Bio-irrigation in simple diagenetic models: A study in the northwestern Adriatic

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Introduction

- Simple diagenetic models are required for coupled setup integrating early diagenesis with pelagic circulation and biogeochemistry.
- Yet, simplification should not restrict the accuracy of resolved benthic fluxes, neither neglects important processes allowing for biological feedbacks.
- Here, we compare two formalisms used to include bioirrigation in simple diagenetic models: enhanced biodiffusion and non-local exchange.

without bioirrigation

$$\frac{\partial C(z)}{\partial t} = \frac{1}{\phi}\frac{\partial}{\partial z}\left[\phi D \frac{\partial C(z)}{\partial z}\right] + \ldots(\text{Advection and reactions})$$

with bioirrigation

Enhanced biodiffusion

$$\frac{\partial C(z)}{\partial t} = \frac{1}{\phi}\frac{\partial}{\partial z}\left[\phi \beta D \frac{\partial C(z)}{\partial z}\right] + \ldots$$

Non-local exchange

$$\frac{\partial C(z)}{\partial t} = \frac{1}{\phi}\frac{\partial}{\partial z}\left[\phi D \frac{\partial C(z)}{\partial z}\right] + -\alpha(C(z) - C(0)) + \ldots$$

Questions

- What impacts bears the formalism used to represent bioirrigation?
- Which formalism provides better description of data?
- How does bioirrigation affect benthic-pelagic fluxes in the northern Adriatic Sea?

Method

We extented the simple diagenetic model OMEXDIA [2] (C,N,O) with:

- P dynamics (following [3])
- Si dynamics
- non-local exchanges

Conclusion

Sensitivity: Bio-irrigation impact on benthic-pelagic budget depends on the adopted formalism, particularly in low flux/high O2 conditions.

Calibration: Non-local formalisms allows a better multivariate and synchronous description of pore waters solutes, solid phase and benthic flux data.

Budget: In the northwestern Adriatic, bioirrigation accounts generally for 50-75% of the net benthic fluxes, depending on the chemical species and the location.

Drawback and potential improvement

- Steady-state calibration → Routine monitoring
- Permeability ? → Model development for continuous permeability spectrum.

References

[1] Hammond, D. et al., *Marine Chemistry*, 66(1), 1999

[2] Soetaert K. et al., *Geochim. Cosmochim. Ac.*, 66(1), 1996

[3] Slomp C. et al., *Limnol. Oceanogr.*, 43(5), 1998

Results

1. Sensitivity

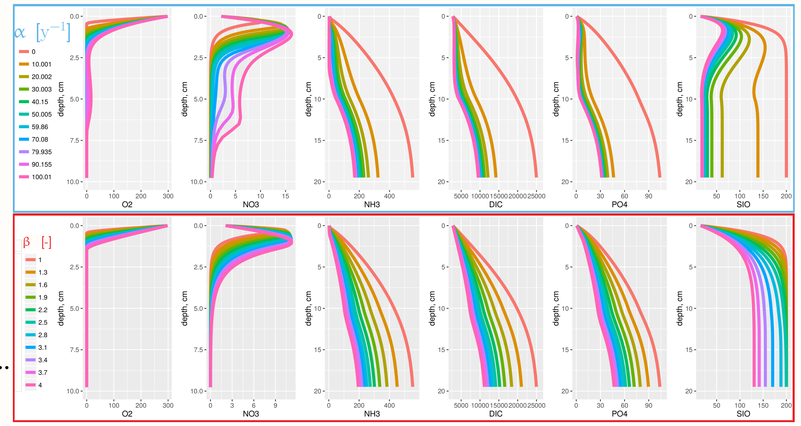


Figure 1 : The qualitative impact of bioirrigation on solute profiles differs according to the adopted formalism.

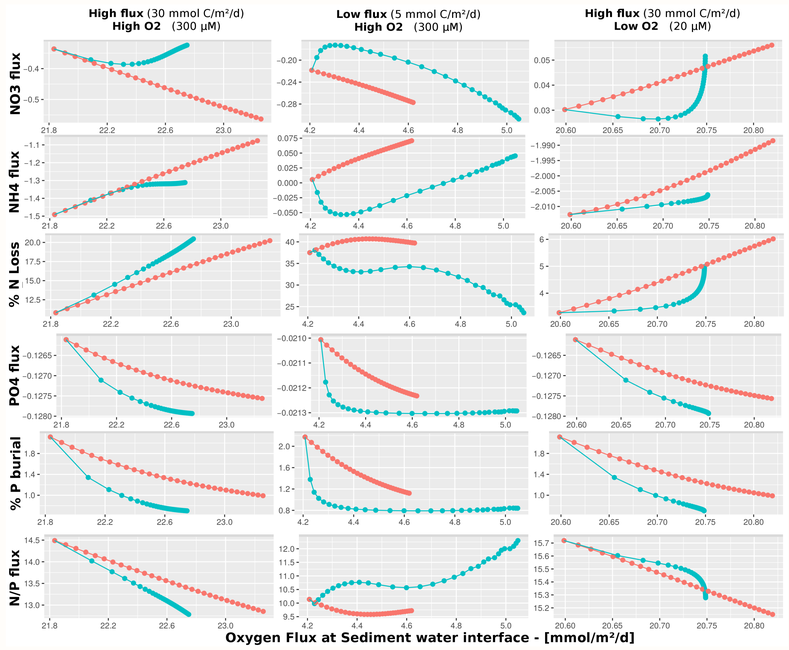
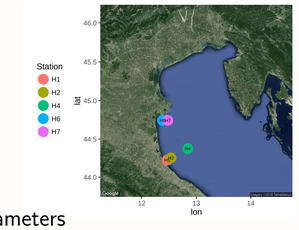


Figure 2 : Fluxes and budgets (Y-axis) are plotted against oxygen fluxes (X-axis), while gradually increasing α or β

2. Calibration

6 stations considered in northern Adriatic [1].
Incremental calibration steps based on

- profiles: solid phase and pore waters solutes
- fluxes : incubation



Step	Data used	Calibrated parameters
1	TOC, F_{DIC}	p_f , w_{POC} , p_{ref} , $D_{b,0}$, r_s
2	TOC, NH_4, DIC, F_{NH_4}, N/C_f, N/C_s, α **or** β , r_{nit}, L, $D_{b,0}$, p_{dep} F_{NO_3}, F_{DIC}, $F_{O_2,tot}$	
3	SIO, F_{SIO}	r_{Si},Si/C_{det}
4	PO4, F_{PO4}	P/C_s, $r_{FeP,ads}$, $r_{FeP,des}$, $r_{CaP,prod}$

w_{POC}: sedimentation flux; p_f: partition in 2 lability classes; p_{ref}: part refractory; $D_{b,0}$: bioturbation coef.; r_s: degradation rate for semi-labile; N/C_f: N/C for labile; N/C_s: N/C for semi-labile; r_{nit}: nitrif. rate; L: mixed layer depth; r_{Si}: Si diss. rate; Si/C_{det}: Si/C for OM; P/C_s: P/C for semi-labile; $r_{FeP,ads}$: FeP adsorption rate; $r_{FeP,des}$: FeP desorption rate; $r_{CaP,prod}$: CaP precip. rate

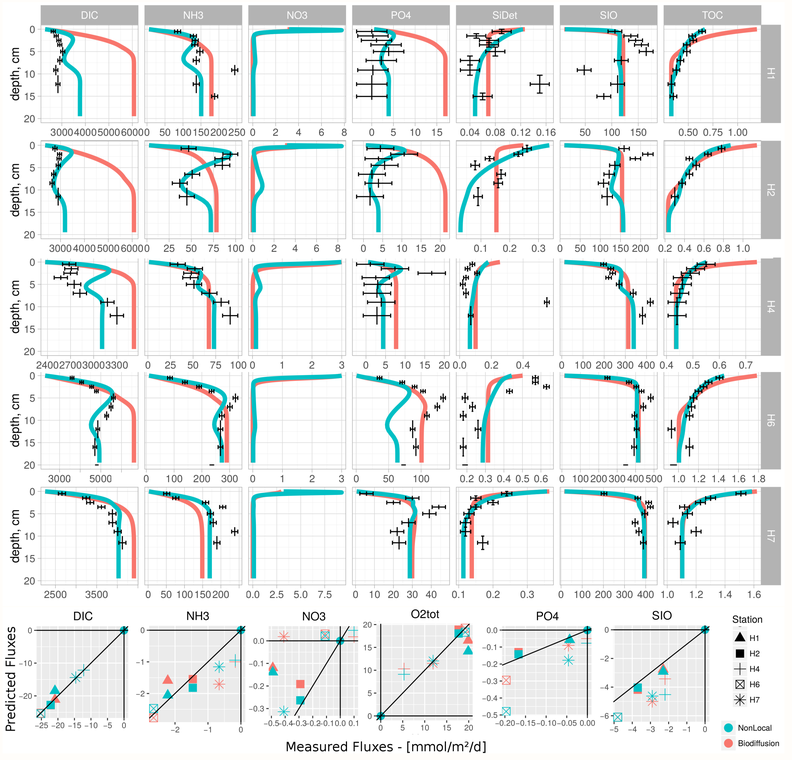


Figure 3 : Non-local formalism provides a better fit of the data.

3. Budget

Bioirrigation contribution to benthic-pelagic fluxes is lower in the northern part (Po delta, St. 6&7) and higher along the Emilia Romagna coast.

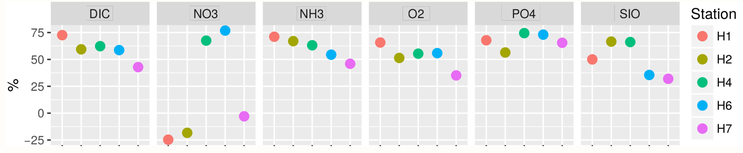


Figure 4 : Bioirrigation contribution to benthic fluxes is computed as percentage of total fluxes.