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When did the present pattern of the thermohaline circulation develop?

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The present thermohaline circulation is characterized by strong deep-water formation in the North Atlantic, while in the Pacific no deep-water formation occurs. This asymmetry has a strong impact on regional climate due to the associated northward heat transport. In our present climate system both continental geometry and atmospheric forcing introduce a preference for this so-called “Conveyor” state of the meridional overturning circulation. During the Cenozoic, however, various ocean gateways have opened and closed, thereby influencing the exchange of heat and salt between the different ocean basins. We expect, therefore, different patterns of the thermohaline circulation to have existed throughout the Cenozoic. The transition between different flow patterns may have influenced climate at least on a regional scale.

Because of its heat transport, the flow pattern of the meridional overturning circulation is necessary to correctly interpret proxy data that record variables such as oceanic temperatures. The flow itself is, however, very difficult to directly reconstruct from proxy data. For example, proxy data indicate that deep-water formation in the North Atlantic has started in the Oligocene but little is known about the global flow pattern in the Oligocene.

In this presentation we show results from model studies within models of varying complexity to determine which flow pattern is most likely under the Oligocene continental geometry. Fully coupled climate model simulations of the late Oligocene and early Miocene have indicated a “northern sinking” type of circulation, with (shallow) deep-water formation in both the North Pacific Ocean and the North Atlantic Ocean. In idealized two-basin setups within an ocean general circulation model it is shown that both the less northward extent of the Atlantic basin and the existence of a circum-global low-latitude gateway facilitates deep water formation in the North Pacific compared to the North Atlantic. Finally, we investigate within an implicit ocean model with realistic Oligocene continental geometry how strong the asymmetries in the continental geometry need to be to maintain a “northern sinking” type of circulation, and which gateways need to be closed to introduce the preference for the present “Conveyor” type of circulation. This gives an indication of when during the Cenozoic the present type of meridional overturning circulation has developed.