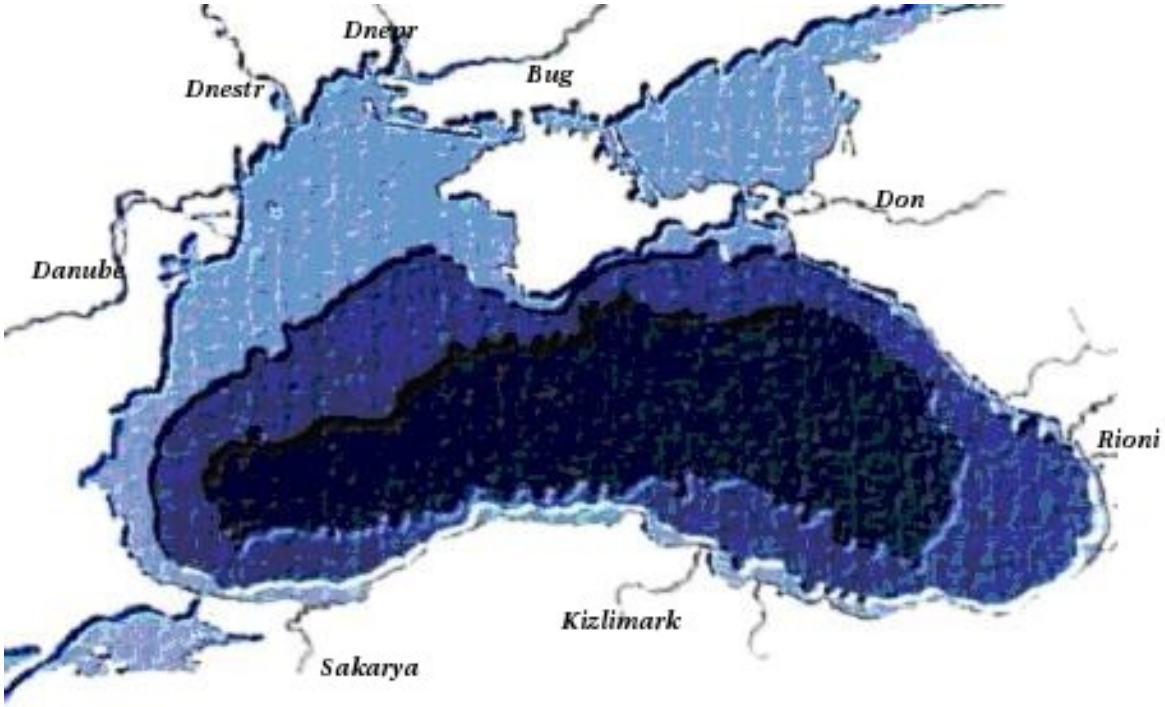
Benthic-Pelagic coupling in the Black Sea – A model study



Capet Arthur, Beckers Jean-Marie, Grégoire Marilaure

Université de Liège

MARE
INTERFACULTARY CENTER FOR MARINE RESEARCH - LIEGE UNIVERSITY

PERSEUS
POLICY-ORIENTED MARINE ENVIRONMENTAL RESEARCH IN THE SOUTHERN EUROPEAN SEAS

SESAME
rn European Seas: Assessing and Modelling Ecosystem chan

GHER
GeoHydrodynamics and Environment Research

FNRS

The Black Sea Context

- Quasi-enclosed basin.

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- Important drainage area

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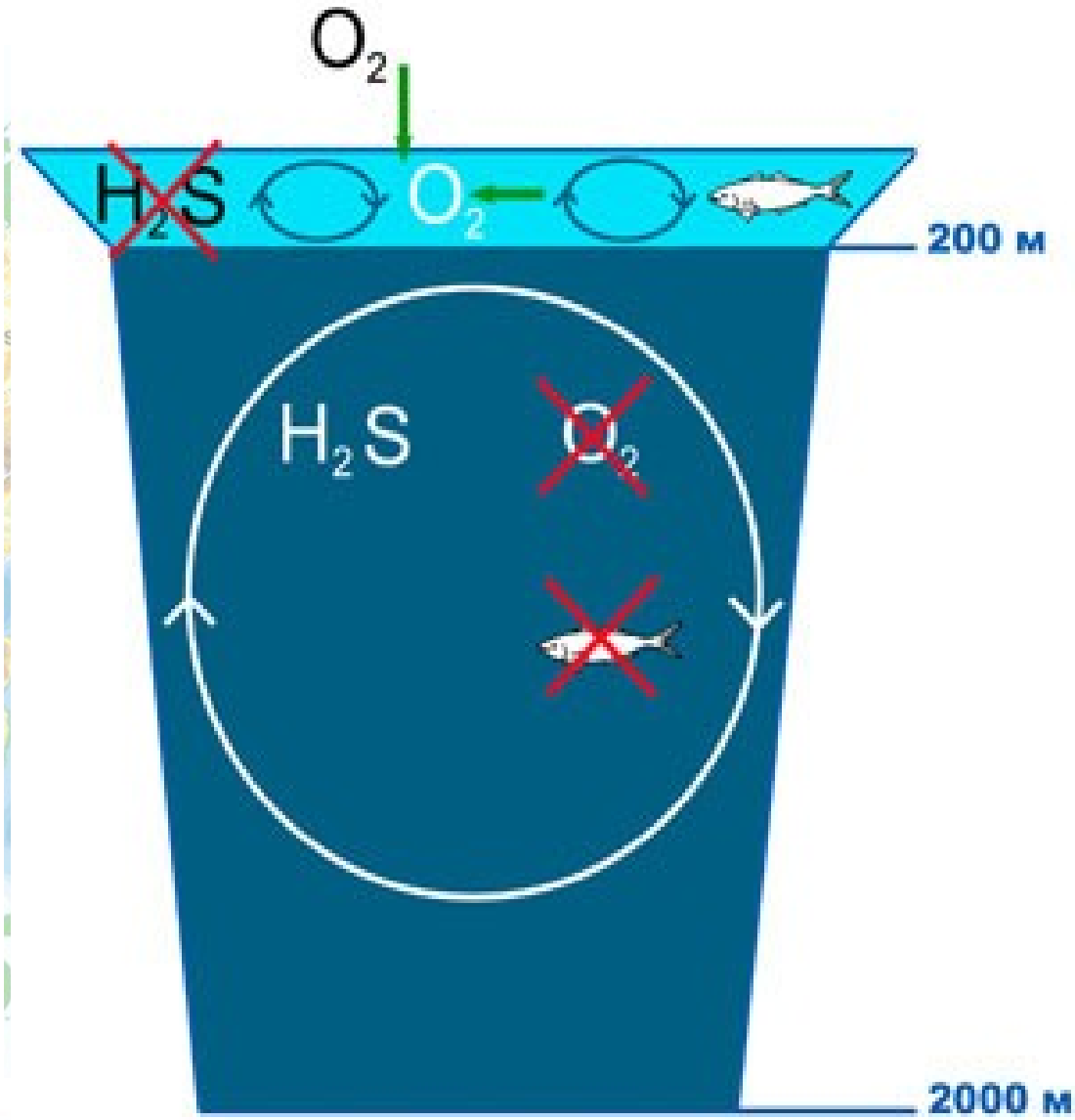

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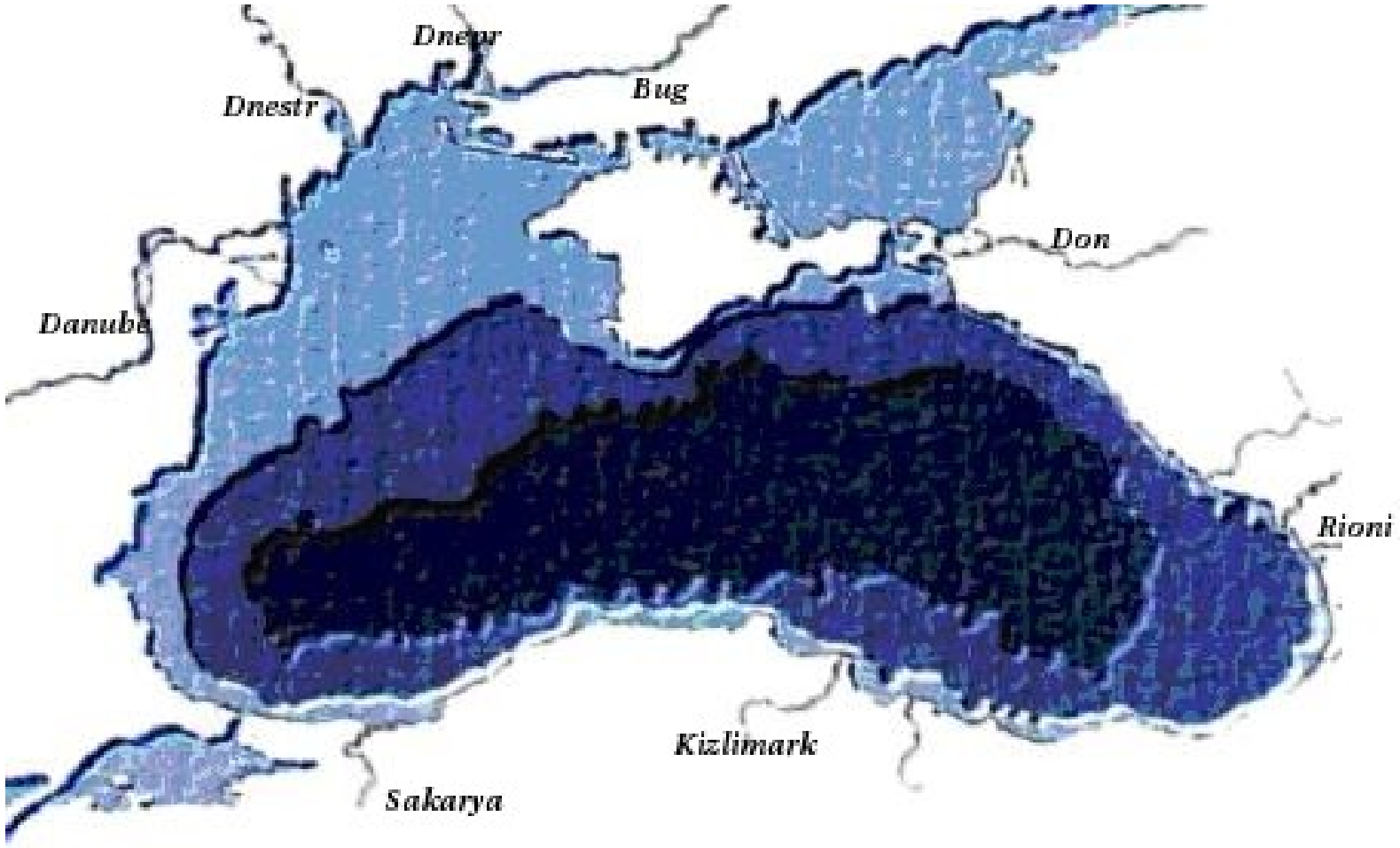
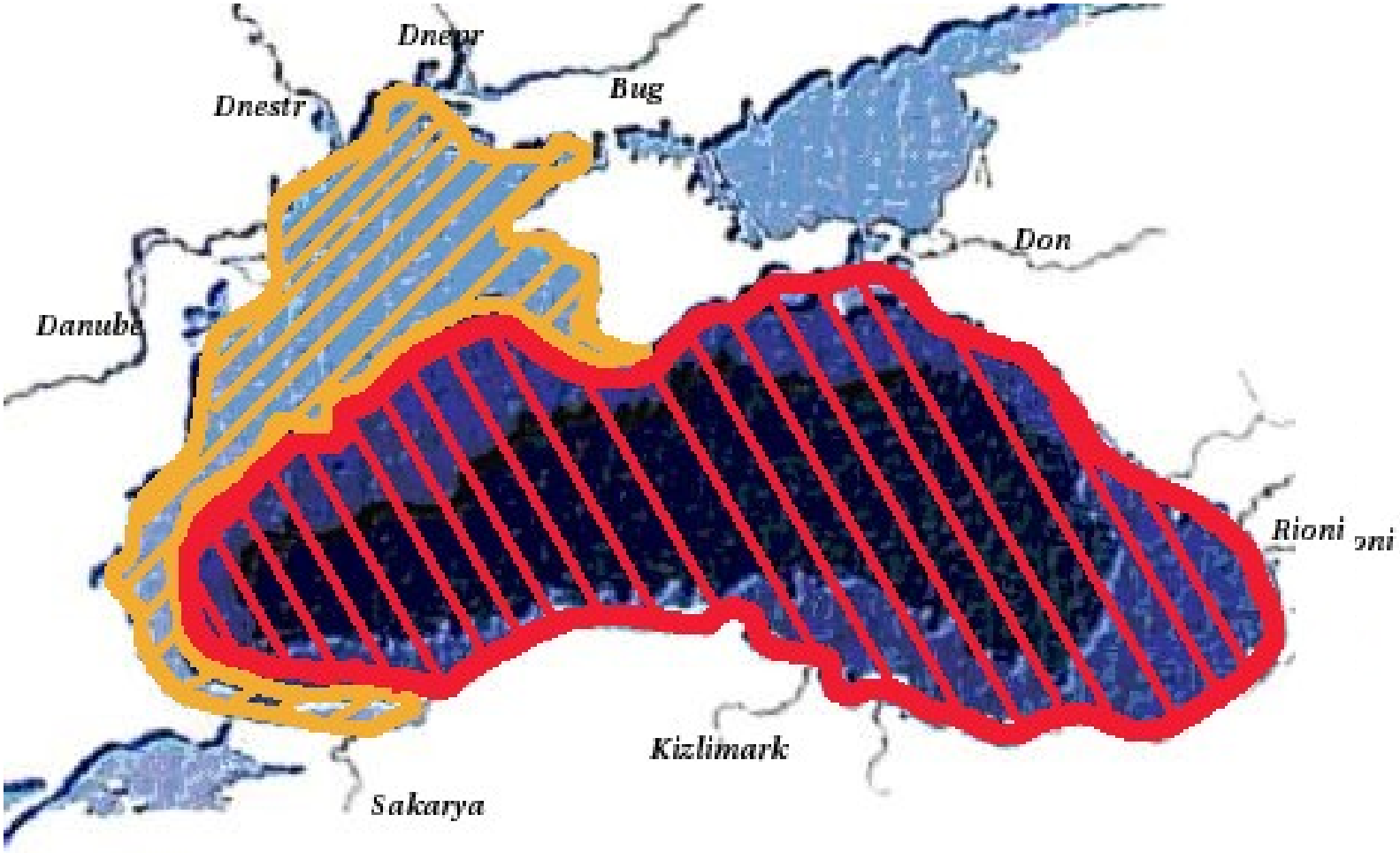
→ Confined active layer

→ High sensitivity

to external forcings

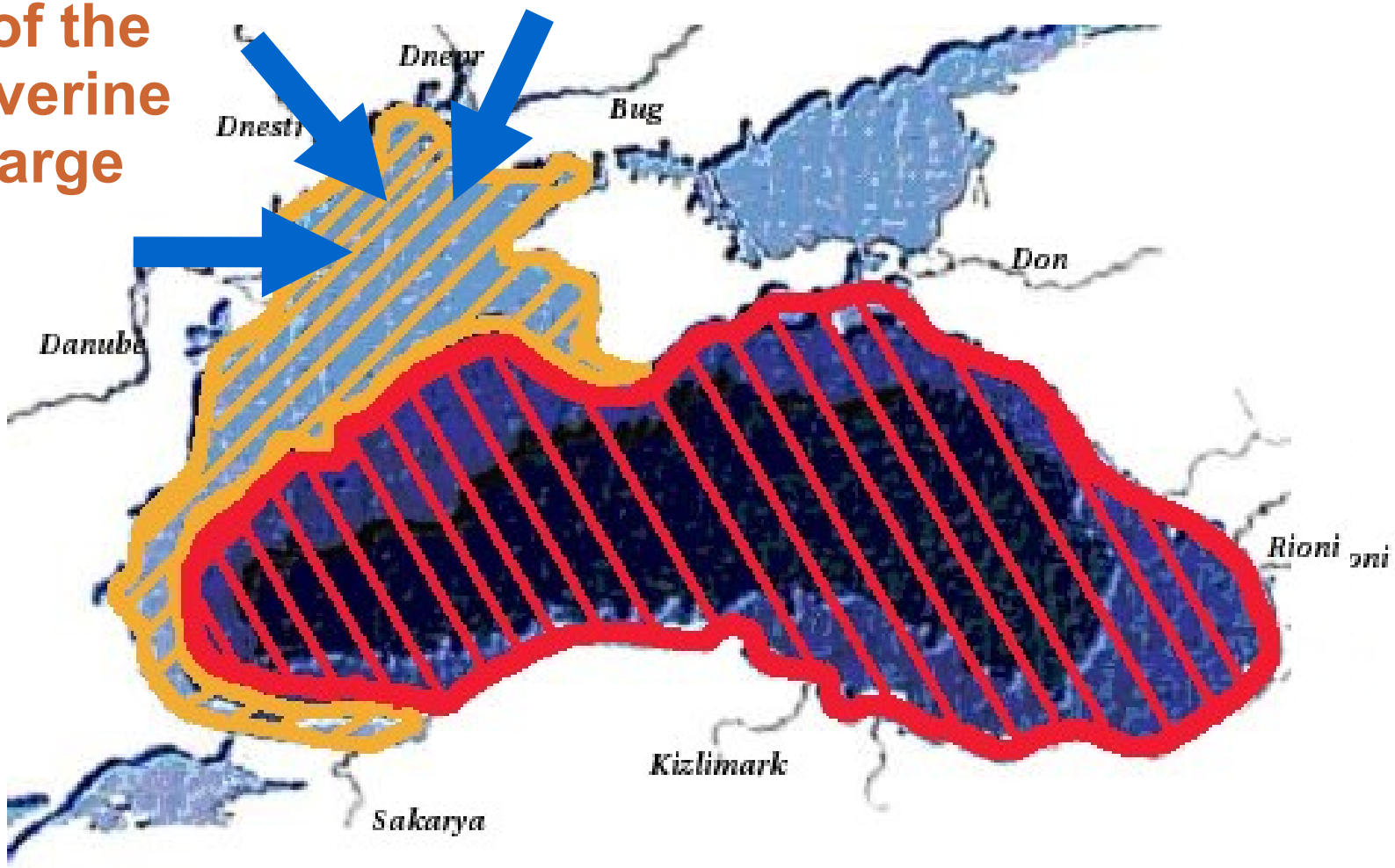

Dnepr
Bug
Dnestr
Don
Danube
Rioni
Kizlimark
Sakarya

North Western Shelf



Open Sea

North Western Shelf
87 % of the BS Riverine Discharge



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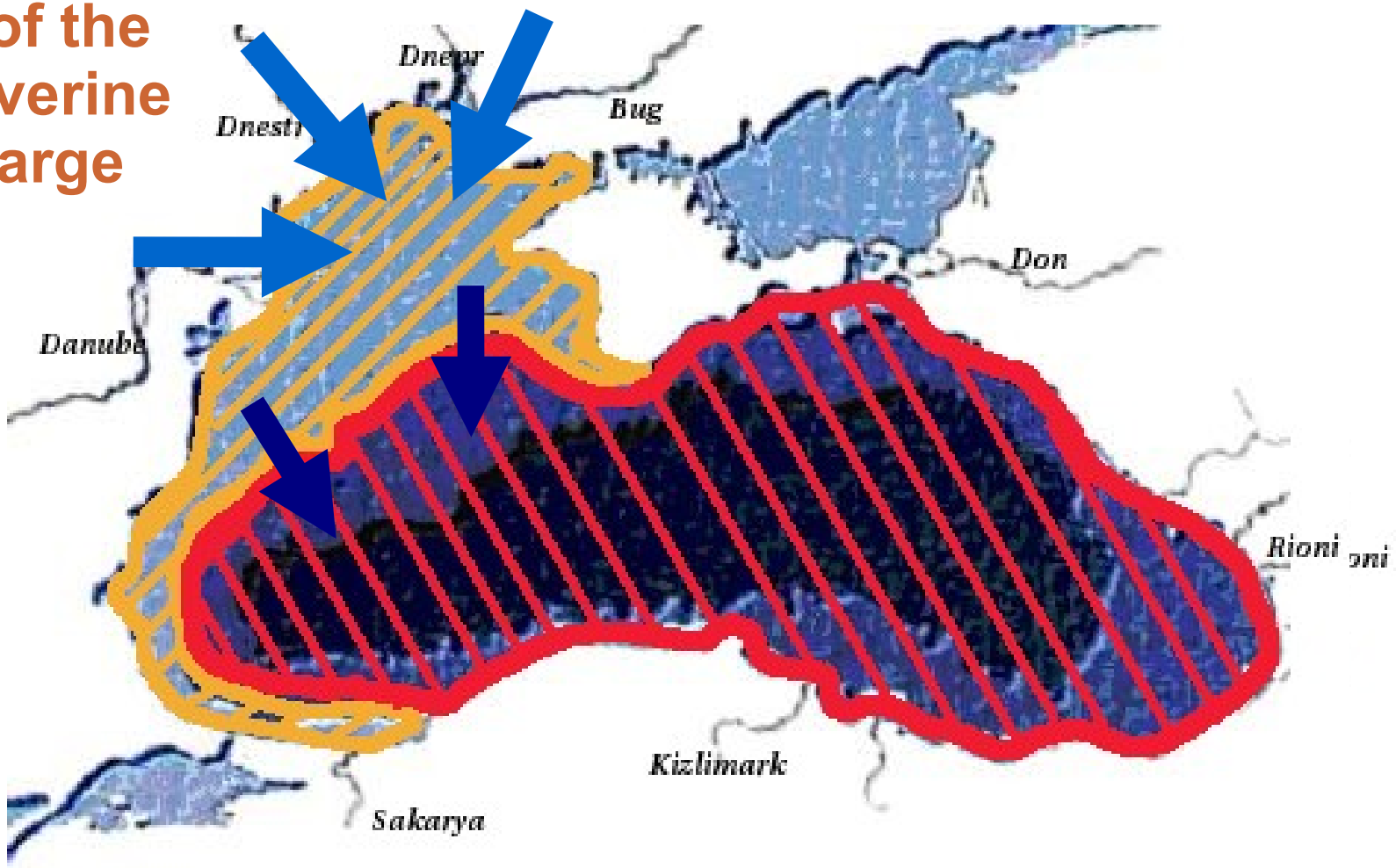
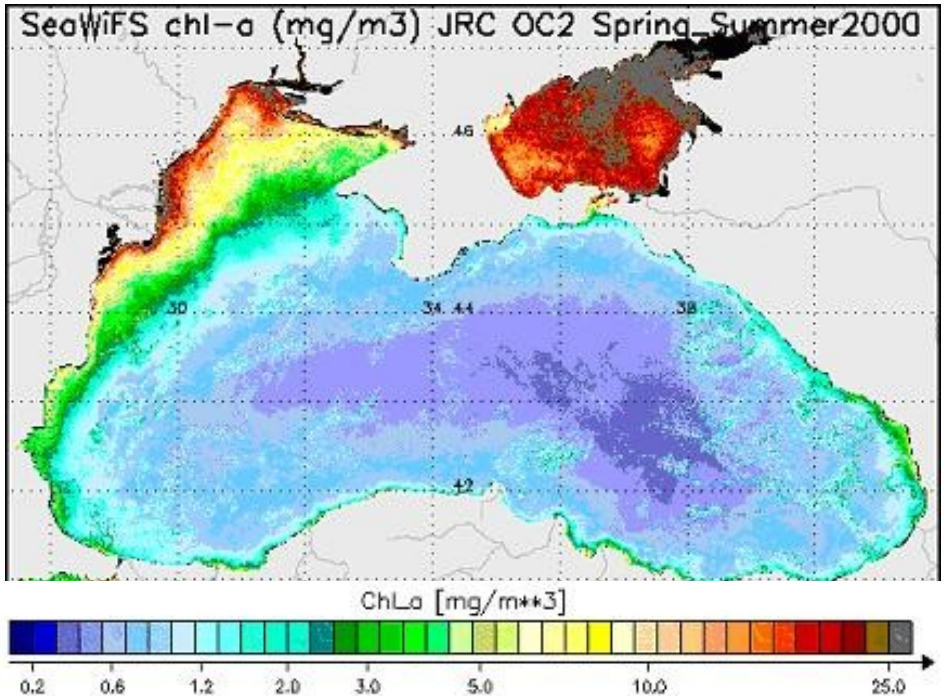
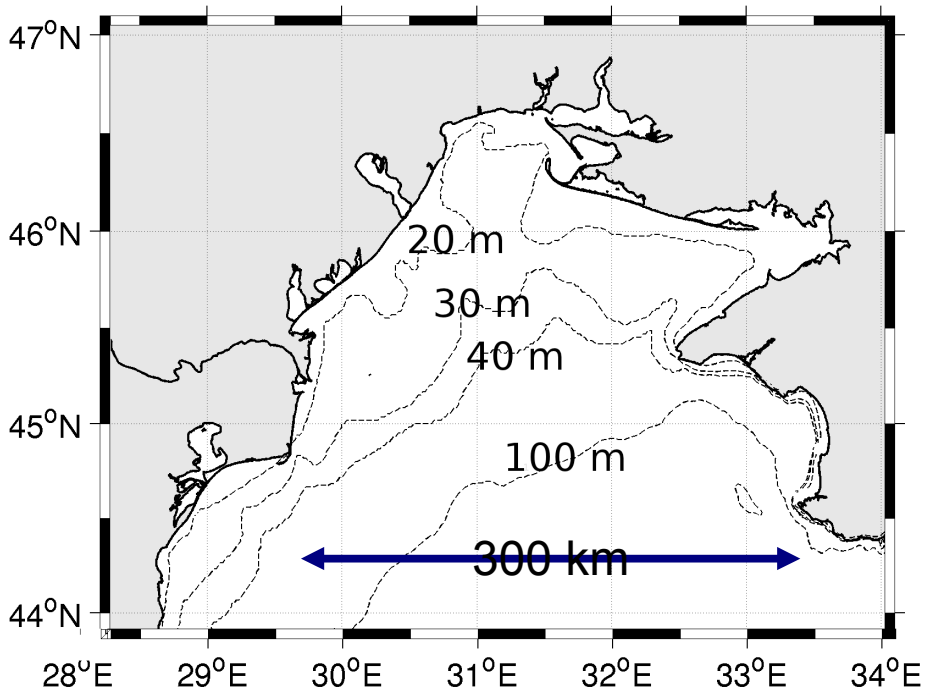


Open Sea : Production driven by the Shelf-Open Sea Export

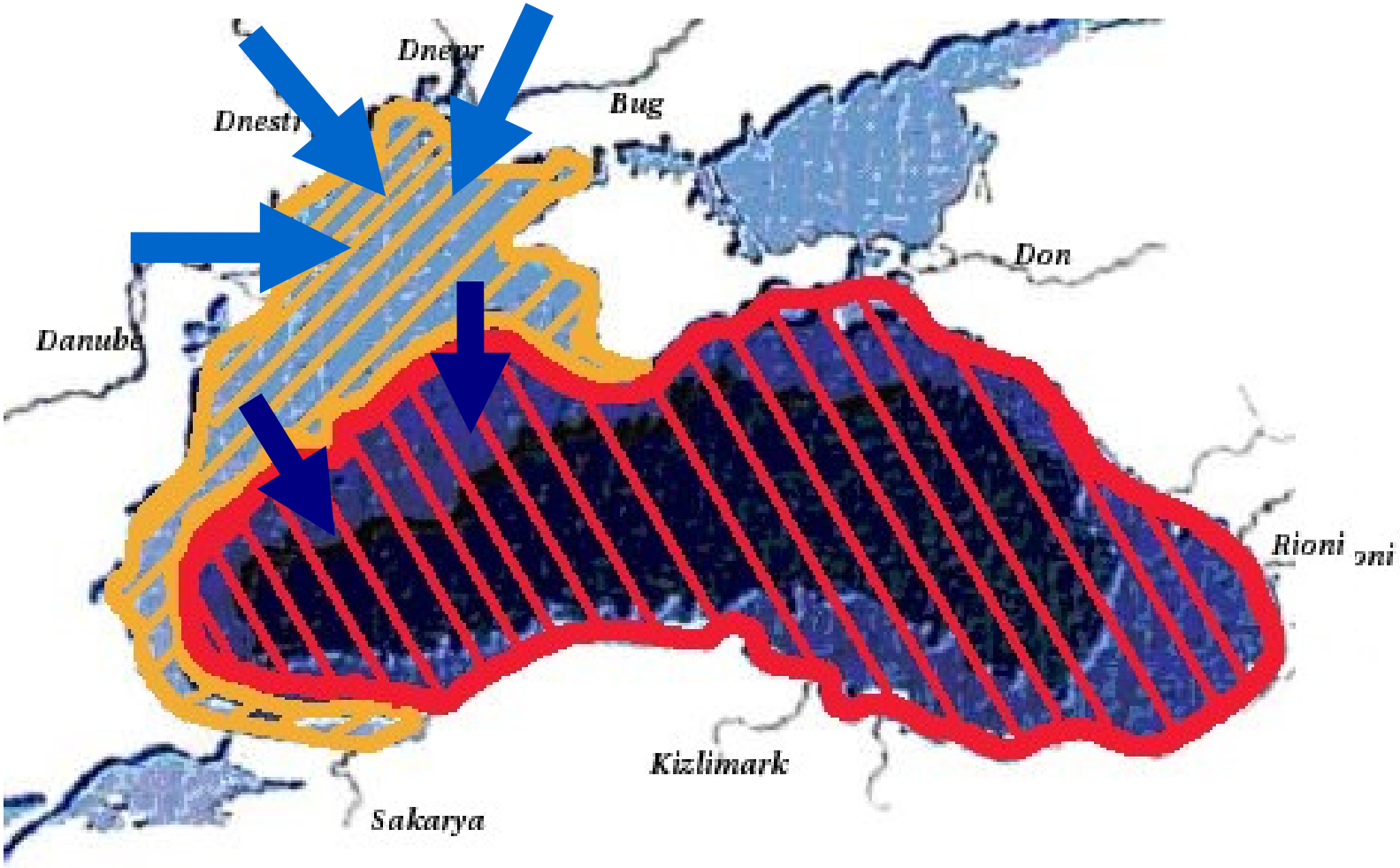
Black Sea Context





- NWS is a large, shallow and productive area.

→ Benthic-pelagic coupling is key to NWS biogeochemistry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Objectives

General objective : Modeling (3D) the biogeochemical cycles in the Black Sea on a wide range of scales

(15 km → basin wide ; 1h → 50 yr)

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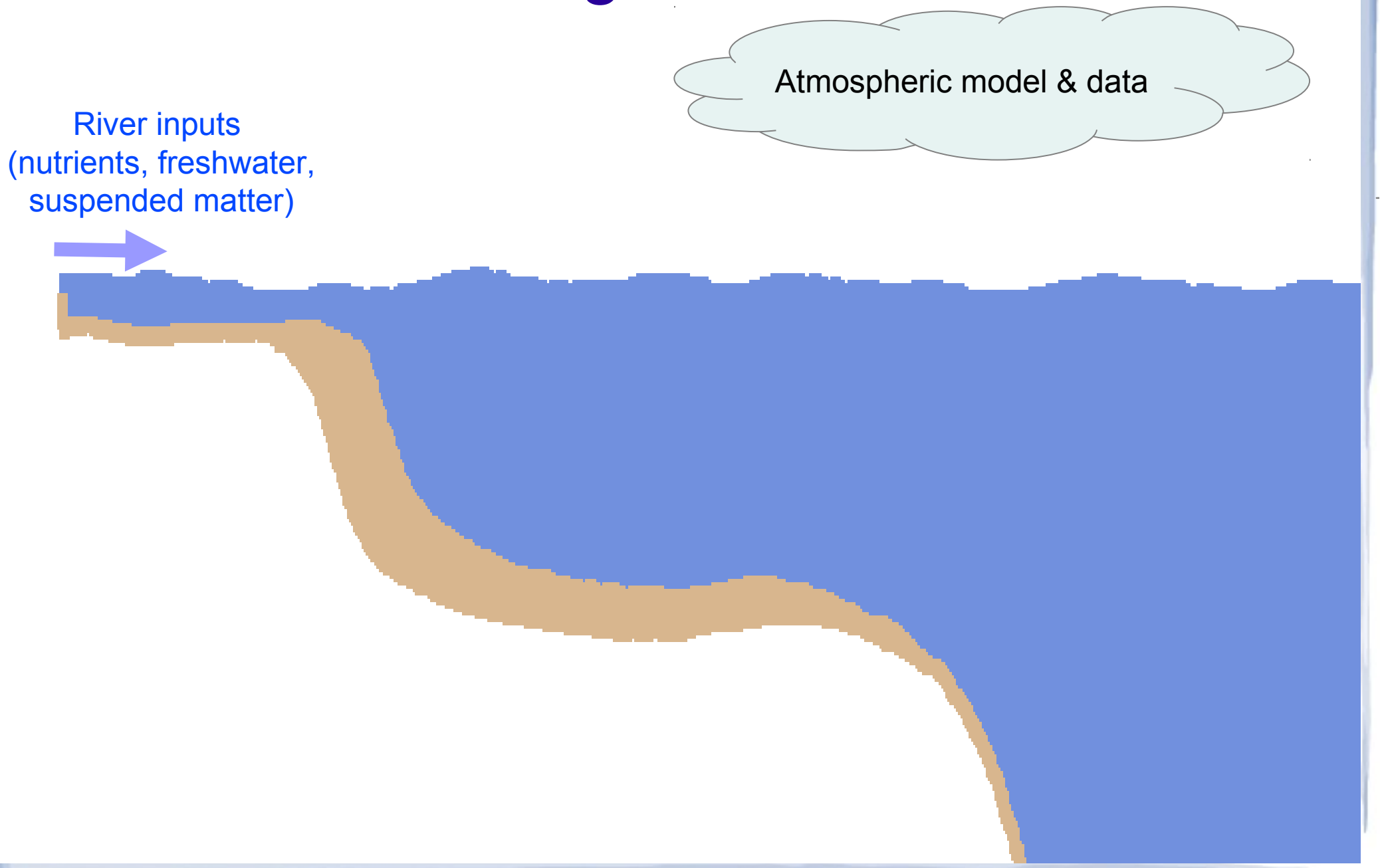
- What are the ***implications*** in terms of biogeochemical budget ?

The Model - GHER3D

GHER 3D biogeochemical model



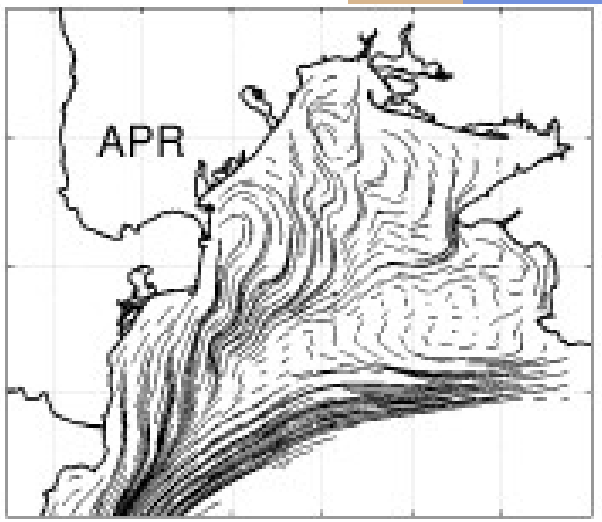
GHER 3D biogeochemical model

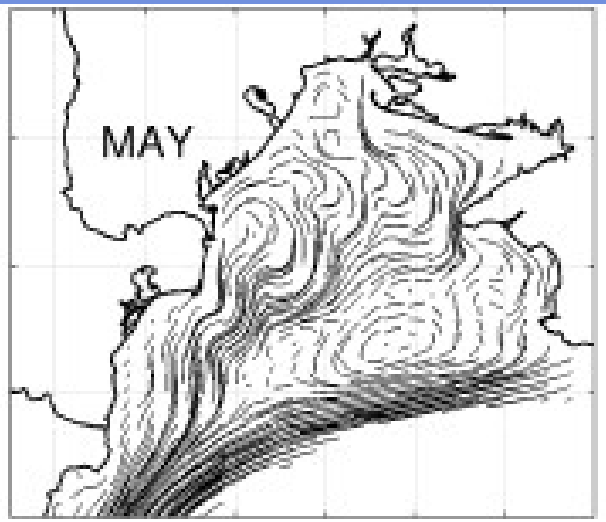
Atmospheric model & data

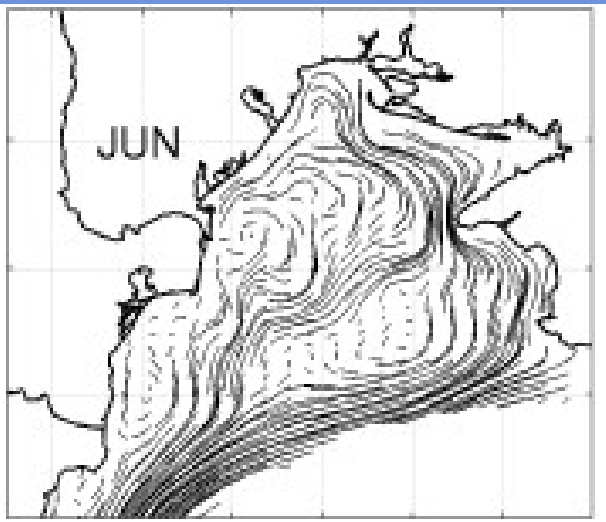
River inputs
(nutrients, freshwater,
suspended matter)

Surface fluxes
(heat , momentum , freshwater)

Hydrodynamics → Currents, mixing, T, S







try

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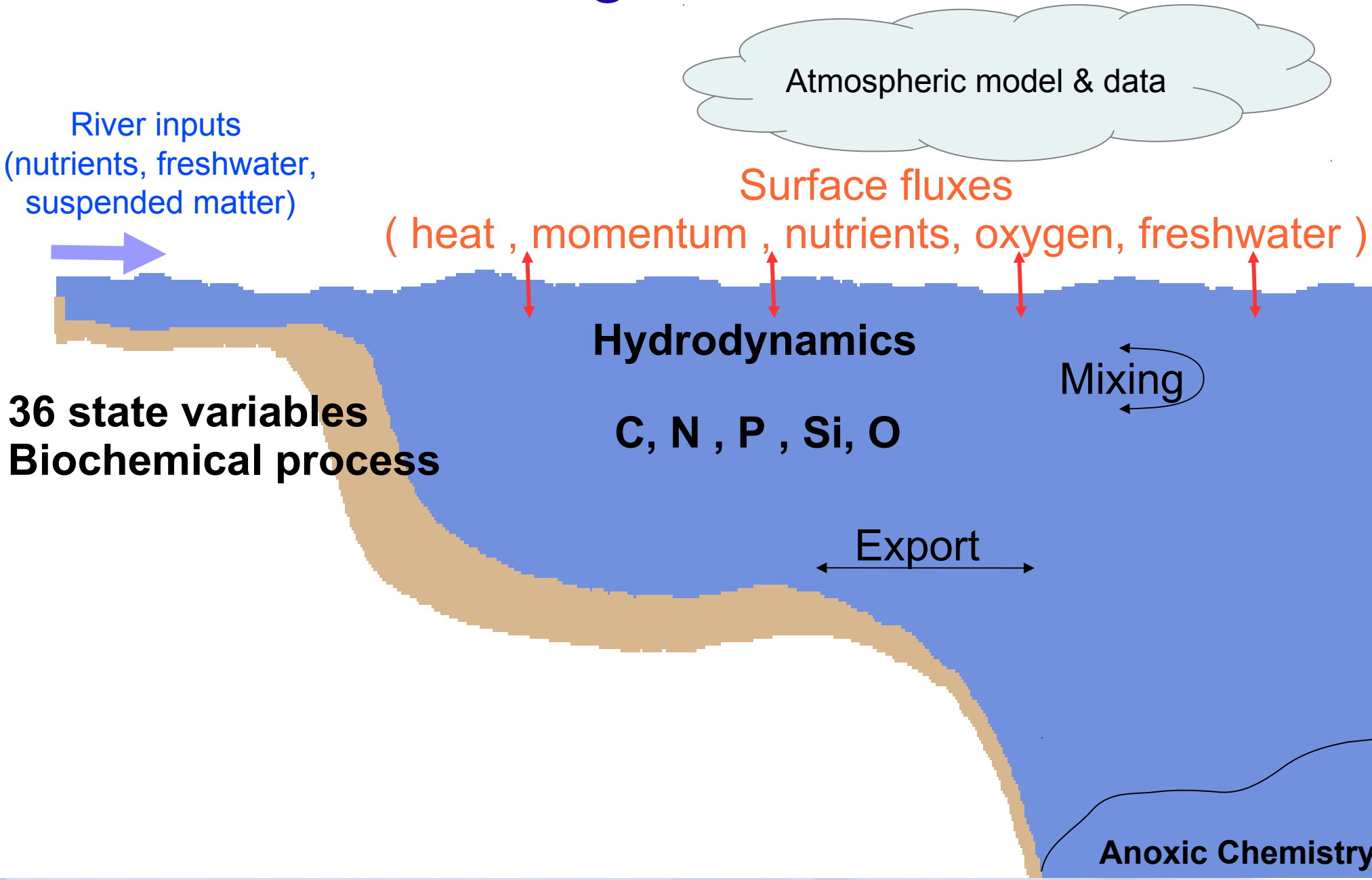

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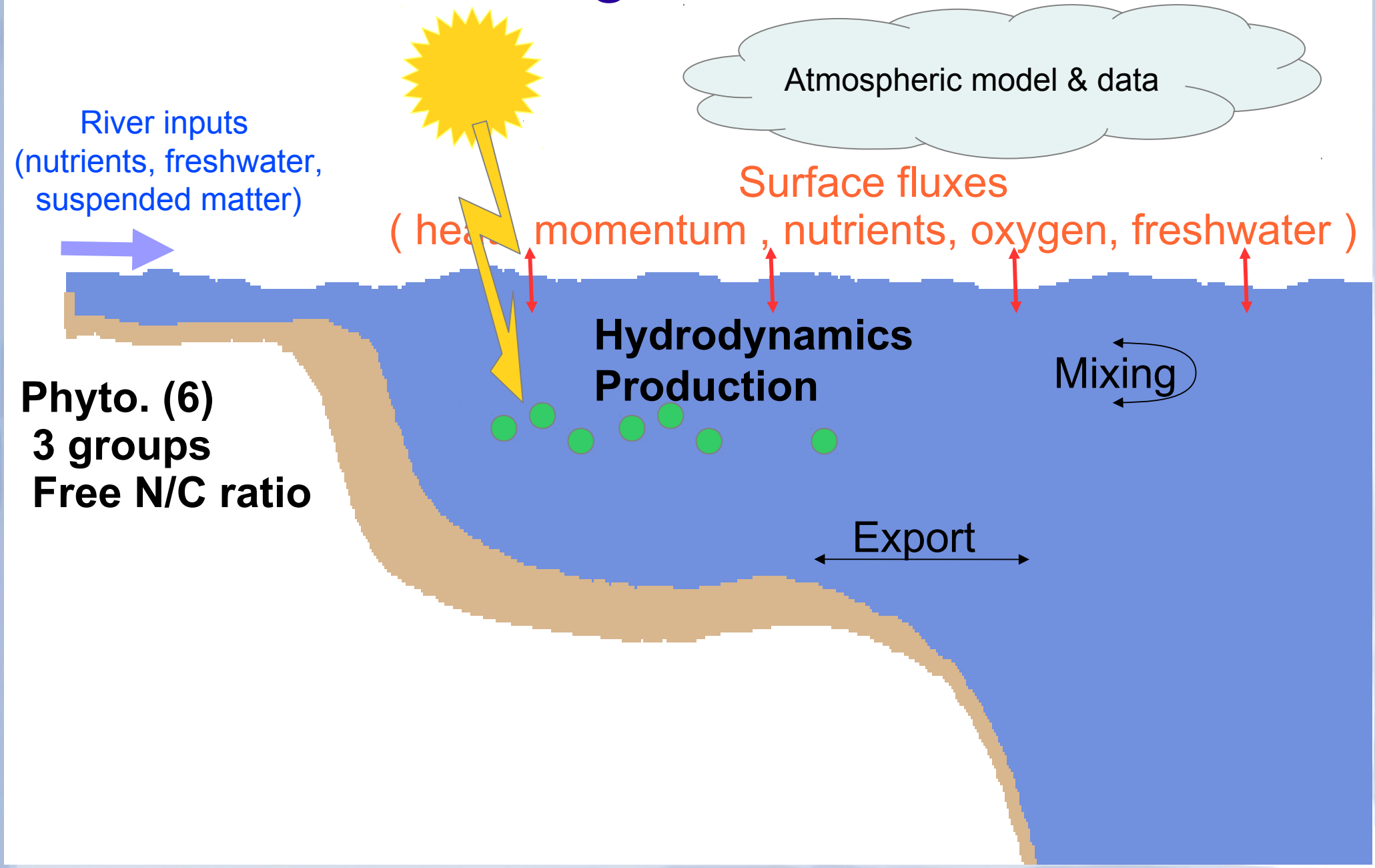

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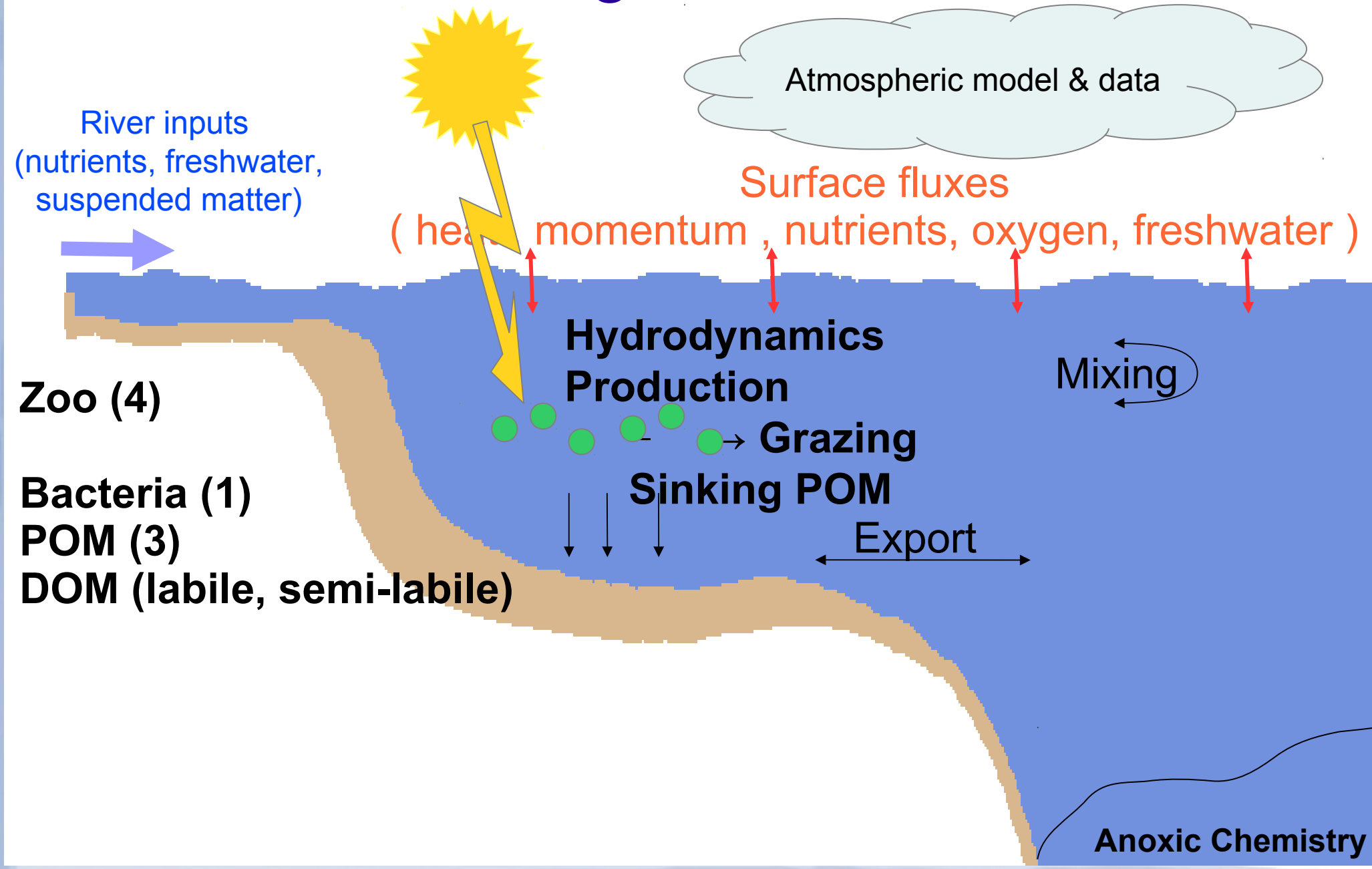

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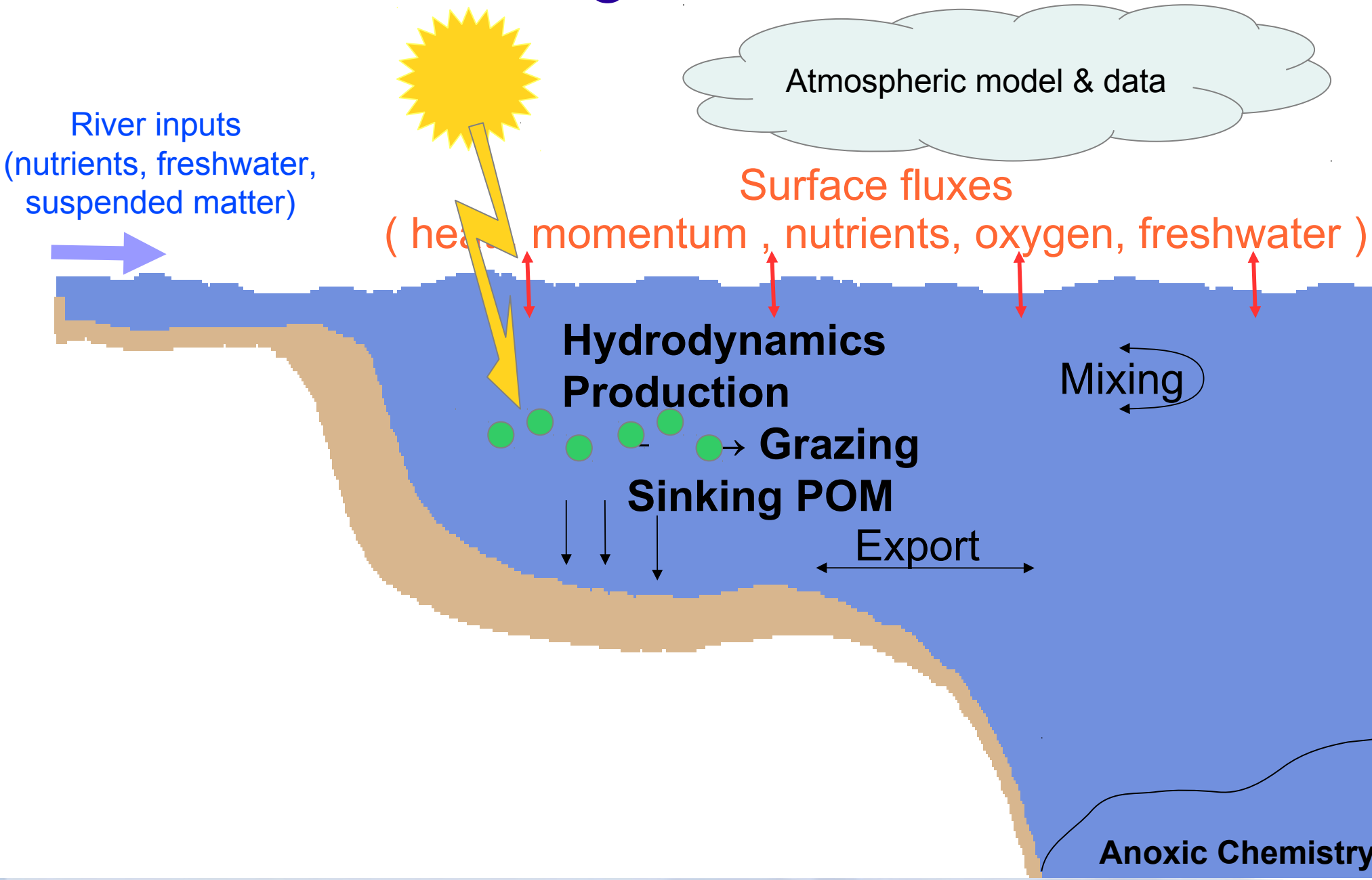
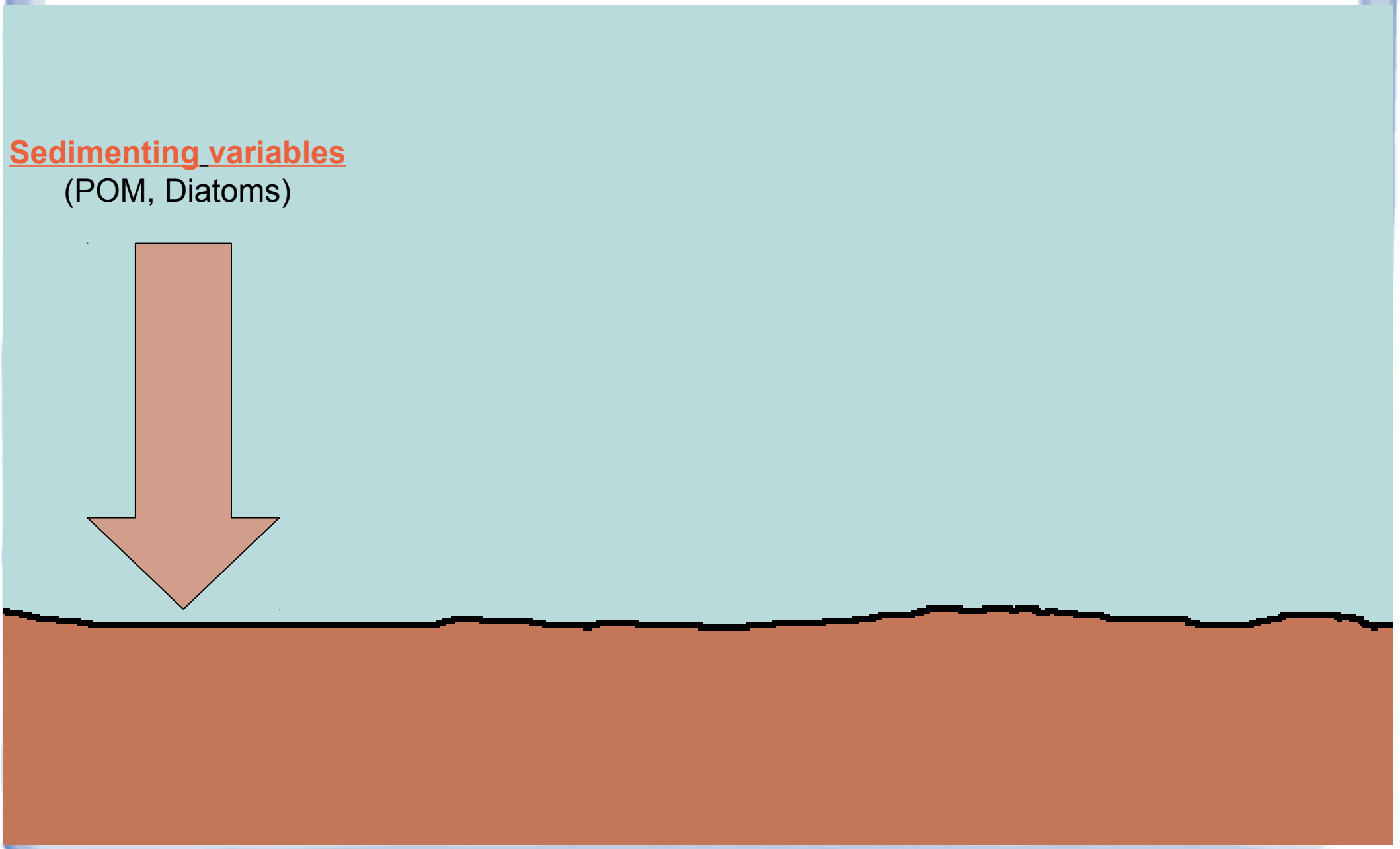


The Benthic Model



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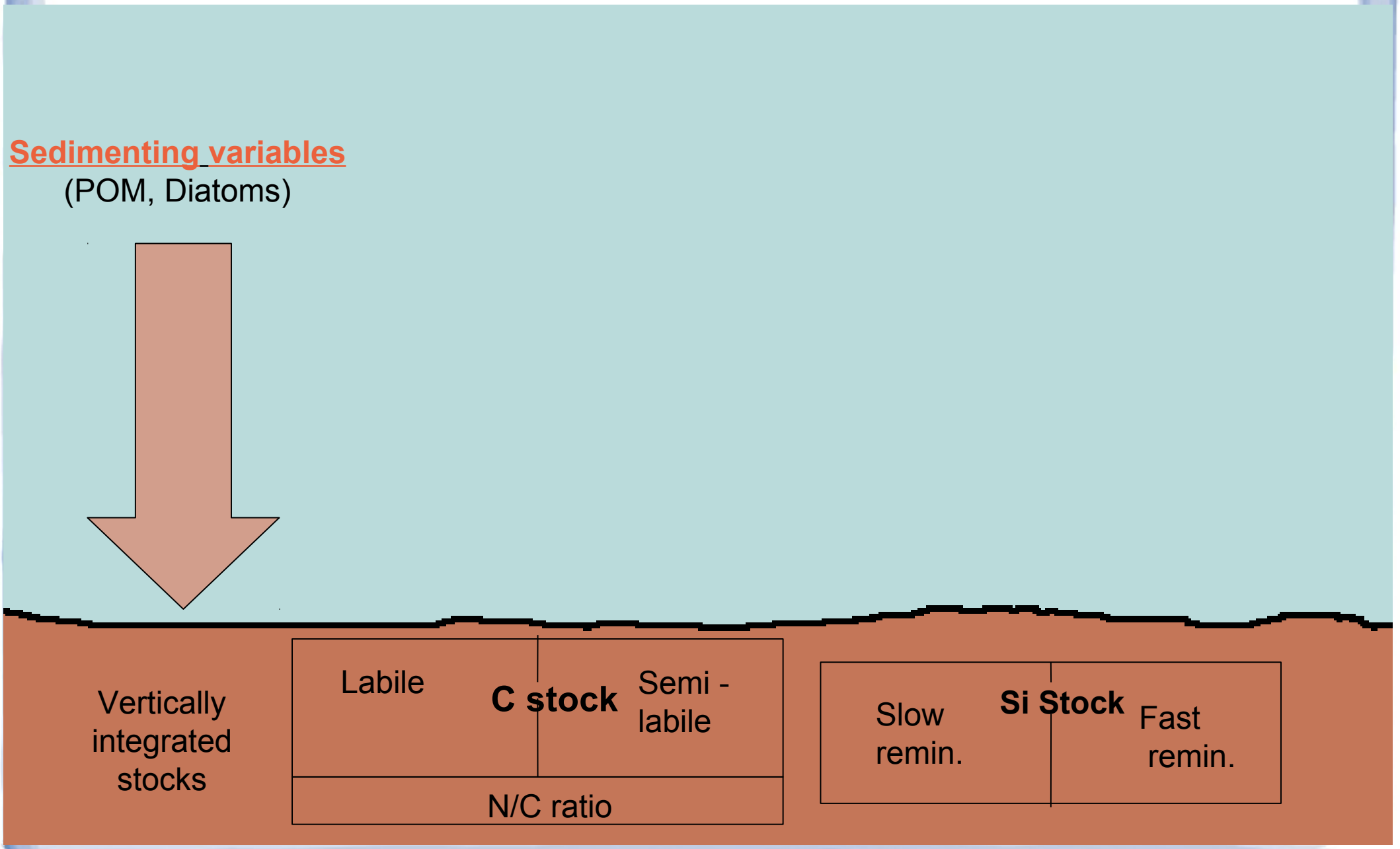

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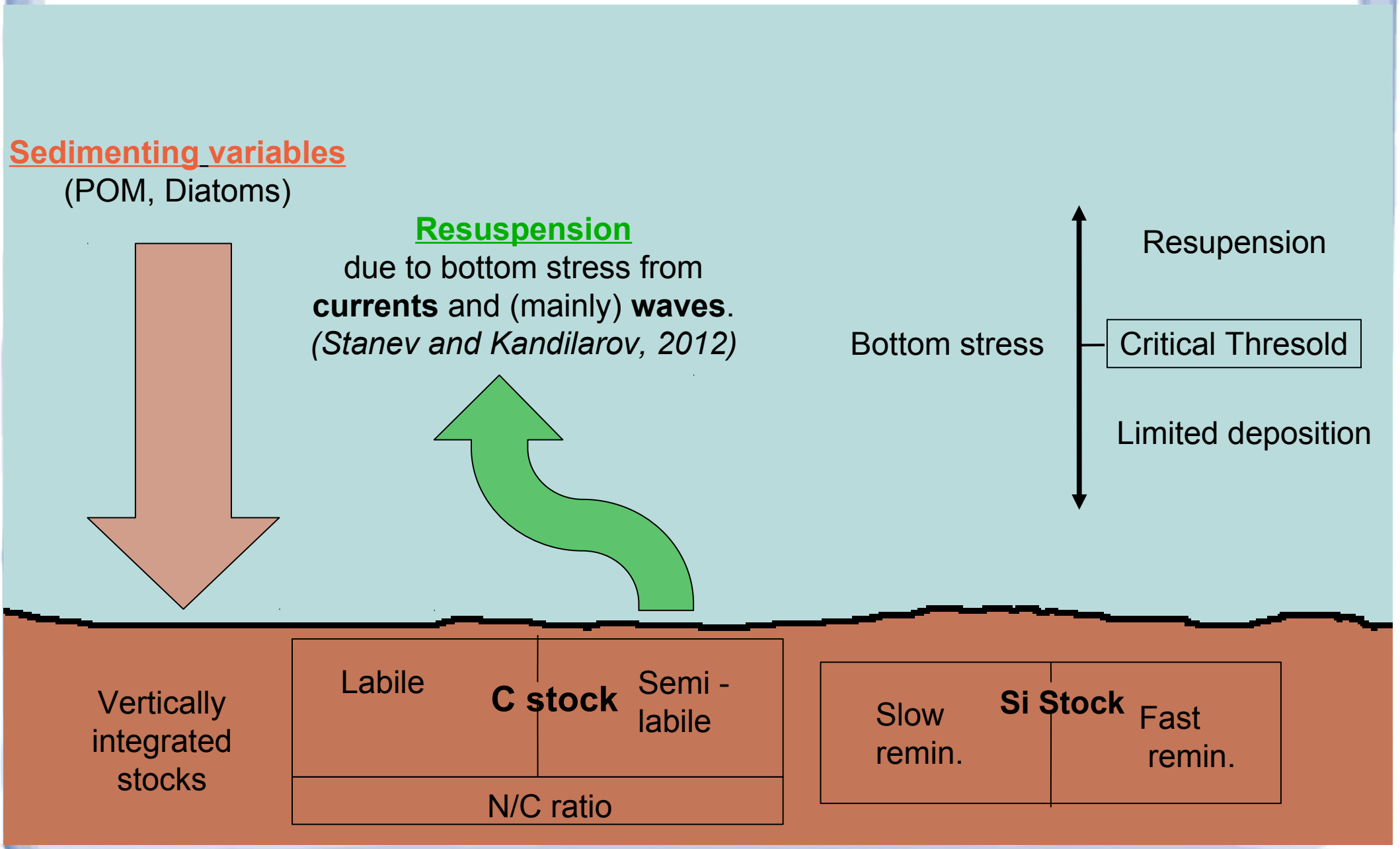


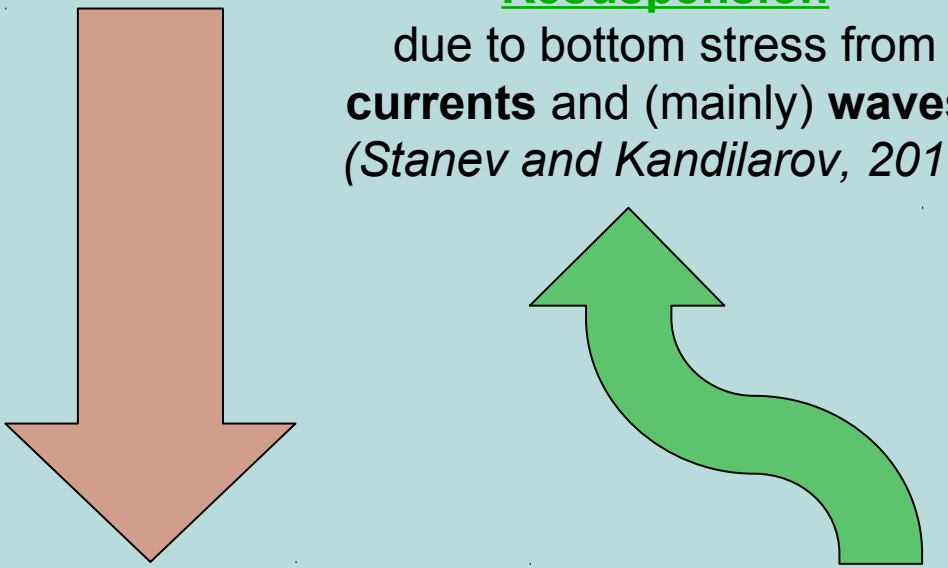
The Benthic Model

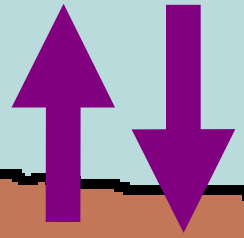
Sedimenting variables
(POM, Diatoms)

Resuspension
due to bottom stress from **currents** and (mainly) **waves**.
(Stanev and Kandilarov, 2012)

Benthic remineralisation
Remineralised content (in mmolC/m²/s)
Cmin = [fast C stock] . K_{fC} . f(T°)
+ [slow C stock] . K_{sC} . f(T°)

Dynamic fluxes of dissolved matter.
(Soetart et al. 2000)





Vertically integrated stocks

Labile | **C stock** | Semi - labile

N/C ratio

Slow remin. | **Si Stock** | Fast remin.

The Benthic Model

$$N_{min}, C_{min}, \ldots \xrightarrow{?} F_{O_2}, F_{NO_x}, F_{NH_4^+}, F_{PO_4^{3-}} ..$$

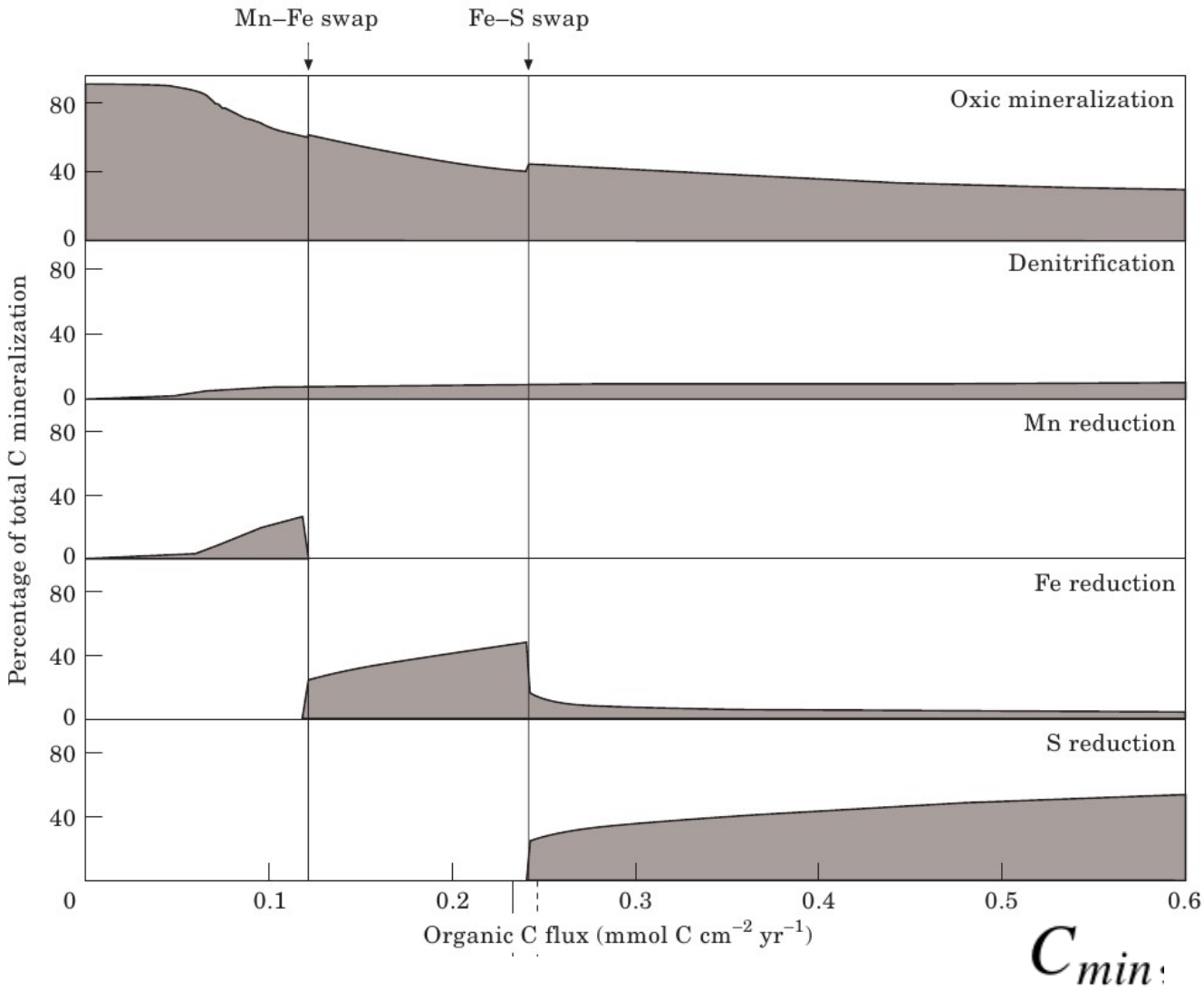
[mmol / m²/s]

Benthic Fluxes

The Benthic Model

Benthic fluxes are not simply proportionnal to the remineralised quantities.

→ Diagenetic processes depends on environmental condition



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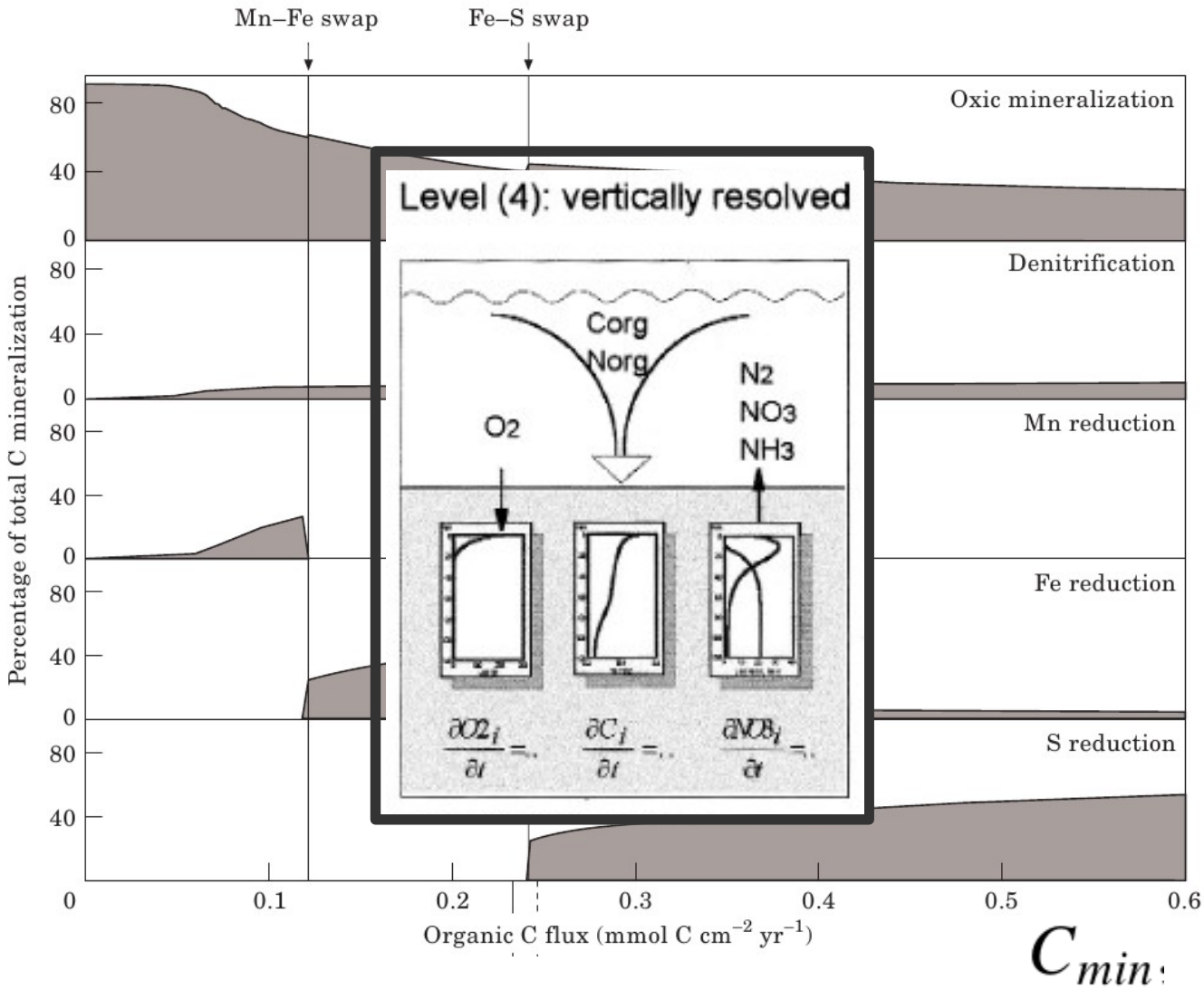
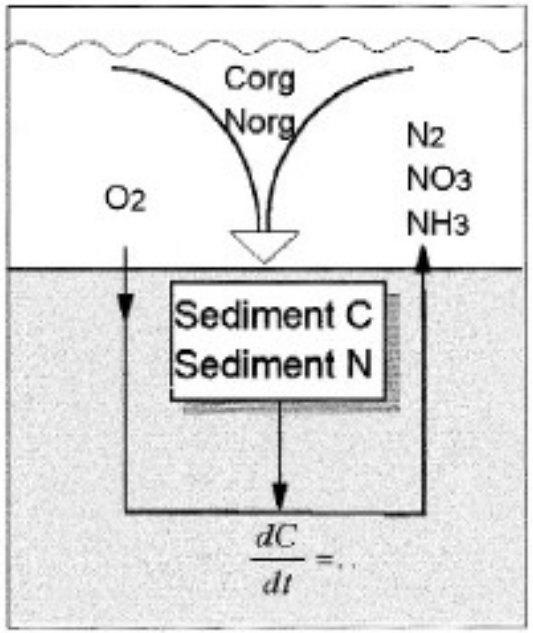


The Benthic Model

Level (3): vertically integrated

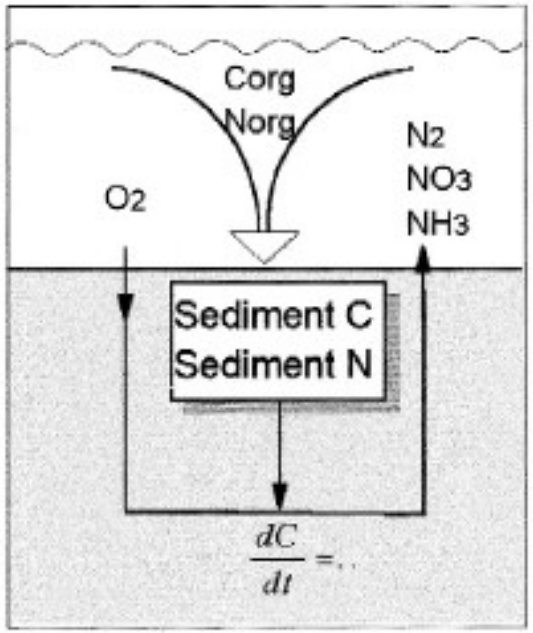


$$F_{\mathrm{NH_4}} = N_{min}.(1 - p_{nit})$$

$$F_{\mathrm{NO_x}} = N_{min}.\, p_{nit} - C_{min}.\, p_{denit}.\, 0.8$$

The Benthic Model

Level (3): vertically integratec



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p_{nit}

p_{denit}

Parameters representing the integrated diagenetic processes

The Benthic Model

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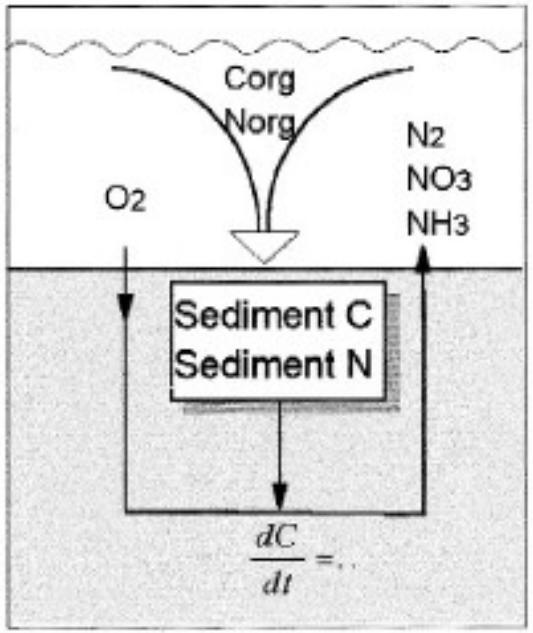

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p_{nit}

p_{denit}

Parameters representing the integrated diagenetic processes

These should vary according to environmental conditions !!

The Benthic Model

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Earth-Science Reviews 51 (2000) 173–201

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On the coupling of benthic and pelagic biogeochemical models

Karline Soetaert *, Jack J. Middelburg, Peter M.J. Herman, Kerst Buis

Netherlands Institute of Ecology, Centre for Estuarine and Coastal Ecology, PB 140, Yerseke 4400 AC, Netherlands

Received 17 February 1999; accepted 7 December 1999

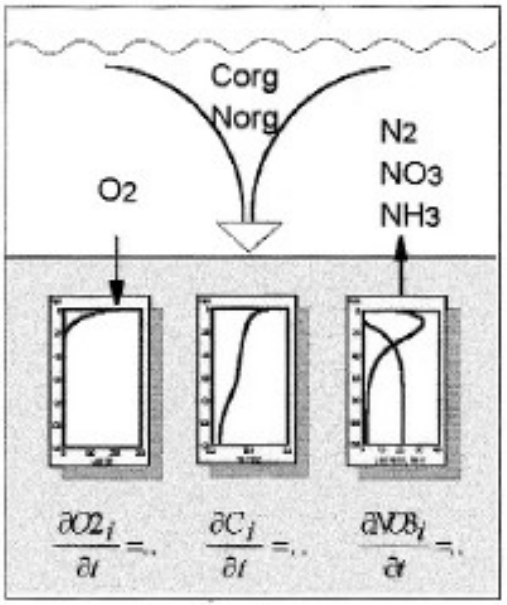
$$\frac{\partial O2_i}{\partial t} = \ldots \quad \frac{\partial C_i}{\partial t} = \ldots \quad \frac{\partial MB_i}{\partial t} = \ldots$$

→ the benthic diagenesis in the 3D model to environmental conditions

The Benthic Model

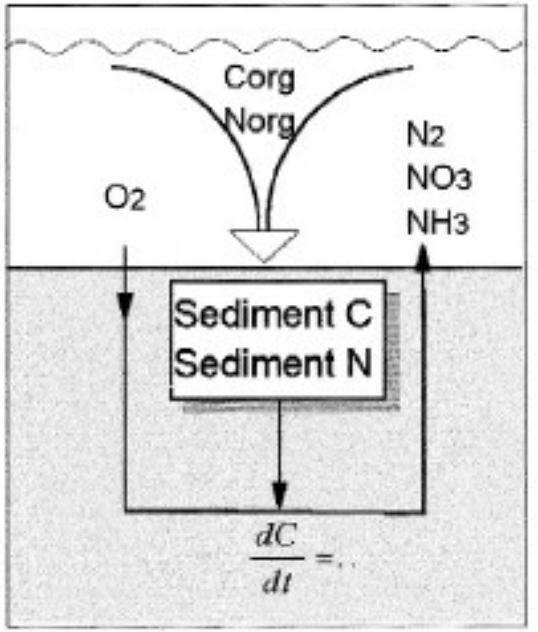
1D sediment model
multiple runs for range of
environmental conditions

Level (4): vertically resolved



$$p_{nit} = f(C_{min}, O_2, \ldots)$$

Level (3): vertically integrated

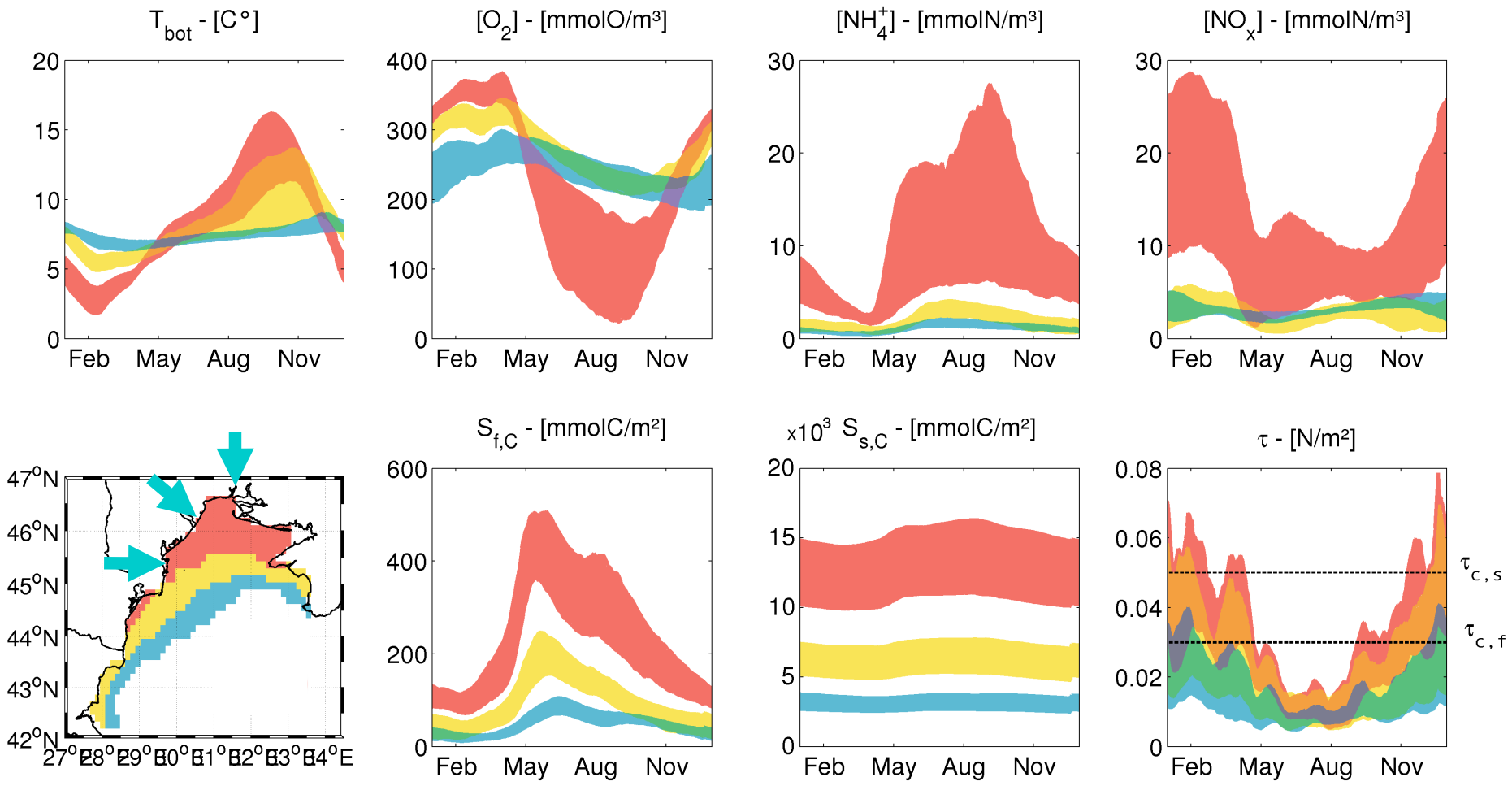


Parametric response of the benthic diagenesis in the 3D model to environmental conditions

K. Soetaert et al. / Earth-Science Reviews 51 (2000) 173–201

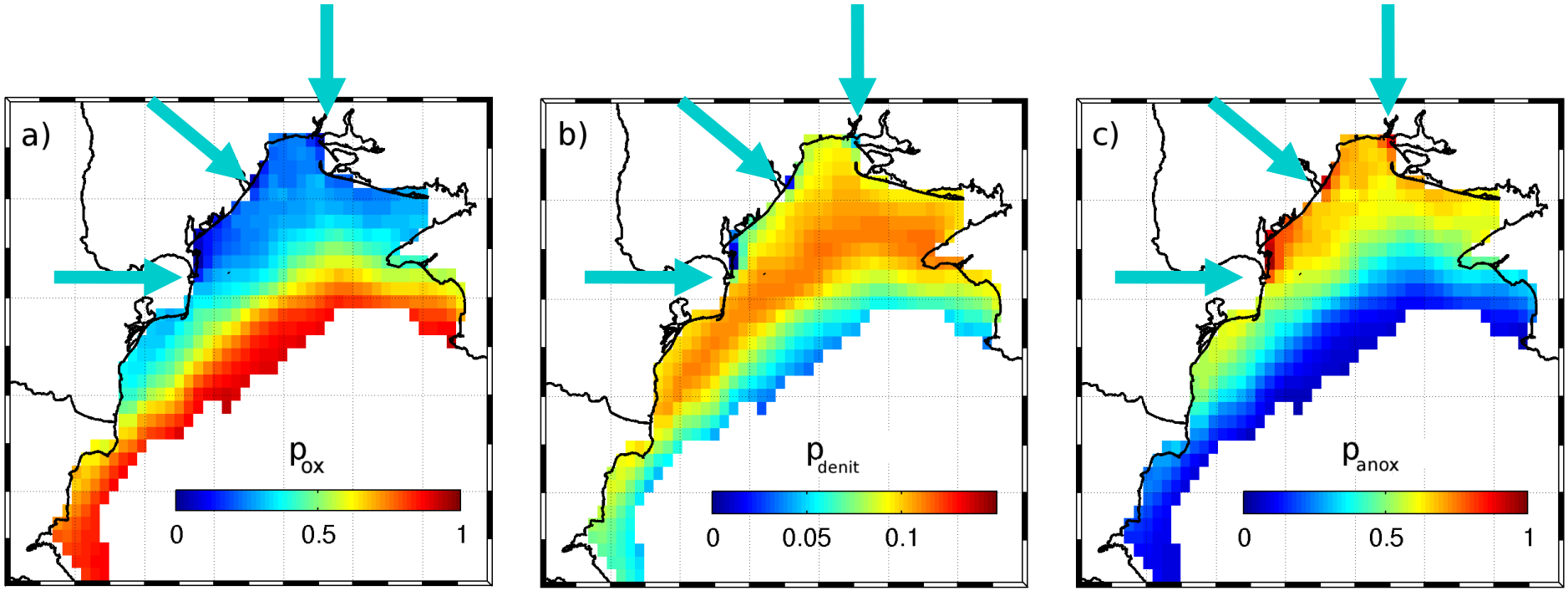
Results

Bottom environmental conditions



25th and 75th interquartile range of spatial variability within each regions

Diagenetic Rates Variability



Aerobic respiration

Denitrification

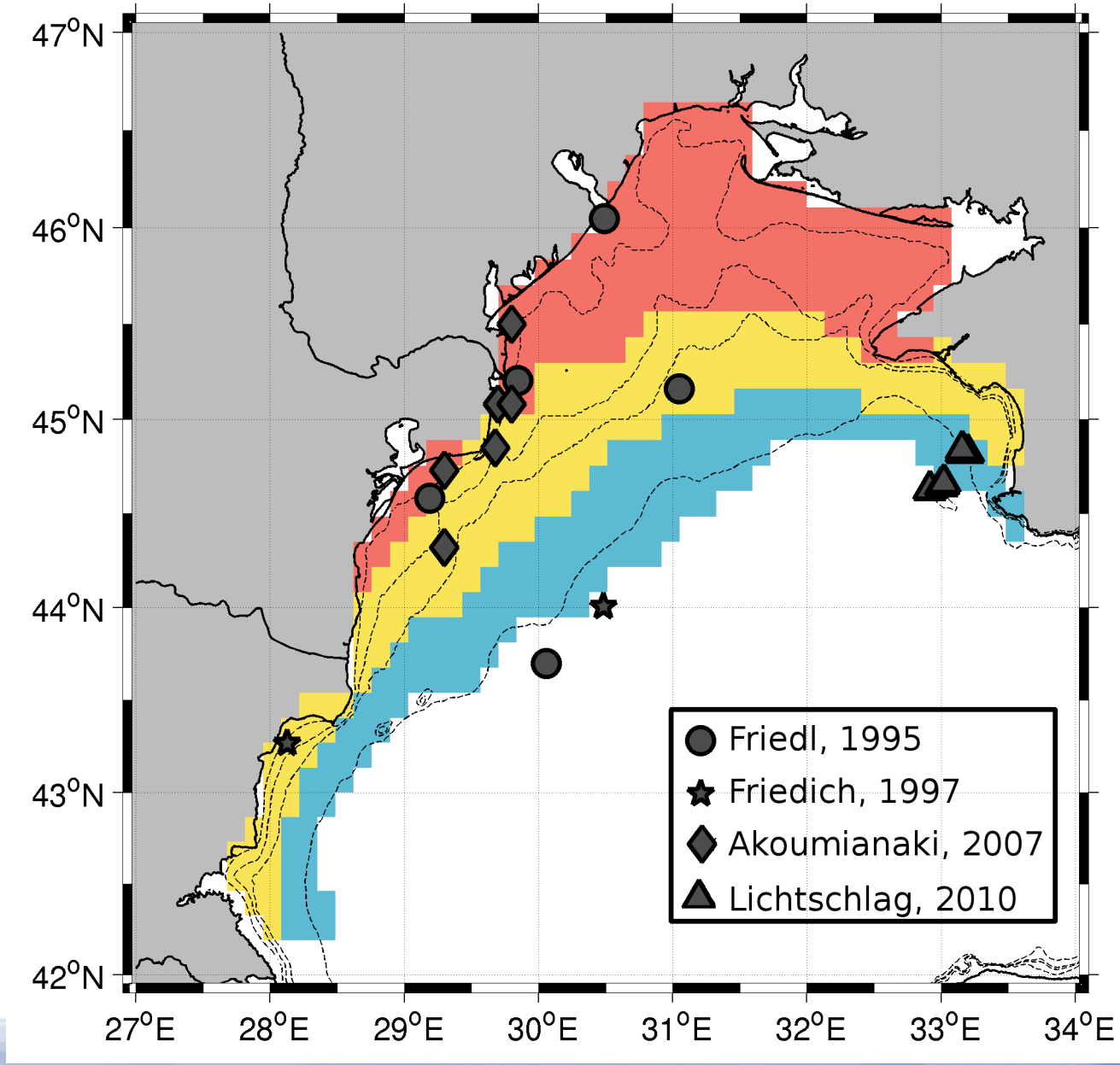
Dissimilatory manganese reduction

Dissimilatory iron reduction

Sulphate reduction

Methanogenesis

Benthic Fluxes



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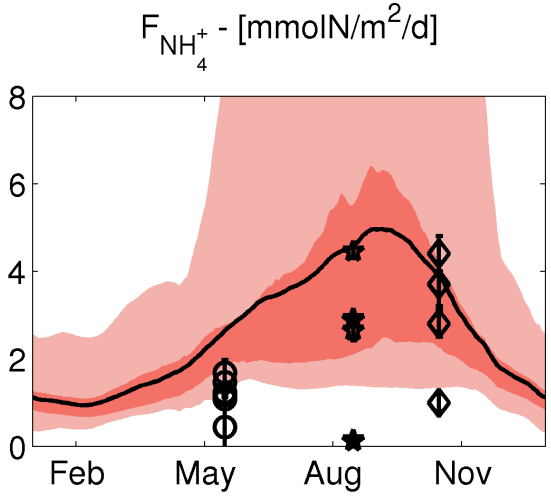
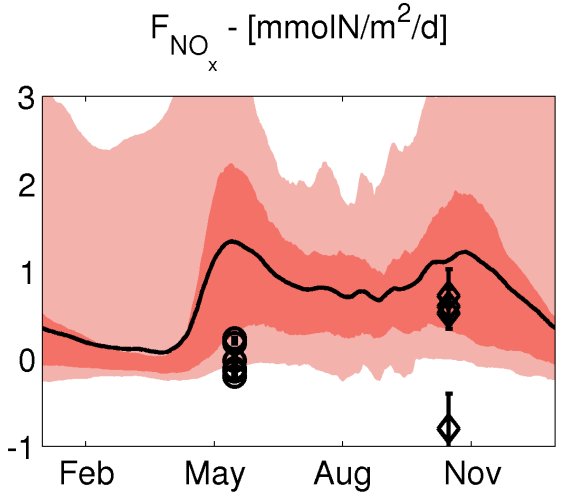
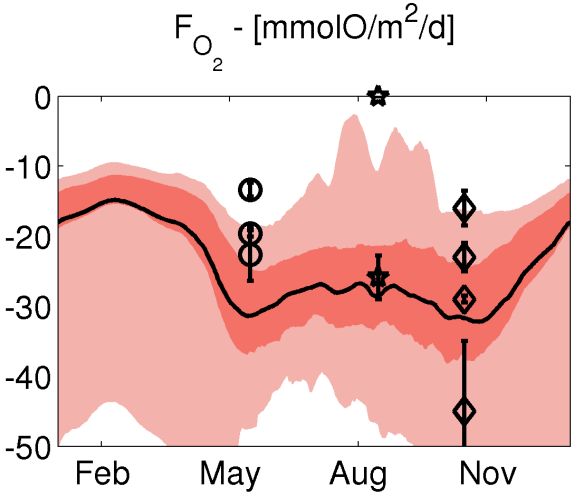
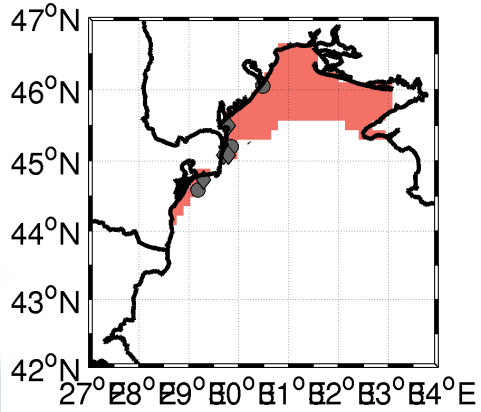
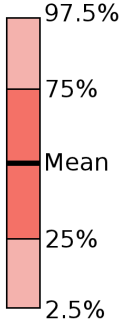
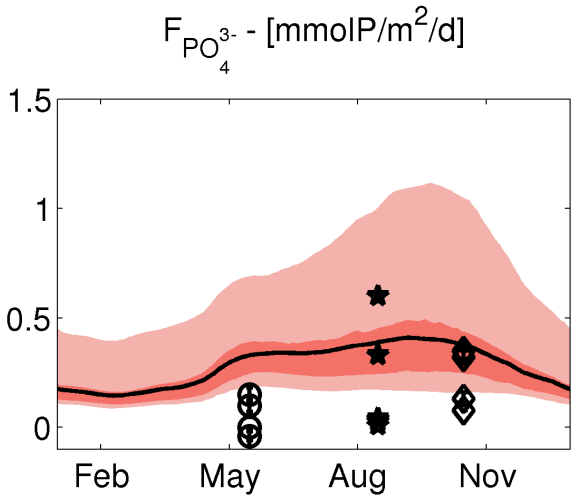


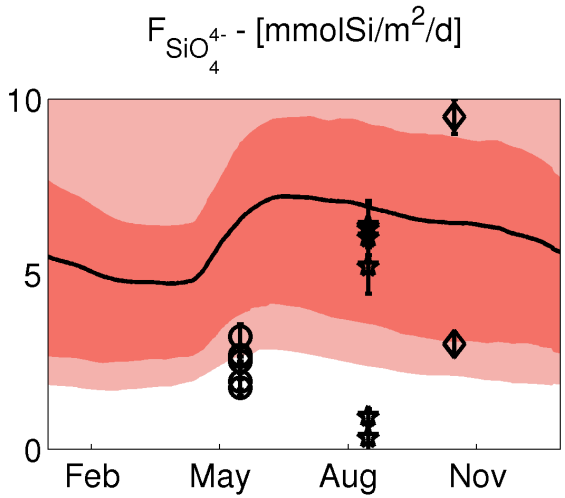




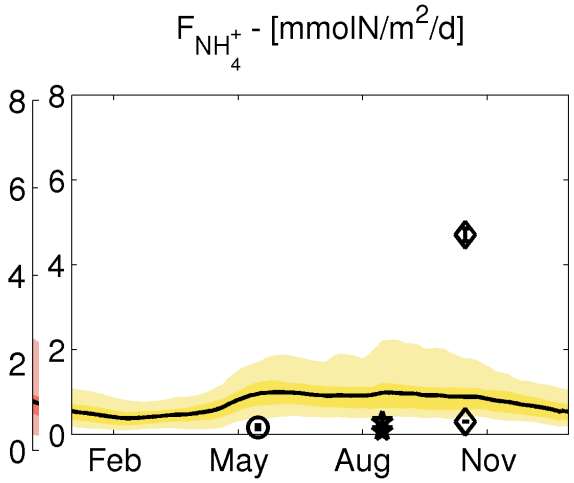


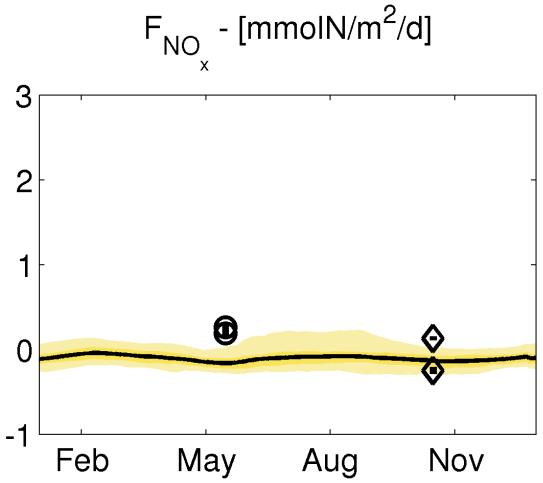


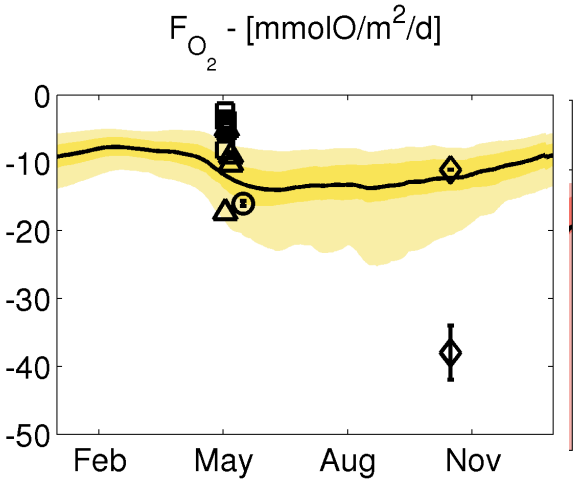


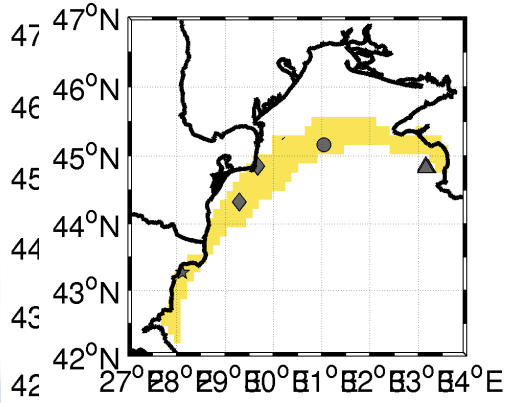


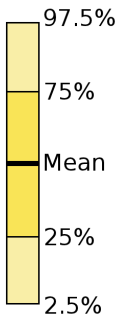
Benthic Fluxes

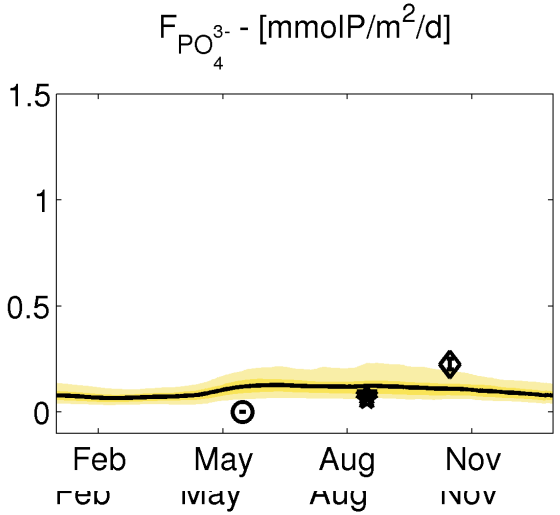


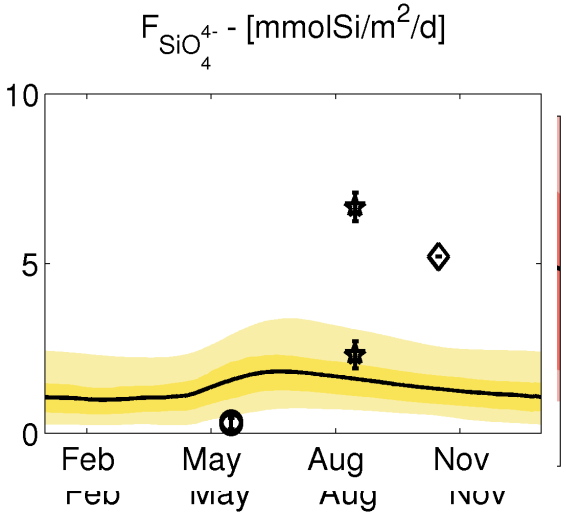




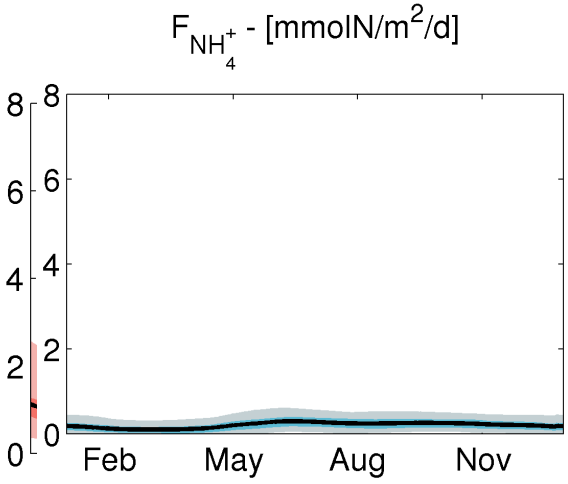


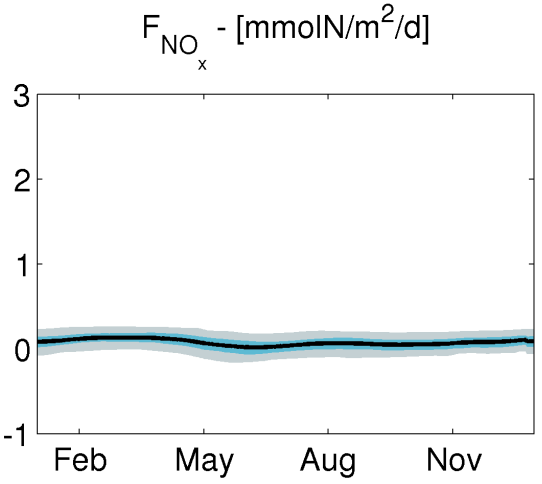


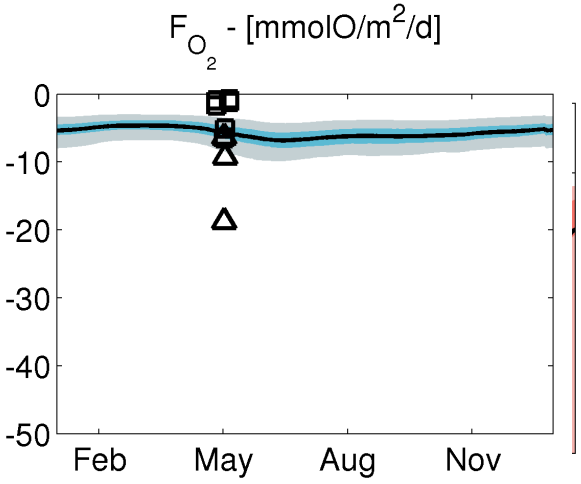


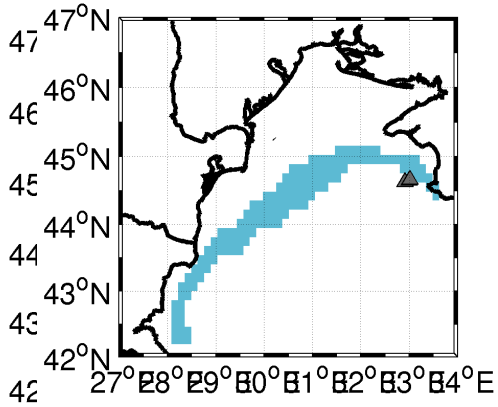


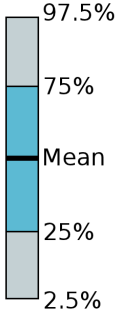
Benthic Fluxes

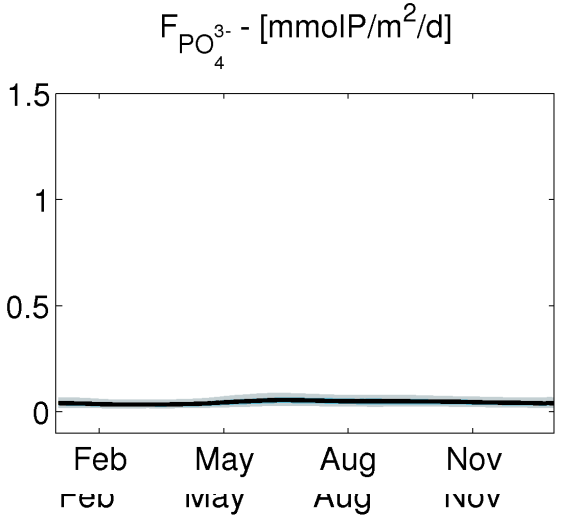


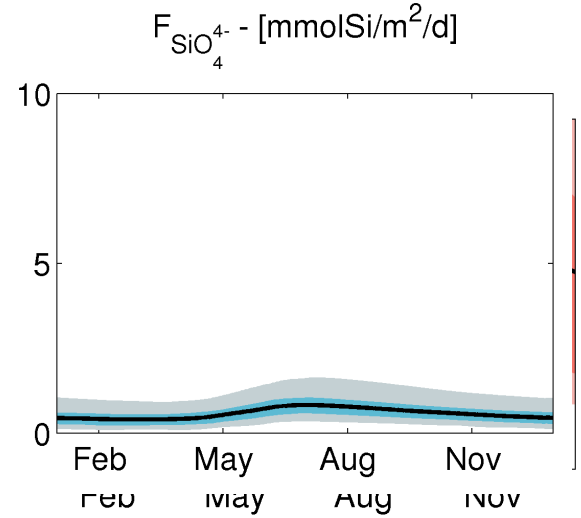






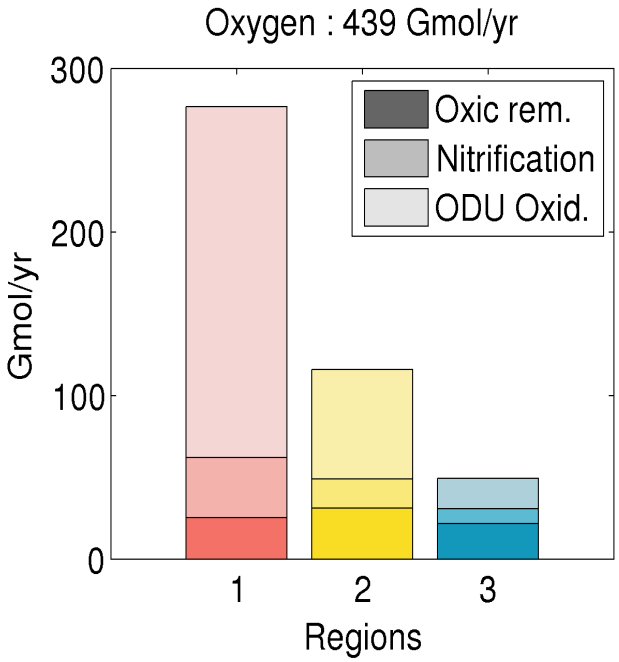


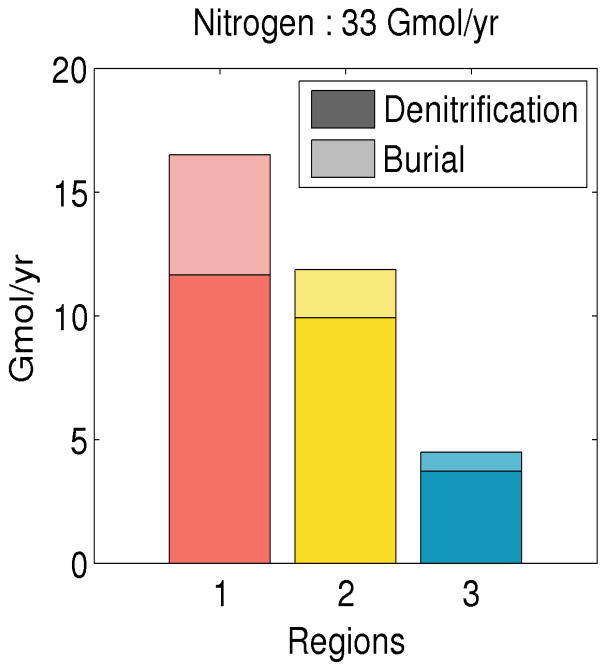


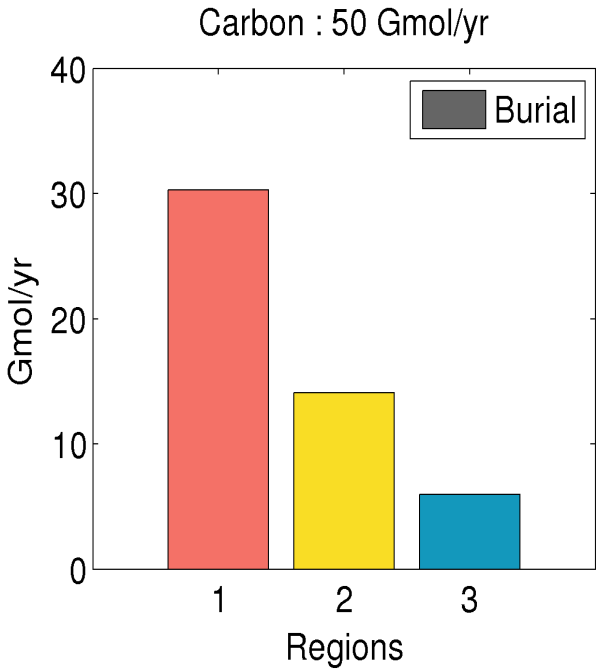


Implications for BGC cycles

Shelf Budgets







Oxygen BOD :

~40 % of oxygen consumption below the mixed layer in summer

Denitrification :

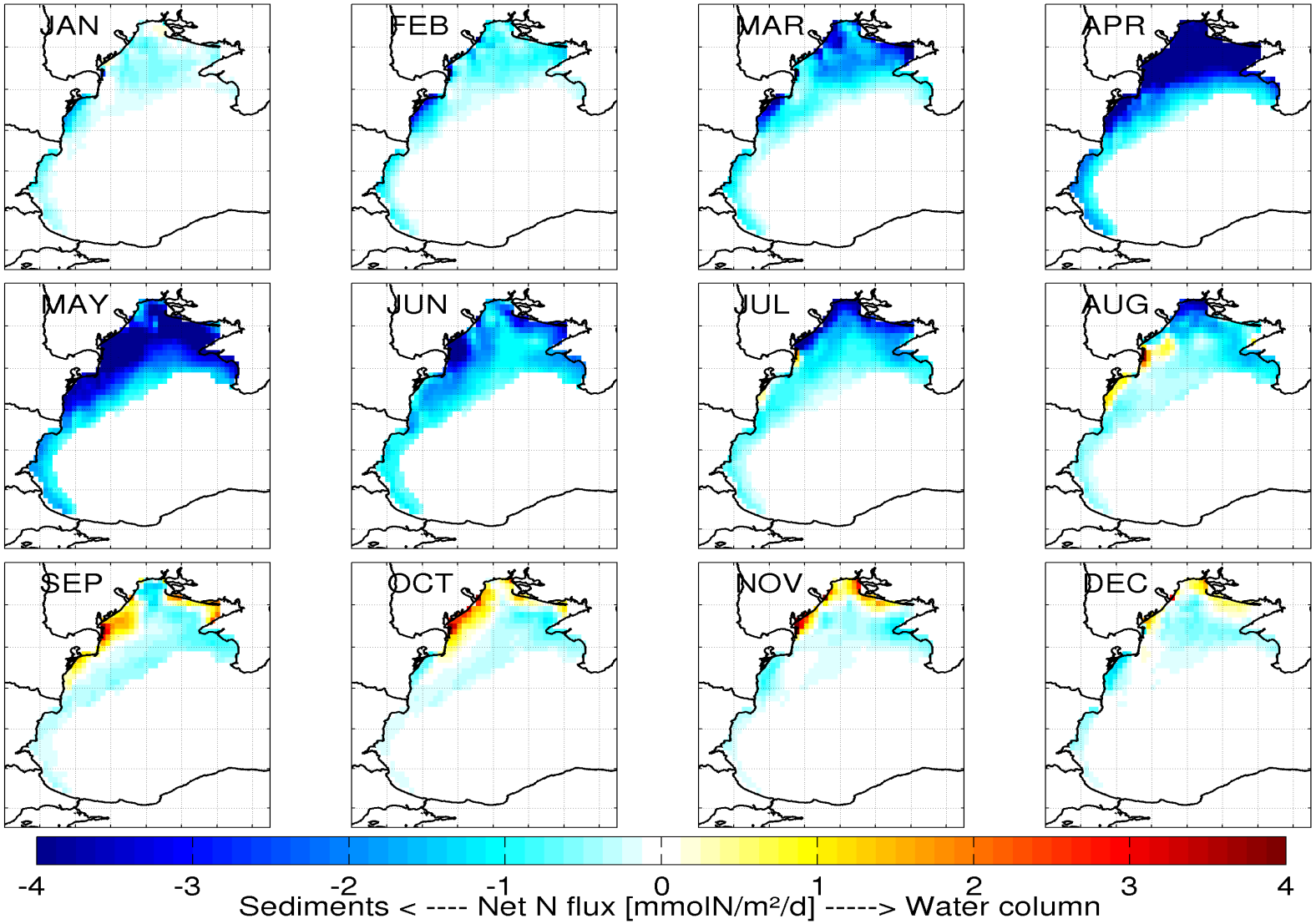
55 % of N input

(River+ Atm. Dep.)

C Burial :

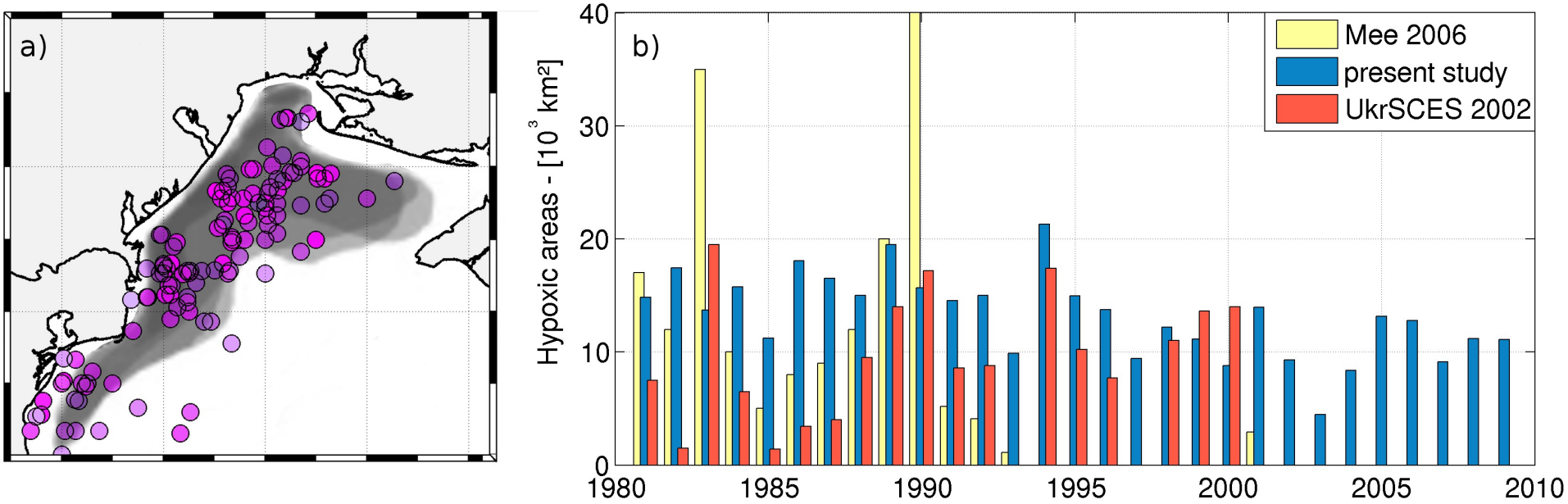
~ 4 % of NPP

Implications : Temporal buffer at seasonal scales



Affect the Seasonal distribution of production

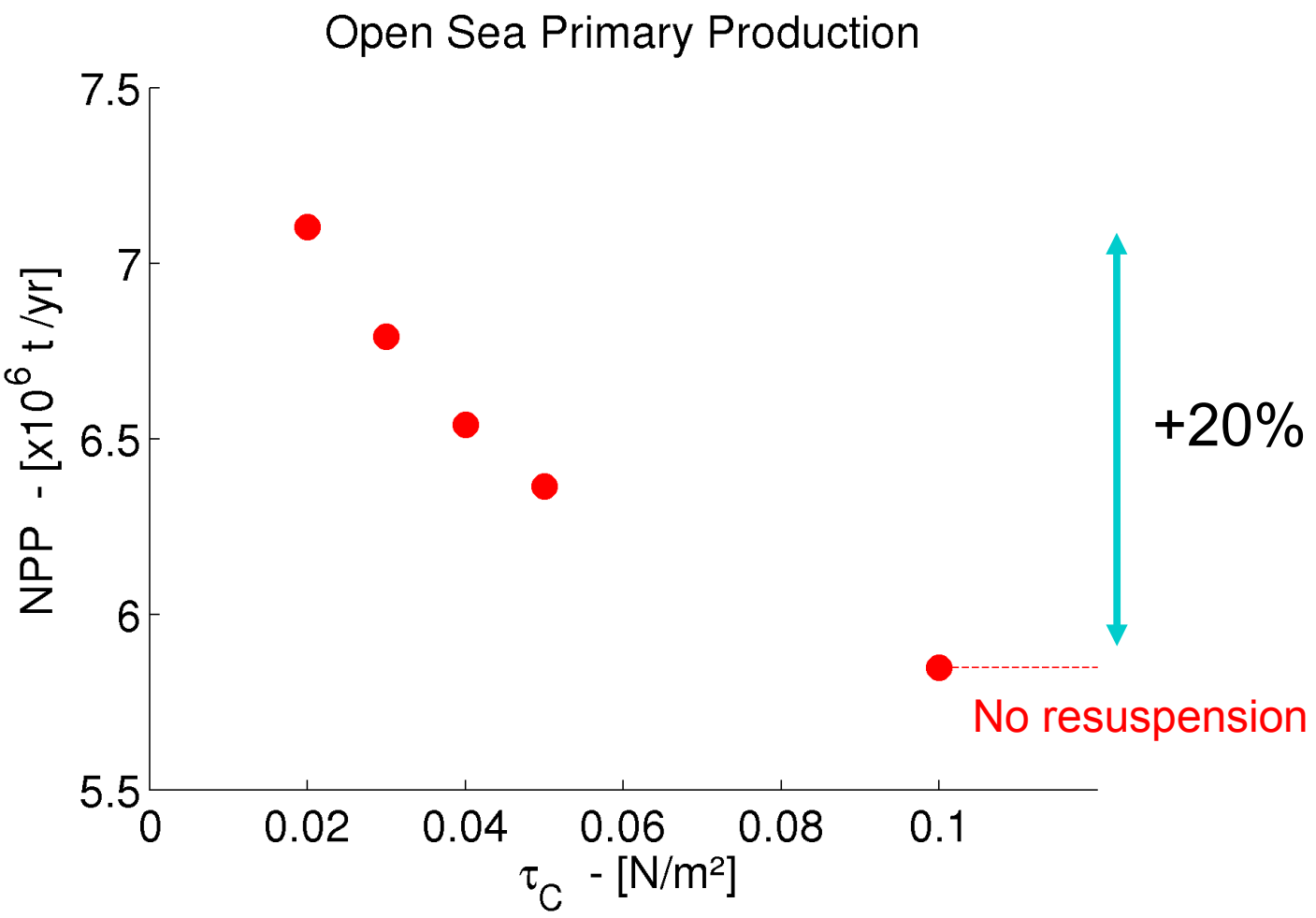
Implications : Temporal buffer at interannual scales



- Hypoxia is intensified by the accumulation of organic matter in the sediments → Inertia after reduction of N discharge.

Capet et al. , 2013, *Drivers, mechanisms and long term variability of seasonal hypoxia in the Black Sea north-western shelf. Is there any recovery after Eutrophication?*, Biogeoscience

Implications : N cycle
Export toward the Open Basin



Conclusion

- Can we ***refine the representation of the benthic-pelagic*** exchanges in a practical way ?

  → Yes , and this is required for a sound representation of the biogeochemical cycles at basin scale.

- What are the ***variabilities of diagenetic process*** and benthic fluxes?

  → Important Spatial variability

  → Important effects on Seasonal and interannual dynamics

- What are the ***implications*** in terms of biogeochemical budget ?

→ Shelf : “Inertial hypoxia”, Denitrification

→ Open Sea : Resuspension allows enhanced export.

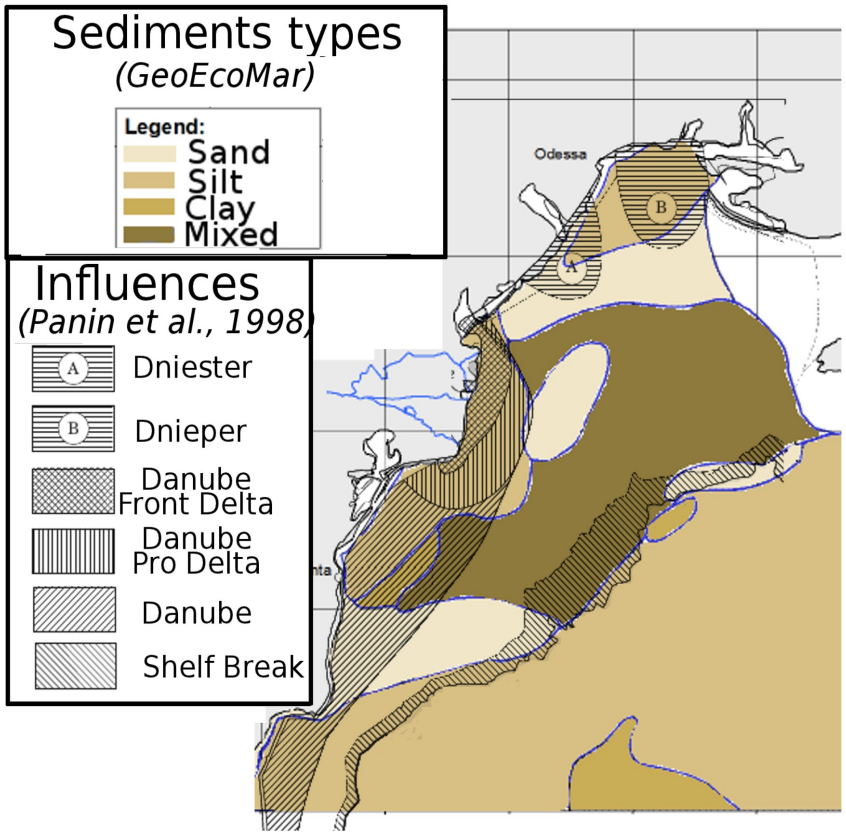
Conclusion

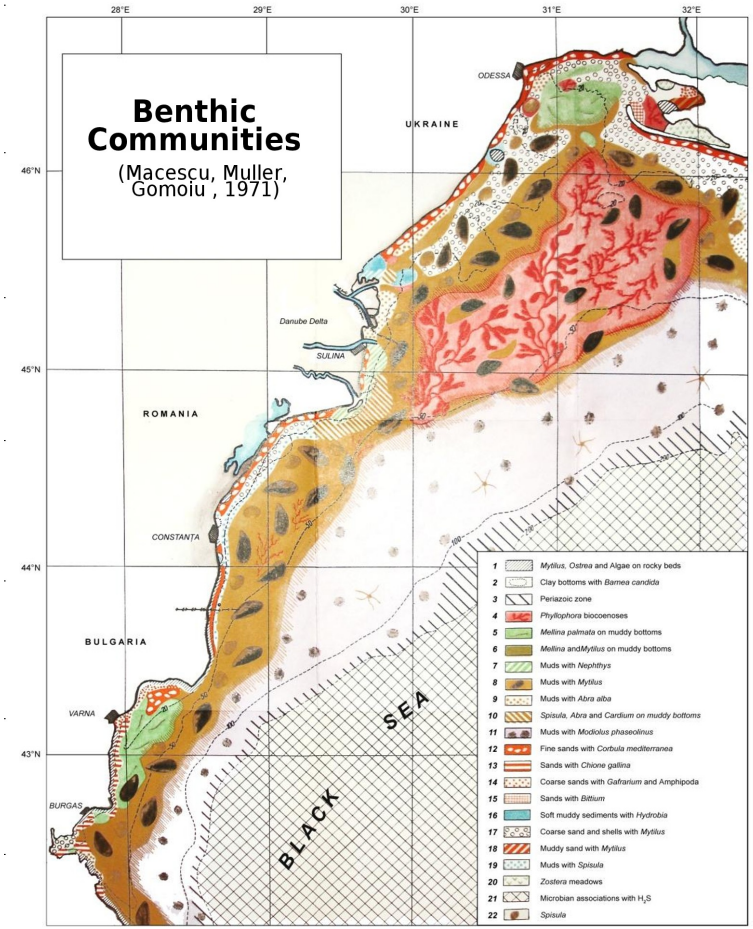
- Are we OK now ?

Conclusion

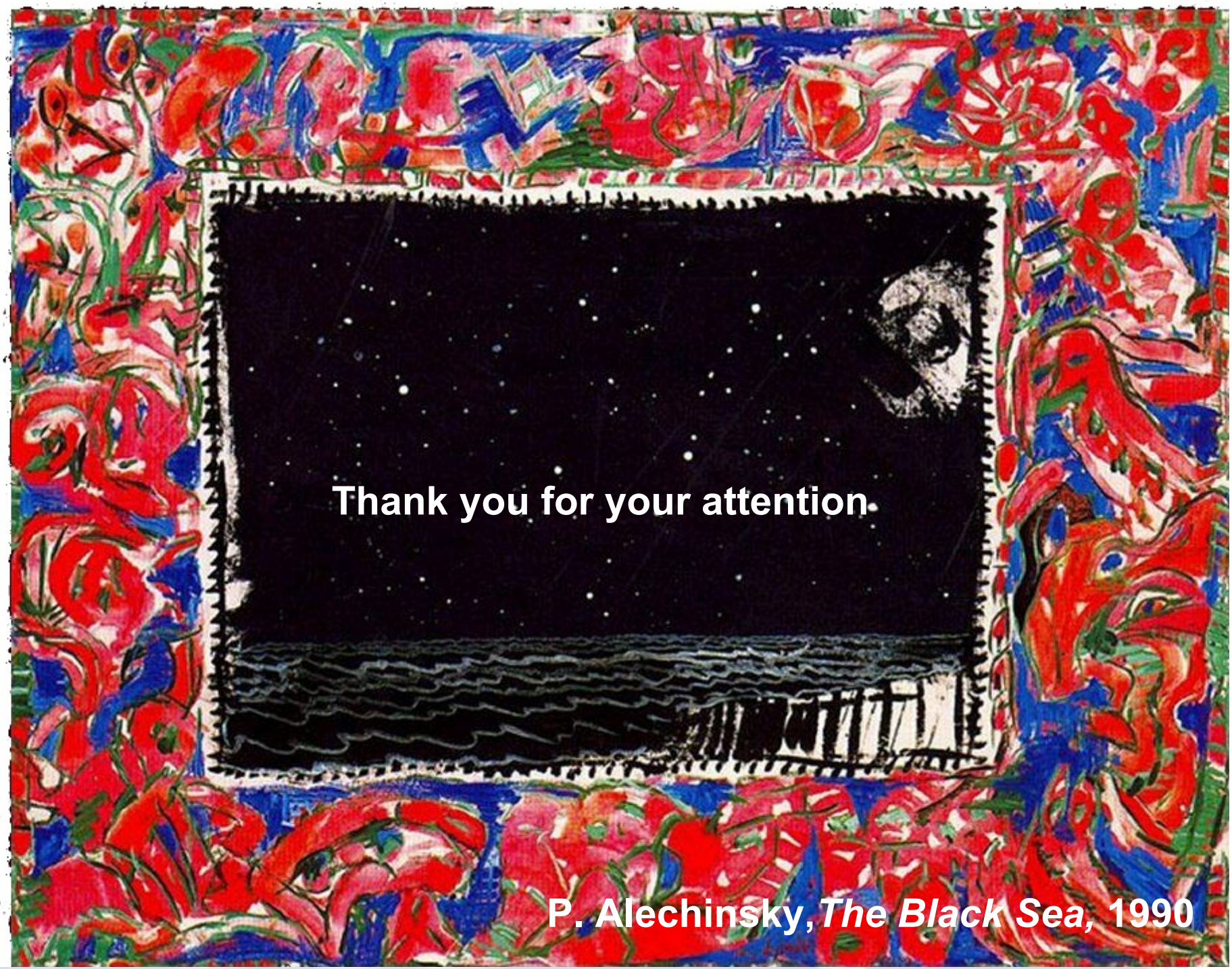
- Are we OK now ? Not yet !

Type of substrate and living benthos affect diagenesis ...

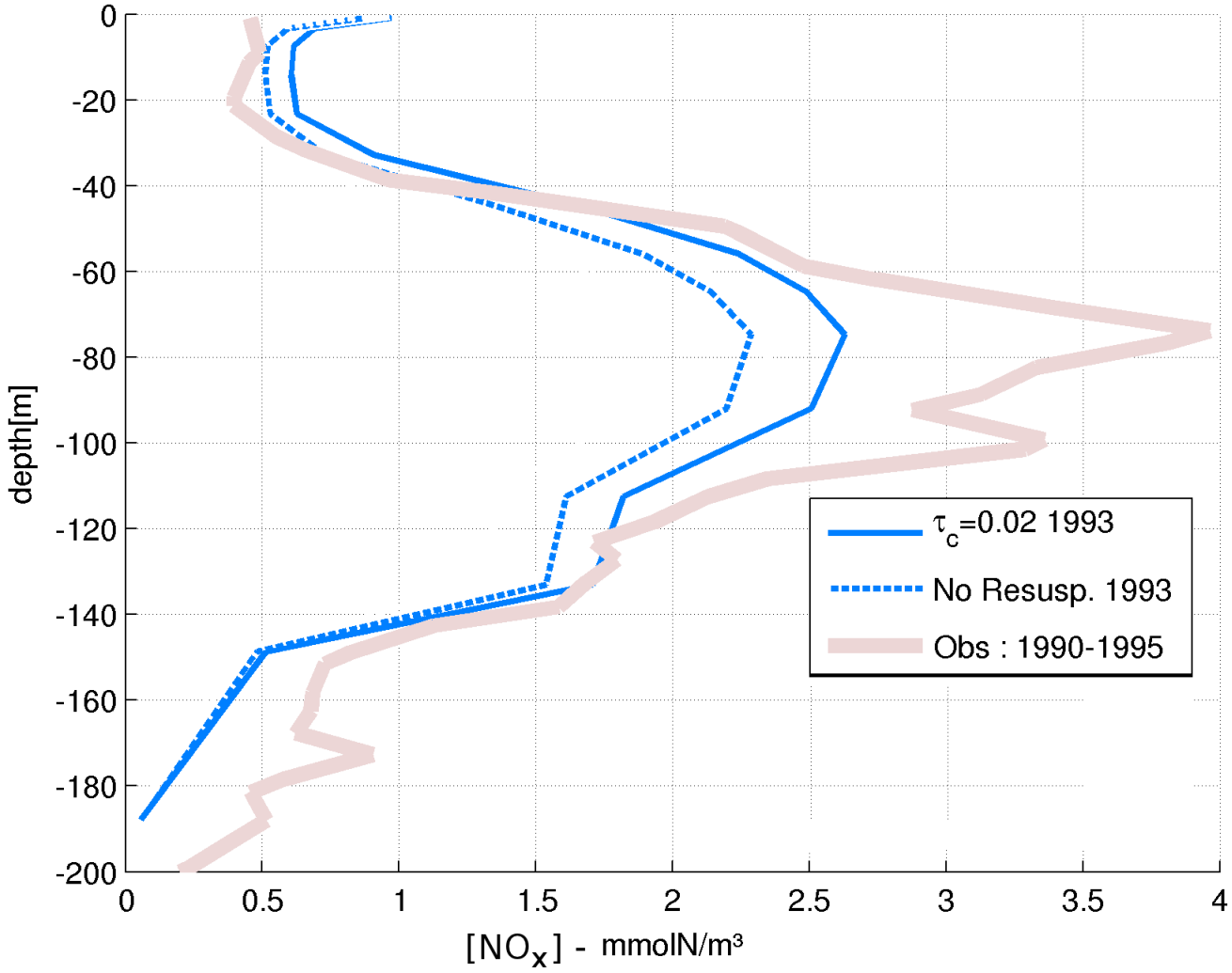




.. And living benthos is responding to environmental conditions ...


Thank you for your attention.
P. Alechinsky, *The Black Sea*, 1990

Implications : N cycle
Export toward the Open Basin



Implications : Hypoxia