Global temperature modes shed light on the Holocene temperature conundrum

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Reconstructions and climate simulations of the global mean annual temperature evolution during the Holocene yield puzzling results. Temperature reconstructions mainly based on ocean sediments show warm conditions in the Early- to Mid-Holocene with a following cooling trend to the Late-Holocene. This global cooling trend is surprising because of increasing greenhouse gases and retreating ice sheets. Moreover the cooling is also opposing to the warming trend simulated by climate models. The processes causing the reconstructed cooling remained elusive. Here we show that both a global warming mode and a cooling mode during the Holocene emerge when performing a spatio-temporal analysis of the annual temperature variability using data of a transient high resolution Holocene simulation. Both corresponding global spatial patterns show different regions as their activity centers. Whereas the warming trend is related to the greenhouse effect and most pronounced in the tropics, the simulated cooling trend - resembling a global-averaged annual temperature reconstruction - is forced by the non-linear effects of changes in the seasonal-cycle of the Arctic sea-ice and are predominant in the Arctic, North Atlantic and Eurasian regions. The warming mode dominates in the Early- to Mid-Holocene whereas the cooling mode takes over in the Late-Holocene. These findings have strong implications on the interpretation of proxy data and the selection of proxy locations to compute global mean temperatures.

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