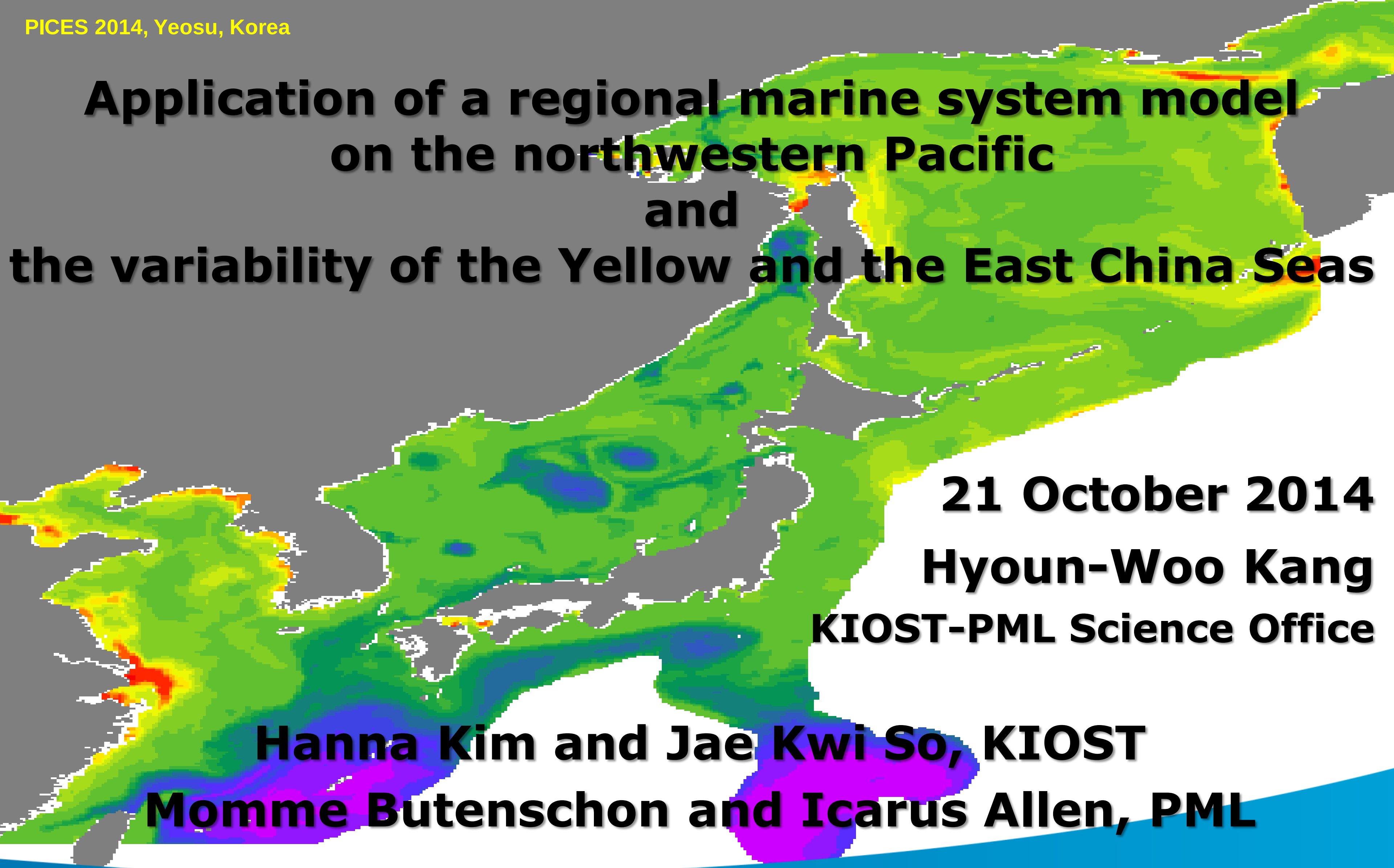
PICES 2014, Yeosu, Korea

Application of a regional marine system model on the northwestern Pacific and the variability of the Yellow and the East China Seas



21 October 2014

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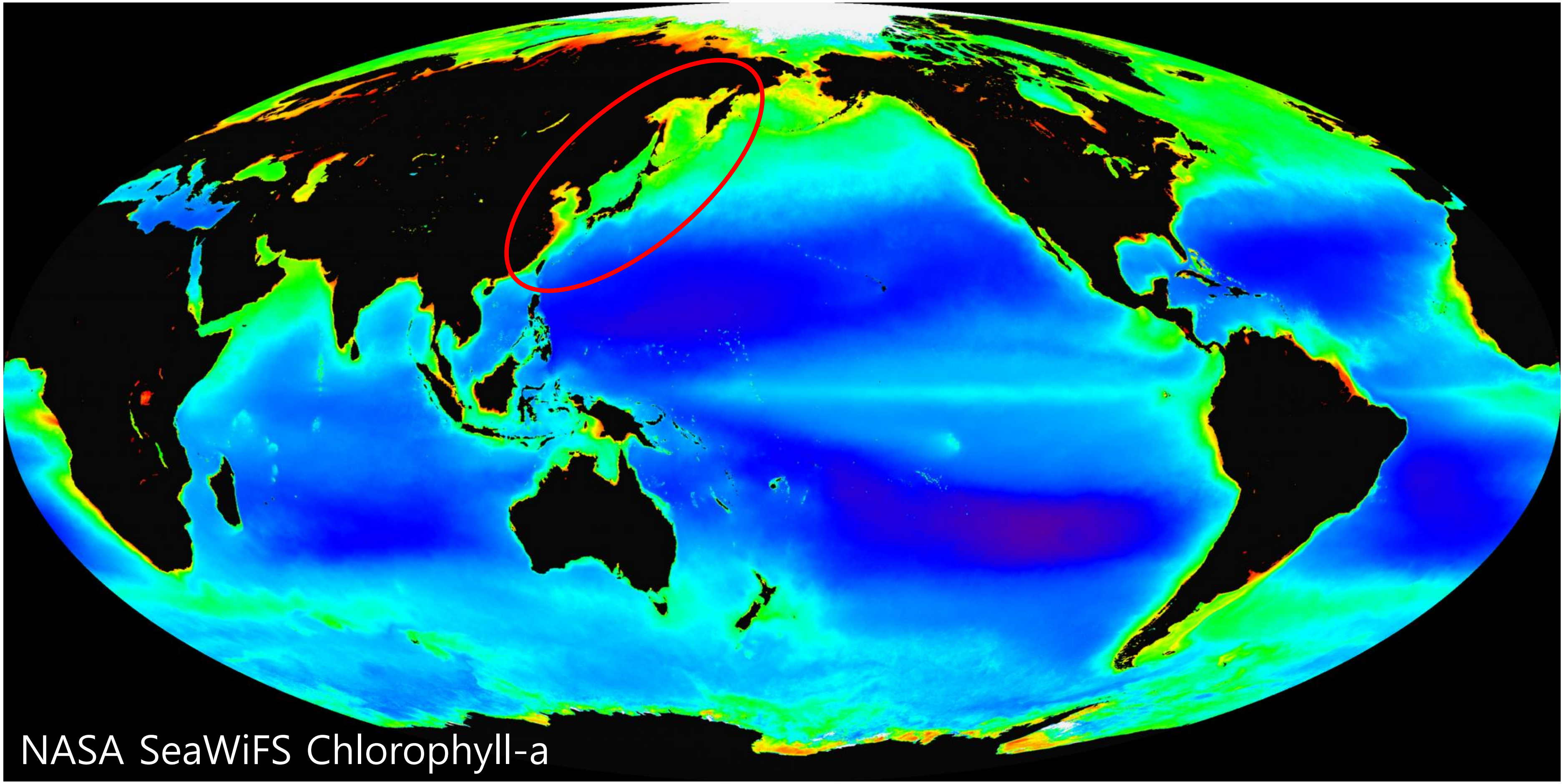
Overview

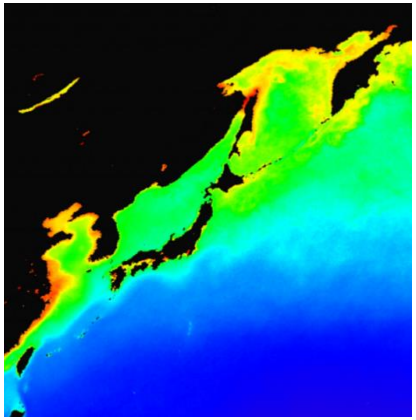
1. Introduction
   - ✓ Northwestern Pacific Marginal Seas
   - ✓ A Regional Marine System Model
2. Seasonal cycle evaluation/validation
3. Ecosystem sensitivity to physical drivers
   - ✓ Role of the Tide
   - ✓ Influence of the Changjiang River
4. Summary and further development plan

Northwestern Pacific Marginal Seas



Northwestern Pacific Marginal Seas

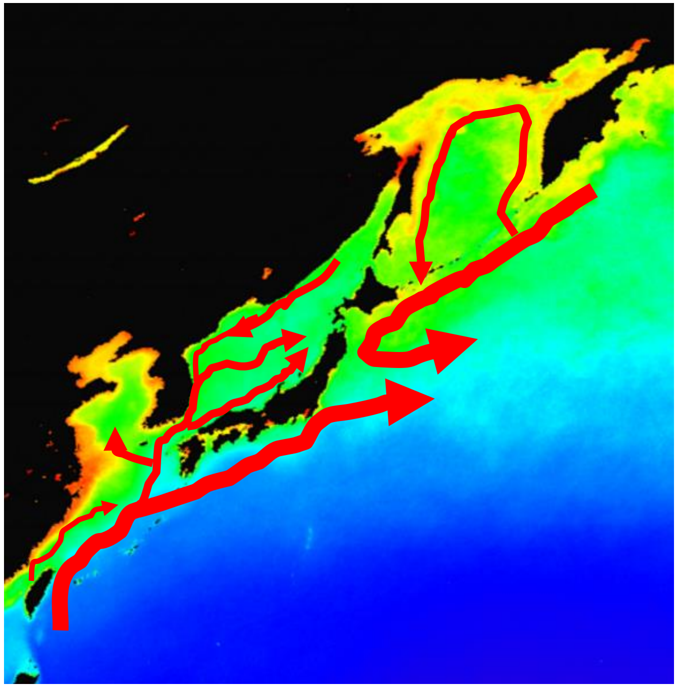
- linked each other through the narrow and shallow straits as well as open to the Pacific
  - ✓ Okhotsk Sea
  - ✓ East (Japan) Sea
  - ✓ Yellow Sea
  - ✓ East China Sea



- Highly populated and productive marine area
- The proper simulation of the physical status is very important to underpin the marine ecosystem assessment and prediction of its future status responding to the changing physical environment.

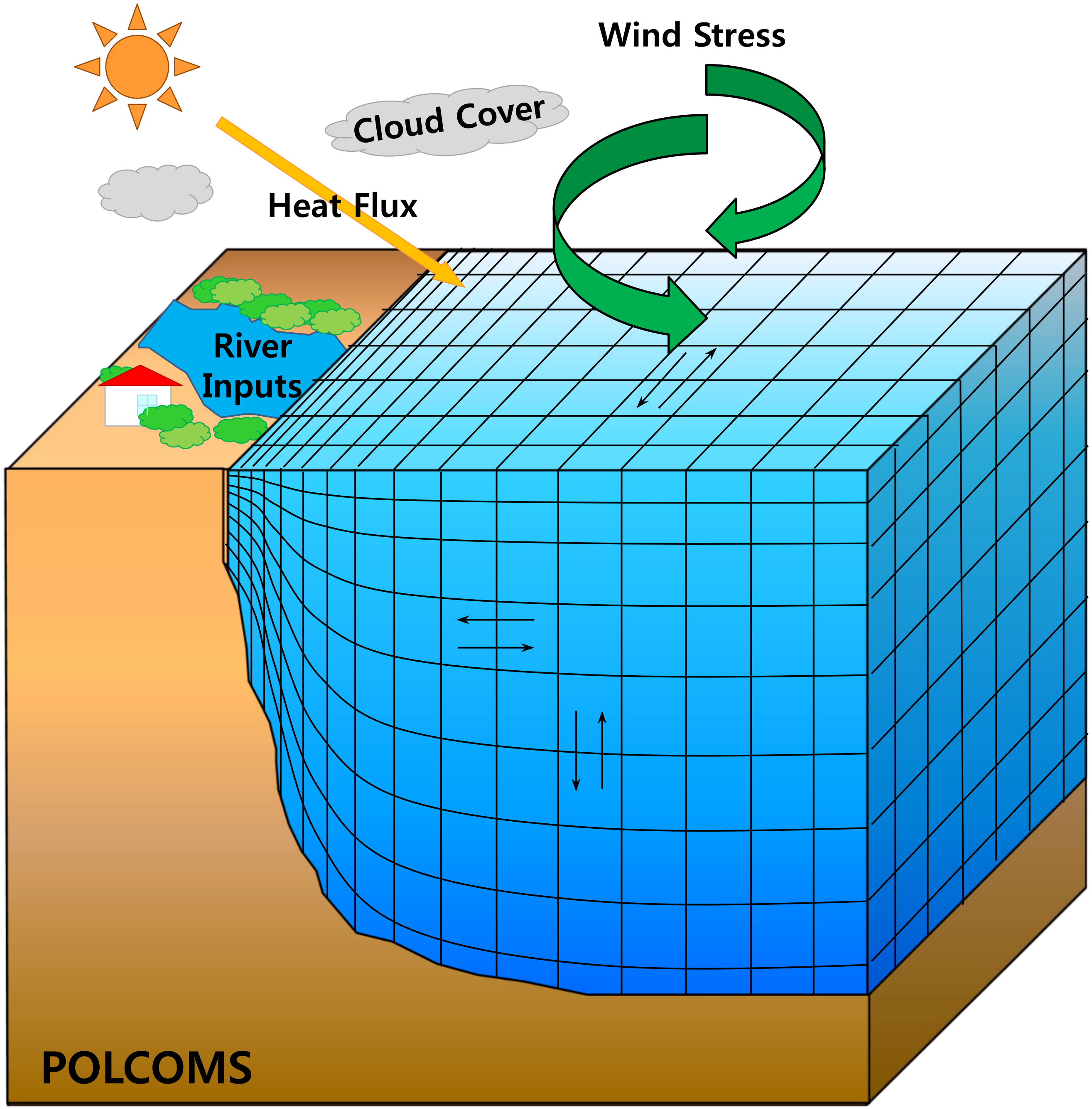
Physical Challenges

- River discharge, nutrient supply, anthropogenic environmental change + complex natural variability
- Part of subtropical and subpolar gyres
  - ✓ The Kuroshio and Oyashio Currents
- High tidal regime
  - ✓ The Yellow and the East China Sea
- Mini ocean in the ocean
  - ✓ East(Japan) Sea
- Sea Ice
  - ✓ Okhotsk Sea, Bohai Sea



POLCOMS

- Proudman Oceanographic Laboratory Coastal Ocean Modelling System developed at POL, *Holt and James 2001*, currently NOC-Liverpool.
- A three-dimensional baroclinic B-grid and vertically s-coordinate model designed for the study of shelf sea processes and ocean-shelf interaction (under hydrostatic and Boussinesq approximation).
- A multi-disciplinary approach
  - ✓ sediment transport module
  - ✓ coupling to the ERSEM and the Los Alamos Sea Ice Model.
- Coupling to the GOTM model for the improvement of turbulence models, *Umlauf & Burchard 2005*
- It has been used extensively in POL and PML's core research programme on North Sea application as well as other marginal seas all over the world, *Holts, 2009*

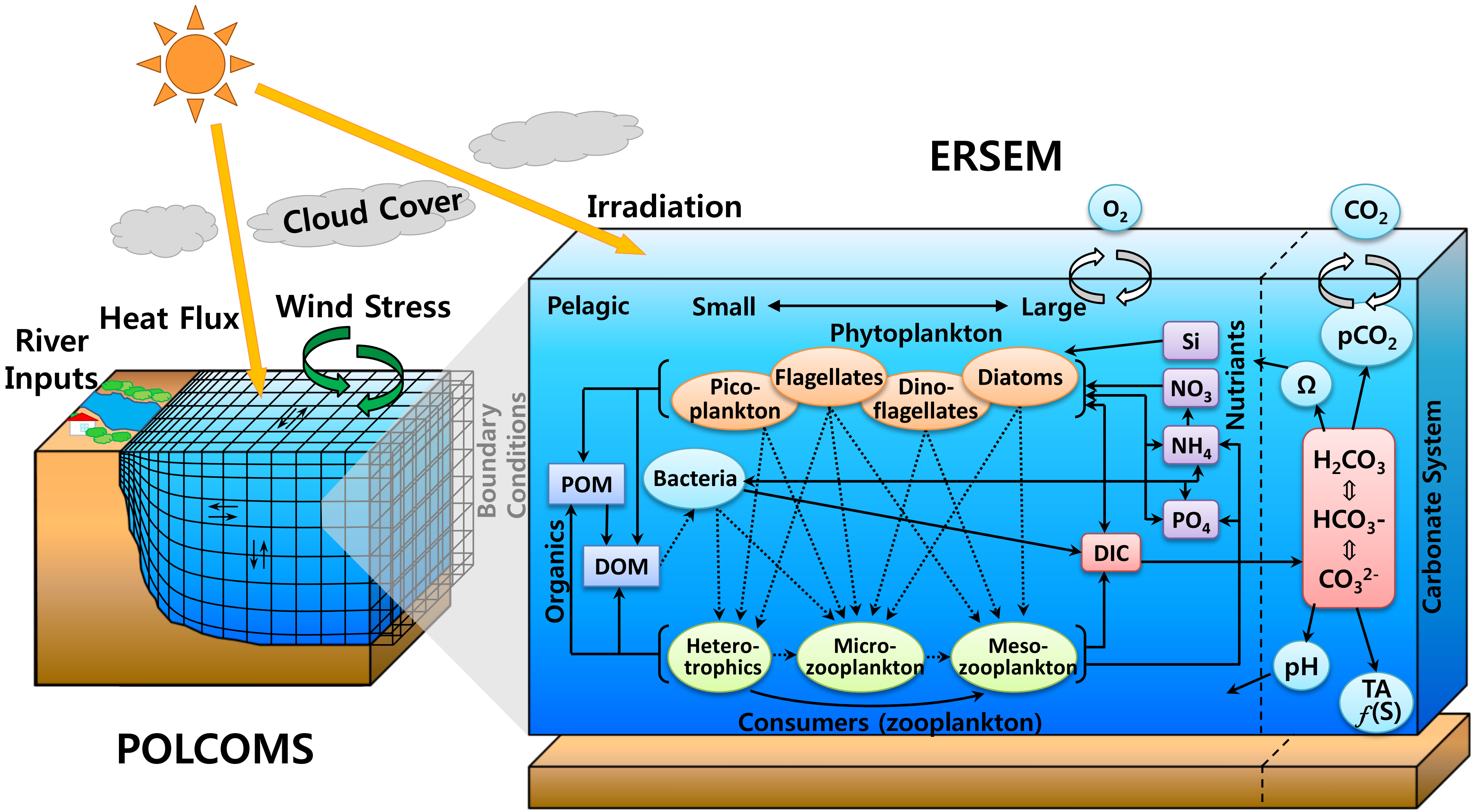


Wind Stress
Cloud Cover
Heat Flux
River
Inputs
POLCOMS

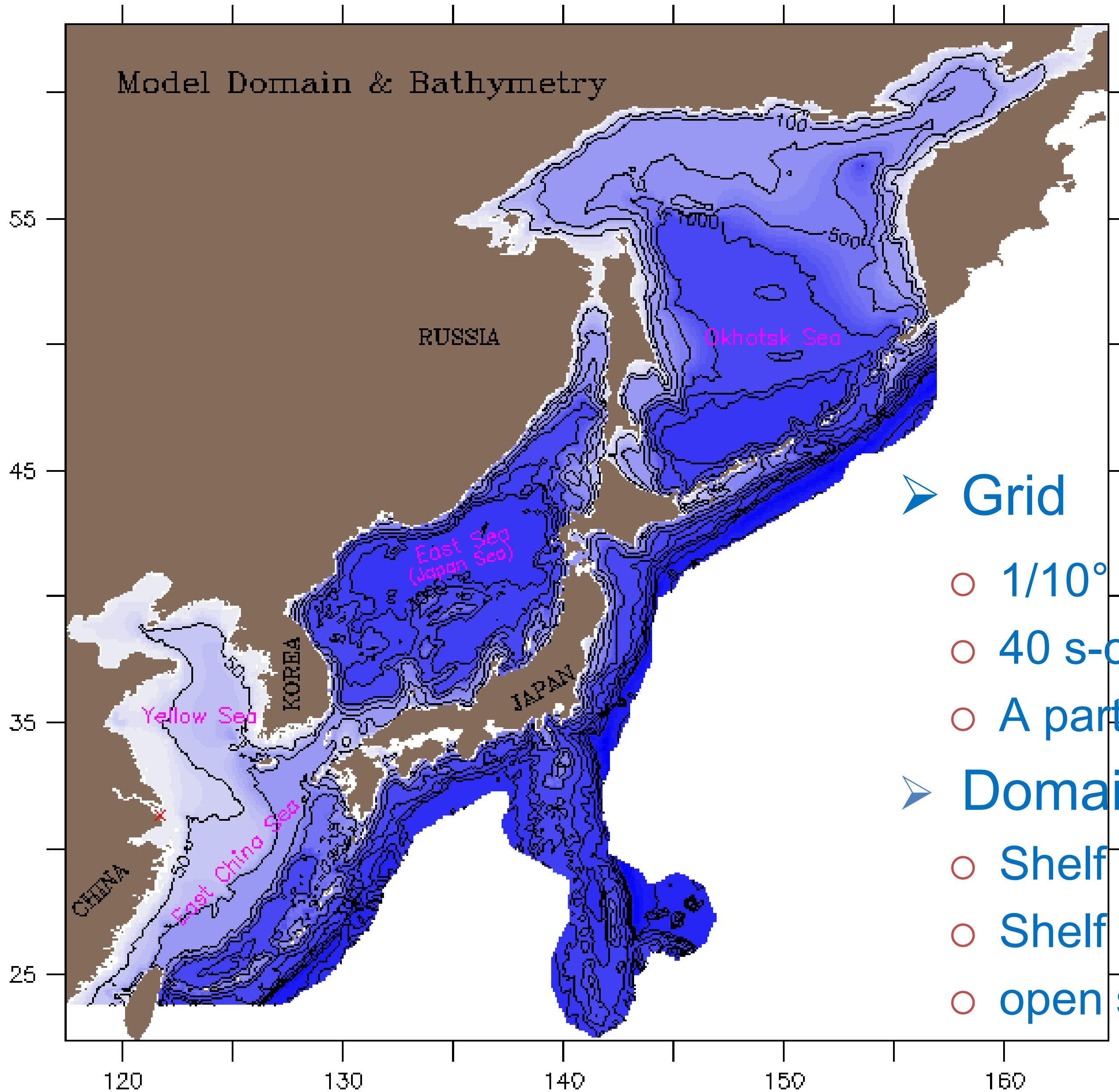
ERSEM

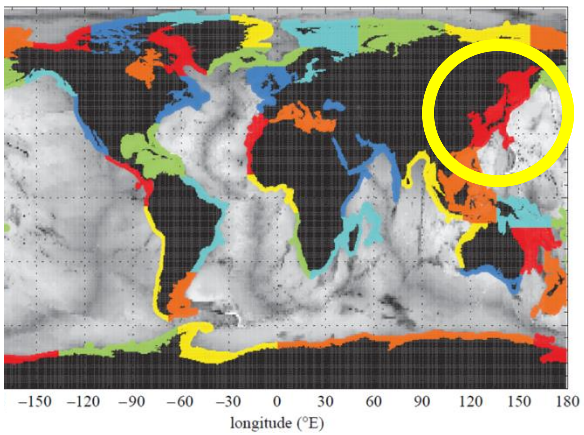
- The European Regional Seas Ecosystem Model, *Blackford et al.,2004*
- A mature plankton functional type model related to NPZD type models
- But includes several refinements necessary to correctly represent the key processes of temperate shelf ecosystems
  - ✓ some plankton community complexity
  - ✓ the microbial loop
  - ✓ variable nutrient stoichiometry
  - ✓ variable carbon : chlorophyll ratios
  - ✓ a comprehensive description of benthic biochemical and ecological processes
- Initially developed in two projects in EU, ERSEM (1990-1993) and ERSEM II (1993-1996) under leadership of Job Baretta at NIOZ with several European institutes (PML, Strathclyde, Aberdeen (UK), Univ. Hamburg, Oldenburg (DE), Ecological modelling Centre (DK) and CEAB (ES))

A Regional Marine System Model coupling POLCOMS and ERSEM models



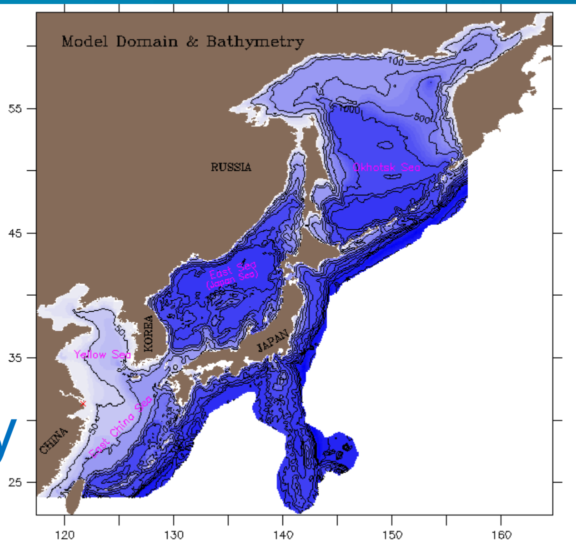
Model Configurations





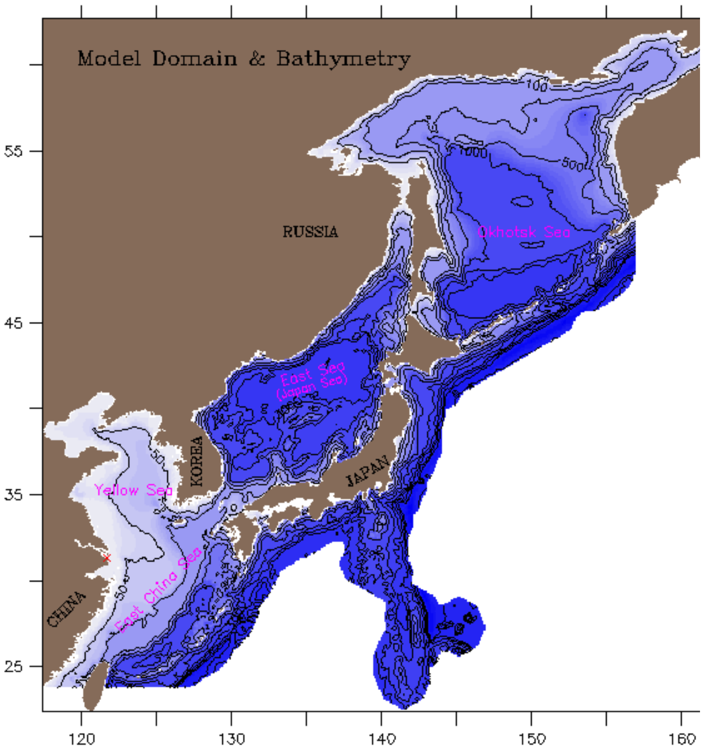
- Grid
  - 1/10° horizontal
  - 40 s-coordinate layers
  - A part of GCOMS domain
- Domain
  - Shelf break (800m)
  - Shelf slope is included
  - open sea extension (200km)

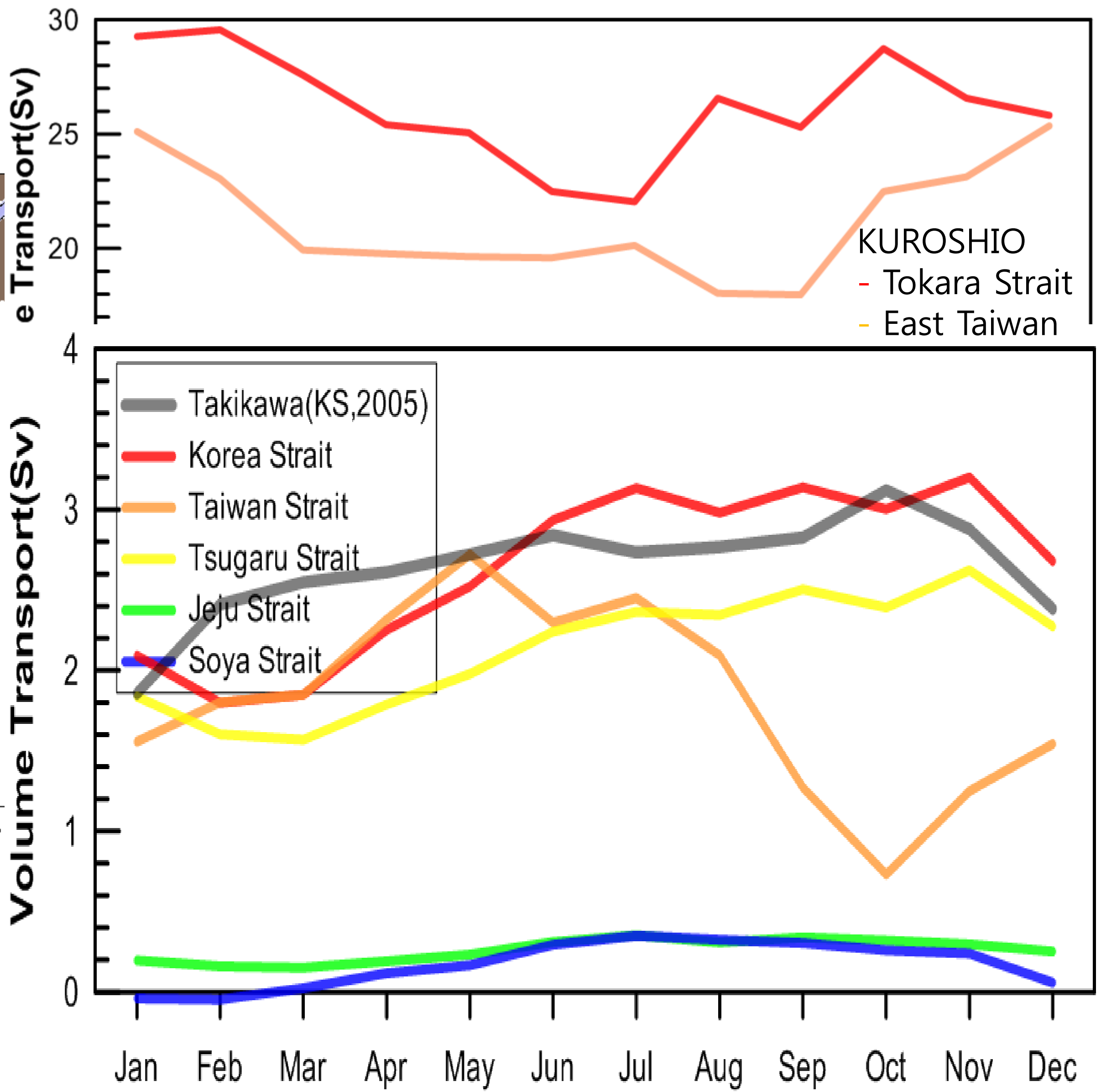
Model Configuration



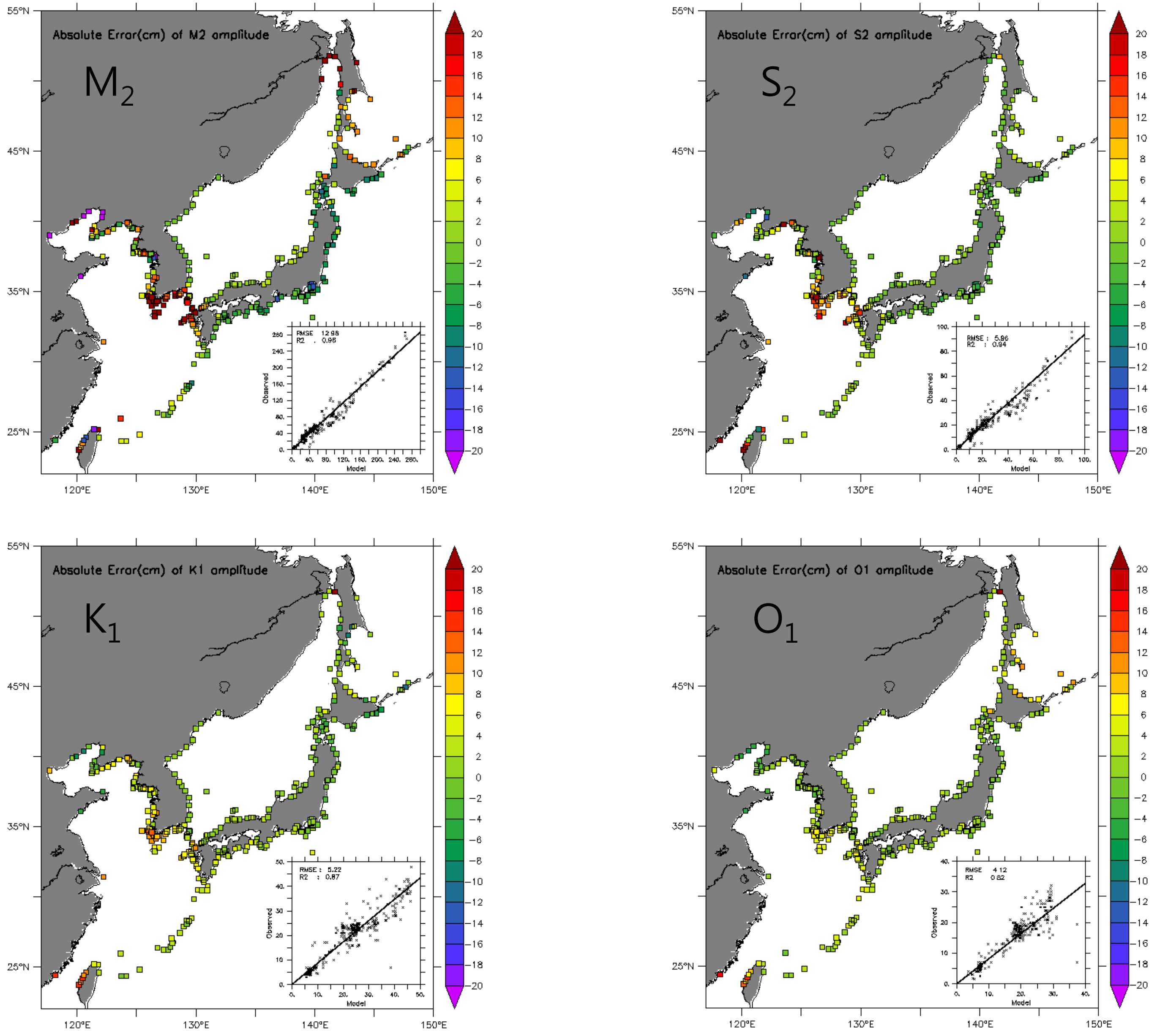
- Simulation Period
  - ✓ 1989 (1992) ~ 2001
- Initial Conditions
  - ✓ T/S - 1/4° NEMO/ORCA025 hindcast
  - ✓ Nutrients - WOA05 January climatology
- Atmospheric Forcing
  - ✓ ERA 40 reanalysis monthly dataset
- Open Boundary Forcing
  - ✓ T/S/U/V/SSH – NEMO/ORCA025 Hindcast
  - ✓ 8 Tidal Constituents - TPXO6.2 (K2,S2,M2,N2,K1,P1,O1,Q1)
  - ✓ Nutrients - WOA05 Monthly Climatology
- Freshwater Discharge
  - ✓ GRDC annual mean volume transport data (343 rivers)
  - ✓ Nutrients (N, P, Si, DOC, DON, DOP, POC, PN, PP)

Volume Transports of Major Straits

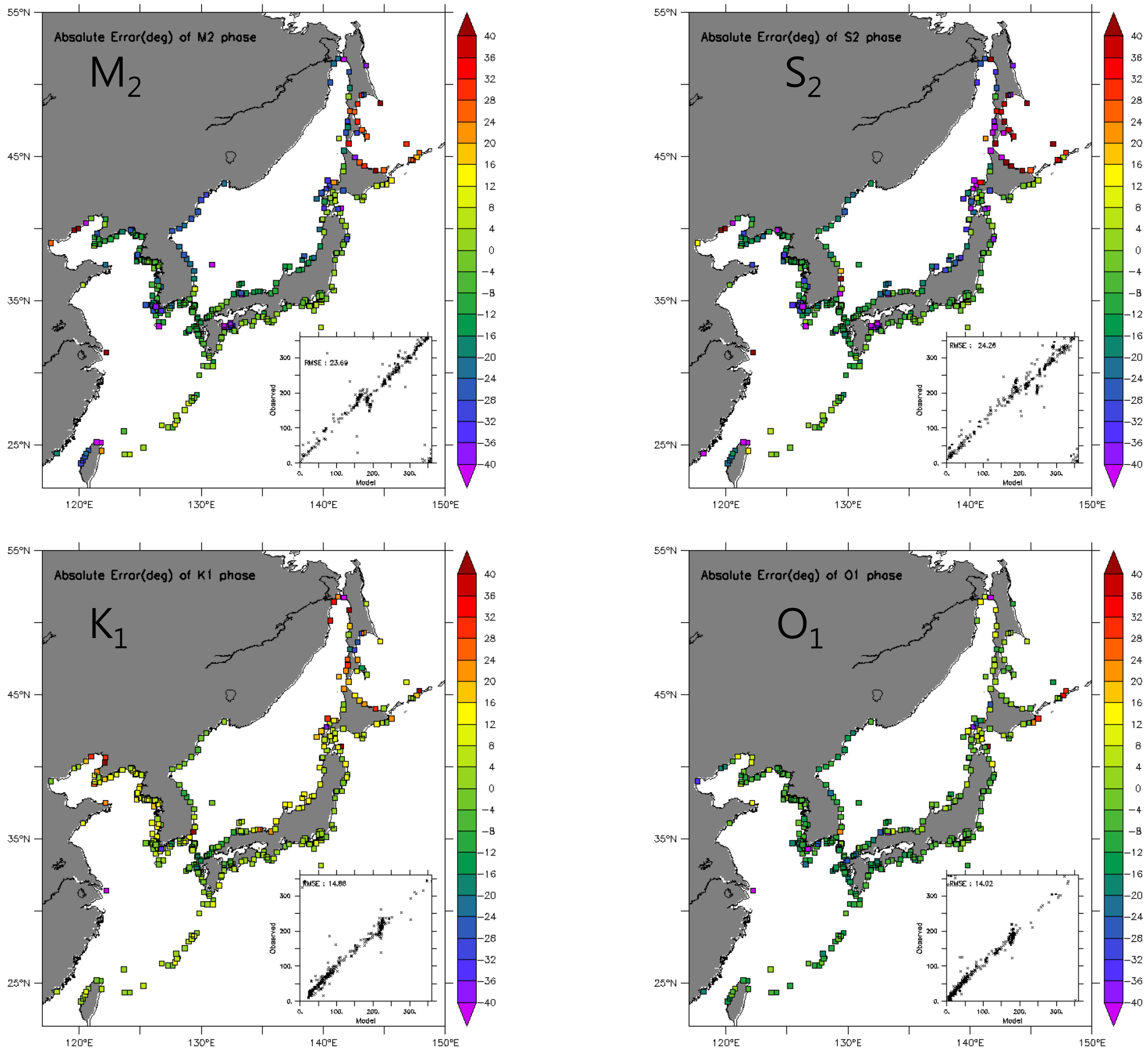




Tide – Amplitude Error



Tide – Phase Error



Tide evaluation summary

Tidal Component		M_2	S_2	K_1	O_1
Amplitude(cm)	RMSE	12.98	5.96	5.22	4.12
	R^2	0.96	0.94	0.87	0.82
Phase(deg)	RMSE	23.69	24.26	14.86	14.02

Assessment Index and Criteria – R^2 & CF

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❖ Correlation Coefficients (R^2)

$$R^2 = \left[\frac{\sum_{i=1}^{N} (M_i - \overline{M_i})(O_i - \overline{O_i})}{\sqrt{\sum_{i=1}^{N} (M_i - \overline{M_i})^2 \sum_{i=1}^{N} (O_i - \overline{O_i})^2}} \right]^2$$

- Seasonal cycle resemblance
  - High (0.65 < R2)
  - Good (0.35< R2 <0.65)
  - Poor (R2 < 0.35)

Allen et al., 2007

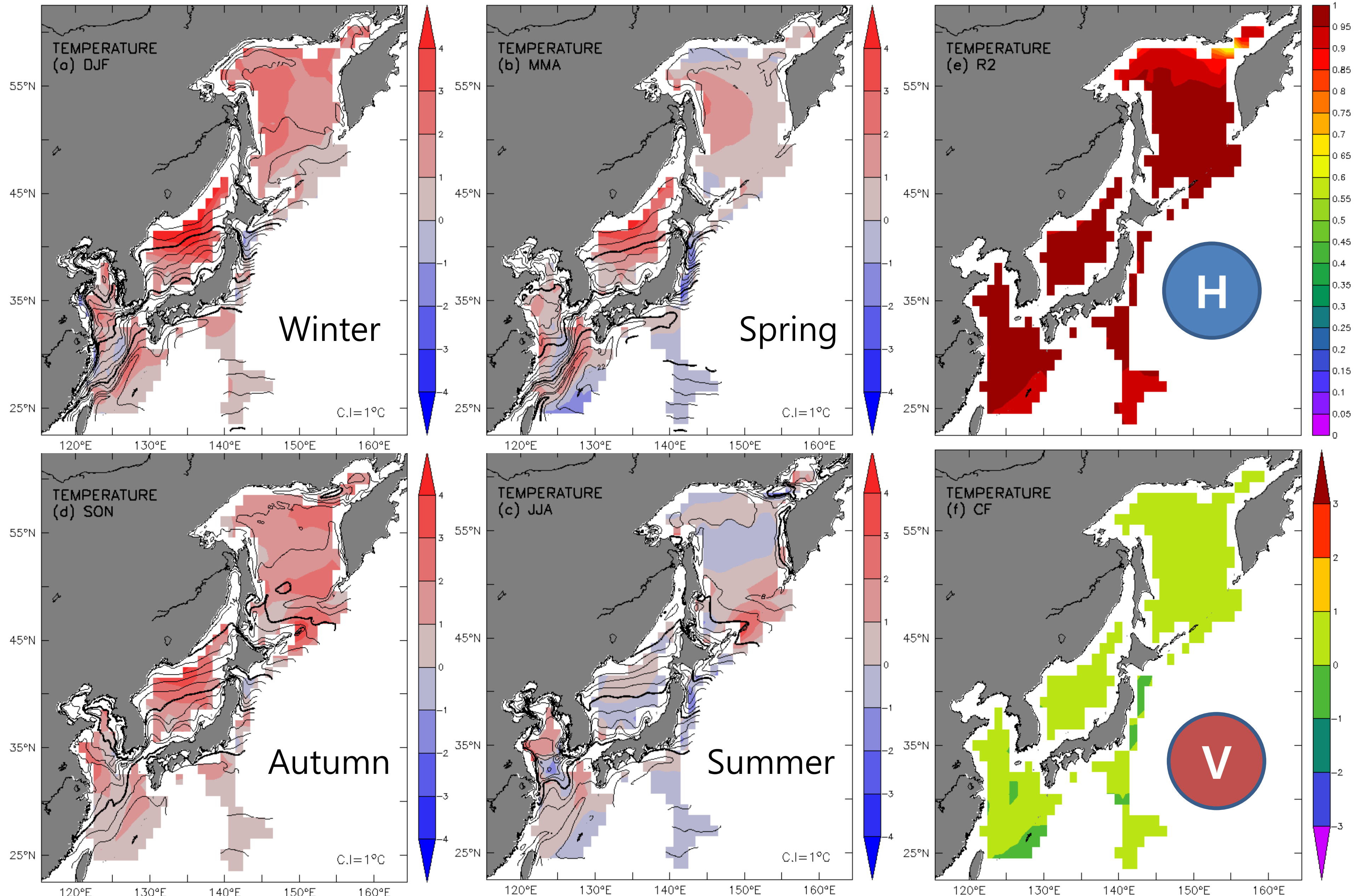
❖ Cost Function (CF)

$$\mathrm{CF} = \frac{\sum_{i=1}^{N} (M_i - O_i)}{N\ STD_o}$$

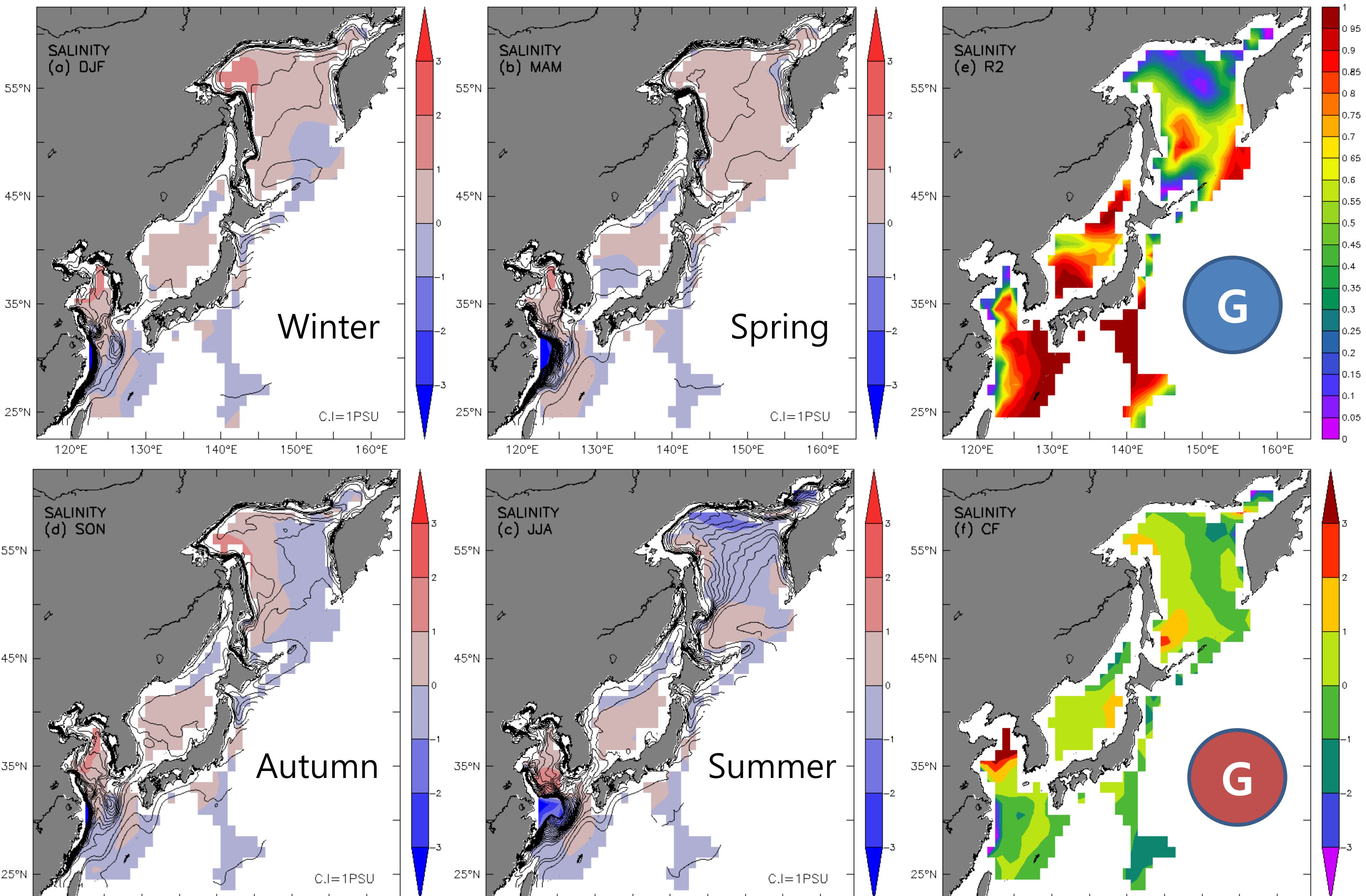
- How far from the observation
  - Very good (|CF| <1)
  - Good (1<|CF|<2)
  - Reasonable(2<|CF|<3)
  - Poor (3<|CF|)

Radach and Moll, 2006

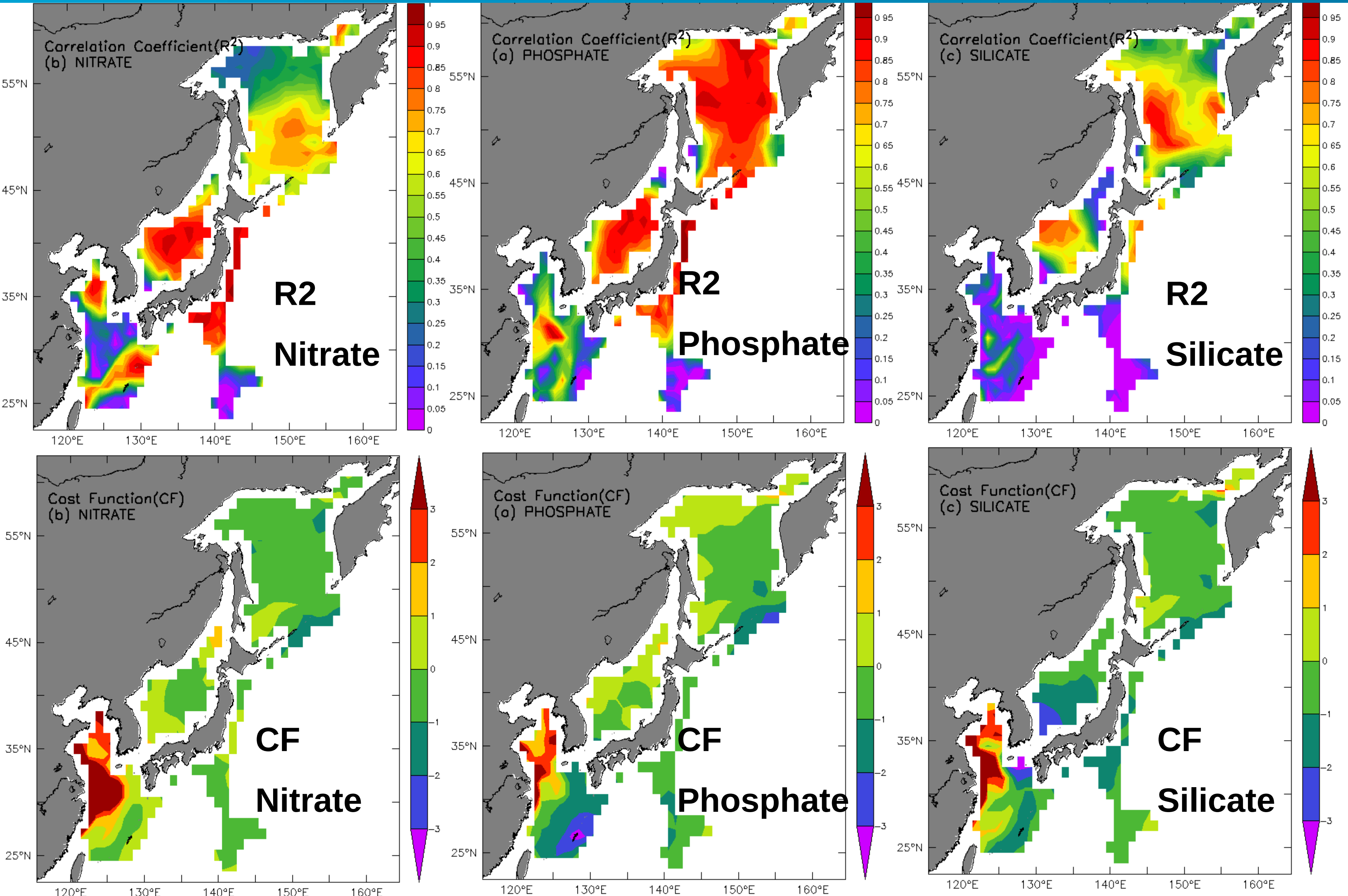
Surface Temperature Difference



Surface Salinity Difference



Nutrients


Correlation Coefficient(R^2)
(b) NITRATE
R2
Nitrate
Correlation Coefficient(R^2)
(a) PHOSPHATE
R2
Phosphate
Correlation Coefficient(R^2)
(c) SILICATE
R2
Silicate
Cost Function(CF)
(b) NITRATE
CF
Nitrate
Cost Function(CF)
(a) PHOSPHATE
CF
Phosphate
Cost Function(CF)
(c) SILICATE
CF
Silicate
55°N
45°N
35°N
25°N
120°E
130°E
140°E
150°E
160°E

Surface Chlorophyll-a

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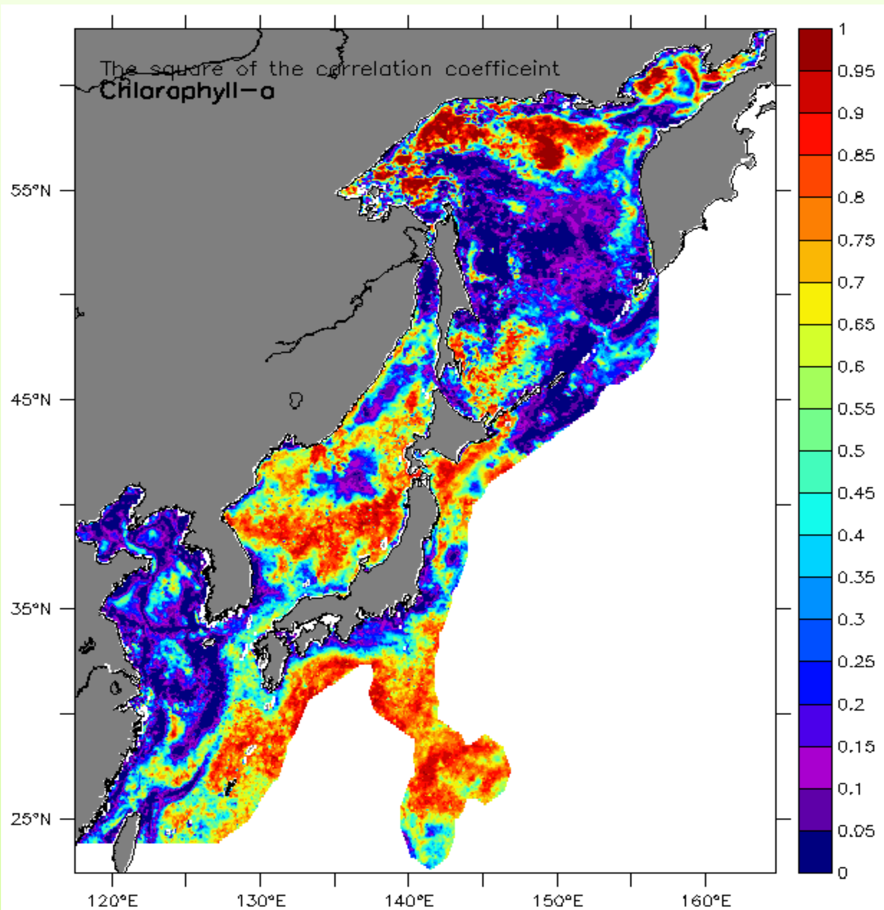
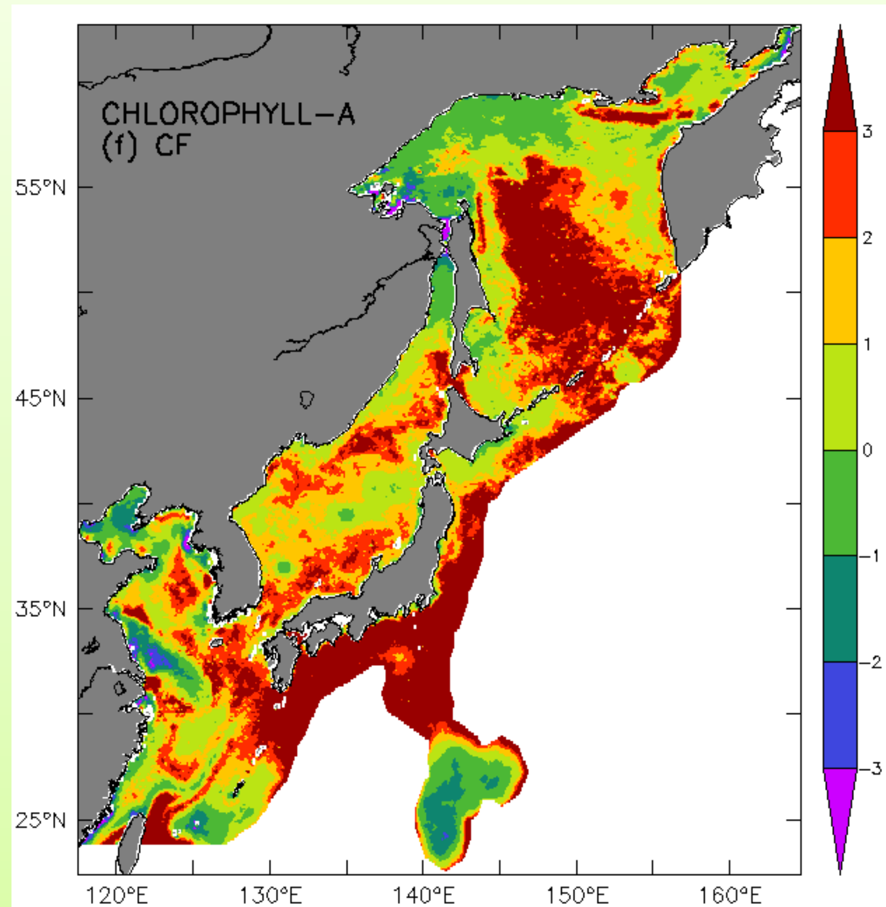
R^2



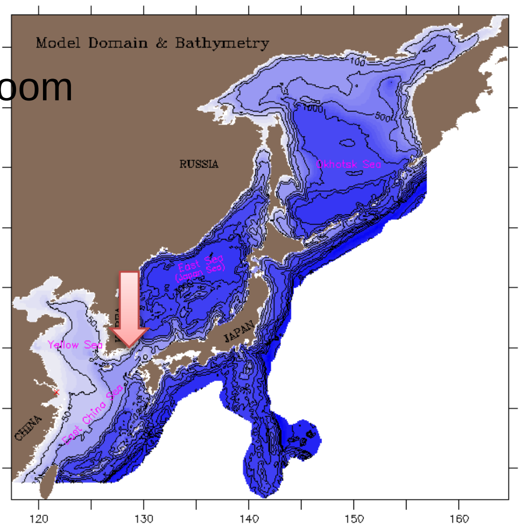
CF

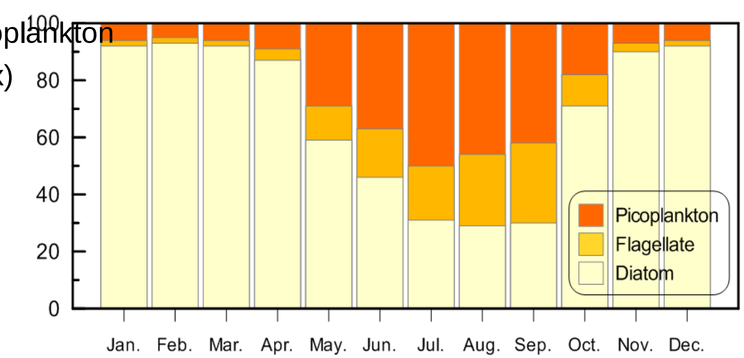


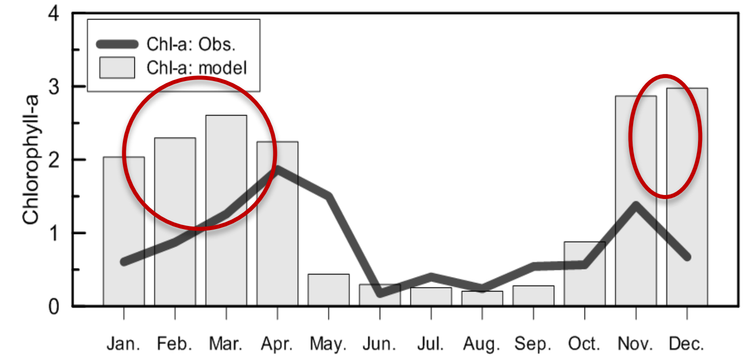
Stn M/129.098°E,34.790°N

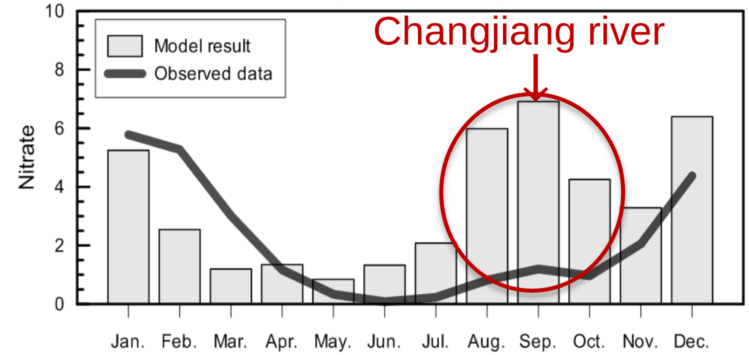
❖ In-situ data

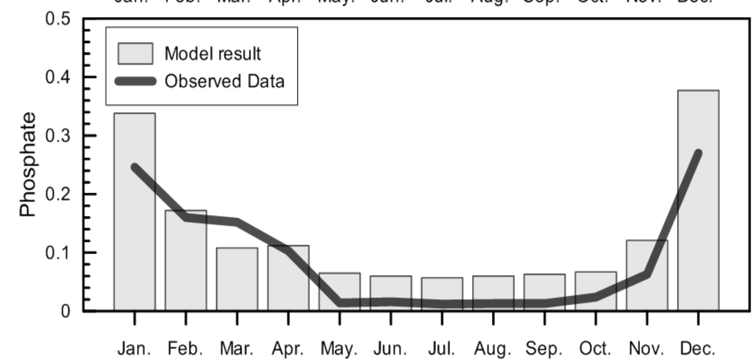
- Monthly observation by KIOST
- 2006 ~ 2012 (6 yrs)
- Mostly similar seasonal cycle
- Chlorophyll
  - High in winter –diatom bloom
  - Bloom timing
- Nutrients(3)
  - Nitrate – high in summer
  - Phosphate
  - Silicate – low in may
- Plankton
  - Dominant species
    - Diatom → picoplankton
    - Dinoflagelalte(x)

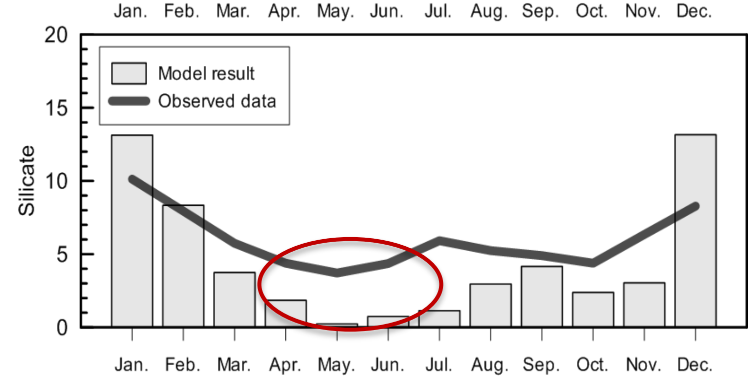












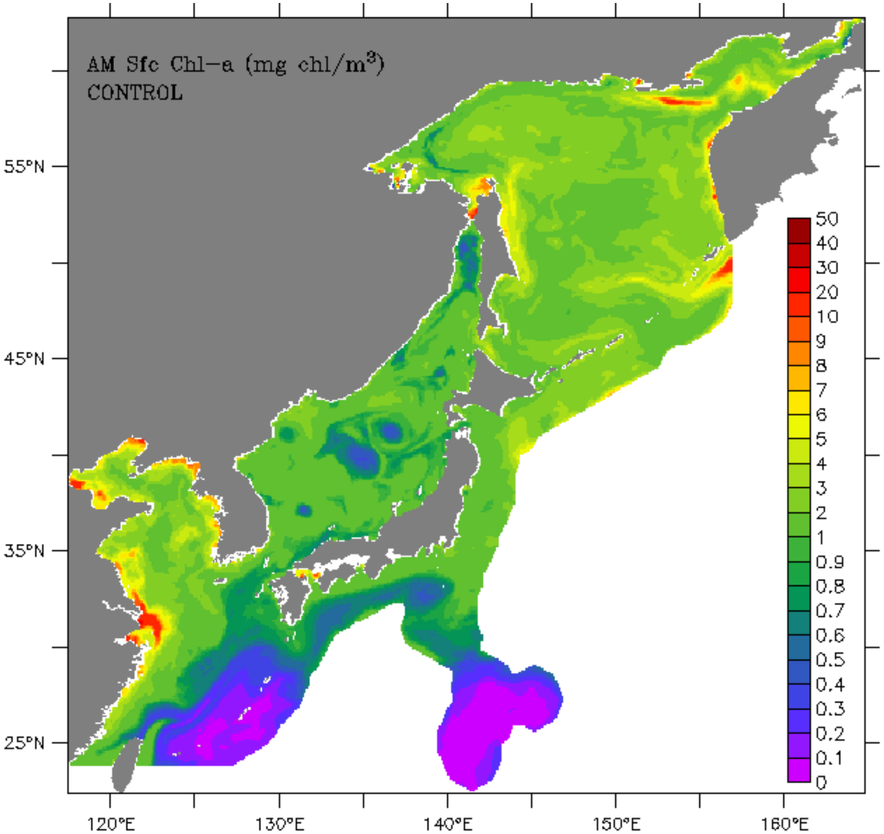
Sensitivity Experiments

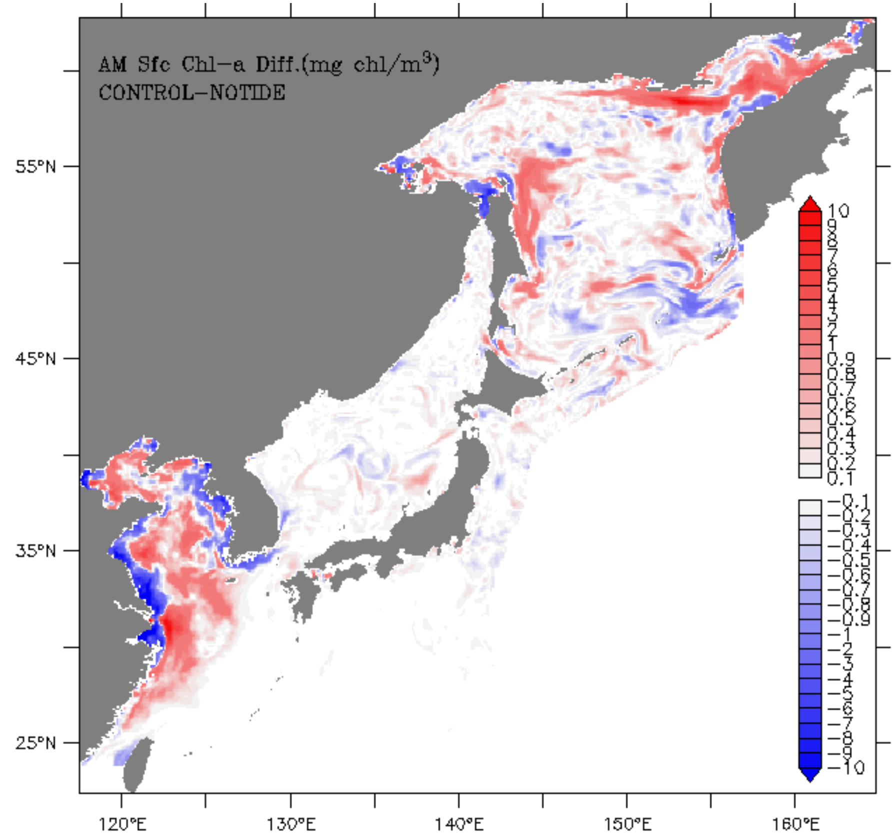
- The role of the tide
- Influence of Changjiang River Discharge

Role of Tide

- Tide is a crucial factor for the proper simulation of the ocean circulation in the Yellow Sea and the East China Sea.
- The different physical status due to the inclusion (or exclusion) of tide in the coupled ocean physics and biogeochemistry system will produce a different ecosystem.
- The influences of the tide on the marine ecosystem as well as the role of the tide on it have been discussed
- Comparisons between the solution after additional simulation without tide in 2001 and the original solution.

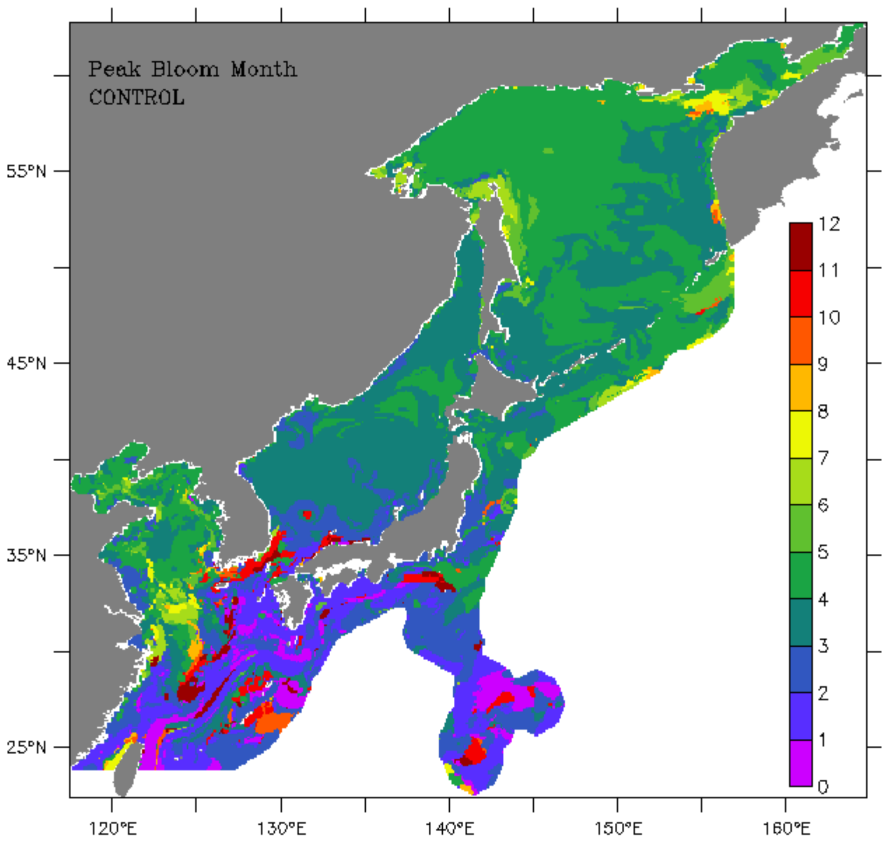
Surface Chlorophyll-a

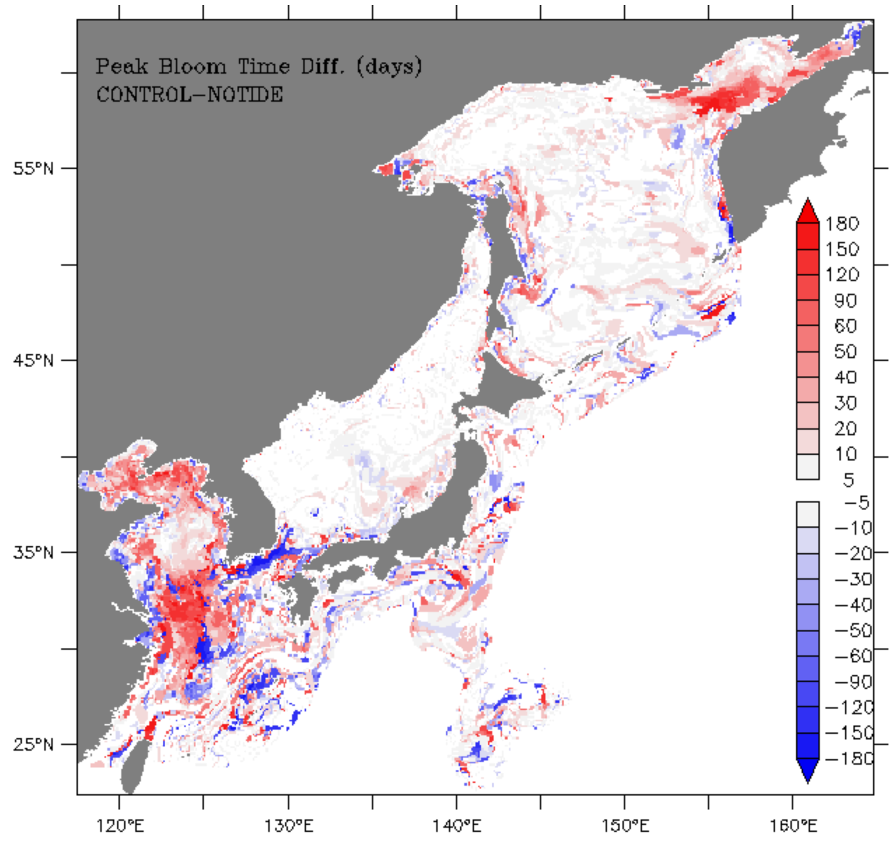




Annual mean surface chlorophyll-a concentration and the difference. Negative (Positive) means the concentration of CONTROL is lower (higher) than that of NOTIDE.

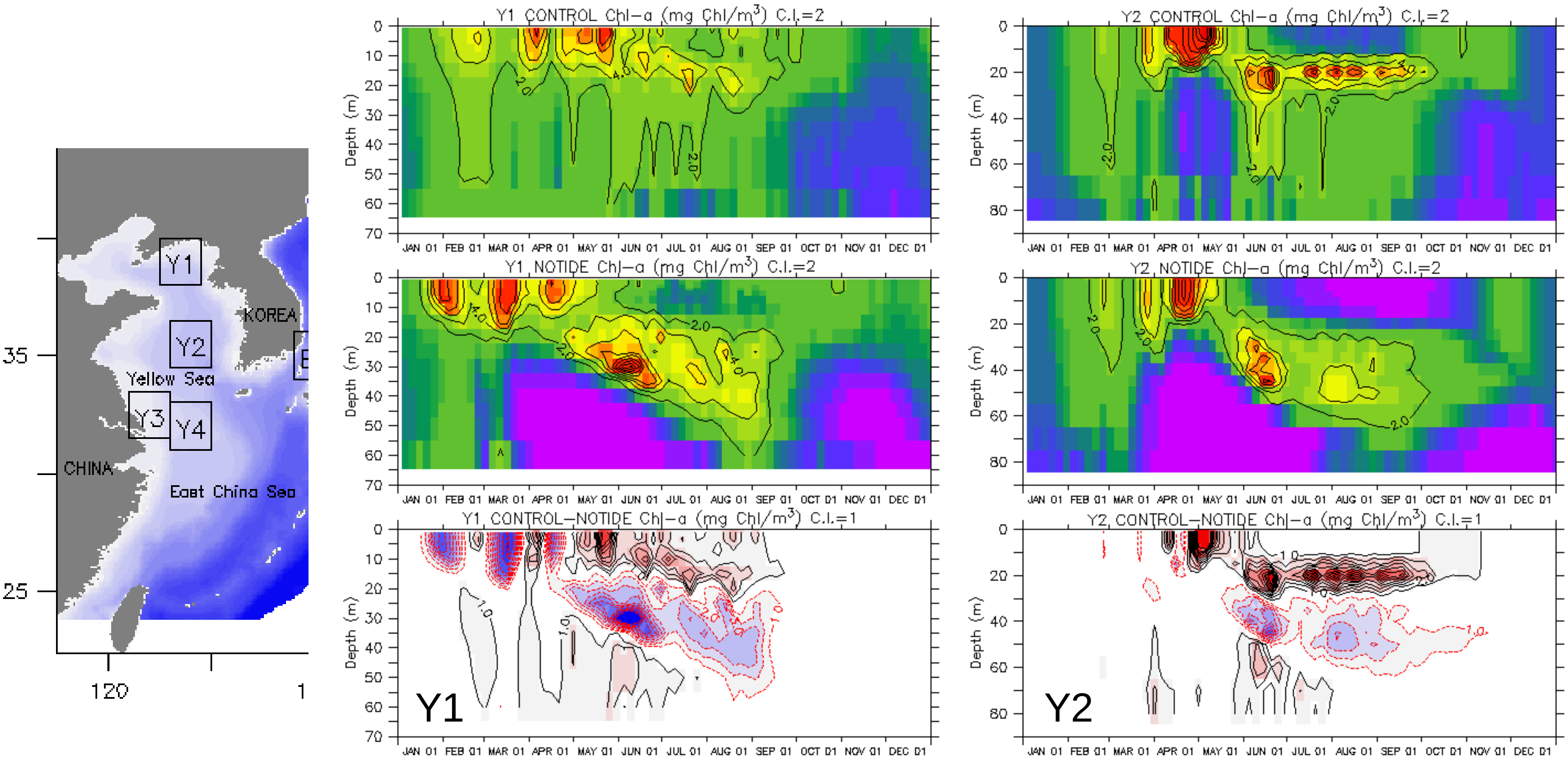
Peak bloom month





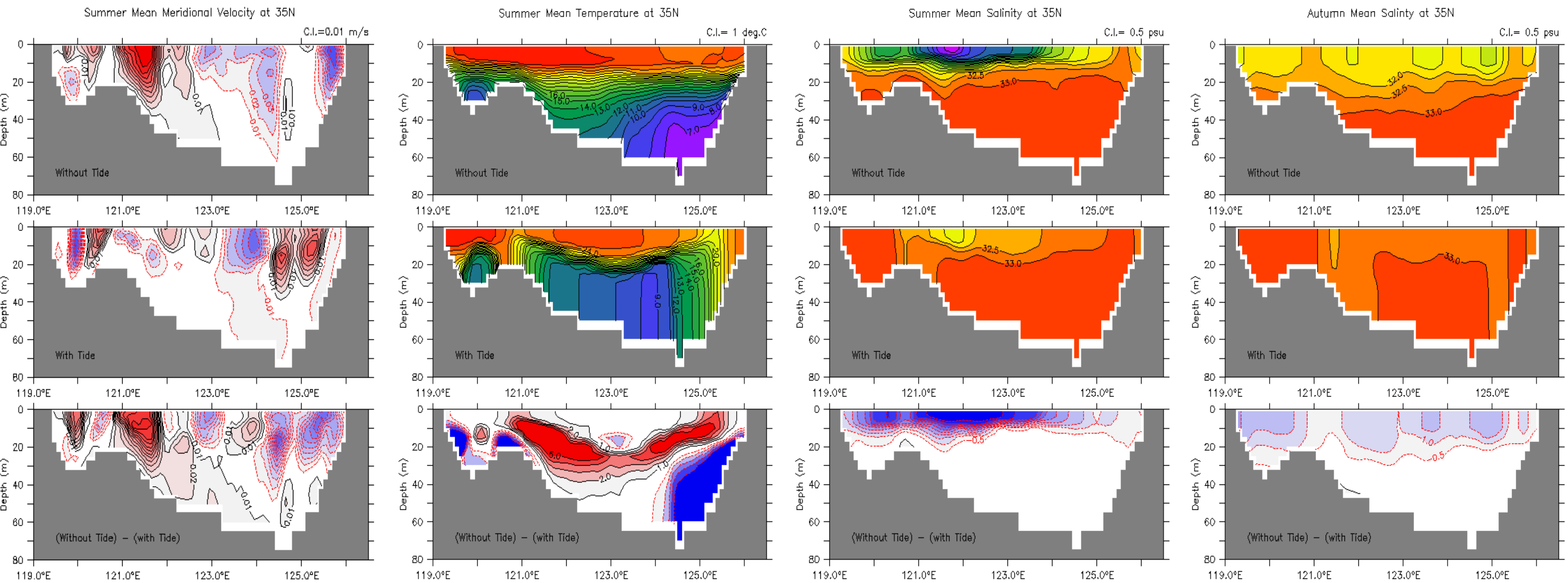
Peak bloom month at the surface and the difference in days. Negative (Positive) means the bloom timing in CONTROL is earlier (later) than that in NOTIDE.

Area averaged chlorophyll-a change



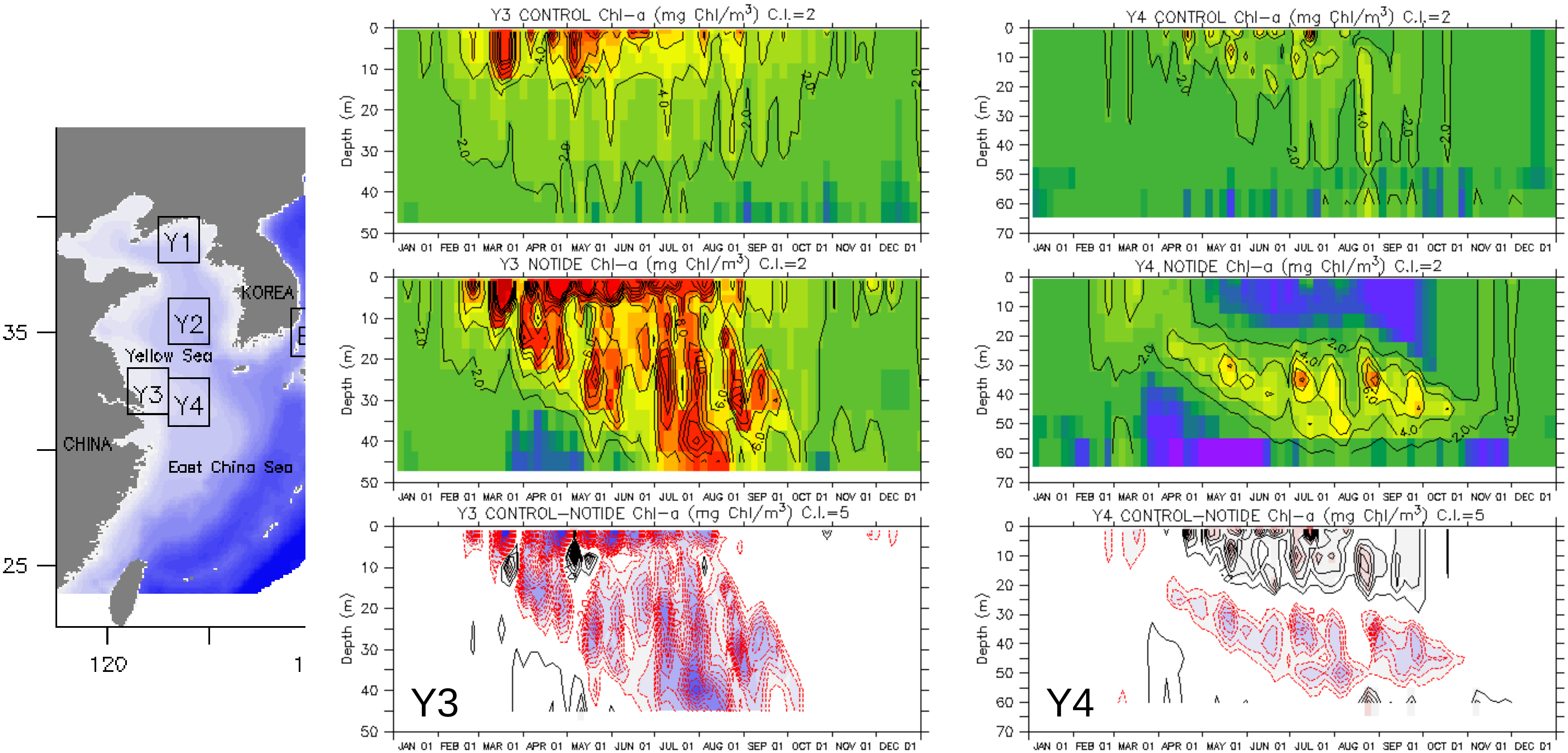
- ✓ SCM (Subsurface Chlorophyll Maximum) depth is deepen without tide
- ✓ Bloom begins earlier in Y1

Physical changes at 35N @ Yellow Sea



Tide prevents the topographic following geostrophic current circulating clockwise in the Yellow Sea and enhances the vertical mixing at the flank of shallow basin. The Yellow Sea Bottom Cold Water during the summer can not simulated properly without tide. The strong northward flow at the western flank in the case of NOTIDE solution also drives the Changjiang Diluted Water (CDW) into the middle of the Yellow Sea which also transporting large amount of nitrogen.

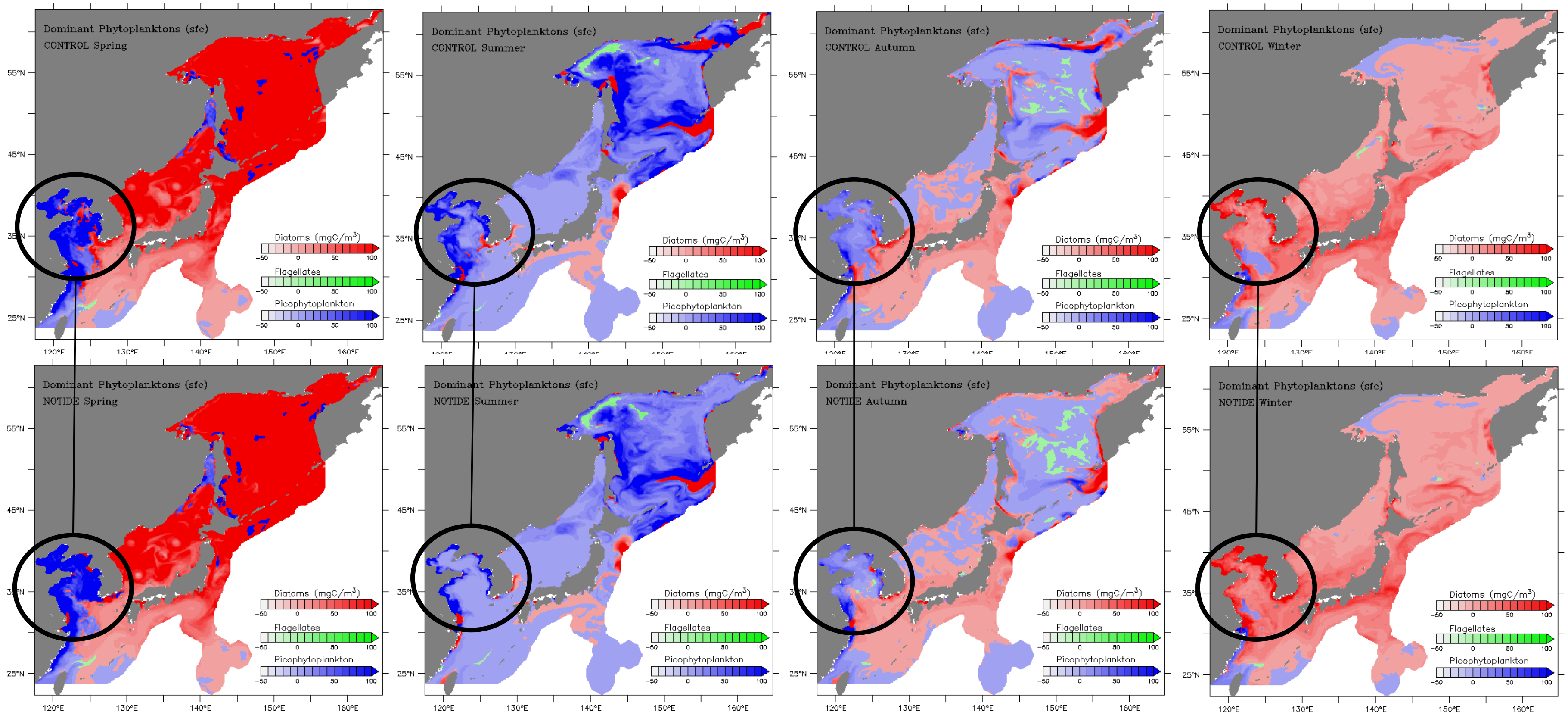
Area averaged chlorophyll-a change



- ✓ SCM (Subsurface Chlorophyll Maximum) depth is deepen without tide
- ✓ Bloom begins earlier in Y3 and Y4 without tide

Changes of surface dominant species

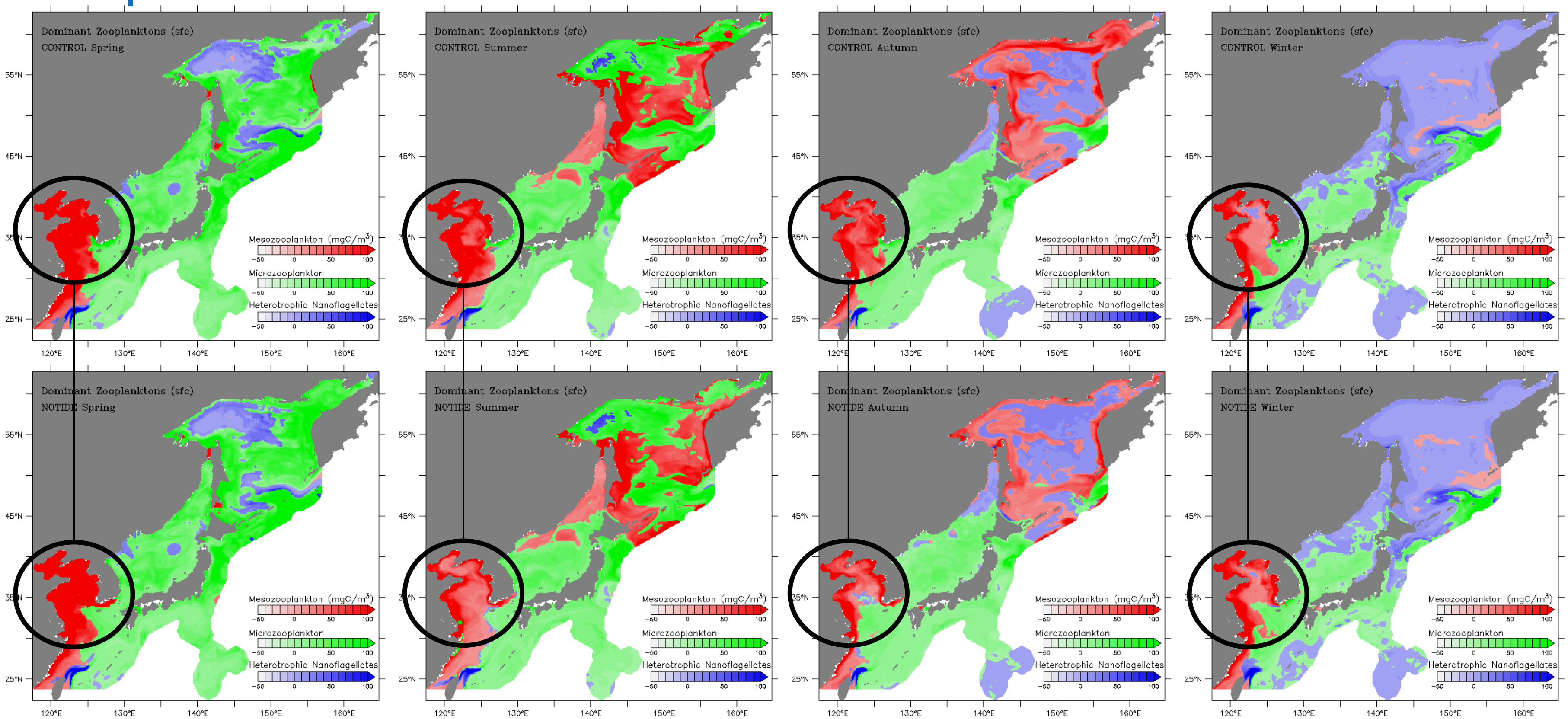
Phytoplankton



Seasonal succession of phytoplankton functional group. The most prominent changes are shown in the border of the Yellow Sea and the East China Sea.

Changes of surface dominant species

Zooplankton



Seasonal succession of zooplankton functional group. As phytoplankon, the most prominent changes are shown in the border of Yellow Sea and the East China Sea

Summary - the role of the tide @ YES

- Lower productivity at coastal region
- Higher productivity in the central basin region
- Later bloom in the CDW region and coastal area
- Lower Subsurface Chlorophyll Max. Depth.
- Longer life time of picophytoplankton in the CDW region
- Enable picophytoplankton & mesozooplankton dominancy near the bottom

- The effects of tide in the physical system, as expected, are prominent in the Yellow Sea and the East China Sea circulation pattern change in terms of the Changiang Diluted Water dispersion path, the Yellow Sea Warm Current, the Yellow Sea Bottom Cold Water distribution as well as local influences driven by tidal mixing.

- These changes of physical status control the changes of nutrients as well as plankton distributions in the Yellow Sea.

Influence of the Changjiang River

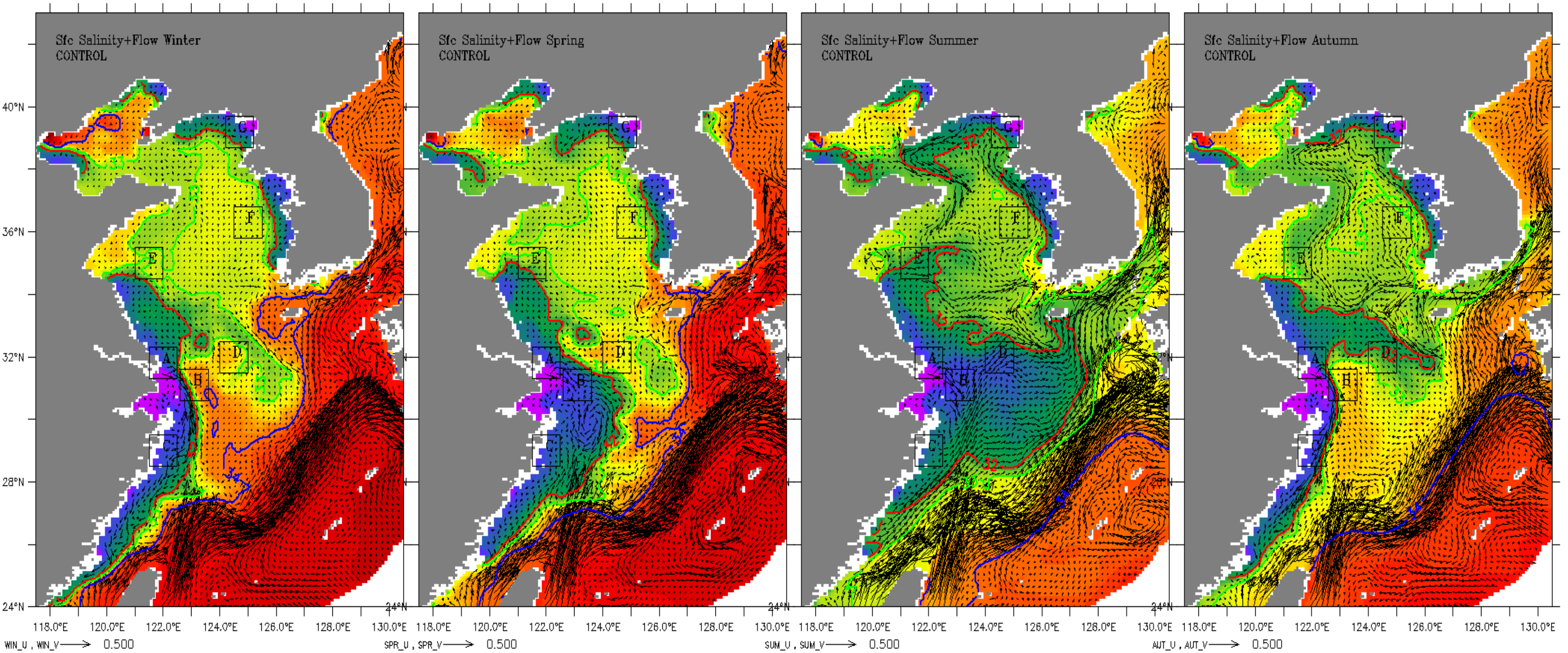
- Changjiang (Yangtze) river is the third-longest in the world and the longest river in Asia. Its discharging volume is controlled by the natural variability of the precipitation as well as the human interventions.
- The final year (2001) solutions are diversified in three different cases in conjunction with CRD forcing

  1) monthly varying full river discharge (MFCRD)

  2) yearly steady discharge (no seasonal variation) with the half of annual mean climatological discharge rate as it was (CNTL)

  3) No Changjiang river discharge at all (NoCRD)

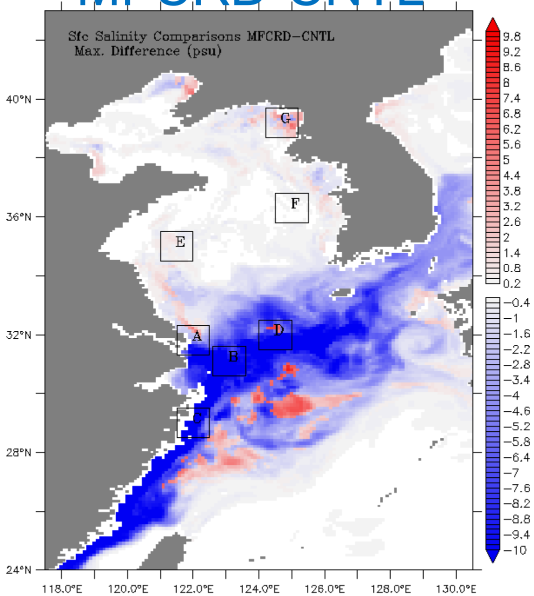
Sea Surface Salinity



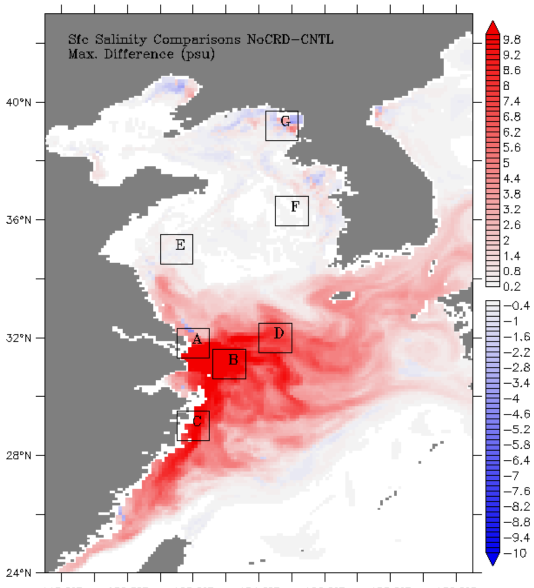
- Color : sea surface salinity
- Contour : 32 psu (red), 34 psu (blue)
- Arrow : surface current vector

Surface Salinity Change

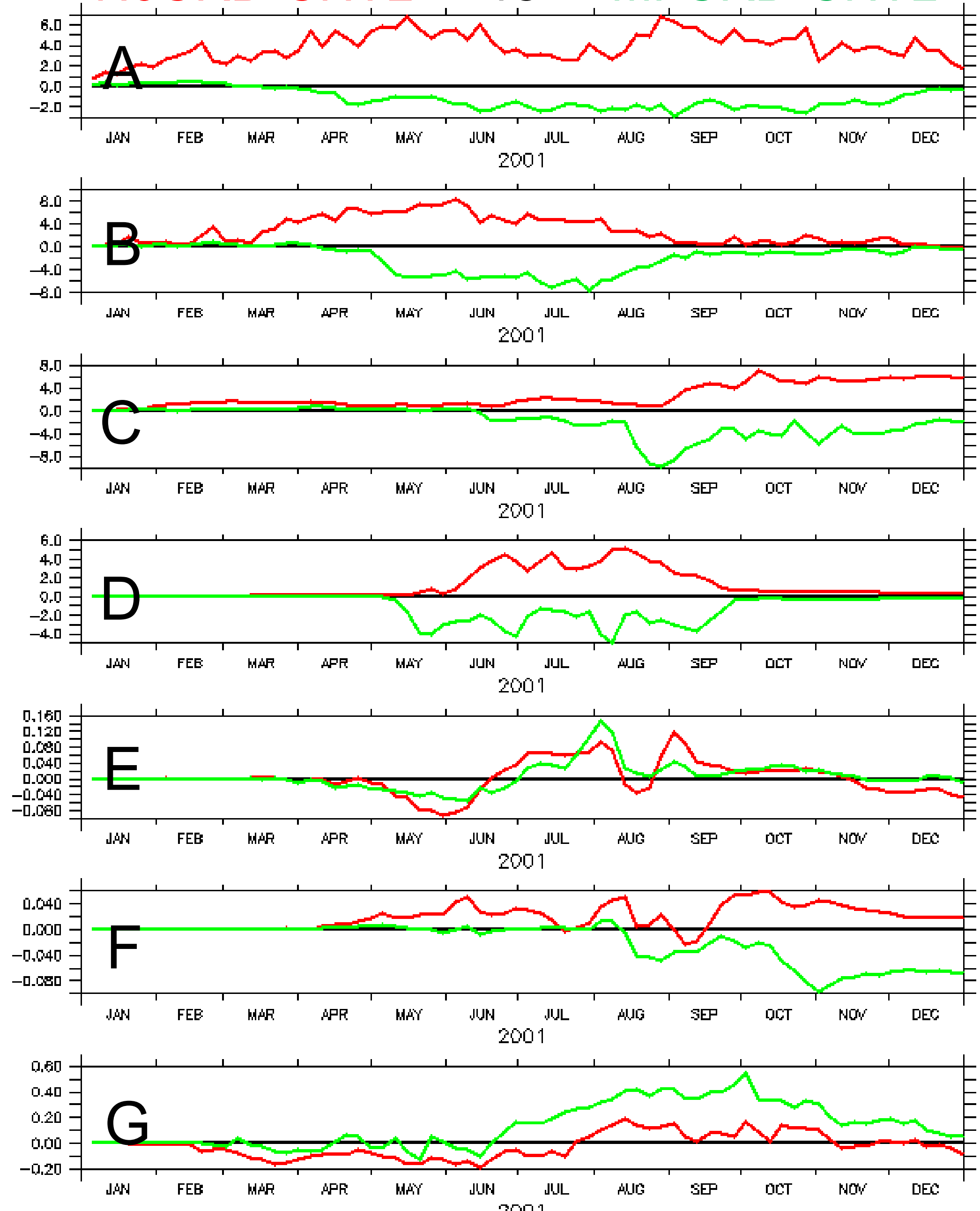
MFCRD-CNTL



NoCRD-CNTL

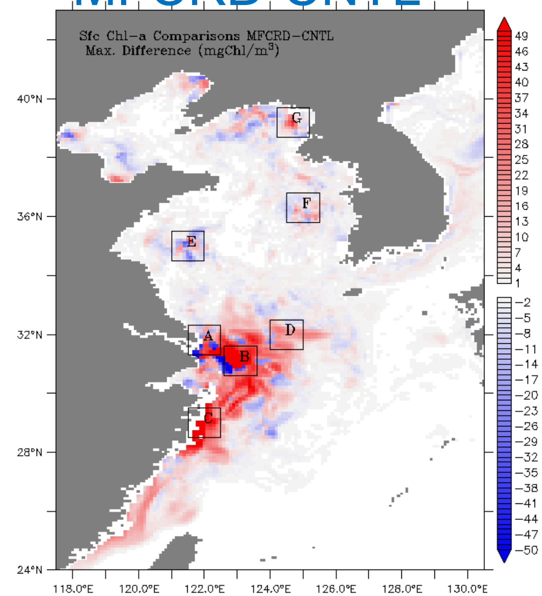


NoCRD-CNTL vs MFCRD-CNTL

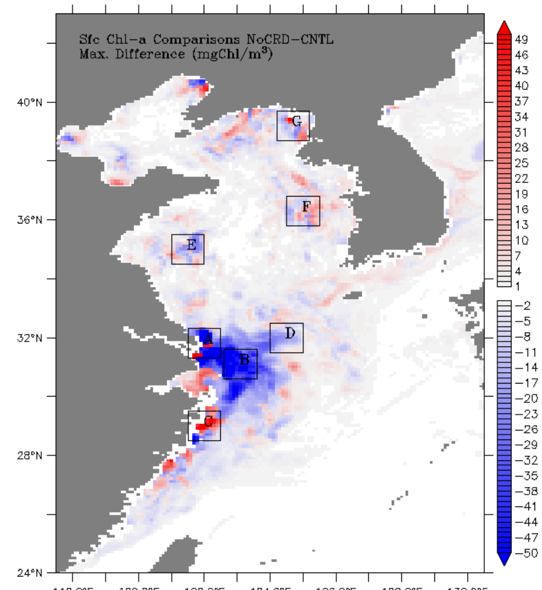


Surface chlorophyll-a change

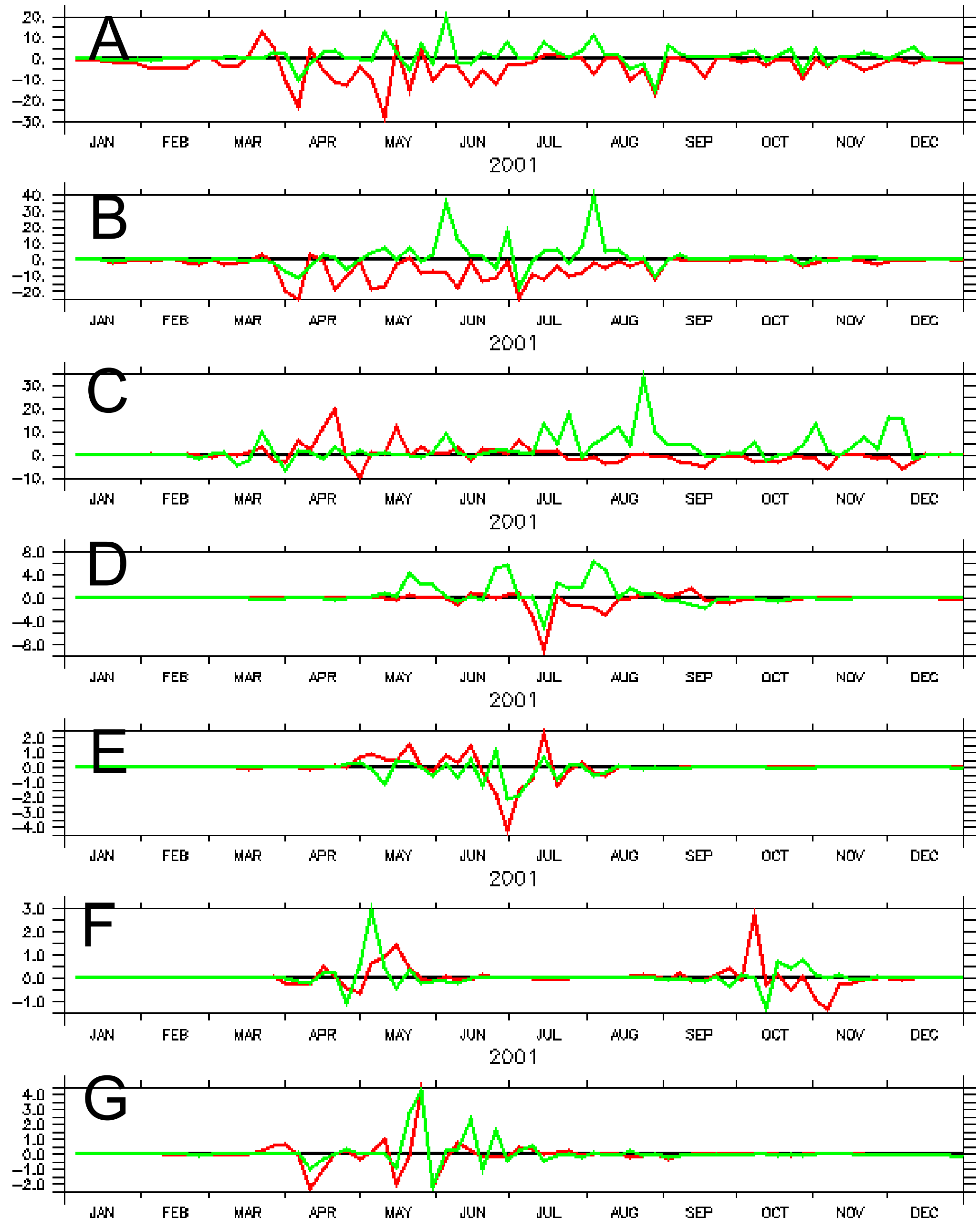
MFCRD-CNTL



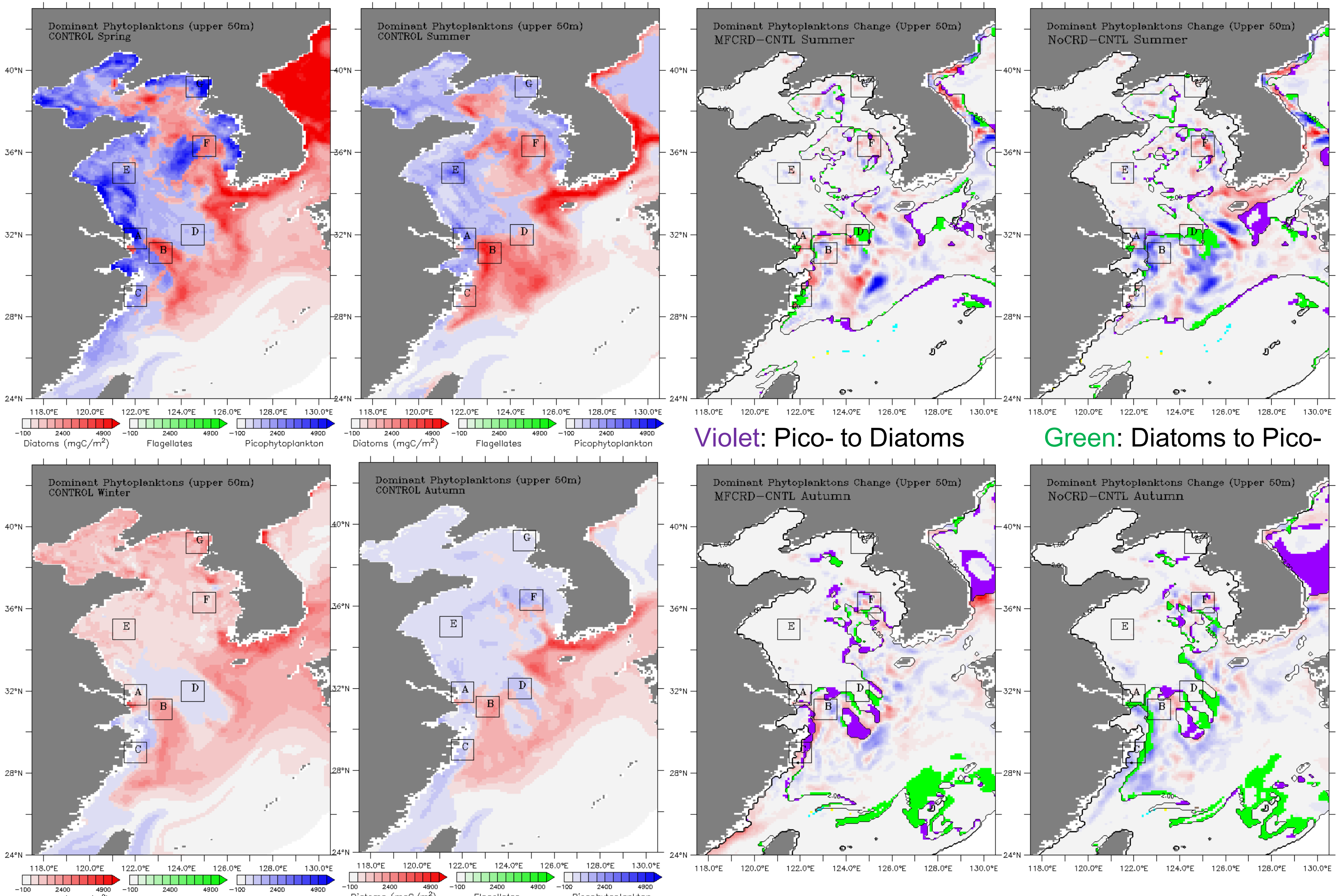
NoCRD-CNTL



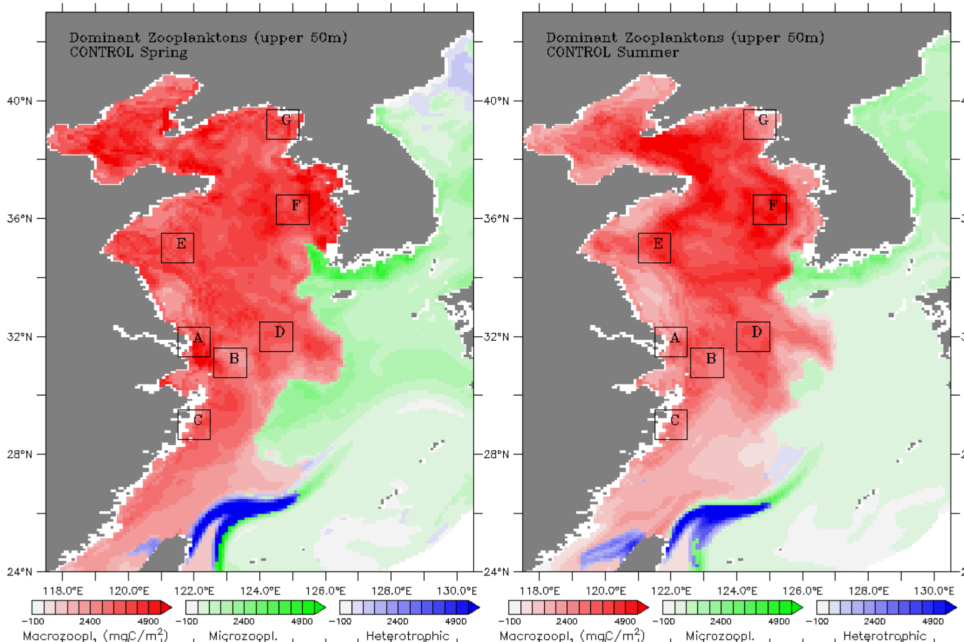
NoCRD-CNTL vs MFCRD-CNTL

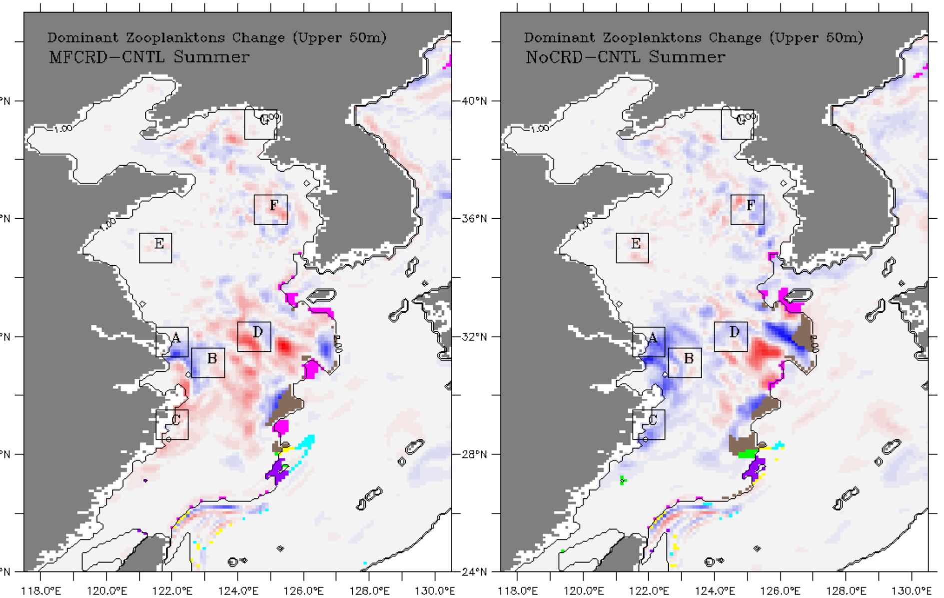


Changes of Phytoplankton Dominant Species



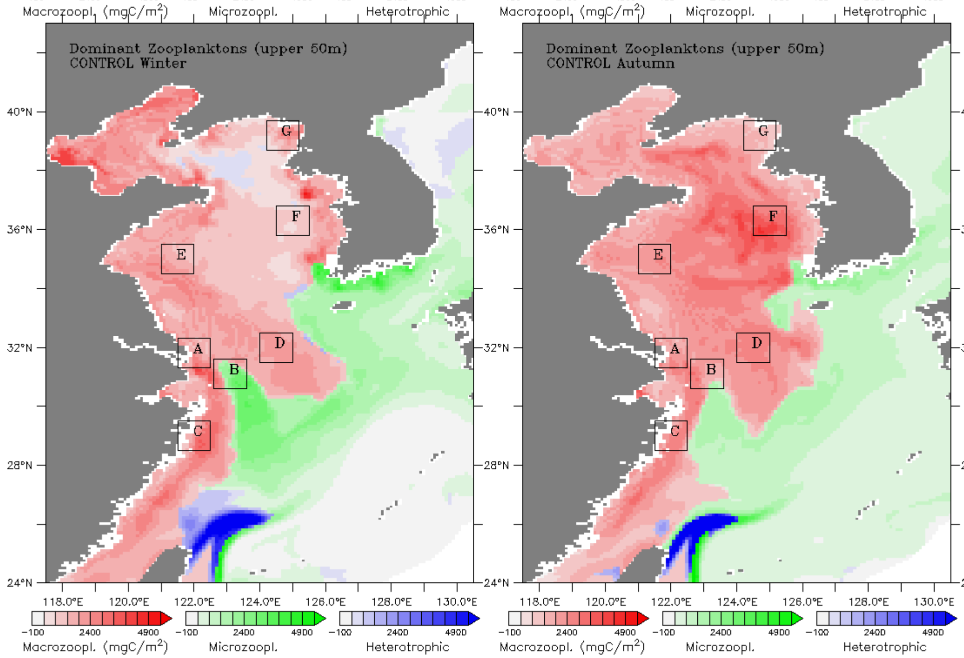
Changes of Zooplankton Dominant Species

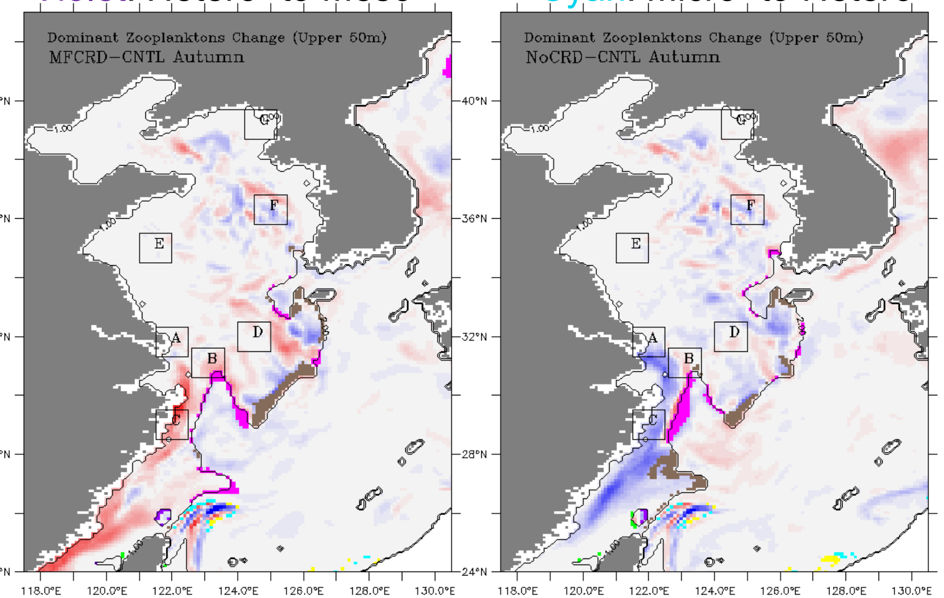




Violet: Hetero- to Meso-

Cyan: Micro- to Hetero-





Brown: Meso- to Micro-

Magenta: Micro- to Meso-

Summary – CDW influence

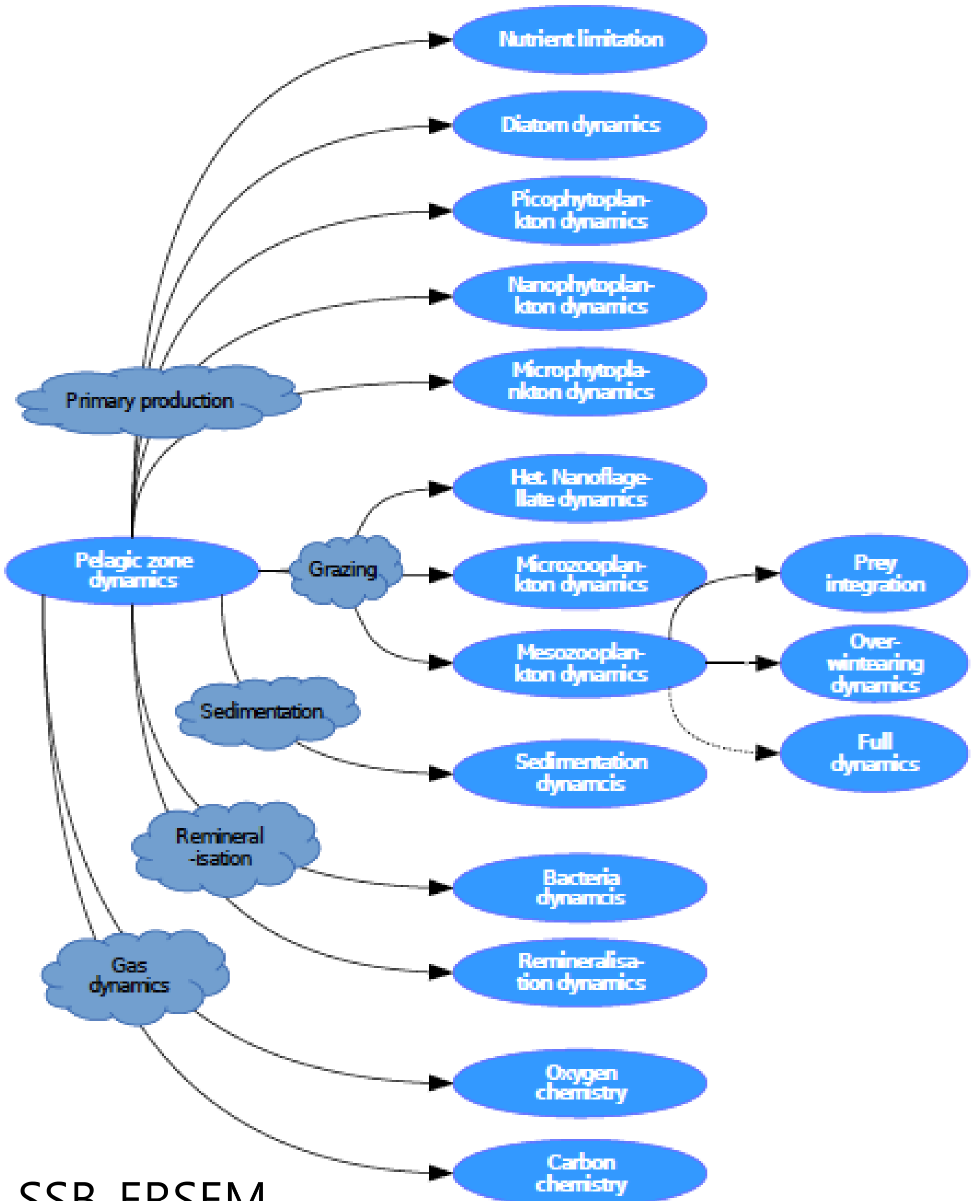
- The most prominent differences appear following the Changjiang Diluted Water (CDW) path centered in the northern border of the East China Sea adjacent to the Yellow Sea and its influences reach up to the East Sea.
- The supply of surface nutrients from the CDW is crucial during the summer while it is negligible during the winter when the vertical mixing drives the surface nutrients from the bottom.
- The most influenced functional groups are the pico-phytoplankton and the meso-zooplankton in context with the abundance change and the peak blooming time.

Further development plan – short term

- Model integration up to 2011 using,
  - ✓ ERA-interim Forcing 2001~2011
  - ✓ GLORYS2v3 Open Boundary Condition
- Near future (2030s) projection – Delta Method
  - ✓ Appling trend of seasonal cycle of atmospheric forcing and the open boundary conditions between 2030s and 2000s based on IPCC AR5 scenario runs
  - ✓ Extrapolation of the last 30 years trend of ERA-interim forcing and GLORYS2v3 open boundary conditions

Further development plan – longer term

- River flux data update
  - ✓ Seasonal cycle of volume and nutrients flux
- ERSEM parameters tuning
- Benthic Coupling
- Coupling with atmospheric model



SSB-ERSEM