Understanding the mechanisms of the interannual variability of phytoplankton in the Ulleung Basin, East Sea: A modeling study

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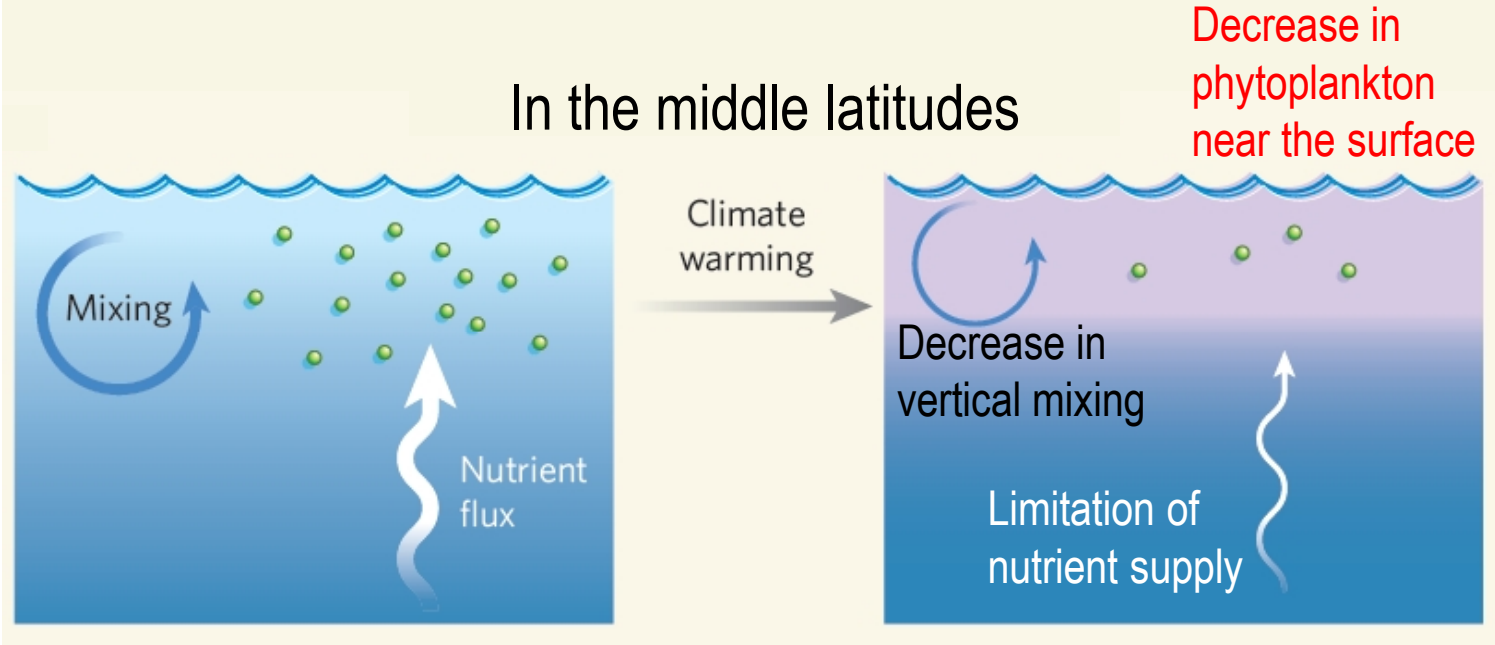
Motivations

- The major environmental changes

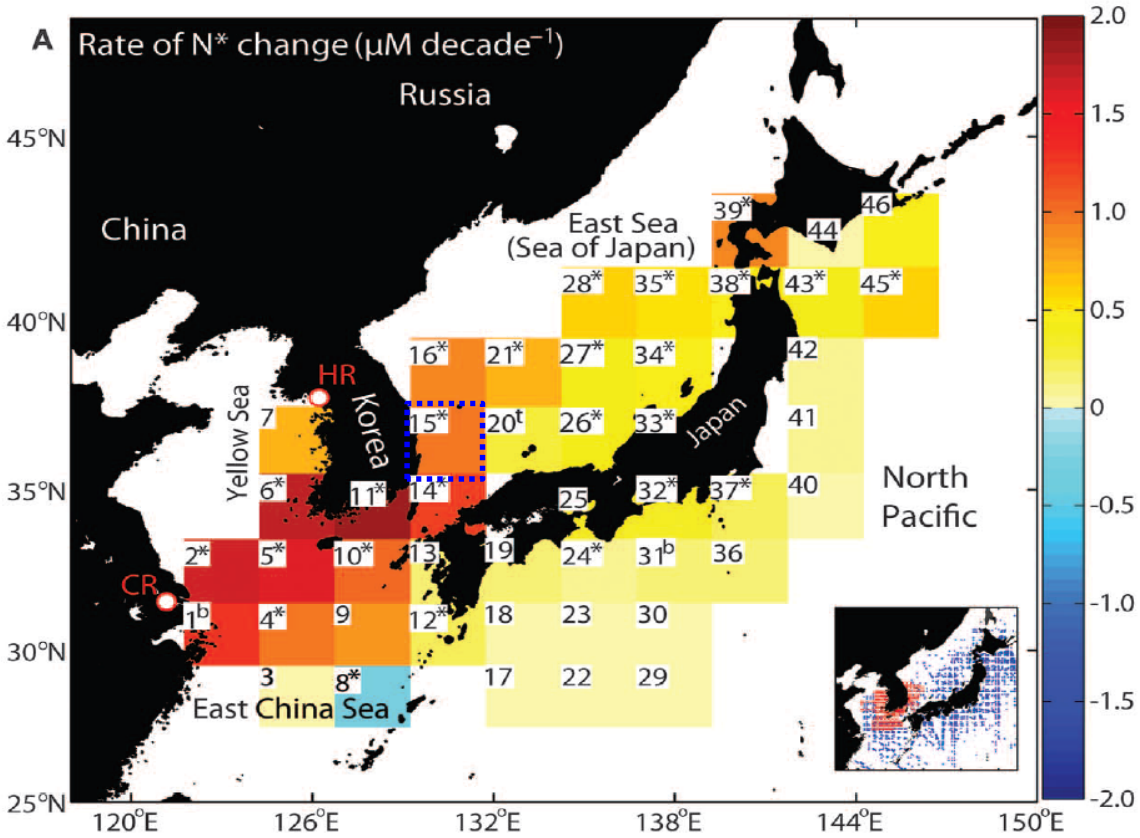


Predicted phytoplankton response to increased temperature in ocean surface waters
[Doney, nature, 2006]

Back Ground

Motivations

- The major environmental changes



Rate of N* [a] change (μM decade^{-1}) in surface waters (≤50 m)

[Kim *et al.*, nature, 2011]

→ Cause: Atmospheric N Deposition

[a] the relative abundance of N over P, $R_{N:P}$ of 13

$N^* = N - (R_{N:P}) \times P$

Back Ground

Previous studies

- Vertical mixing and atmospheric N deposition

Vertical mixing in winter

- Focus on phenological response
  [Yamada *et al.*, 2004; Kim *et al.*, 2007, etc.]

Atmospheric N deposition

- The effect on primary production
  [Onitsuka *et al.*, 2009]

→Lack of long-term observation

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

[a] Phytoplankton functional types

Objectives

1. To understand the role of vertical mixing in modulating the interannual variability of total phytoplankton

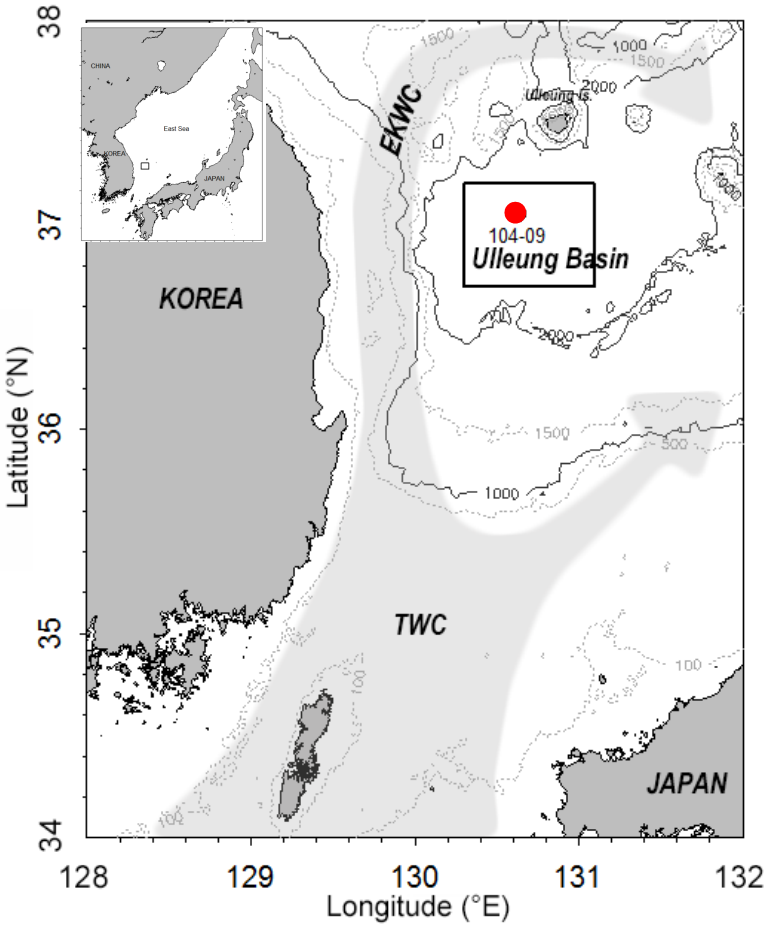
2. To examine the effect of atmospheric N deposition on PFTs[a]

→ Focus on nitrogen cycle in mixed layer

[a] Phytoplankton functional types

Data sources

Study area & data sources



TWC: Tsushima Warm Current

SST	• 0~MLD average (KODC[a], bimonthly)
SSS	• 0-~MLD average (KODC, bimonthly)
MLD	• Density threshold method (bimonthly, Sprintall and Tomczak, 1992) • monotone cubic interpolation
SPAR	• Astronomical formula (Rosati and Miyakoda, 1988) • Cloud cover from KMA[b] (daily)
Chl [c]	• SeaWiFS & MODIS Aqua merged data (Oc v6 algorithm, monthly)

[a] Korea Ocean Data Center, 104-09 (37.057°N, 130.63°E), 2001-2012

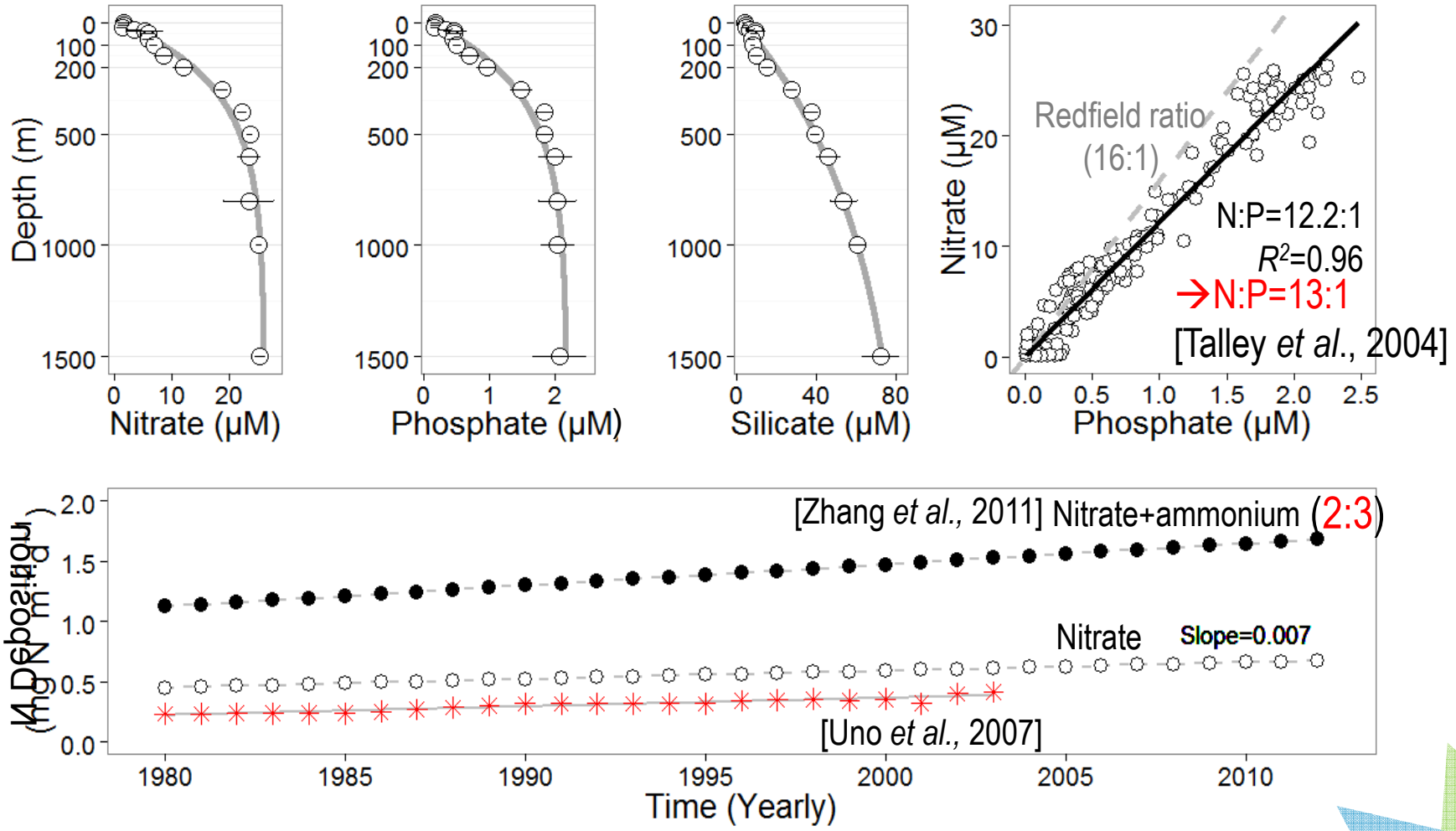
[b] Korean Meteorological Administration, Ulleung Island (37.47°N, 130.88°E)

[c] Range: 36.9-37.1°N, 130.5-131.7°E

Data sources

Nutrients input

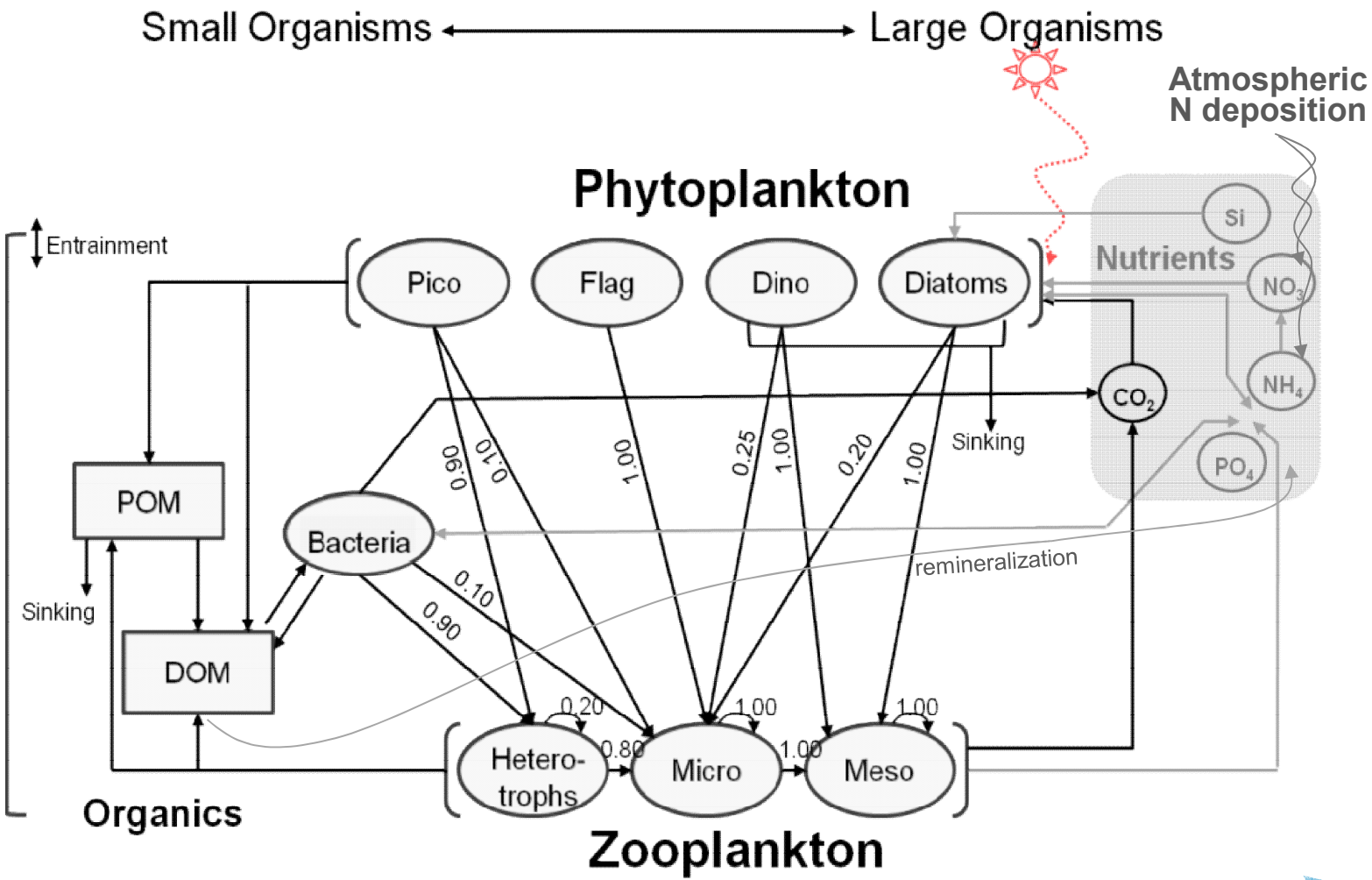
- Vertical mixing and atmospheric N deposition



Model setting

Model description

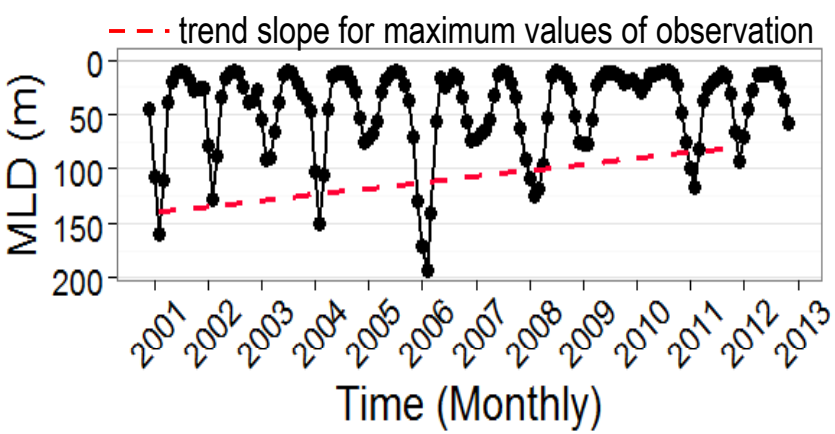
- A schematic diagram

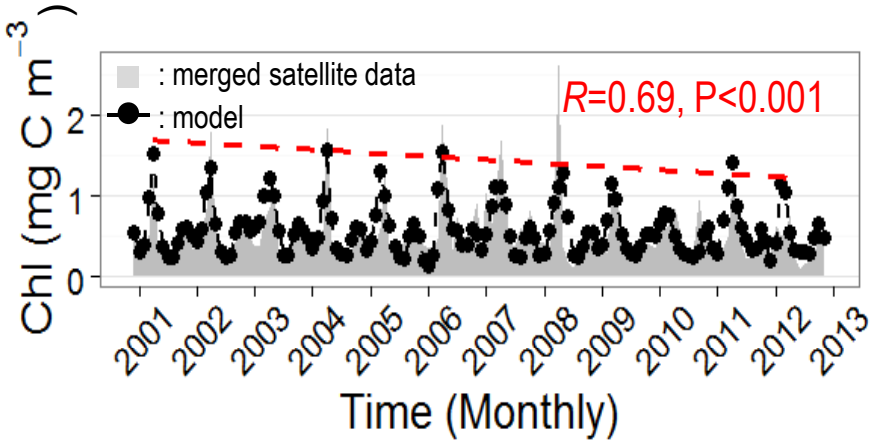


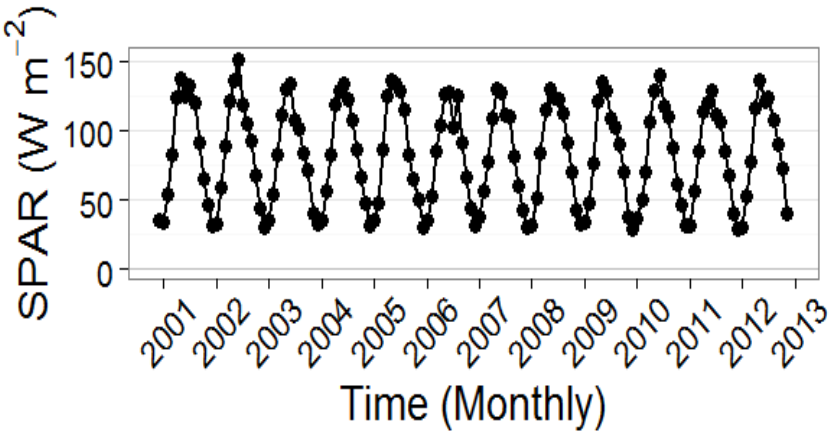
Results & Discussion

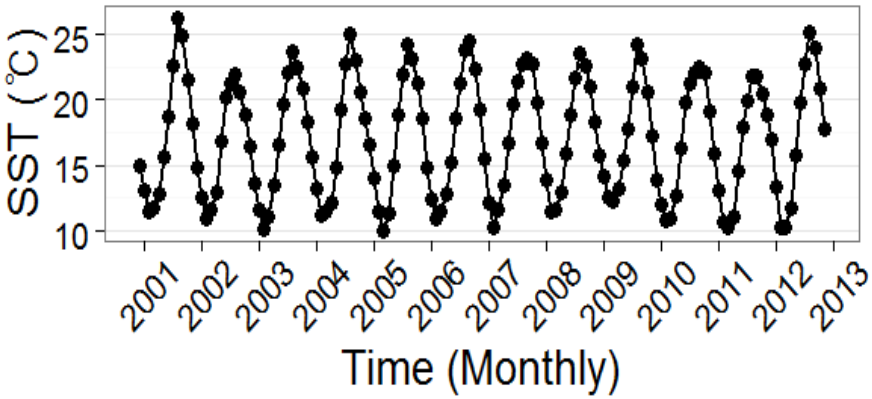
Physical forcings and Chl trends

- MLD, SST, SPAR and Chl





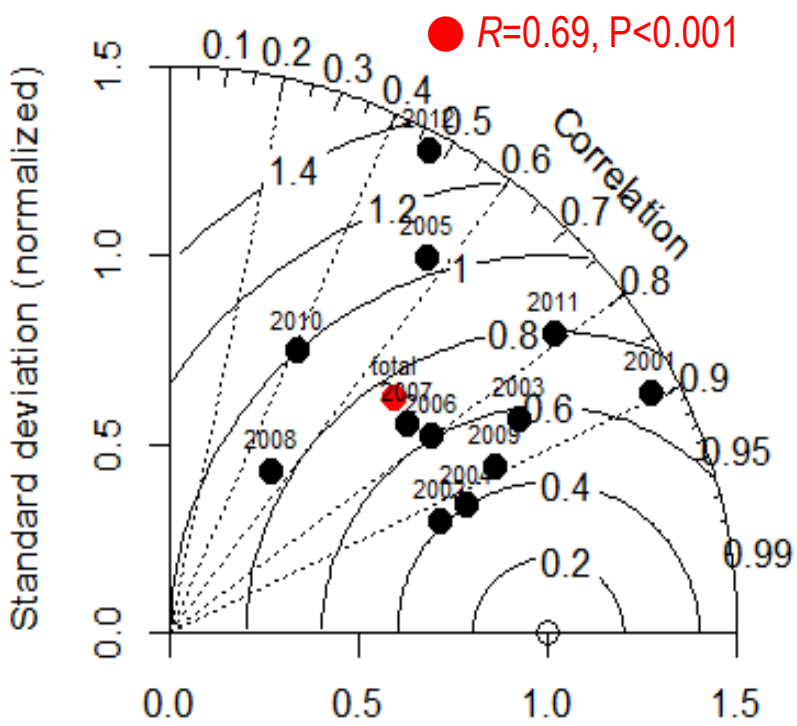




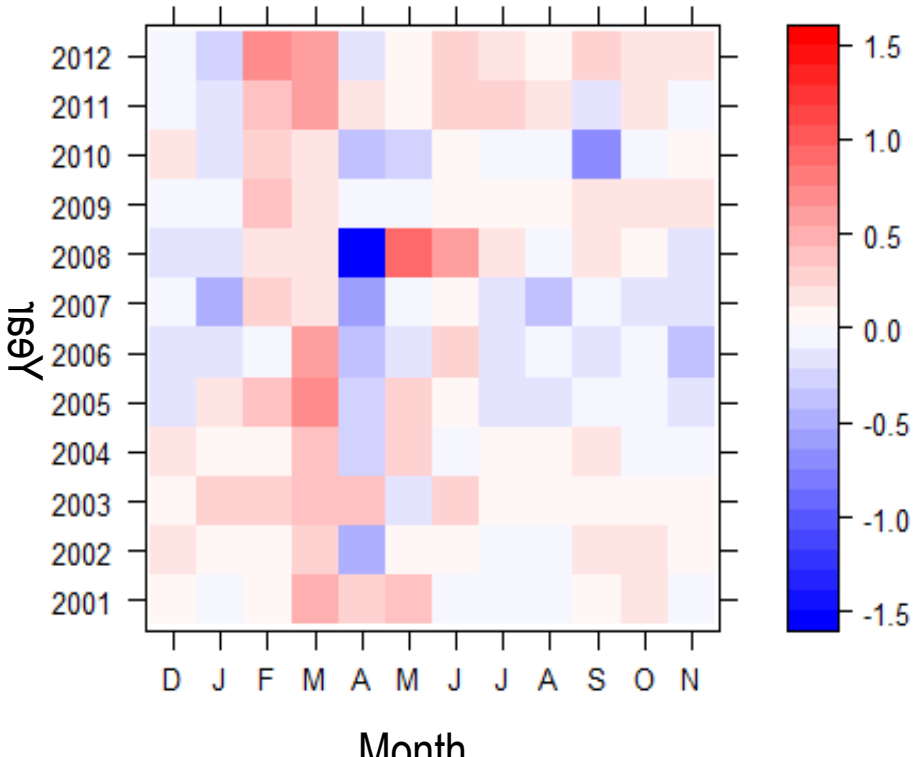
Results & Discussion

Model evaluation

- Model vs observation



Taylor diagram for evaluation

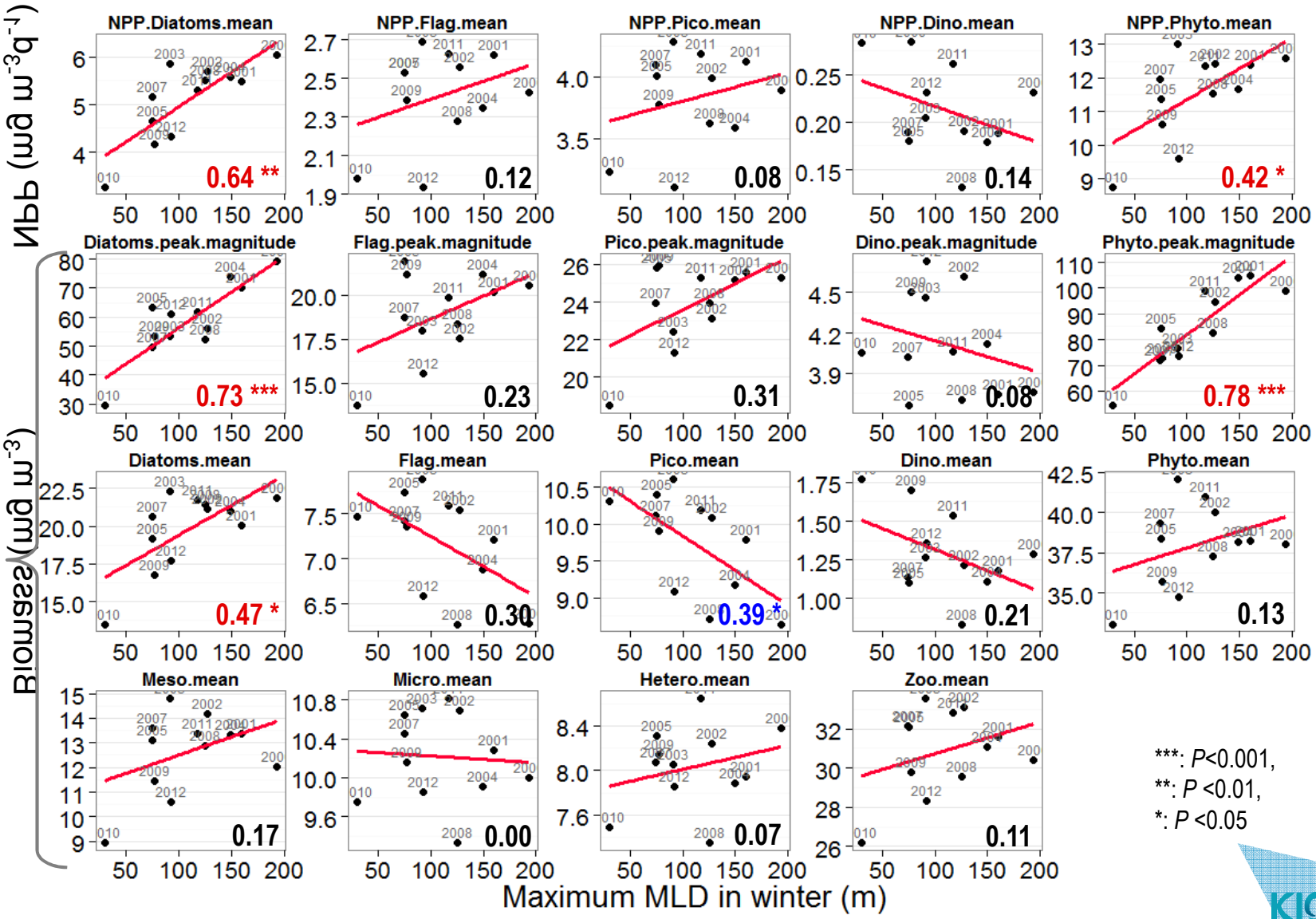


Difference (model-observation)

Results & Discussion

The effect of vertical mixing

- Relationship between variables and maximum MLD

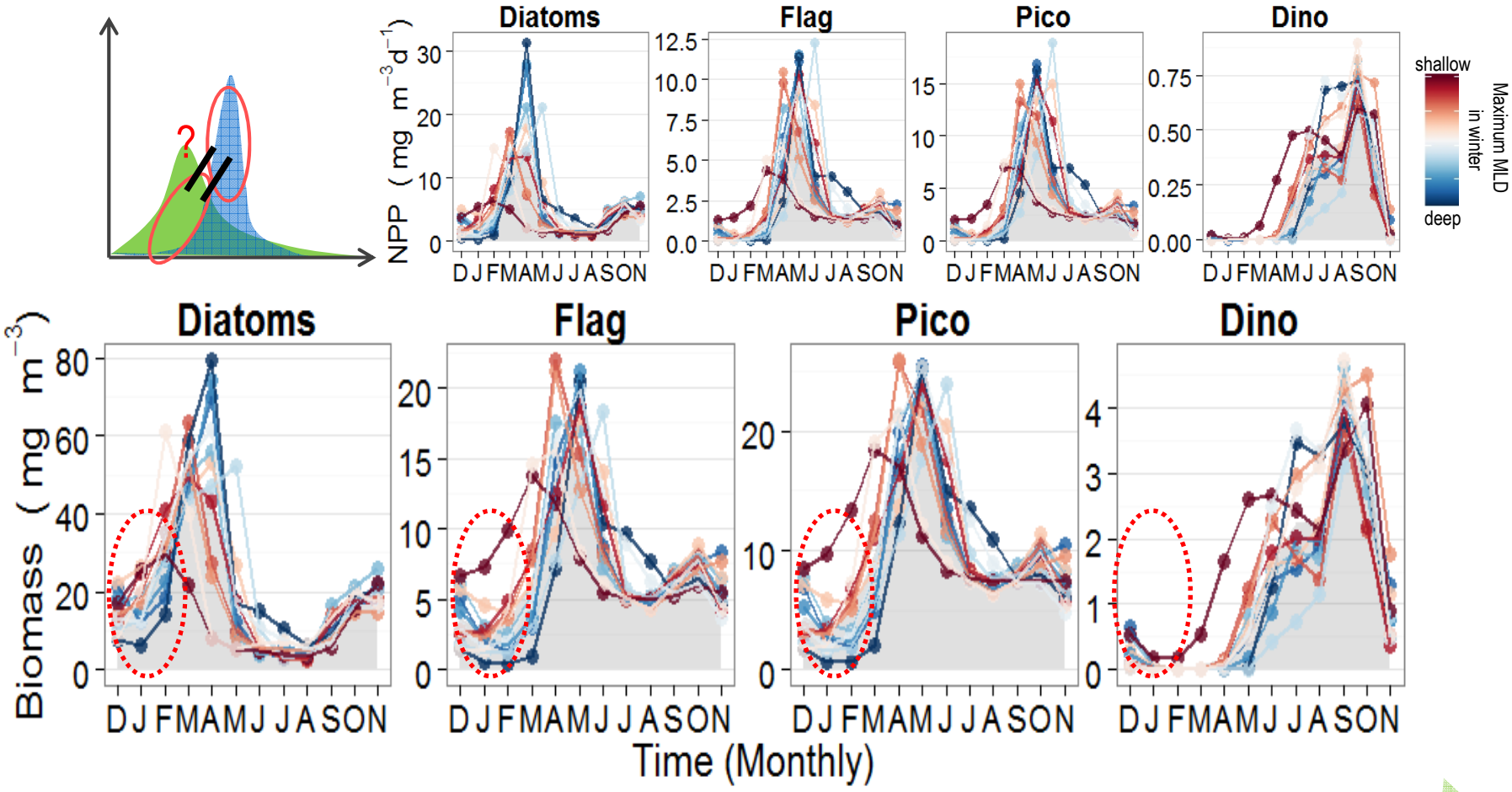


***: $P<0.001$,
**: $P<0.01$,
*: $P<0.05$

Results & Discussion

The effect of vertical mixing

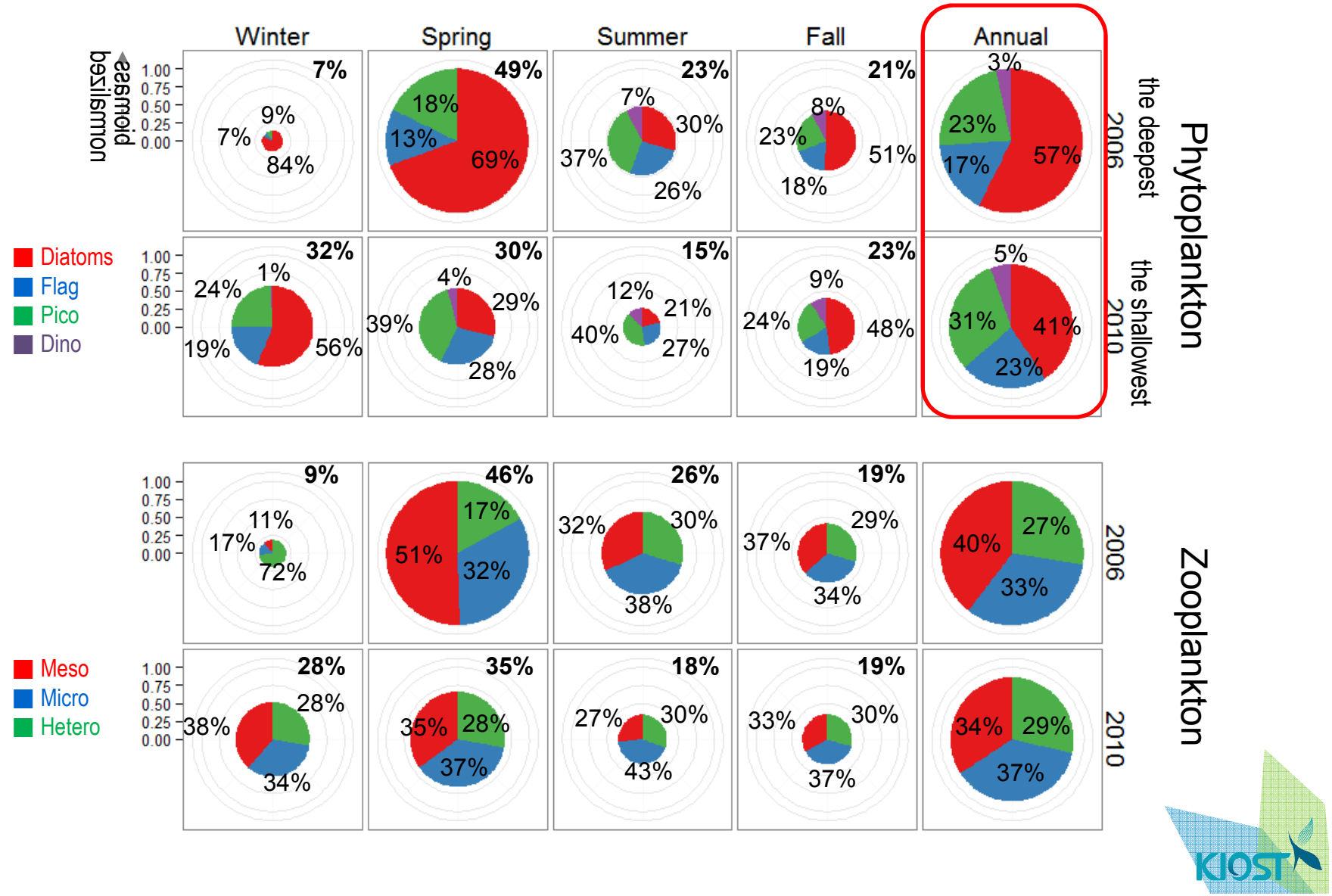
- NPP vs Biomass



Results & Discussion

The effect of vertical mixing

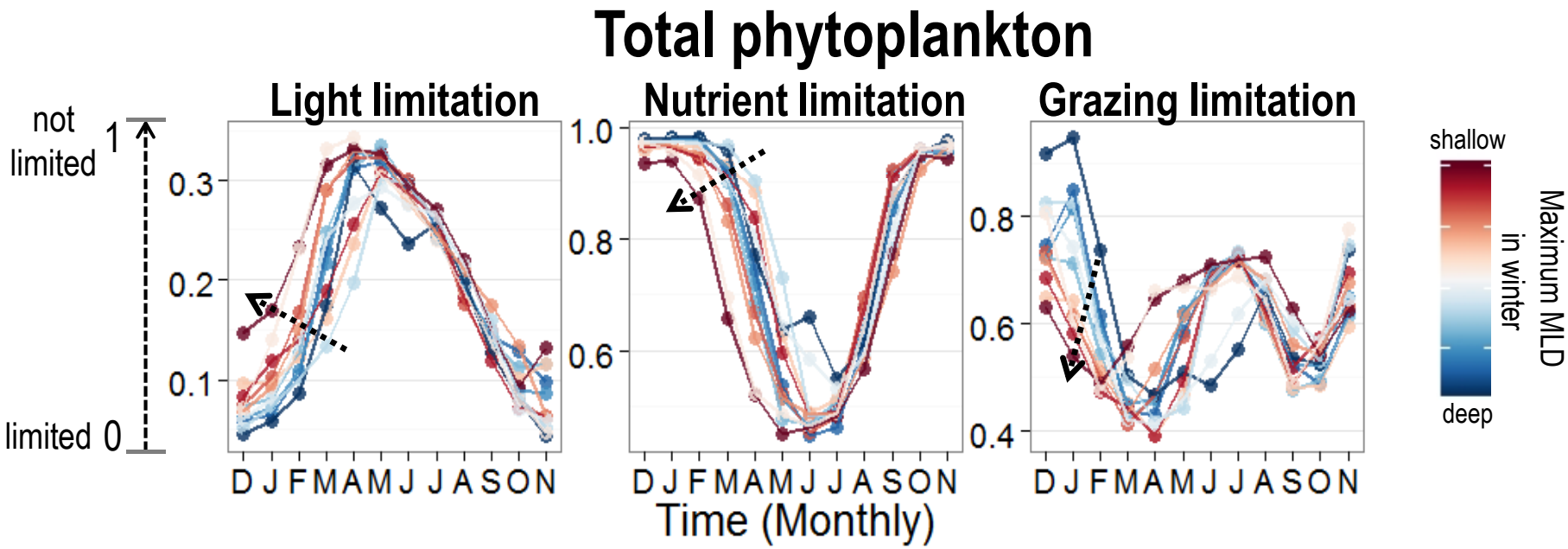
- Comparison between 2006 (the deepest MLD) and 2010 (the shallowest MLD)



Results & Discussion

The effect of vertical mixing

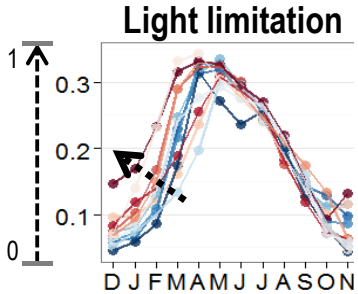
- The changes in ecological factors

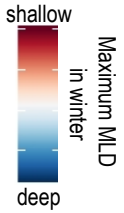


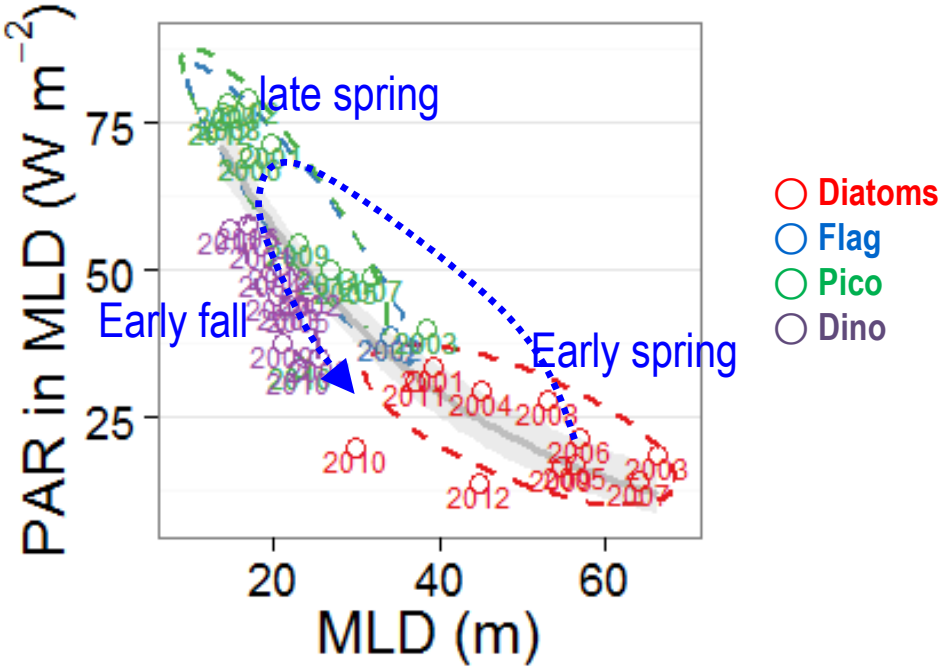
Results & Discussion

The effect of vertical mixing

- Light



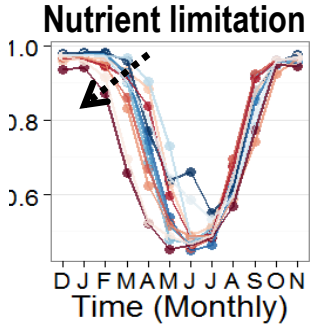


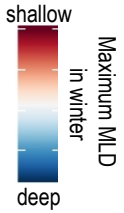


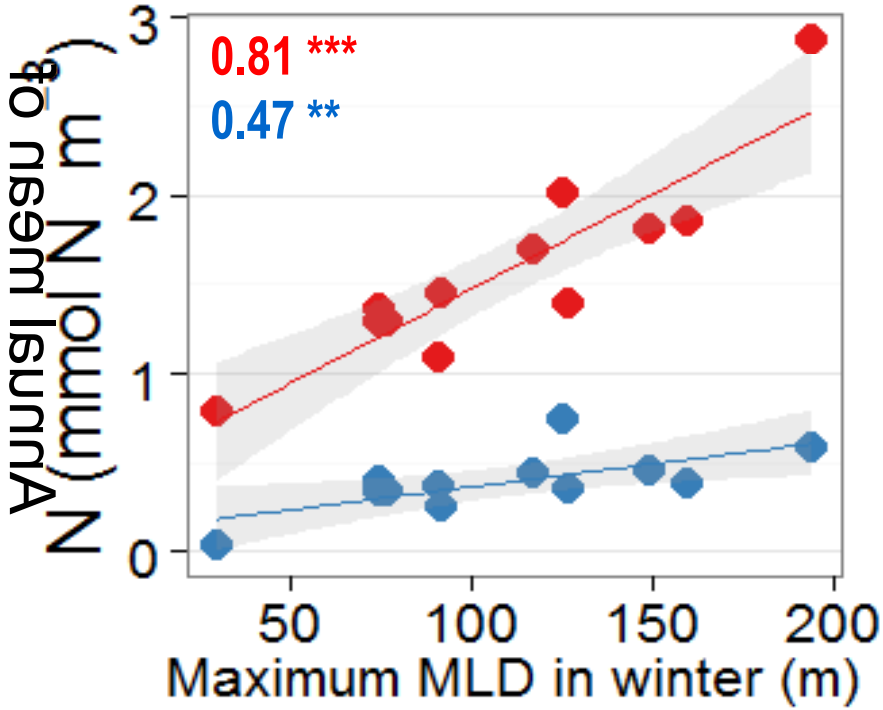
Results & Discussion

The effect of vertical mixing

- Nutrient







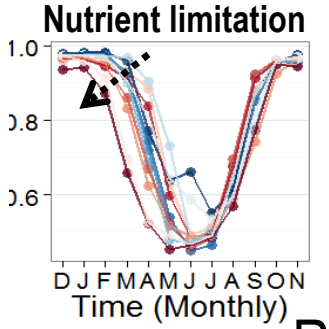
● Nitrate
● Ammonium

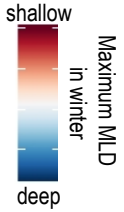
***: *P*<0.001,
**: *P* <0.01,
*: *P* <0.05

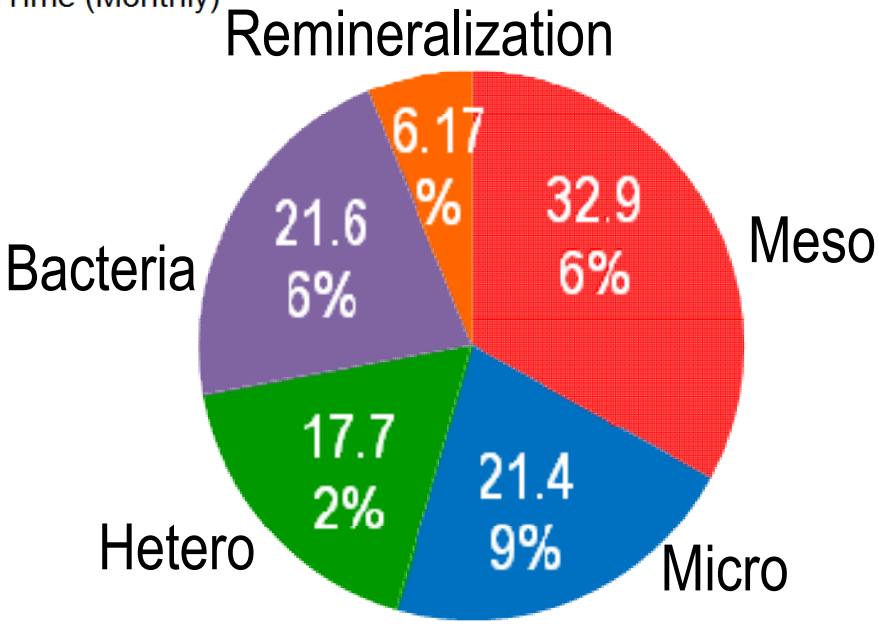
Results & Discussion

The effect of vertical mixing

- Nutrient





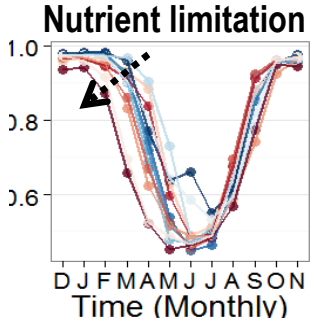


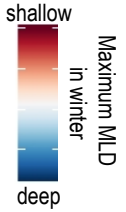
Composition of ammonium sources (%)

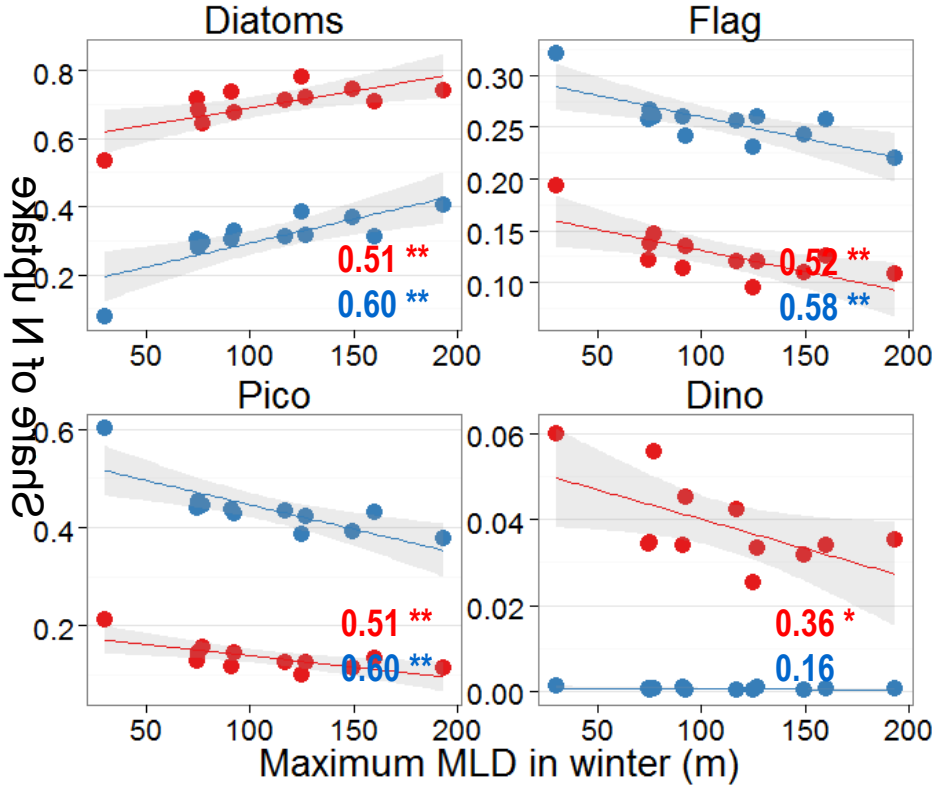
Results & Discussion

The effect of vertical mixing

- Nutrient





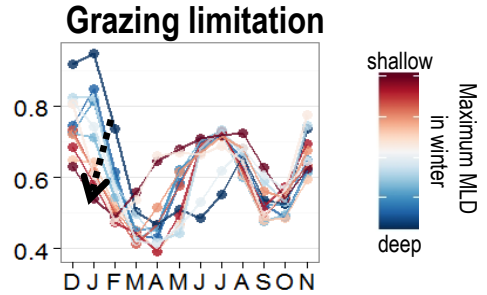


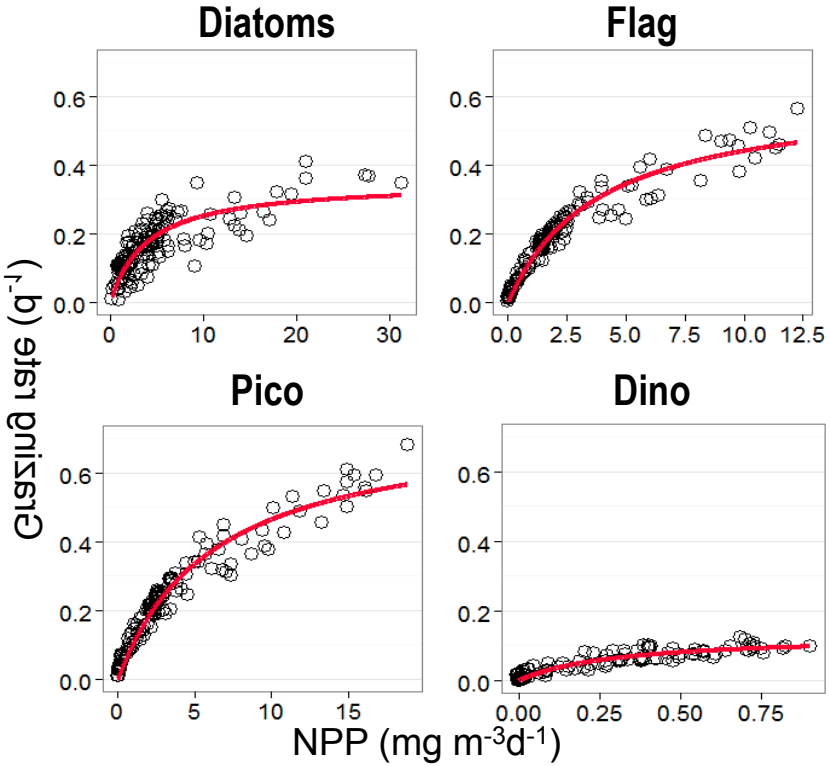
Nitrate
Ammonium

***: *P*<0.001,
**: *P* <0.01,
*: *P* <0.05

The effect of vertical mixing

- Grazing

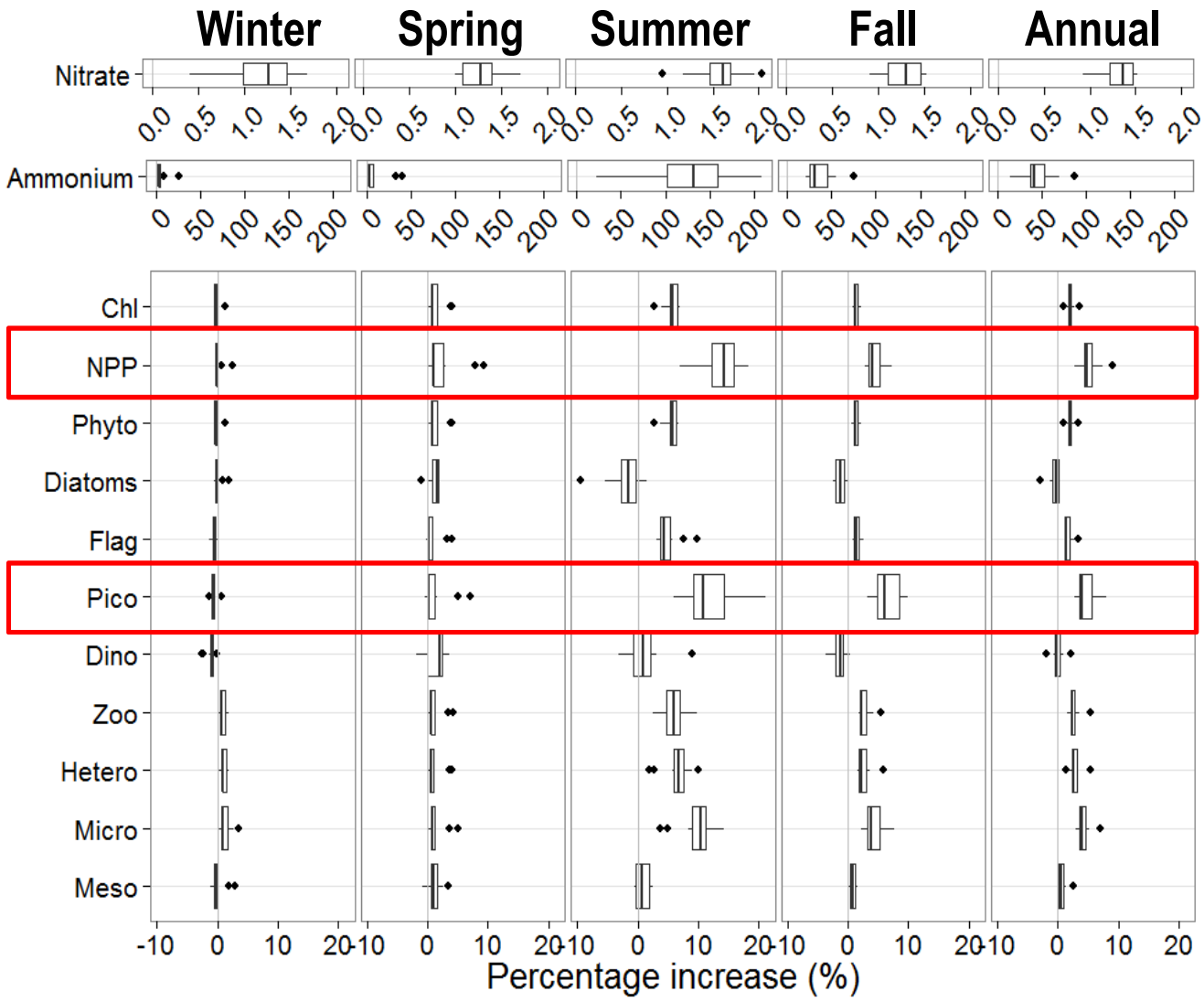




Results & Discussion

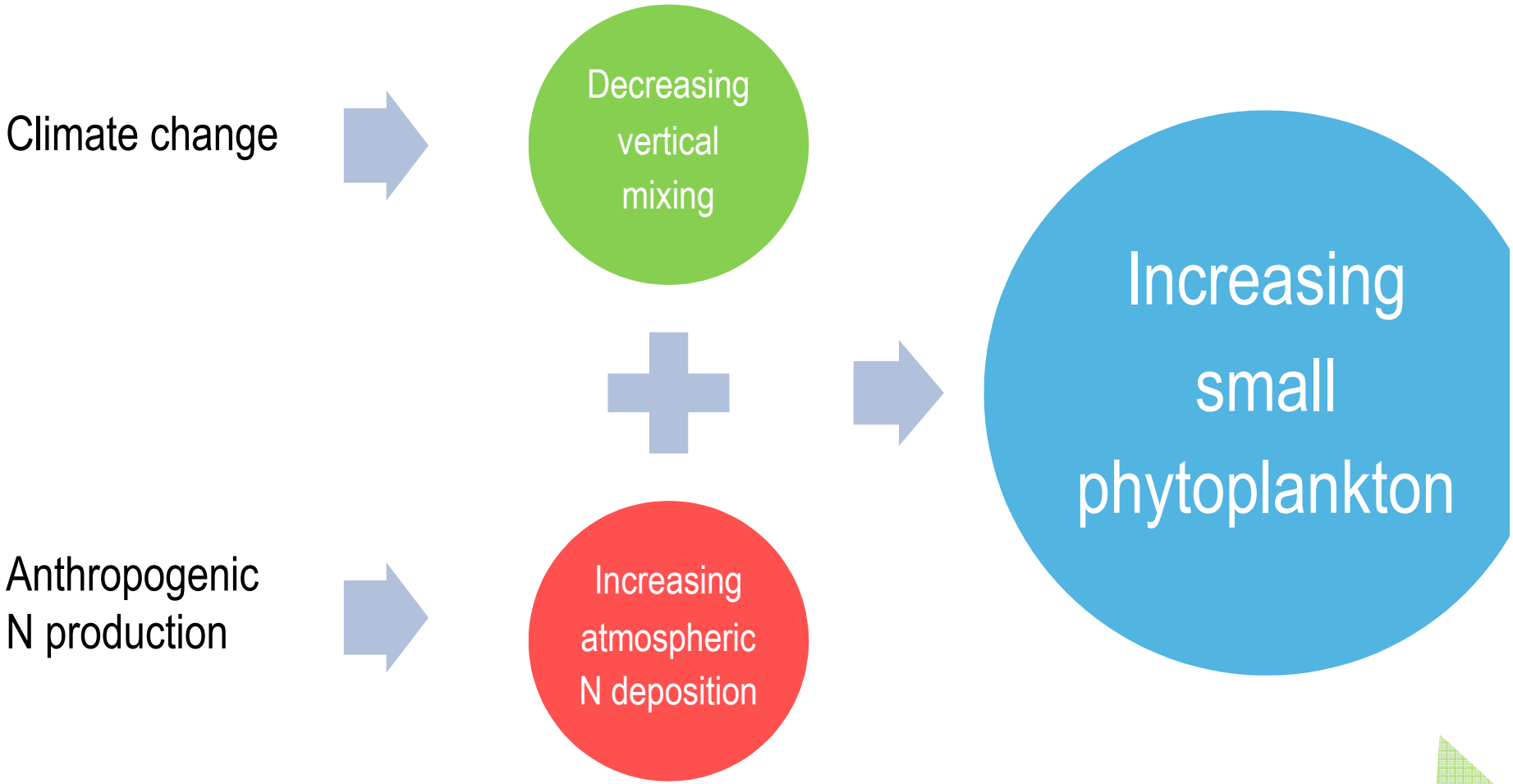
The effect of atmospheric deposition

- The percentage increase (%) of variables



The combined effect

- Decreasing vertical mixing and increasing atmospheric N deposition



In future

Further study

- Nitrogen sources

Comparison of the DIN input fluxes for individual paths to the East Sea (Tmol yr^{-1})

Sources	Time Period	DIN	References
Current-N (TWC)	1999-2003	~0.45	Kim *et al.*, 2013
Current-N (TWC)	1999-2000	0.39	Kim *et al.*, 2013
Current-N (TWC)	1997-2003	0.25~0.57	Chung *et al.*, 2000; Zhang *et al.*, 2007
Air-N	1997-2005	~0.036	Zhang *et al.*, 2011
Air-N	1980-2010	~0.026	Kim *et al.*, 2011

[Kim *et al*., GRL, 2013]

- ❖ The nitrogen flux by Tsushima Warm Current was an order of magnitude greater than the atmospheric N deposition.
- → We will investigate the combined effect of vertical mixing, atmospheric N deposition and advection on PFTs.

Summary

- The vertical mixing has critical effects on light (-), nutrient (+) and grazing (-).
- The PFTs responded differently to the changes in vertical mixing and atmospheric N deposition.
- Compared with vertical mixing, the atmospheric N deposition did not have a great effect on phytoplankton.


THANK
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