Early Deglacial AMOC Decline and its Role for Atmospheric CO_2 Rise Inferred from Carbon Isotopes

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Questions:

1. Was AMOC reduced during the early deglacial Heinrich Stadial event 1 (HS1; 18-15 ka BP)?
2. Did AMOC decline contribute to rise in CO_2?

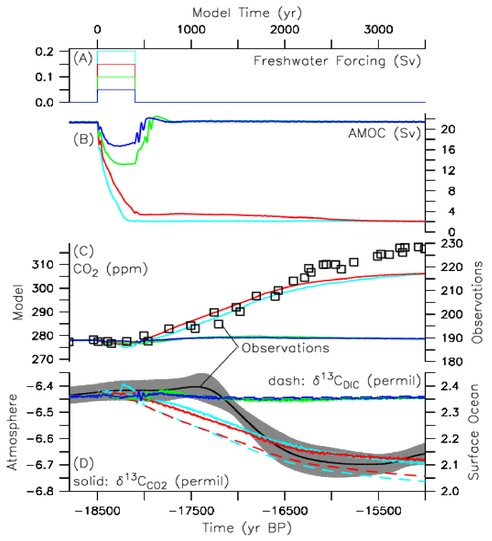


Fig. 1: Timeseries of forcing (A) and AMOC (B), CO_2 (C), $\delta^{13}C_{CO2}$ (D) for four model experiments starting from pre-industrial conditions: FW0.05 (blue), FW0.1 (green), FW0.15 (red), and FW0.2 (cyan). Symbols and grey bar with black line show ice core data (bottom time scale). Note that absolute scales are different for model (left) and observations in (C), but the range is the same.

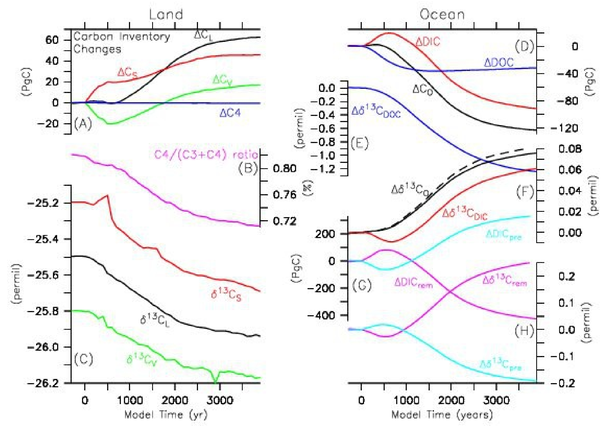
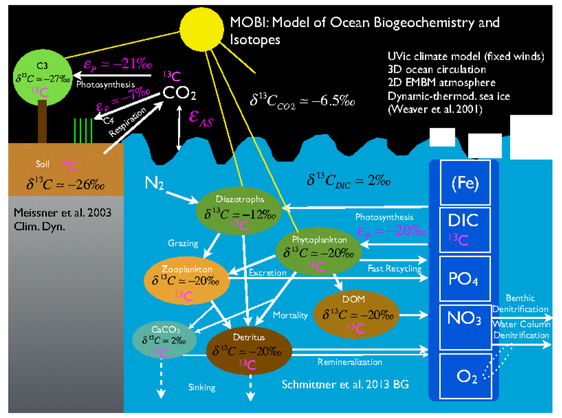


Fig. 2: Response of land and ocean carbon pools in experiment FW0.15.

UVic Climate model:

3D ocean 1.8x3.6 deg, 19 levels
2D atmospheric Energy Moisture Balance
Land and ocean carbon cycle
Model of Ocean Biogeochemistry and Isotopes (MOBI 1.4) includes carbon isotopes in ocean, land, and atmosphere



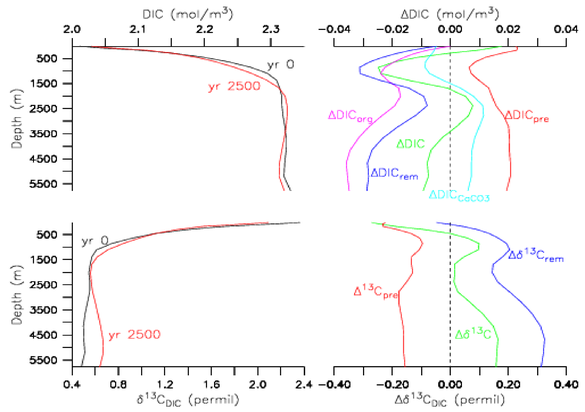


Fig. 3: Globally averaged vertical profiles at years 0 and 2,500 of DIC and $\delta^{13}C_{DIC}$ for model experiment FW0.15 (left). Right panels show the differences as well as contributions from organic matter (org), CaCO3, their sum (rem) and preformed (pre).

Sediment Data: Compilation of 23 high-resolution carbon isotope records.---------->>

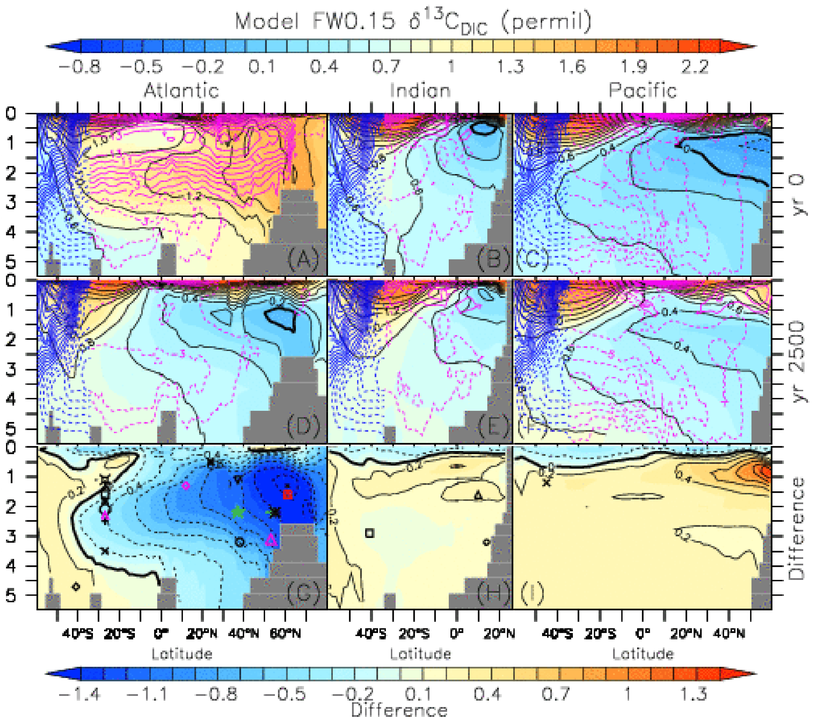


Fig. 4: $\delta^{13}C_{DIC}$ distributions (color shading and black isolines) and MOC (purple and blue isolines) for model years 0 and 2,500 as well as their differences (bottom). The symbols in the bottom panels denote locations of high-resolution $\delta^{13}C$ sediment data shown in Fig. 5.

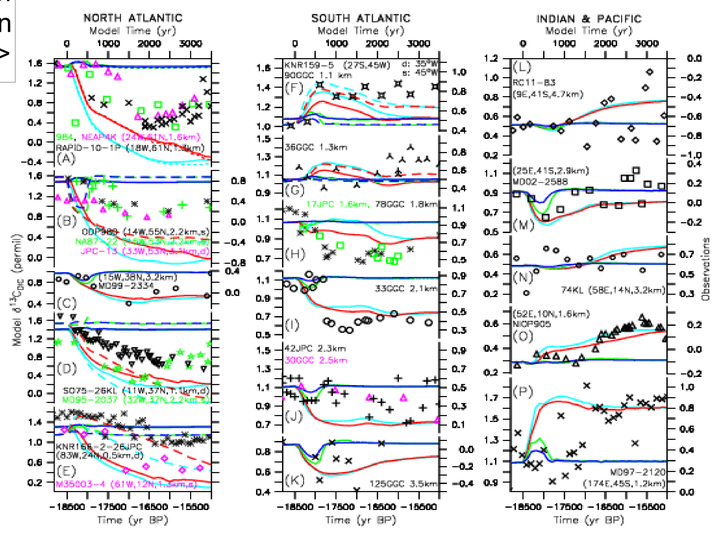


Fig. 5: Timeseries of sediment data (symbols) and model results at the corresponding grid points (color lines as in Fig. 1). See Fig. 4 for location of data.

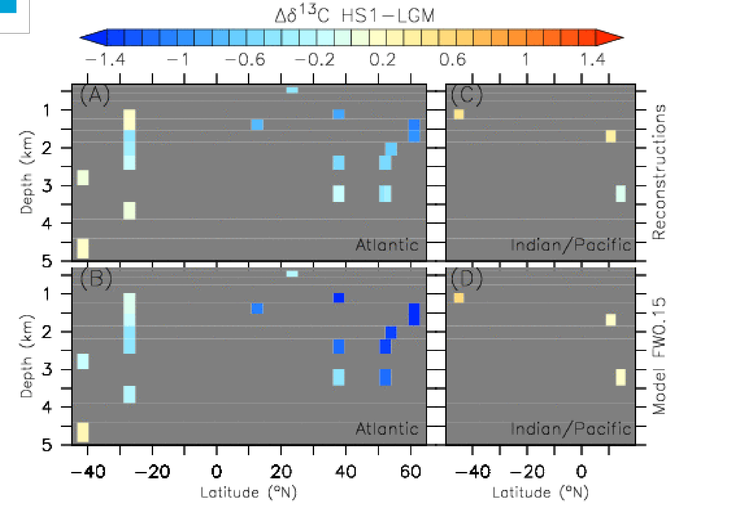


Fig. 6: Sections of changes in carbon isotopes between the Last Glacial Maximum (19-20 ka BP) and HS1 (15.5-16.5 ka BP) from sediment data (top) and experiment FW0.15 (bottom). Note that while the pattern of changes is similar the model overestimates the amplitude in the North Atlantic.

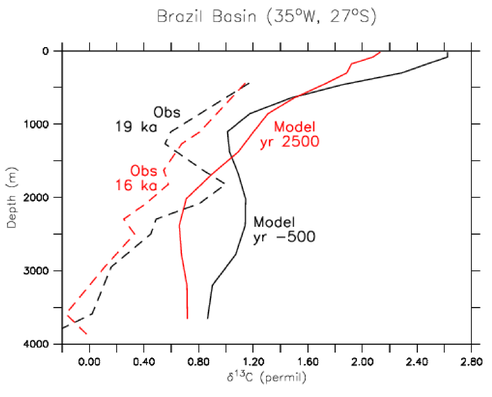


Fig. 7: Vertical profiles of carbon isotopes along the Brazil Margin from sediment data (dashed) and model FW0.15 (solid).

Model	R	RMS error
FW0.05	0.77	0.48
FW0.1	0.77	0.48
FW0.15	0.89	0.42
FW0.2	0.9	0.55

Table: Correlation coefficient (R) and root-mean-squared (RMS) error for model data comparison.

Results:

Simulated AMOC collapse

- decreases efficiency of biological pump (Figs. 2, 3)
- causes CO_2 to increase, $\delta^{13}C_{CO2}$ to decrease, consistent with ice core data (Fig. 1)
- has large effect on ocean $\delta^{13}C$ distribution (Fig. 4)
- modeled changes agree with sediment data from LGM-HS1 (Figs. 5,6,7,8; Table)
- but model overestimates changes in North Atlantic. Why?
  - HS1 AMOC changes were smaller than simulated, or
  - different initial conditions (Fig. 7) could affect results

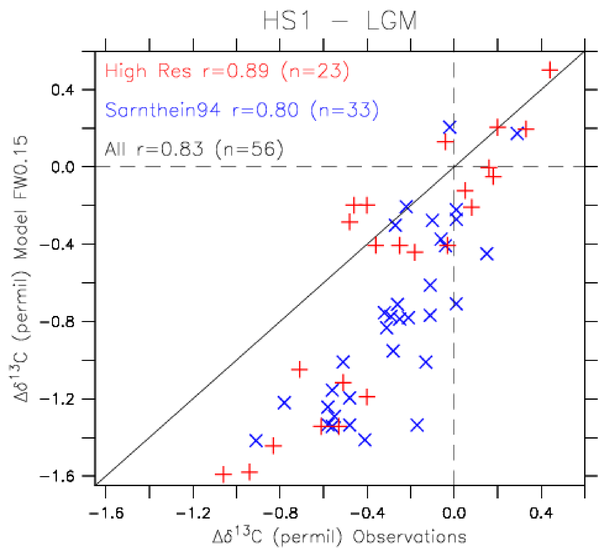


Fig. 8: Modeled vs observed carbon isotope changes from our high-resolution sediment data (red) and a previous study using lower resolution data (Sarnthein et al. 1994).

Conclusions:

1. **AMOC was substantially reduced for a multi-millennial time period during HS1 compared to the prior LGM.**
2. **Early deglacial CO_2 rise and decrease in $\delta^{13}C_{CO2}$ may have been caused by AMOC reduction.**

Reference: Schmittner, A., and Lund, D. C. (2014) Carbon Isotopes Support Atlantic Meridional Overturning Circulation Decline as a Trigger for Early Deglacial CO_2 rise, Climate of the Past Discussions.

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