Estimates of global ocean cooling at the Last Glacial Maximum based on sea-surface temperature and oxygen-isotope reconstructions

André Paul¹, Stefan Mulitza¹, Martin Losch² and MARGO Isotope Group
(1) MARUM - Center for Marine Environmental Sciences and Department of Geosciences, University of Bremen, Bremen, Germany (apaul@marum.de)
(2) Alfred Wegener Institute for Polar and Marine Research, Bremerhaven, Germany

Motivation
The MARGO (Multi-proxy Approach for the Reconstruction of the Glacial Ocean Surface) sea-surface temperature (SST) reconstruction for the Last Glacial Maximum (LGM, ~23,000-19,000 a before present) has been criticized to yield a low estimate of the fast-feedback climate sensitivity of less than 3 °C for a doubling of the atmospheric CO₂ concentration.

Methods
- Combined oxygen isotope ratios measured on planktic foraminifera δ¹⁸Oc (Fig. 1, 2) with published MARGO SST anomaly for LGM (Fig. 3).
- Used variational method “Data-Interpolating Variational Analysis” (DIVA – Troupin et al.) to estimate MARGO SST anomaly including error field.

Results
- Global change in analyzed SST 1 °C with large uncertainty and in surface δ¹⁸Ow at core locations 0.9‰ ± 0.1‰.
- Regional patterns in Δδ¹⁸Oc (Fig. 2) similar to SST anomaly (Fig. 3), e.g. in the Mediterranean.

Discussion
- Preliminary variational analysis using DIVA yields small global SST cooling with large uncertainty due to large regions void of data.
- However, climate models consistent with the MARGO SST data (Hargreaves et al., 2011) still show a global cooling larger than 3 °C; those that simulated best the MARGO LGM SST reconstruction have a medium climate sensitivity between 2.8 °C and 3.3 °C for a doubling of the atmospheric CO₂ concentration (Otto-Bliesner et al., 2009).
- In contrast, the “adjoint method” applied to a simplified climate model gives a low climate sensitivity of 2.2 °C to 2.5 °C (Fig. 4 – cf. Paul and Losch, 2012).

Conclusions
1. The estimated global surface change in δ¹⁸Ow of 0.9‰ ± 0.1‰ agrees with the global average change estimated by Labeyrie et al. (1987), Adkins et al. (2002) and Duplessy et al. (2002).
2. Thus the global mean cooling implied by the MARGO annual-mean SST anomaly, albeit uncertain, appears to be consistent with the MARGO oxygen isotope ratios measured on planktic foraminifera δ¹⁸Oc.
3. This gives support to the MARGO SST reconstruction, without necessarily implying a low climate sensitivity.