



Reviewing the Proxy-Data Evidence for the Ocean Circulation during the LGM

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Climate modellers wish to use observations to “constrain” the information obtained from coupled climate models, including the simulated atmospheric and ocean circulations and the overall climate sensitivity. We therefore review the paleo-proxy data available for a model-data comparison on the ocean circulation at the Last Glacial Maximum (LGM), including the surface, shallow and deep overturning circulations as well as the distribution of the major water masses. The proxies discussed are microfossil assemblages, magnesium/calcium (Mg/Ca) ratios and the Uk’37 index based on alkenones for surface and sub-surface water temperatures (e.g. by projects such as GLAMAP – Glacial Atlantic Ocean Mapping and MARGO – Multi-proxy Approach for the Reconstruction of the Glacial Ocean Surface), oxygen ($\delta^{18}\text{O}$) and carbon ($\delta^{13}\text{C}$) stable isotope ratios as well as neodymium isotope composition for water-mass distributions, cadmium/calcium (Cd/Ca) ratios for nutrient concentrations, and radiocarbon ($\delta^{14}\text{C}$) and protactinium-231/thorium-230 (Pa-231/Th-230) ratios for past ocean circulation rates. We find that although much is already known about the distribution of the water masses at the LGM, at the surface as well as at depth (e.g. in the Atlantic Ocean, low nutrient concentrations down to about 2 km depth, higher than today below 2 km depth, with a sharp property gradient between the shallower and deeper water masses), the rates of the shallow and deep overturning circulations are still poorly constrained (with possibly a bias towards an ocean circulation slightly slower than at present).