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Constraints on the magnitude and patterns of ocean cooling at the Last Glacial Maximum: report of the MARGO Project

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Reconstructions of sea surface temperature (SST) from relatively stable periods in the past, such as the Last Glacial Maximum (LGM), represent one of the best means to constrain climate sensitivity and provide targets to evaluate coupled atmosphere-ocean general circulation models. The first quantitative global reconstruction of SST at the LGM was developed by the CLIMAP (Climate: Long-Range Investigation, Mapping and Prediction) project. Since then, there has not been any concerted effort to synthesize existing paleodata at the global scale, although several shortcomings of CLIMAP pioneering work have become apparent.We present a LGM global synthesis of SST reconstructions undertaken by the MARGO (Multiproxy Approach for the Reconstruction of the Glacial Ocean Surface) project. The objective has been to compile and analyse available estimates of LGM SSTs based on all prevalent microfossil-based (i.e., transfer functions based on planktonic foraminifera, diatoms, dinoflagellate cysts and radiolarians abundances) and geochemical (i.e., alkenones and planktonic foraminifera Mg/Ca) paleothermometers. The MARGO project approach is to argue that no current proxy method is objectively better than another to provide an accurate picture of past SST, and that consequently the multiproxy approach yields the least biased representation of past reality.

As originally suggested by CLIMAP, the strongest annual mean cooling (up to -10˚C) occurred in the mid-latitude North Atlantic and extended into the western Mediterranean (-6˚C). However, in contrast to CLIMAP, MARGO data indicate that the cooling was more pronounced in the eastern than in the western basin. The magnitude and position of a steep temperature gradient between 60 and 45˚N are supported by four different proxies. In contrast with the CLIMAP reconstruction, all proxies also agree on ice-free conditions in the Nordic Seas during glacial summer. However, large discrepancies with respect to glacial temperatures recorded by different microfossil proxies remain. The best convergence between the various proxy estimates occurs within the 30˚N to 30˚S band. Strong inter-basins differences as well as clear west-east gradients within each basin mark the equatorial oceans, although anomalies are smaller in the Pacific and Indian Ocean than in the Atlantic. Tropical cooling is more extensive than that proposed by CLIMAP. Large cooling of the Eastern Boundary Current (EBC) systems in the Southern hemisphere is reconstructed by all proxies, making this a very robust feature of the climate and ocean circulation during the LGM.

Existing coupled atmosphere-ocean general circulation models (AO-GCMs) simulations for the LGM show significant disagreement with respect to the location and magnitude of the North Atlantic cold anomaly while exhibiting stronger glacial cooling in the western than in the eastern Atlantic (http://pmip2.lsce.ipsl.fr/). This demonstrates that the robust MARGO North Atlantic East-West SST anomaly gradient is a good target with which the skill of models can be evaluated. With the advent of the multi-proxy method, we have not only been able to produce a new reconstruction of the glacial ocean surface, but also to deliver uncertainty estimates. Taken together, this yields new observational bounds on the sensitivity of Earth's climate system, with the perspective of improving existing climate models that are being used in the assessment of ongoing and future climate change.