

On the magnitude of Primary Production Eddy Effects in the ocean

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« Primary production in the ocean: from the synoptic to the global scale »

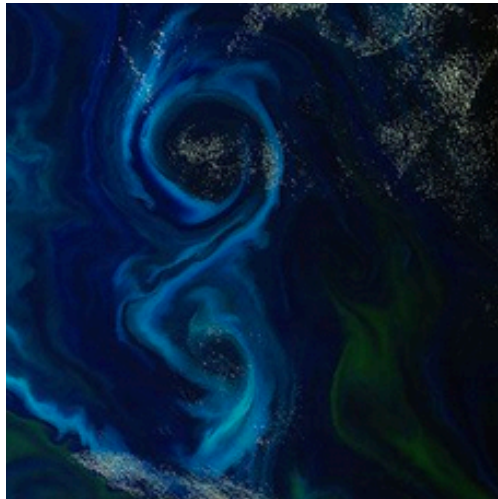
Liège, 13-17 May 2013

- Previous studies on the role of (sub-)mesoscale have focused on quantifying **vertical eddy advection** of nitrate, phyto, heat, ..
- Separate the contribution of the large scale circulation and of the eddy fluctuations in the Nitrate budget

Decomposition between large & small scales $N = \bar{N} + N'$

$$\partial_t \bar{N} = - \underbrace{\bar{u} \cdot \nabla \bar{N}}_{\text{Mean advection}} - \underbrace{\overline{u' \cdot \nabla N'}}_{\text{Eddy advection}} + \underbrace{\bar{B}(\bar{N})}_{\text{Bio reaction}} + \underbrace{\partial_z \left(\overline{k_z \partial_z N} \right)}_{\text{Vertical mixing}}$$

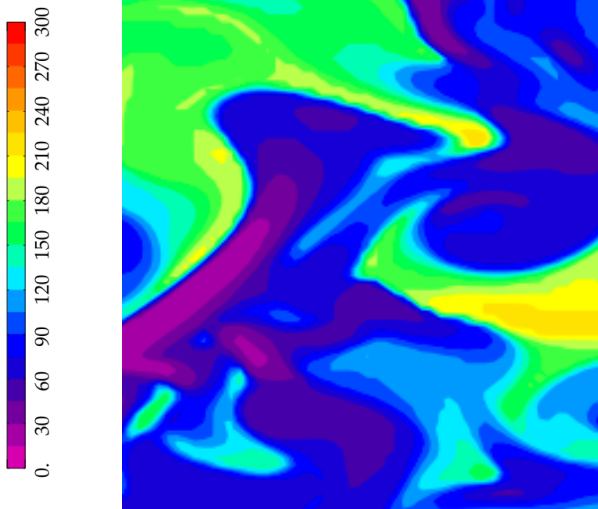
Phytoplankton



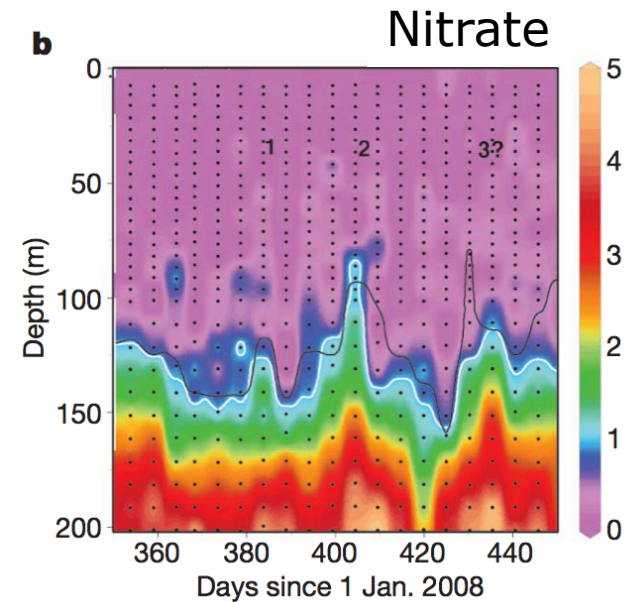
Ocean color image

~200 km

Mixed-layer depth



Levy et al., 2005



Johnson et al., 2010, Nature

Observational evidence : Quantities involved in PP present strong variability at scales < 100 km

Evaluation of PP based on large-scale fields biased due to non-linear dependance of PP on light and nutrients.

Eddy reactions arise from non-linearities in the biological equations (primary production, grazing, ...)

$$\overline{\mathcal{B}_n(P, N, A, Z, D, sw, \dots)} \neq \mathcal{B}_n(\overline{P}, \overline{N}, \overline{D}, \overline{Z}, \overline{A}, \overline{sw}, \dots)$$

Total reaction (PP, grazing)

Mean field approximation used in
Coarse resolution models,
satellite algorithms

$$\overline{\mathcal{B}_{n'}} = \overline{\mathcal{B}_n(P, N, A, Z, D, sw, \dots)} - \mathcal{B}_n(\overline{P}, \overline{N}, \overline{D}, \overline{Z}, \overline{A}, \overline{sw}, \dots)$$

Eddy reaction

$$N = \bar{N} + N'$$

$$\partial_t \bar{N} = \underbrace{-\bar{u} \cdot \nabla \bar{N}}_{\text{Mean advection}} - \underbrace{\overline{u' \cdot \nabla N'}}_{\text{Eddy advection}} + \underbrace{B(\bar{N})}_{\text{Bio reaction}} + \underbrace{\overline{B'(N)}}_{\text{Eddy reaction}} + \underbrace{\partial_z \left(\overline{k_z \partial_z N} \right)}_{\text{Vertical mixing}}$$

Objectives

Examine the strength of eddy PP, eddy grazing, eddy mortality

Compare them to mean PP, grazing, mortality

Compare them to eddy advection

Method

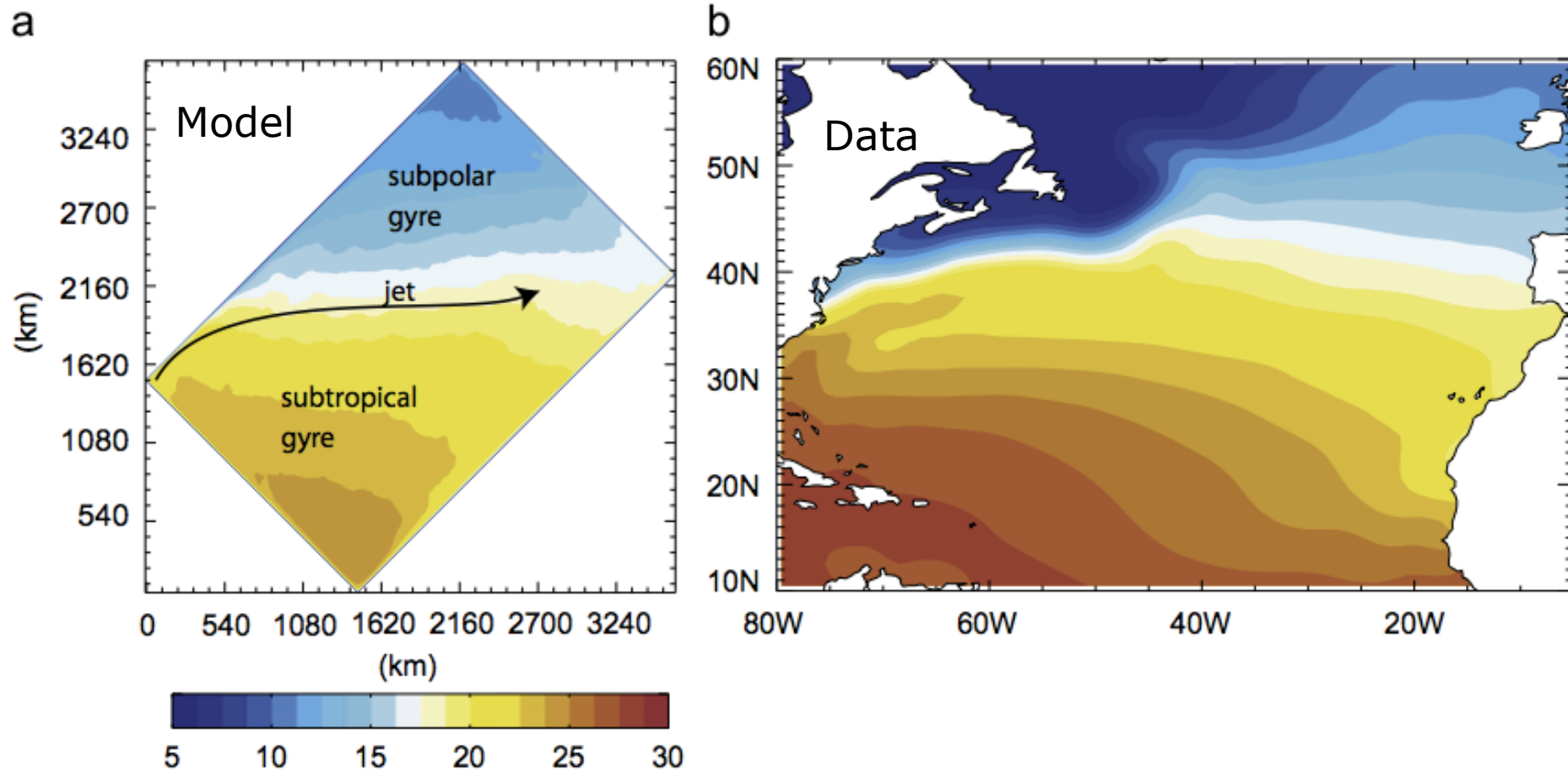
Synthetic data from high-resolution model of the NA

Dynamically consistent fields at the small-scale

Enables to derive large-scale estimates

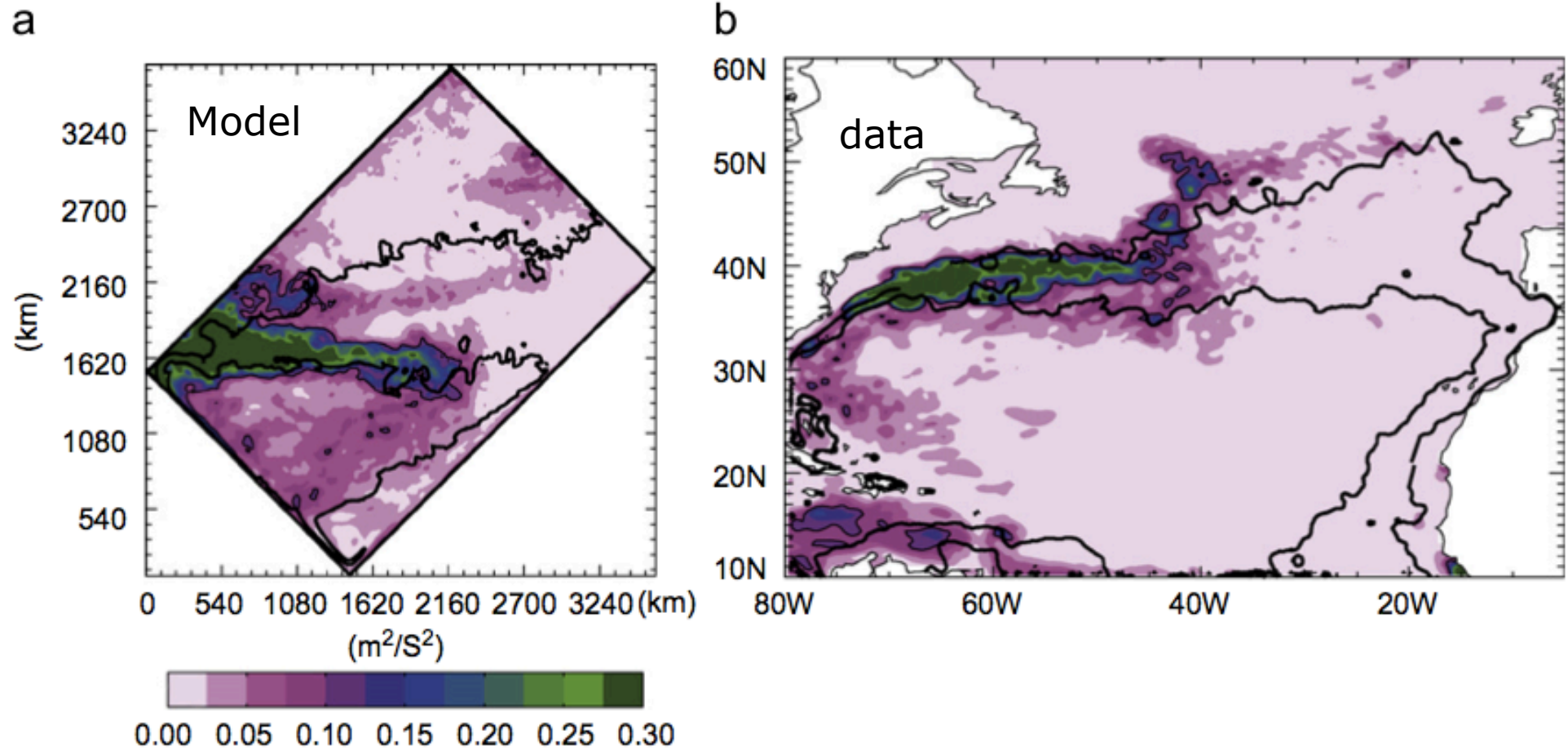
Analytical formulations of PP, grazing, mortality

Submesoscale permitting: 2 km resolution

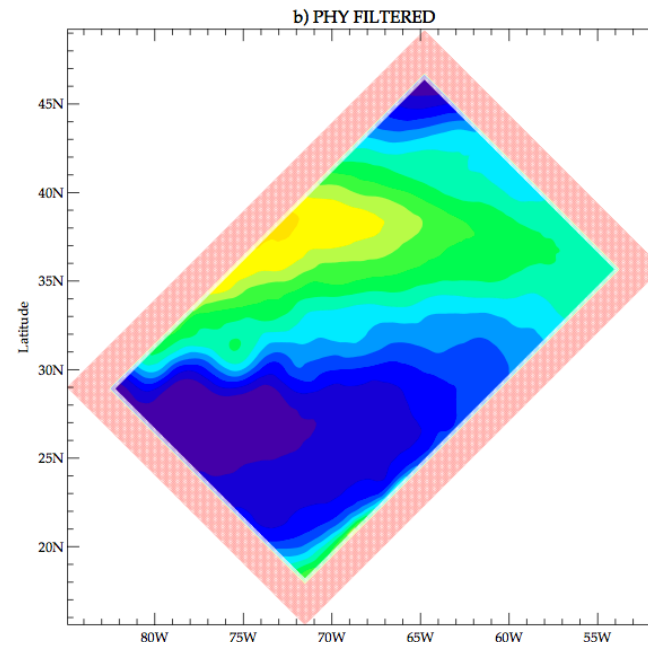
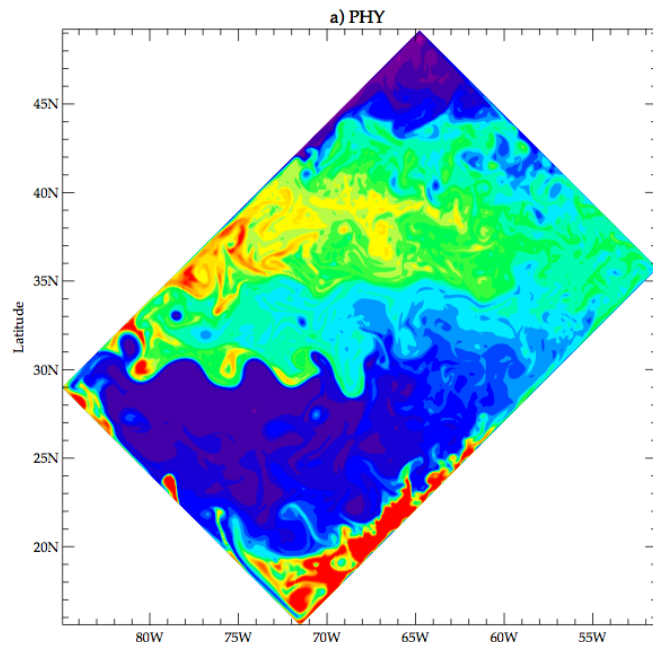


Annual mean SST

EKE



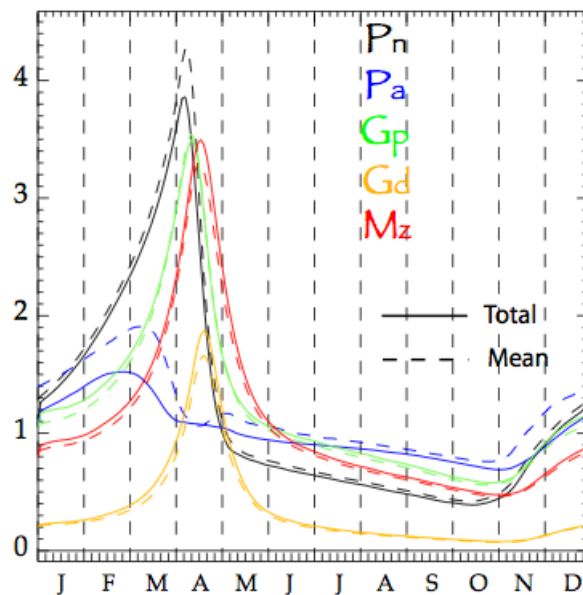
$$N = \overline{N} + N'$$



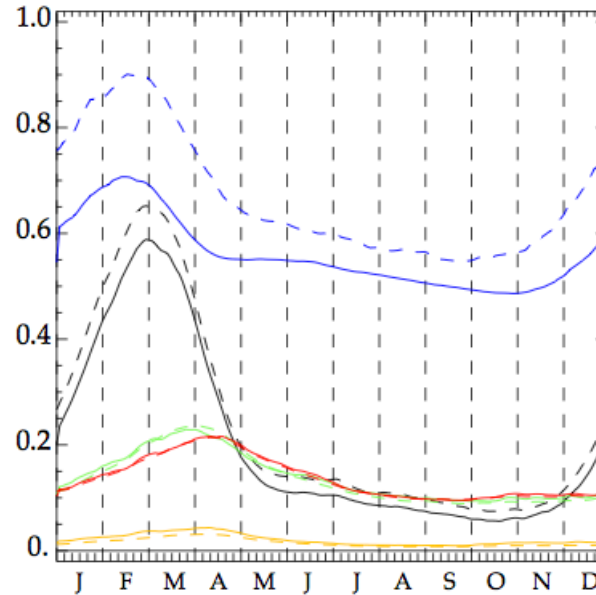
2° filter

Magnitude of eddy reactions: seasonality

a) Total and Mean reactions in subpolar gyre

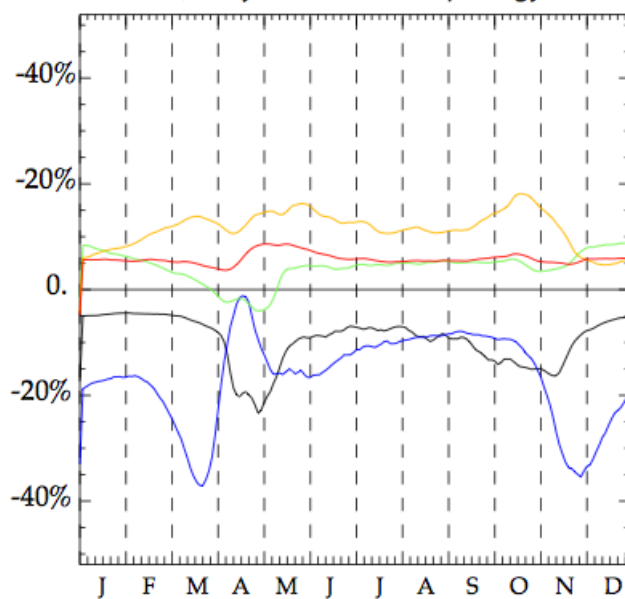


b) Total and Mean reactions in subtropical gyre

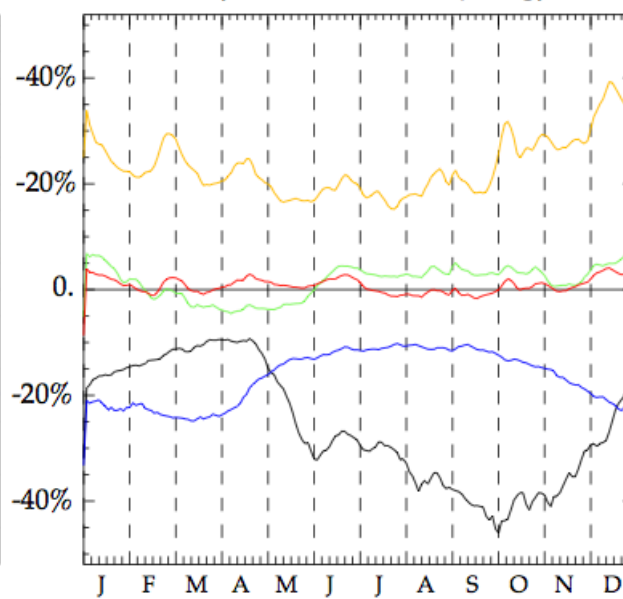


Range : 10-40%

c) Eddy reactions in subpolar gyre



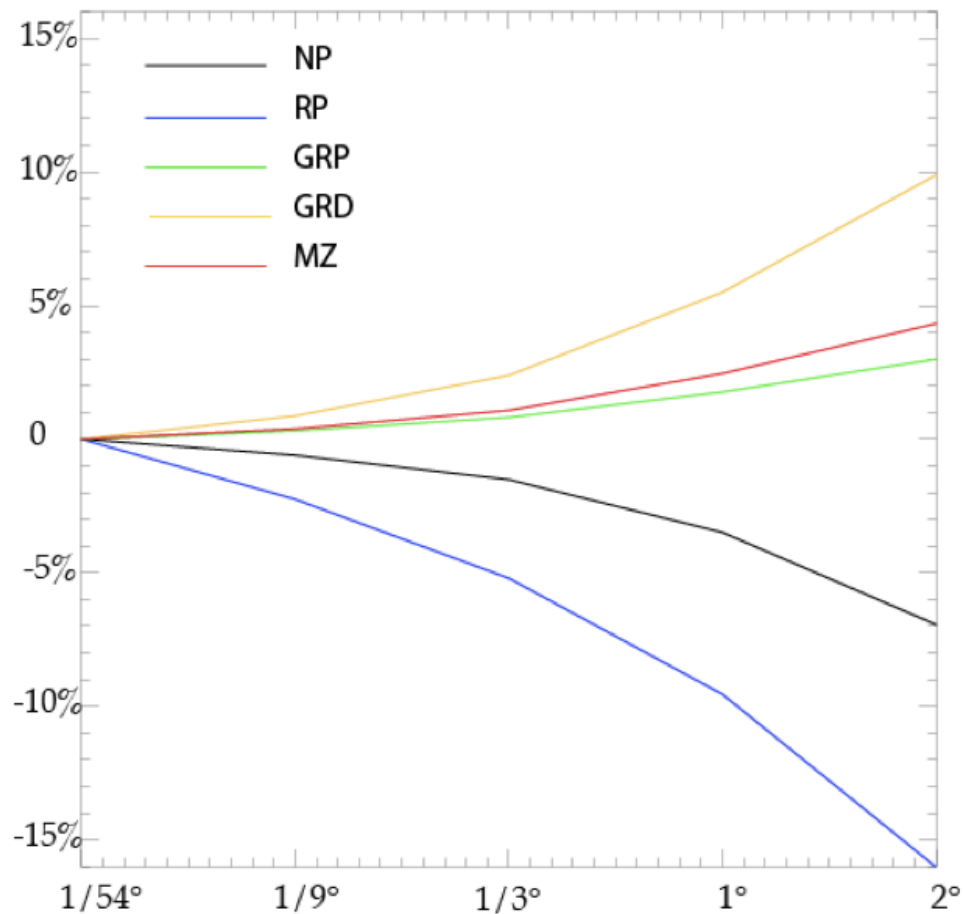
d) Eddy reactions in subtropical gyre





Magnitude of eddy reactions: scale dependance

2/3 Mesoscale
1/3 Submesoscale

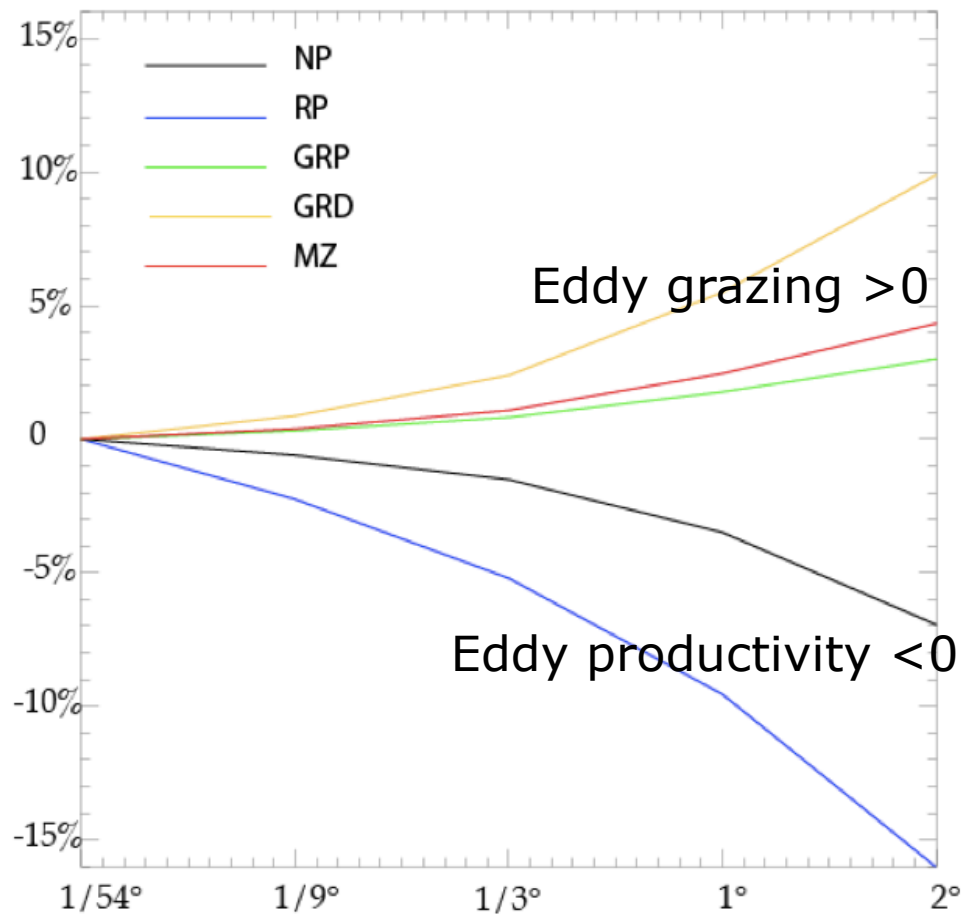


Sub-mesoscale

Mesoscale

Size of the filter

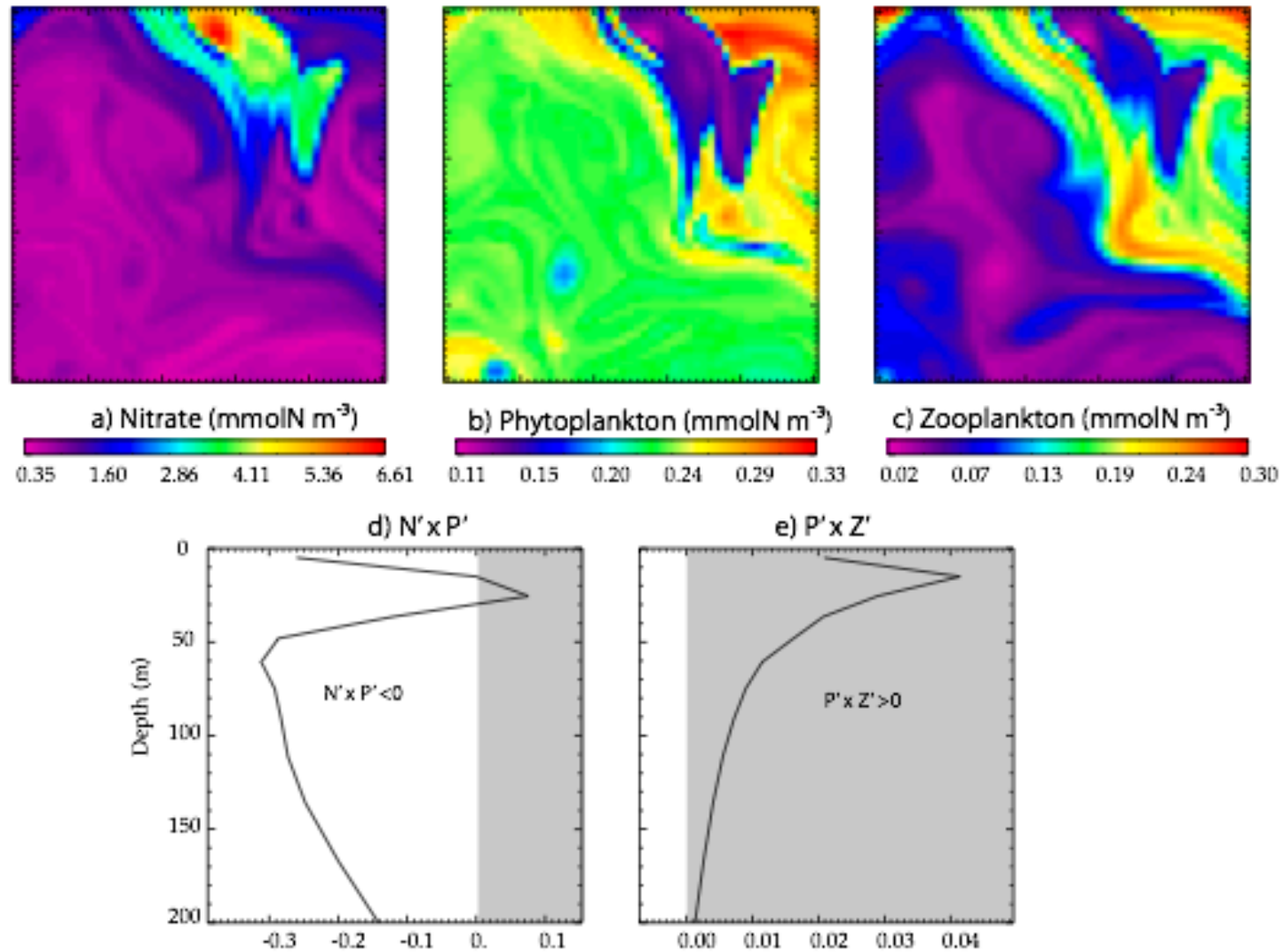
2/3 Mesoscale
1/3 Submesoscale



Sub-mesoscale

Mesoscale

Size of the filter

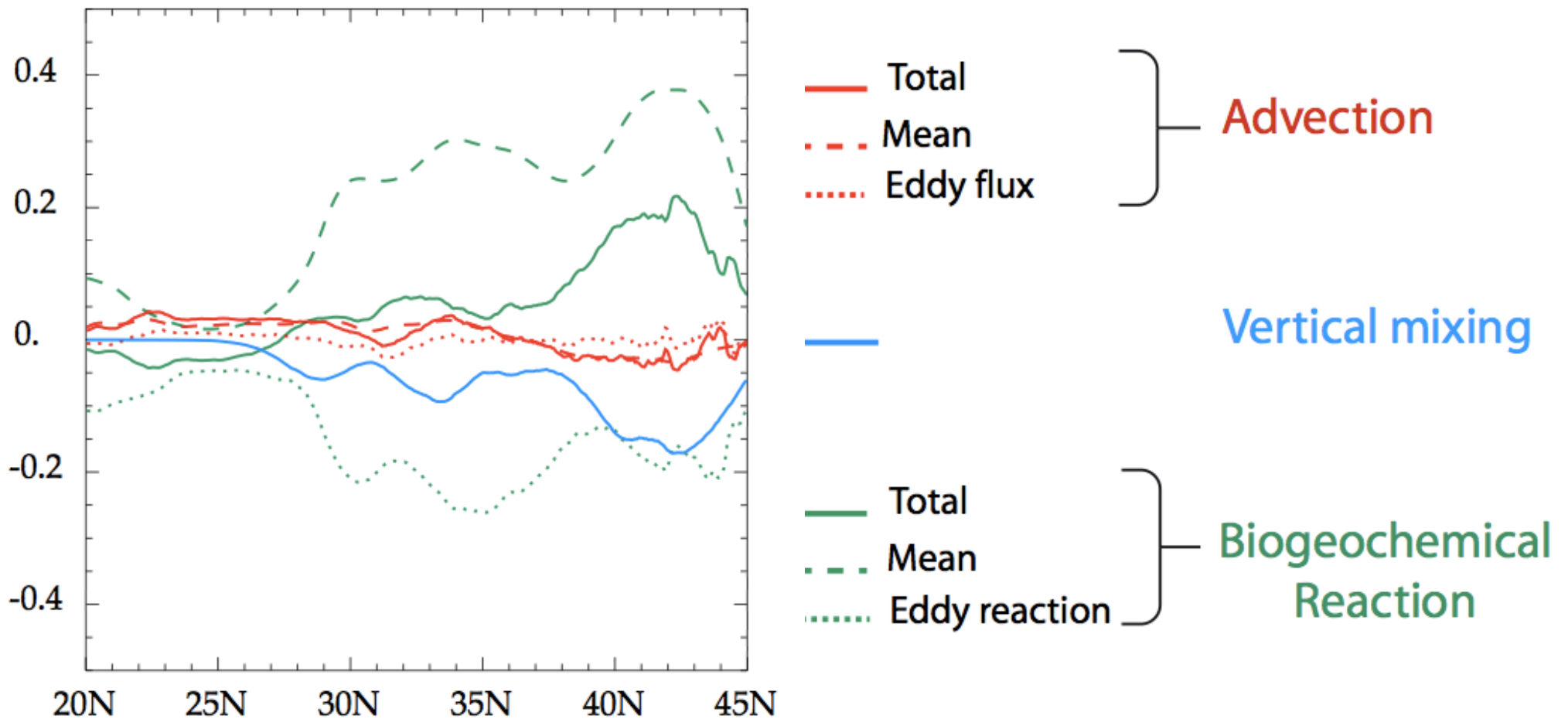


$$\partial_t \bar{N} = \underbrace{-\bar{u} \cdot \nabla \bar{N}}_{\text{Mean advection}} - \underbrace{\overline{u' \cdot \nabla N'}}_{\text{Eddy advection}} + \underbrace{\overline{B(\bar{N})}}_{\text{Bio reaction}} + \underbrace{\overline{B'(N)}}_{\text{Eddy reaction}} + \underbrace{\partial_z \left(\overline{k_z \partial_z N} \right)}_{\text{Vertical mixing}}$$

For $N = \text{PHY}$ $B'(N) = PP' - \text{grazing}'$

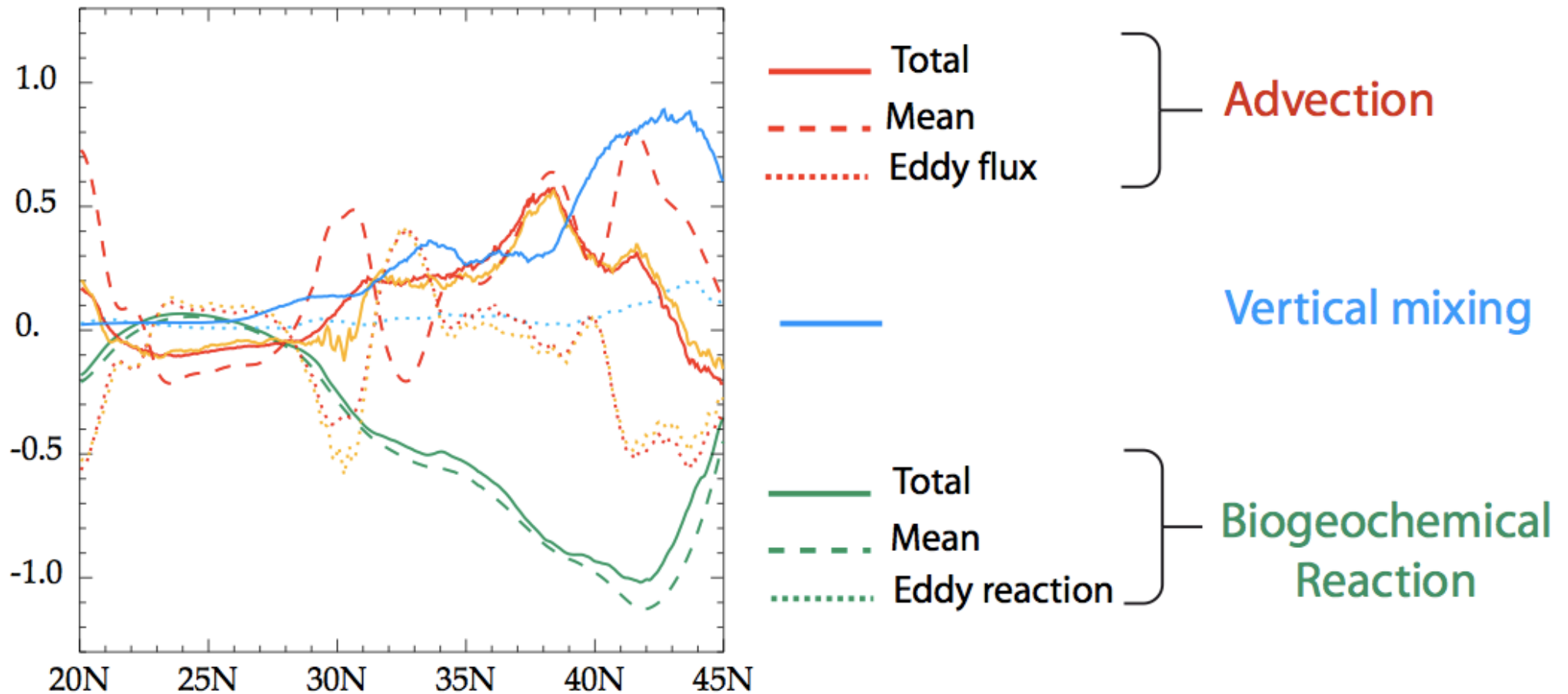
For $N = \text{NO}_3$ $B'(N) = -NP'$

b) PHY balance



YES, it is very important !

a) NO₃ balance



No, it is not important !

It's not all about eddy advection: eddy reactions also matter

Eddy productivity can reach up to 40% of PP

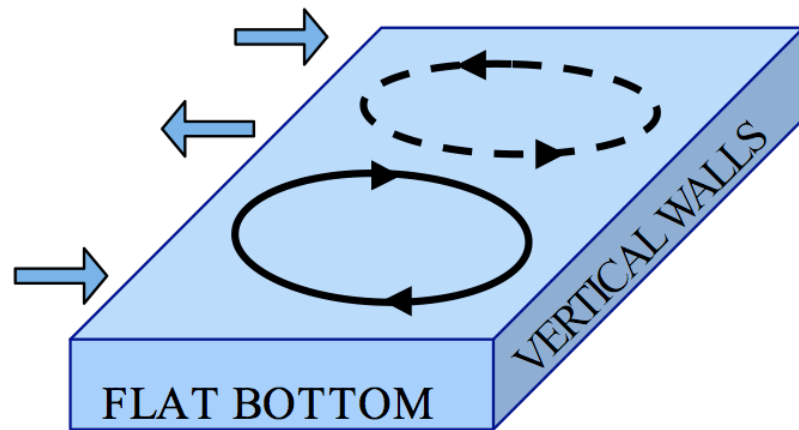
2/3 Mesoscale (30-200 km), 1/3 submesoscale (2-30 km)

Eddy productivity is negative: PP estimates at coarse scales are overevaluated

Eddy reactions are not much less important than eddy fluxes for biogeochemical budgets

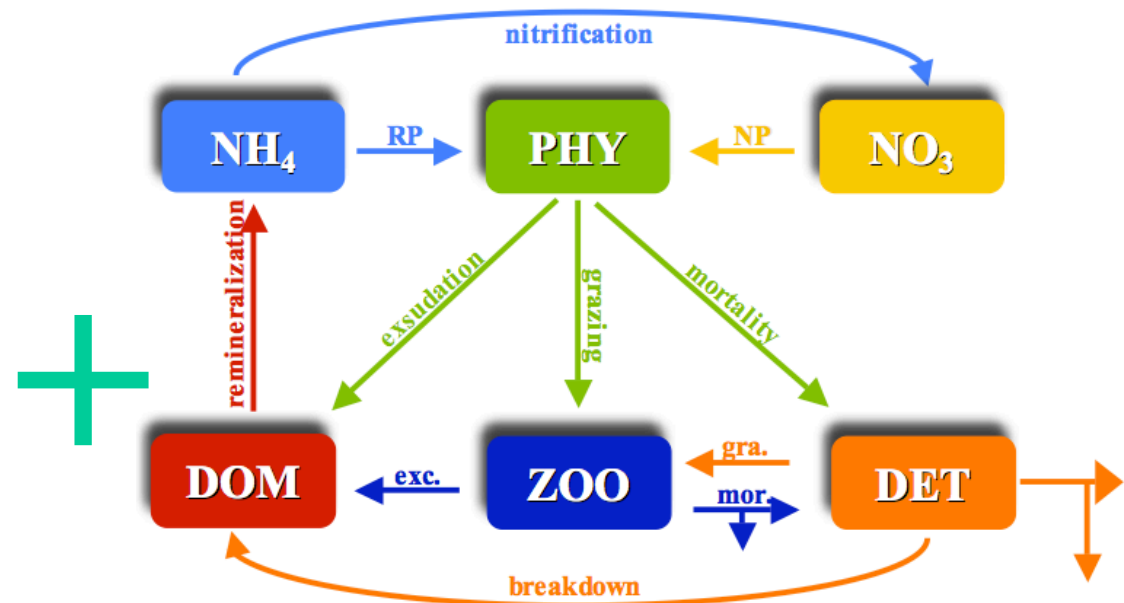
But they seem crucial for ecological studies and possibly play an important role on the community structure

Lévy, M. and A. Martin, Biogeochemical eddy reactions: large-scale estimates in seasonally varying ocean gyres, in revision for GBC



NEMO OGCM

2000 km x 3000 km x 4 km



LOBSTER biogeochemical model

Submesoscale permitting: 2 km resolution

Surface Chlorophyll

