A STUDY OF GLACIAL–INTERGLACIAL VARIATIONS OF THE MARINE STABLE CARBON ISOTOPE RECORD USING A NON-REDFIELD BIOGEOCHEMICAL MODEL

PALMOD GERMAN CLIMATE MODELING INITIATIVE

Federal Ministry of Education and Research

Martin Butzin, Peter Köhler, Christoph Völker
Alfred-Wegener-Institut Helmholtz Zentrum für Polar- und Meeresforschung, Bremerhaven
Martin.Butzin@awi.de

Motivation

Photosynthetic plankton has a lower ^{13}C concentration than the aqueous CO_2 from which it was formed. The isotopic discrimination during photosynthesis increases the ^{13}C:^{12}C ratio (or $\delta^{13}C$) of dissolved inorganic carbon (DIC). Here, we investigate the effect of two different parametrizations of biogenic fractionation on the carbon-isotopic signature of DIC under present and glacial climate conditions.

Biogenic carbon fractionation

We consider two parametrizations of biogenic fractionation. Rau (1994) found that the isotopic depletion of phytoplankton $\delta^{13}C_P$ increases with the availability of aqueous carbon dioxide CO_2^*:

$$\delta^{13}C_P = -a_0 CO_2^* - b_0$$

Laws et al. (1997) found that $\delta^{13}C_P$ also depends on the isotopic composition of CO_2^* (depending on temperature and $CO_3^=$) and photosynthesis μ:

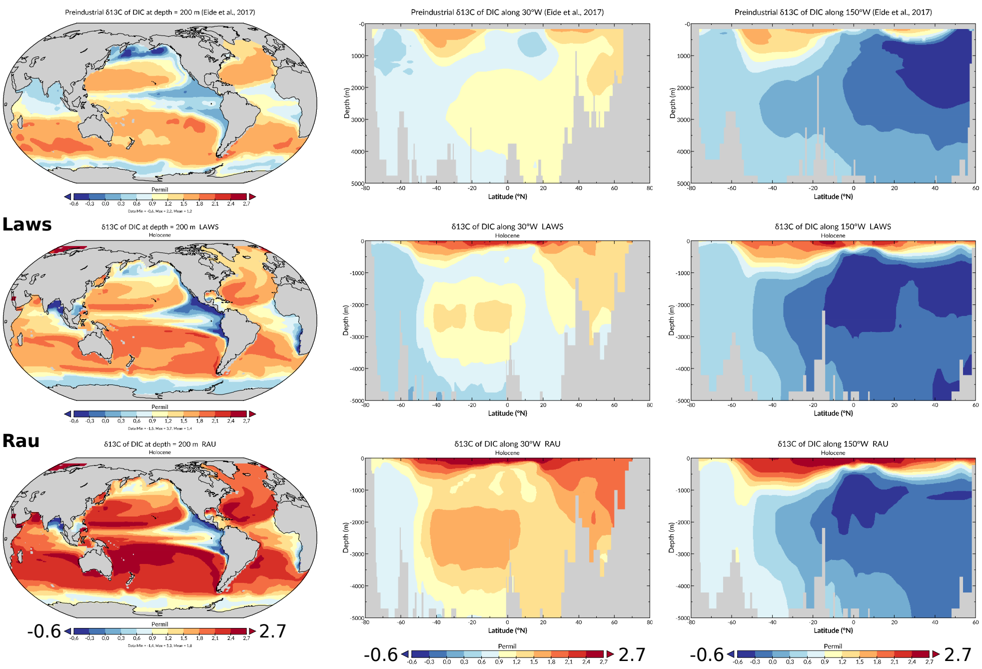
$$\delta^{13}C_P = \delta^{13}CO_2^* - (a_1 CO_2^* + b_1\mu) / (a_2 CO_2^* + b_2\mu)$$

Holocene

Reconstruction 200 m Atlantic Pacific

Laws

Rau

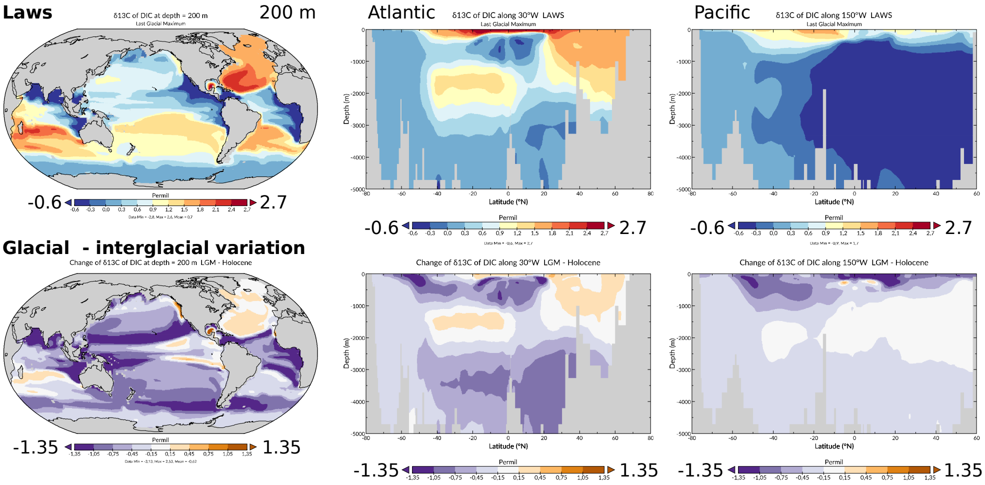


The biogenic fractionation parametrization according to Rau leads to higher values of $\delta^{13}C$ of DIC than the parametrization by Laws et al. The elevation is not limited to the euphotic zone but is also obvious in deeper waters. In our Holocene simulations the parametrization according to Laws et al. leads to better agreement with the reconstruction by Eide et al.

Last Glacial Maximum

Laws 200 m Atlantic Pacific

Glacial - interglacial variation



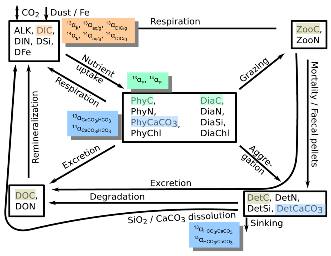
We find isotopic depletion of DIC except for small areas such as the subtropical North Atlantic and the Indian.

Conclusion / Summary / Outlook

Different parametrizations of biogenic fractionation lead to discernable changes in the carbon-isotopic composition of DIC. The differences are seen in the entire water column. This may be particularly an issue in future model – data comparisons for the glacial ocean.

Model setup

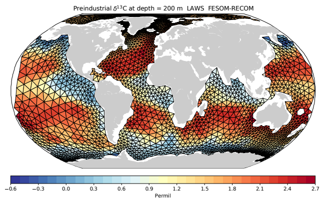
We use the Regulated Ecosystem Model RECOM which does not rely on fixed Redfield ratios for organic soft tissue. Instead, the C:N and C:Chl ratios in phytoplankton respond to light, temperature and nutrient supply. We consider isotopic fractionation during uptake and dissolution of CO_2, calcification, and photosynthesis of phytoplankton, plus radioactive decay of ^{14}C.



Tracers are transported via the MITgcm, forced with climatological fields derived in fully coupled climate simulations for the Holocene (Wei & Lohmann, 2012) and the Last Glacial Maximum (Zhang et al., 2013). Our MITgcm-RECOM simulations build upon previous work by Völker & Köhler (2013). Dust fields are by Albani et al. (2016). Model resolution is 2° longitude x 0.38° to 2.0° latitude x 30 levels. Integration time (so far): 2 – 3 kyears.

Current model development

RECOM has become part of the most recent version of the AWI climate model. The AWI climate model features FESOM, a multi-resolution sea ice-ocean model solving the equations of motion on unstructured meshes. The figure below gives an early impression of a test run with prescribed preindustrial climate forcing.



References

Albani S et al. (2016), doi:10.1002/2016GL067911
Eide M et al. (2017), doi:10.1002/2016GB005473
Laws, EA et al. (1997), doi:10.4319/lo.1997.42.7.1552
Rau GH (1994), in: Zahn R et al. (eds), Carbon cycling in the glacial ocean: constraints on the ocean's role in global climate change Springer, Berlin, p 307-322
Völker C & Köhler P (2013), doi:10.1002/2013PA002556
Wei W & Lohmann G (2012), doi:10.1175/JCLI-D-11-00667.1
Zhang X et al. (2013), doi:10.5194/cp-9-2319-2013