Ulva mass deposits on a beach in the French bay of Douarnenez (Brittany) –July, 2012

Phaeocystis foam along the French « Côte d'Opale » (North Sea) – 12th May, 2014 *(FR3 photo)*

Modelling the marine coastal eutrophication

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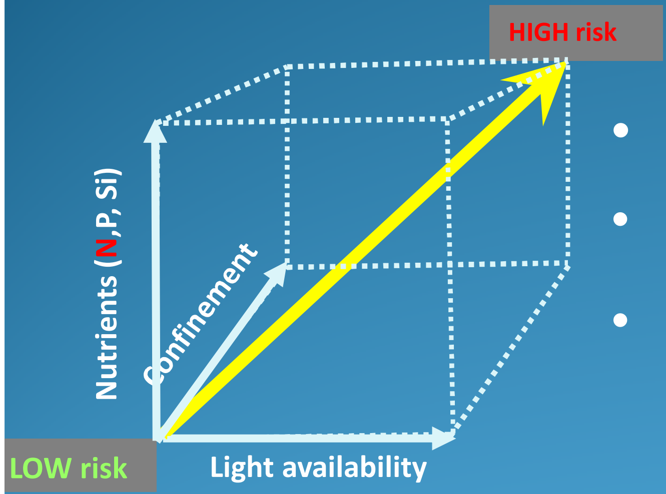
Presentation outline

1. Why? (the aims)
2. Where? (the main sites)
3. Which tools? (the various models)
4. What results? (some specific inputs)
5. What future needs?

1. Why?

- Reproduce the main symptoms (algal blooms, bottom hypoxia, HAB toxins…)
- Quantify the respective roles of main drivers :

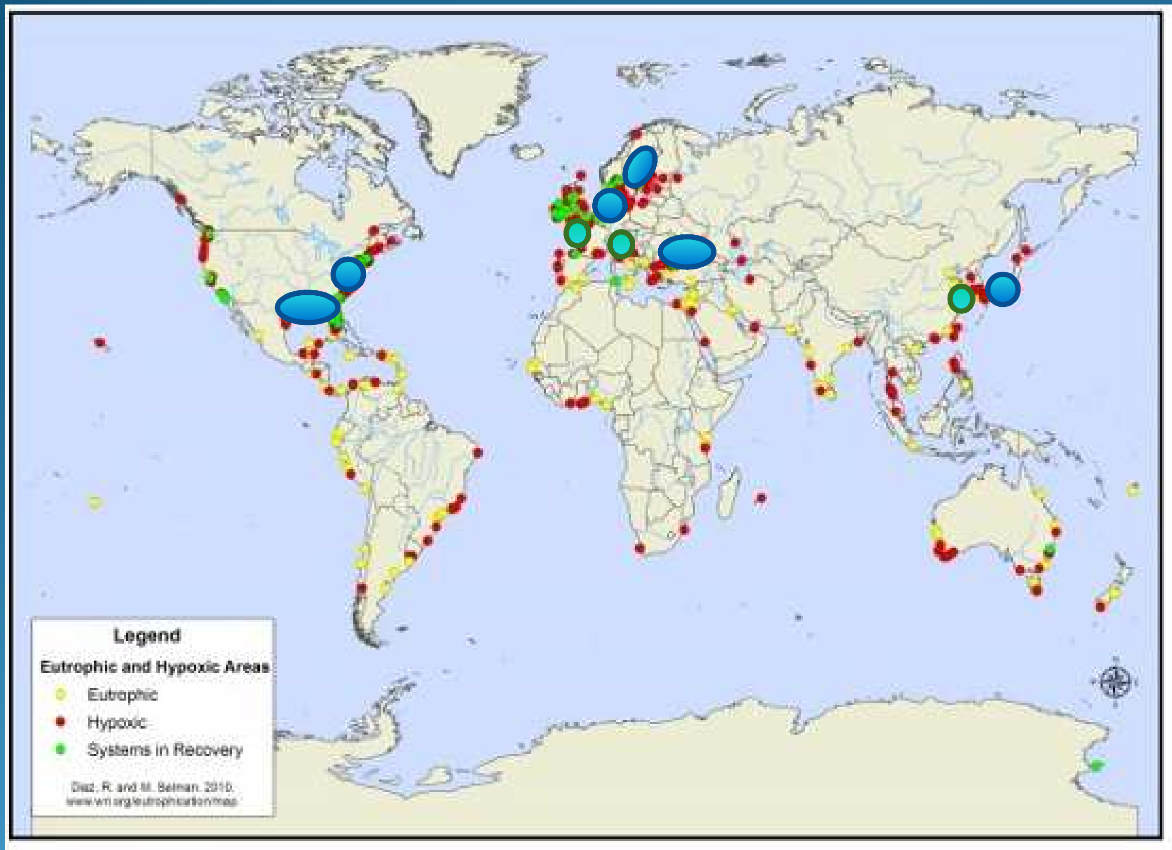


- Light availability
- Nutrient absolute and relative richness
- Local residence time

Often linked to river plumes

- Assess the effects on trophic webs and biodiversity
- **Test various scenarios of nutrient reductions with or without climatic changes**

2. Where?



<u>Scientific papers identified</u>:
Phytoplanktonic eutrophication:
Estuaries=83, Lagoons=30, Coastal shelf=145
Macrophytic eutrophication: 25

<u>Main coastal seas with recurrent phytoplankton proliferations</u>:

- Gulf of Mexico
- Chesapeake bay
- Baltic Sea
- North Sea
- Black Sea
- Japan inland sea

<u>Main lagoons and embayments with recurrent green macroalgae proliferations</u>:

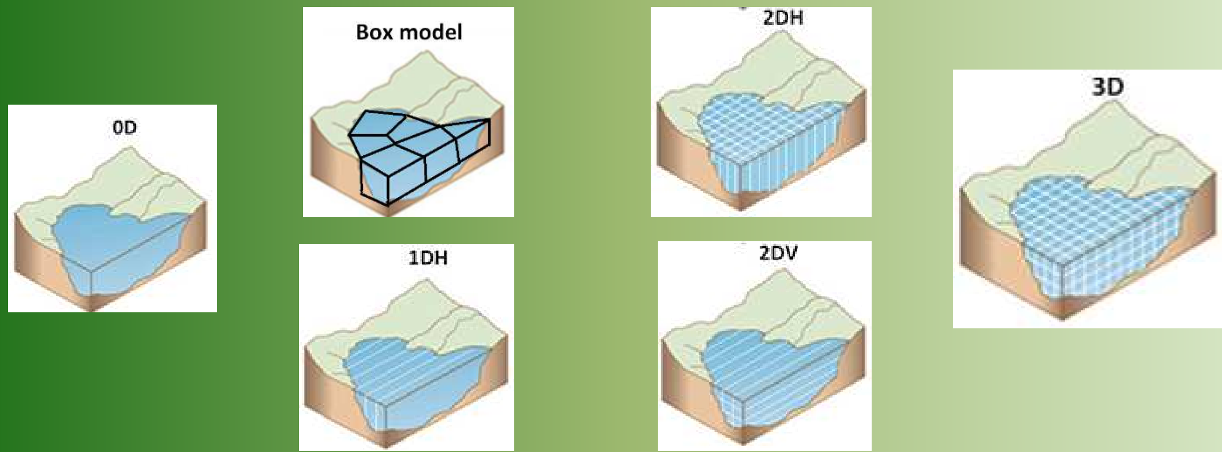
- Venice lagoon
- French Brittany embayments
- Qingdao shore

3.1 Which tools?

1970 ------------------1990----------2000---------------2015

Mathematical type:
- Statistical (linear) models
- Mechanistic differential equations

Spatial dimension:



Water biogeochemistry:
Nothing — NPZD (N,P,Si,O) — ECOPATH — algal biodiversity

Sediment biogeochemistry:
N,P,Si, O, Fe, S, Mn

3.2 Which tools?

1970 ------------------1990----------2000---------------2015

Forcing from watersheds

Statistical relationships (concentration vs flow rates)

Watershed mechanistic models

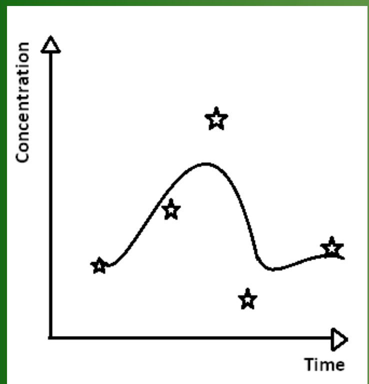
Forcing from atmosphere:

Meteorological models N deposition models

Calibration: By hand Gauss-Newton Bayesian optimization

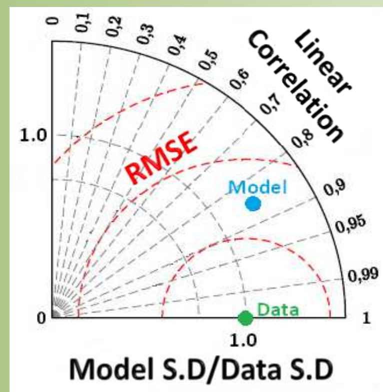
Validation:

Visual comparison



Scatterplots

Metrics in Taylor's graph

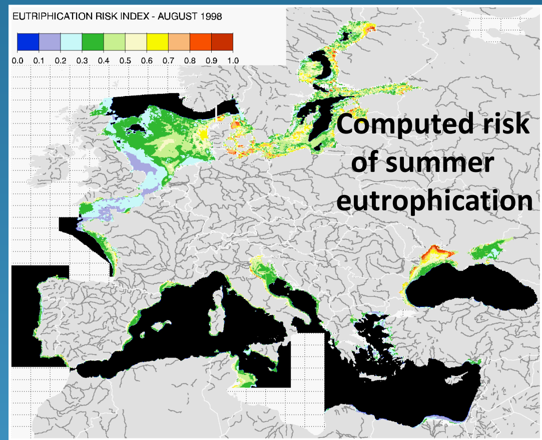


3.3 Which specific capabilities?

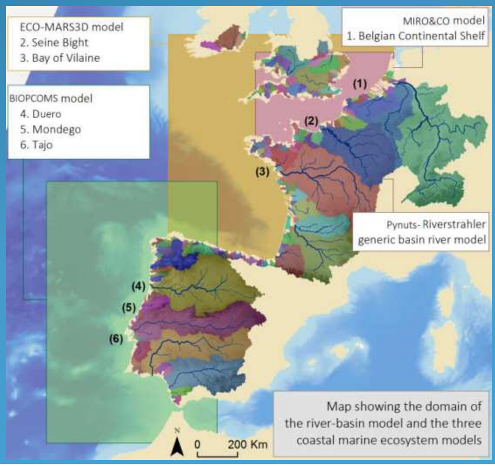
- Quantitative coupling between hydrodynamics, chemistry, ecology, economics

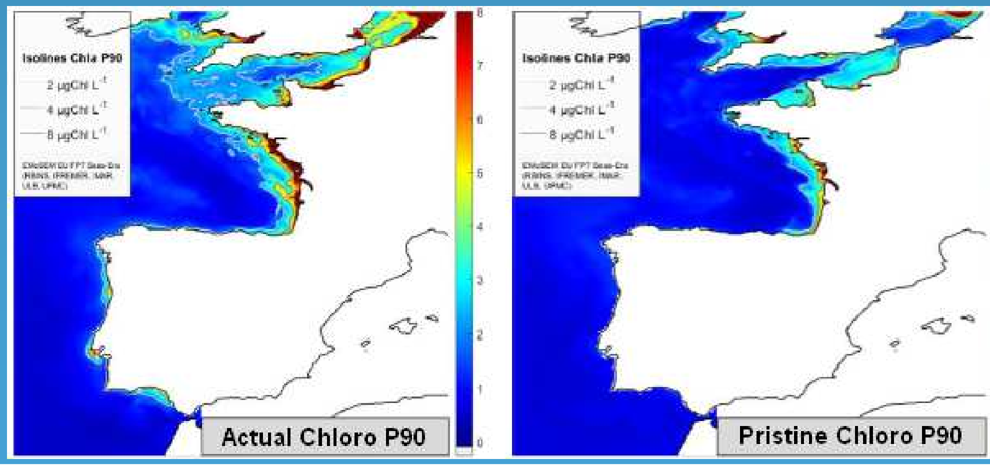
- Quantitative coupling between watersheds, atmosphere, marine ecosystems

Druon et al. (2004)



- Simulating past environments (e.g. pristine) and future scenarios

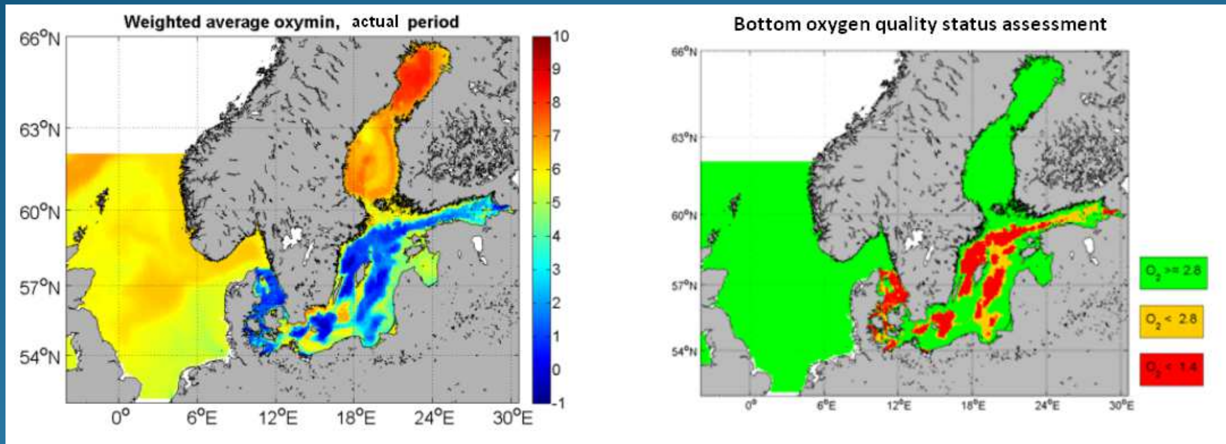




Lacroix et al. (2015)

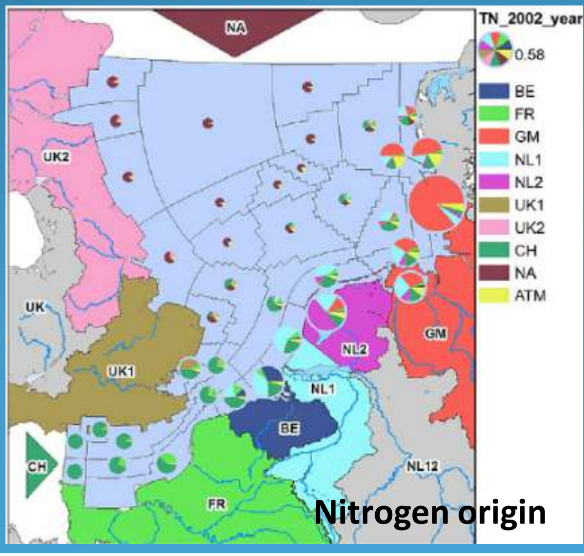
3.3 Which specific capabilities?

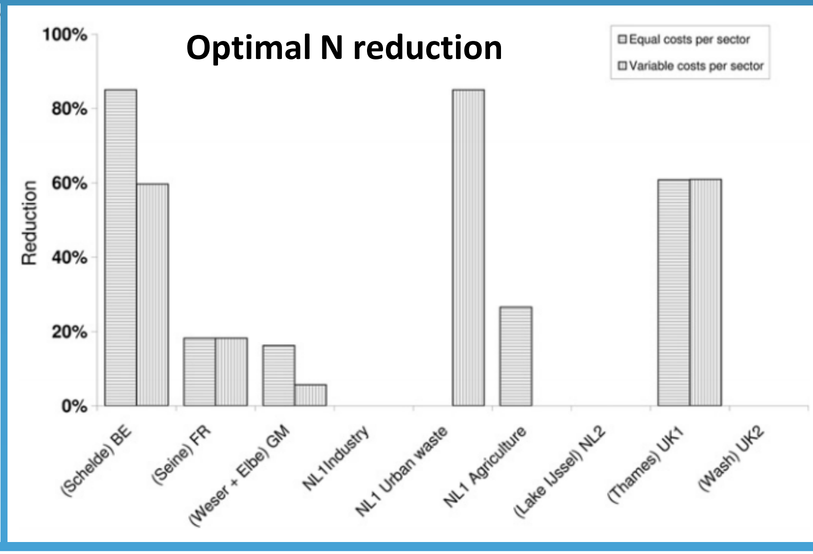
➢ Computing continuous maps of common descriptors



Eilola et al., 2013

➢ Computing unmeasurable quantities (e.g. tracking nitrogen in the 3D food web) and optimal remediation strategies

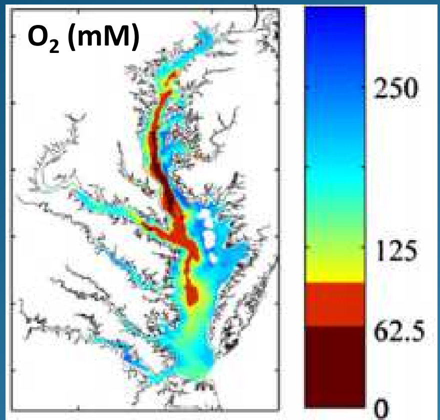


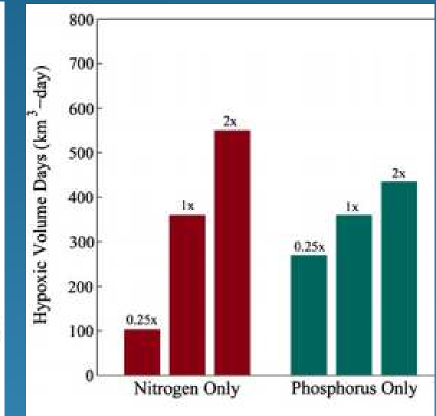


Los et al. (2014)

4.1 What results?

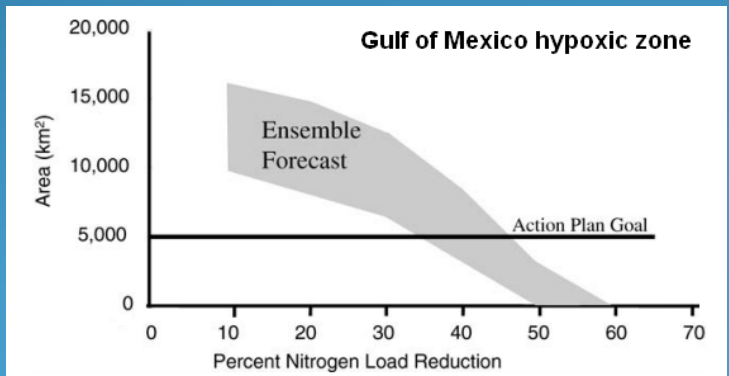
Testa et al. (2014)



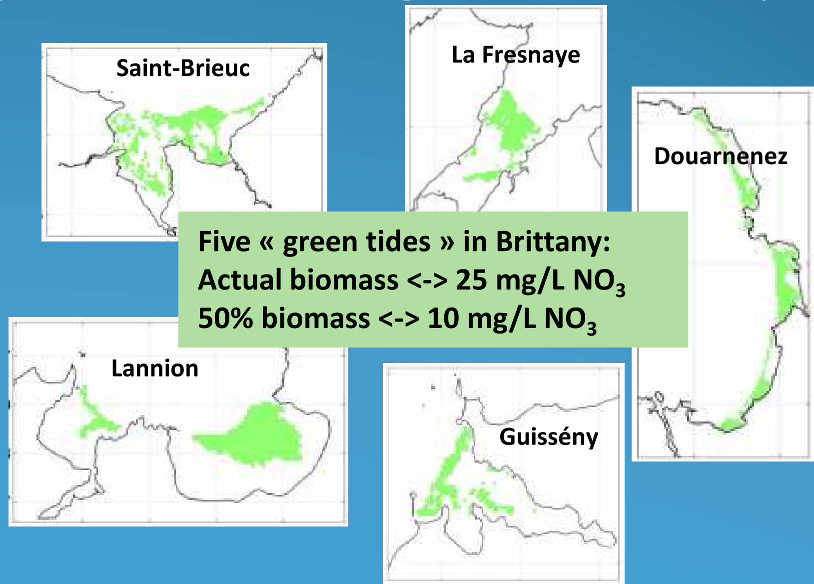


1. The first element controlling the intensity of coastal eutrophication is:
   - **Nitrogen** in salty ecosystems (lagoons, marine side of estuaries, shelf)
   - Phosphorus in brackish inland seas (Baltic Sea) or some inner estuaries

2. In heavily eutrophicated sites , going back to Good Ecological Status will require **strong nitrogen abatement**



Justic et al. (2007)

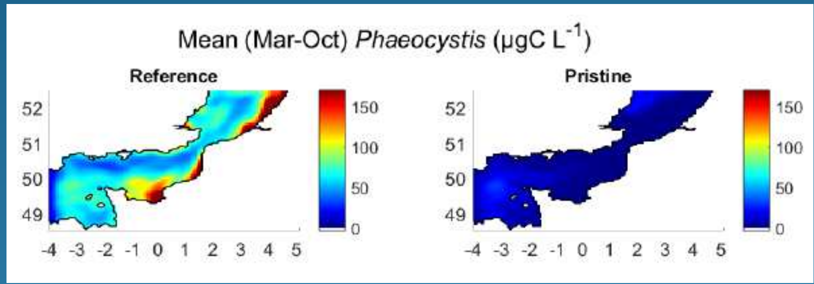


Five « green tides » in Brittany:
Actual biomass <-> 25 mg/L NO_3
50% biomass <-> 10 mg/L NO_3

(Perrot et al., 2014)

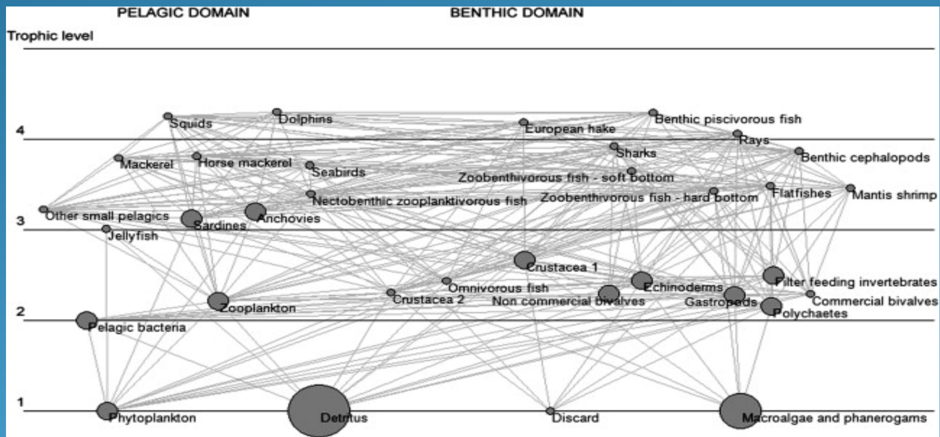
4.2 What results?

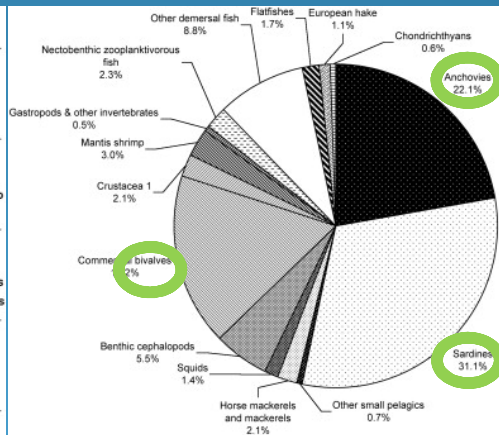
3. Eutrophication enhances **non-diatom species**



Lacroix et al. (2015)

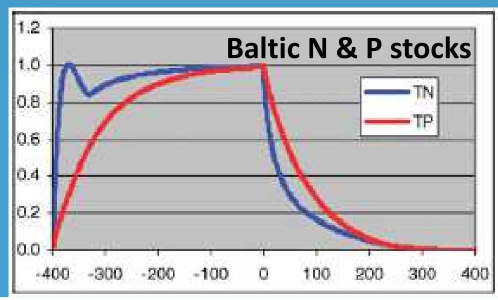
4. Eutrophication may enhance the global production, but in a **less diversified food web**





Barausse et al., 2009)

5. Return to the Good Ecological Status following a remediation scenario may suffer **a delay because of sedimentary stocks of nutrients** (P mainly) and warming trend.



Savchuk (2009)

5. What future needs?

1. More systematic **assessment of statistical confidence** in the results

2. Better validation against **long and HF series of measurements**

3. More biological knowledge about physiological **adaptation** and species **selection**

4. More **realistic forcing** from watersheds and atmosphere and **more systematic sediment/water interaction**

And…a little bit **more science-based values of thresholds for eutrophication indicators !**

Thank you for your attention !