Spatial patterns of opal and CaCO3 fluxes in sediments traps: application to the LGM carbon cycle

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Introduction

Model studies by *Archer et al.* [2000] have shown that possibly one of the most important factors driving interglacial to glacial variations in atmospheric pCO_2 are changes in the Particulate Organic Carbon/CaCO3 (POC/PIC) rain ratios to the sediments caused by shifts in the plankton community in surface water. We have shown that deep-sea fluxes of organic carbon can be predicted using the mechanistic model of *Armstrong et al.* [2002] implying that minerals ballast or protect POC sinking at depth. Our results have been incorporated into the Hamburg Large Scale Geostrophic Ocean Circulation Carbon Cycle Model [LSG-HAMOCC2, *Heinze* et al.,1991] as configured by *Archer et al.* [2000] to include iron chemistry and phytoplankton functional groups. Model simulations will be used to constrain variability of present and glacial ocean carbon cycle.

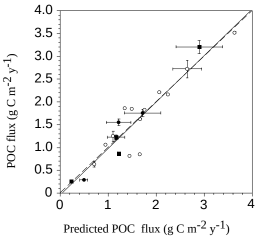
The POC-mineral association model [*Armstrong et al*., 2002]

The model partions export production of POC in two fractions a free POC fraction and a mineral associated fraction. Both fractions have characteristic remineralization scales which correspond to the dissolution scale of the mineral for the mineral associated POC. The original model also assumes that some fraction of the mineral does not dissolve . The POC flux at a given depth is given as follows:

$$F_z = FP.e^{\left(\frac{z-z_o}{\mu_p}\right)} + f.FP.\,F_\infty + f.FP.(1-F_\infty).e^{\left(\frac{z-z_o}{\mu_b}\right)}$$

where: z_o: base of the euphotic layer
F_z: POC at depth z
F_e: free POC
FP: total export production
F_∞: insoluble mineral fraction
f: fraction of export production associated to the mineral fraction

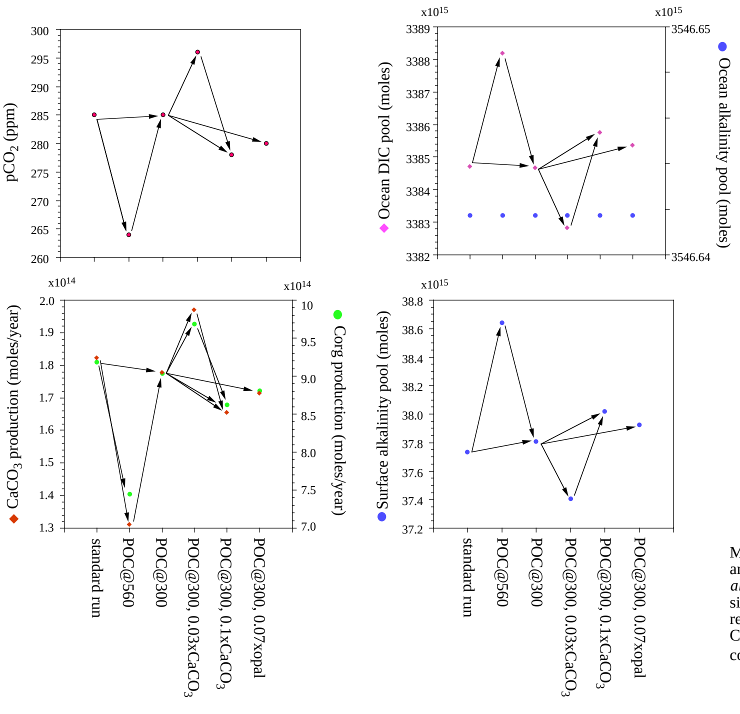
We tested the association of POC and mineral fluxes using fluxes from deep sediment trap experiments and by assuming that all free POC has been remineralized at the trap depth range ($F_e = 0$), and the fraction of POC associated to the mineral fraction (carrying coefficient) is characteristic for each mineral ($CaCO_3$, opal and lithogenic material).

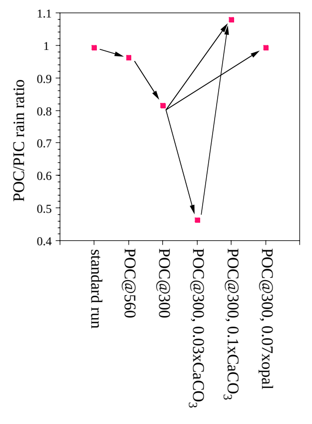


Predicted POC fluxes *vs.* measured fluxes below 3000 m depth The carrying coefficients for POC associated to the minerals fluxes are 0.03, 0.07 and 0.065 for opal, CaCO3 and lithogenic material, respectively [*Klaas and Archer*, In press].

GCM simulations using the POC-mineral association model

The sensitivity of GCM simulations to different formulations of the POC-mineral associations model has been tested by varrying the free POC remineralization depth and the carrying coefficients of the different mineral fractions. Simulations were done using interglacial flow fields and no sediment chemistry. For comparison model results using the configuration of *Archer et al.* [2000] for present-day conditions (standard run) are presented. The carrying coefficients used were obtained by the analysis of sediment trap experiments below 3000 m depth when no values are mentioned.





standard run: present-day model as in *Archer et al.* [2000].

POC@300: e-folding depth at 300 m for free POC.

POC@560: e-folding depth at 560 m for free POC.

POC@300, 0.07xopal: POC@300 and assuming a carrying coefficient of 0.07 for opal.

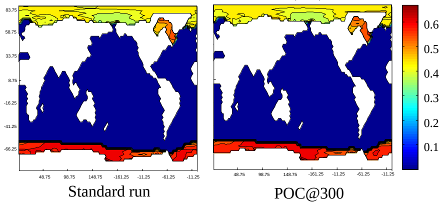
POC@300, 0.1x$CaCO_3$: POC@300 and assuming a carrying coefficient of 0.1 for $CaCO_3$.

POC@300, 0.03x$CaCO_3$: POC@300 and assuming a carrying coefficient of 0.03 for $CaCO_3$.

Preliminary results

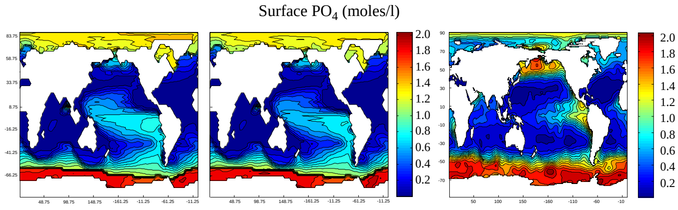
Model results indicates that carrying coefficients as obtained by sediment trap analysis combined with an e-folding depth of 300 for free POC are similar to the present-day simulation as done by *Archer et. al.* [2000]. The shallow remineralization depth used with the POC-mineral association model results in similar remineralization curve as when assuming a power law function and a coefficient of -0.7]. Model results vary significantlsy with changes in POC remineralization depth and in the carrying coefficient for $CaCO_3$. Because $CaCO_3$ largely dominates mineral fluxes in the Ocean changes in the carrying coefficient for opal does not significantly affect the results.

Surface iron concentration (nM)



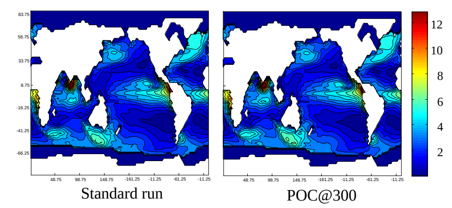
Standard run POC@300

Surface PO_4 (moles/l)



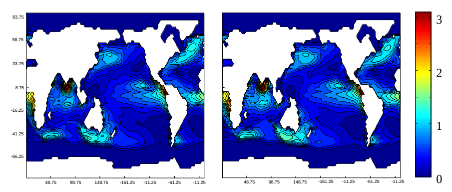
Standard run POC@300 *Levitus* [1994]

Corg production (moles/m^2/year)



Standard run POC@300

$CaCO_3$ production (moles/m^2/year)



Standard run POC@300

References

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Armstrong, R. A., C. Lee, J. I. Hedges, S. Honjo, and S. G. Wakeham, *Deep-Sea Res.* II, 49, 219-236, 2002.
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Levitus, S., *A climatological atlas of the World Ocean*, U.S. Gov. Print. Off., Washington, D. C., 1982.