Upscaling macro-benthic activity from local diagenesis to biogeochemical cycles

Arthur Capet[1], Audrey Plante[2], Lei Chou[2], Nathalie Fagel[3], Adrian Teaca[4], and Marilaure Grégoire[1]

[1] Modeling for aquatic systems (MAST), ULiege, Belgium, [2] Biogéochimie et modélisation du système Terre, ULB, Belgium, [3] UR AGEs - Argiles, Géochimie et Environnements sédimentaires, ULiege, Belgium, [4] NIRMD, Romania

The Benthox Project: Objectives & Concepts

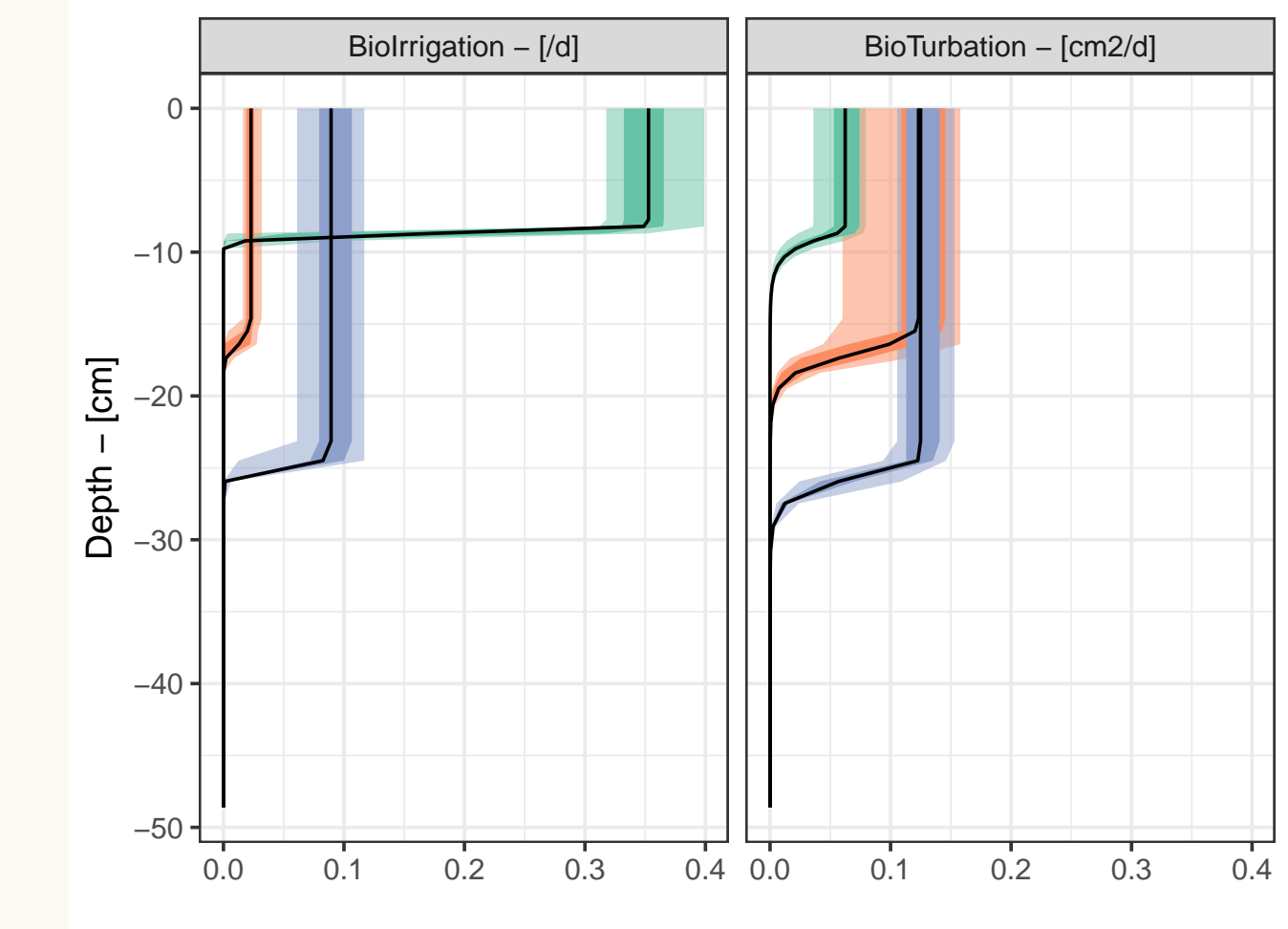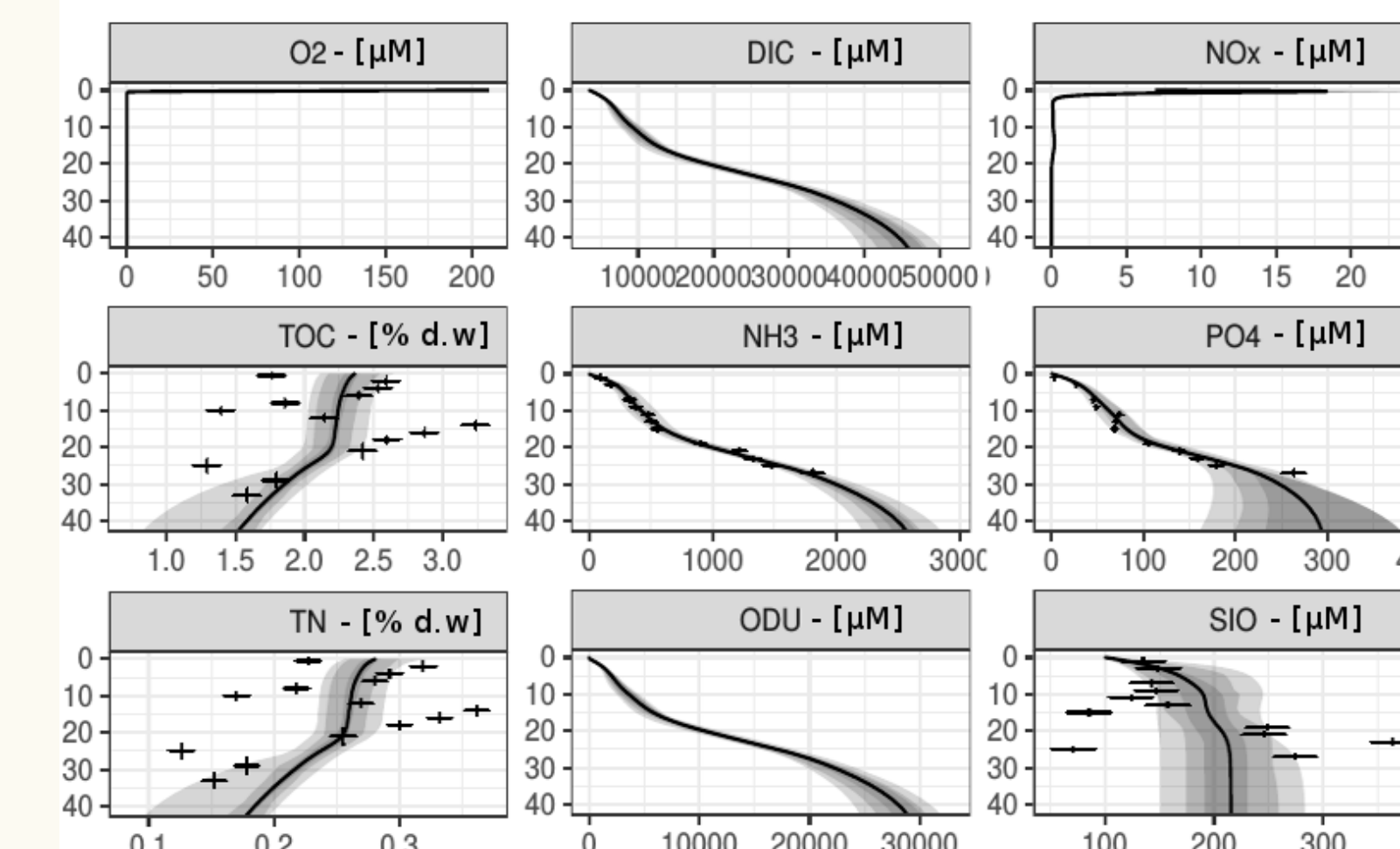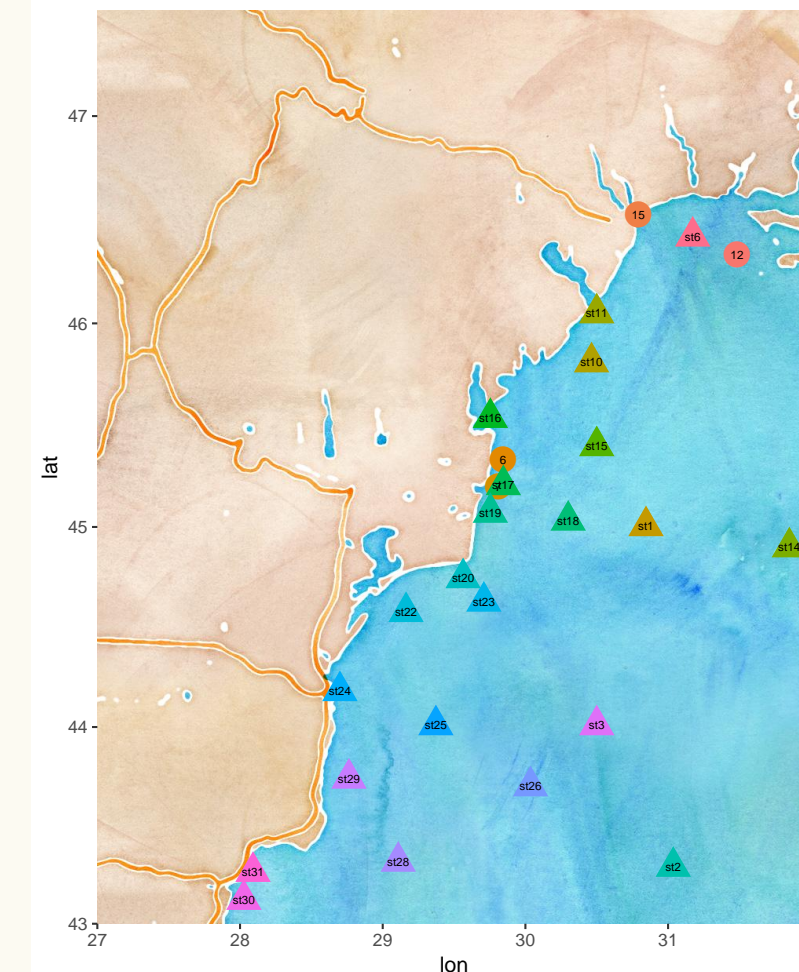To resolve the **role and response** of **macrobenthos** in coastal **hypoxia** dynamics

Coastal Hypoxia — Habitat — Meta-Modelling — Traits — Macrobenthos — Functions

km ◁ Scales ▷ mm
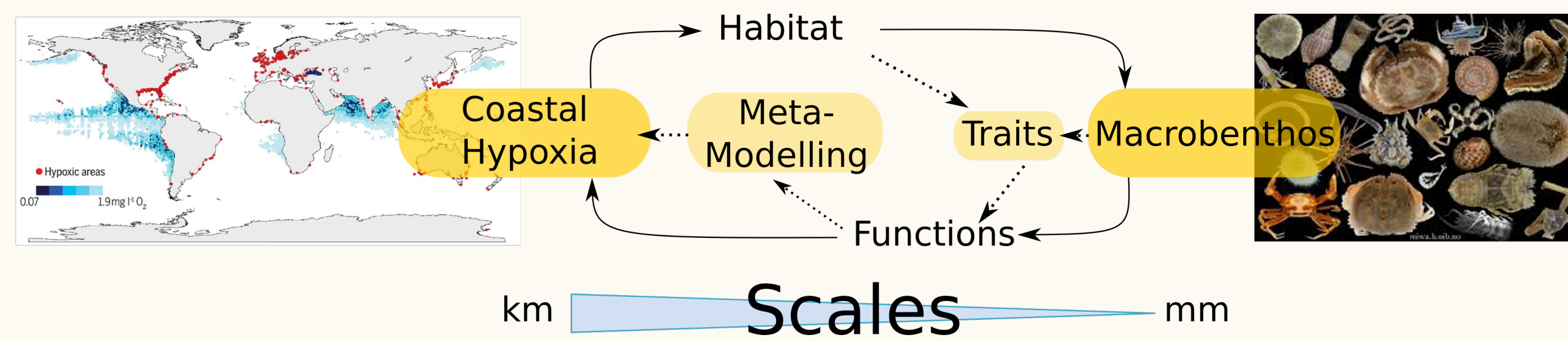
Work hypotheses
- $[O_2]$ shapes the distribution of **benthic populations & activity**
- **Macrobenthic activity** affects **Benthic-Pelagic coupling**

Assumptions to conciliate spatial scales
- We use **functional traits** to synthetize macrobenthic activity
- We use **bentic meta-models** to represent diagenesis in a 3D model

Methodology

In-Situ → Profiles / Fluxes → Calibration → 1D Diagenetic model (OMEXDIA)
Van Veen → Sed. characs → Species
Databases → Traits → Trait Distribution → 3D model (BAMHBI)
Perturbation → Meta-Models
Regression (logistic)
Incubation / Coring

Conclusions & Perspectives

Conclusions
- Facies of macrobenthic activities are identified from sediment core analyses
- Accounting for diversity in macrobenthic activity affect pelagic biogeochemistry in coupled models
- Restrained irrigation limits benthic denitrification

Perspectives
- Functional Traits-Habitat analyses will be used to set the distribution of facies in the 3D model (see poster by M. Grégoire).

References

1 Capet, A., Meysman, F. J. R., Akoumianaki, I., Soetaert, K. & Grégoire, M. Integrating sediment biogeochemistry into 3D oceanic models: a study of benthic-pelagic coupling in the Black Sea. Ocean Model. (2016).
2 Soetaert, K., Middelburg, J. J., Herman, P. M. J. & Buis, K. On the coupling of benthic and pelagic biogeochemical models. Earth-Sci. Rev. 51, 173–201 (2000).
3 Wijsman, J. W. M., Herman, P. M. J. & Gomoiu, M. T. Spatial distribution in sediment characteristics and benthic activity on the northwestern Black Sea shelf. Mar. Ecol. Prog. Ser. 181, 25–39 (1999).

1D diagenetic calibration → Facies of macrobenthic activity


Domain: The Black Sea northwestern shelf.
Data: porewater nutrient, solid phase, benthic fluxes
**Campaigns** Wijsman et al., 1995, Emblas2016, Emblas2017

Calibration identifies **probability distributions** for parameters of the OMEXDIA diagenetic model (Here: Station 6, Emblas 2016 Campaign)

Macrobenthic activity is represented by profiles of **bioturbation** (solid phase extra diffusion) and **bioirrigation** (non-local exchanges of liquids)
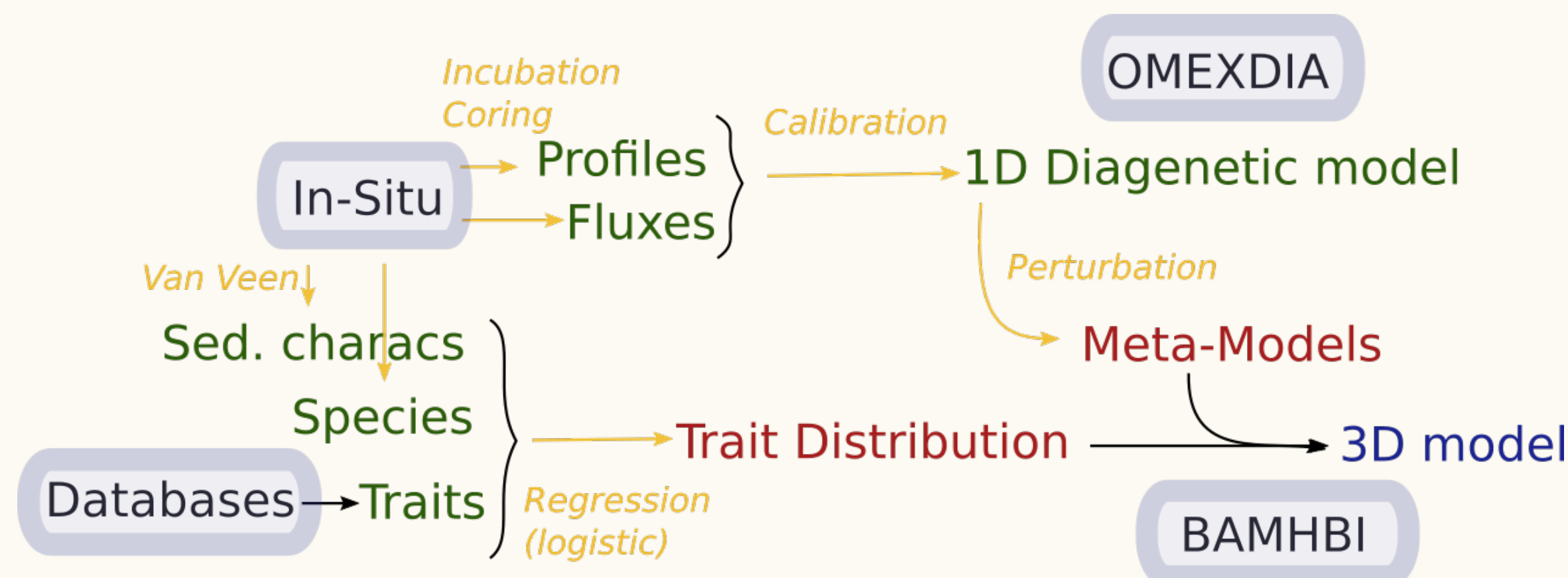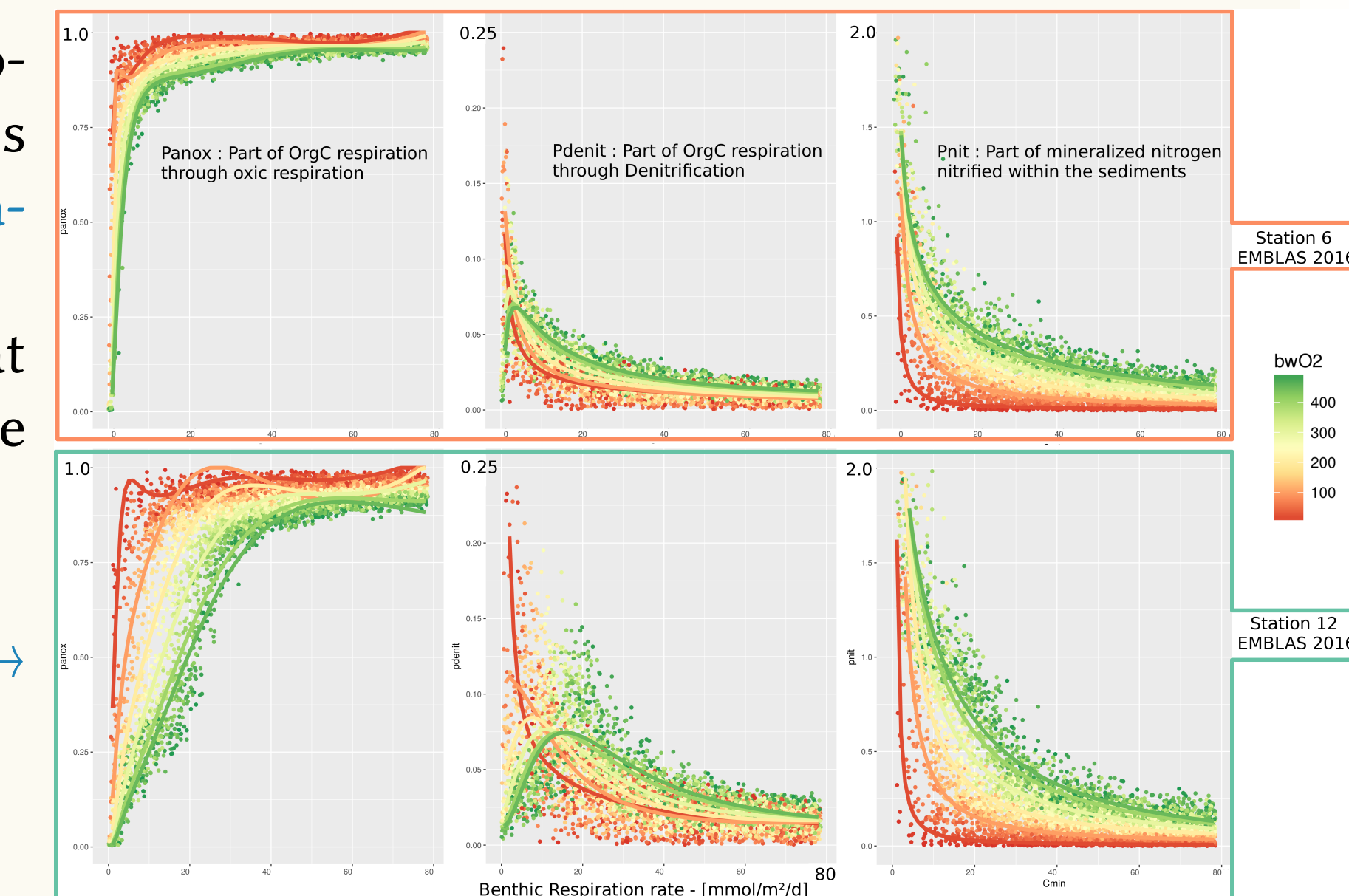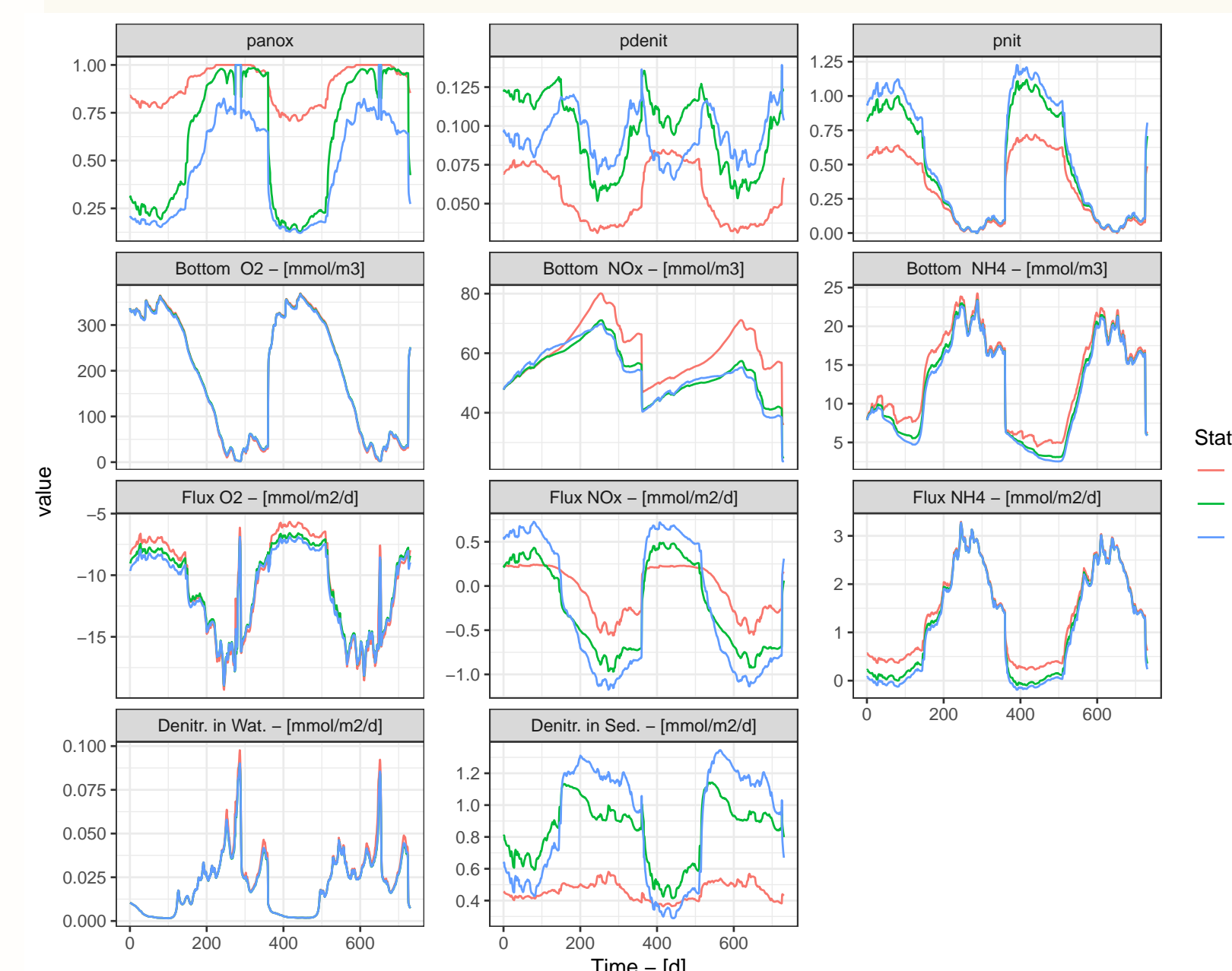
Macrobenthic Facies → Meta-Models for Benthic-Pelagic Coupling
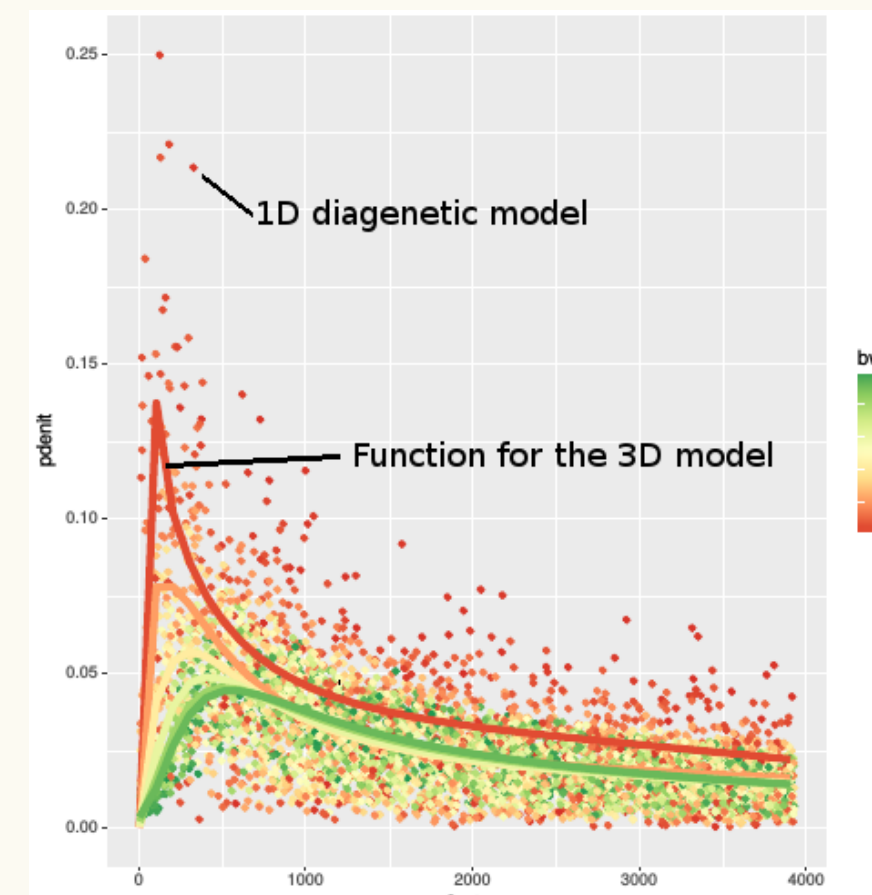
← The **1D diagenetic model** is run multiples times while perturbing **Bottom water nutrients and organic input** within ranges obtained from 3D simulations , and **Macrobenthic activity parameters** within ranges obtained during calibrations.
Those simulations are used to adjust meta-model functions, that are implemented in the 3D water-column model to represent the behavior of the 1D diagenetic model.

Set of functions are issued for different facies of macrobenthic → activity, to be used for different regions of the 3D model.

pdenit: Part of benthic respiration led by denitrification. **Cmin**: Carbon mineralized per unit of time. **bwO2**: Bottom Oxygen concentration. Other dimensions are not represented.

Benthic-Pelagic coupled simulations 1D & 3D

← The sensitivity of Benthi-Pelagic coupling is explored with **1D simulations**, for typical shelf conditions.
To mitigate the lack of lateral flows, a weak relaxation towards 3D model outputs is imposed.
The three simulations shown here differ only in terms of macrobenthic facies (see above).
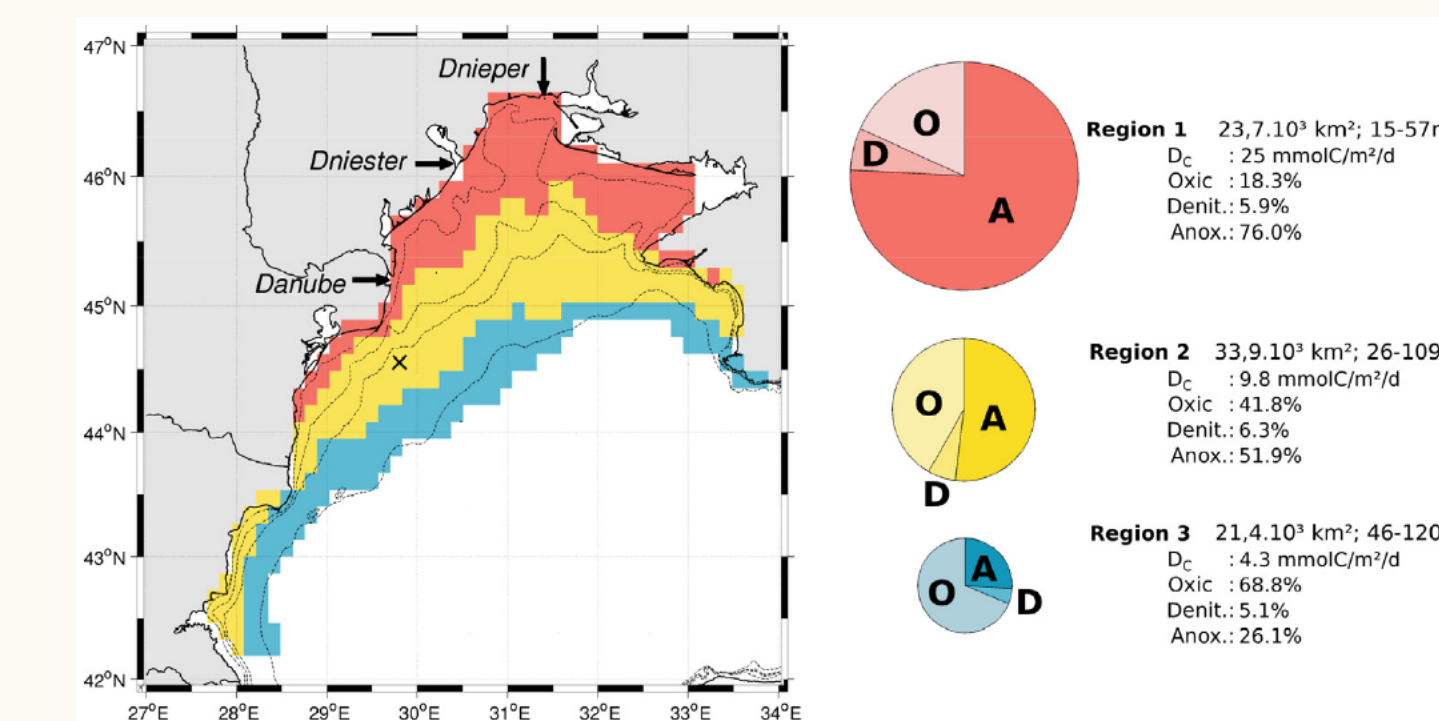
3D simulations resolve the coupled dynamics of the Black Sea north western shelf. Those are used to reproduce the diversity of benthic-pelagic coupling (above) and the dynamics of seasonal hypoxia (right).