Variability of the phytoplankton functional types under changing winter vertical mixing in the Ulleung Basin, East Sea: A modeling study

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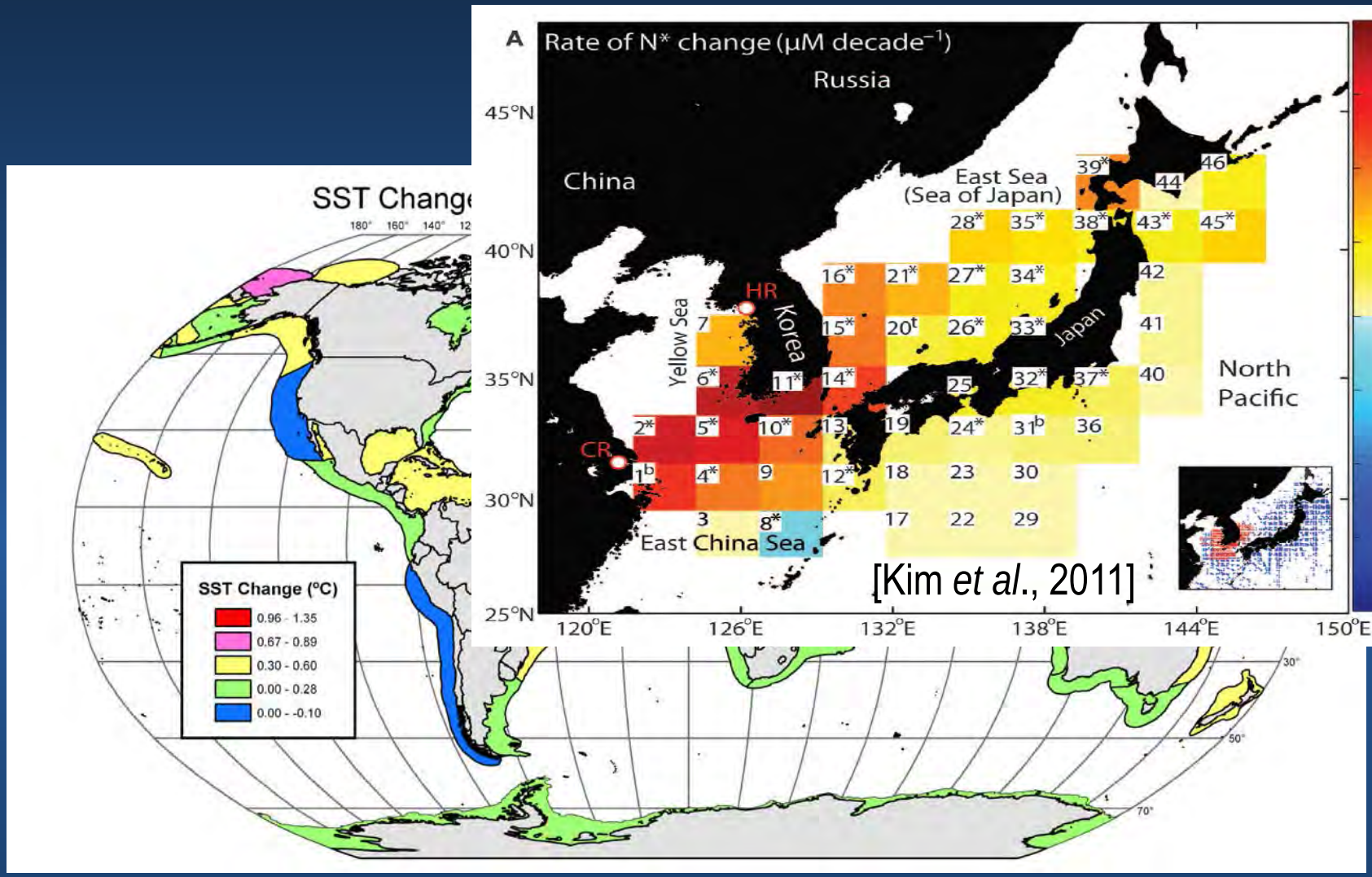

SST Change
SST Change (°C)
0.96 - 1.35
0.67 - 0.89
0.30 - 0.60
0.00 - 0.28
0.00 - -0.10
A
Rate of N* change (μM decade⁻¹)
Russia
China
East Sea
(Sea of Japan)
Yellow Sea
Korea
Japan
North
Pacific
East China Sea
HR
CR
45°N
40°N
35°N
30°N
25°N
120°E
126°E
132°E
138°E
144°E
150°E
2.0
1.5
1.0
0.5
0
-0.5
-1.0
-1.5
-2.0
[Kim et al., 2011]

Belkin (2009)

Introduction

Previous studies and objective

Vertical mixing

- Focus on the phenological response of total phytoplankton or primary production
[Yamada *et al.*, 2004; Kim *et al.*, 2007, etc.]
- Simplistic model approach: NPZD/COM9
[Onitsuka and Yasuda, 2008]

Atmospheric deposition

- Focus on the primary production
- Simplistic model approach: NPZD
[Onitsuka *et al.*, 2009]

Lack of clear understanding of the interannual variability and shifts in PFTs[a]

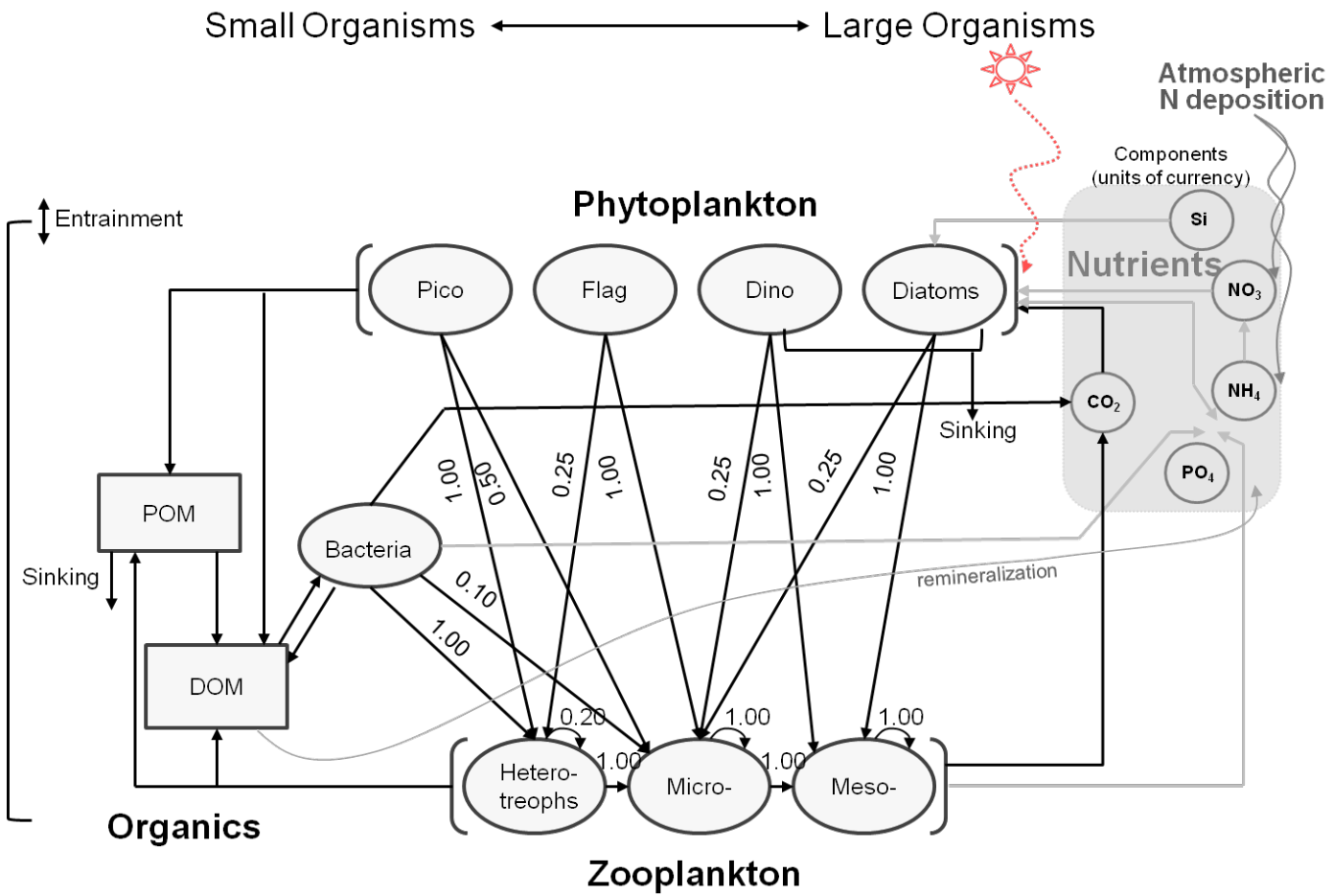
[a] Phytoplankton functional types

Objective:

to understand the role of vertical mixing and atmospheric deposition in modulating the interannual variability of PFTs using an ERSEM[b].

[b] European Regional Seas Ecosystem Model

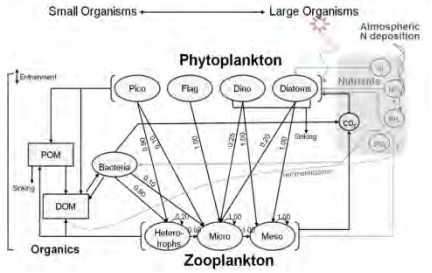
European Regional Seas Ecosystem Model (ERSEM; Blackford et al., 2004)

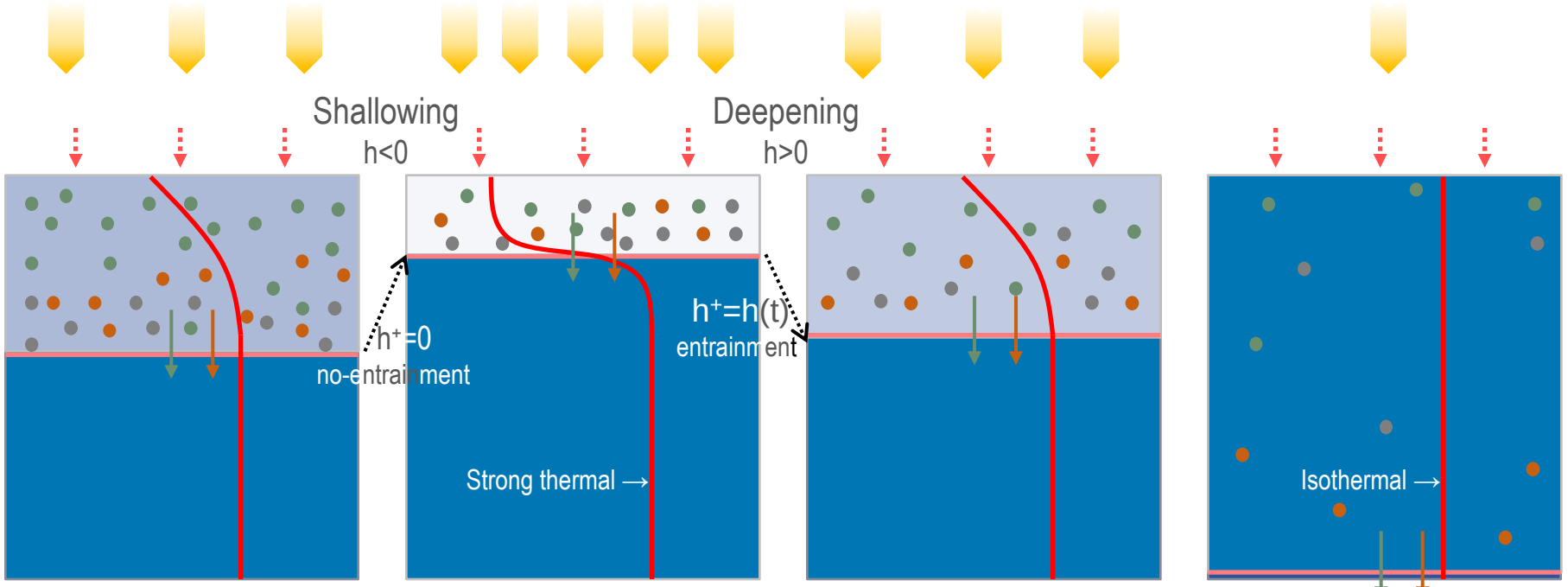


Data and Methods

Model setup

$$I_{mld} = \frac{1}{Z_{mld}} \int_0^{Z_{mld}} I_0 e^{-k_e Z_{mld}} dz$$





I_0 = Surface Irradiance

I_{mld} = Irradiance in MLD

D = Diffusion for others

k = diffusive mixing across the thermocline

Z_{mld} = MLD

$h^+(t)$ = the rate of entrainment nutrient into MLD

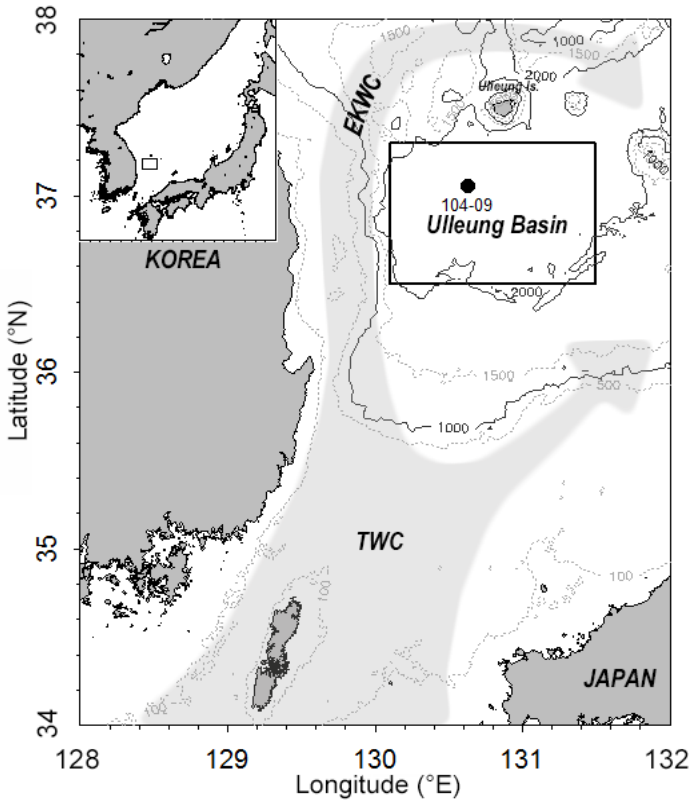
$h(t)$ = the time rate of MLD change

$$D = \frac{k + h^+(t)}{Z_{mld}}$$

$$h = \frac{dt}{dZ_{mld}} \qquad h^+(t) = max\,(h(t), 0)$$

Data and Methods

Study area and data sources



SST [sea surface temperature]
- 0~MLD average (KODC[a], bimonthly)

SSS [sea surface salinity]
- 0~MLD average (KODC, bimonthly)

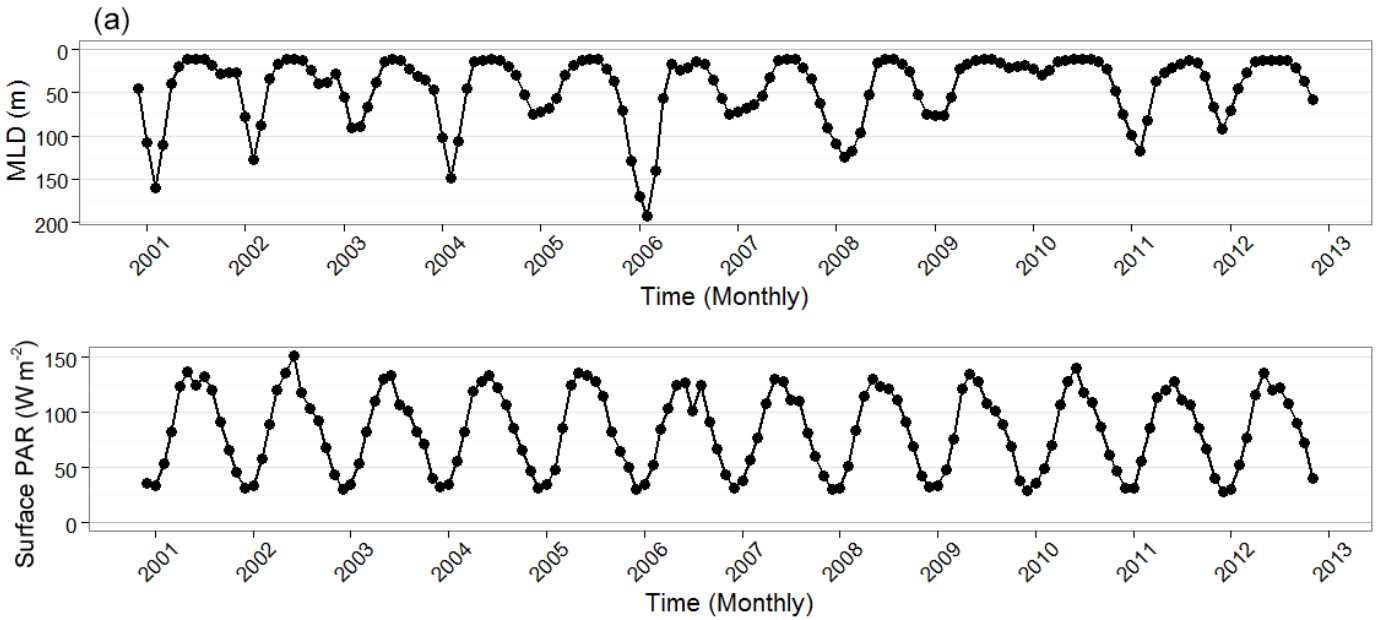
MLD [mixed layer depth]
- Density threshold method (bimonthly, Sprintall and Tomczak, 1992)
- monotone cubic interpolation

SPAR [surface photosynthetically active radiation]
- Cloud cover from KMA[b] (daily)
- Astronomical formula (Rosati and Miyakoda, 1988)

Chl [chlorophyll *a*]
- SeaWiFS & MODIS Aqua merged data[c] (Oc v6 algorithm, monthly)

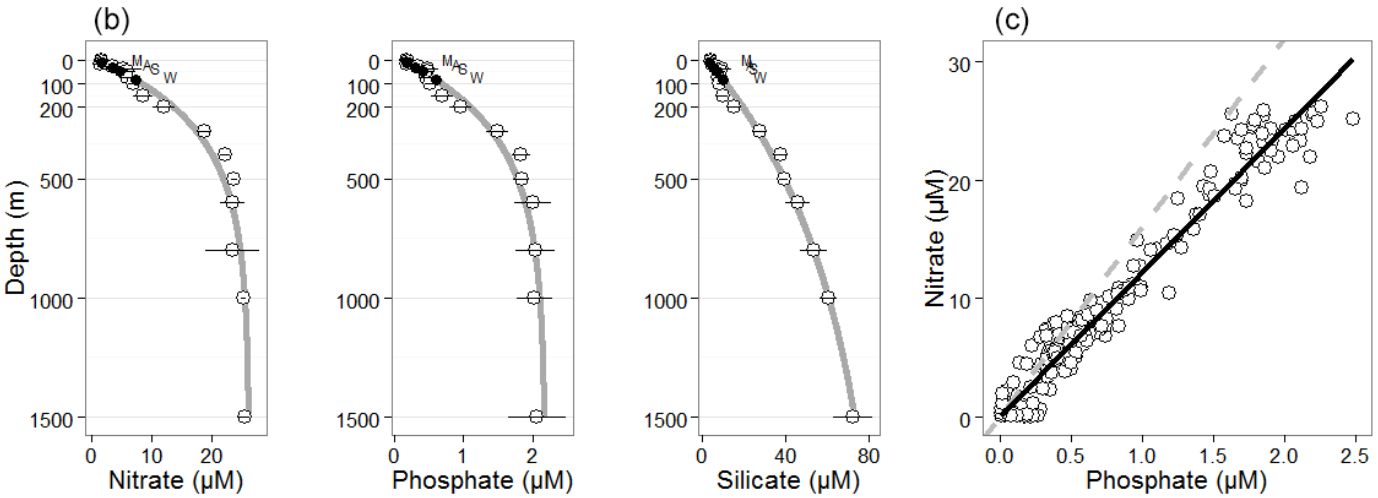
[a] Korea Ocean Data Center, 104-09 (37.057°N, 130.63°E), 2001-2012
[b] Korean Meteorological Administration, Ulleung Island (37.47°N, 130.88°E)
[c] 37.0°N, 130.6°E

Model input

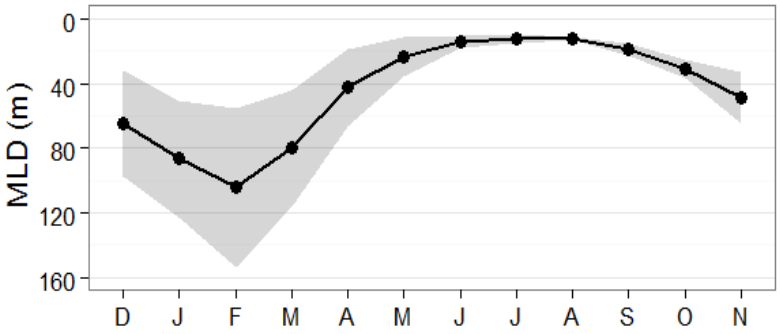


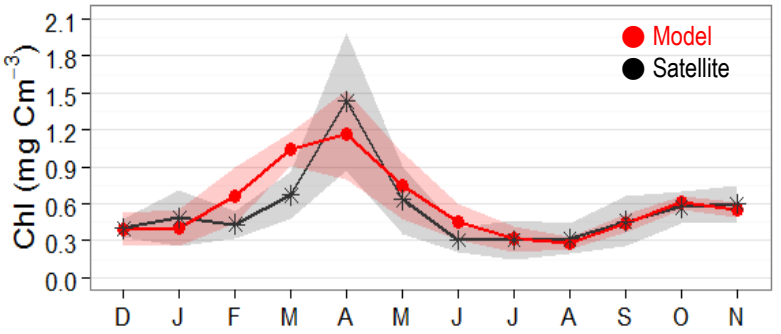
- Nurient data from KIOST[a] survey from Nov. 2000 to Jul. 2010

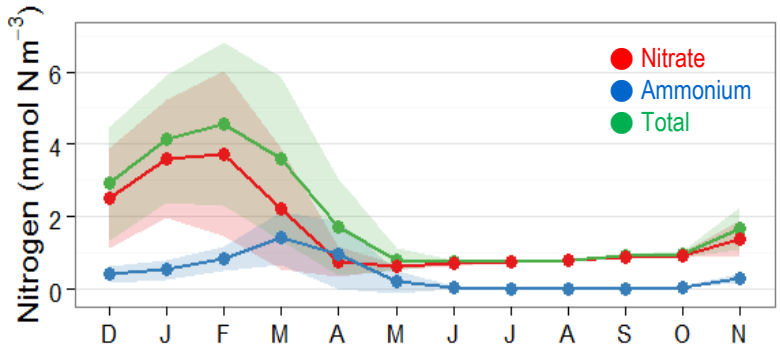
[Nov. 2000, Apr. 2001, Oct. 2001, Sep. 2002, Jul. 2005, Apr. 2006, Aug. 2007, Feb. 2008 Oct. 2008 and Jul. 2010]

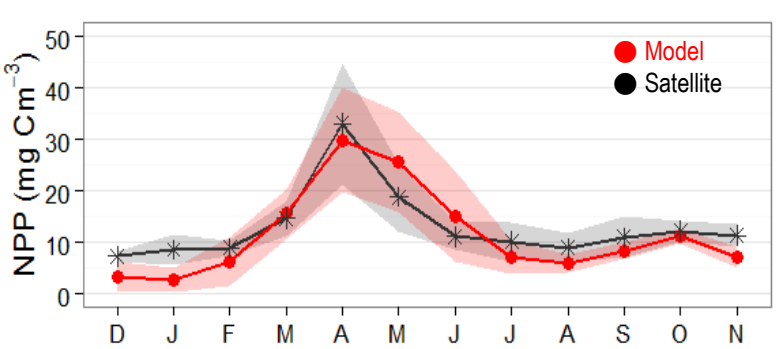


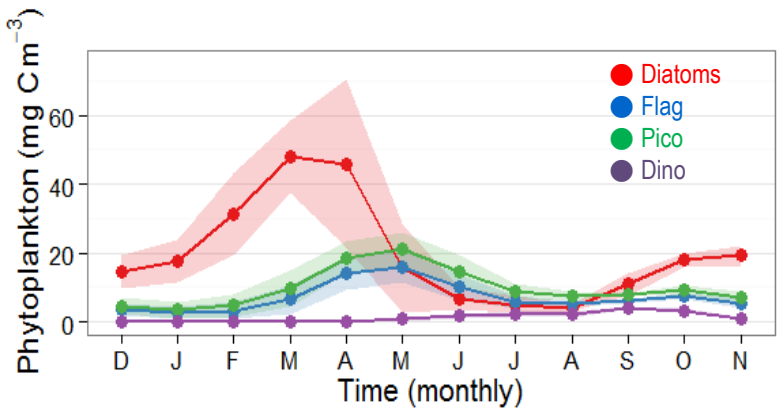
Model outputs: Seasonal cycle

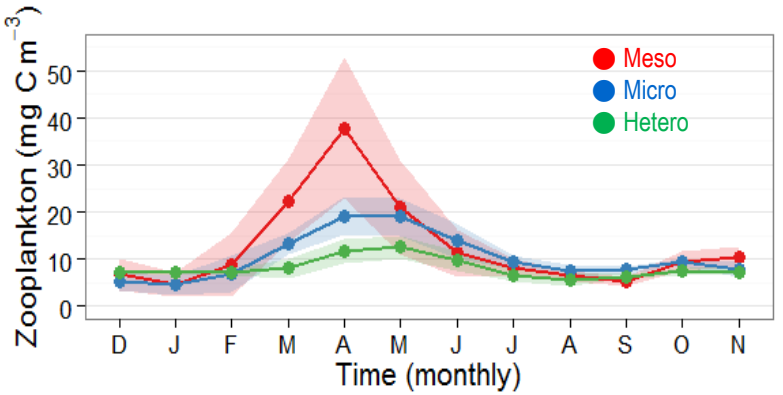




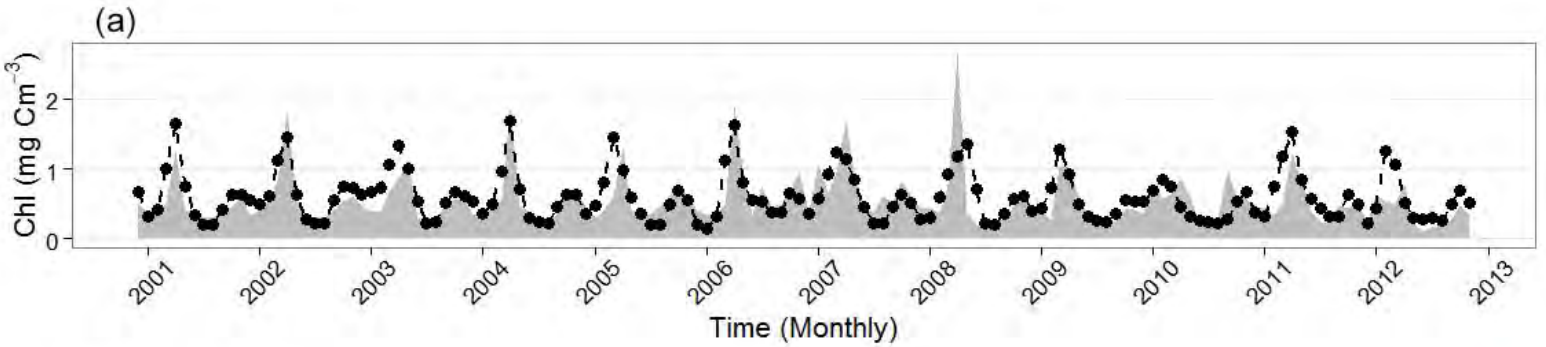


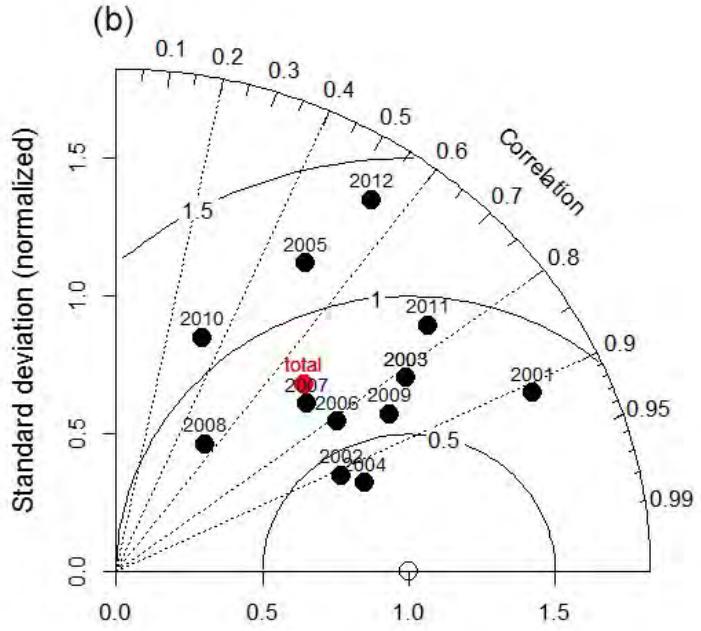


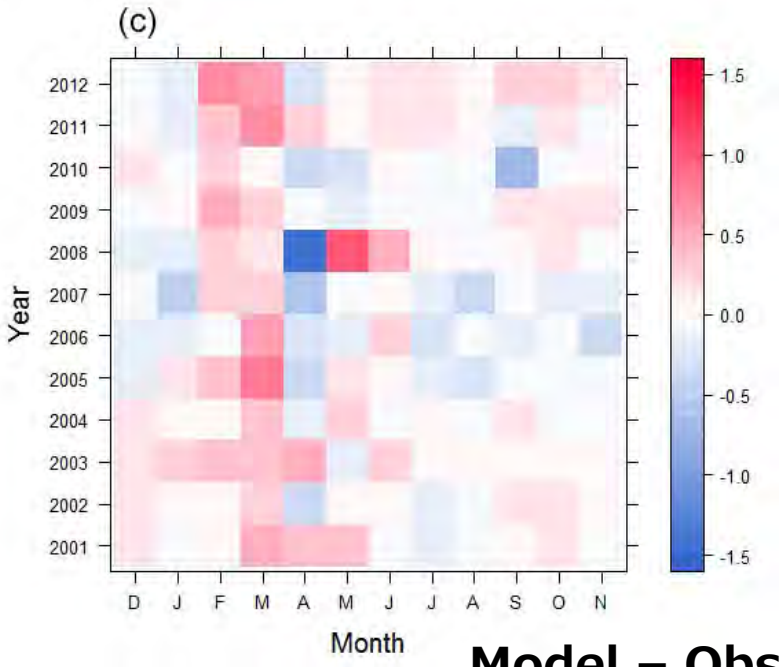




Model evaluation



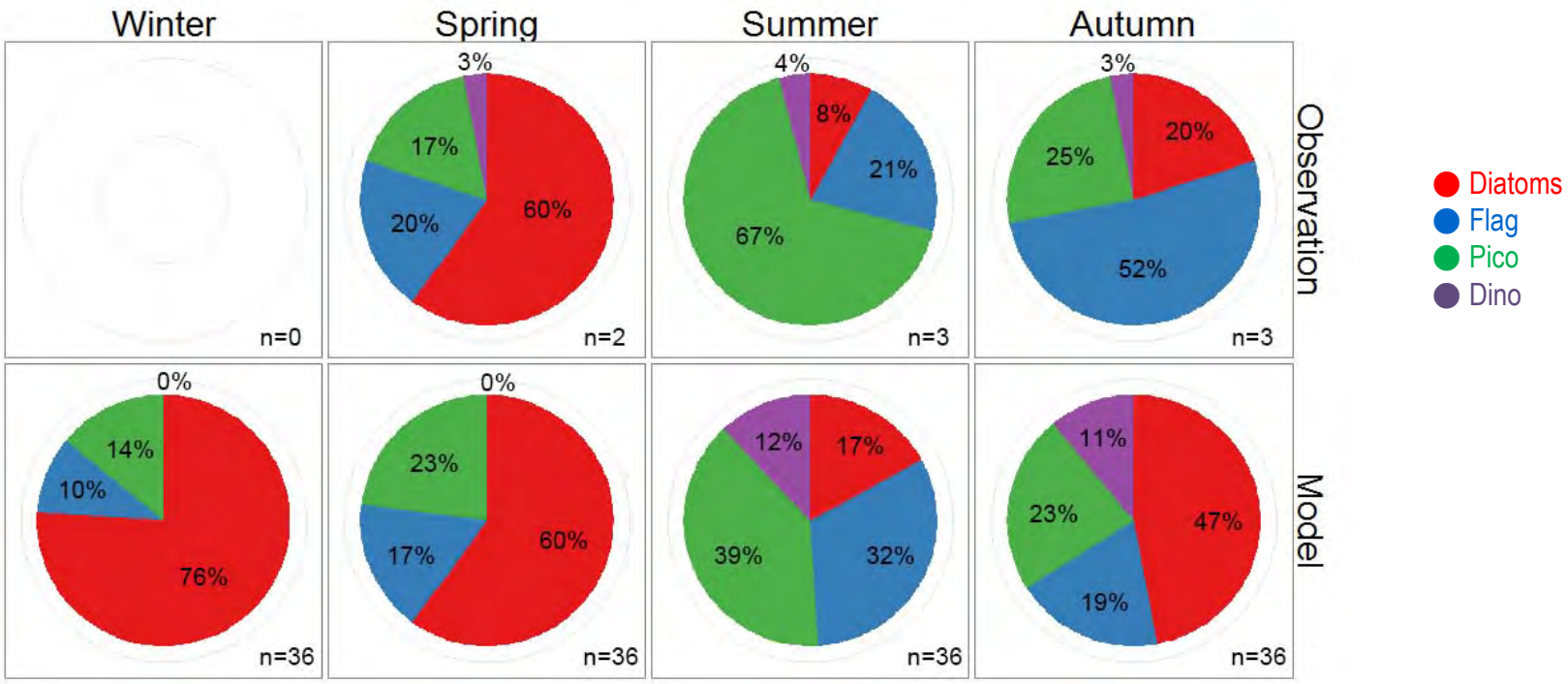




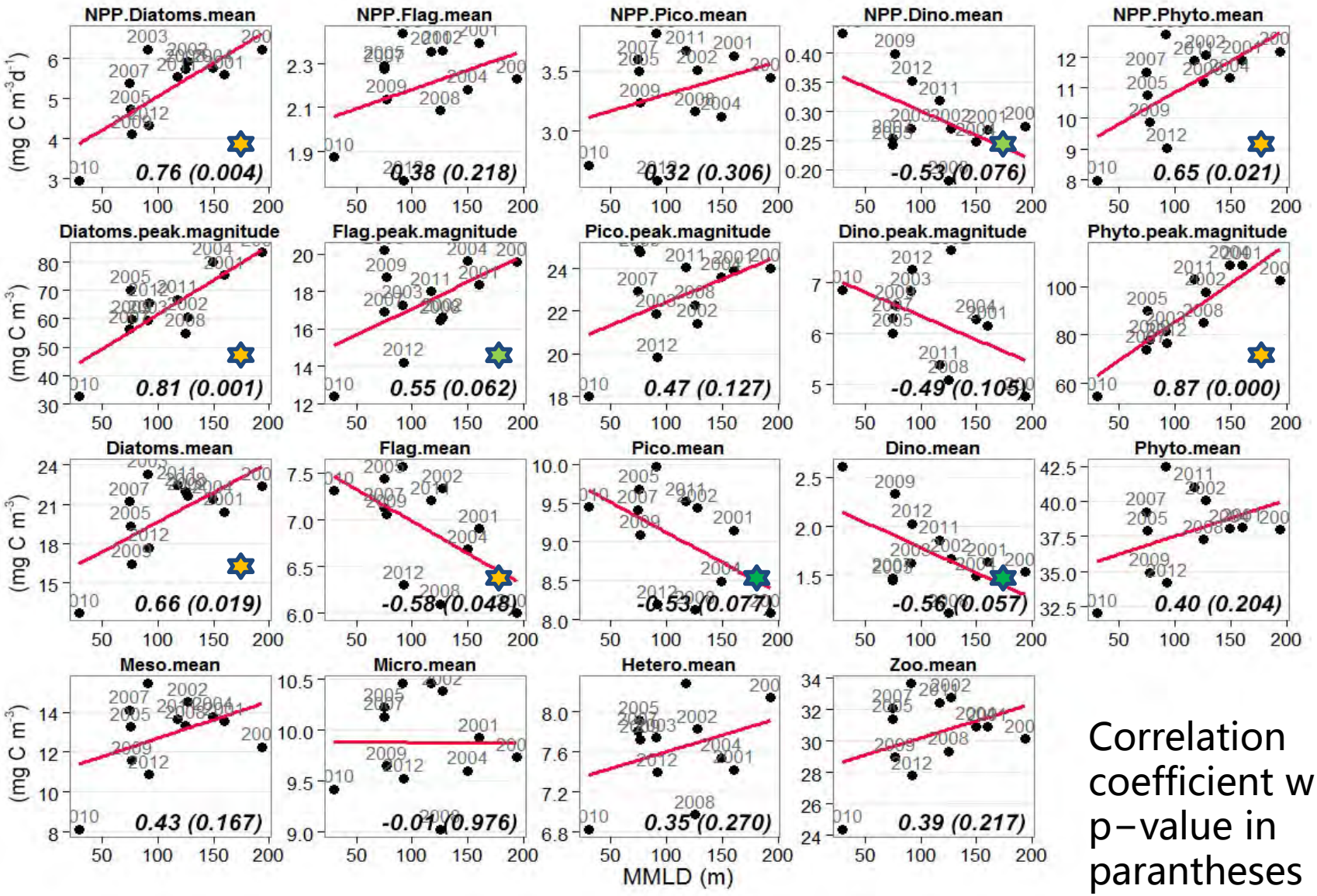
Model – Obs.

● *R*=0.69, P<0.001

Comparison of PFT composition by observation and model



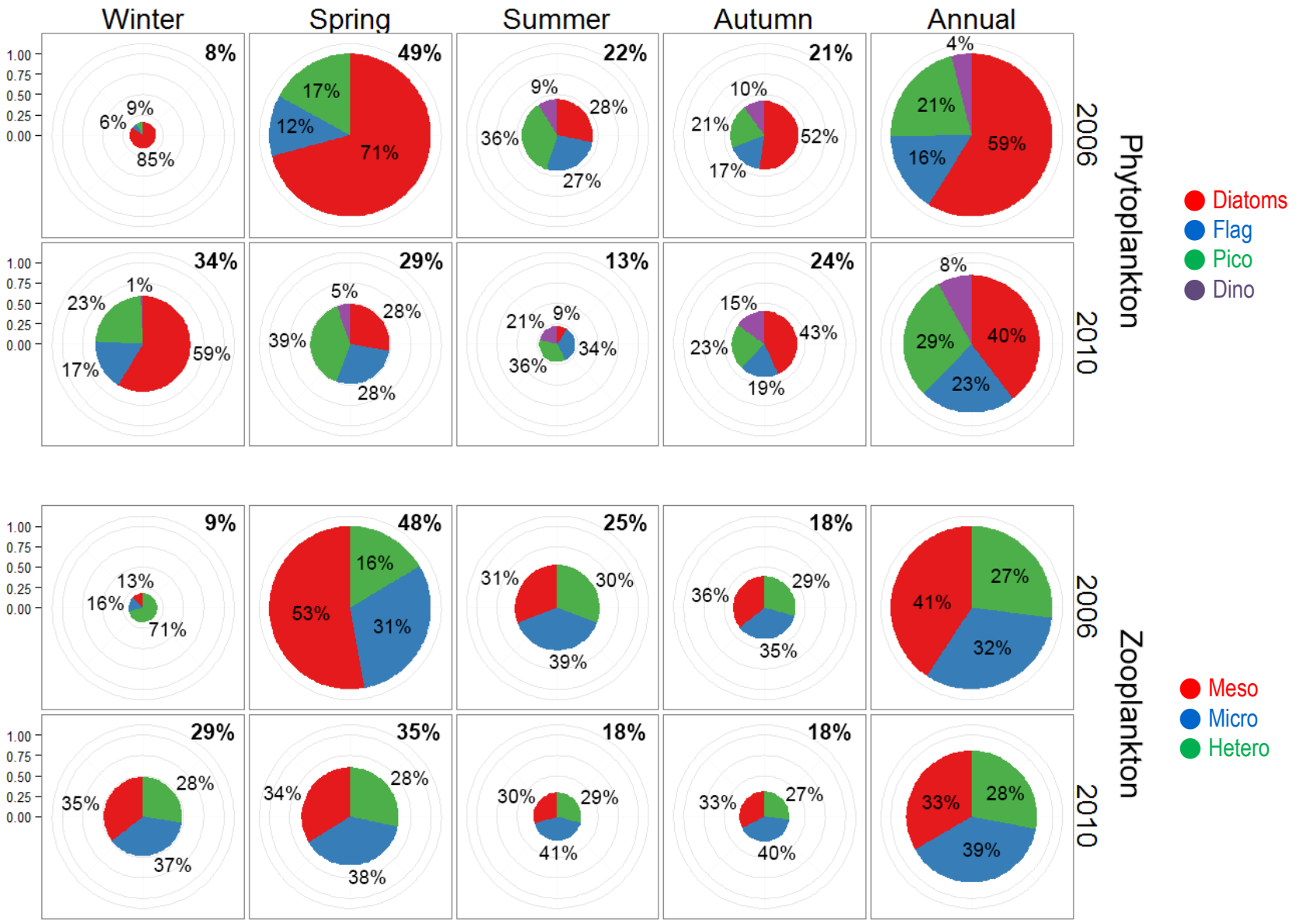
The effect of vertical mixing



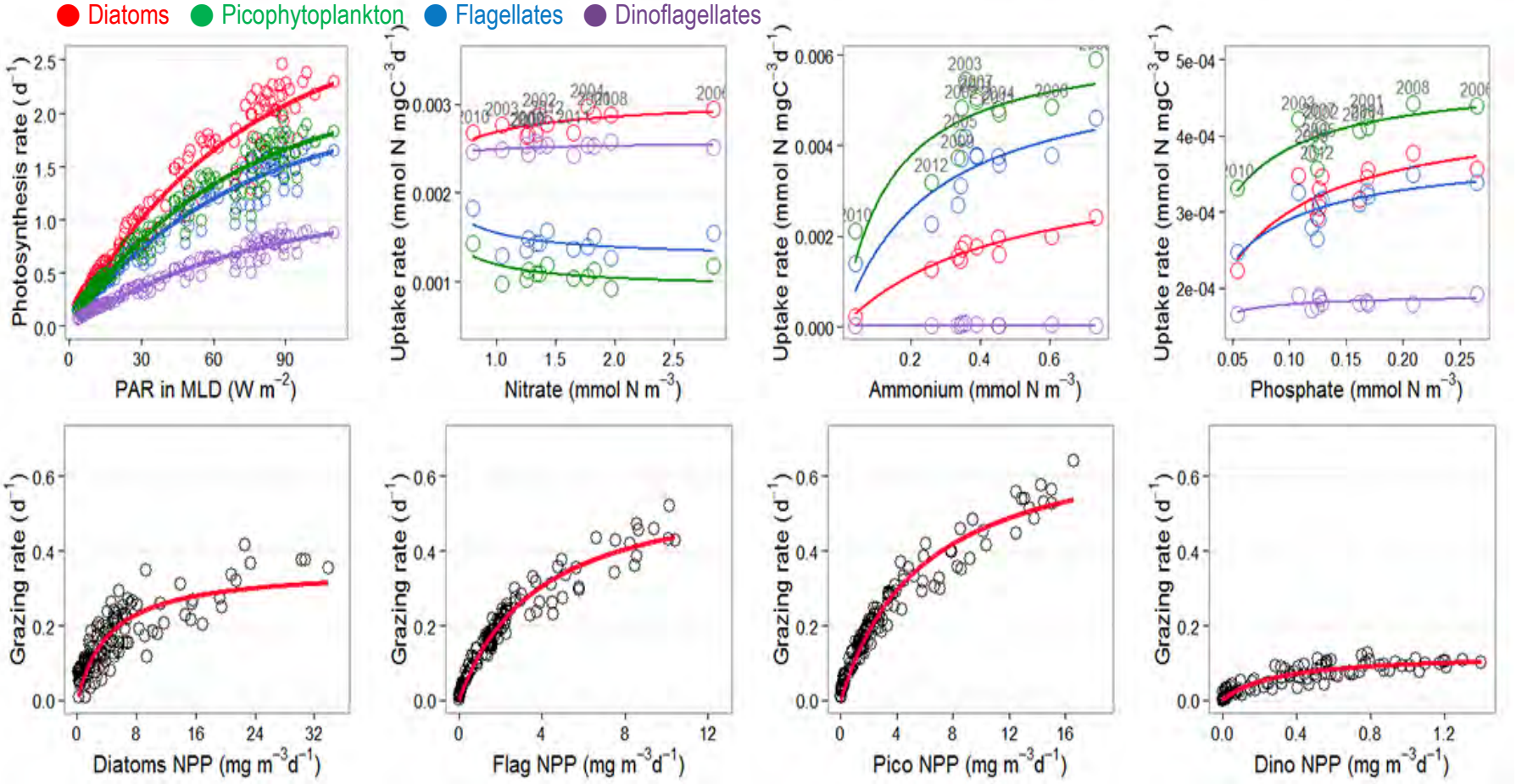
Correlation coefficient with p−value in parantheses

MMLD = Maximum MLD

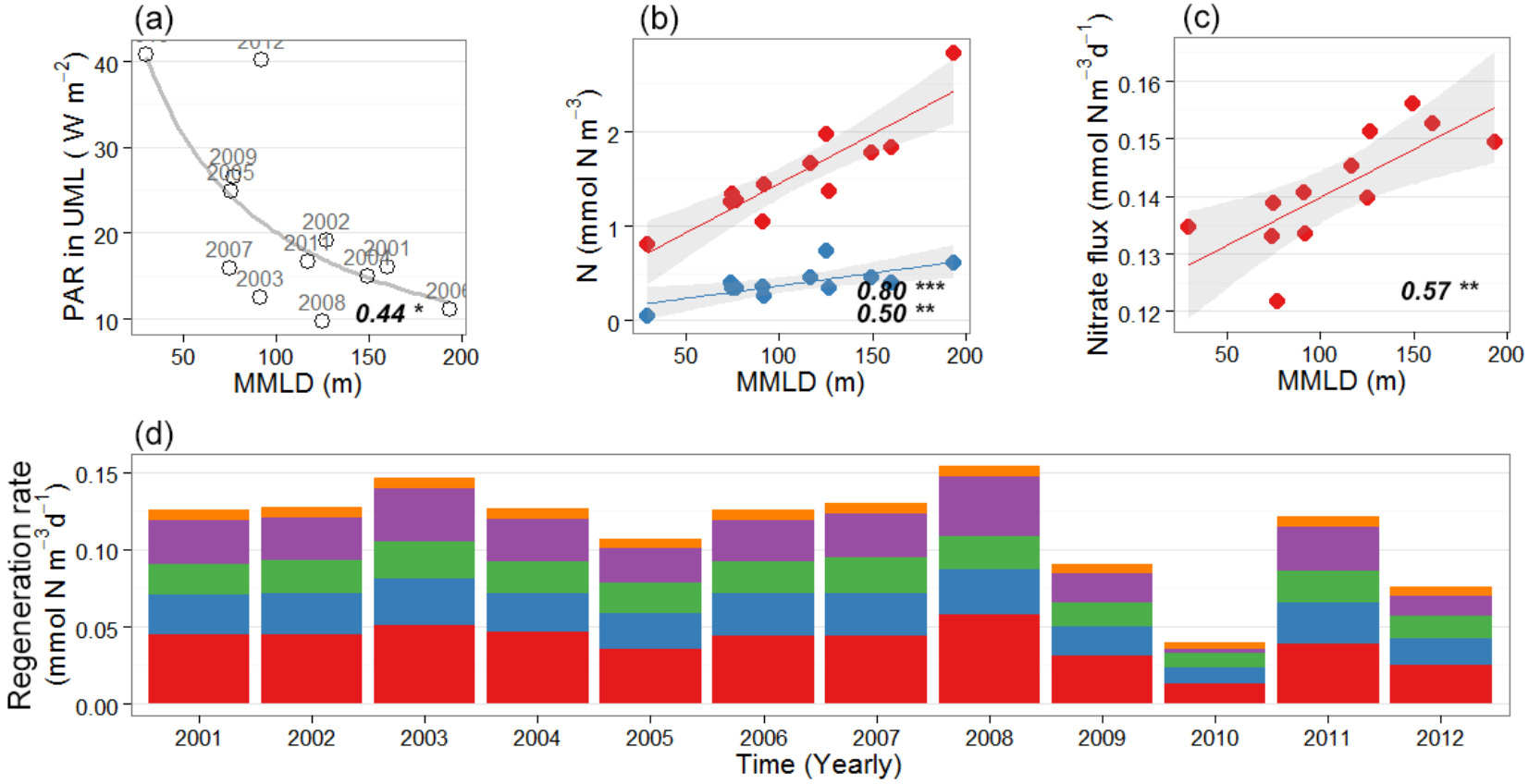
The deepest MLD : The shallowest MLD



Why do PFTs respond differently as such?



Monthly means of photosynthesis rate and annual means of nutrient uptake rates (upper panels) and monthly grazing rate of PFTs (lower panels).

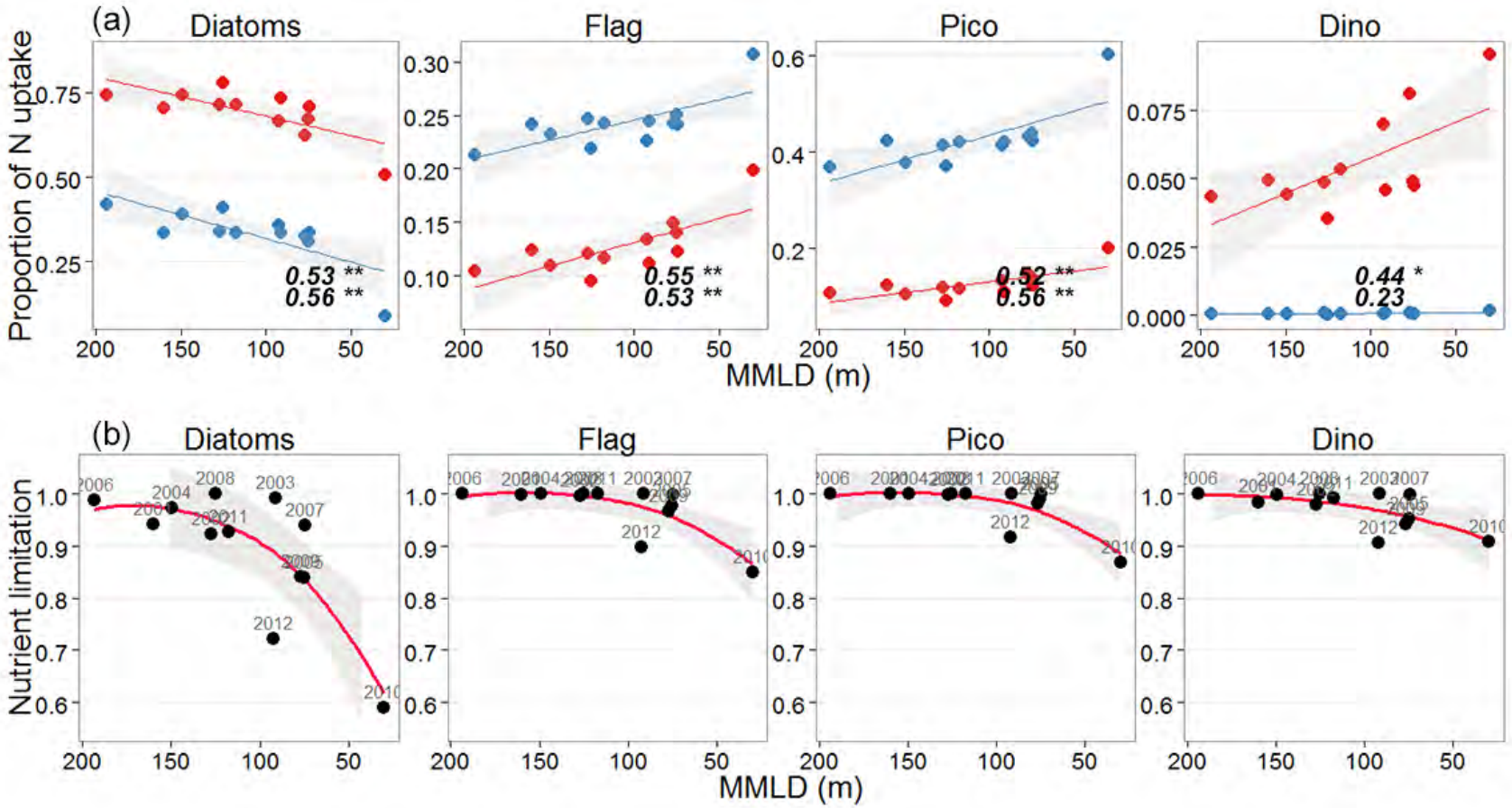


(a) Relationship between Feb-Apr mean of PAR in the upper mixed layer and MMLD,

(b) Relationship between annual mean of nitrogen concentration and MMLD (red: nitrate, blue: ammonium),

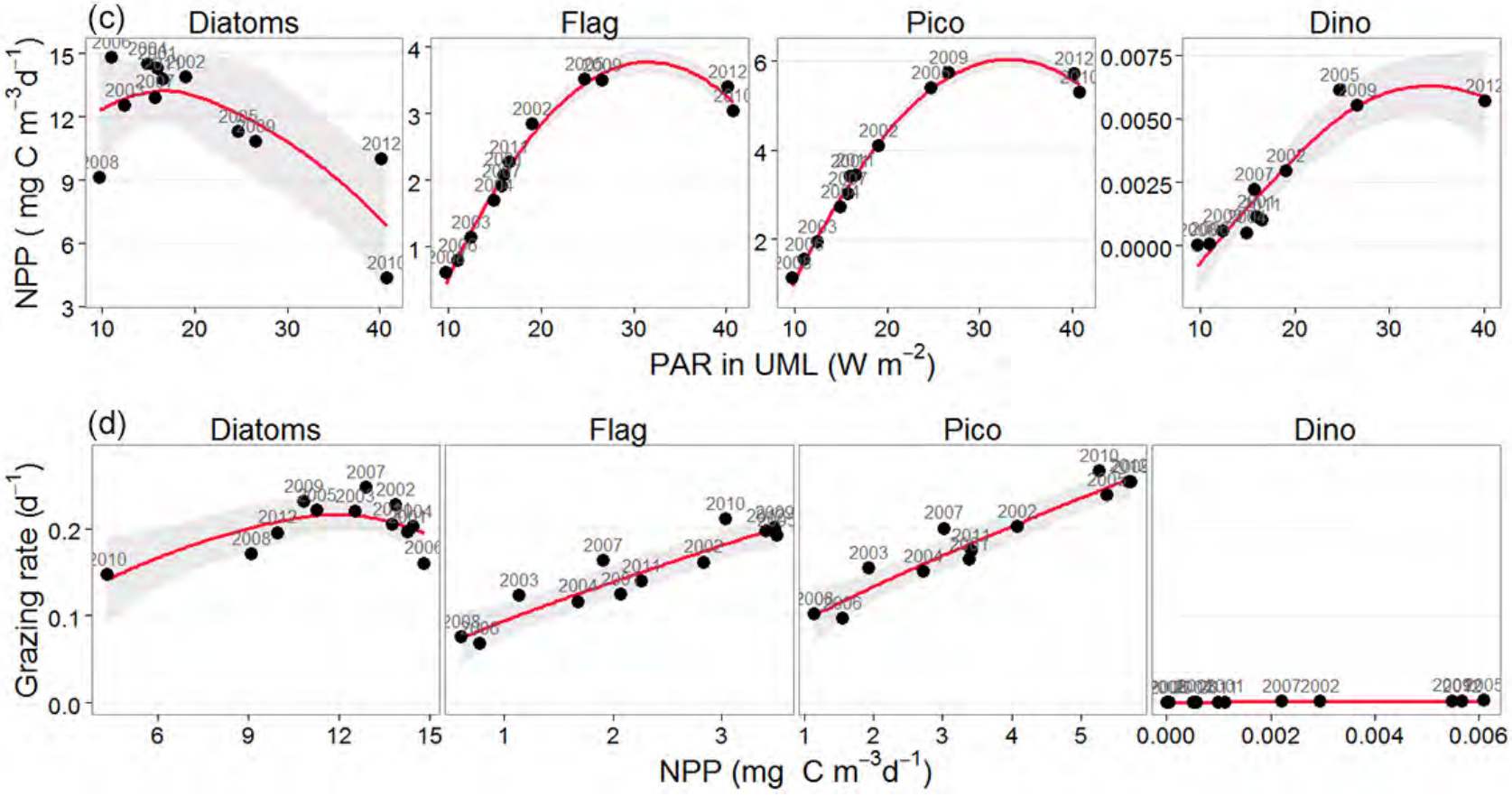
(c) Relationship between annual mean of nitrate flux and MMLD,

(d) Composition of ammonium regeneration (red: mesozooplankton excretion, blue: microzooplankton excretion, green: heterotrophic nanoflagellates excretion, violet: bacteria excretion, orange: remineralization).



(a) Relationship between annual mean proportion of nitrogen uptake (PFT/total) and MMLD.

(b) Relationship between annual means of nutrient limitation (equation (8) of Blackford *et al.*, 2004) and MMLD,



(c) Relationship between Feb-Apr means of NPP and Feb-Apr means of PAR within the upper mixed layer

(d) Relationship between Feb-Apr means of grazing rate and Feb-Apr means of NPP.

Summaries

- Diatoms preempt the early spring growth by better utilization of light and nitrate.
- Diatoms' advantages lessen as MMLD decreases.
- Flagellates and picophytoplankton show mixed responses to increased winter vertical mixing.
  - Higher NPP and peak biomass but lower annual biomass due to increased grazing
- Dinoflagellates are always doing better with shallower MLD.
- If warming continues and winter vertical mixing decreases, the total NPP will decrease although flagellate, pico-, and dinoflagellate yearly biomass will increases.

Thanks for your kind attention!

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