AGU PUBLICATIONS

*Paleoceanography*

Supporting Information for

# Complementary Constraints from Carbon (13C) and Nitrogen (15N) Isotopes on the Efficiency of the Glacial Ocean's Biological Pump

A. Schmittner[1], and C. J. Somes[2]

[1]College of Earth, Ocean, and Atmospheric Sciences, Oregon State University, Corvallis OR, USA.

[2] GEOMAR Helmholtz Centre for Ocean Research, Kiel, Germany.

## Contents of this file



## Carbon and $^{13}C$ Budget

The two conservation equations of total carbon (C = $^{12}C$ + $^{13}C$) and $^{13}C$ in the Earth system can be written as

$$\sum_R C_R = C_O + C_L + C_A = C = \text{const1} \quad (1)$$

$$\sum_R \delta_R C_R = \delta_O C_O + \delta_L C_L + \delta_A C_A = {}^{13}C = \text{const2}\,, \quad (2)$$

where the delta value $\delta = ({}^{13}C/C)/({}^{13}C/C)_{std} - 1$ is the ratio of $^{13}C$ over C normalized to that of a standard and the index $R \in (O, L, A)$ refers to the three reservoirs: ocean, land, and atmosphere. Since here we're interested in changes between the LGM and the Late Holocene (LH) we can re-write those equations as

$$\sum_R \Delta C_R = \sum_R C_{R,LGM} - C_{R,LH} = 0 \quad (3)$$

$$\sum_R \delta_{R,LGM} C_{R,LGM} - \delta_{R,LH} C_{R,LH} = \sum_R \delta_{R,LH} \Delta C_R + \Delta\delta_R C_{R,LGM} = 0 \quad . \quad (4)$$

Assuming no changes in the atmospheric delta value $\Delta\delta_A = 0$ eq. (4) yields

$$\Delta C_O = \frac{\Delta C_A(\delta_{L,LGM} - \delta_{A,LH}) - C_{L,LH}\Delta\delta_L - C_{O,LH}\Delta\delta_O}{\delta_{O,LGM} - \delta_{L,LGM}}\,. \quad (5)$$

Inserting $\delta_{L,LGM} = -25‰$, $\Delta\delta_L = 1‰$, $\delta_{A,LH} = -6.5‰$, $\delta_{O,LGM} = 0.25‰$, $\Delta\delta_O = -0.35‰$, $\Delta C_A = -190\text{Pg}$, $C_{O,LH} = 37{,}000\text{Pg}$, $C_{L,LH} = 1{,}800\text{Pg}$ we diagnose an increase in the ocean's carbon reservoir of $\Delta C_O$ ; $550\text{Pg}$ and a decrease in land carbon of $\Delta C_L$ ; $-360\text{Pg}$. The sensitivity of the ocean carbon reservoir change to the change of the whole ocean delta value is approximately

$$\frac{\partial \Delta C_O}{\partial \Delta \delta_O} ; \frac{C_{O,LH}}{\delta_{L,LGM}} ; -1{,}500\text{Pg/‰}.$$

MOBI's carbon inventory $C_O=C_{DIC}+C_{DOC}+C_{PO}+C_{PD}+C_Z+C_D \approx C_{DIC}+C_{DOC}$ is comprised of mainly dissolved inorganic and dissolved organic carbon, whereas the carbon stored in living biomass and particulate organic matter is negligible. Similarly, the nitrogen inventory is $N_O = N_{DIN}+N_{DON}+N_{PO}+N_{PD}+N_Z+N_D \approx N_{DIN}+N_{DON}$. Changes in dissolved organic matter are very small between all experiments and are thus not reported.

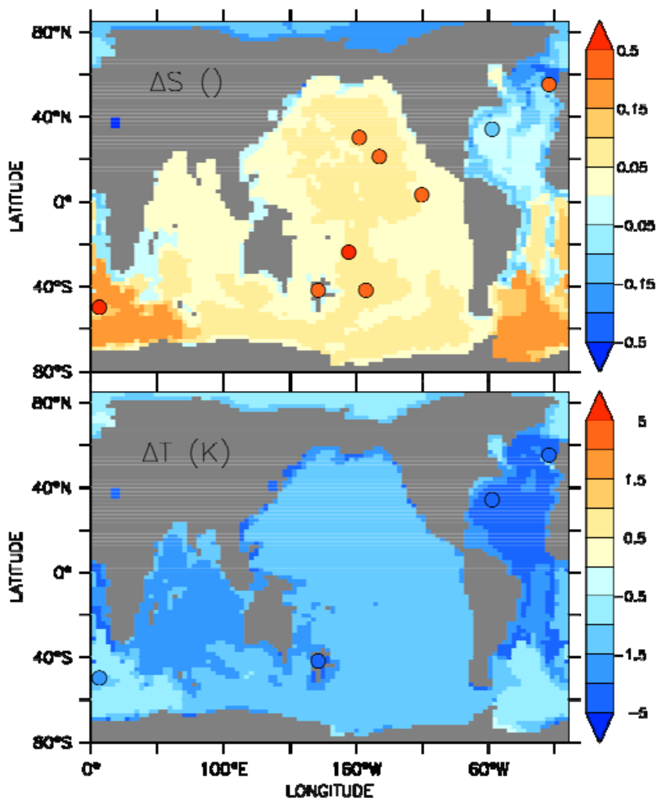

**Figure S1.** Changes in bottom water salinity (top) and temperature (bottom) below 1 km depth between LGM and piCtrl. Circles indicate reconstructions [Adkins et al., 2002; Insua et al., 2014]. The changes in salinity in the reconstructions have been reduced by one in order to account for the effect of global mean salinity change due to sea level rise, which is not included in the model simulations. Color intervals are (±0.5, ±0.2, ±0.15, ±0.1, ±0.05, 0) and (±5, ±2, ±1.5, ±1, ±0.5, 0) for salinity and temperature, respectively.

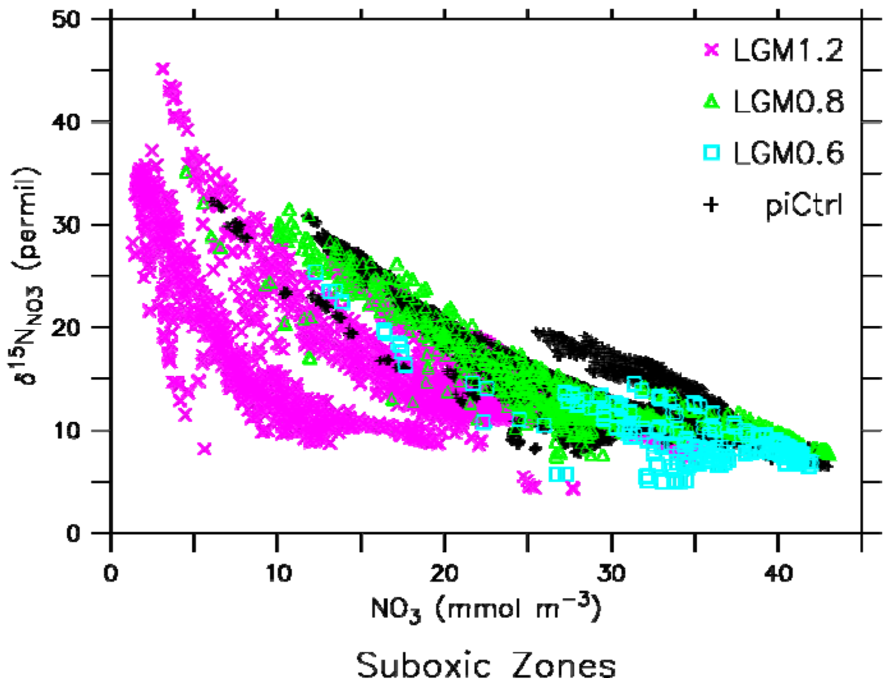


**Figure S2.** $\delta^{15}N_{NO3}$ versus $NO_3$ in suboxic zones ($O_2$ < 10 mmol/m$^3$) in four models.