Effects of photoaclimation of phytoplankton and benthic-pelagic coupling on primary production in the South China Sea: Recent observations and modeling

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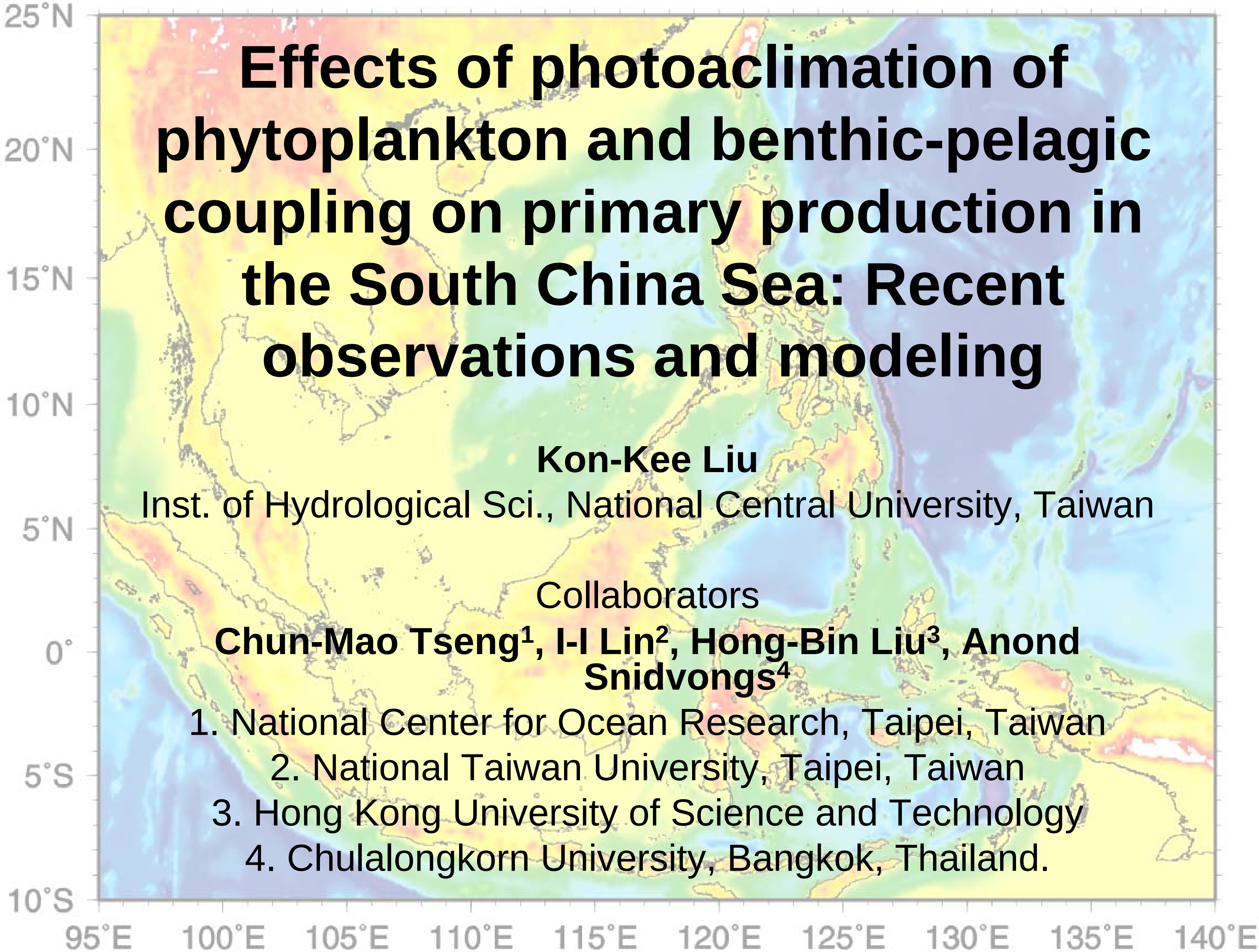
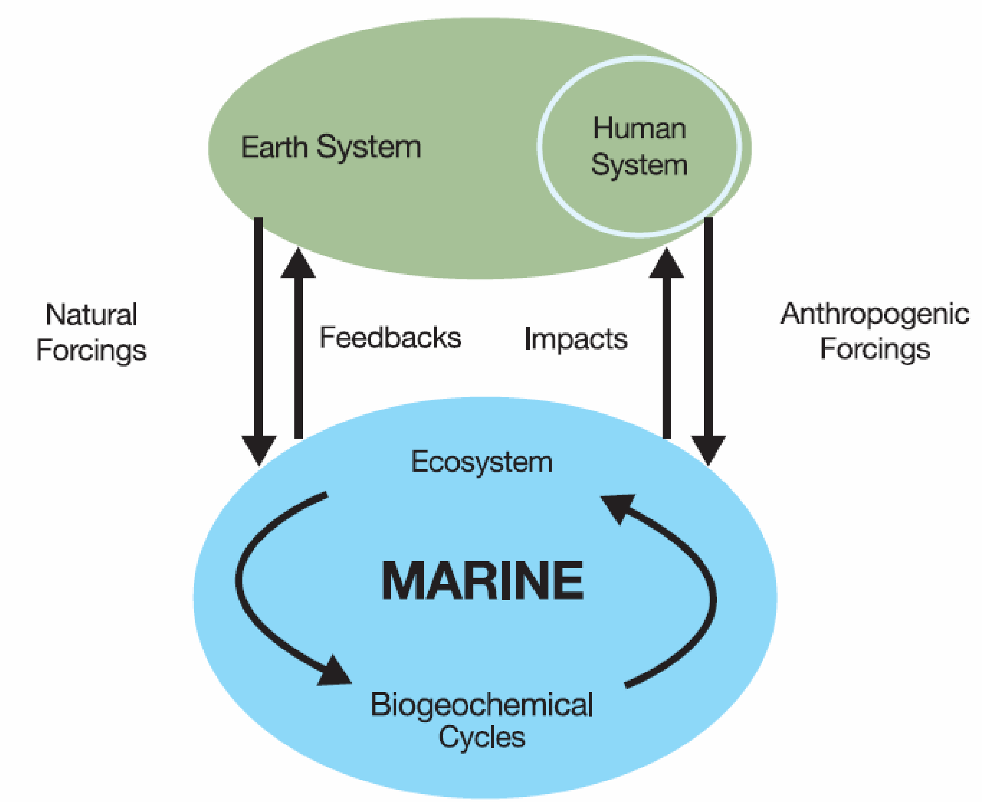


Outline

- Introduction: IMBER & Ocean Boundary
- South China Sea: Monsoon driven biogeochemical dynamics
- Photoacclimation: Survival in oligotrophic waters
- Benthic-pelagic coupling: material transport and transformation
- Conclusions

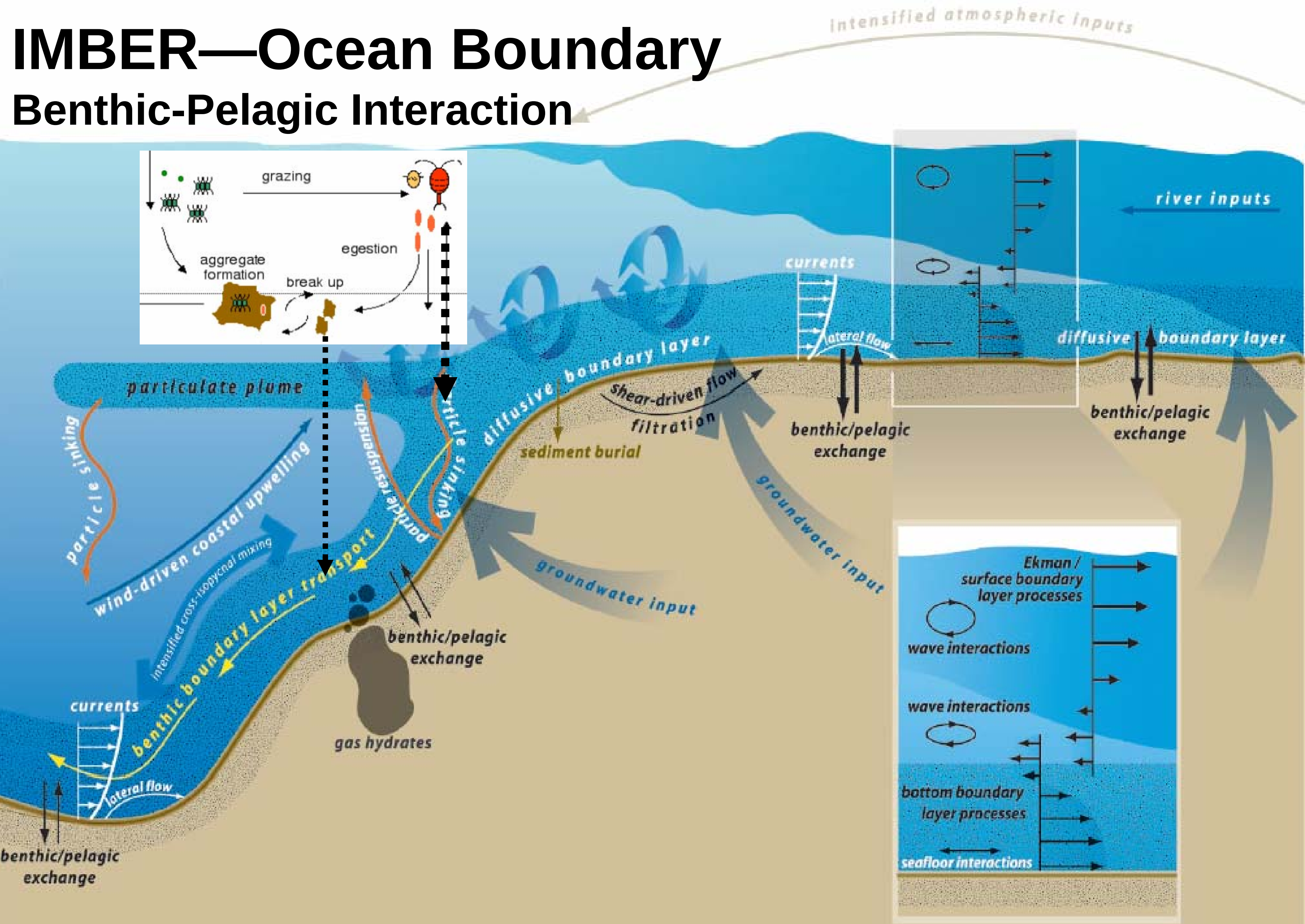
Integrated Marine Biogeochemistry & Ecosystem Research (IMBER)



Theme 1: Interactions Between Biogeochemical Cycles and Marine Food Webs

IMBER—Ocean Boundary

Benthic-Pelagic Interaction



Reimers et al., 2004)

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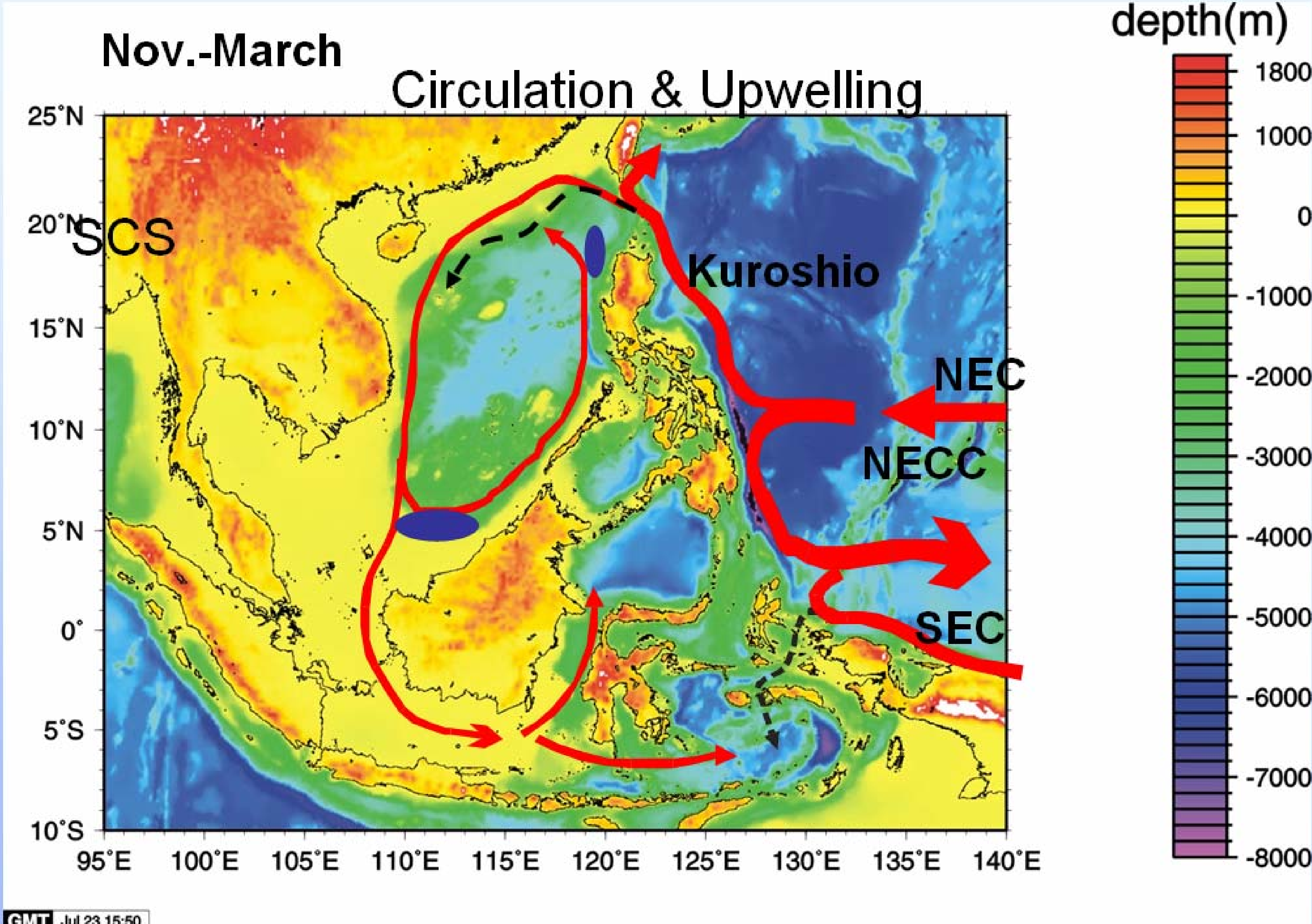

Nov.-March
Circulation & Upwelling
depth(m)
1800
1000
0
-1000
-2000
-3000
-4000
-5000
-6000
-7000
-8000
SCS
Kuroshio
NEC
NECC
SEC
25°N
20°N
15°N
10°N
5°N
0°
5°S
10°S
95°E
100°E
105°E
110°E
115°E
120°E
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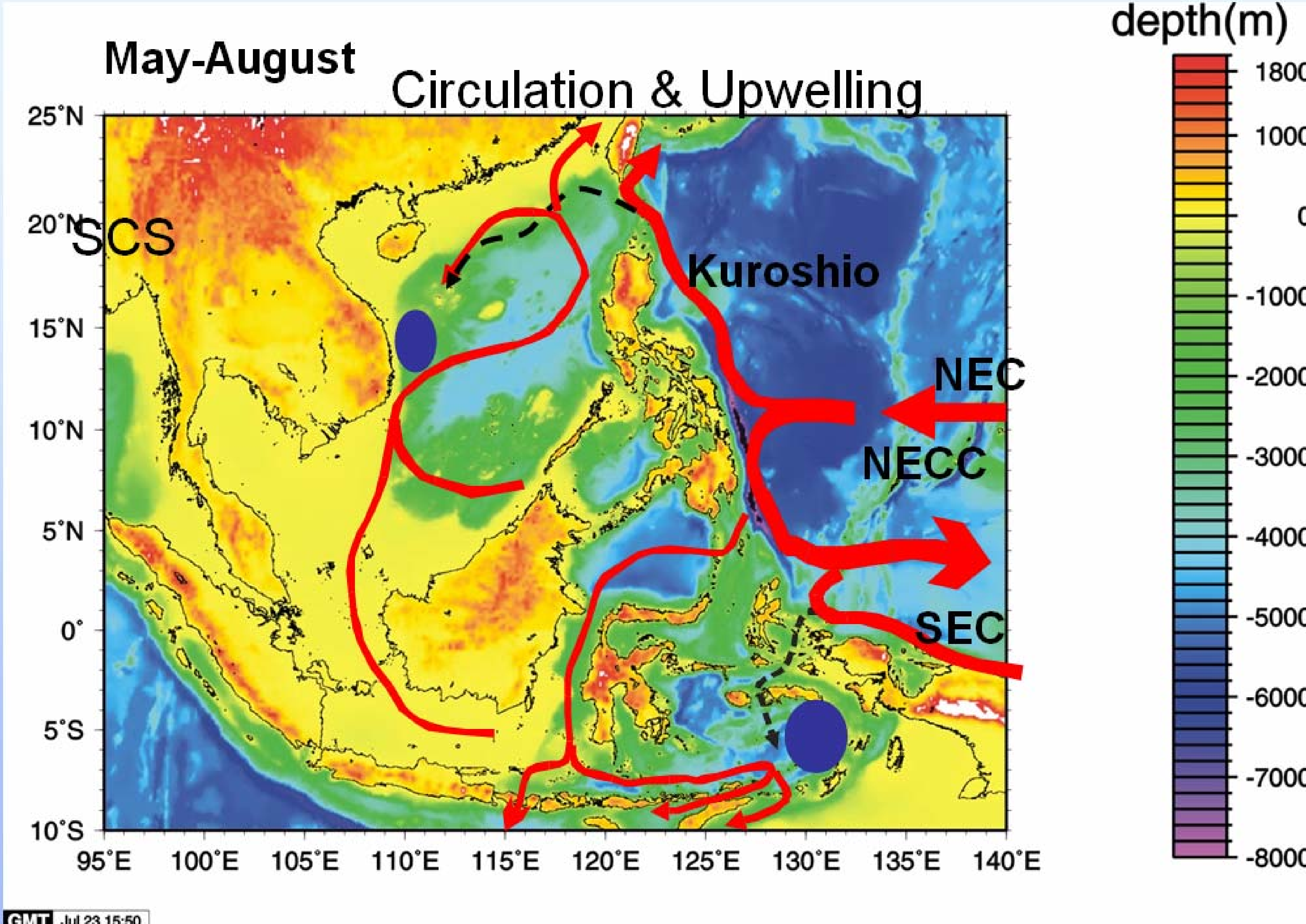
130°E
135°E
140°E
GMT Jul 23 15:50


May-August
Circulation & Upwelling
depth(m)
1800
1000
0
-1000
-2000
-3000
-4000
-5000
-6000
-7000
-8000
SCS
Kuroshio
NEC
NECC
SEC
25°N
20°N
15°N
10°N
5°N
0°
5°S
10°S
95°E
100°E
105°E
110°E
115°E
120°E
125°E
130°E
135°E
140°E
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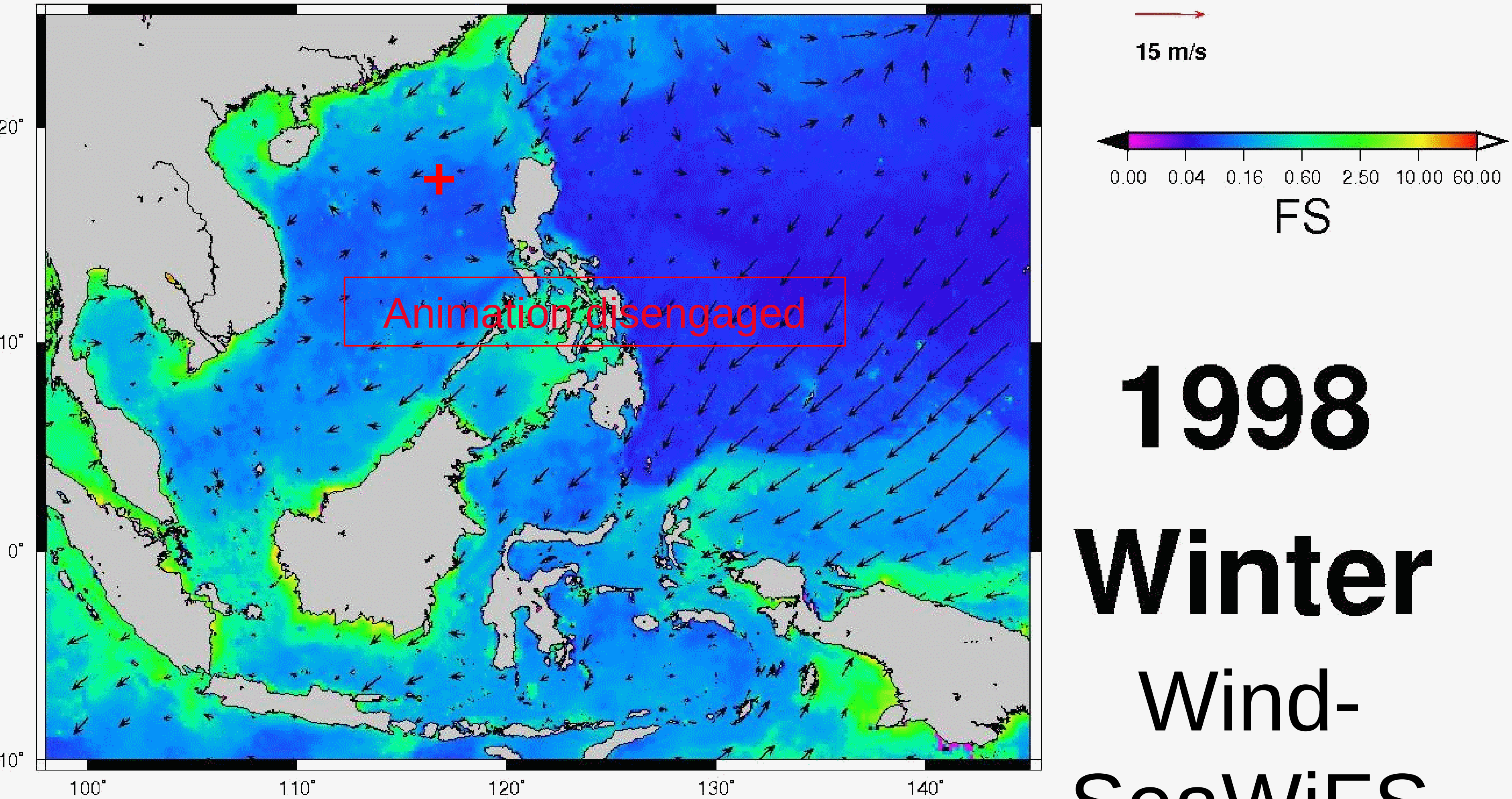
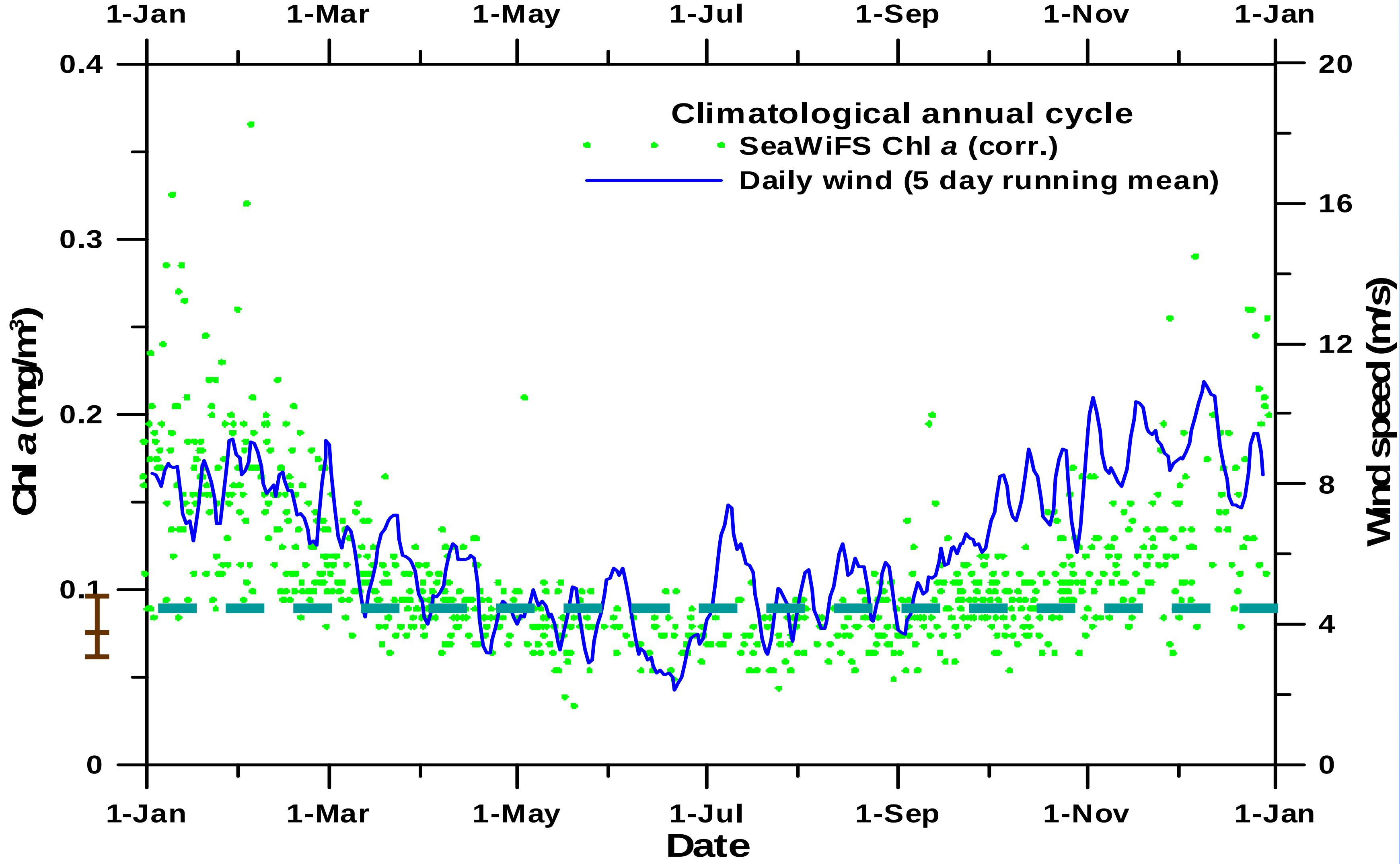
South-East Asia Time-series Study (SEATS) site



1998 Winter

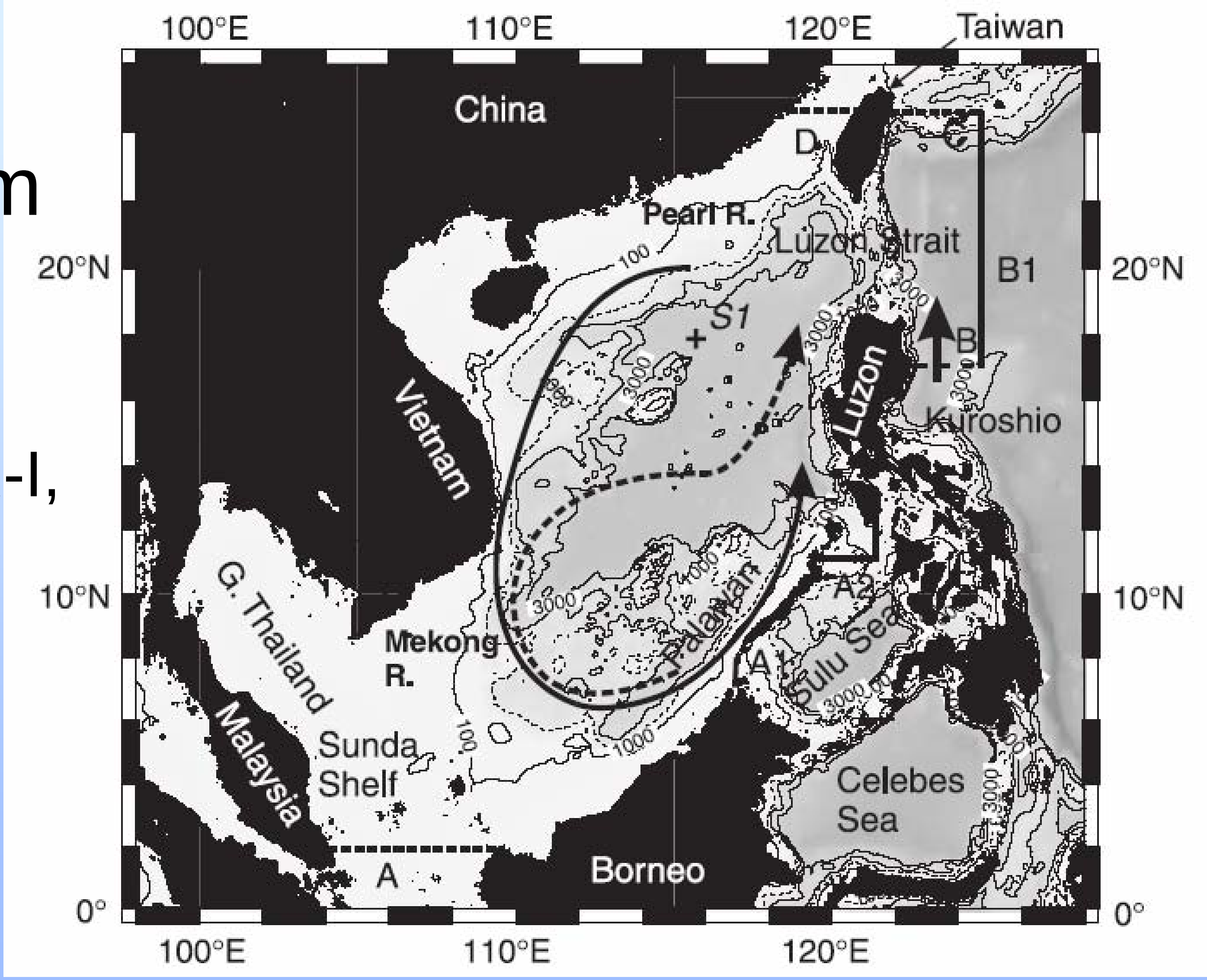
Wind-SeaWiFS Chl *a*

What causes the strong seasonal variation of Chl *a*?



SCS Biogeochem Model-I domain

(Liu et al., DSR-I, 2002)



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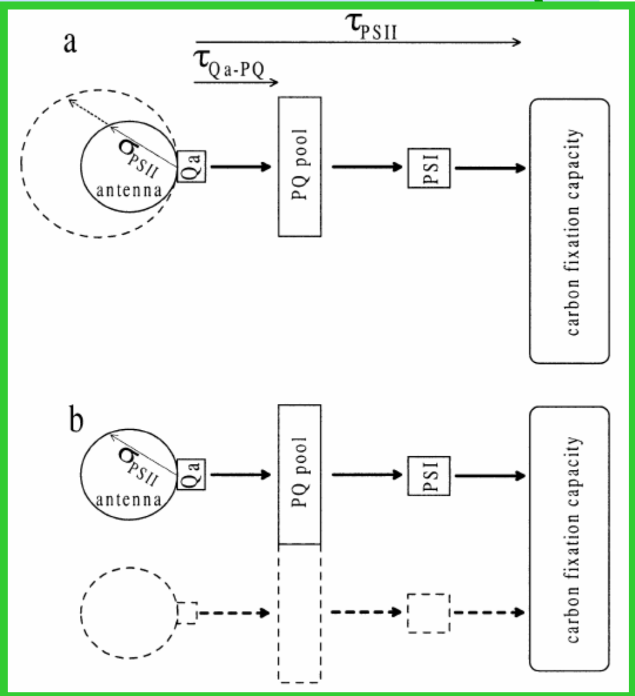
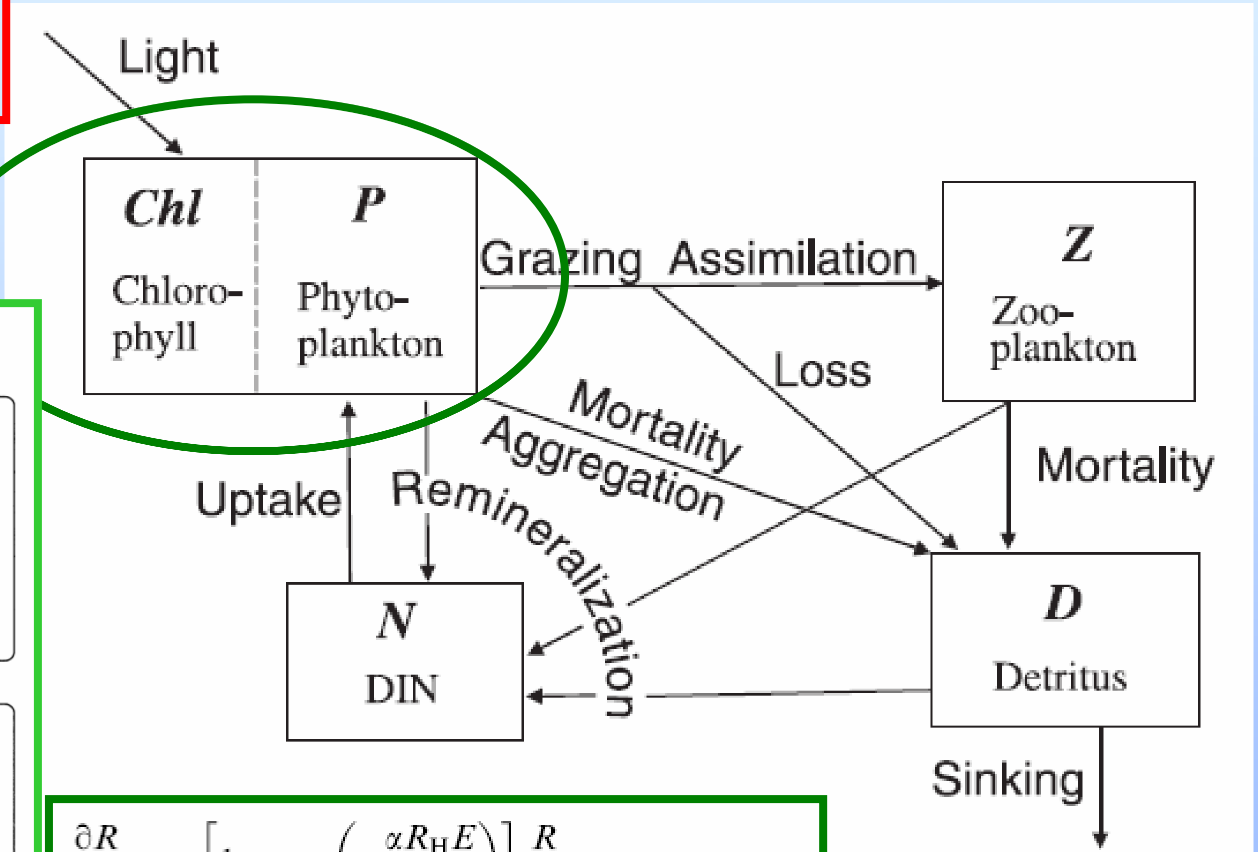
Ecosystem model

Chl/N_{phy} = 1-2.5
OC_{phy}/Chl = 80-32

Photo-acclimation (Moore et al., 2006)

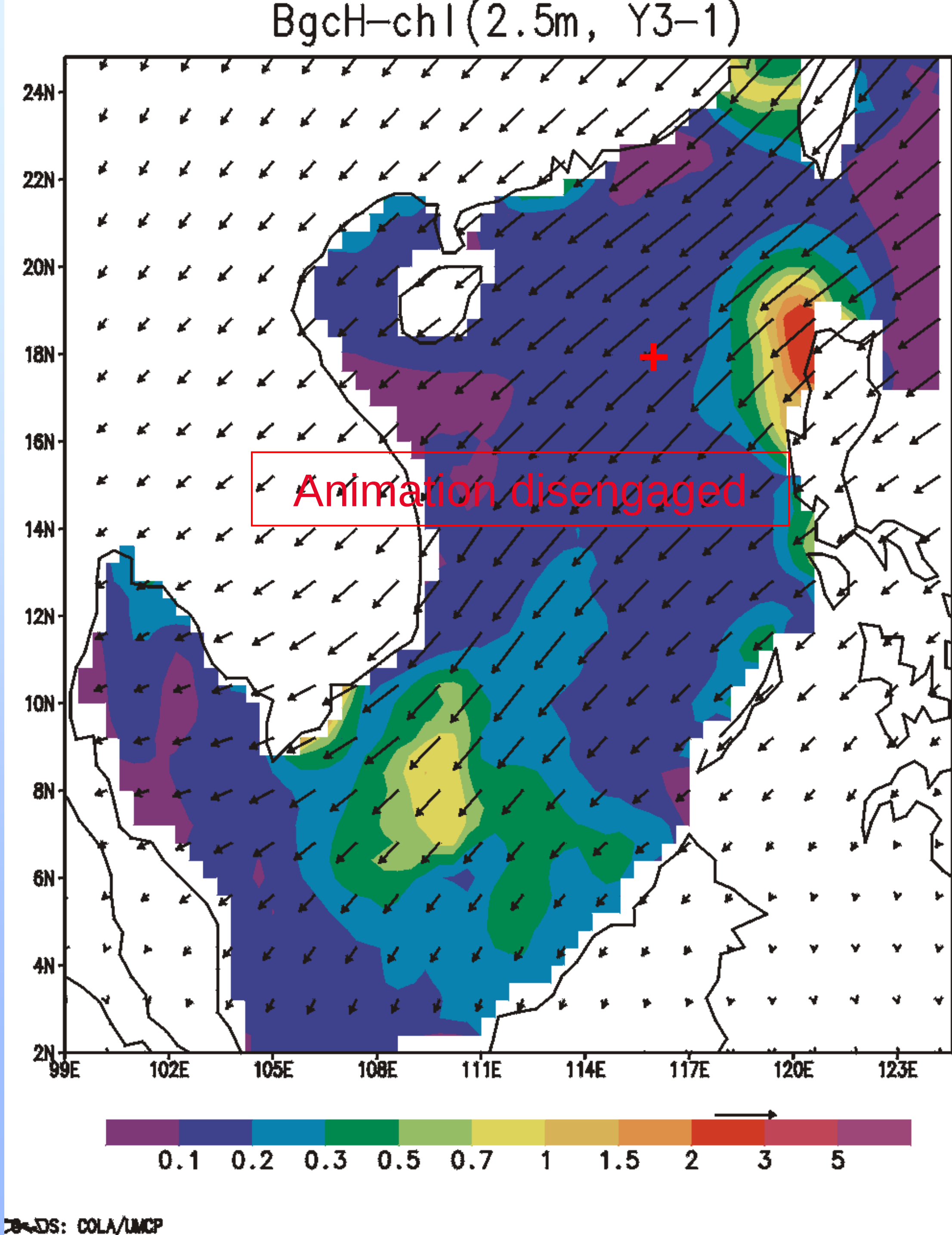




$$\frac{\partial R}{\partial t} = \mu_P \left[1 - \exp\left(-\frac{\alpha R_H E}{\mu_P}\right)\right] \frac{R}{R_H} \times \left\{ \frac{N}{N + \kappa_N} \left[R_L - (\Delta R)\min\left(\frac{E}{E_k}, 1\right)\right] - R \right\}$$

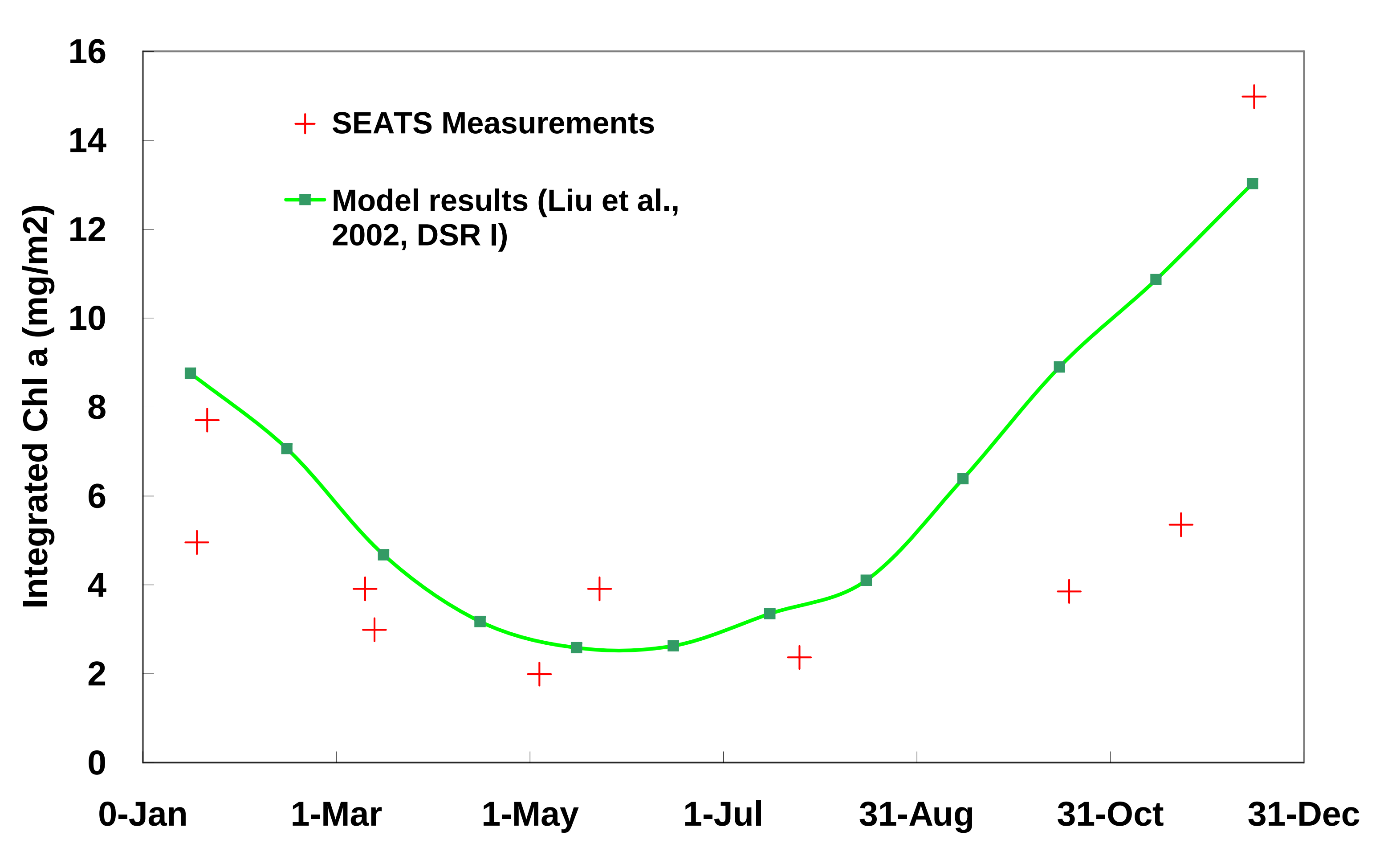
(Geider et al., 1996 Doney et al., 1996)

SCS Biogeo-chemical model (Liu et al., 2002, DSR I): Effect of monsoons on Chl-a

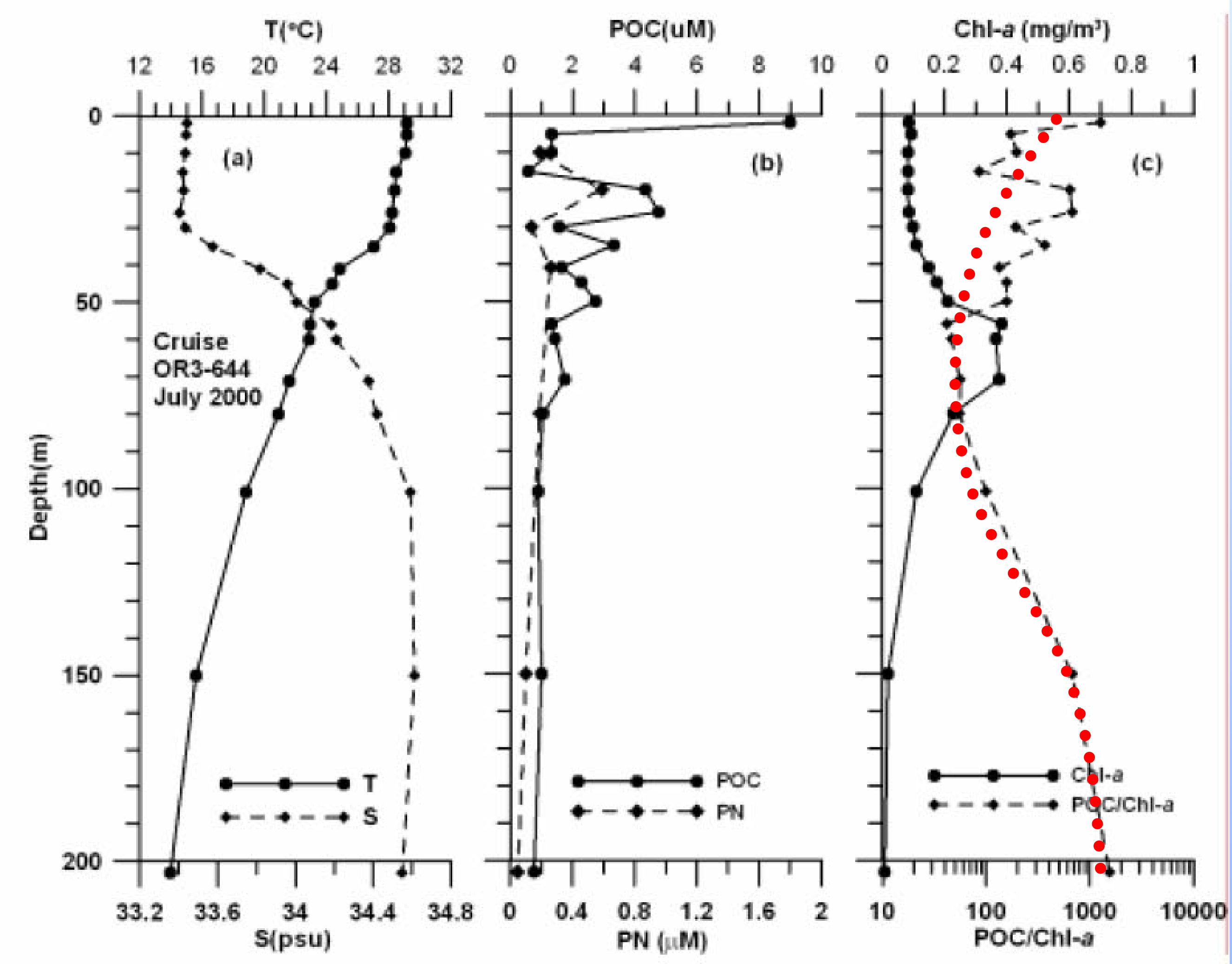


Oct 19, 2006
Yokohama

Chl a inventory (0-30 m): Observed vs Modeled results



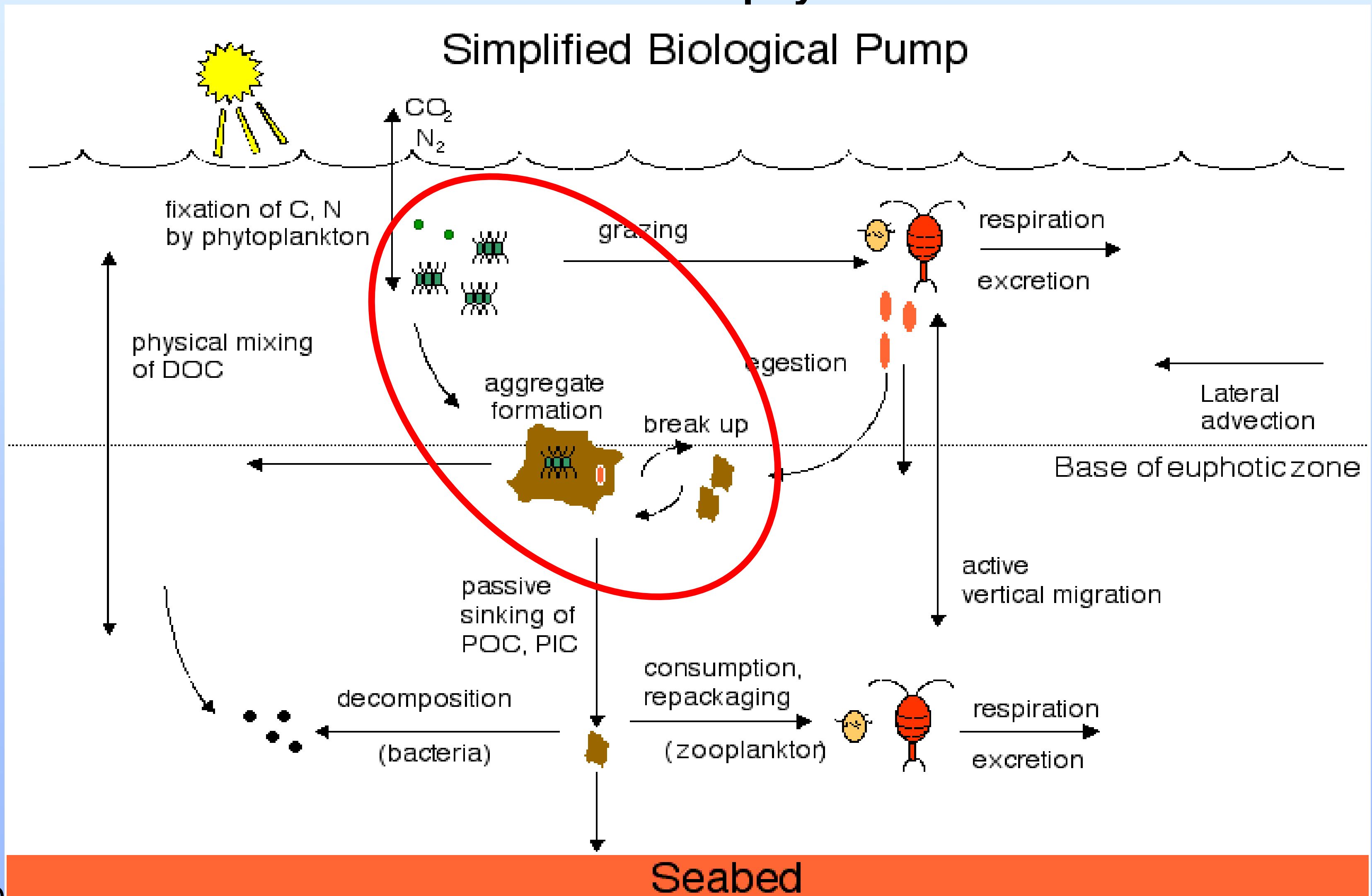
SEATS Observations



Variable POC/Chl-a ratio

$POC = OC_{phy} + OC_{det}$

$POC/Chl >= OC_{phy}/Chl = R$



Obs. & Modeled POC/Chl (SEATS)

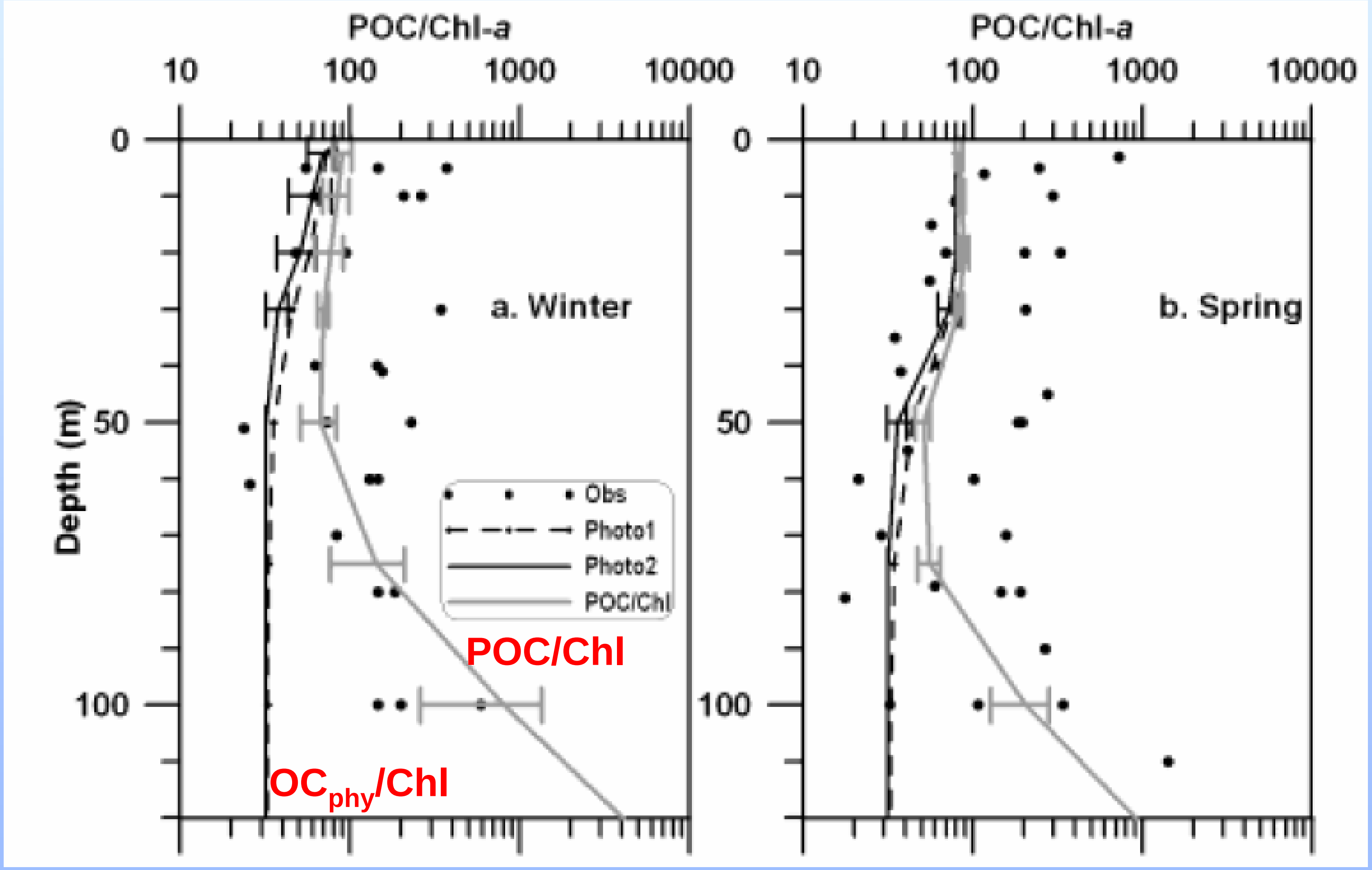


Photo-acclimation & Subsurface Chlorophyll Maximum

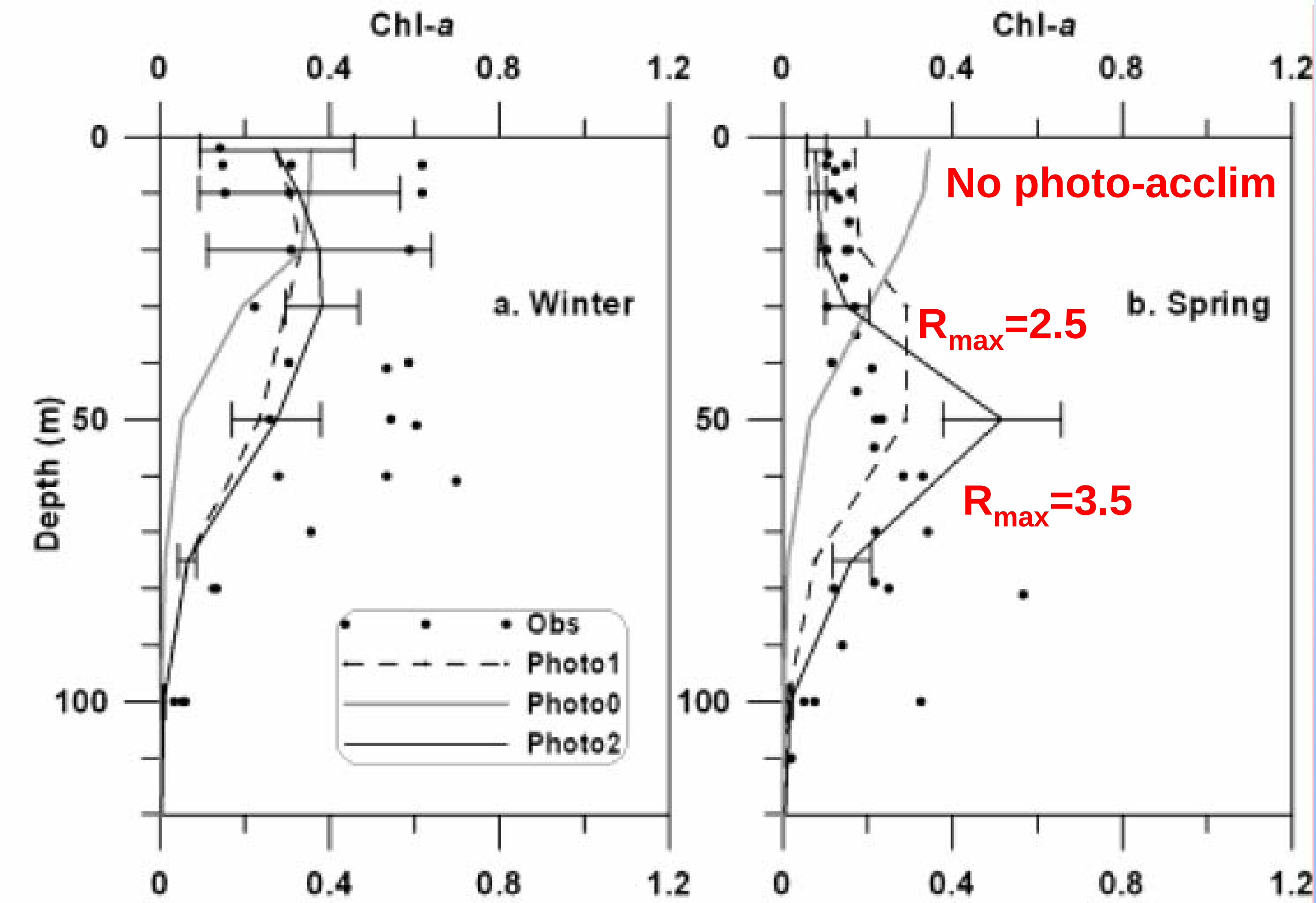


Table 2. Increase in relative cellular chlorophyll fluorescence (in the numbers of fold) between the low fluorescence cells in the surface mixed layer and high fluorescence cells in the deeper layer (mean ± 1 SD, n = 10 for SEATS), at the HOT and SEATS sites. Data for HOT are obtained from Campbell et al. (1997).

	HOT	SEATS
Prochlorococcus	35 ± 14	14 ± 7
Synechococcus	20 ± 14	10 ± 7
picoeukaryotes	15 ± 36	5 ± 2

Increase in cell volume (carbon):

Prochlorococcus 3.6 – 4.7 fold

Synechococcus 4.1 – 5.3 fold

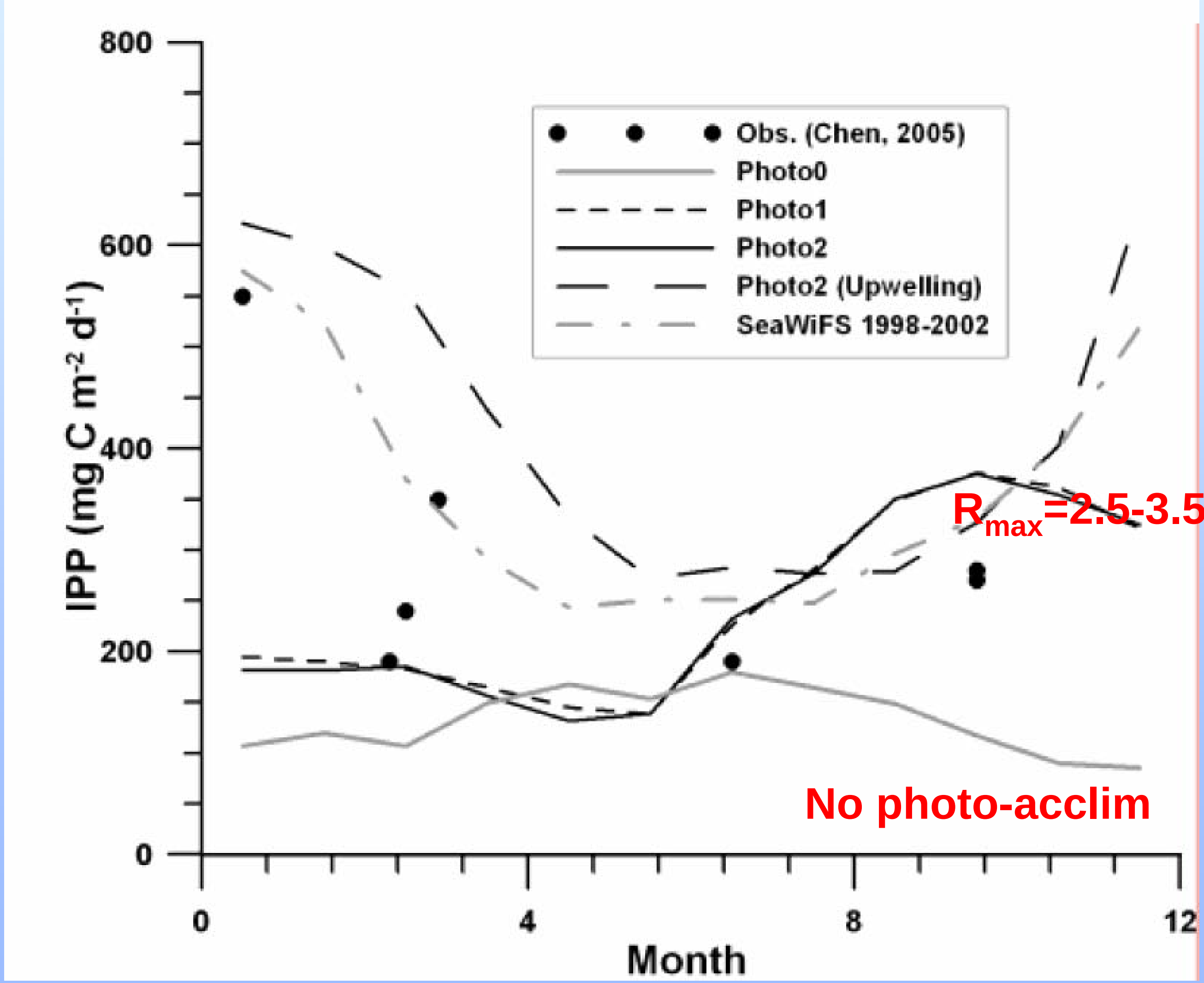
Change in chlorophyll to carbon ratio:

Prochlorococcus ~3.4 fold

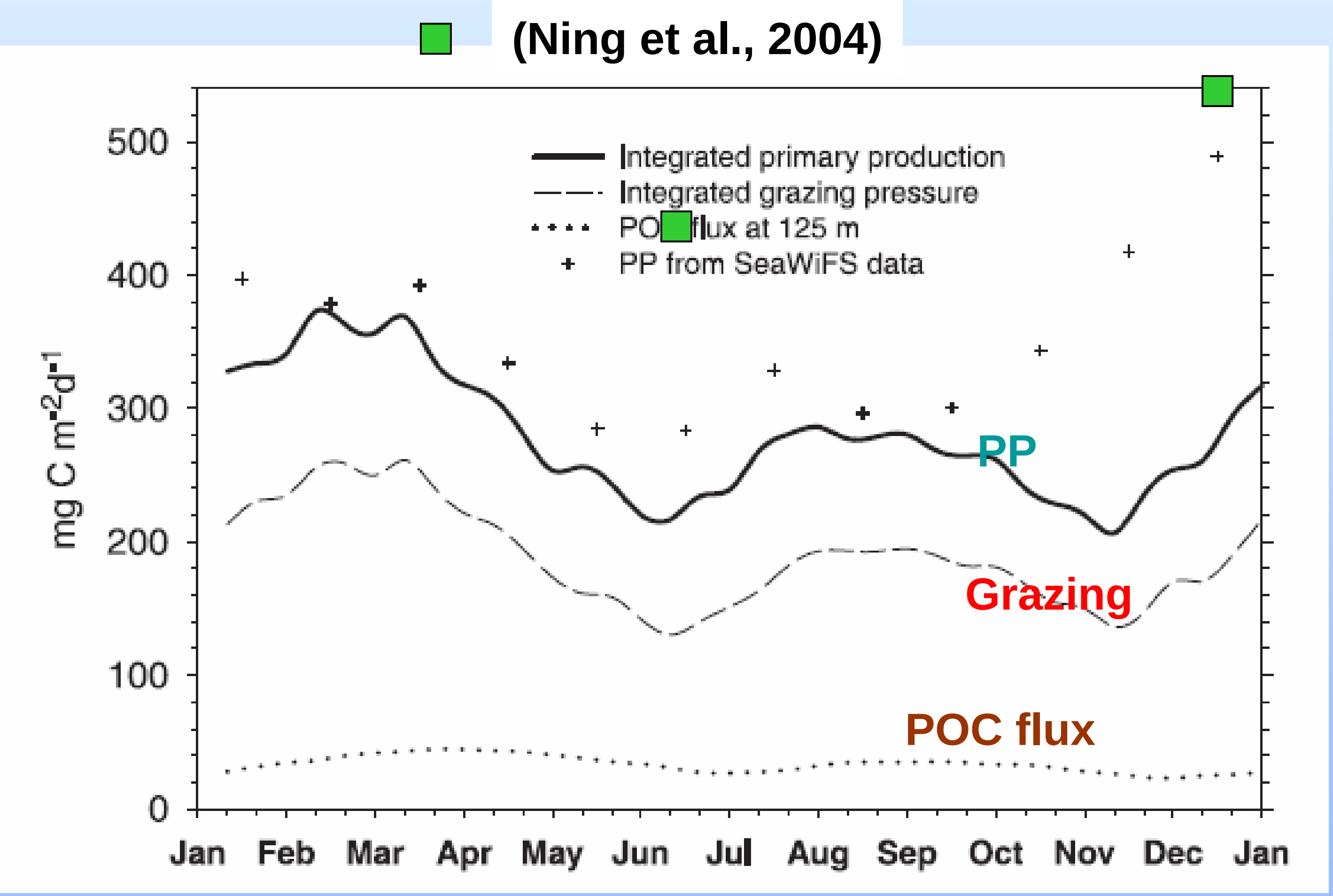
Synechococcus ~2.1 fold

(H. Liu et al., DSR-II, 2007)

Obs. & modeled PP at SEATS



PP (Whole SCS): Modeled vs SeaWiFS/B&F



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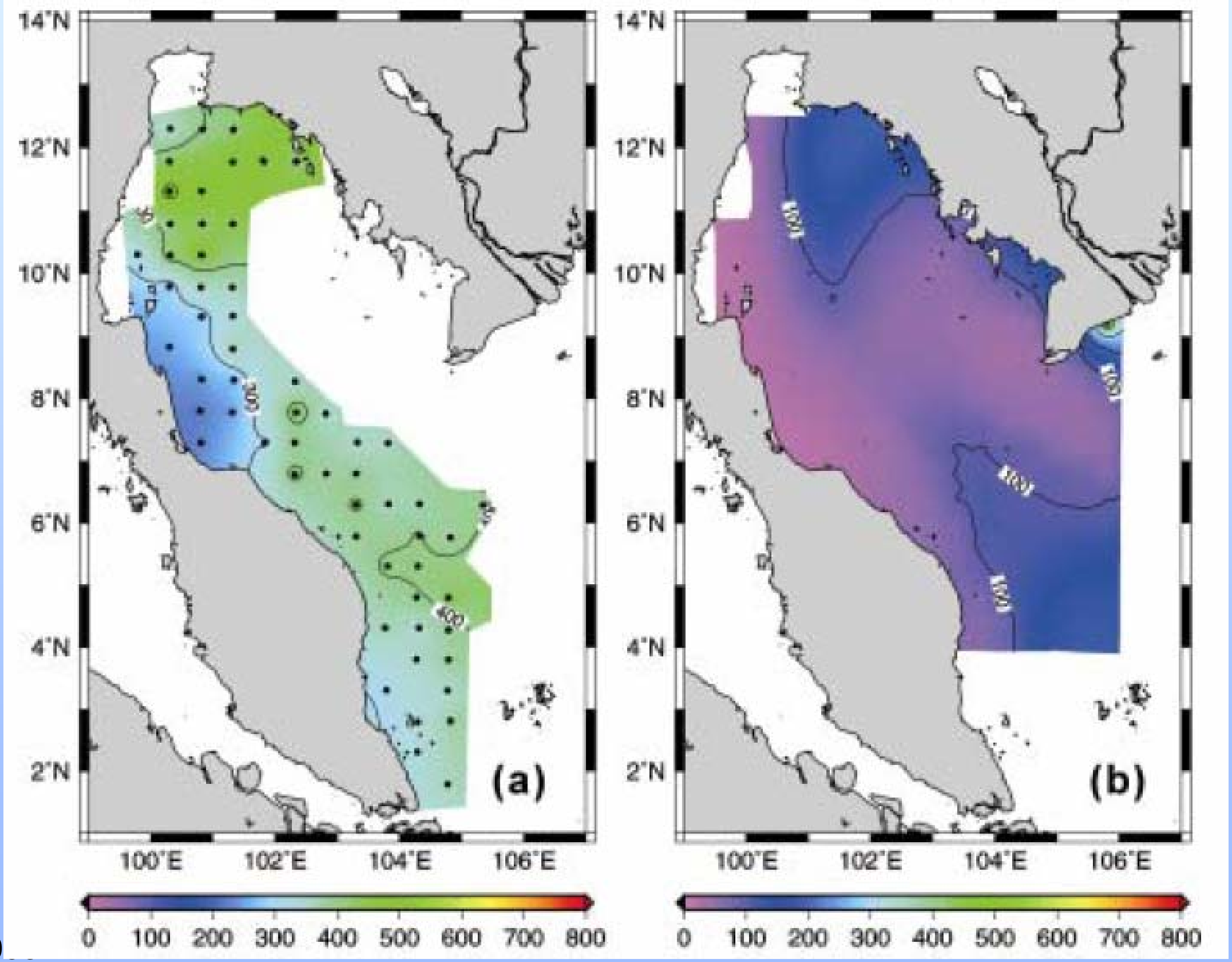
Obs. & modeled PP

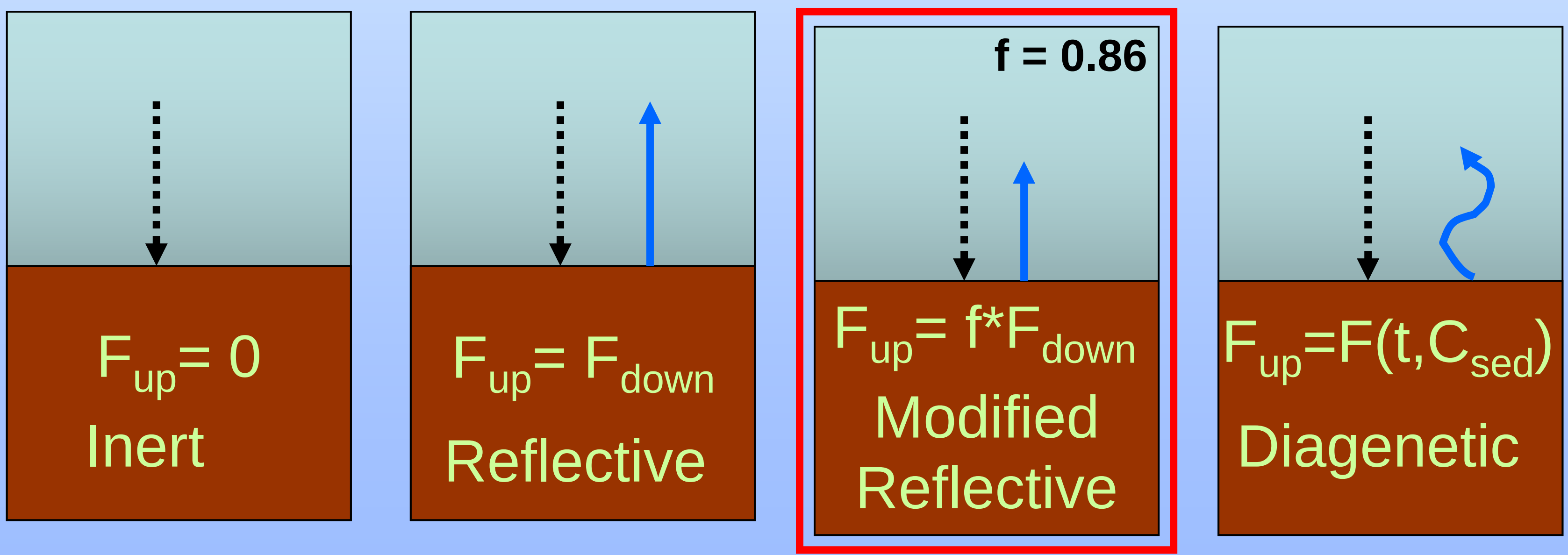
Gulf of Thailand, Sept.-Oct. (Liu et al. DSR-II, 2007)

Sep.-Oct. 1995

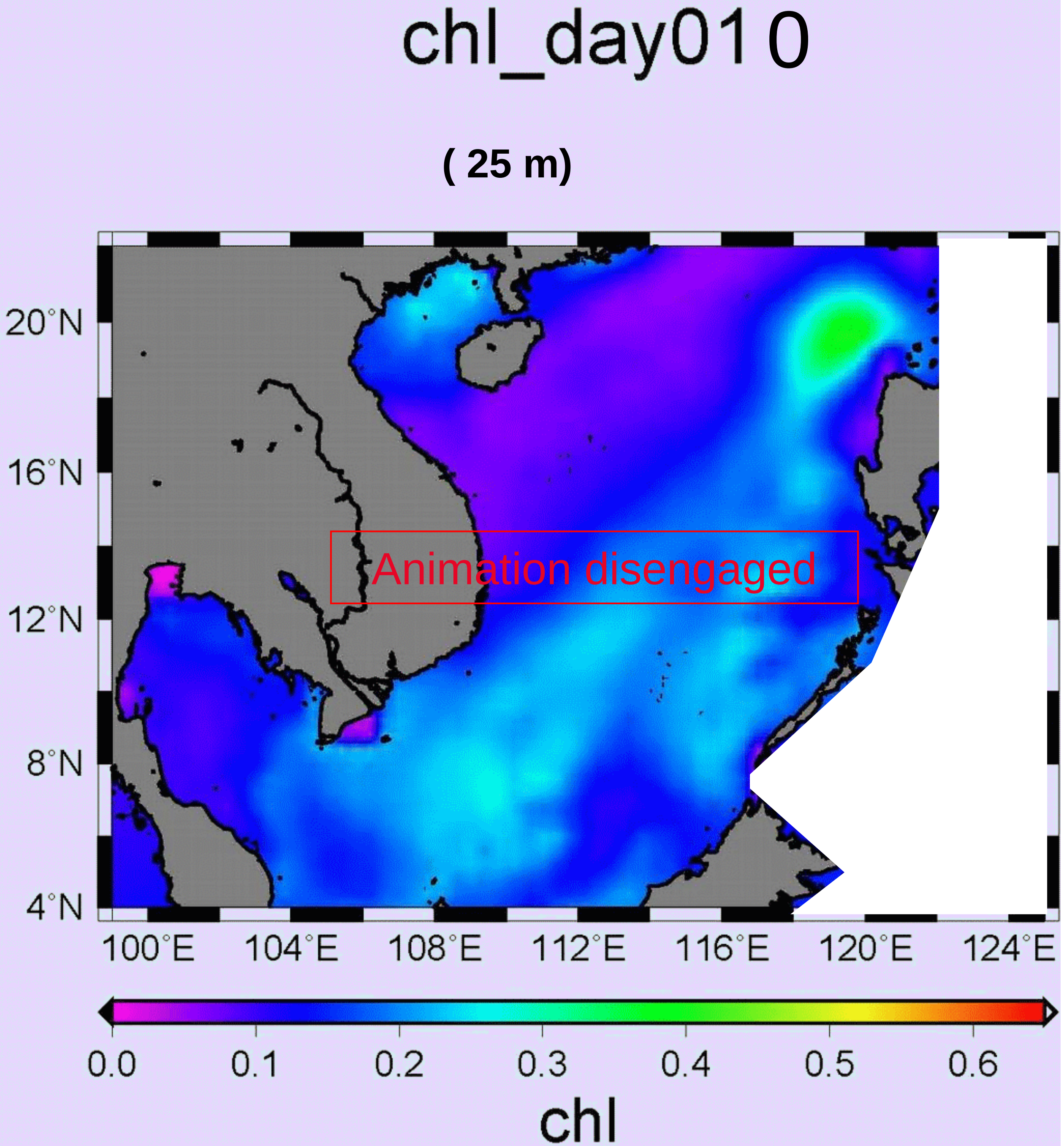


Benthic-pelagic coupling

- Benthic boundary condition
  - $w \bullet DIN - kz(\partial DIN/\partial z) = -fB \bullet [(w+wsink) \bullet Det - kz(\partial Det/\partial z)]$



(Soetaert et al., 2000; Fennel et al., 2006)



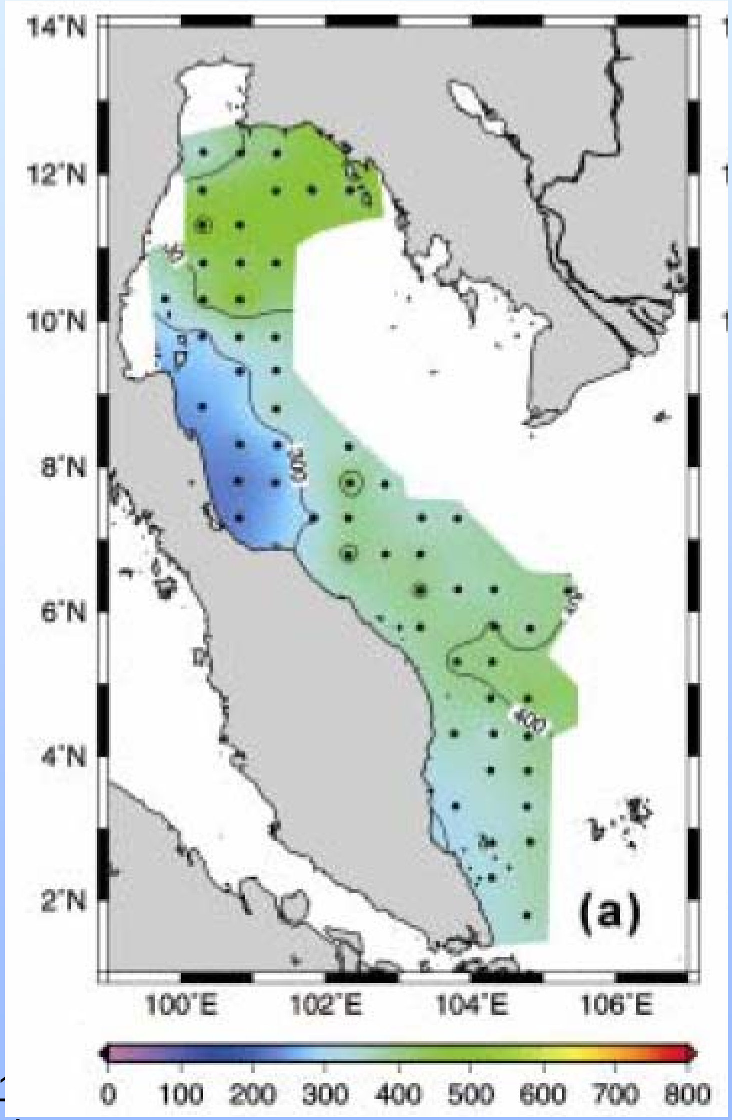
SCS Biogeo-chemical model-II

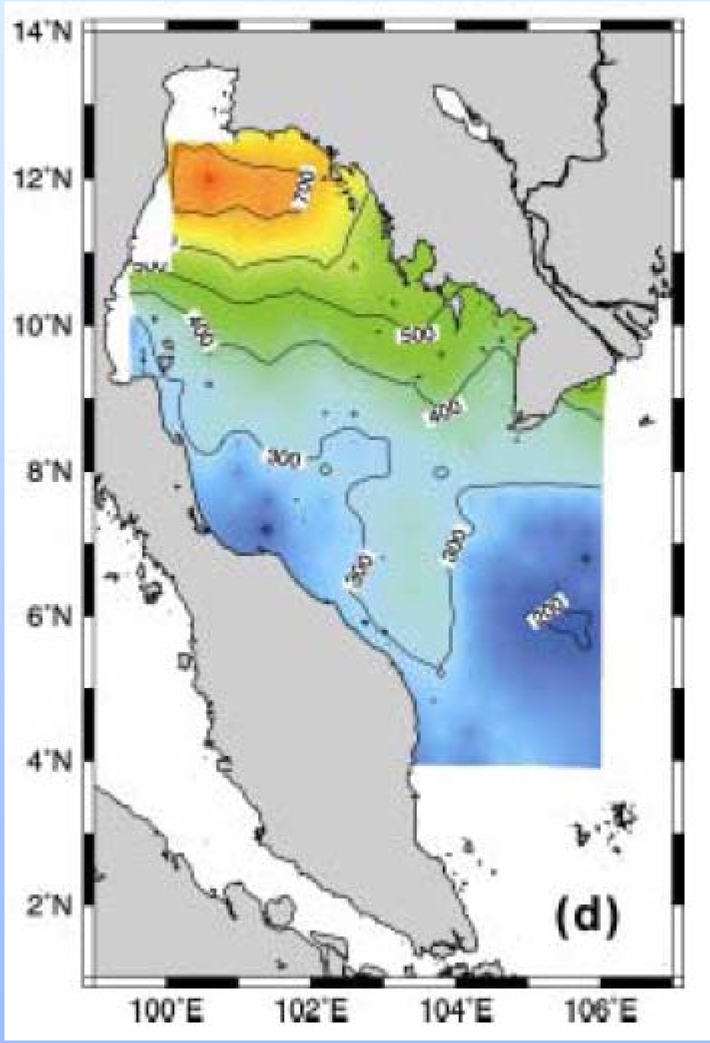
(Liu et al. , DSR II, 2007)

Gulf of Thailand (Sept.-Oct.)

Obs. & modeled PP (SCSmodel-II)

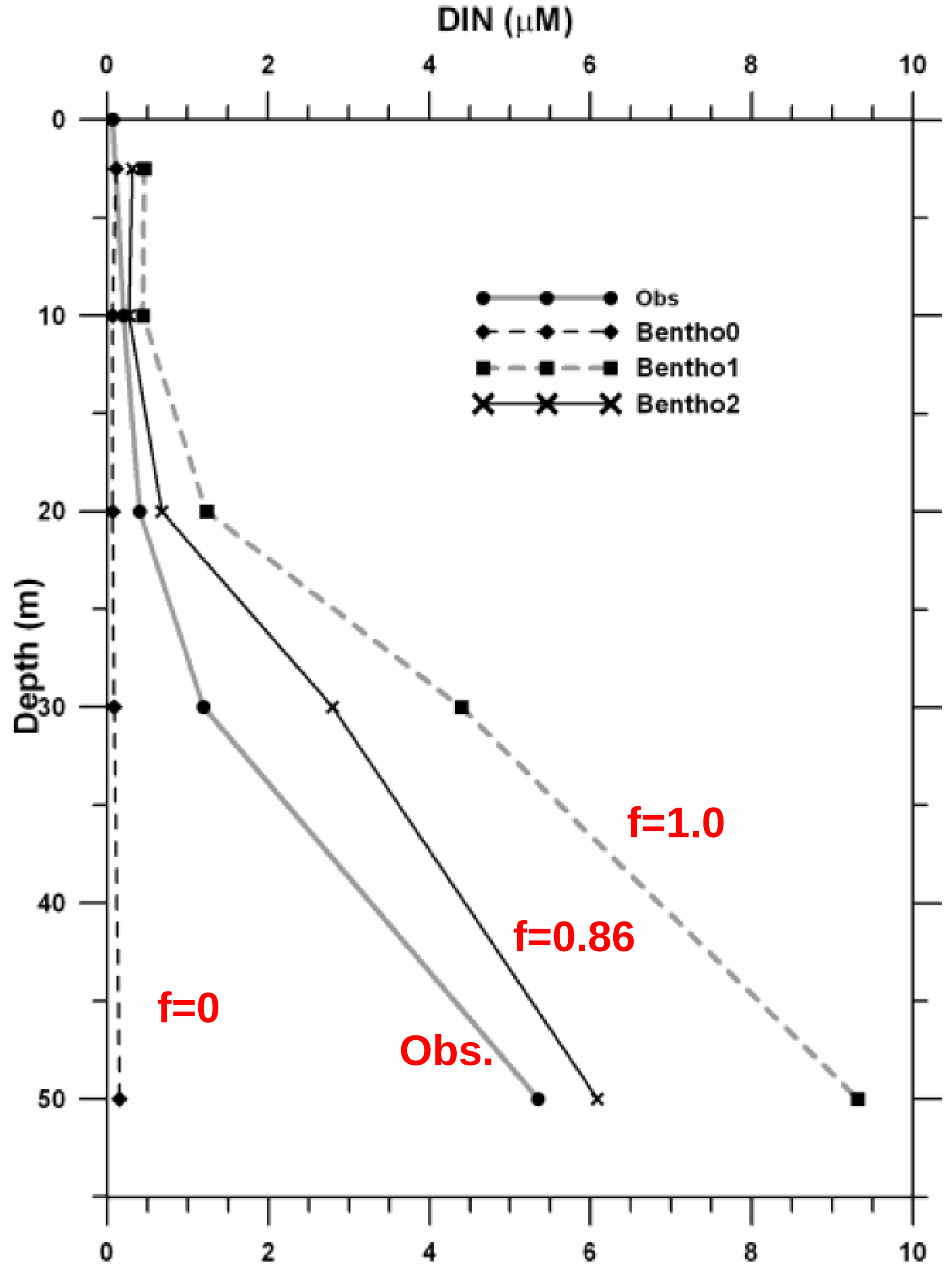
371 mgC $m^{-2}d^{-1}$



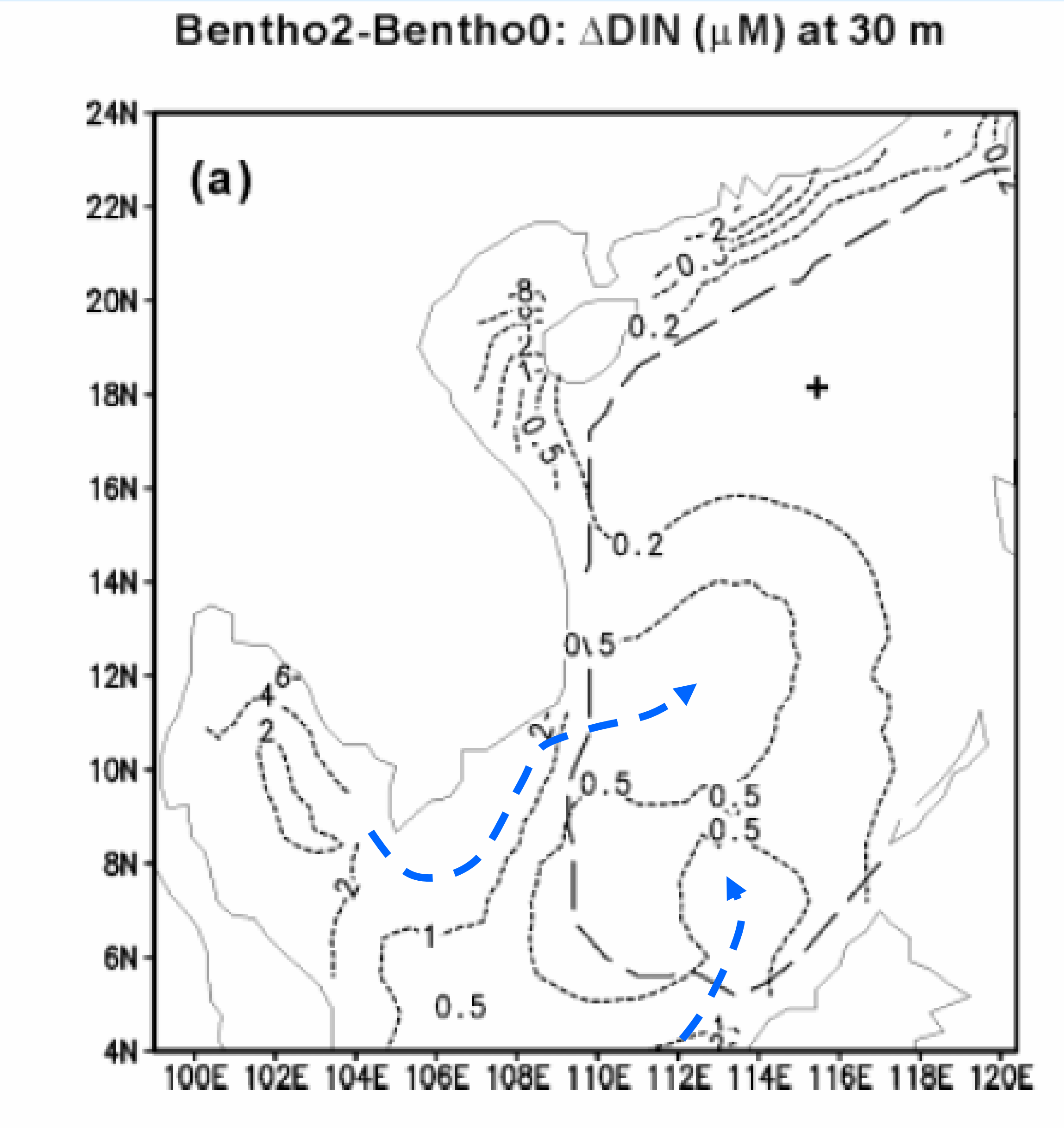


399 mgC $m^{-2}d^{-1}$

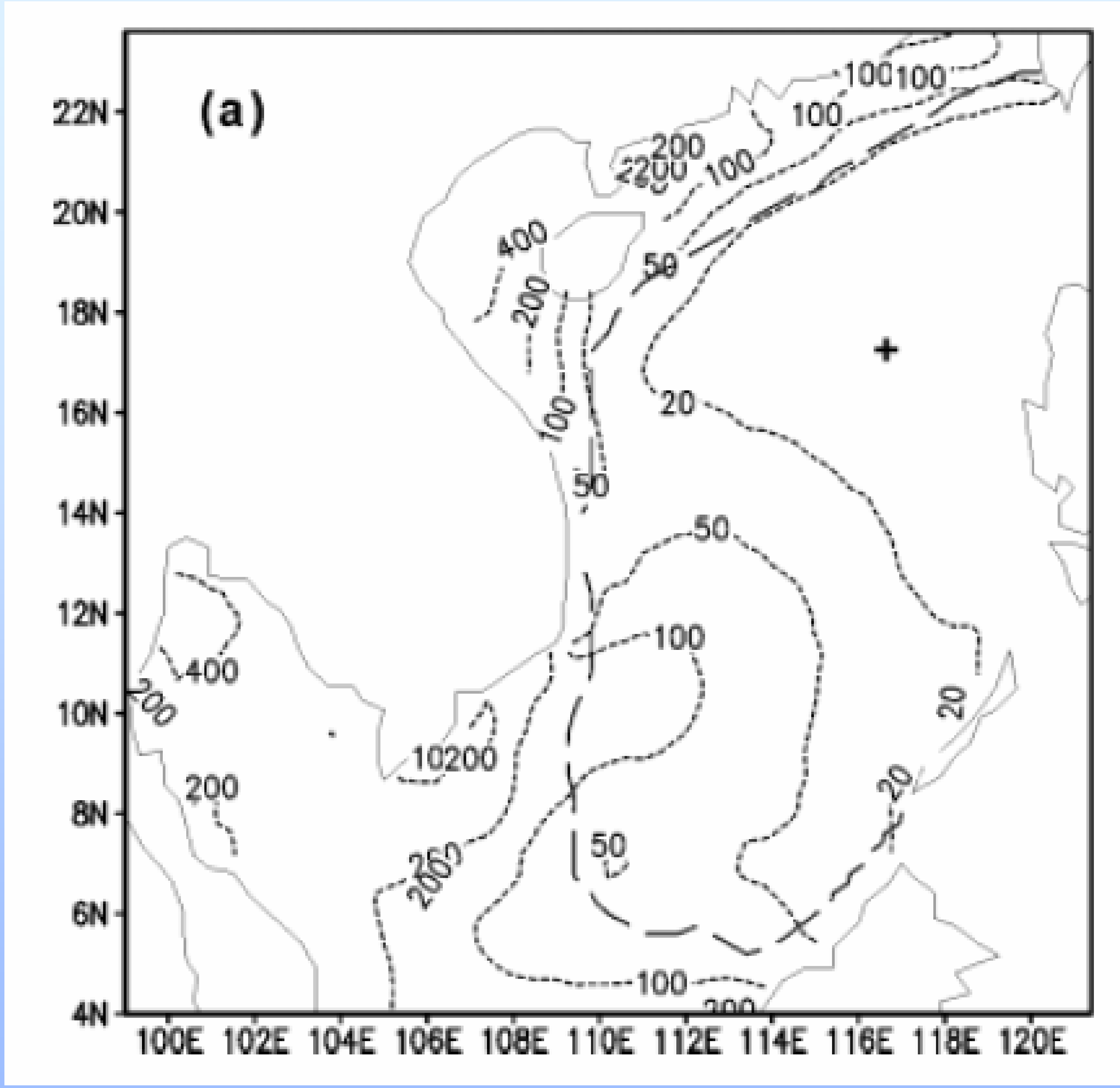
Observed & Modeled nitrate profile in the Gulf of Thailand



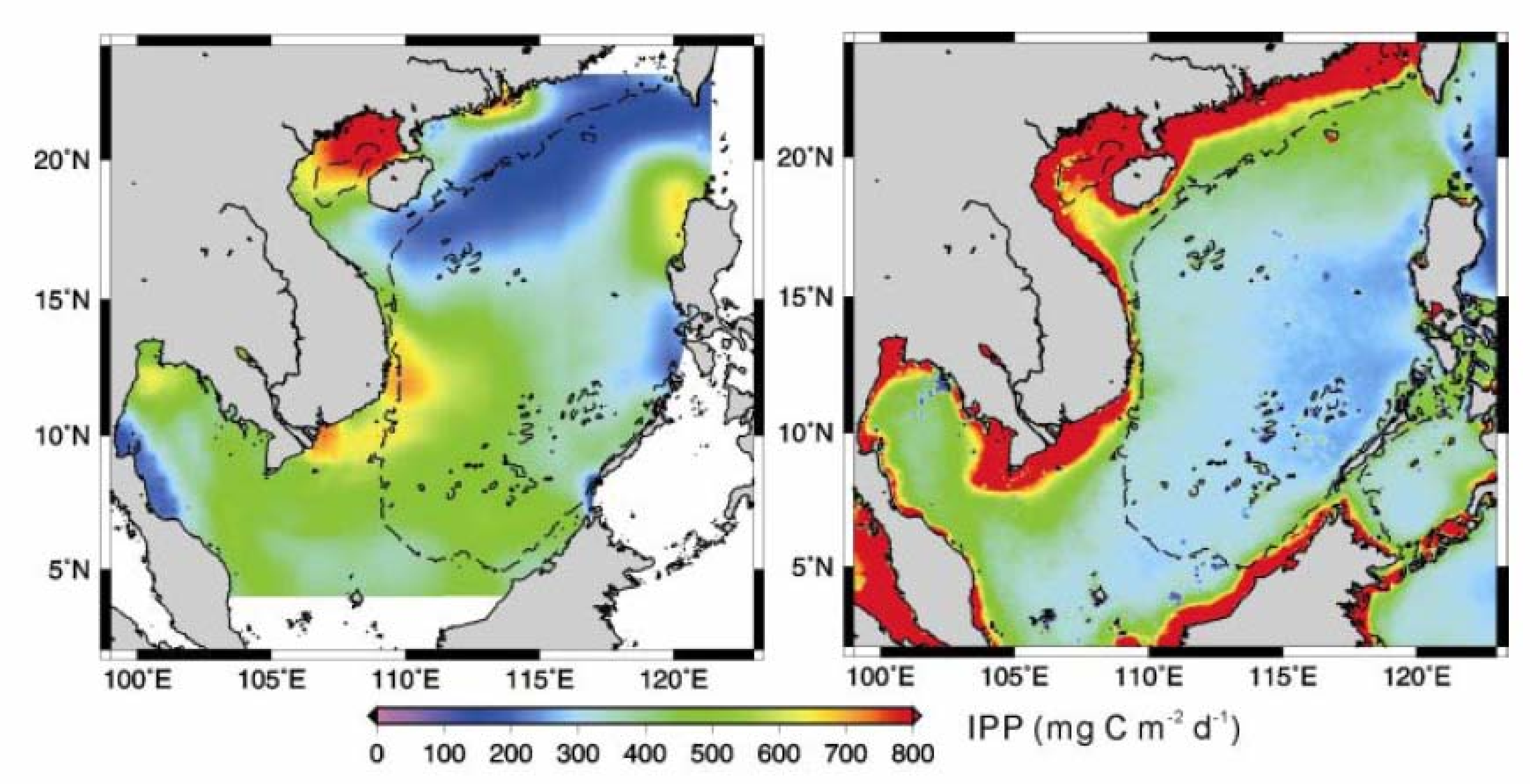
Seaward dispersion of shelf regenerated nitrate (30 m below surface)



Effect of benthic nutrient regeneration on PP (mg C $m^{-2}d^{-1}$)

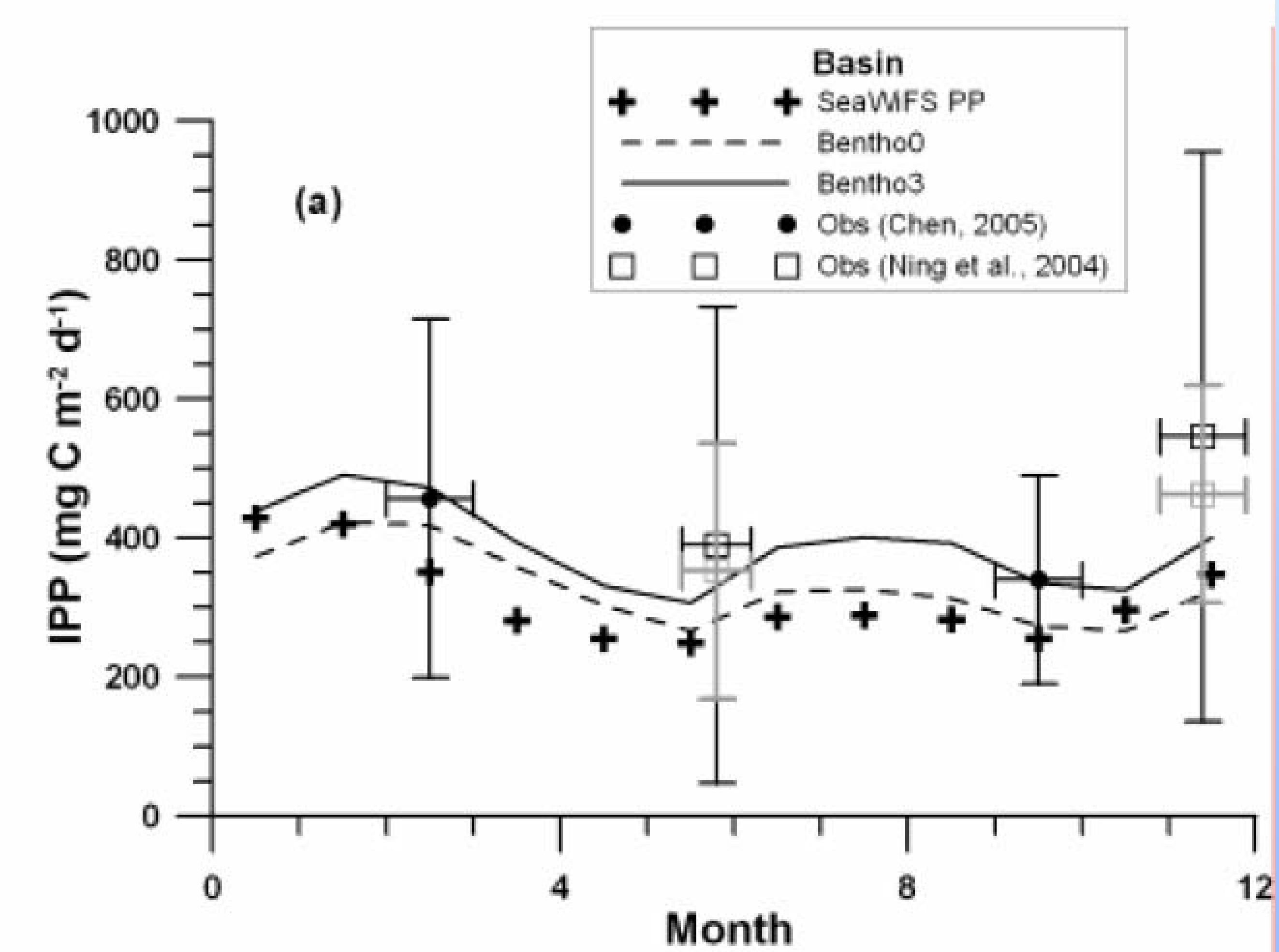


PP: SCS model-II vs SeaWiFS/B&F



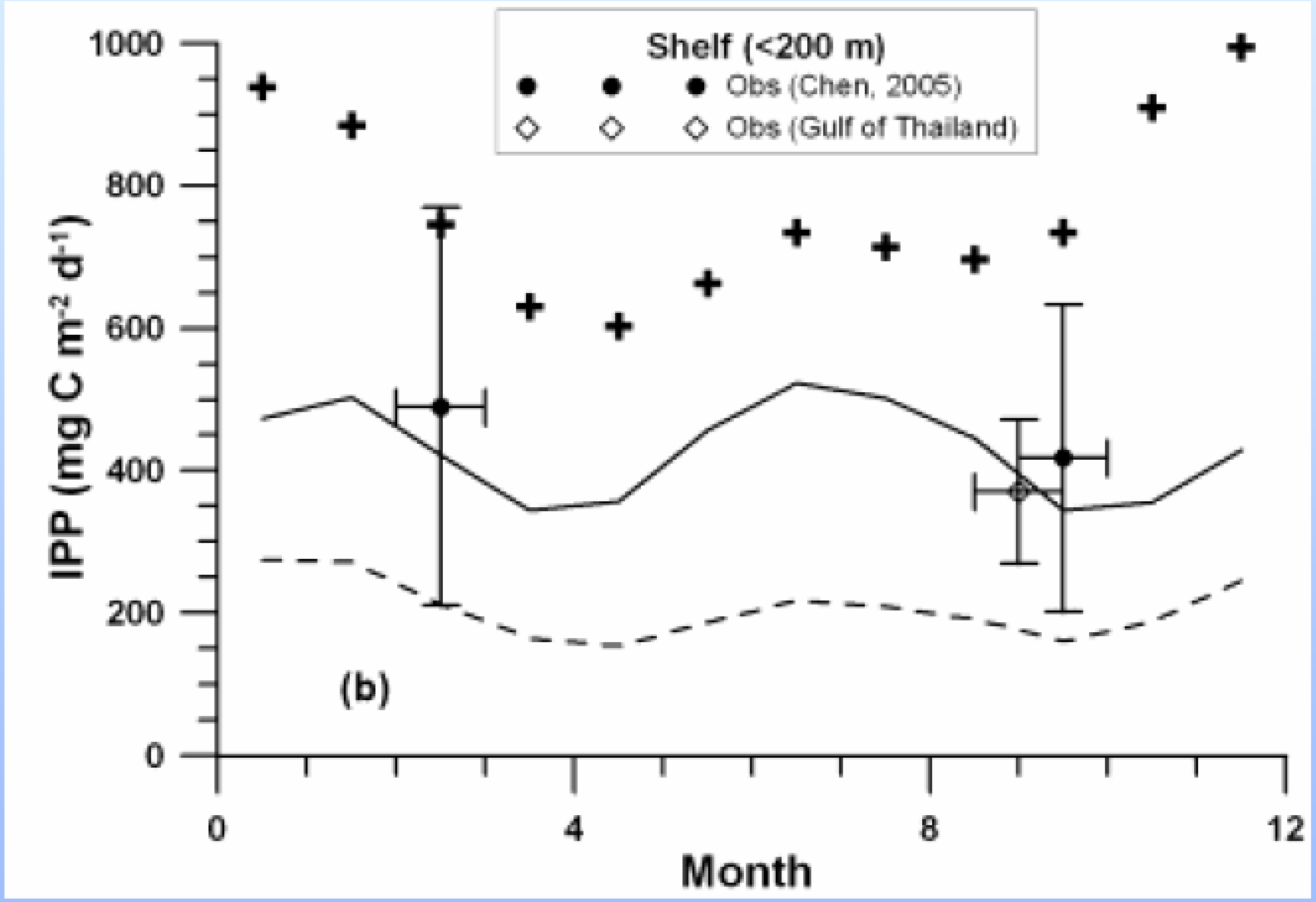
PP: Obs. vs. Modeled

Basin (z>200 m)



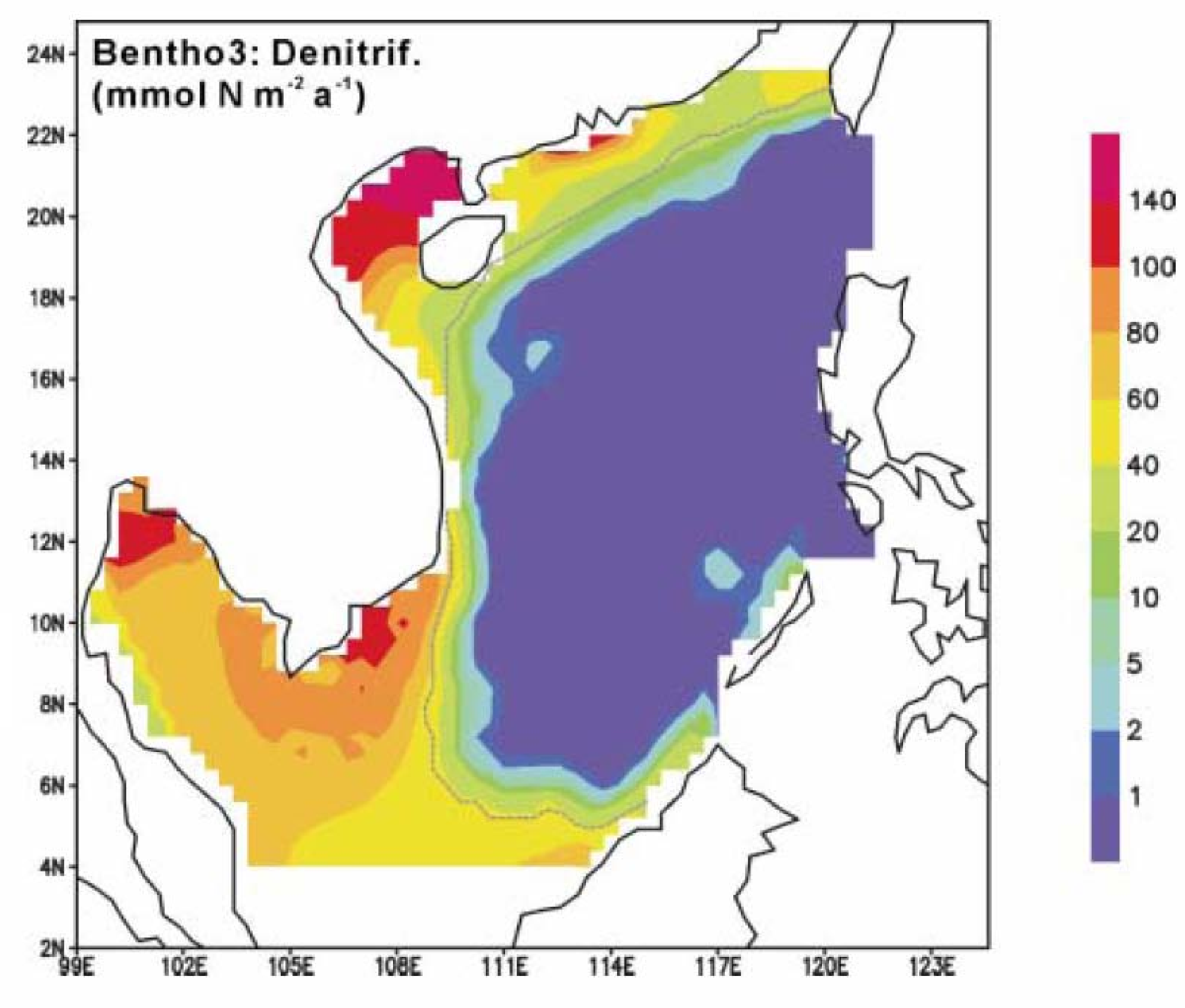
PP: Obs. vs. Modeled

Shelf (z<=200 m)

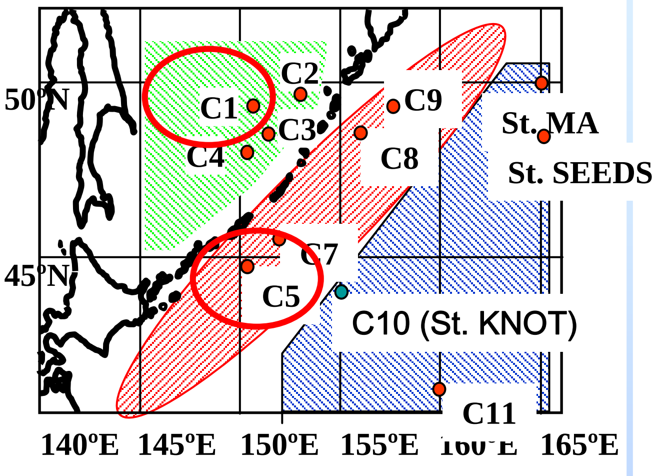


Modeled denitri-fication flux

100 mmol N m^{-2} a^{-1} = 8 g C m^{-2} a^{-1}



Source of iron in the intermediate water

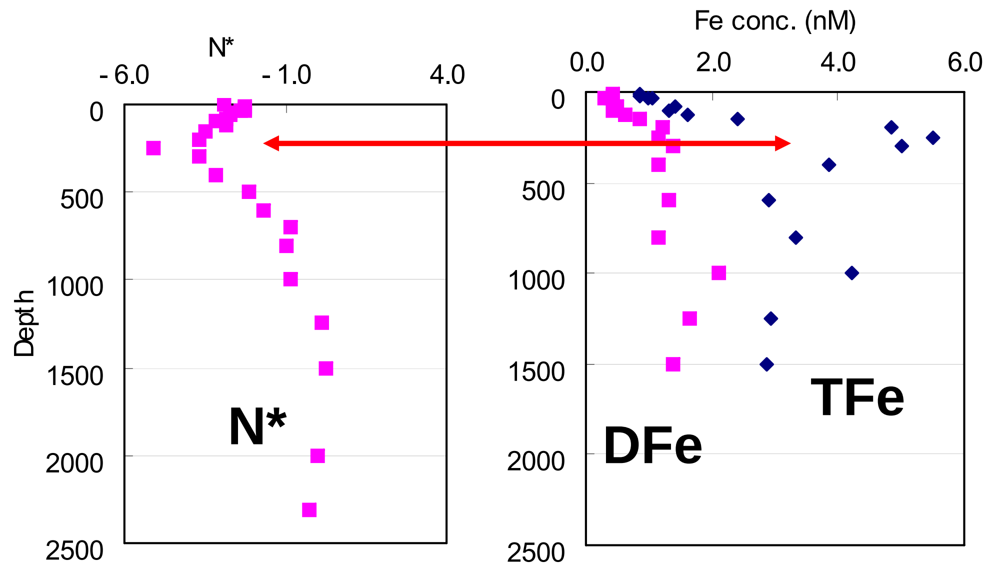


DSW,OSIW:
low N* value, due to benthic denitrification in shelf region （Yoshikawa et al., 2006)

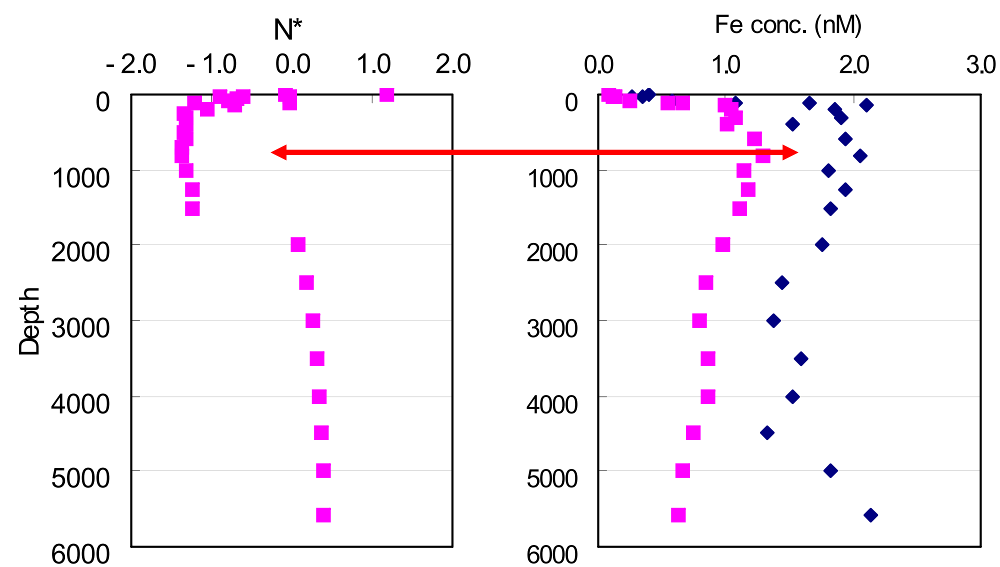
Courtesy of Nishioka et al.

Oct 19, 2006
Yokohama

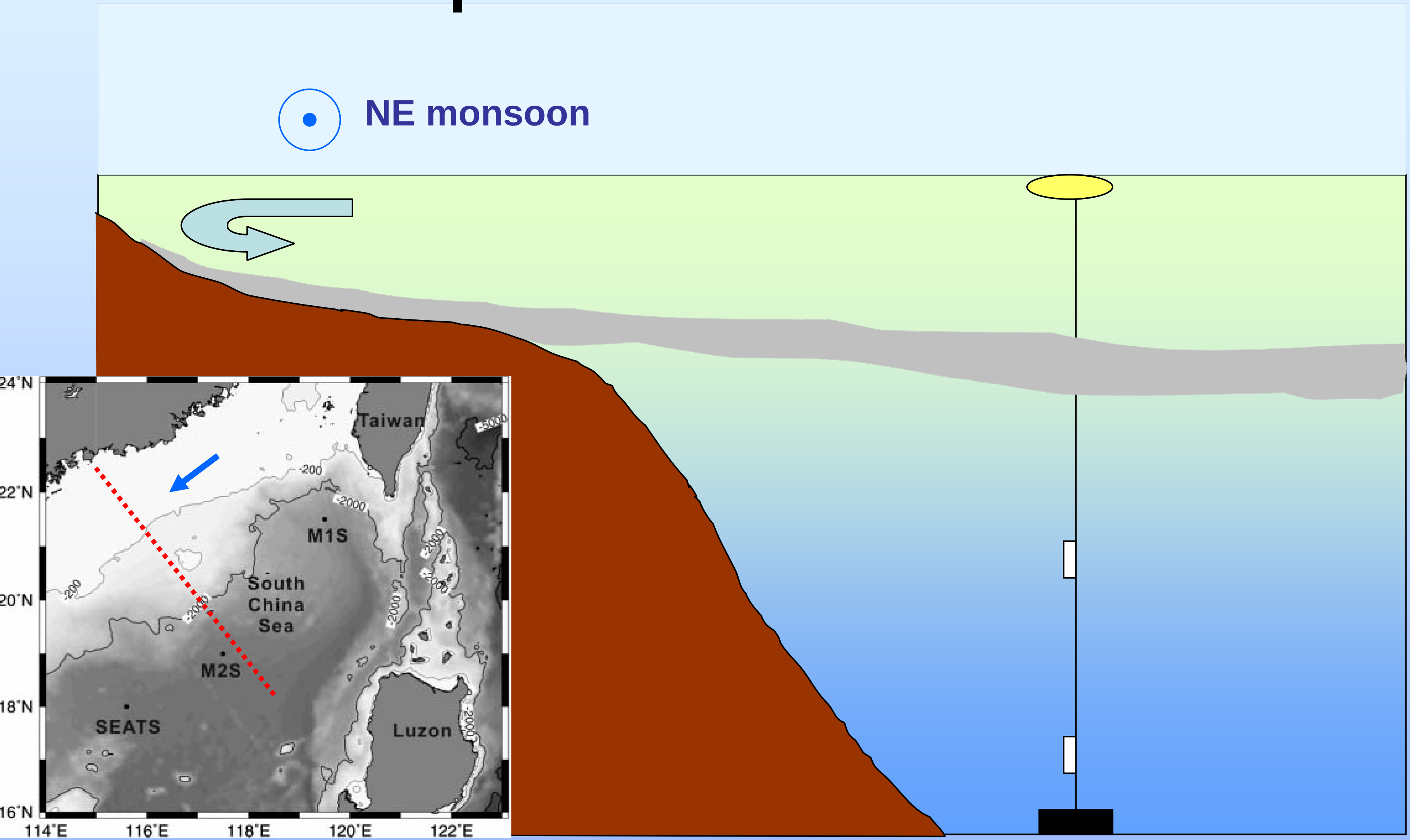
Sea of Okhotsk (C1)



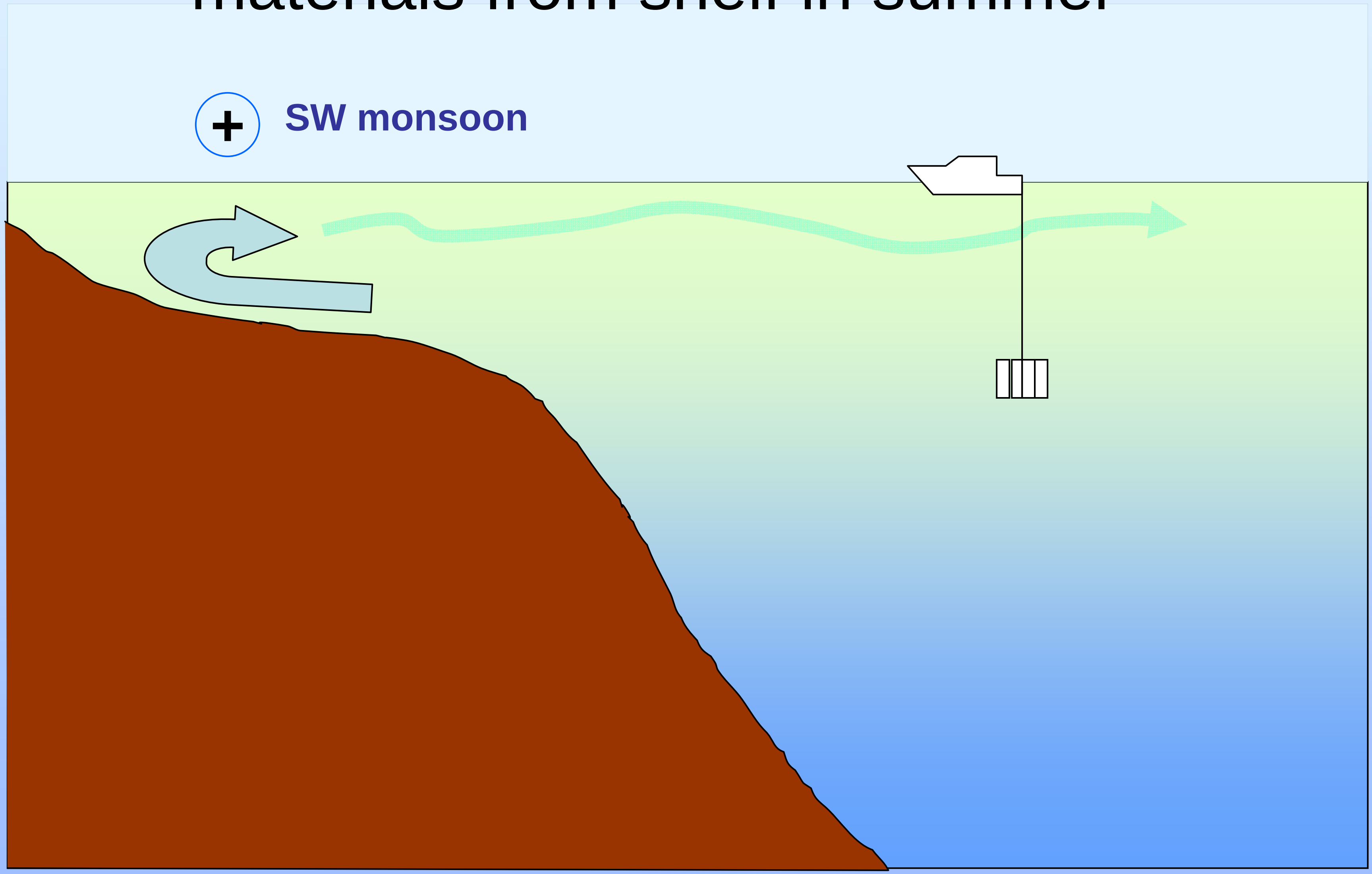
Oyashio region (C5)



SCS: Seaward transport of suspended particles in winter



SCS: Seaward dispersion of dissolved materials from shelf in summer



Conclusions-1

- **Photo-acclimation is critical to phytoplankton growth, especially for the development of the subsurface chlorophyll maximum.**
- **Without photo-acclimation, the model would underestimate PP by 43% in the SCS proper.**
- **Benthic nutrient regeneration is critical to the build-up of the nutrient reserve in the shelf, which serves as a nutrient source for the open sea.**
- **Without benthic nutrient regeneration the model would underestimate primary production by 13% in the SCS proper and 50% in the shelf region.**

Conclusions-2