Session CL1.27

Modelling the impact of biogenic particle flux intensity and composition on sedimentary Pa/Th

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Motivation

Changes in the Atlantic Meridional Overturning Circulation (AMOC) are thought to be an important driver of millennial scale climate variability. In the Atlantic, past deep circulation flow rates have been inferred using the sedimentary Pa/Th ratio. However, the use of this circulation proxy is challenging because Pa and Th are highly sensitive to changes in composition and flux intensity of biogenic particles (opal, $CaCO_3$ and organic carbon (POC)).

To date, there is no quantitative estimate of the potential impact of past changes in biogenic particle fluxes on the available paleo Pa/Th records.

We use the Pa/Th enabled iLOVECLIM Earth System Model of Intermediate Complexity to evaluate the impact of particle flux intensity and composition on the simulated Atlantic sedimentary Pa/Th.

Methods: Sensitivity tests

We use the iLOVECLIM Pa/Th module, embeded in the CLIO ocean model (3° x 3°- 20 depth levels-[1]). We consider 3 particle types ($CaCO_3$, POC and opal) and a single particle size with a uniform settling speed of 1000 m/y. The 3D particle fields are prescribed and derived from NEMO-PISCES [2].

Table 1. Sensitivity simulations (1000 yrs) based on preindustrial (PI) boundary conditions

Simulation	POC	CaCO3	Opal
CTRL-PI	CTRL	CTRL	CTRL
All_2	CTRL/2	CTRL/2	CTRL/2
POC_2	CTRL/2	CTRL	CTRL
CaCO3_2	CTRL	CTRL/2	CTRL
Opal_2	CTRL/2	CTRL	CTRL
CaCO3 x2	CTRL	CTRL x2	CTRL
CaCO3_x2_opal_2	CTRL	CTRL x2	CTRL/2

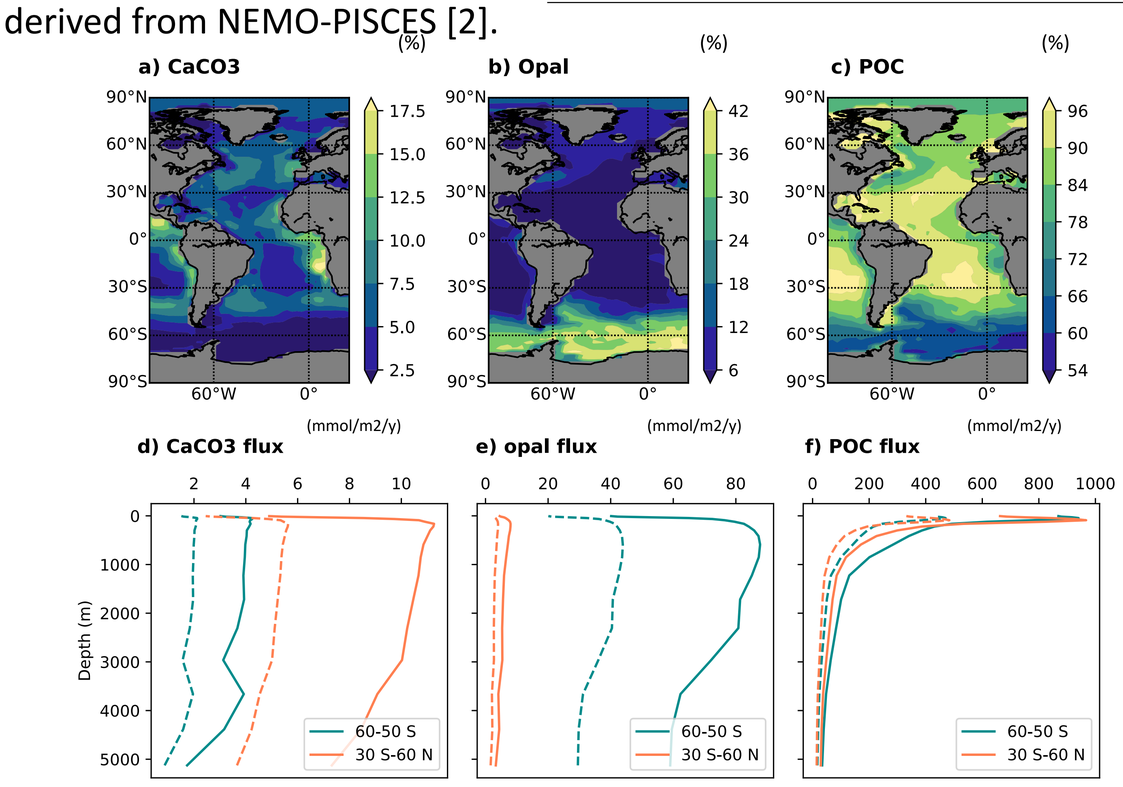

Figure 1. Particle forcing
a)-c) Integrated particle concentration normalized by the sum of all particles (%) d)-f) Particle flux profiles (mmol/m²/y). The dashed lines indicate the modified field (fluxes globally halved)

Sedimentary Pa/Th response

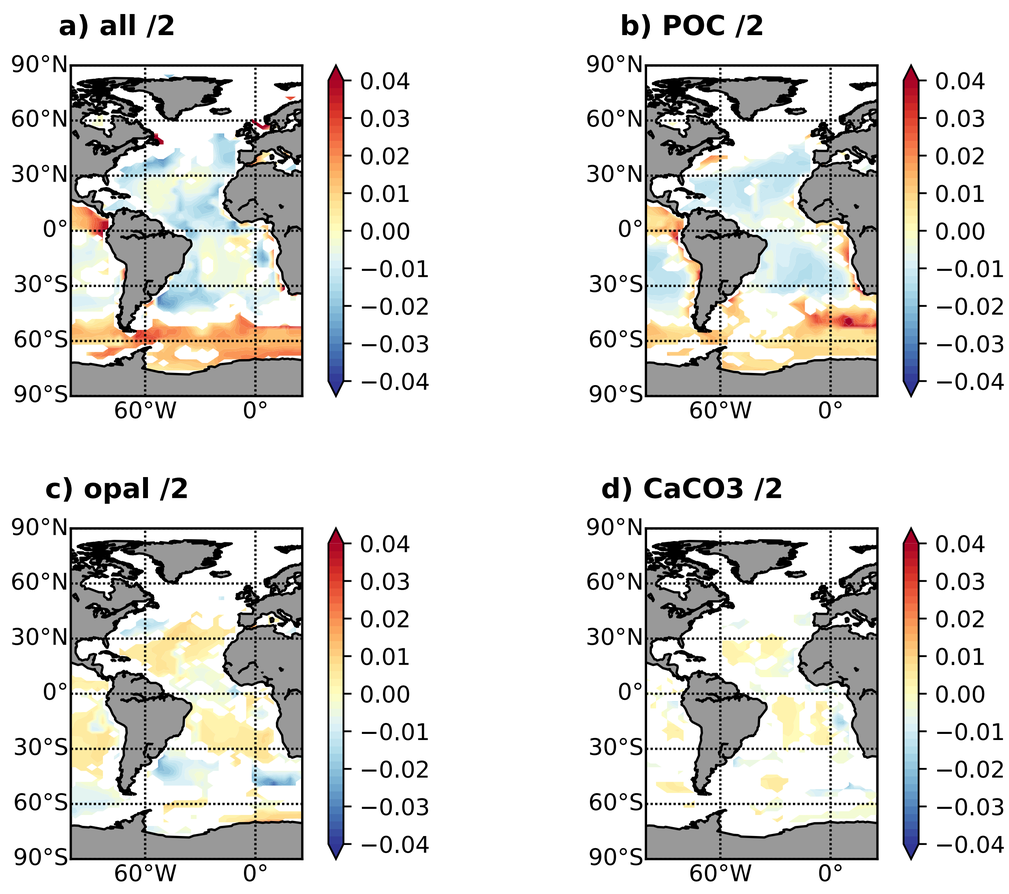

Figure 2. Sedimentary Pa/Th response
Sedimentary Pa/Th anomaly (perturbed –ctrl PI). White regions did not display significant sedimentary variations compared to the natural variability assessed from 100 years of PI CTRL run.

- POC has the largest impact on sedimentary Pa/Th followed by opal (Fig. 2).
- Decreasing the opal flux intensity increases the sedimentary Pa/Th in the open ocean and opal depleted regions (Fig. 1- Fig. 2).
- Halving the opal and $CaCO_3$ concentrations generates Pa/Th responses of ~0.01 in the mid latitudes of the Atlantic, which corresponds to ~30% of the observed Pa/Th increase across Heinrich Stadial 1 [3].

Sedimentary Pa/Th response to plankton assemblage switch

Proxy data suggest that a switch from plankton assemblages dominated by diatoms (opal producers) to coccolithophores ($CaCO_3$ producers) may have occurred during the last deglaciation [4].

To test this hypothesis, we simulated a global decrease in opal production simultaneous with an increase of the $CaCO_3$ production (Table 1).

- Opal mostly affects the sedimentary Pa/Th in the North Atlantic sub-tropical gyre while $CaCO_3$ is prevailing along the African coast between 30°N and 40°S (Fig. 3).

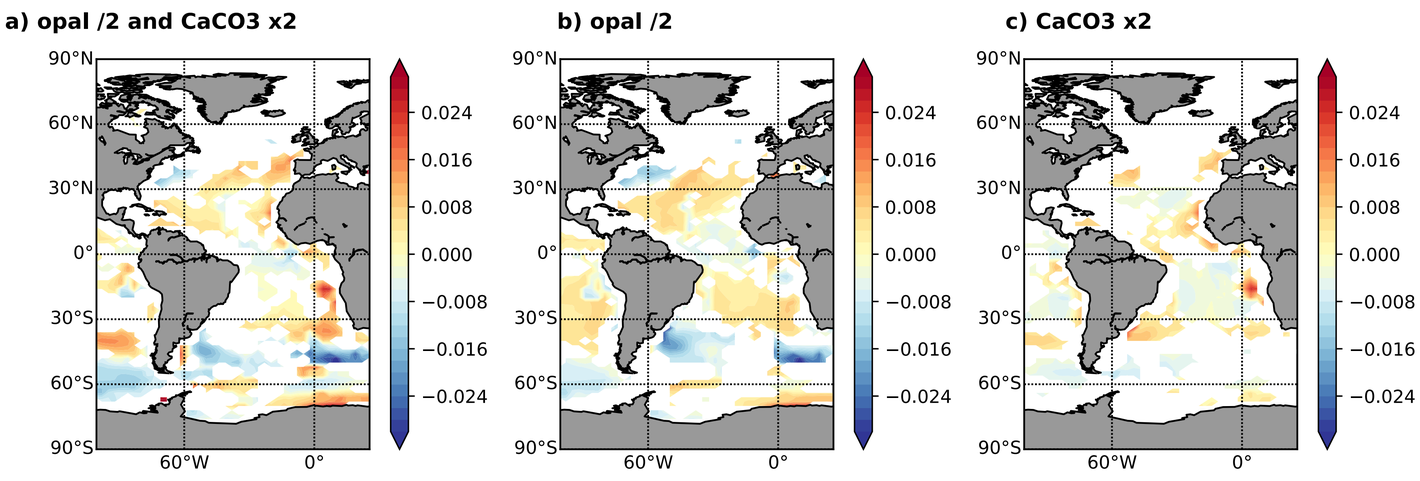

Figure 3. Sedimentary Pa/Th response to a switch from opal producers to $CaCO_3$ producers
Anomaly between the perturbed simulations and the CTRL PI.

Conclusions

- Changes in biogenic particles flux intensity can significantly impact the sedimentary Pa/Th.
- In our simulations, the Pa/Th changes are predominantly driven by POC and to a lesser extent by opal.
- Halving the particle fluxes could account for ~30% of the observed Pa/Th increase in the North Atlantic across Heinrich Stadial 1.
- The Pa/Th response may be sensitive to the geographical particle repartition (3D).
- Future progress in quantifying the particle-induced Pa/Th signal requires (i) a 3D evaluation of the biogenic productivity changes, (ii) a proper representation of the Pa and Th scavenging regimes and (iii) correct representation of the Atlantic water masses pathways in climate models.

REFERENCES

[1] Missiaen et al., CP discussion, 2019
[2] Van Hulten et al., GMD, 2018
[3] Ng et al., Nature Communications, 2018
[4] Matsumoto et al., GGC, 2002