Application of 3D-NEMURO to an eddy permitting general circulation model for global domain

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[3]Creation of technological seeds responding to social demands (CREST), JST
[4]Innovative Program of Climate change Projection for the 21st Century, MEXT,

Outline

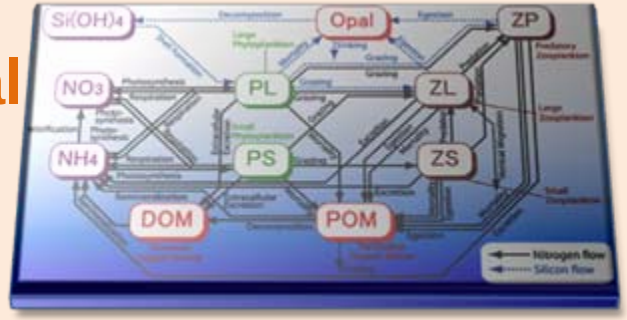
1. Motivation
2. Numerical model
3. Preliminary result
4. Summary and future plans

Motivation

1. Construct a basis of integrated ocean models connecting lower to higher trophic levels.
2. Further understanding of relation between inter-annual variability of biogeochemical cycles and climate.
3. Quantify effects of eddy transport on basin-scale biogeochemical cycles
4. Preparation of ocean ecosystem model for next IPCC report.

Model overview

Biogeochemical Part



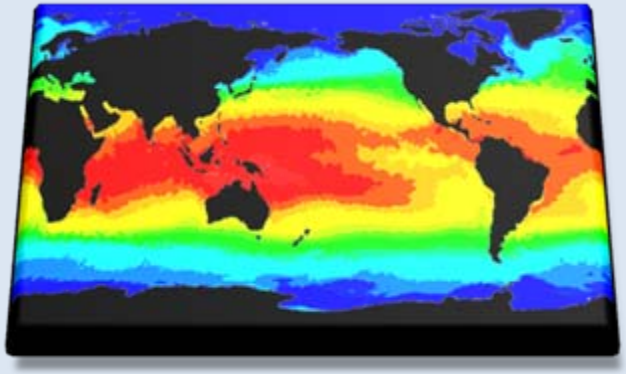
Biogeochemical Ecosystem Model
3D-NEMURO

Nitrogen and Silicon cycles with
2 types of phytoplankton and
3 types of zooplankton

Offline-coupling

5days mean T, S, U, V, SH, SWA,
A_{HV} and frequency of convective ac

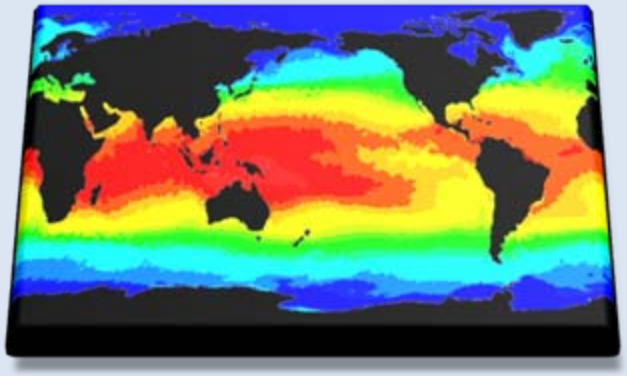
Physical Part



Ocean General Circulation Model
IcedCOCO4.3

Eddy permitting OGCM with multi-category Sea-Ice,
1/4°x 1/6°resolution with
51 vertical levels .
(including Bottom Boundary Layer)

Physical model experiment



Ocean General Circulation Model
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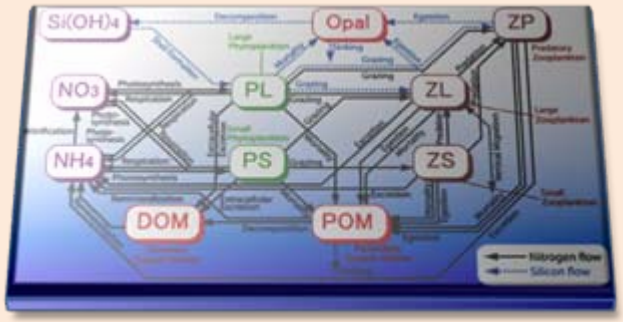
Eddy permitting OGCM with multi-category Sea-Ice,
1/4°x 1/6°resolution with
51 vertical levels .
(including Bottom Boundary Layer)

Hindcast Experiment: 46 years historical run (1959-2004)

- Initial condition: December climatology of WOA01
- Sea surface forcing: Common Ocean-ice Reference Experiments (CORE)
- Spin-up time: 20 years (11 years CORE climatology forcing and 9 years of 1958 forc

Biogeochemical model experiment



Biogeochemical Ecosystem Model
3D-NEMURO

Nitrogen and Silicon cycles with
2 types of phytoplankton,
3 types of zooplankton.

All compartments are treated as passive tracer of physical field

Hindcast Experiment: 46 years historical run (1959-2004)

■ Initial condition: WOA05 annual mean of NO_3 and $Si(OH)_4$,
constant value for NH_4 (0.5 μmol/l), phyto- and zoo-plankton
(0.1 μmol/l), and DOM, POM (0 μmol/l)

■ Physical forcing: 5days mean of physical-model output data
(T, S, U, V, SH, SWA, A_{HV}, frequency of convective

Preliminary Result

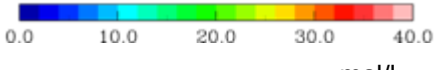
1. Modeled Nutrient distribution
2. Modeled seasonal cycles of Chlorophyll-a and plankton biomass
3. Modeled Inter-annual variability of plankton biomass

Annual mean Nutrient distribution

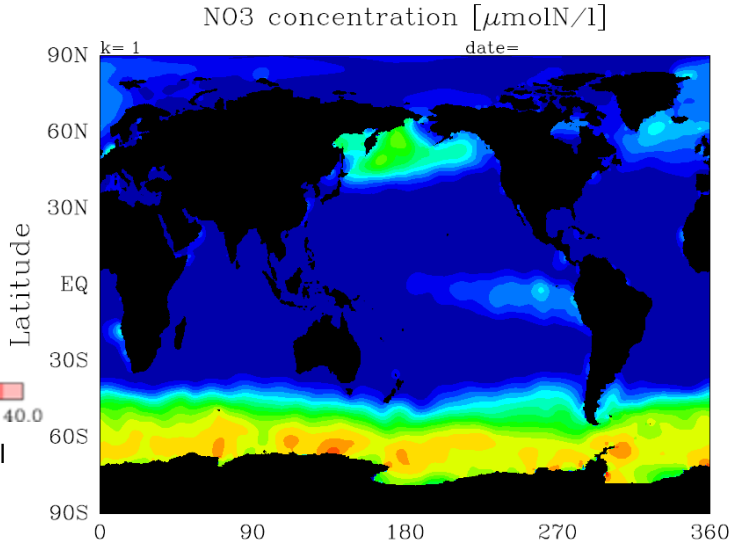
WOA05

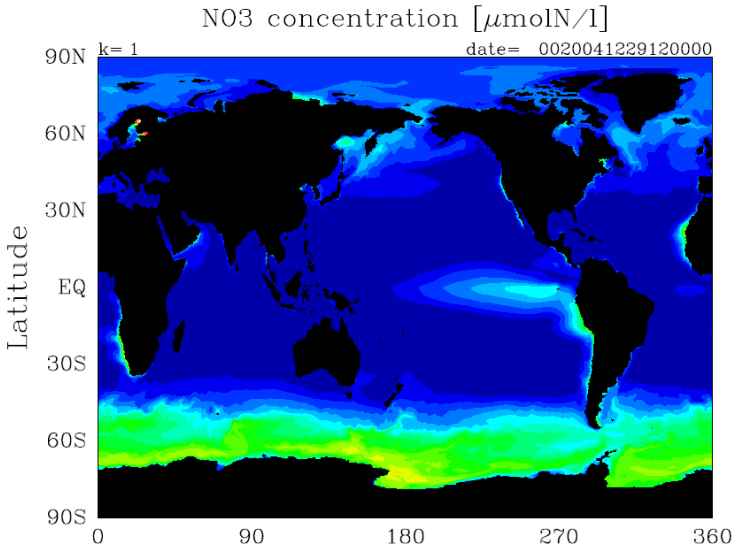
Model: 1959-2004 mea

NO_3



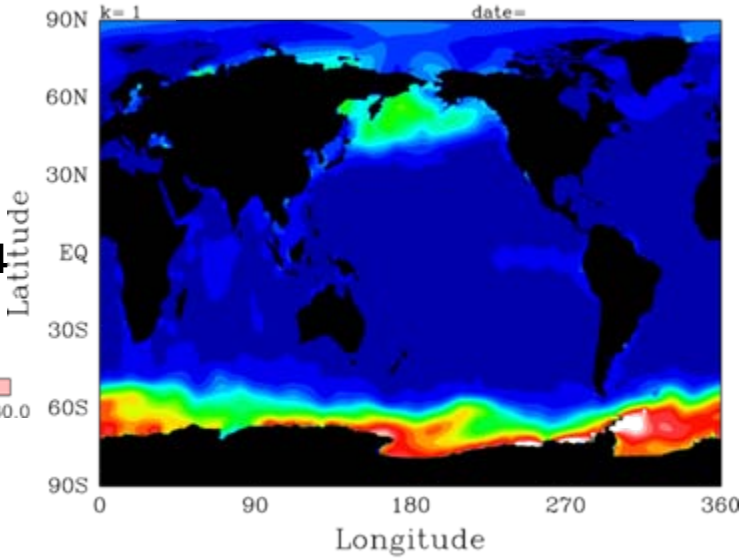
µmol/l

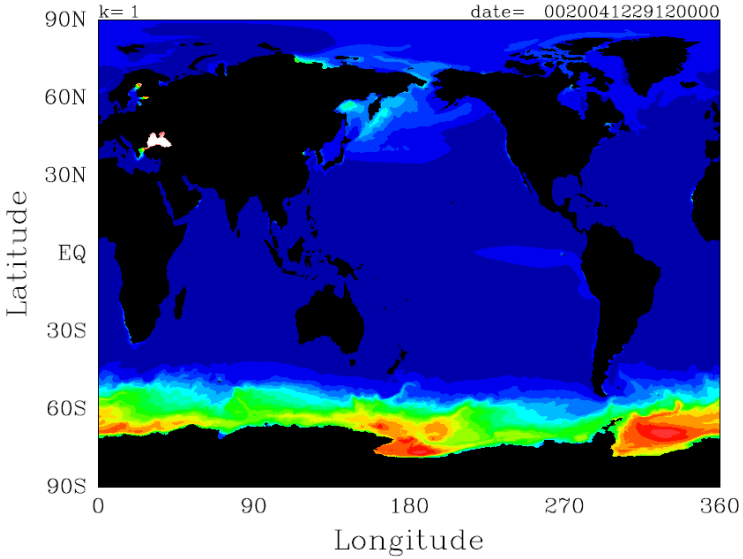




$Si(OH)_4$

µmol/l



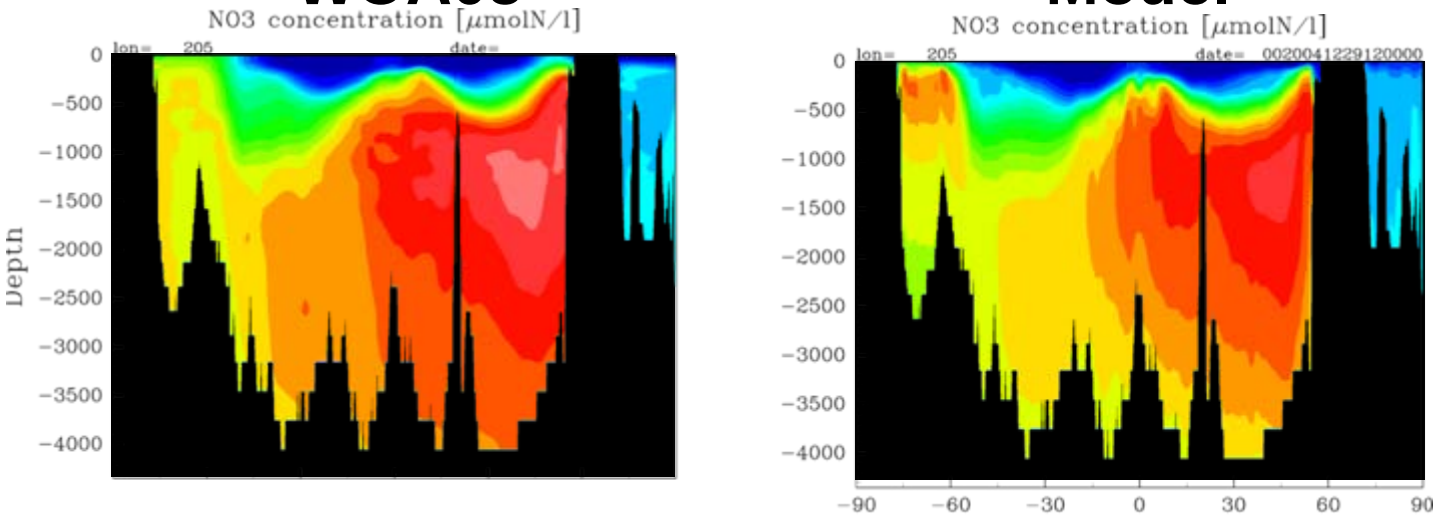


Vertical section of Nitrate

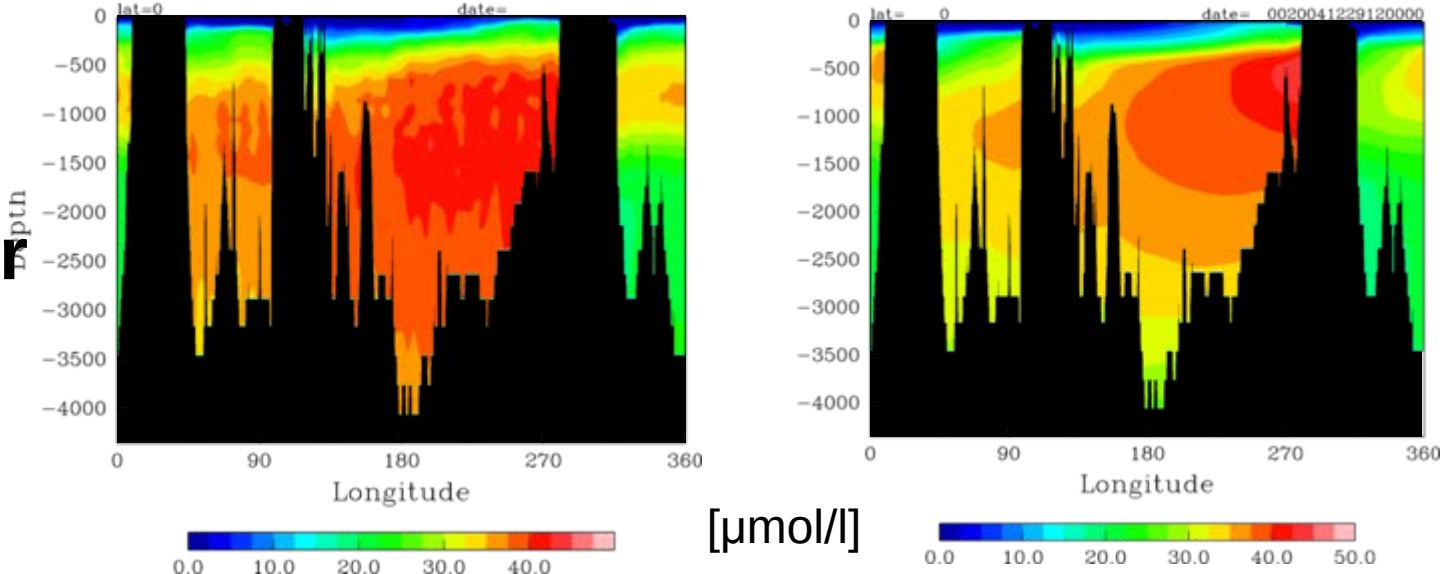
WOA05

Model

NO_3 155W



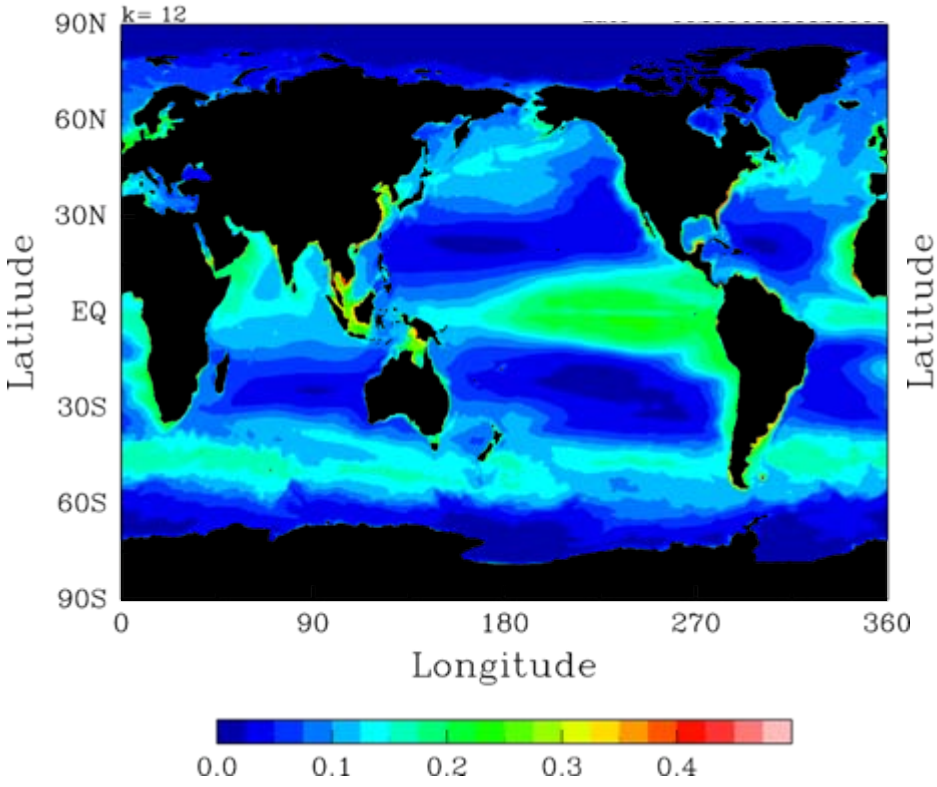
NO_3 Equator



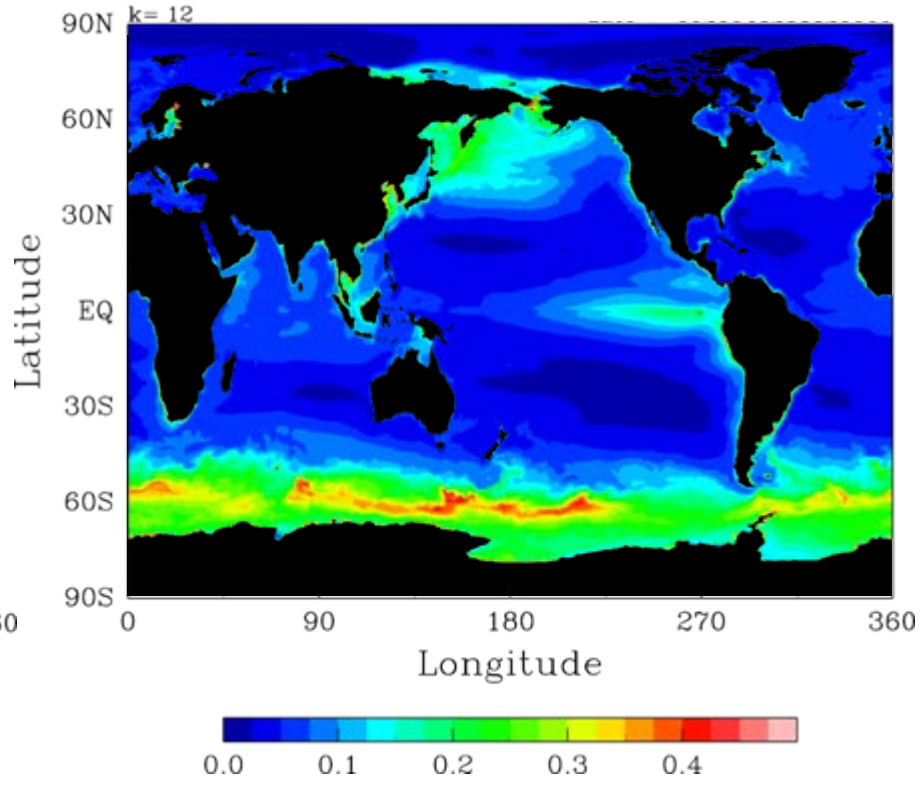
[μmol/l]

Modeled Phytoplankton biomass
1959-2004 annual mean
(0-110m mean)

Annual mean PS

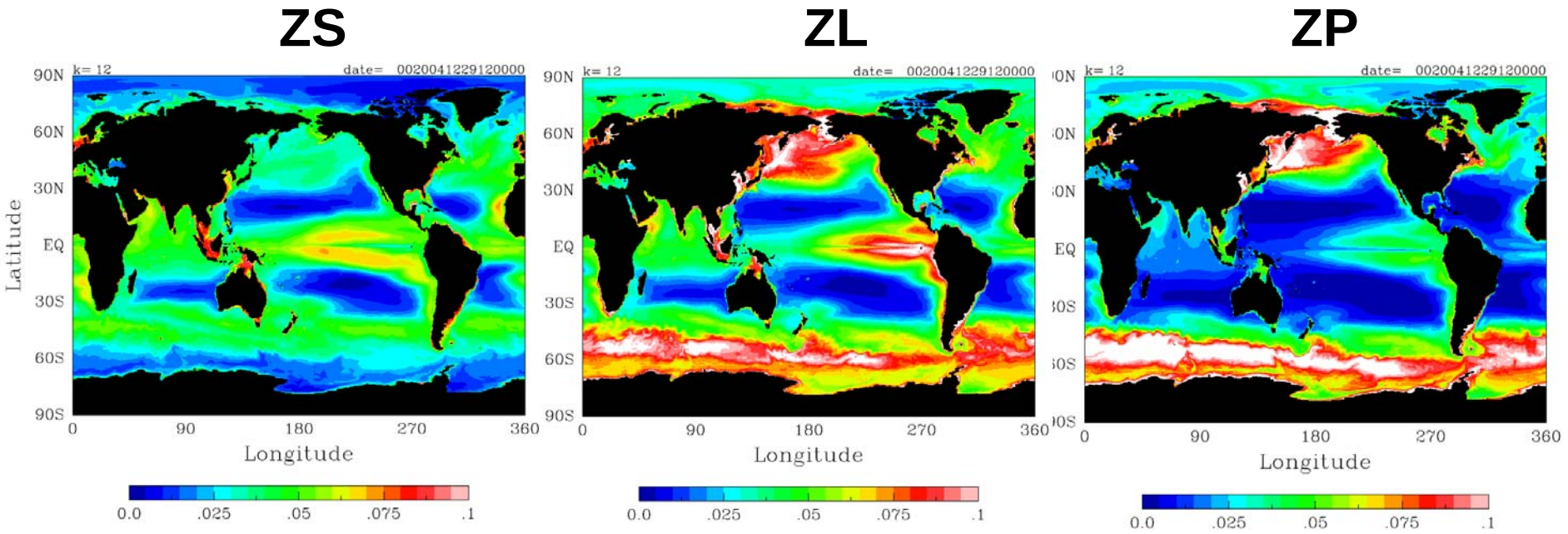


Annual mean PL



The model well captures plankton biomass distribution except for the Southern Ocean

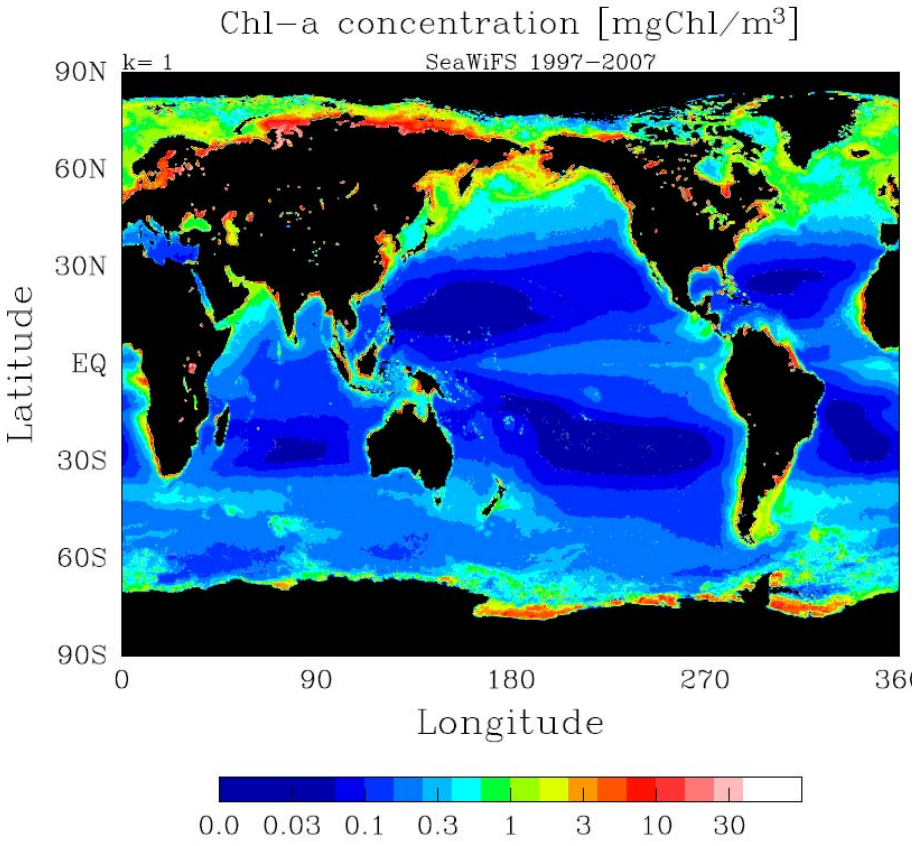
Modeled Zooplankton biomass
1959-2004 annual mean (0-110m)



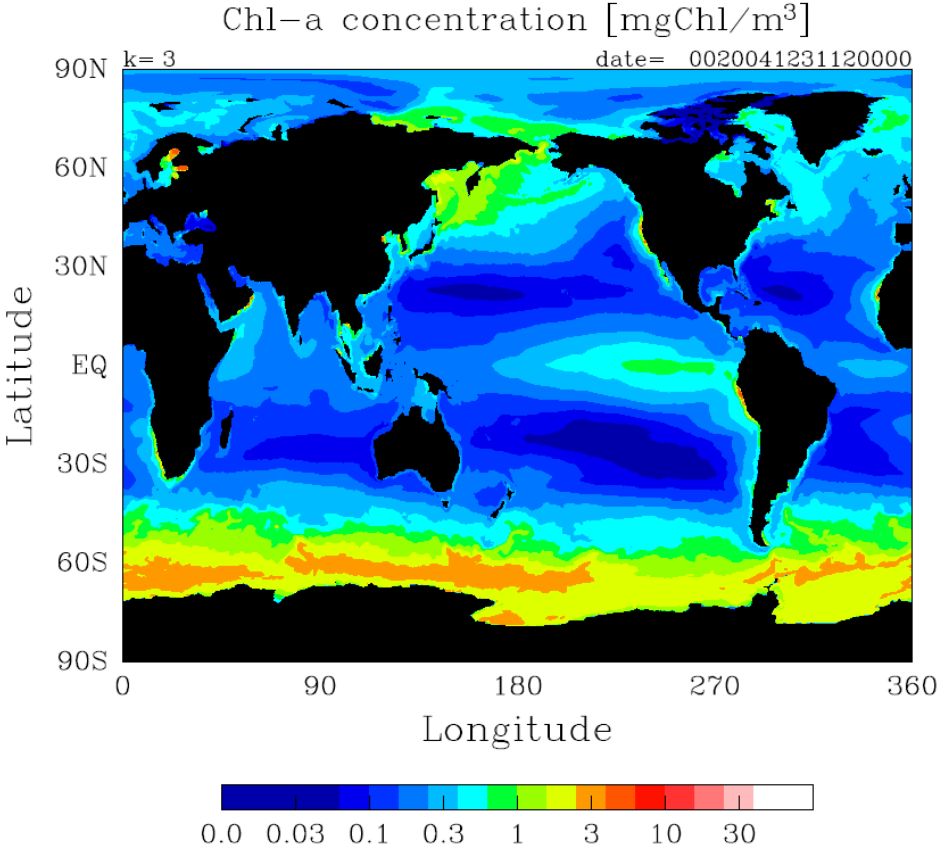
The model also captures zooplankton biomass distribution except for the Southern Ocean

Annual mean Chlorophyll-a (0-12m mean)

SeaWiFS (1997-2007)



Model (1959-2004)

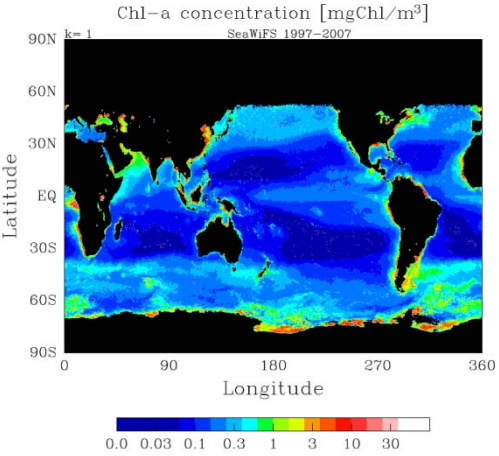


The model well reproduces chlorophyll distribution of SeaWiFS observation except for the Southern Ocean

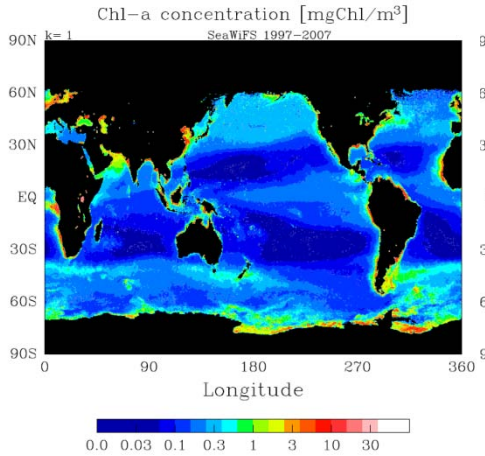
Seasonal cycles of Chlorophyll-a

SeaWiFS

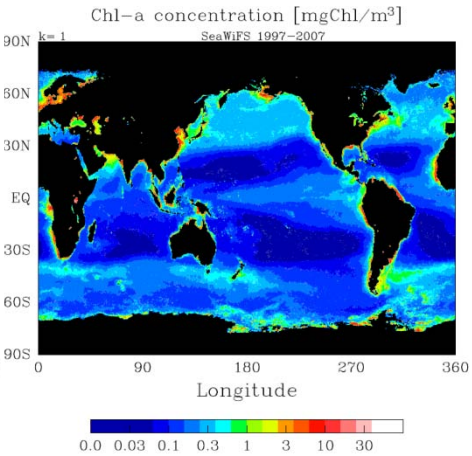
Jan.



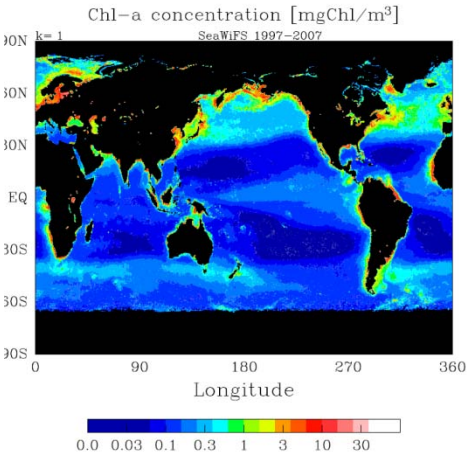
Feb.



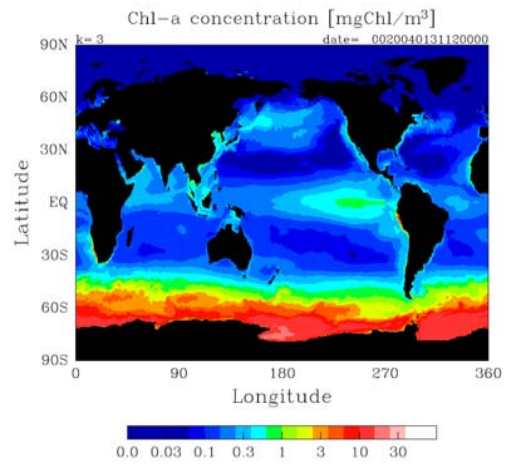
Mar.

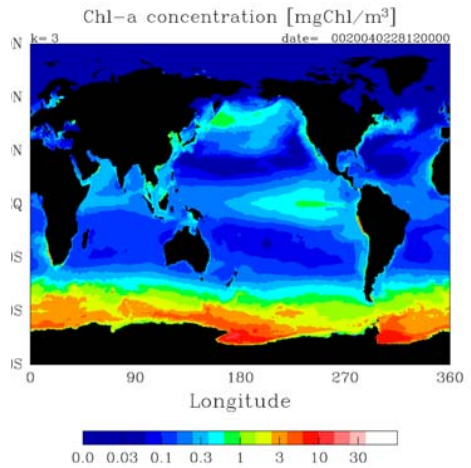


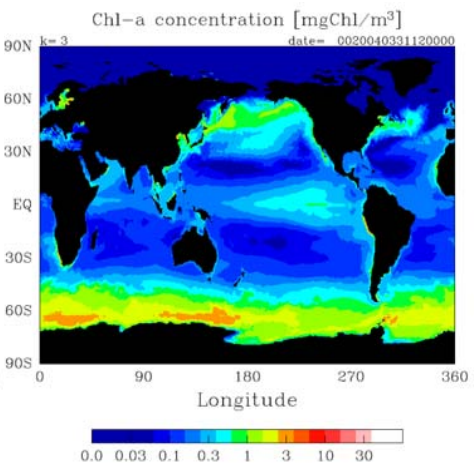
Apr.

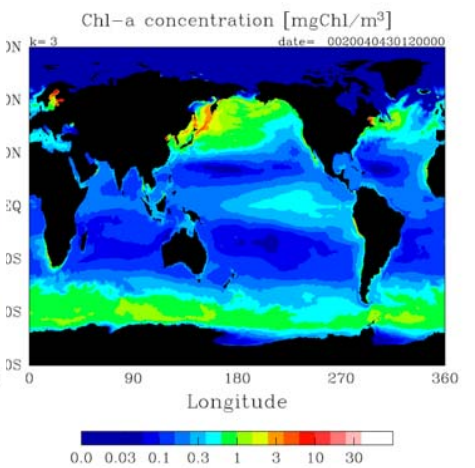


Model







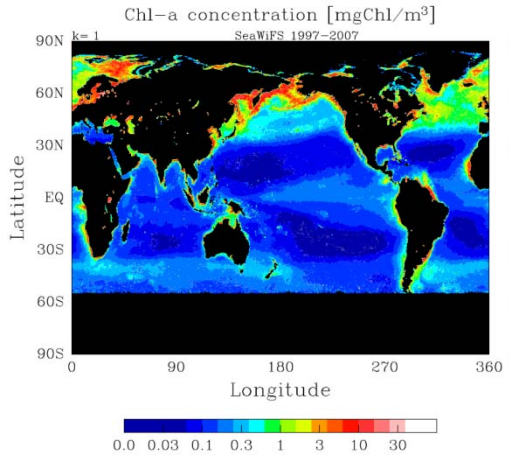


The model roughly captures initiation of spring bloom in the North Pacific

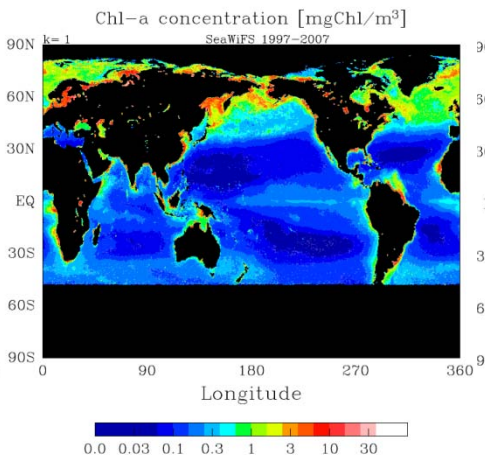
Spring to Summer

SeaWiFS

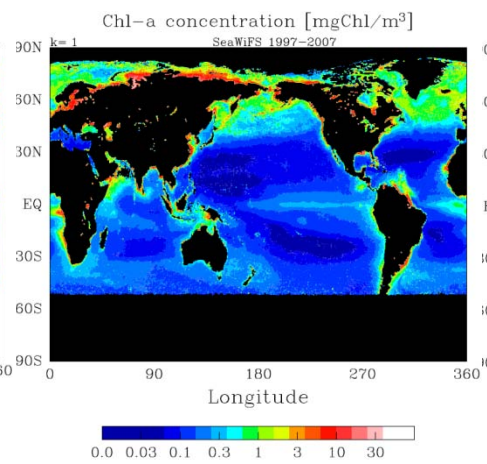
May



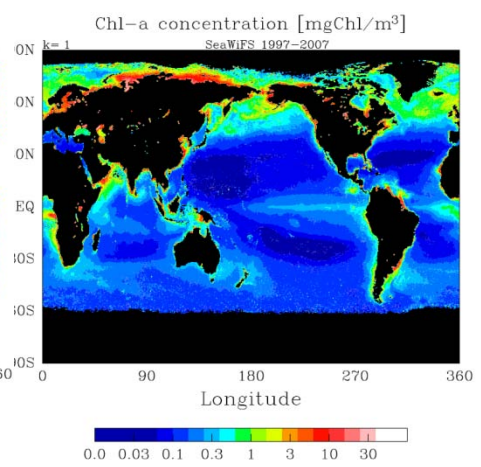
Jun



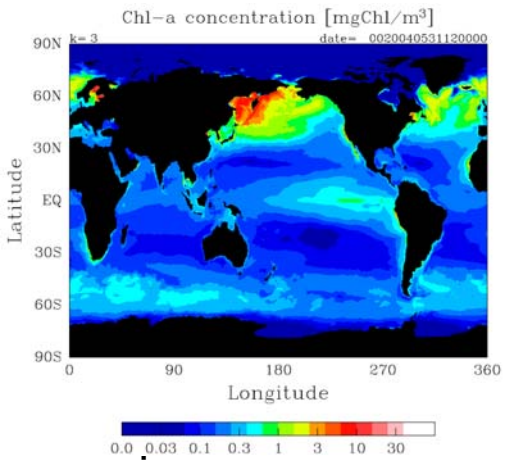
Jul.

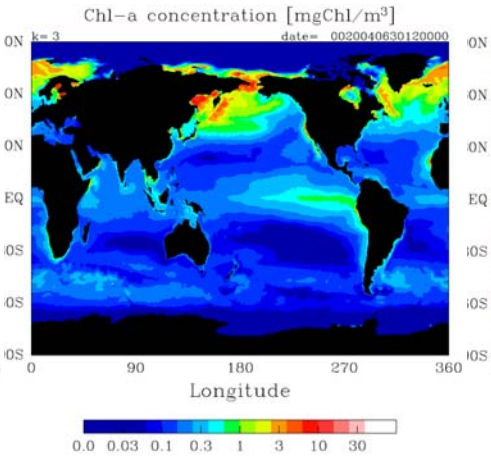


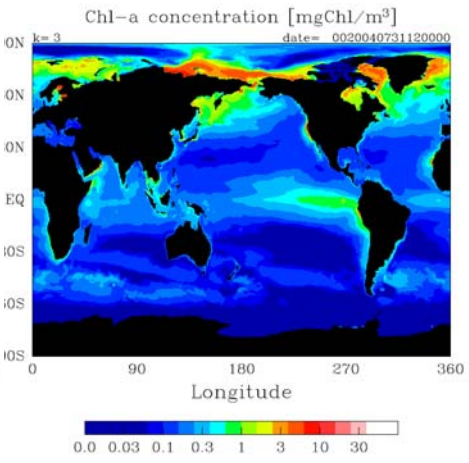
Aug.

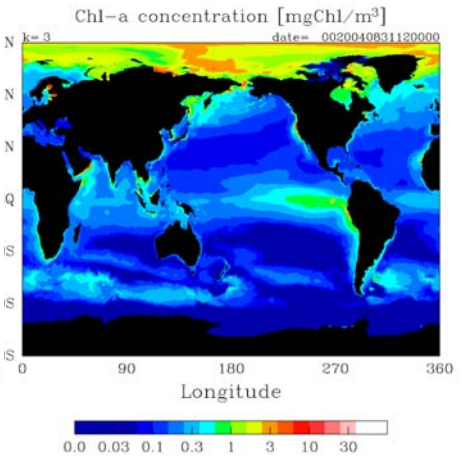


Model







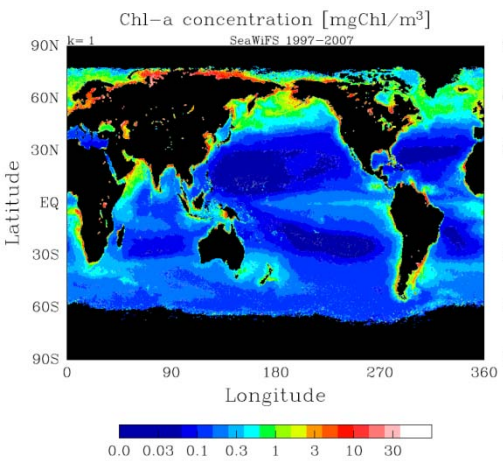


The model captures spring bloom in May, and also termination of bloom in July and August.

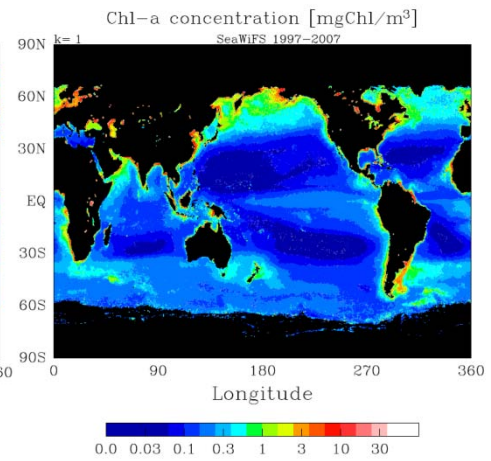
Autumn to Winter

SeaWiFS

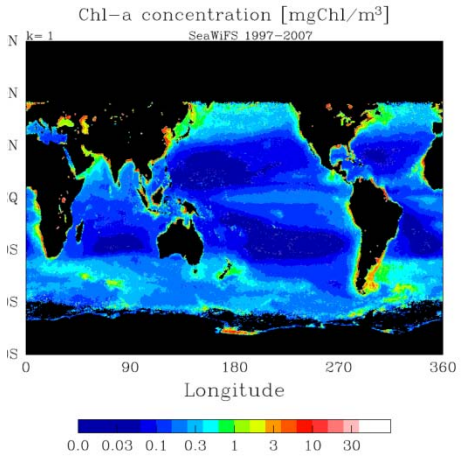
Sep.



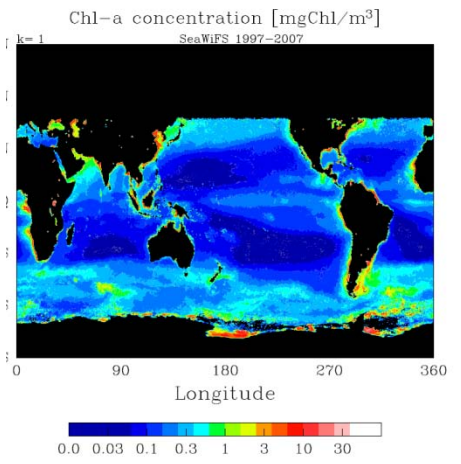
Oct.



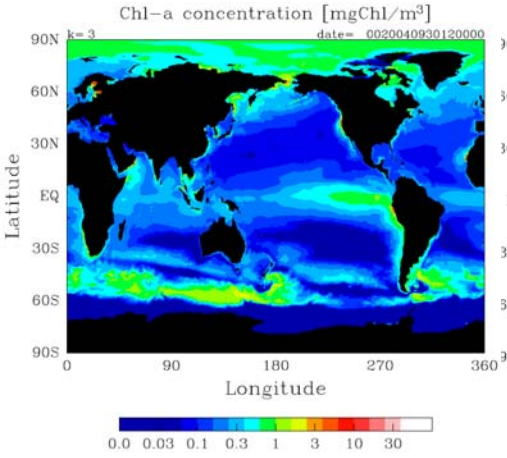
Nov.

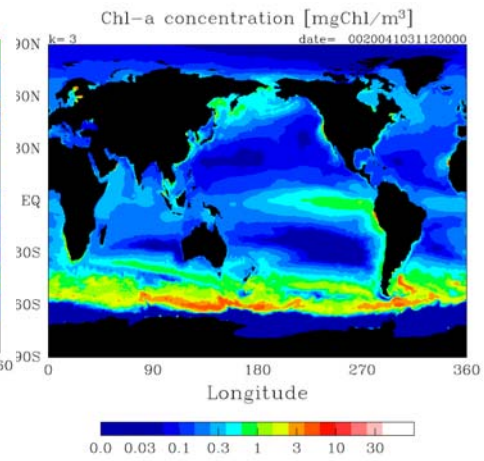


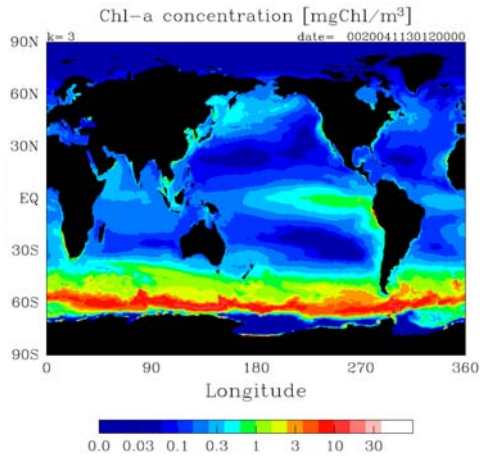
Dec.

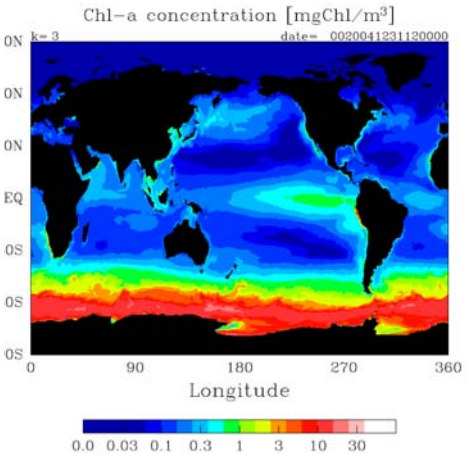


Model







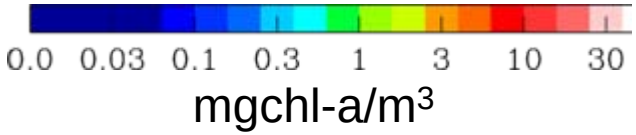


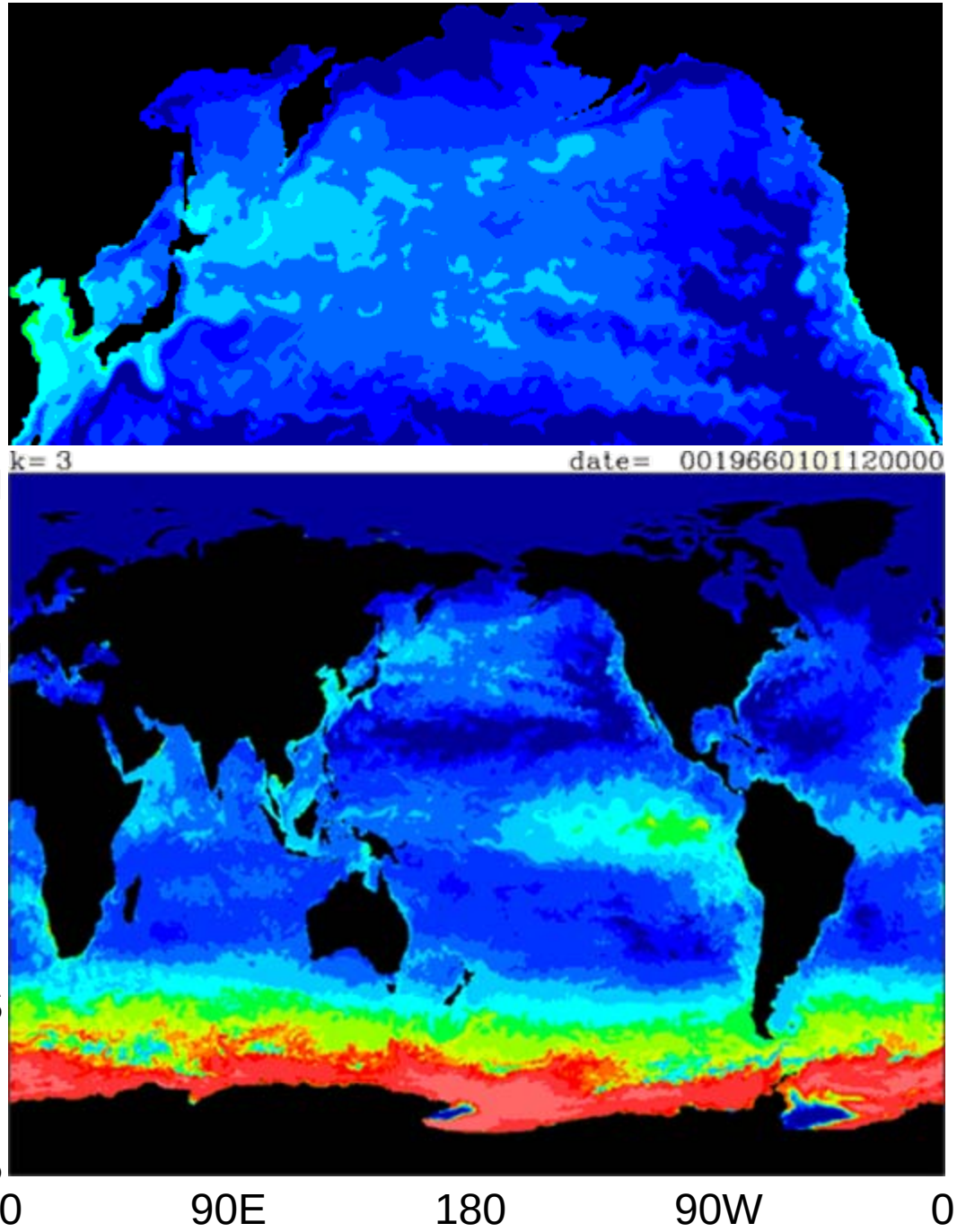
From Autumn to Winter, the model also well reproduces the observed seasonal transitions.

Seasonal variation of modeled surface Chlorophyll-a in 1966

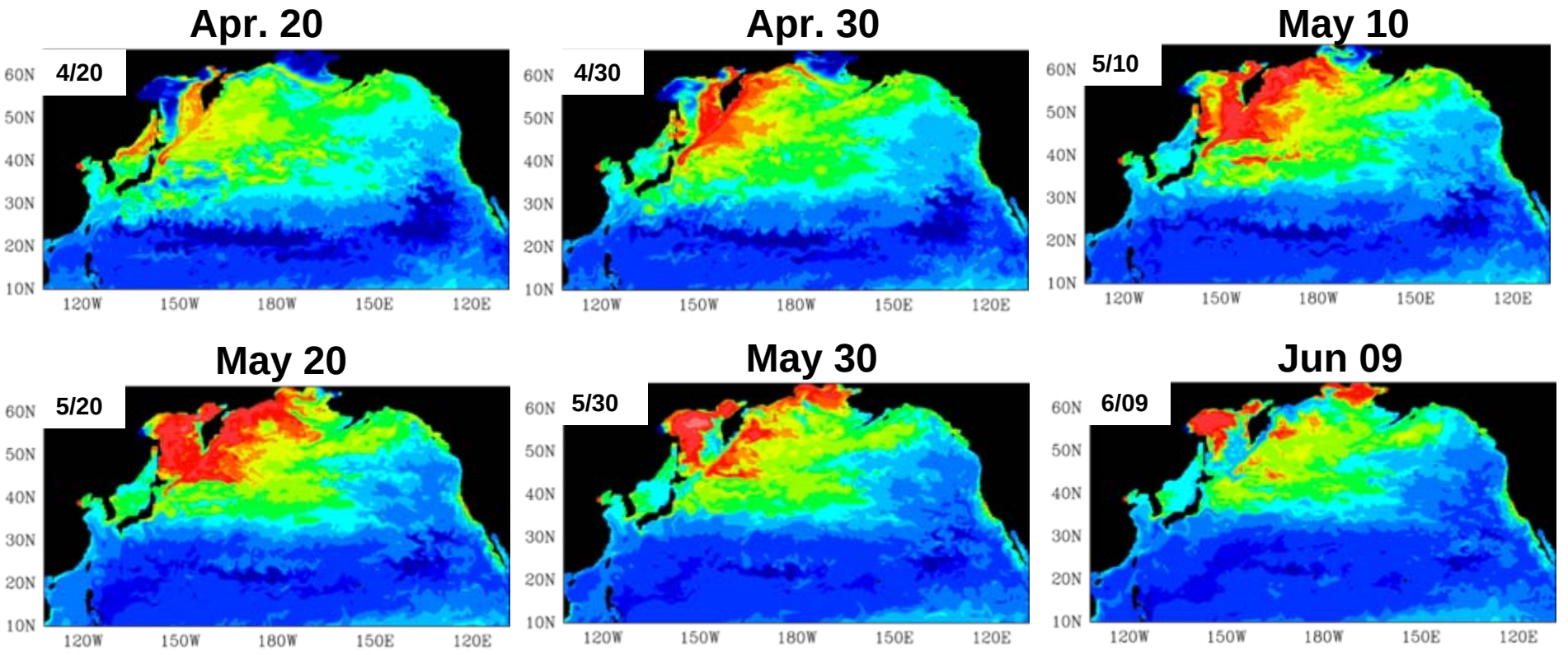
1/4° x 1/6° with global domain

The model well reproduces
- eddying field of chl-a,
- western boundaries,
- Coastal upwelling regoion, etc.





Sequence of modeled Spring bloom



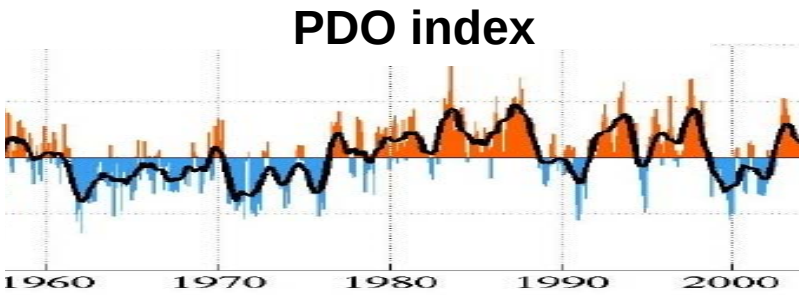
Surface Chlorophyll-a distribution from 20 Apr to 9 Jun in 1986.

Okhotsuku Sea ← Along Kuril Island → Western North Pacific → Bering sea

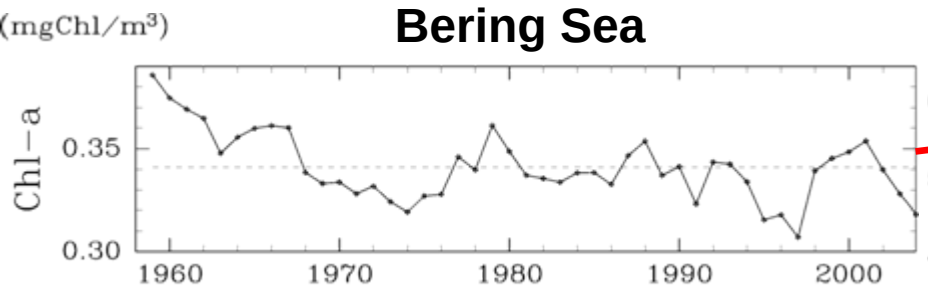
East of Tohoku ↑

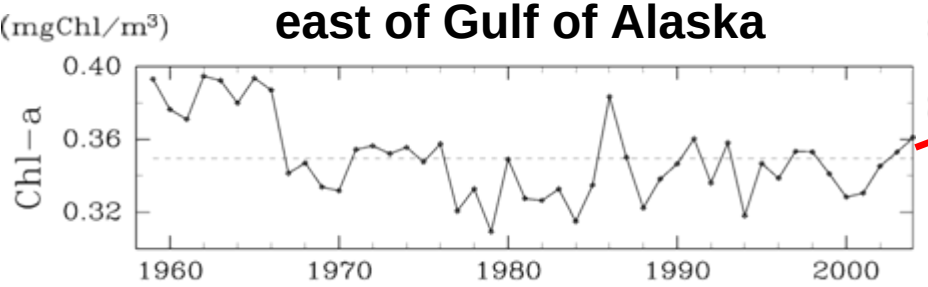
Along Kuril Island → Kuroshio Extension

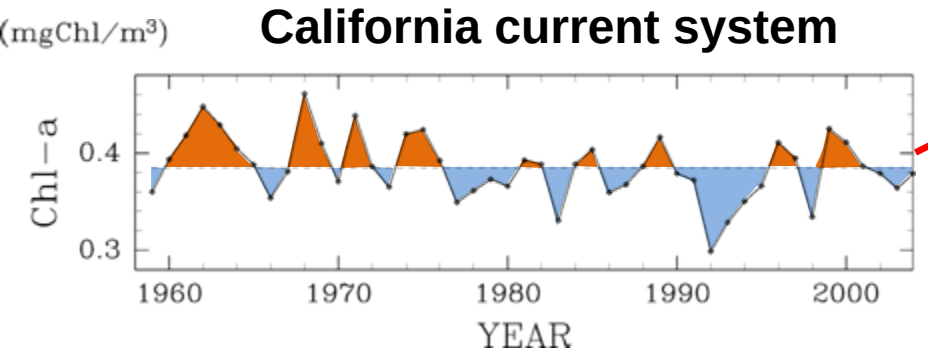
Interannual variation of annual mean

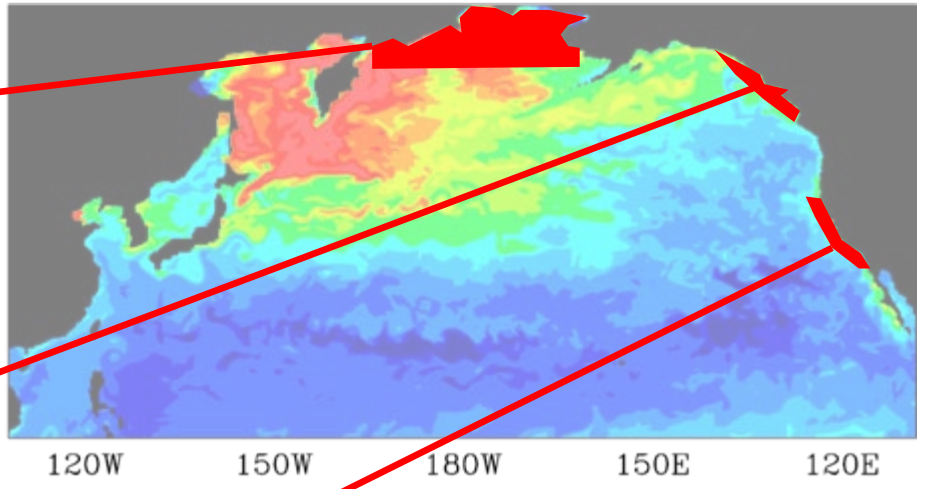


POX index: http://jisao.washington.edu/pdo/





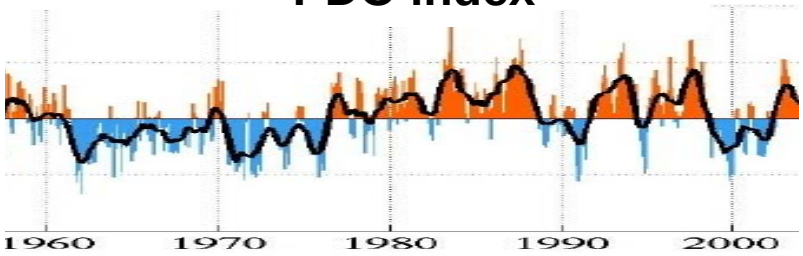




- Decadal variation of Chl-a over Bering Sea and Gulf of Alaska
- Negative correlation between PDO index and Chl-a on CCS region

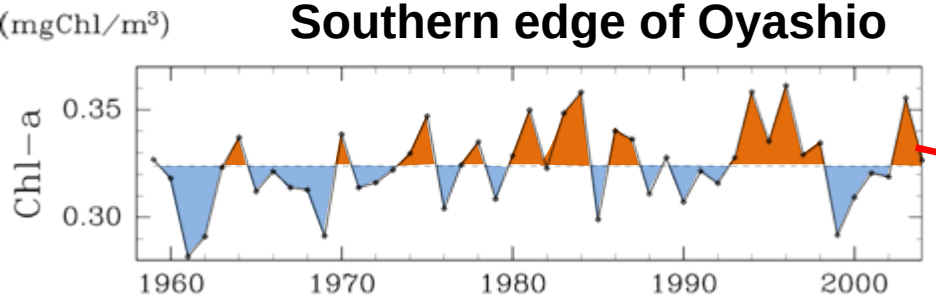
Interannual variation of annual mean

PDO index

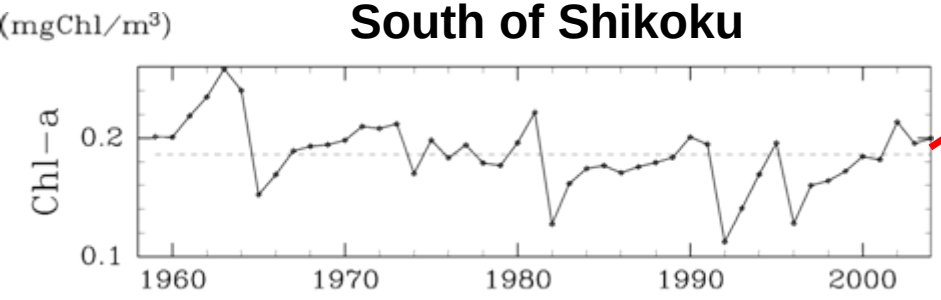


POX index: http://jisao.washington.edu/pdo/

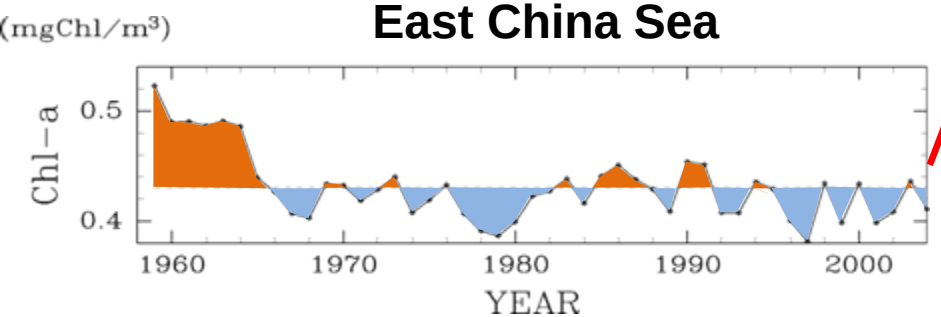
Southern edge of Oyashio

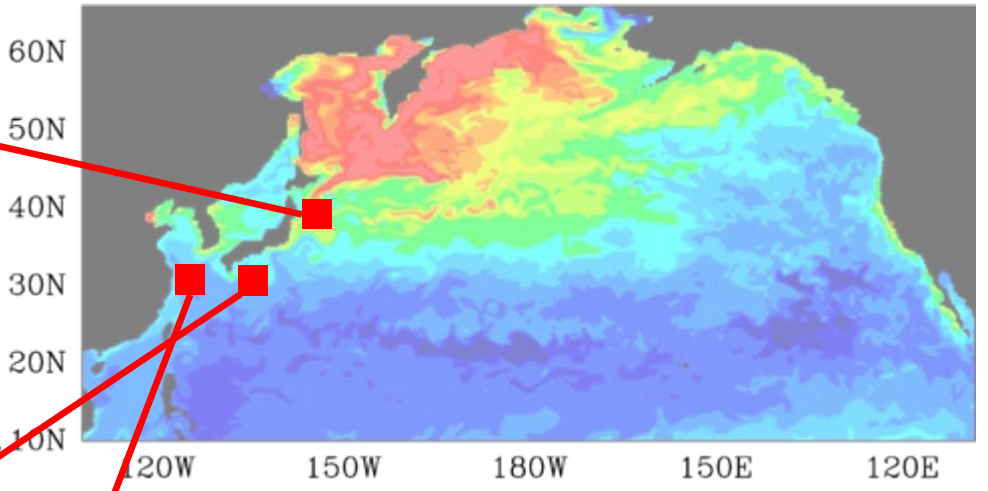


South of Shikoku



East China Sea

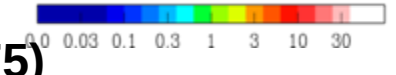


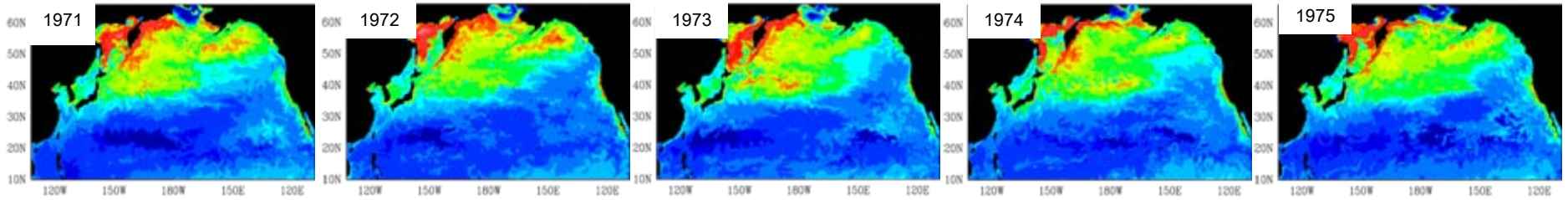


- Positive correlation between PDO index and Chl-a on east Tohoku
- Decadal scale Chl-a variation in south of Shikoku and East China Sea

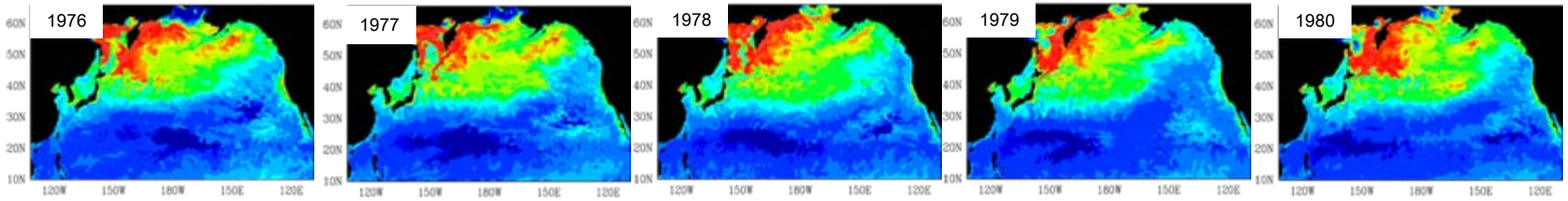
Interannual variation of Spring bloom

Modeled Chlorophyll-a at May 15 (from 1971 to 1975)





(from 1976 to 1980)



Climate shift in 1970's affects timing or maximum strength of spring bloom?

We are going to examine Interannual variation of
- **annual cycles of plankton biomass**
- **strength (or maximum) of spring bloom**
- **sequence of blooming location**

and their relation to ocean physics

Summary and Future plans

We performed 3D-NEMURO with an eddy permitting OGCM.

1.The model adequately simulates Nutrient distribution except for the Southern Ocean, where iron limitation is important.
2.Seasonal cycles of plankton biomass in the Northern Hemisphere is appropriately simulated.

Future plan: we are going to examine..

1.Mechanisms that connecting inter-annual variability of plankton biomass and climate indices such as ENSO, PDO and NPGO.
2.Effects of eddy transport on basin-scale biogeochemical cycles.
3.Introduce iron limitation to the model. (Fe-NEMURO)

We are willing to collaborate with regional studies and model inter-comparisons.
We can provide our model data if you want.

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