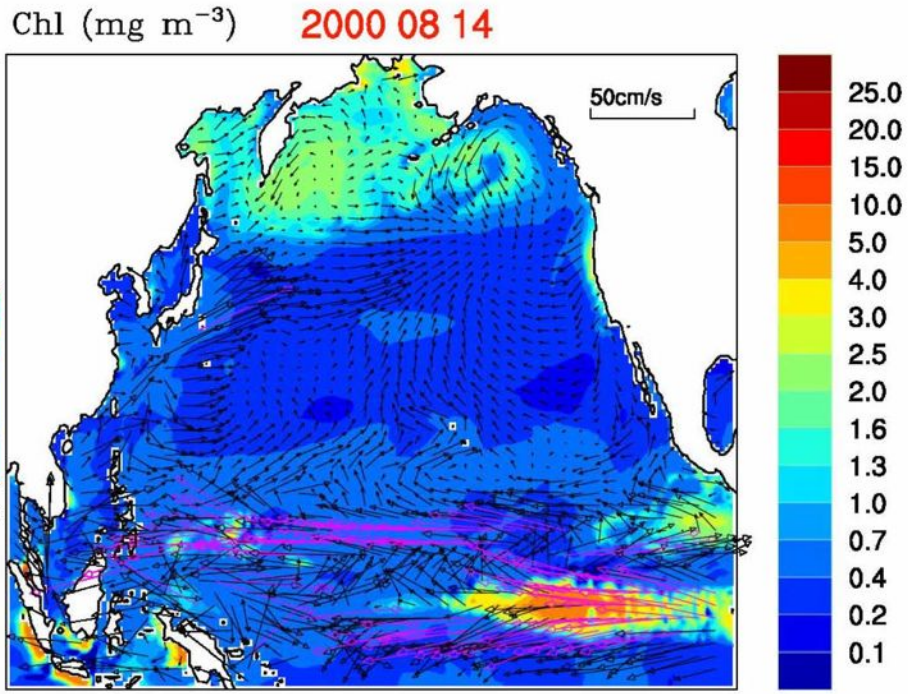

Our future research focus with this global POP-CICE-ecosystem model: model validation of the following processes:

- 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.