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Sea-surface temperatures and deepwater production of the mid-Piacenzian Nordic Seas and Arctic Ocean

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The mid-Piacenzian warm period (∼3.3 to 3.0 Ma) is the most recent interval in earth's history in which global temperatures reached and remained at levels similar to those projected for the near future. Model simulations of this warm period are often used to infer future climate scenarios due to the similarities of this past warm period to modern. The similarities, however, are not without exception. For example, the distribution of global warmth was different during the mid-Piacenzian in that the high latitudes warmed more than the tropics. Multiple temperature proxies indicate significant sea-surface warming in the Nordic Seas and Arctic Oceans during the mid-Piacenzian warm period, but predictions from a fully coupled ocean-atmosphere model (HadCM3) have so far been unable to fully predict the large scale of sea surface warming in the high latitudes. Presumably, either climate proxies inaccurately represent Pliocene conditions, or model boundary conditions are in error or are missing an essential element, or a weakness exists in the physics of the model itself.

We estimated sea surface temperatures (SST) from Ocean Drilling Program Sites 907 and 909 in the Nordic Seas and from Site 911 in the Arctic Ocean based on Mg/Ca of Neogloboquadrina pachyderma (sin) and alkenone unsaturation indices to provide the first quantitative climate data from this region during this interval. We found evidence of much warmer than modern conditions in the Arctic Ocean during the mid-Piacenzian with temperatures as high as 18°C. In addition, SST anomalies (mid-Piacenzian minus modern) increase with latitude across the North Atlantic and into the Arctic, extending and confirming a reduced mid-Piacenzian pole-to-equator temperature gradient. The agreement between proxies and with previously documented qualitative assessments of intense warming in this region corroborate a poleward transport of heat and an at least seasonally ice-free Arctic.

An increase in poleward heat transport may explain the magnitude and distribution of Pliocene warmth, potentially in concert with increased CO2, but a mechanism to redistribute surface warmth toward the higher latitudes has remained elusive. We tested the idea that ocean circulation was modified by changes in the bathymetric expression of the Greenland-Scotland Ridge, as related to mantle plume activity beneath the Icelandic Hot Spot. We show an increase in both Arctic SST and deepwater production in preliminary model experiments that incorporate an exaggerated reduction in the bathymetric expression of the Greenland-Scotland Ridge. Deep ocean temperatures in this experiment were nearly 1°C warmer than modern outside the Arctic, and up to 4°C warmer inside the Arctic, due to the southward flow of relatively warm deepwater across the ridge, similar to the 3-dimensional PRISM thermal reconstruction of the mid-Piacenzian global ocean .

These results offer a mechanism for both the warming in the North Atlantic and Arctic Oceans and the increased deepwater production indicated by numerous proxies, and in addition, provide an explanation for the apparent disparity between proxy data and model simulations of Pliocene Arctic conditions. Determining the causes of Pliocene warmth remains critical to fully understanding comparisons of the Pliocene warm period to possible future climate change scenarios.