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Coupling of CESM and MEDUSA: the impacts of a sediment model on ocean biogeochemistry modelling

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Federal Ministry
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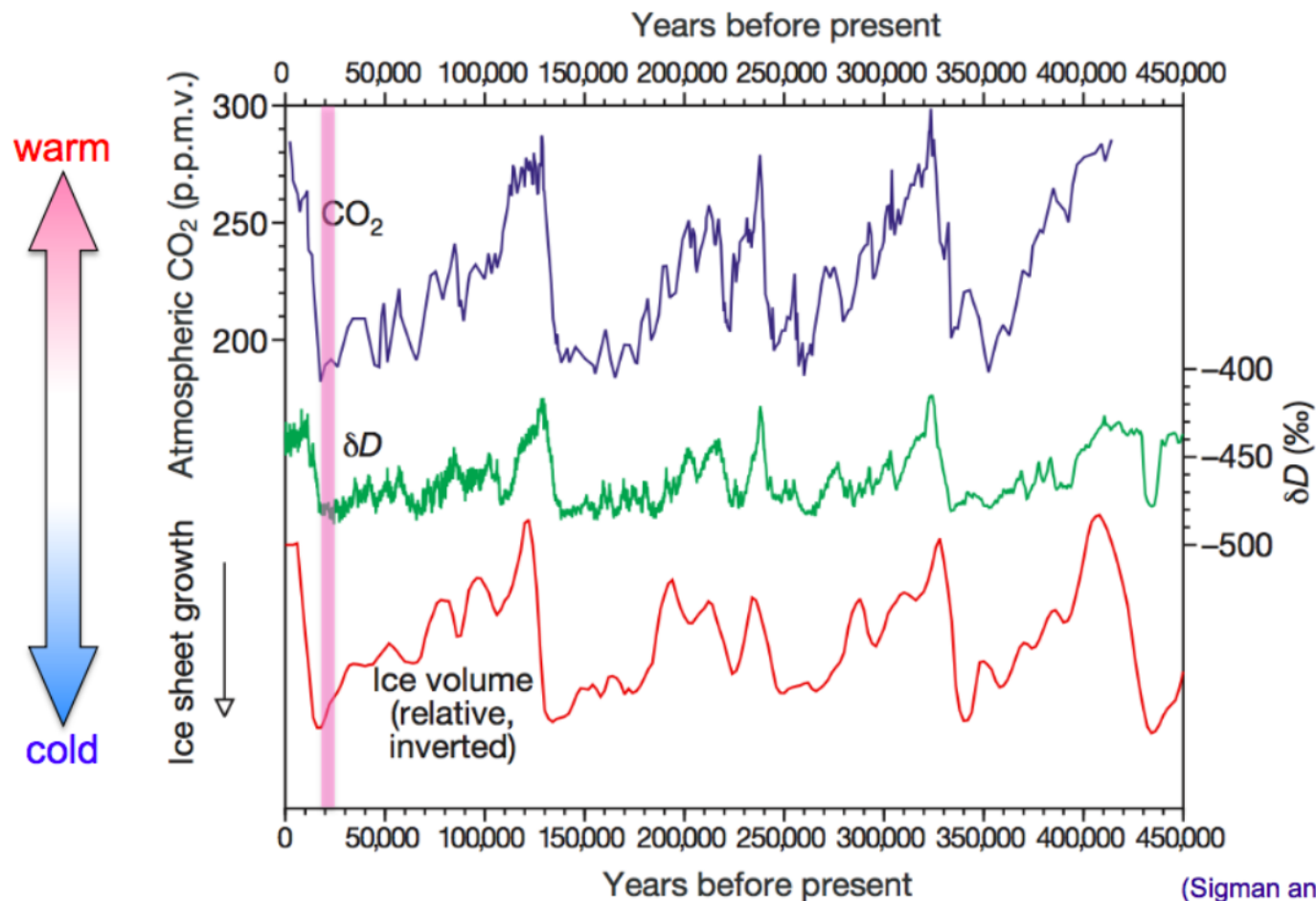
MOTIVATION - WHY SEDIMENT MODEL?



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Long-timescale climate simulations including biogeochemistry components from a G-IG perspective



(Sigman and Boyle, 2000)



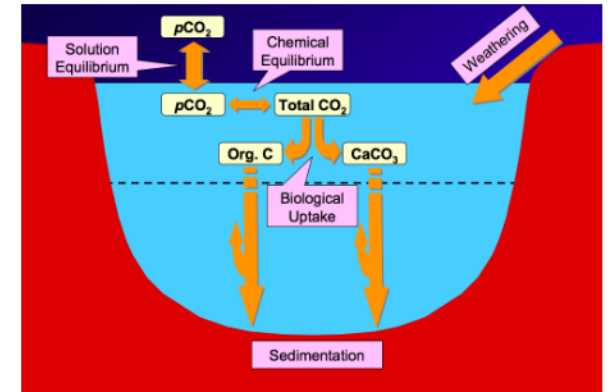
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MOTIVATION - WHY SEDIMENT MODEL?

- ▶ to have a model including *slow* processes.
= marine carbon cycle as an “open” system.



- ▶ to have sedimentary “archives” in the model
- ▶ to assess the influence on bottom water chemistry



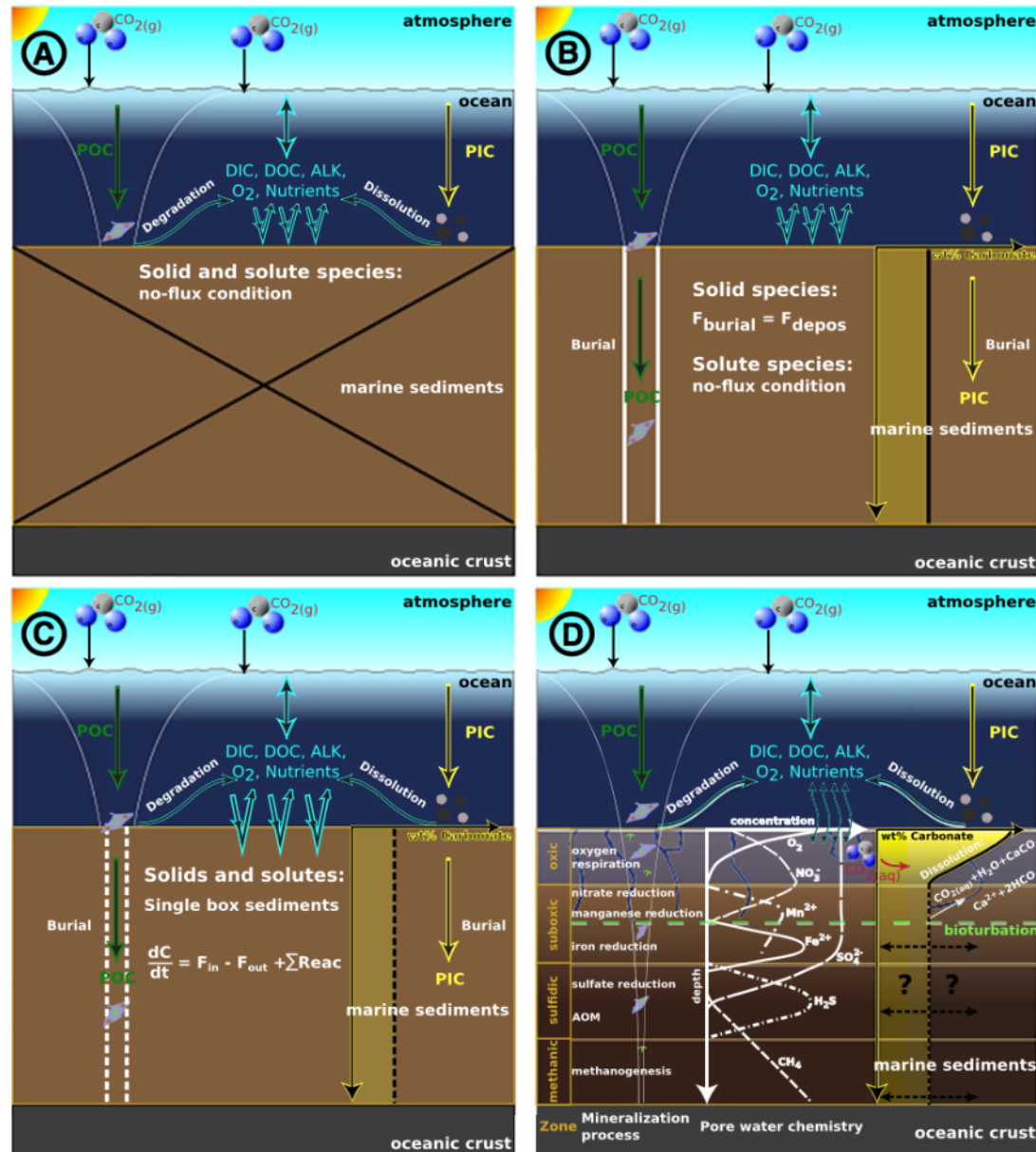
Community Earth System Model v1.2 (CESM1.2)
the Parallel Ocean Program v.2 (POP2)
Biogeochemical Elemental Cycling model (BEC)
[e.g., Moore et al., 2004; Moore et al., 2013; Lindsay et al., 2014]

- low resolution: T31_gx3v7
- carbon isotope components (^{13}C and ^{14}C) [Jahn et al., 2015]
- simplified empirical treatment of sediment processes

Model of Early Diagenesis in the Upper Sediment
of Adjustable complexity (MEDUSA) v. 2 [Munhoven, 2020]

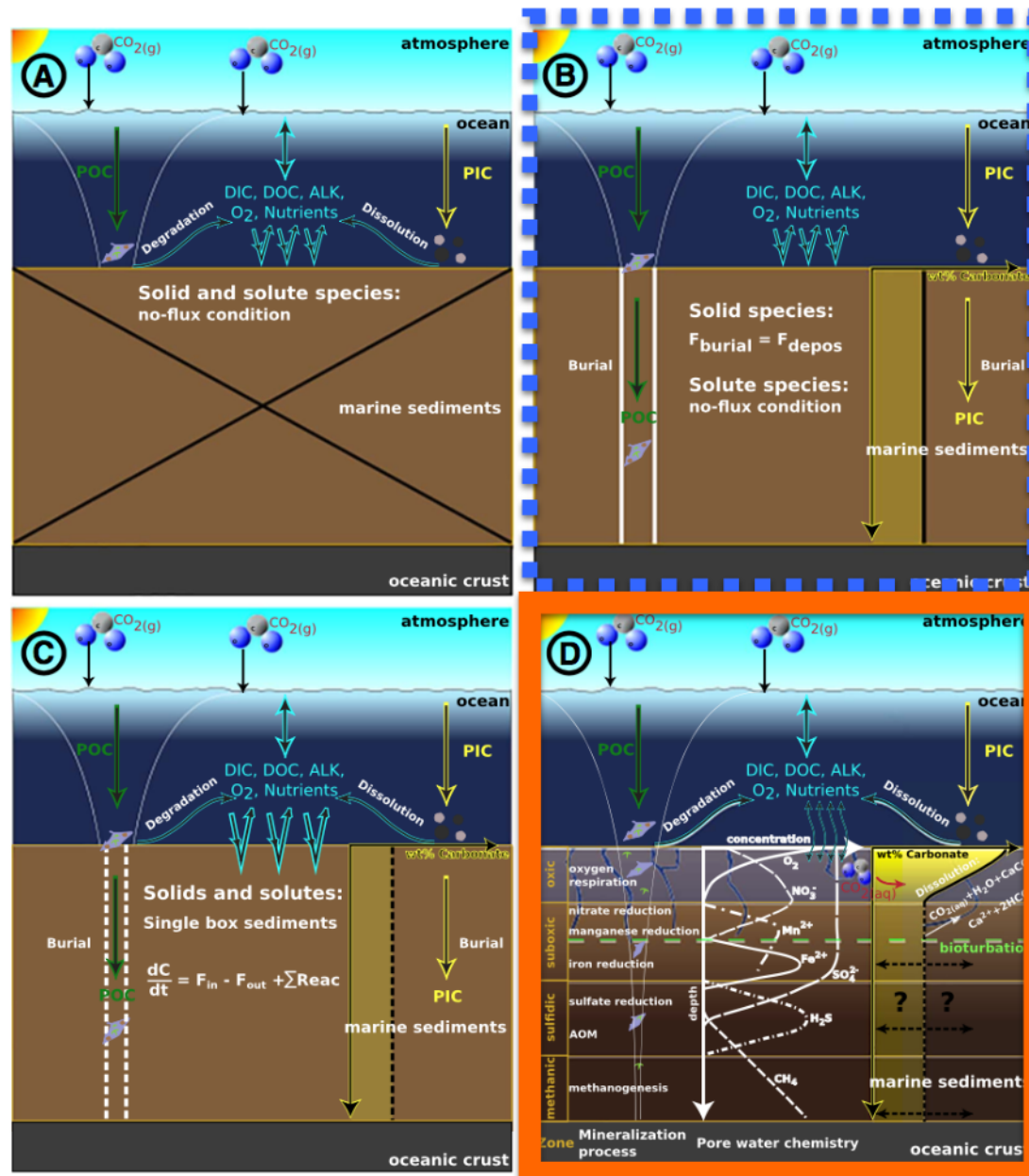
- vertically resolved
- oxic and suboxic remineralization of organic matter
- parameterized CaCO_3 and opal dissolution

4 DIFFERENT SEDIMENT APPROACHES

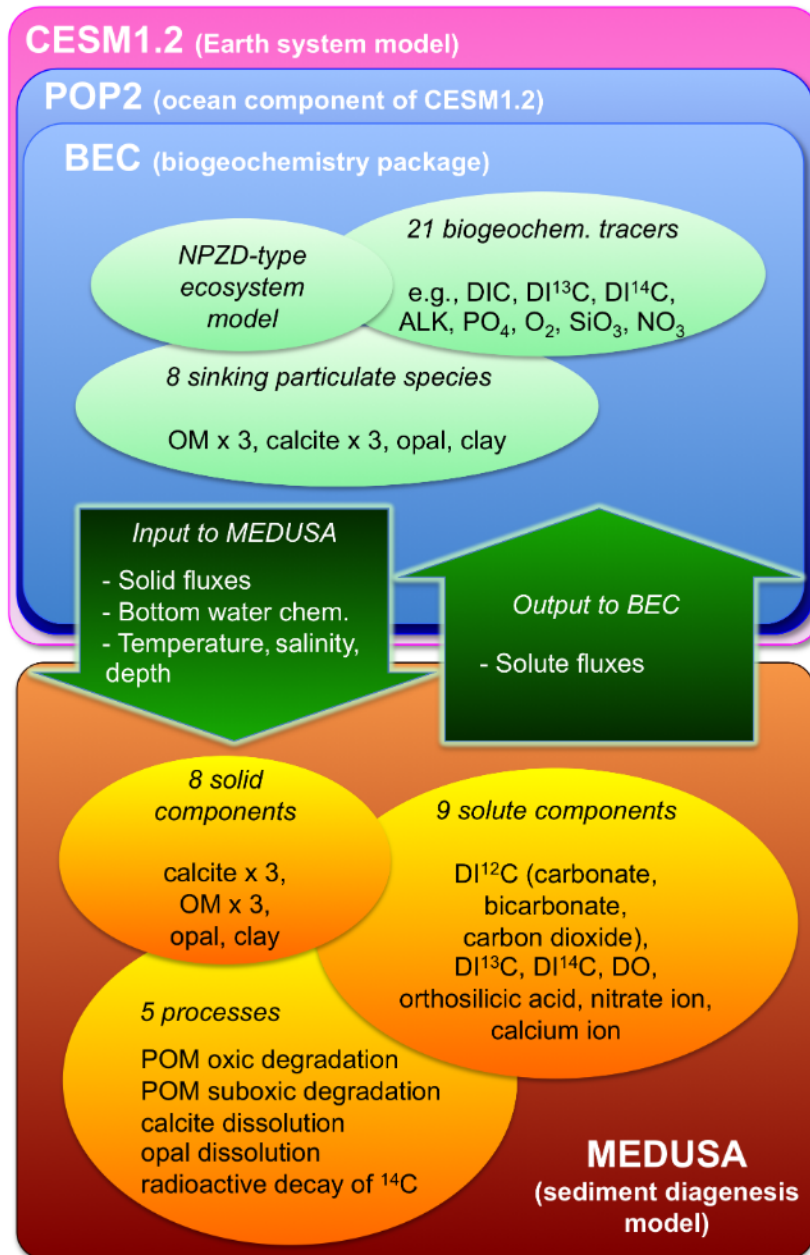


[Hülse et al., 2017]

4 DIFFERENT SEDIMENT APPROACHES



[Hülse et al., 2017]



“Off-line” coupling

- separate and sequential model runs
- manageability of model development and maintenance

Modifying the models

- new variables
- writing/reading routines
- unit conversion
- source/sink terms
- boundary structure

Interface

- one-time/one-way coupling
- automation: a wrapper-level routine to repeat it

EXPERIMENTS

Shields et al. (2012)
+
the prescribed
ecosys initial state
"ecosys_jan_IC_gx3v7_Nov2012_corrO2.nc"

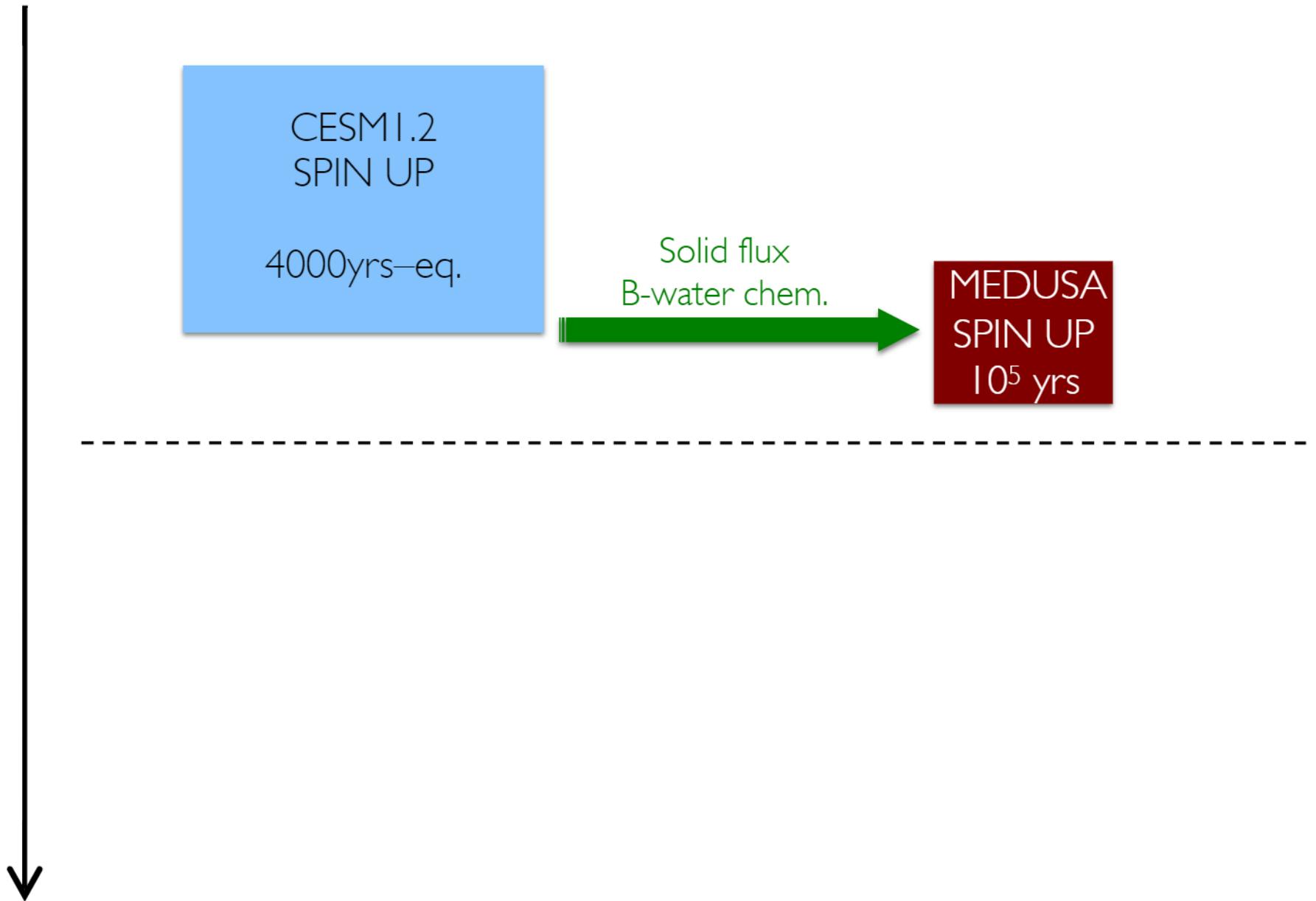


EXPERIMENTS

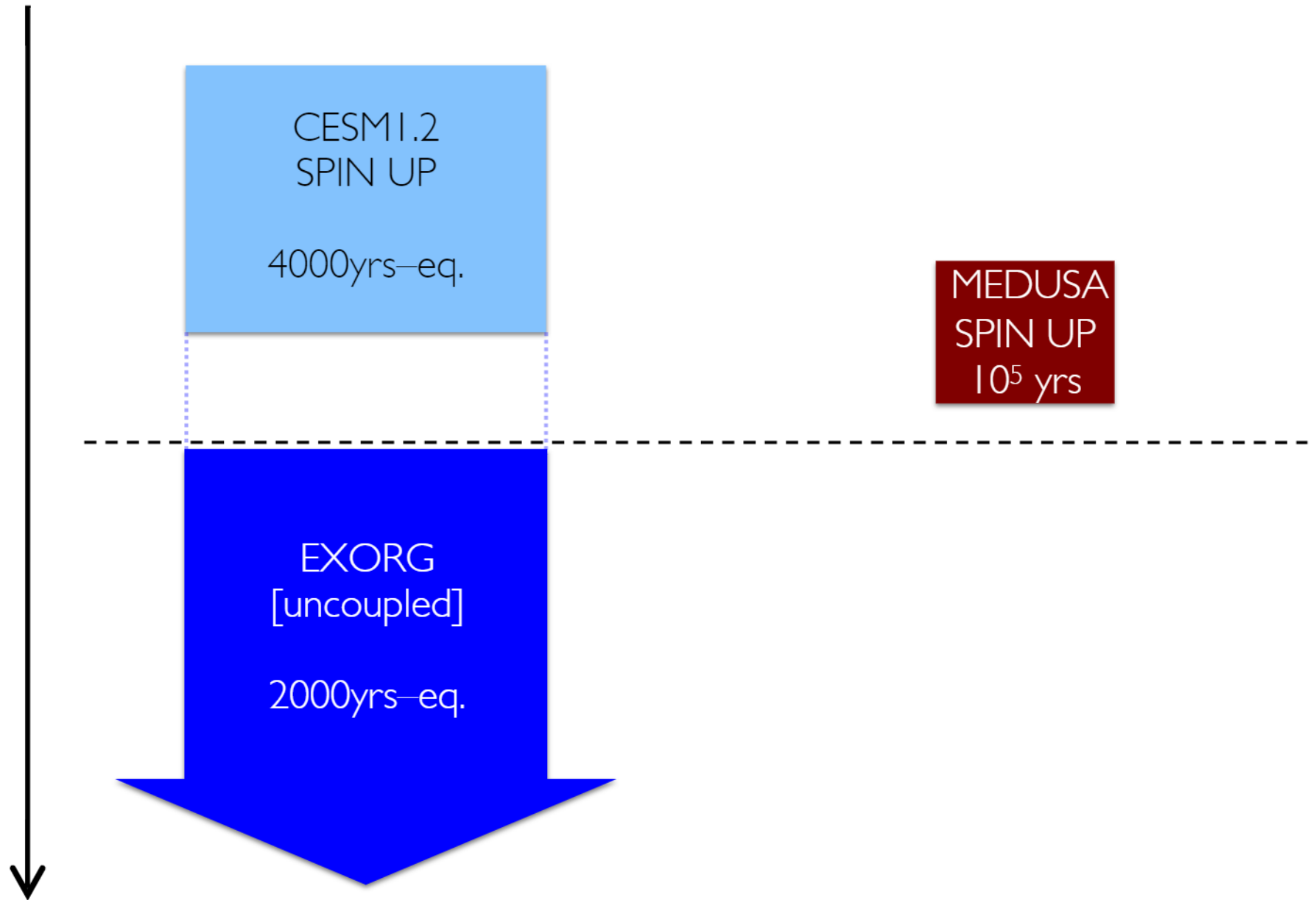
CESM1.2
SPIN UP
4000yrs-eq.



EXPERIMENTS



EXPERIMENTS

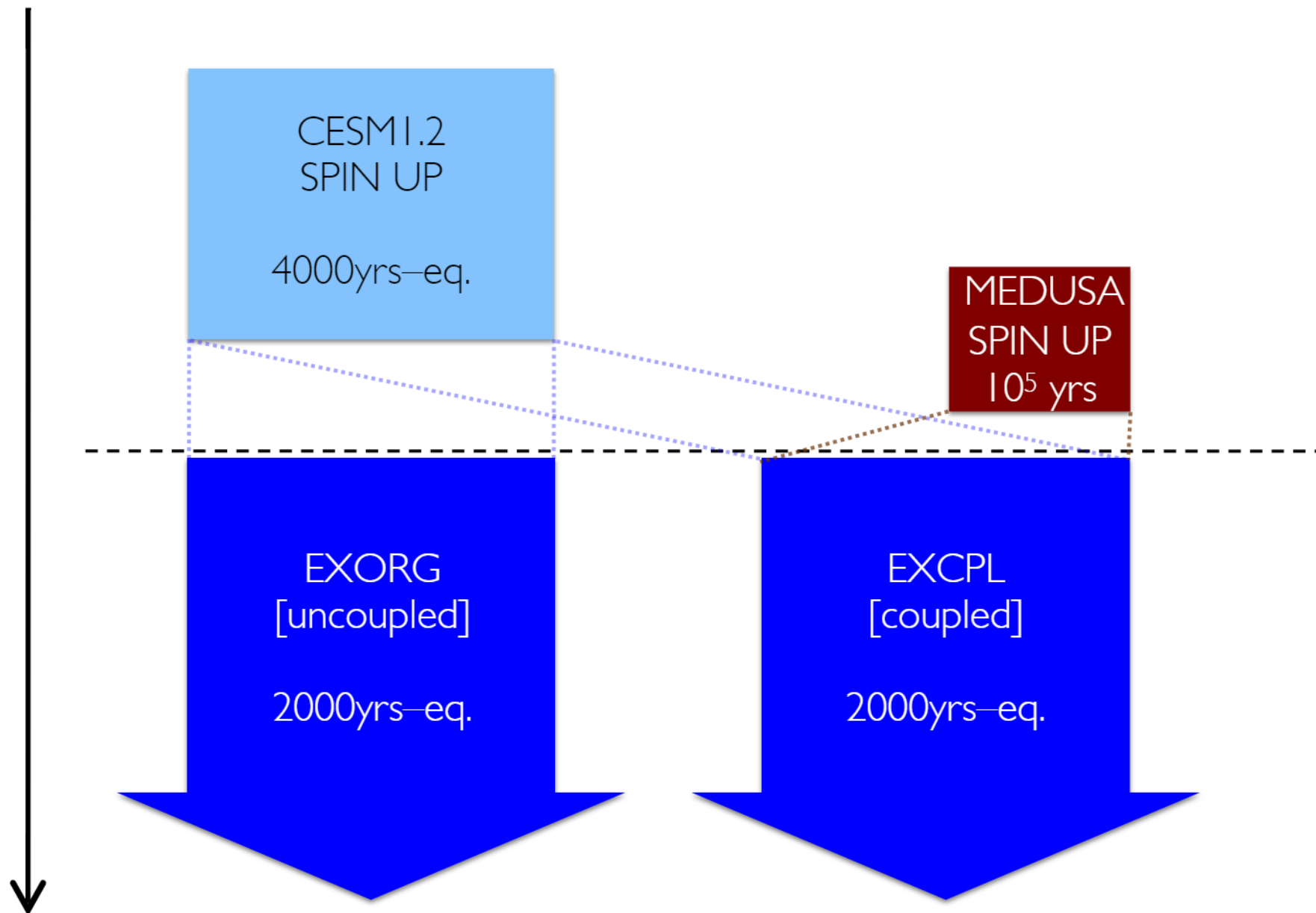


EXPERIMENTS

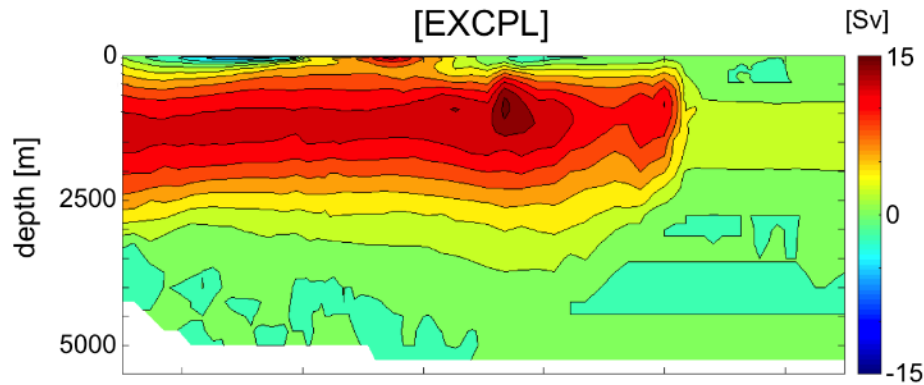


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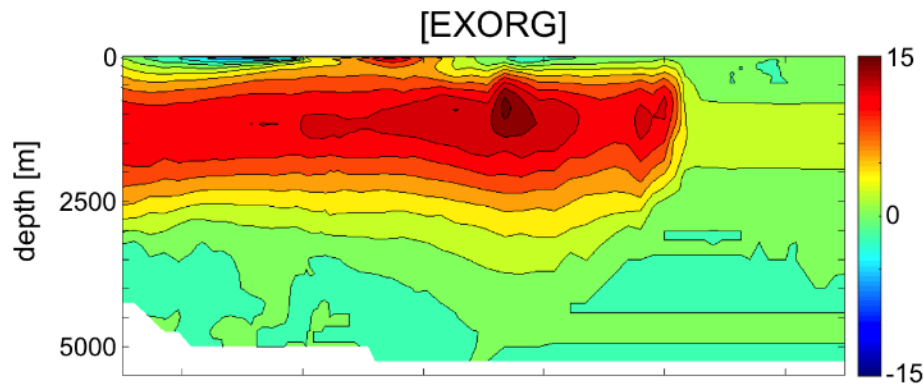
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AMOC AND MORE



AMOC: 16.6 Sv
 Exp Prod: 8.1 GtC
 Rain Ratio: 0.13
 $p\text{CO}_2$: 276.94 ppm



AMOC: 16.7 Sv
 Exp Prod: 8.0 GtC
 Rain Ratio: 0.13
 $p\text{CO}_2$: 276.57 ppm

Total inventories in the global ocean

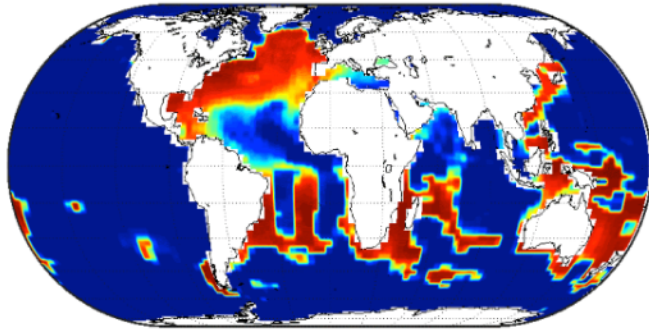
| | EXCPL | EXORG |
|------------------------|---------------------|---------------------|
| DIC (GtC) | 3.660×10^4 | 3.657×10^4 |
| ALK (Peq) | 3.201×10^3 | 3.201×10^3 |
| PO ₄ (Pmol) | 2.948 | 2.923 |

The outlines of ocean state was hardly affected by the different ways of sediment-process treatment at a millennial timescale.

UPPER SEDIMENT COMPOSITION

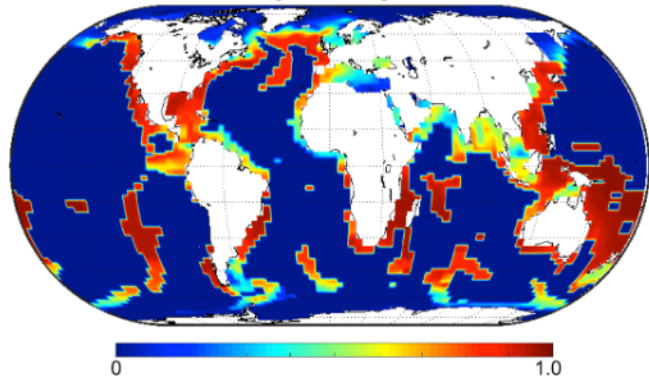
Weight fraction: CaCO_3

[EXCPL]



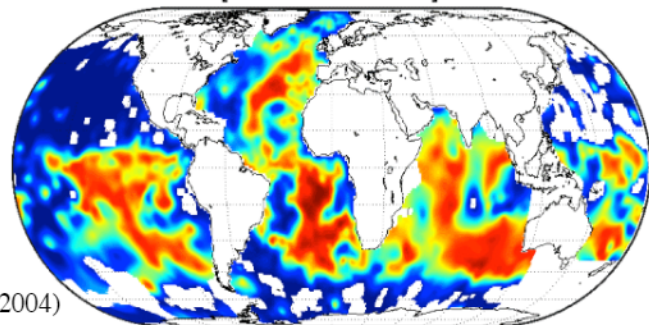
- process-based calculation by the model
- more reliable in another climate state

[EXORG]



- prescribed spatially-constant lysocline depth
- not necessarily adequate for another climate state

[Obs.-based data]

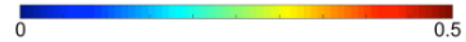
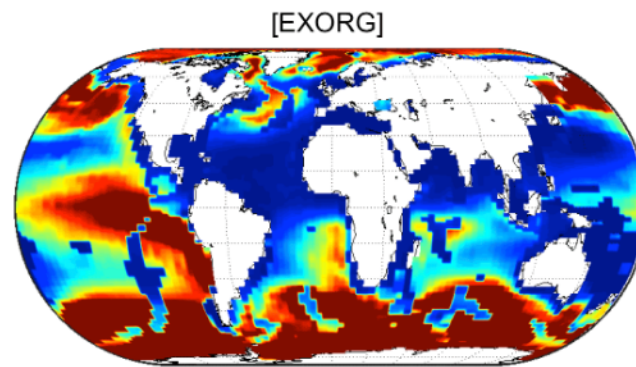
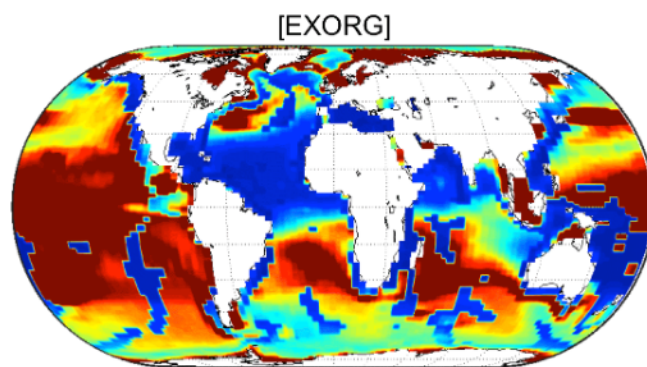
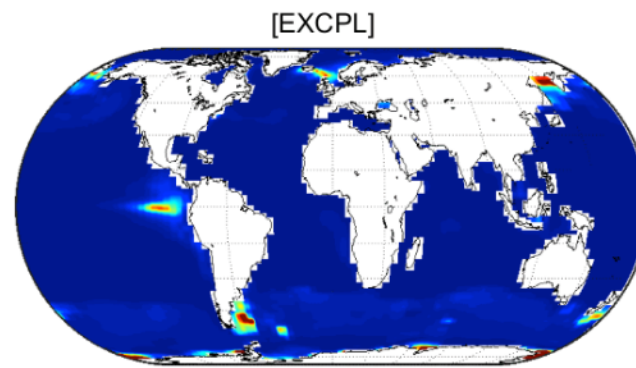
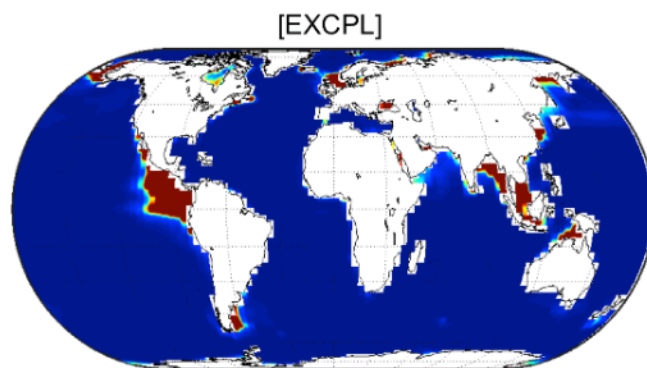


Seiter et al. (2004)

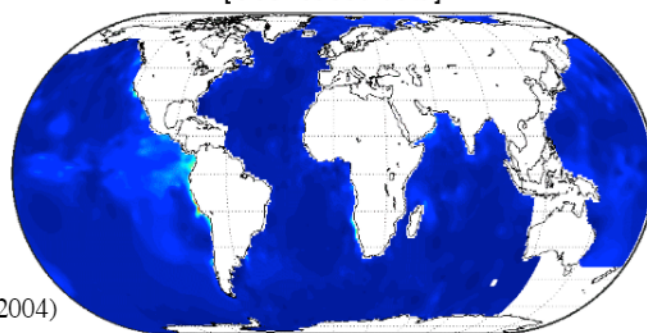
UPPER SEDIMENT COMPOSITION

Weight fraction: org. C

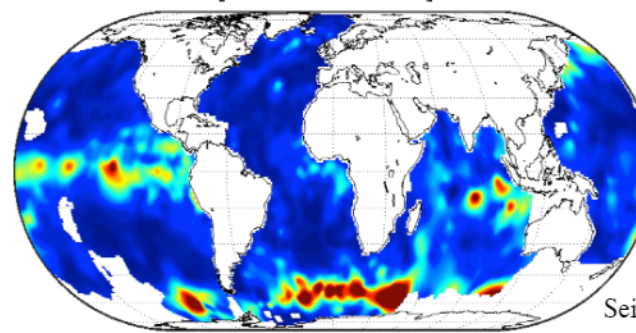
Weight fraction: opal



[Obs.-based data]



[Obs.-based data]



Seiter et al..(2004)

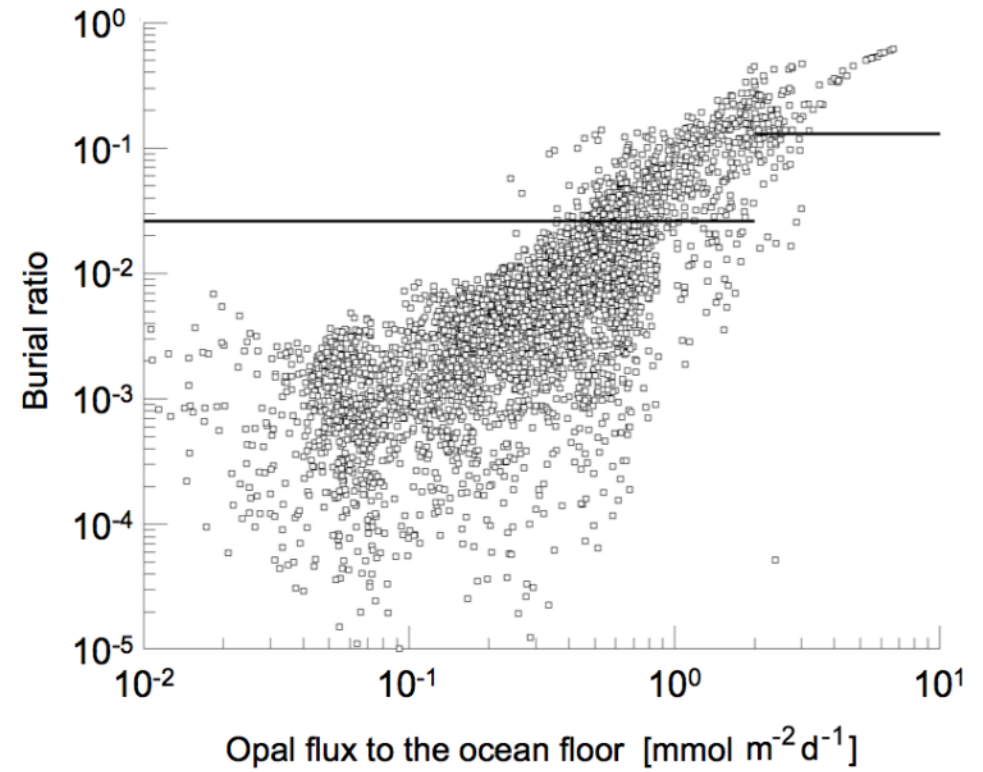
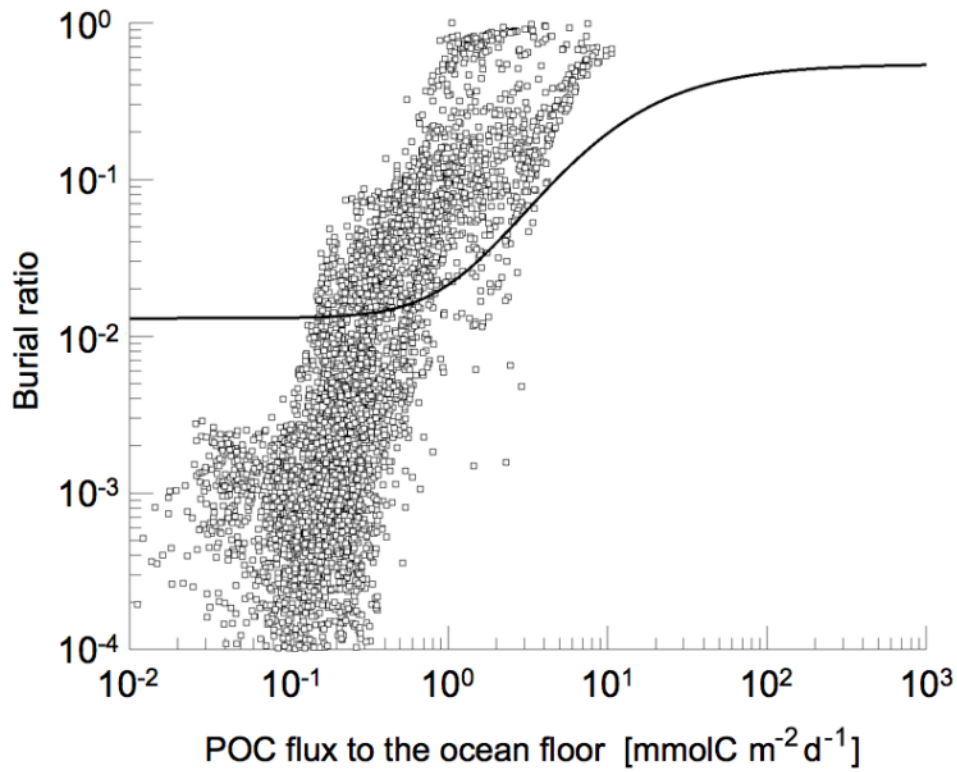
Seiter et al..(2004)

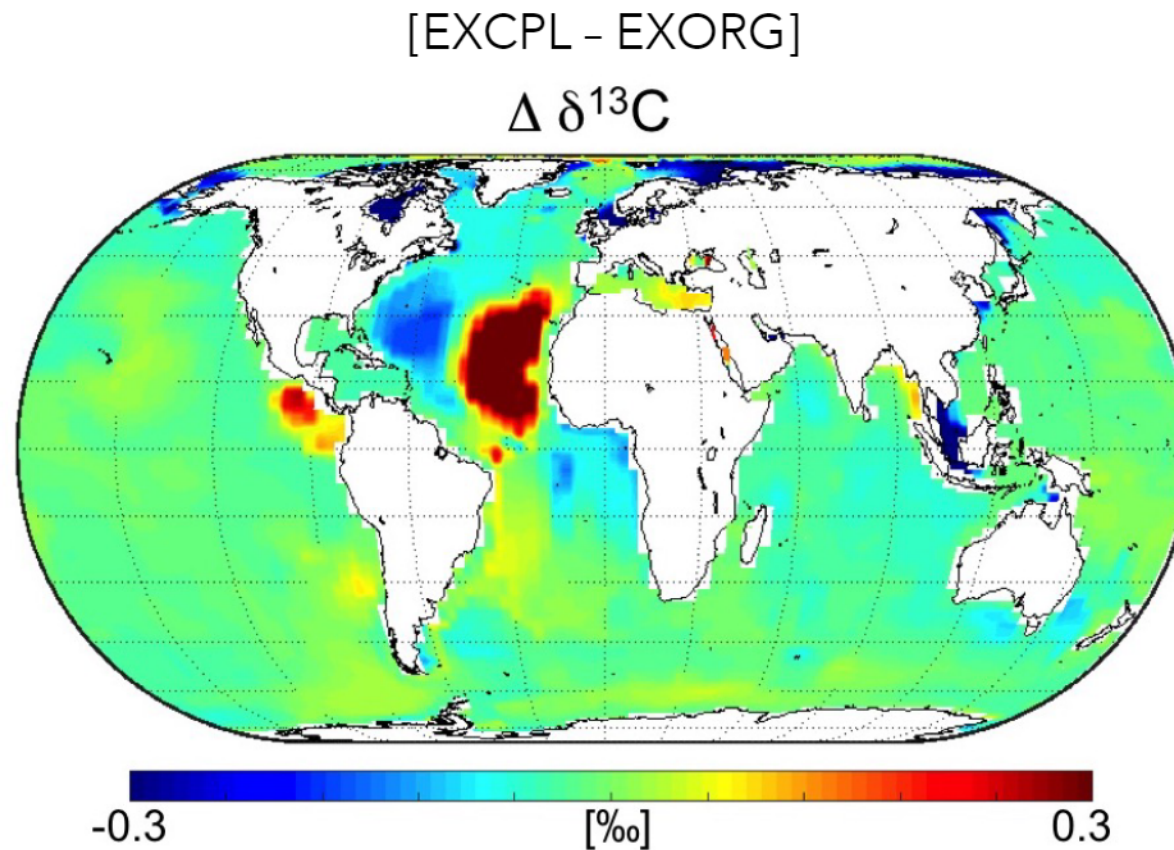
POC & OPAL BURIAL RATIO



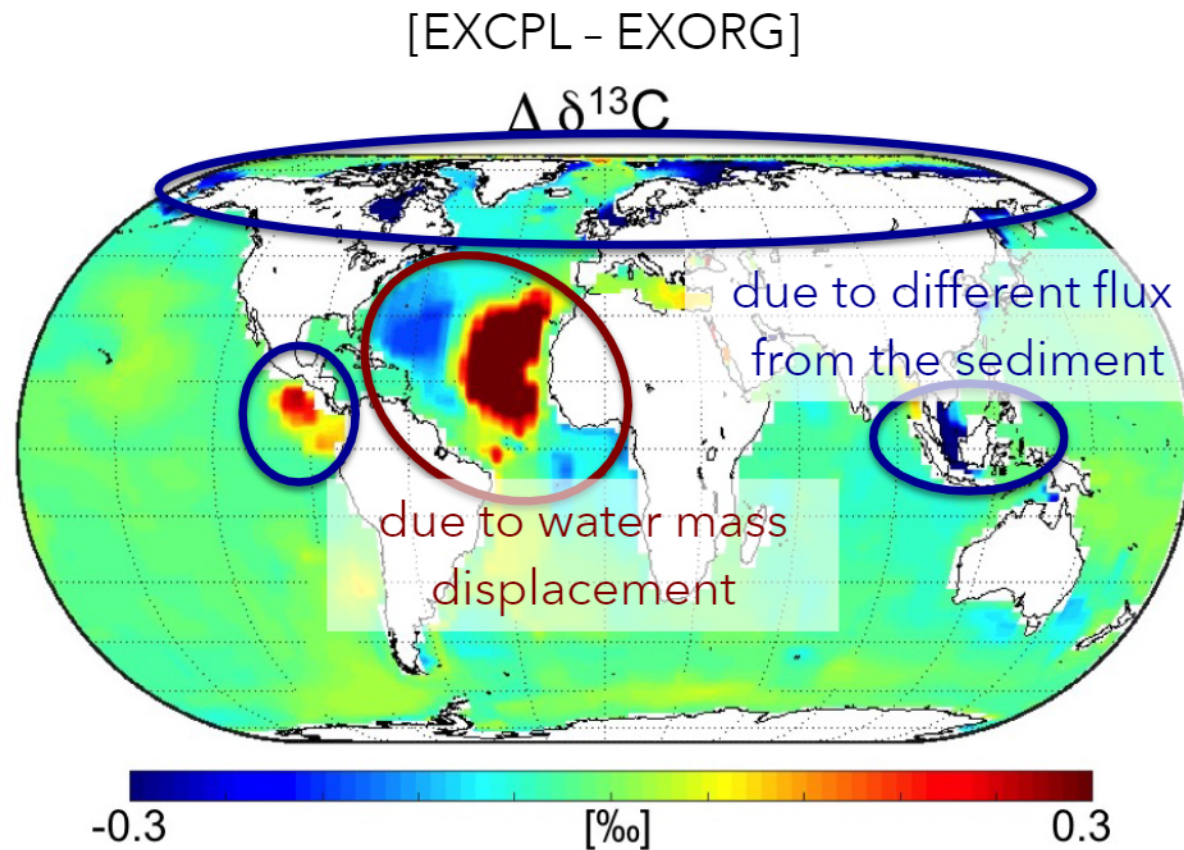
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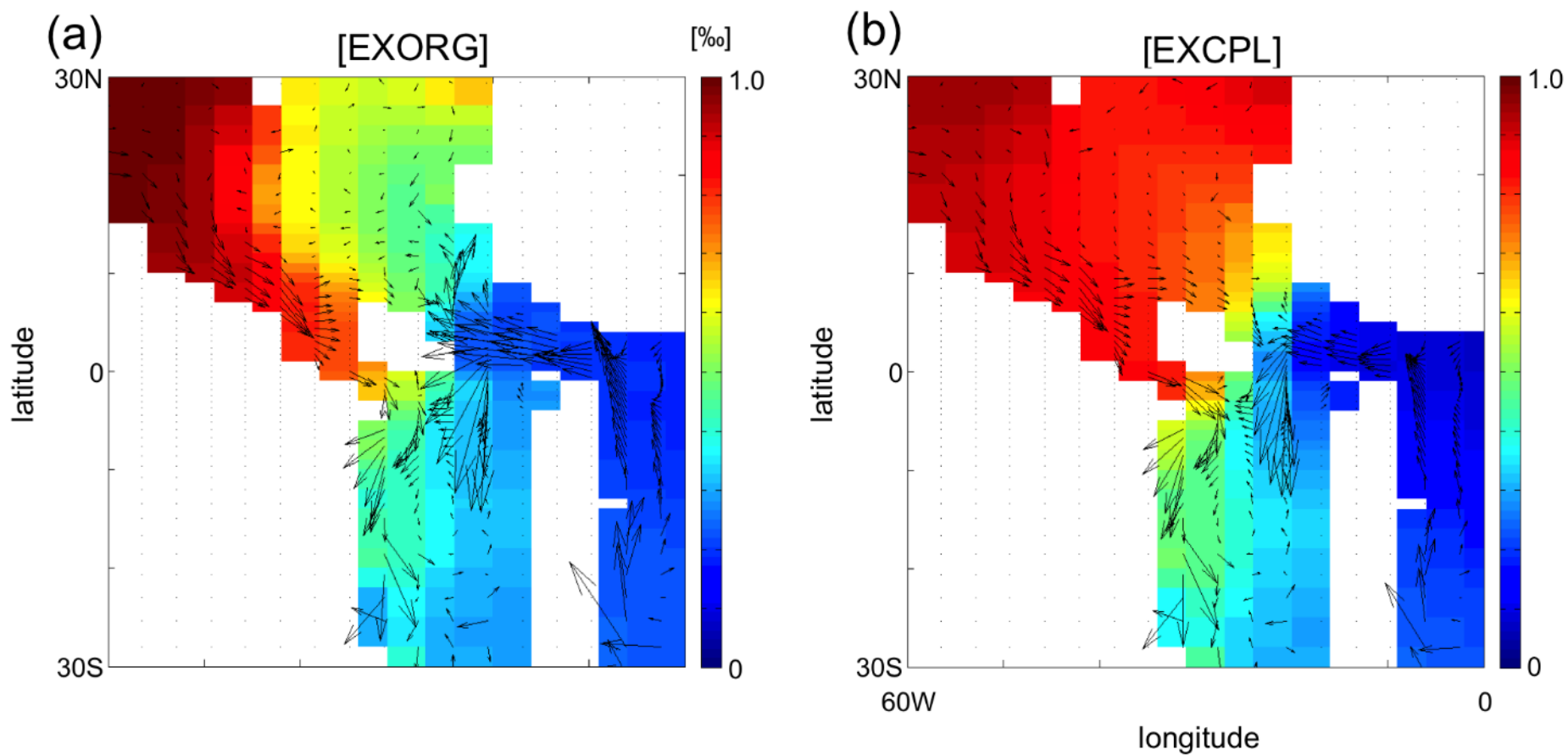


0.2‰ or larger difference in a millennial-scale simulation
→ non-negligible in model-data comparison



0.2‰ or larger difference in a millennial-scale simulation
→ non-negligible in model-data comparison

V and $\delta^{13}\text{C}$ @ ~3900 m



- ▶ Interactive coupling of CESM1.2 and MEDUSA.
- ▶ Much better reconstructed upper sediment properties.
 - Additional measures for model performance by direct comparison with the sedimentary archives.
- ▶ Non-negligible effects on the chemical composition of bottom water at a millennial timescale.
 - Influence on model-data comparisons.
- ▶ Dynamical CaCO_3 diagenesis for future long-term simulations.

