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The Miocene Atlantic Ocean

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We model paleoclimate and ocean circulation during the Miocene climatic optimum (∼17 ¬ 14.5 Ma) using the Community Climate System Model 3 (CCSM3), focussing particularly on the effect of Miocene model boundary conditions including reconstructed topography, bathymetry, and vegetation. The modelled Miocene climate exhibits broad increases in mean annual precipitation over central and northern Africa, northern Eurasia, northern North America and Greenland compared to the present. In northern Africa, summer precipitation is significantly higher in the Miocene due to the replacement of desert with broadleaf vegetation, consistent with previously published sensitivity studies. Our results qualitatively support interpretations of carbon and neodymium isotope records indicating NCW formation in the North Atlantic as well as a dominant bottom water source in the Southern Ocean. Major tectonic changes in our Miocene Atlantic bathymetry compared to the present day are the severe constriction of the Fram Strait, closure of the Panama Strait and the less elevated Greenland-Scotland Ridge. We find that the structure of ocean circulation in the Miocene Atlantic is somewhat opposite to the present day, with the primary region of Miocene bottom water formation in the Weddell Sea. The strength of Weddell Sea bottom water and North Component Water (NCW) formation are moderated by atmospheric CO_2 levels, which suggests that very weak NCW formation could have existed under significantly higher concentrations than the present-day CO_2 concentration used in our model. Such a state would be consistent with the hypothesis of negligible NCW formation in the early Miocene, suggested previously. In our model, the NCW is relatively warm and saline compared to modern North Atlantic Deep Water (NADW). This is likely a robust result, caused by a northward deflection of North Atlantic subtropical water below the mixed-layer, a weakening of the subpolar gyre and weaker convection, as opposed to warm Tethys outflow. An interesting model result concerns the importance of the geometry of reconstructed gateways. Regarding the Panama gateway we find only a small eastward throughflow, in contrast in contrast with other published estimates. The difference appears to be related to the exact orientation of the reconstructed gateway. A gateway oriented in a zonal direction results in a natural extension of the equatorial countercurrent, whereas a more meridionally oriented gateway, as in our reconstruction, largely prohibits such a current, emphasizing the effect of subtle model boundary conditions. A decreased northern hemisphere ocean heat transport in the Miocene compared to the present is a result of a significant weakening of North Atlantic Deep Water formation. Modelled flow into the Arctic Ocean is consistent with the idea of an enclosed estuarine sea. Coupled with a relatively deeper Greenland-Scotland Ridge it permits substantial Miocene ocean warming. Determining how this warming varied under changes in modelled bathymetry may elucidate ways in which near ice-free Arctic conditions were sustainable.