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

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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 CO_2 concentration.

Fig. 1 MARGO isotope data.

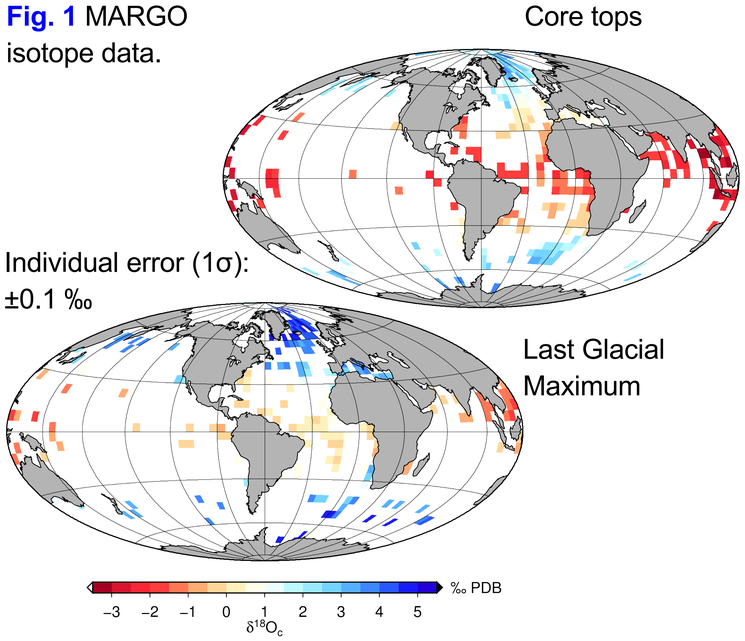
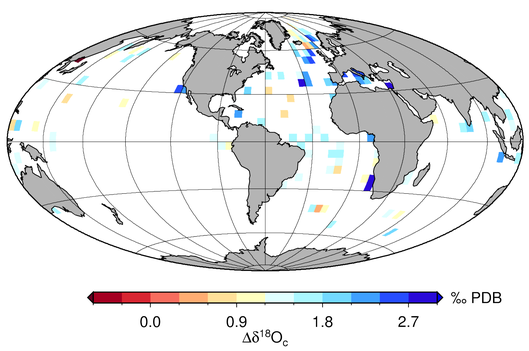


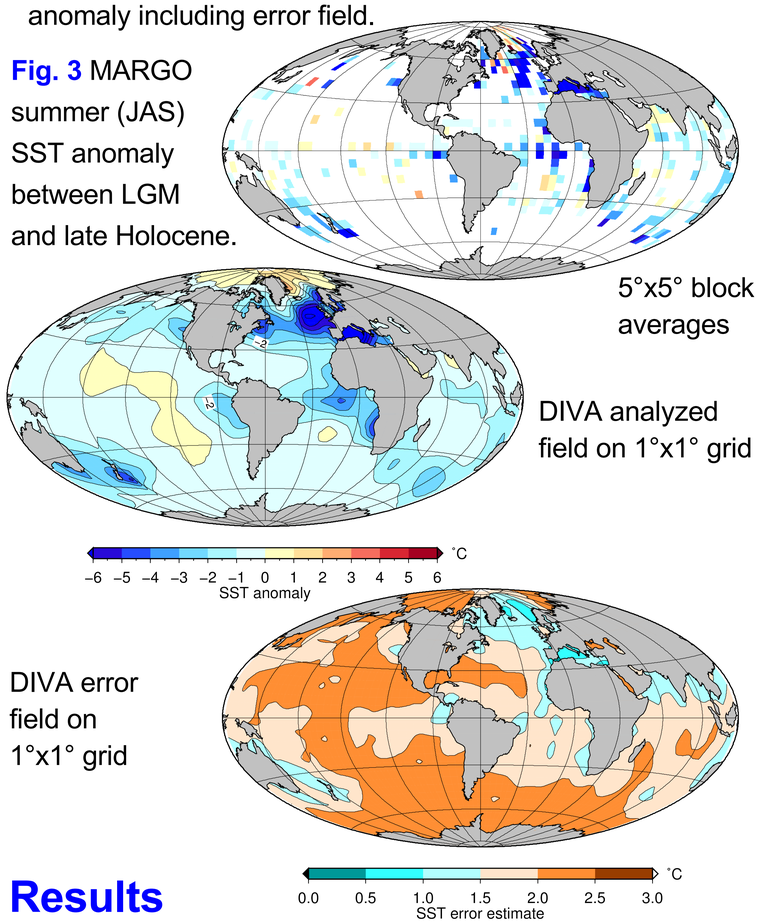
Fig. 2 Species-specific difference $\Delta\delta^{18}O_c$ between LGM and late Holocene.



Methods

- Combined oxygen isotope ratios measured on planktic foraminifera $\delta^{18}O_c$ (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.

Fig. 3 MARGO summer (JAS) SST anomaly between LGM and late Holocene.



Results

- Global change in analyzed SST 1 °C with large uncertainty and in surface $\delta^{18}O_w$ at core locations 0.9 ‰ ± 0.1 ‰.
- Regional patterns in $\Delta\delta^{18}O_c$ (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 CO_2 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).

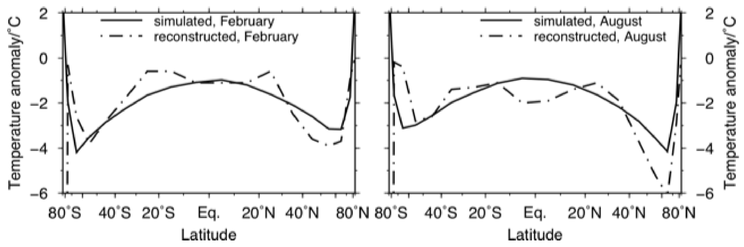


Fig. 4 Classical EBM fitted to data from GLAMAP 2000 project (Sarnthein et al., 2003). Control variables: radiative forcing parameter ΔQ_{2xCO2} and diffusion coefficients.

Conclusions

1. The estimated global surface change in $\delta^{18}O_w$ 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 $\delta^{18}O_c$.
3. This gives support to the MARGO SST reconstruction, without necessarily implying a low climate sensitivity.

➔www.glacialoceanatlas.org
➔www.marum.de/en/OC5.htm

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