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A permanent El-Nino state during the Pliocene? A modelling perspective

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Oxygen isotope and Mg/Ca analyses carried out on planktonic formaminifera (Wara et al., 2005) suggest that, during the Pliocene, Eastern Equatorial Pacific (EEP) sea-surface temperatures (SSTs) were warmer than present-day. Furthermore, the SST gradient which currently exists between the tropical east and west Pacific may have been absent at this time. Philander and Federov (2003) suggest that the prevailing warm climate of the Pliocene deepened the thermocline preventing the upwelling of cool nutrient rich waters in the EEP, leading to the establishment of a permanent El-Nino state. They argue that this altered tropical cloud cover, surface albedo and the global energy balance in a way that helped to maintain Pliocene warmth. Later, as climate cooled, the thermal structure of the oceans changed (at ∼3 Ma BP) leading to the first appearance of cold surface waters in the EEP and coastal zones of southwestern Africa and California; contributing to the cooling of global climate and the initiation of Northern Hemisphere glaciation (NHG). Rickaby & Halloran (2005) have questioned this view by reconstructing a permanent La-Nina, rather than El-Nino conditions for the Pliocene based on Mg/Ca analyses of planktonic formainifera from the same EEP site used by Wara et al. (2005).

To test these suggestions we performed a series of experiments using the Hadley Centre GCM examining the role of the oceans and ocean structure on Pliocene warmth. Firstly, we present results from a fully coupled Pliocene ocean-atmosphere GCM simulation (‘Plio^{Control}’) which examines the thermal structure of tropical oceans and longitudinal temperature gradients in the Pacific and other ocean basins, with the objective of identifying if the Pliocene was a period characterised by a permanent El-Nino state. Secondly, we present results from three sensitivity experiments ('PlioPacific^{NoGradient}', 'PlioPacific^{Dateline}' & 'PlioGlobal^{NoGradient}') where the gradient of SSTs in the tropical Pacific and other ocean basins is altered so that the influence of tropical ocean conditions on high-latitude precipitation and temperatures estimates, and therefore indirectly NHG, can be quantified.

A permanent El-Nino state is not predicted in experiment Plio^{control}. Annual mean EEP SSTs increase by a maximum of 2 to 5˚C, however a gradient in SSTs across the tropical Pacific is maintained. In experiments Plio^{NoGradient}, Plio^{Dateline} & PlioGlobal^{NoGradient}, where the model is forced to maintain a flat SST gradient across the Pacific and other ocean basins (from 40˚N and 40˚S), the maximum contribution to global warmth never exceeds 0.6˚C as an annual mean. These results indicate that even if the Pliocene was characterised by permanent El-Nino conditions, it is unlikely that it provided more than a minor contribution to the warmth that existed at that time, and therefore, it is unlikely that the termination of this state, at $\sim$3 Ma BP, significantly contributed to the onset of NHG.