The Ocean During the Last Glacial Maximum (LGM) and Early Deglaciation Constrained by Isotopes

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Methods

•Can we constrain the LGM ocean circulation of the LGM using isotopes?

•We have a model that simulates three key isotopes: Radiocarbon, δ13C, and δ15N, which can be compared to reconstructions

•We propose different configurations:

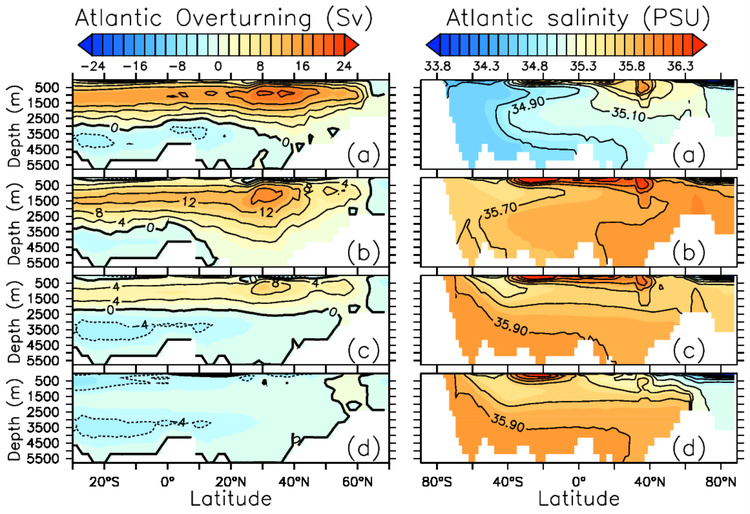


Figure 1: *Atlantic circulation and salinity sections used in the simulations: (a) preindustrial (PI), (b) LGM strong circulation, (c) LGM weak circulation, (d) LGM collapsed circulation*

•But some of these isotopes depend both on ocean circulation AND biogeochemistry (e.g., strength of the biological pump).
•By varying the LGM's atmospheric soluble iron flux we produce changes in export production.
•Higher export production in the Southern Ocean increases LGM δ15N, in agreement with observations.

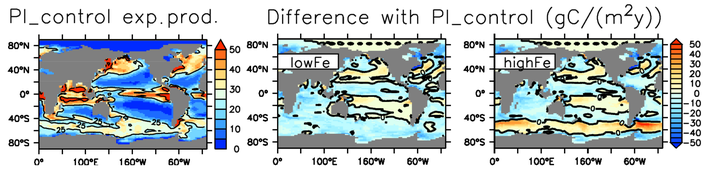


Figure 2: *Top: PI export production and LGM-PI differences for (b) and (c).*

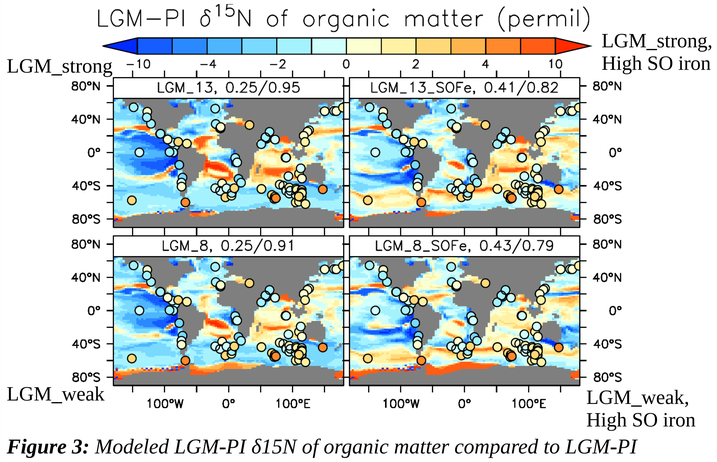
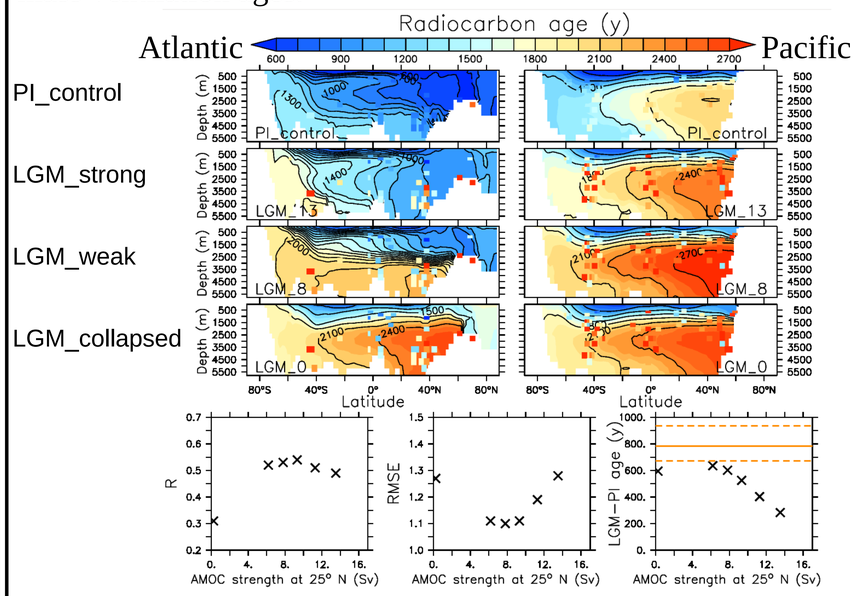


Figure 3: *Modeled LGM-PI δ15N of organic matter compared to LGM-PI reconstructions (Francois et al., 1997, Schmittner and Somes, 2016, Wang et al., 2017), for different AMOC states and SO iron fluxes.*

Results: Which ocean circulation states best reproduce radiocarbon and δ13C from the LGM?

Radiocarbon ages: Radiocarbon is a proxy for water mass ventilation ages.



δ13C: δ13C of dissolved inorganic carbon (preserved in benthic foraminifera shells) is a proxy for water mass distribution.

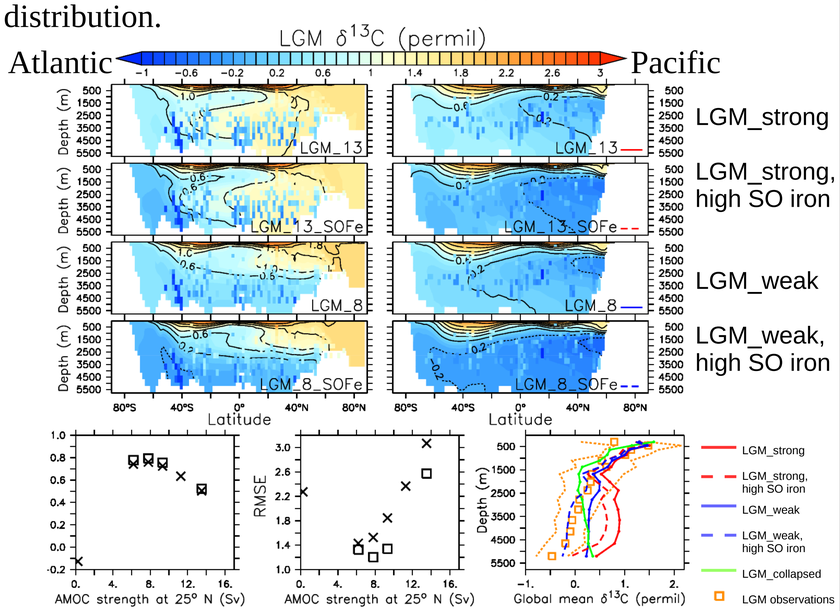
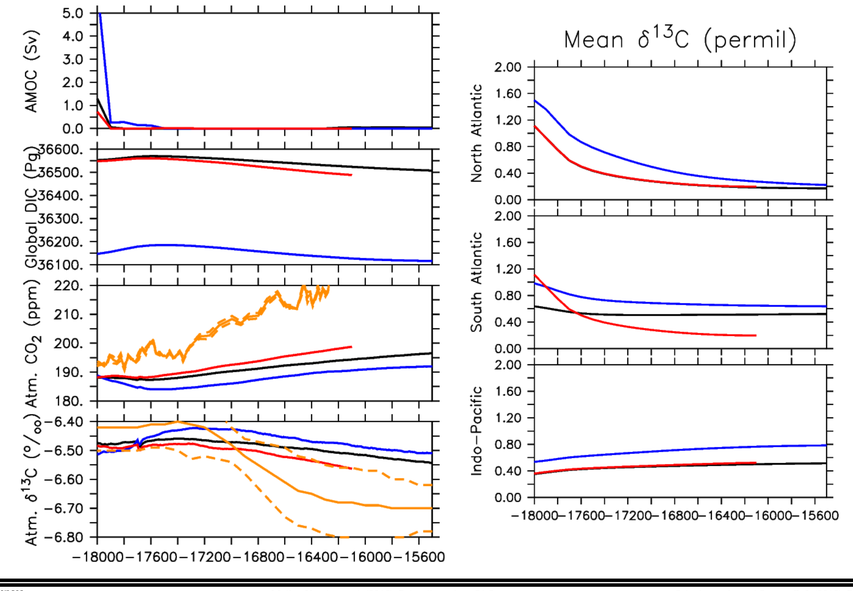


Figure 5: *Modeled δ13C compared to PI and LGM observations (Peterson et al., 2014; Molina-Kescher et al., 2016; Sikes et al., 2016; Burckel et al., 2016), for different AMOC states and SO iron fluxes.*

A weak, shallow AMOC and voluminous Antarctic Bottom Water produces the best reproduction of glacial isotopes Higher Southern Ocean export production is needed to reproduce LGM-Late Holocene changes in δ15N, and improves the representation of glacial δ13C.

We can use our LGM state as an initial condition for deglacial simulations. What are the parameters that dominated changes in atmospheric CO2 and isotopes during the transition towards warmer global conditions?

More on this in Muglia et al., 2018, EPSL



Early deglacial simulation results, during and after a 400 y uniform hosing in the North Atlantic of 0.2 Sv.

- LGM_weak as initial condition
- LGM_strong as initial condition
- LGM_weak as initial condition with deglacial wind stress anomalies from Trace simulations (He et al., 2013)
- Deglacial CO2 (Marcott et al., 2014) and atmospheric δ13C (Schmitt et al., 2012) recontructions, with uncertainties as dashed lines.

• North Atlantic hosing produces time series of CO2 and atmospheric δ13C with a weak AMOC as initial condition.

• Deglacial changes in wind stress produce effects originated in the Atlantic sector of the Southern Ocean.

• Many other configurations will be tested in the future, for example, differences in the geometry and the volume transport of fresh water forcing from ice sheet melting.

•A compilation of deglacial δ13C is being produced (OC3 project, ask me about it!)

References
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