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Tropical cooling of the ocean surface during the Last Glacial Maximum

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Many studies have shown the importance of a correct evaluation of the mean tropical cooling to estimate the relative impact of climate forcings during the LGM, notably the effect of lower concentrations of atmospheric greenhouse gases, and in turn, have applied these results to quantify the so-called equilibrium climate sensitivity (ECS) to a CO_2 doubling.

Several geochemical paleothermometers have been used to estimate the tropical sea surface temperatures (e.g. SST based on alkenones and magnesium/calcium ratios measured in ocean sediments) that can be compared with model estimates (e.g. Bard 1999 Science for a short discussion). For alkenones, the TEMPUS group (Rosell-Mele et al. 2004 GRL) and MARGO group (Waelbroeck et al. Nat. Geo. 2009) used a linear equation of UK37' vs. SST based on the global core top calibration compiled by Müller et al. (1998 GCA). This calibration is indistinguishable from the original calibration based on Emiliana huxleyi cultures (Prahl et al. 1988 GCA).

However, it has also been shown that the warm end of the UK37' calibration is flatter than indicated by a single straight line over the full SST range. For the warm end, this started with our study by Sonzogni et al. (1997 QR) based on low-latitude core tops from the Indian Ocean including samples representing SST between 24 and 30°C. This UK37' versus SST linear equation has a reduced slope (0.023/°C) when compared to that (0.033/°C) derived from the linear equation based on core tops compiled from all oceans (Müller et al. 1998). Support for this complexity also comes from close inspection of the global compilation by Müller et al., suggesting that the relationship flattens out at high temperatures (see also Pelejero & Calvo 2003 G3). In addition, culture studies of different strains of Gephyrocapsa oceanica and E. huxleyi (Conte et al., 1998 GCA) and measurements of sinking particulate matter from Bermuda (Conte et al. 2001 GCA) strongly suggest that the real shape of the UK37' vs. SST is probably sigmoidal, i.e. the UK37' index converges asymptotically toward 0 and 1, for low and high temperatures, respectively (Conte et al. 2006 G3).

Incidentally, this additional complexity had already been taken into account by Bard et al. (1997 Nature) for which we derived an LGM cooling for the Indian Ocean of 1.7°C (sigma = 0.7°C) with the global calibration and 2.4°C with the warm-end calibration (hence an extra-cooling of 0.7°C). The first value is very close to the MARGO 30°S-30°N Indian Ocean and 30°S-30°N global estimates of 1.3 ±0.7°C and 1.5 ±1.2°C, respectively.

Based on LGM data-model comparison with a simplified climate model, Schmittner et al. (2011 Science) estimated an ECS of ca. 2.3°C, a rather low value mainly linked to the SST database. Taking a larger tropical cooling into account would lead to an increase towards an ECS of 3°C. By analyzing the outputs of state of the art atmosphere-ocean GCMs, which participated in the PMIP2 project, Hargreaves et al. (2012 GRL) found a significant statistical relationship between the ECS and the mean tropical SST cooling (ECS $\approx$ 1.2xΔTtropicsLGM). Based on a large LGM data compilation, Hargreaves et al. derived an ECS of 2.3°C. A rough upper end estimate of the data bias could be calculated by assuming that the warm end calibration of alkenones applies directly to the tropical ocean fraction of their compiled data for the tropics (1.8°C). This would in turn lead to an ECS of around 2.8°C instead of 2.3°C. This calculation is not precise since not all used data are based on alkenones. This exercise merely serves to illustrate the sensitivity of the ECS to the accuracy of geochemical paleothermometers, which I will briefly review in this presentation.