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Constraints on SST estimates for the northern North Atlantic/ Nordic Seas during the LGM

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Abstract

A map of estimated calcification temperatures of the planktic foraminifer *Neogloboquadrina pachyderma* sinistral (T_{Nps}) for the Nordic Seas and the northern North Atlantic for the Last Glacial Maximum was produced from oxygen isotopes with support of Mg/Ca ratios. To arrive at the reconstruction, several constraints concerning the plausible salinity and $\delta^{18}O$-fields were employed. The reconstruction indicates inflow of temperate waters in a wedge along the eastern border of the Nordic Seas and at least seasonally ice-free waters. The reconstruction from oxygen isotopes shows similarities with Mg/Ca based paleotemperatures in the southern and southeastern sector, while unrealistically high Mg/Ca values in the central Nordic Seas prevent the application of the method in this area. The oxygen isotope based reconstruction shows some agreement with temperature reconstructions based on the modern analogue technique, but with somewhat lower temperatures and a stronger internal gradient inside the Nordic Seas. All told, our results suggest a much more ice-free and dynamic high latitude ocean than the CLIMAP reconstruction.

1. Introduction

The state of the sea surface in the North Atlantic and Nordic Seas provide important constraints on the climate in Europe and Eurasia, and strongly influence the strength of the meridional overturning circulation. The reliability of reconstructions for past climate states are crucial for developing a physical understanding of past climate changes, their dynamics, magnitude and underlying driving mechanisms. Reliable sea surface reconstructions are also critical as boundary conditions for atmospheric General Circulation Model (GCM) experiments of the Last Glacial Maximum (LGM) and as data for validation of experiments with fully coupled GCMs.

The problem of acquiring reliable SST reconstructions in the low temperature end is a long-standing issue. Due to the problem of low planktic foraminifer diversity in Arctic and Polar water masses, SST estimates based on planktic foraminiferal transfer functions are unreliable when summer temperatures are below 4–5 °C (e.g. Pflaumann et al., 1996, 2003). Other approaches also have their inherent problems: diatoms are often absent in LGM samples, the alkenone and dinocyst assemblage methods have difficulties in the low temperature end (Rosell-Melé and Comes, 1999; de Vernal et al., 2000), and the sensitivity of Mg/Ca ratios to temperature change is less at low temperatures than at higher (e.g. Elderfield and Ganssen, 2000; and see below).

Despite its wide usage, it has been clear for some time that the reconstruction of CLIMAP (1981) (Fig. 1a) based on the transfer function method of Imbrie and Kipp (1971) may be unreliable in the high latitude North Atlantic/Nordic Seas. In the CLIMAP reconstruction there is a permanent sea-ice cover over most of the area,

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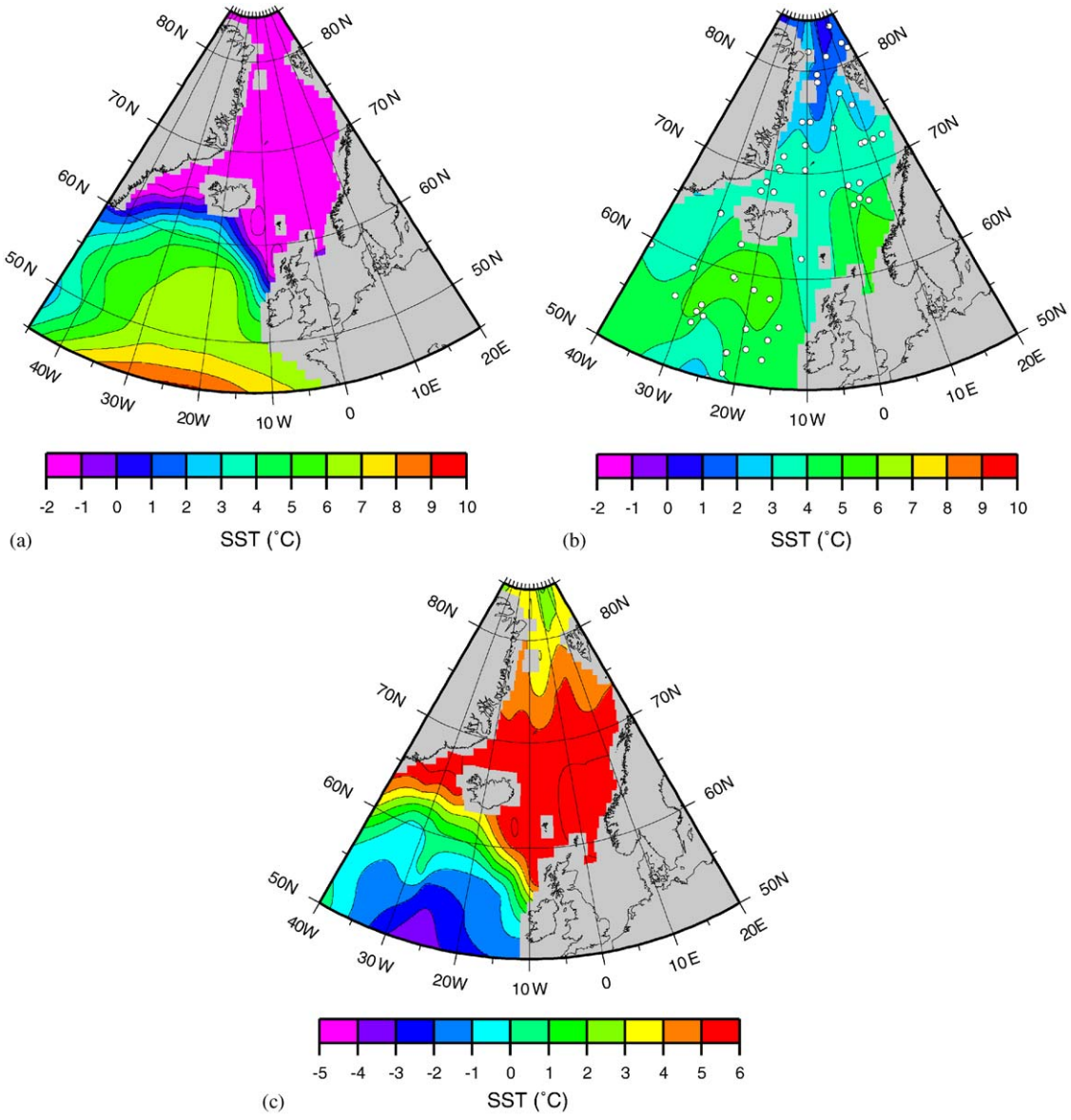

Fig. 1. (a) Summer (August) SST reconstruction for the LGM of CLIMAP (1981). CLIMAP placed the summer sea ice margin along the 0 °C isoline, with a perennial sea-ice cover inside this isoline. (b) Summer SST reconstruction for the LGM, based on gridding and contouring of the published SST data set of GLAMAP (Pflaumann et al., 2003). The SSTs were calculated from foraminiferal transfer functions using the SIMMAX-28 modern analogue technique. The white dots show the data locations. (c) Difference in SST between the GLAMAP and CLIMAP reconstructions, calculated as: $\Delta SST = SST_{GLAMAP} - SST_{CLIMAP}$. Grey coloured areas indicate land areas during the LGM (Peltier, 1994).

although newer evidence clearly point at least to seasonally open waters (e.g. Figs. 1b, 1c; Veum et al., 1992; Hebbeln et al., 1994; Wagner and Henrich, 1994; Sarnthein et al., 1995; Weinelt et al., 1996). The diversity problem of the transfer function approach, i.e. that there is only one dominant species, *Neogloboquadrina pachyderma* (sinistral coiled), in the Polar water, make these alternate reconstructions at least partially unreliable in the sense that they provide a more qualitative reconstruction rather than an accurate or realistic SST field.

The difference between a perennially frozen ocean and an open or seasonally open ocean has, however, wide climatic implications, for example in the possibility for the ocean to steer storm tracks and provide moisture supply to the high latitude ice sheets, to interact with marine based ice sheets and not least to constrain the location of deep water formation and the possible strength and northward extent of the meridional overturning circulation. Renewed attempts to better constrain the LGM state of the Nordic Seas and the northern North Atlantic should therefore be pursued.