

Testing glacial ocean theories by model-data comparison

Diapycnal mixing and the LGM distribution of ^{13}C , Cd/Ca & Pa/Th in GENIE



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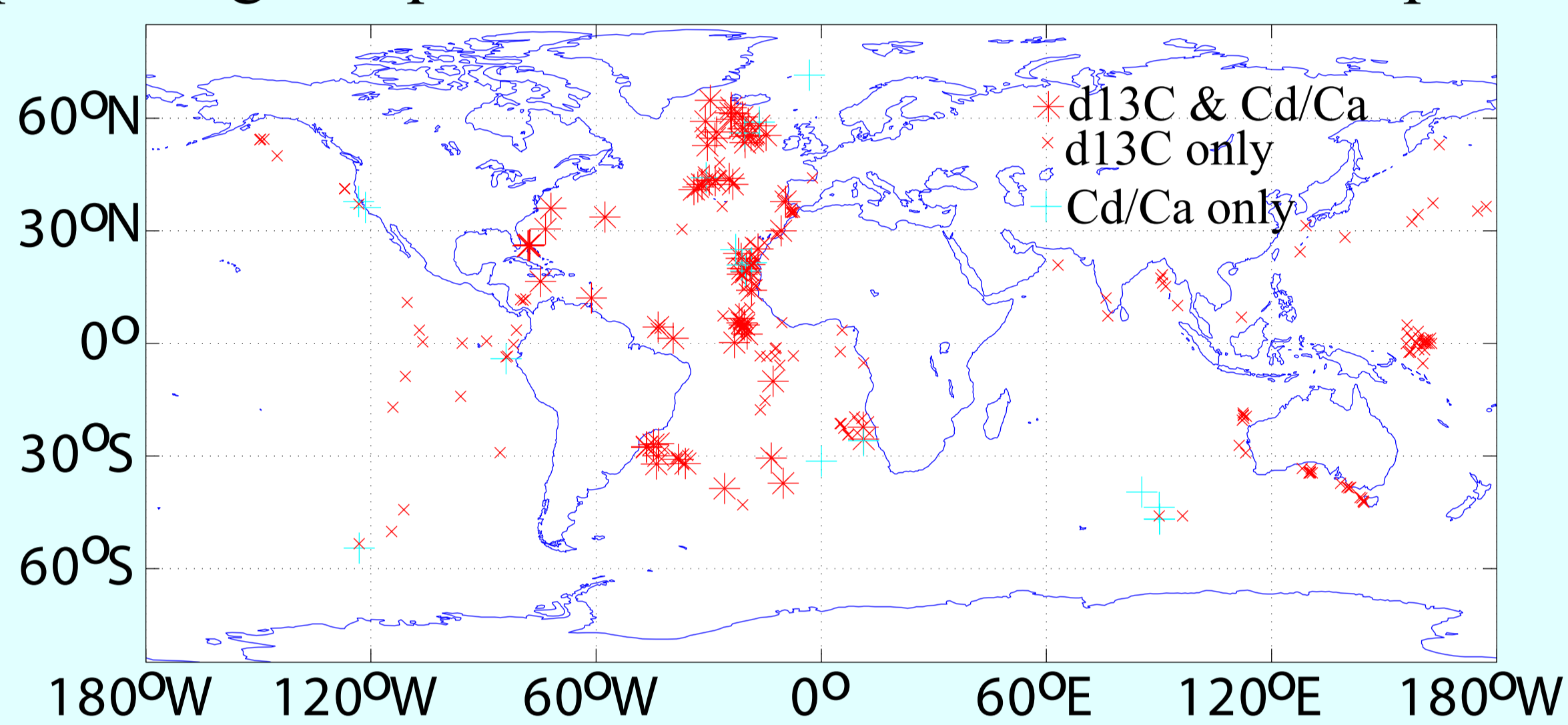


1. Motivation

Several marine-based mechanisms have been invoked to explain glacial cycles in atmospheric CO_2 , including changes in **iron fertilisation**, the **rain rate ratio**, surface or deep **diapycnal mixing** rates, **wind-stress** over the Antarctic Circumpolar Current, or **sea-ice cover** over the Southern Ocean. An important test for these theories is that they can reproduce the glacial distribution of geochemical proxies. This demands comparison between the output of models capable of simulating geochemical proxies, and suitable proxy datasets.

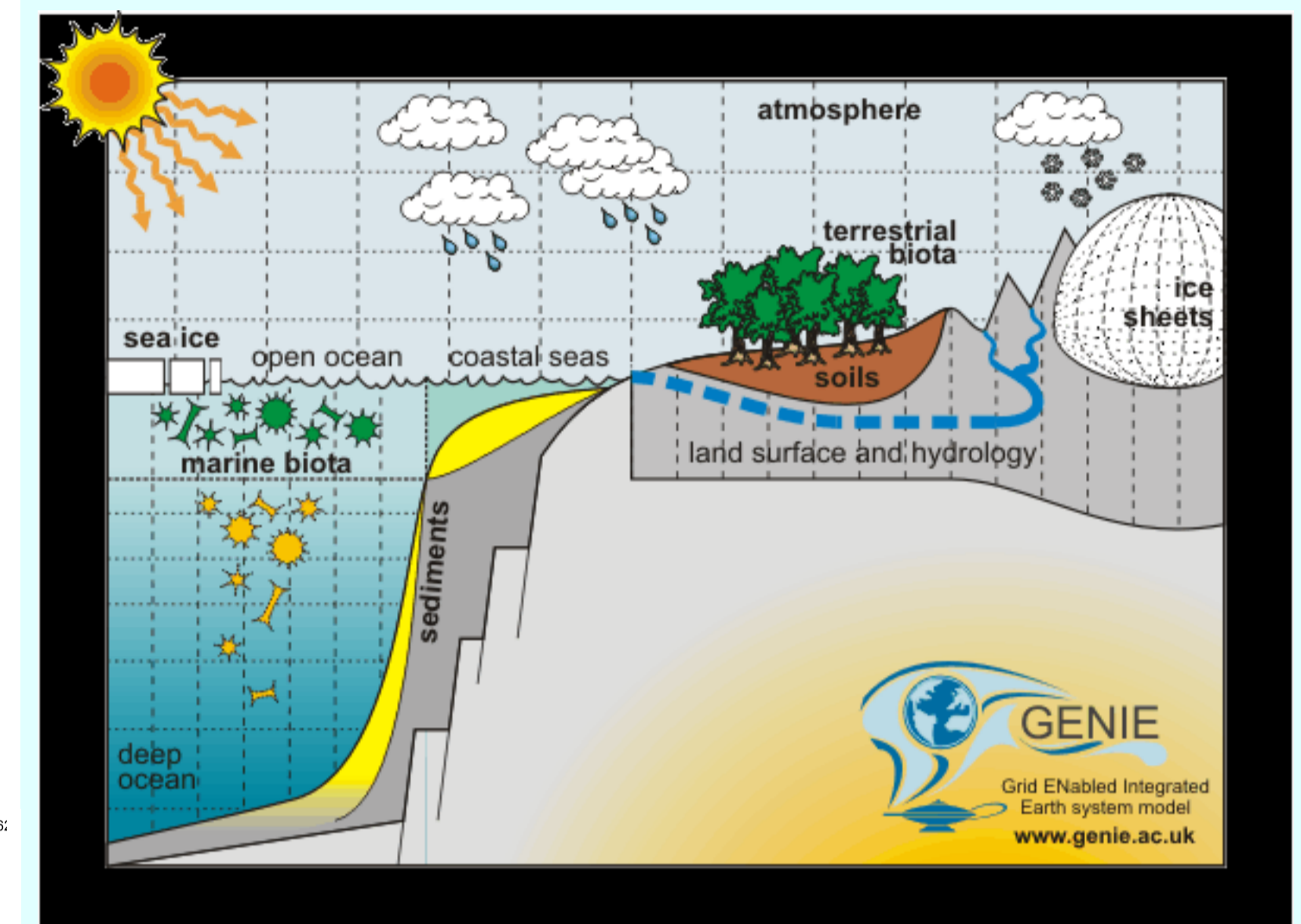
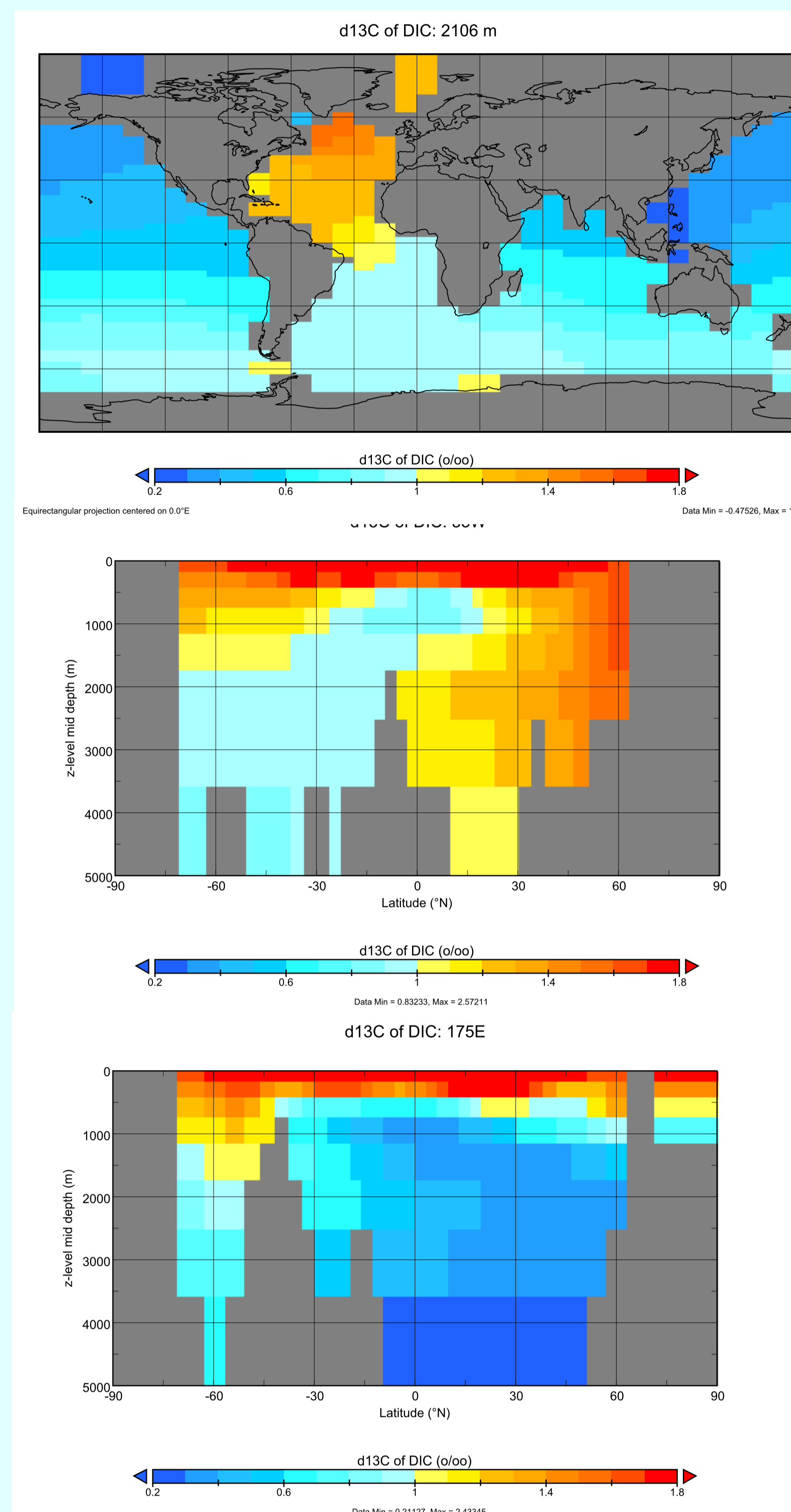
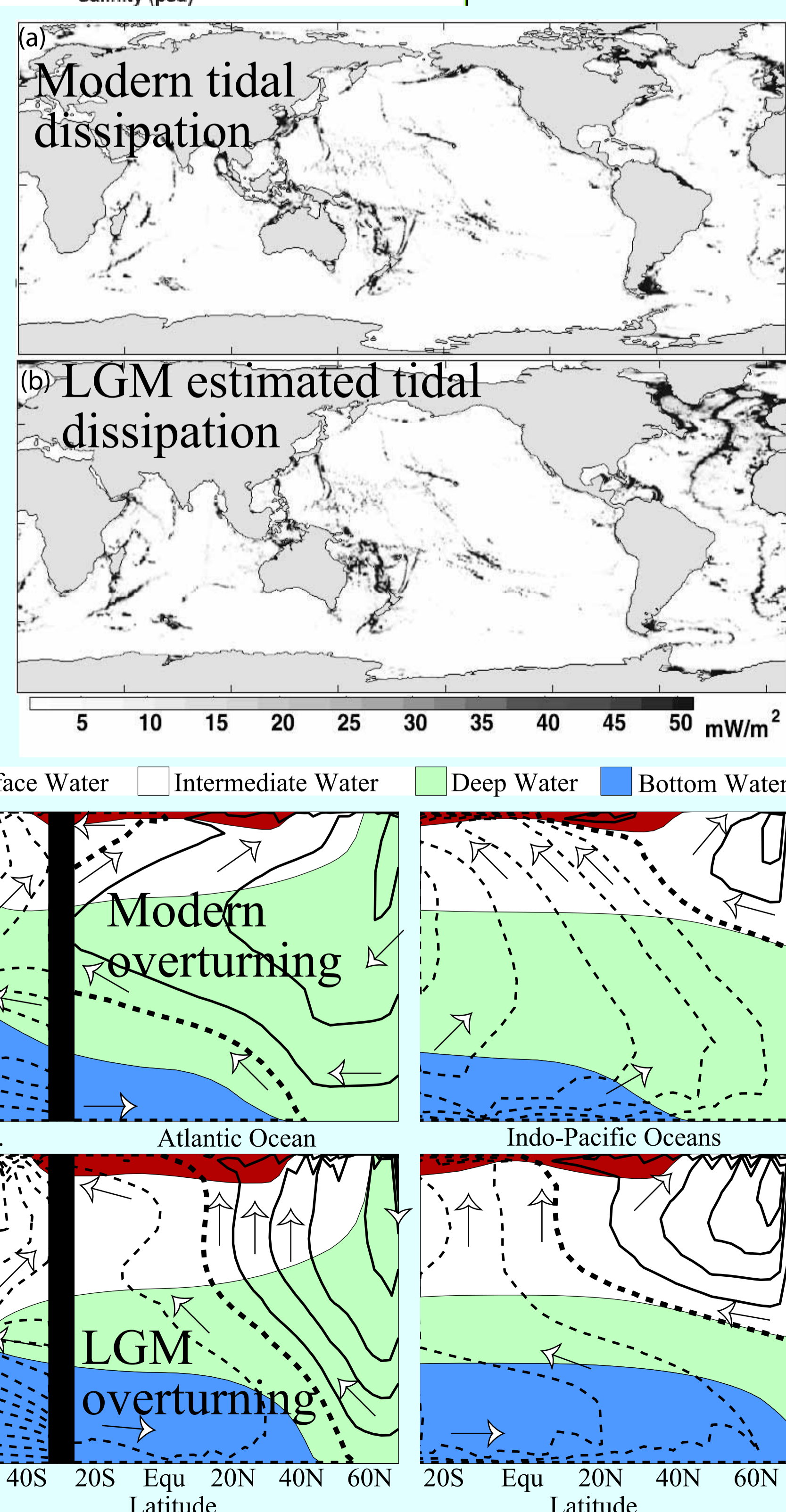
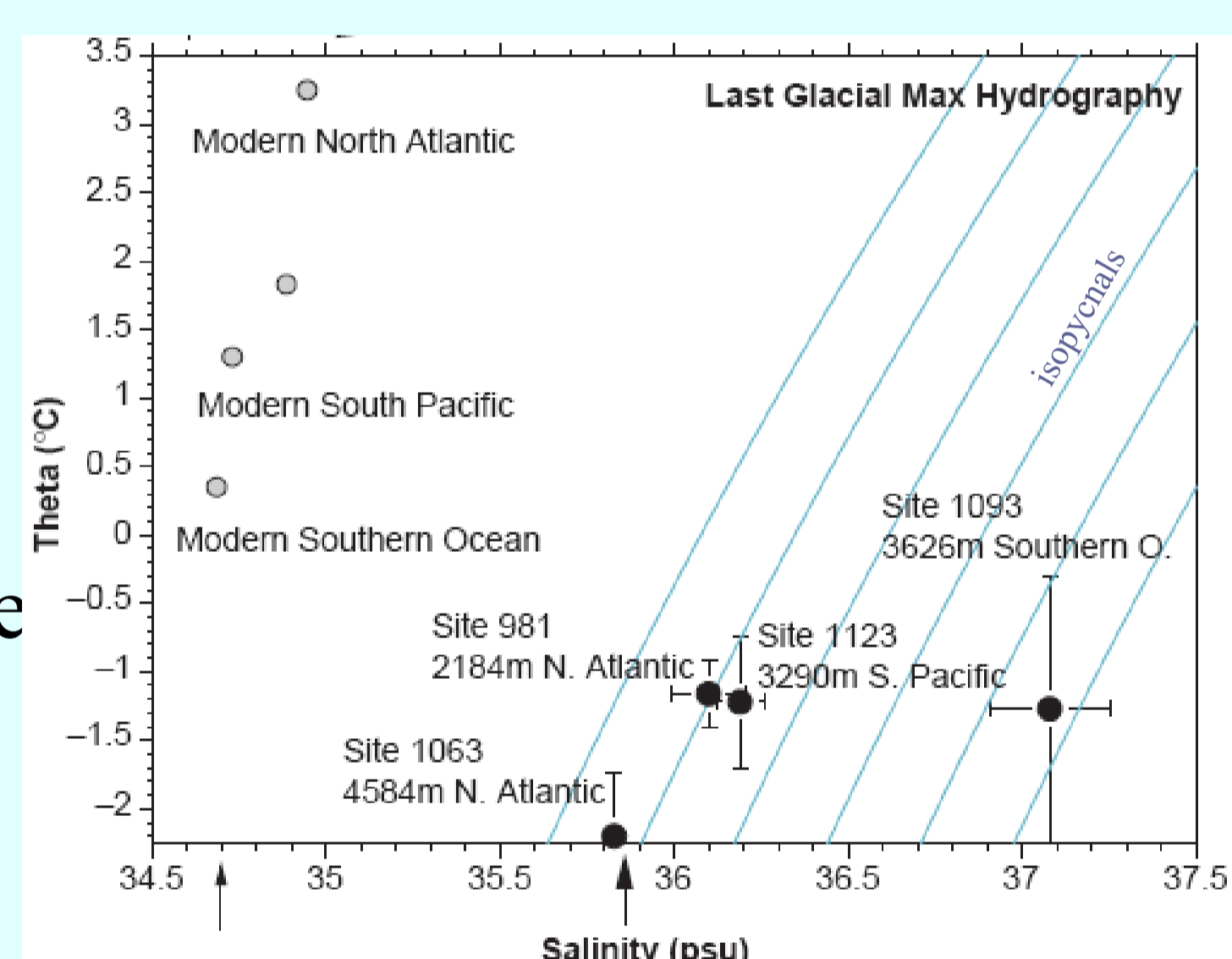
2. The Data

The data used in this study¹ is a subset of the Quaternary QUEST synthesis of marine core proxies (see Elderfield et al. poster: *A synthesis of time-series data of marine, ice and terrestrial cores for the last 140,000 years*), including all Cd/Ca data and selected d^{13}C data (below). The more complete d^{13}C dataset will be used in future experiments, as will Pa/Th which is particularly useful in providing independent information from nutrient proxies.



4. Diapycnal mixing at the Last Glacial Maximum

In this preliminary study, we focus solely on the role of diapycnal mixing. The Southern Ocean was probably strongly salinity stratified at the LGM² (above right). This would be expected to reduce diapycnal mixing in the Antarctic Circumpolar Current (ACC), possibly isolating CO_2 rich deep water from the atmosphere in the major region of the ocean where productivity is not nutrient limited, driving down atmospheric CO_2 . It has also been proposed that there was more energy available for diapycnal mixing globally, due to stronger winds or to dramatic changes in tidal dissipation in the North Atlantic³ (middle right). This could have led to a higher portion of deep water upwelling at low latitudes, maintaining the atmospheric carbon sink that depends on meridional overturning (below right). Here, the plausibility of this mechanism is tested against proxies.



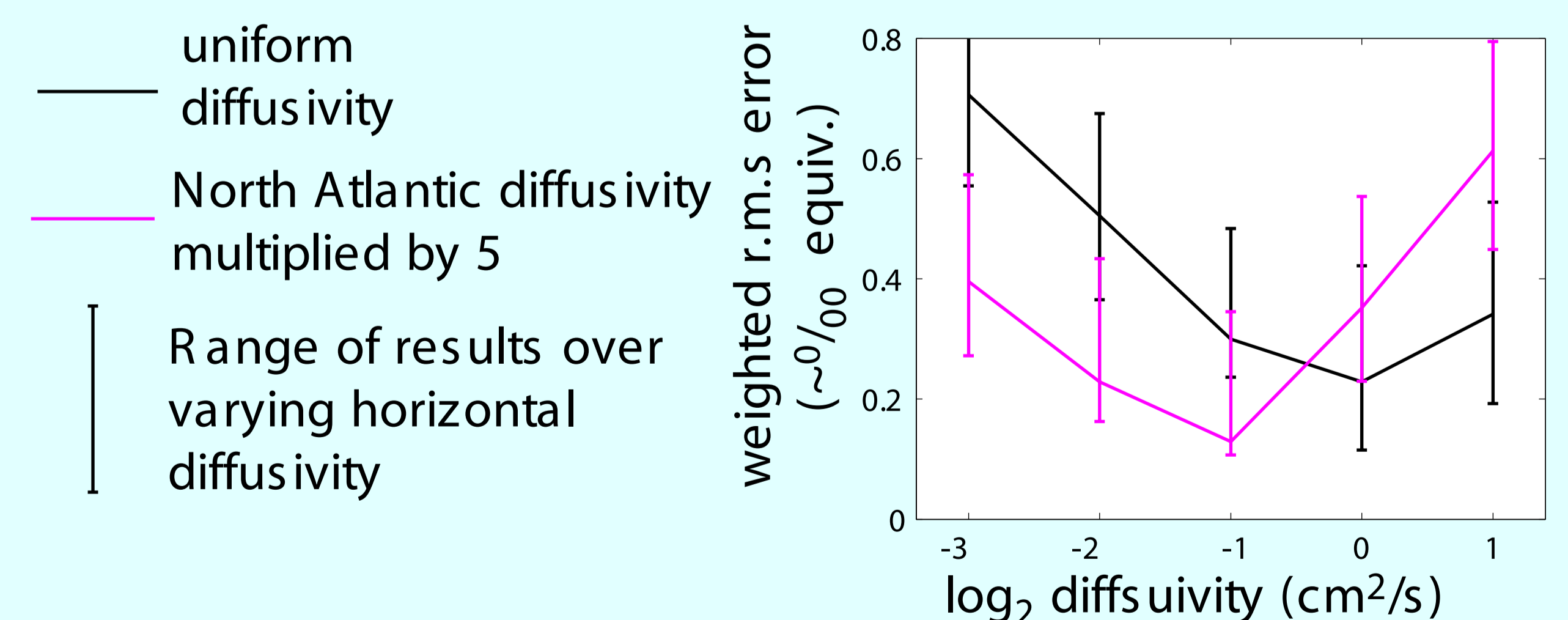
3. The model

The efficient earth system model GENIE (above) is used in experiments. Here, a **low resolution** (36x36x8) version is used, which does not fully resolve the layering of water masses in the Atlantic Ocean (middle left). A higher resolution version largely solves this issue, and will be selectively used in future experiments. Otherwise, the distribution of (e.g.) d^{13}C in the global modern ocean is reasonably well reproduced (left), although the Southern Ocean is slightly too stratified.

References and Acknowledgements: 1 - H. Elderfield et al. poster for data synthesis. Data compiled in collaboration with Babette Hoogakker and Simon Crowhurst; thanks to Andy Ridgwell. Further data from Marchitto, T. M., & Broecker, W. S., *Geochem., Geophys., Geosys.* 7, 10.1029/2006GC001323 (2006); 2 - Adkins, J. F. et al., *Science* 298, 1769-1773 (2002). 3 - Egbert, G. D. et al., *J. Geophys. Res.* 109, 10.1029/2003JC001973 (2004).

5. Results

Using climatological SST (CLIMAP) and freshwater forcing for the LGM, and not varying biological parameters, the optimum fit occurs if uniform diffusivity matches that used in the modern day (below). However, the fit can be improved if high diffusivity in the North Atlantic (and regions of weak stratification) is permitted.



6. Future Work

This preliminary study lacks the resolution necessary for the layering of the Atlantic and adequate representation of the Southern Ocean and ACC, and further exploration of parameter space is required. These, as well as the examination of other proposed mechanisms for glacial changes in CO_2 , will be the subject of future research.