Clear as mud: middle Miocene Atlantic Ocean circulation

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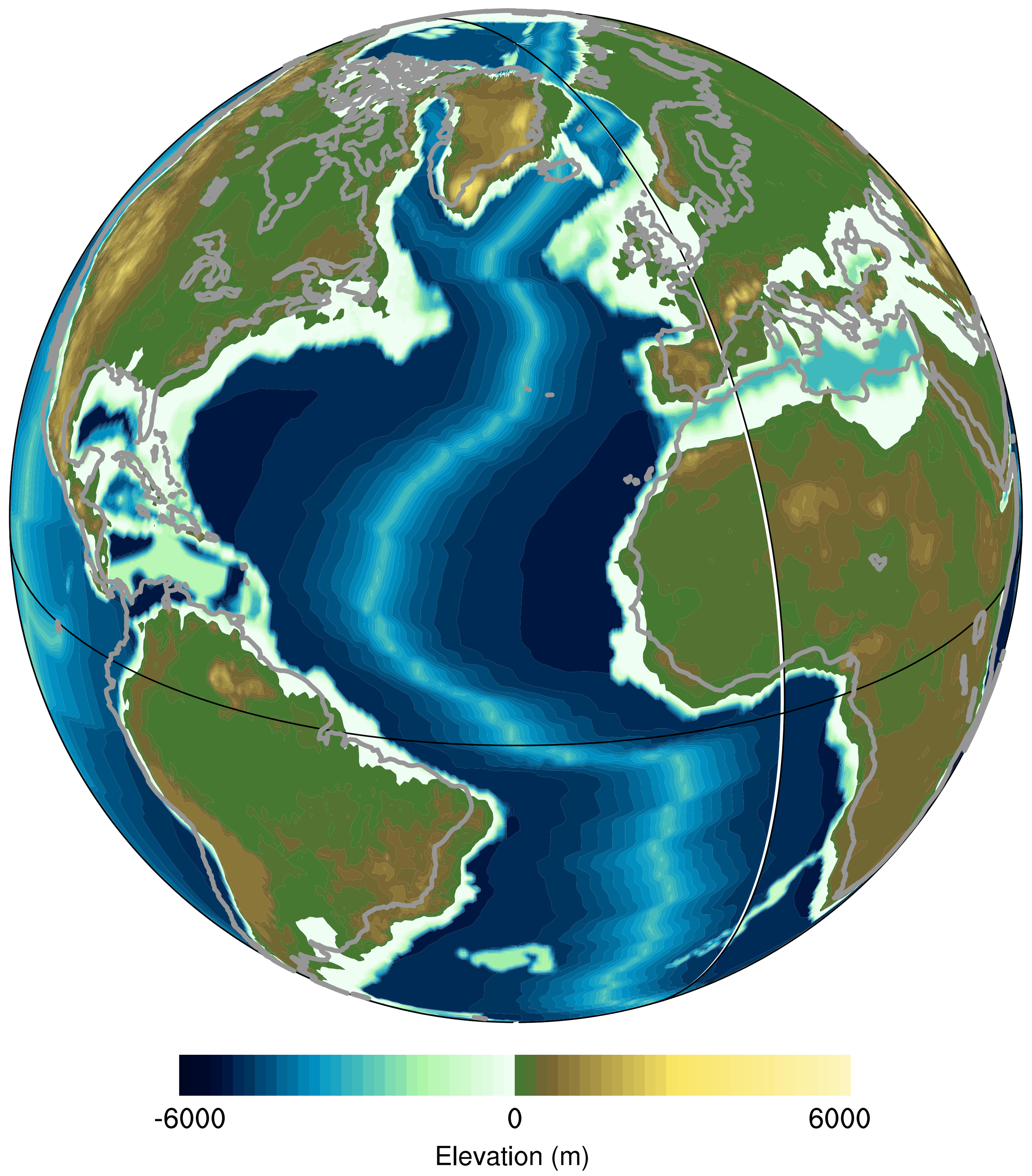

Figure 1: Miocene Atlantic Ocean bathymetry

Middle Miocene Atlantic Ocean bathymetry with the modern shoreline shown in grey. Important differences compared to the present day include an open Tethys gateway, open Panama gateway, closed Canadian Archipelago and a constricted Fram Strait.

Abstract

We assess current evidence of middle Miocene Atlantic Ocean circulation from Carbon isotope records (Cramer et al., 2009) and climate simulations to infer how it differed to the present day and further to infer the nature of ocean heat transport during the Miocene climatic optimum (~17.5—14 Ma). Based on our analysis we suggest that during the Miocene climatic optimum deep water formation was dominant in the South Atlantic Ocean, with weaker-than-present deep water formation in the North Atlantic. This is supported by contourite drift sedimentation rates and Miocene climate simulations, providing strong evidence for an Atlantic Ocean circulation that was opposite to the present day.

Methods

- We analyse a recent compilation of Carbon isotope records (Cramer et al., 2009). Shown in figures 2 and 3.
- High $\delta^{13}C$ values in these figures indicate younger water.
- Climate simulations with the Community Climate System Model 3, forced with Miocene topography, bathymetry and vegetation (Herold et al., 2012). Shown in figures 2 and 4.
- Water age in these figures indicate number of years separated from the surface.

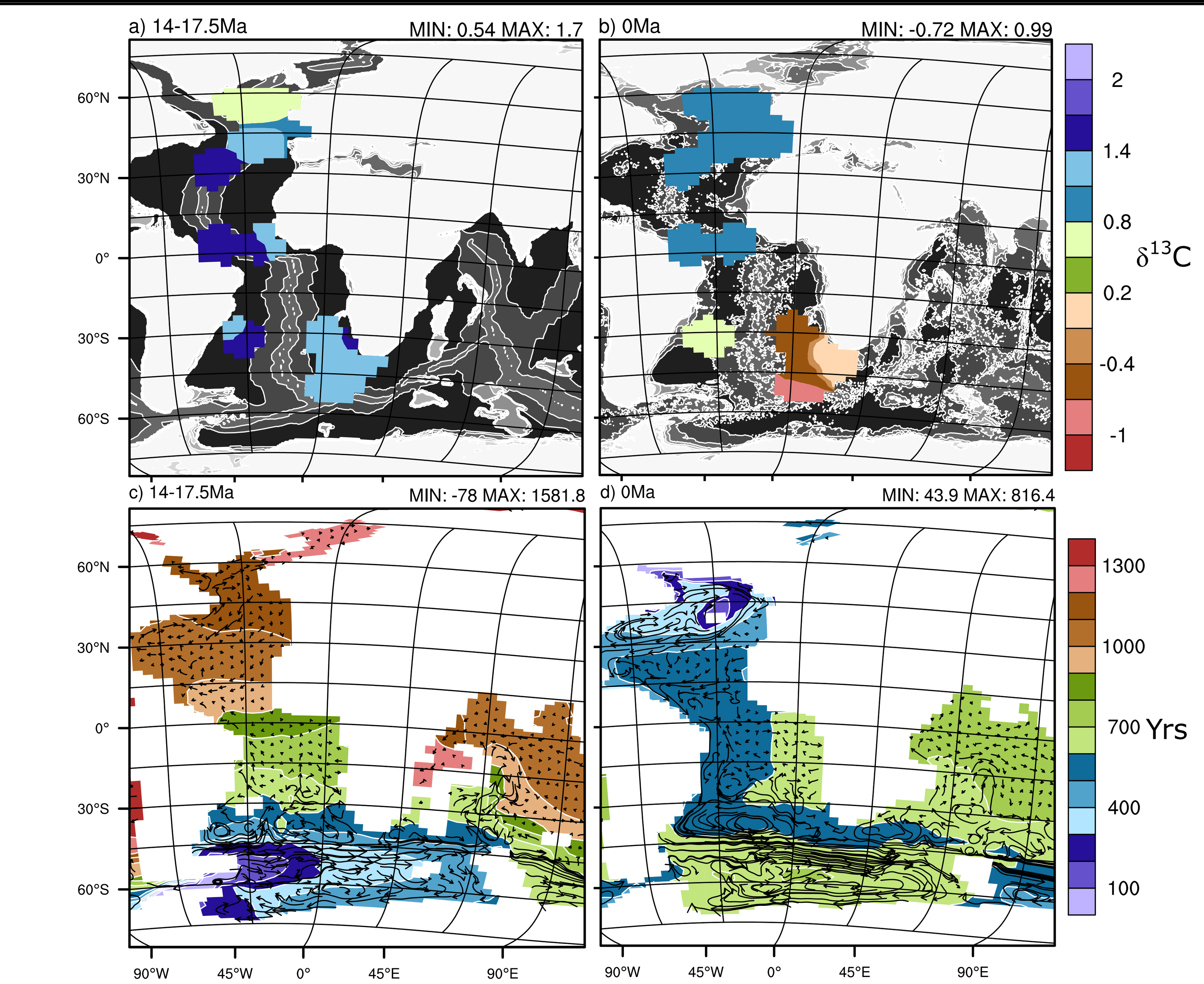

Figure 2: $\delta^{13}C$ records and modelled water age

$\delta^{13}C$ values in the Miocene Atlantic Ocean (panel a) suggest relatively young water filled the South and North Atlantic Oceans, with older water in the far North Atlantic, opposite to modern $\delta^{13}C$ (panel b). This indicates middle Miocene circulation was opposite to the present and is supported by ocean simulations showing young water at 2.5 - 3.5 km depth in the Weddell Sea and old water in the North Atlantic (panel c), opposite to the present (panel d).

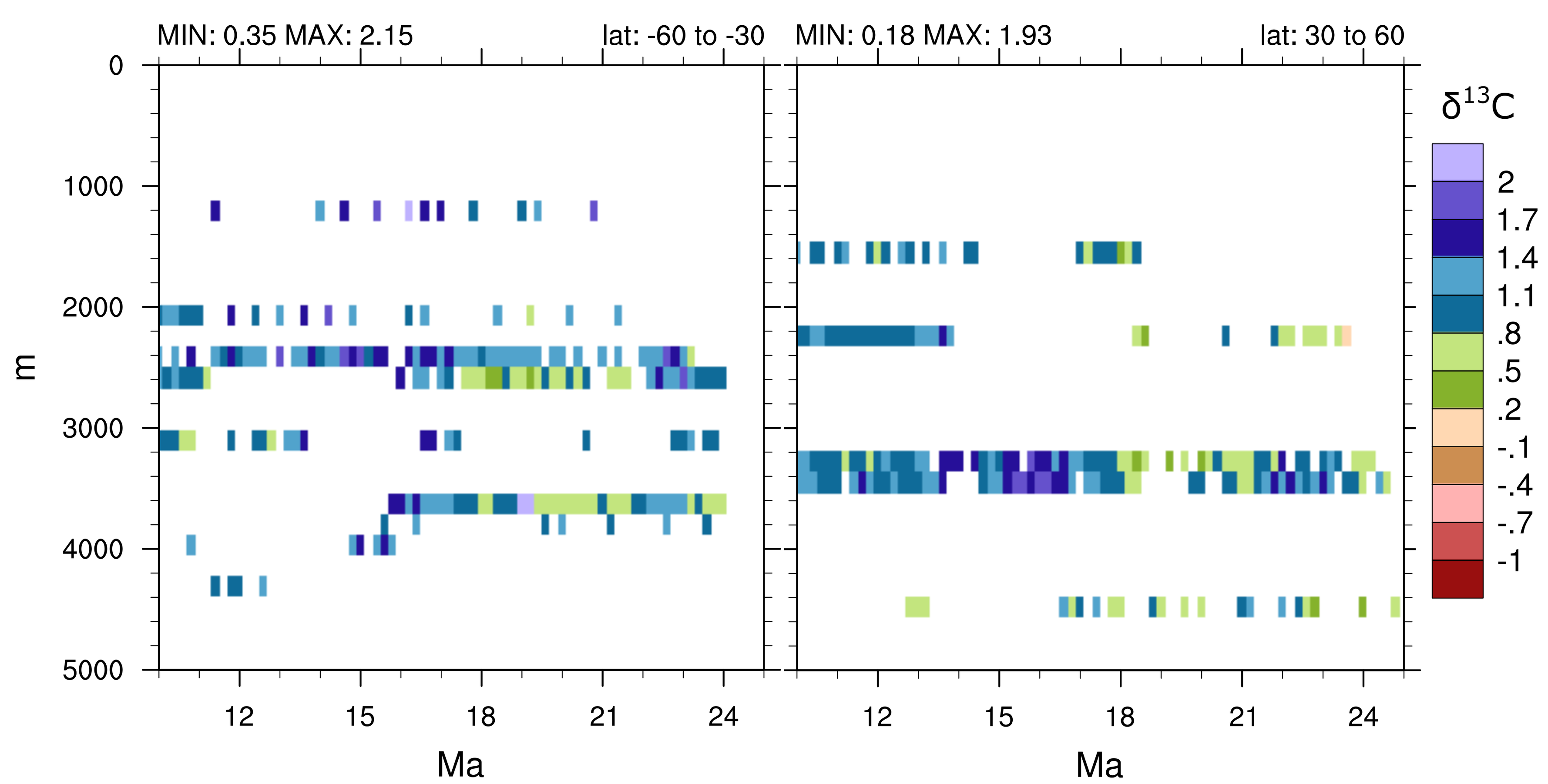

Figure 3: Time evolution of Atlantic Ocean $\delta^{13}C$

The change in $\delta^{13}C$ values over time in the South and North Atlantic (panels a and b, respectively) suggests that the young water began to fill the basins at onset of the Miocene climatic optimum, ~17.5 Ma.

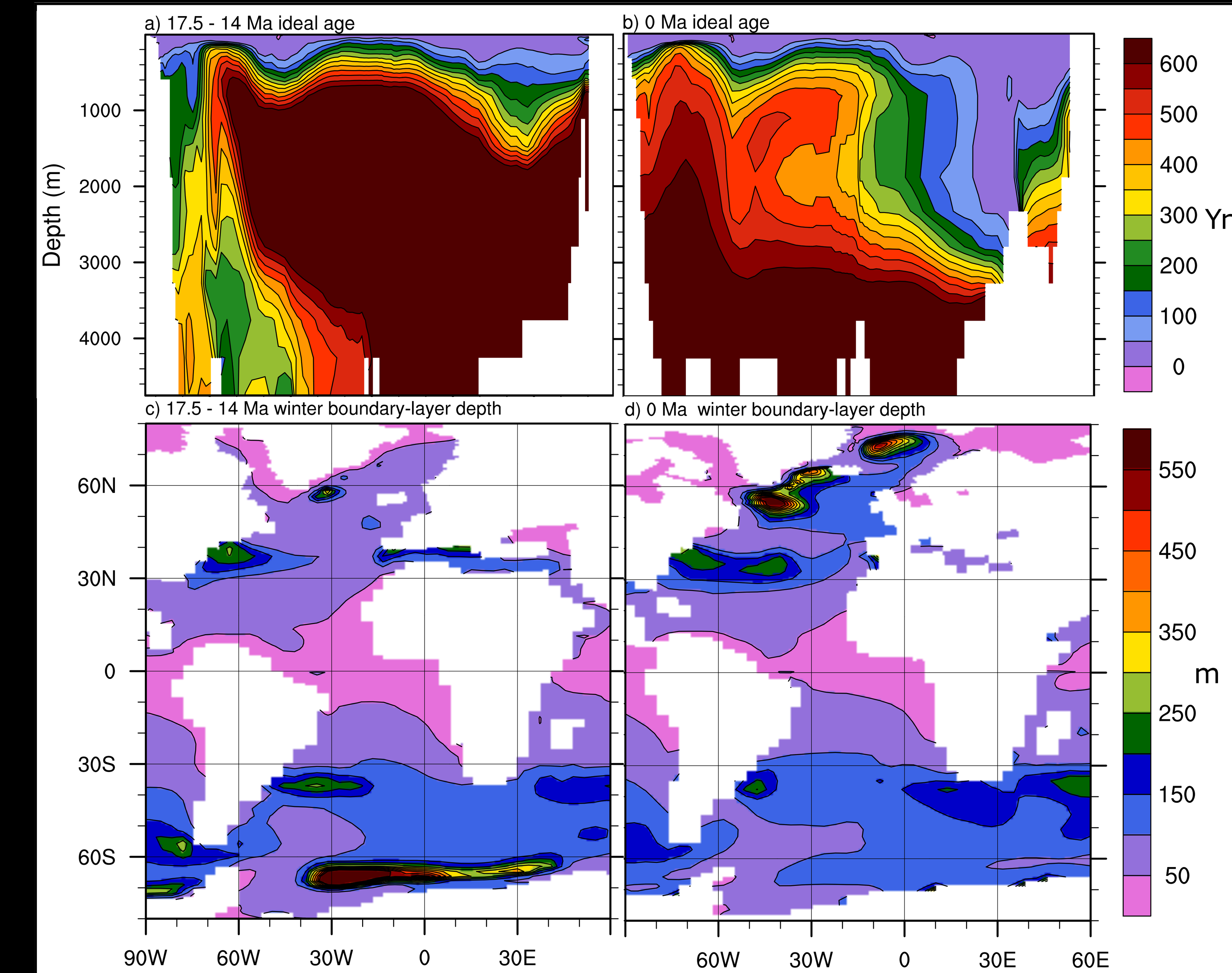

Figure 4: Modelled water age and convection

Simulated water age (in years) illustrates the potential large-scale structure of the middle Miocene Atlantic Ocean circulation (panels a and b, respectively), with strong deep water formation in the South Atlantic and weak deep water formation in the North Atlantic, opposite to the present. Wintertime boundary-layer depths show the locations of surface convection to the east of the Weddell Sea in the Miocene, with little in the far North Atlantic (panel c).

Results

Based on paleoceanographic proxies and climate modelling we suggest that;

1) During the middle Miocene Atlantic Ocean overturning circulation was opposite to the present regime, with the majority of deep water formation occurring in the South Atlantic and little in the North Atlantic.

2) This circulation started approximately in unison with the onset of the Miocene climatic optimum (~17.5 Ma). What caused this weakening at ~17.5 Ma is unknown, though Miocene climate simulations show that increases in CO_2 lead to weaker North Atlantic deep water formation. This behaviour is similar to modern day CO_2 sensitivity simulations.

References/funding/affiliations

Cramer, B. S., J. R. Toggweiler, J. D. Wright, M. E. Katz, and K. G. Miller (2009), Ocean overturning since the Late Cretaceous: Inferences from a new benthic foraminiferal isotope compilation, Paleoceanography, 24(4), PA4216.

Herold, N., M. Huber, R. D. Müller, and M. Seton (2012), Modeling the Miocene climatic optimum: Ocean circulation, Paleoceanography, 27 (1), PA1209.

Knutz, P. C. (2008), Palaeoceanographic Significance of Contourite Drifts, in Developments in Sedimentology, edited by M. Rebesco and A. Camerlenghi, pp. 511-535, Elsevier.

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