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Modelling mid Pliocene warmth: contribution of atmosphere, oceans and cryosphere *revisited*

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In 2004 Haywood and Valdes published the first fully coupled ocean-atmosphere GCM study of the mid-Pliocene. The work was performed to determine the relative role of the atmosphere, oceans and cryosphere in driving/maintaining elevated global temperatures during the mid Pliocene warm period. The model (the HadCM3 GCM) was initialised with boundary conditions derived from the U.S. Geological Survey PRISM2 data set and an atmospheric carbon dioxide concentration of 400 ppmv. The results from the 2004 study were based on a single model run in which all the boundary conditions were changed simultaneously to a mid Pliocene state. This made it difficult to ascertain the exact contribution of each boundary condition change to mid Pliocene warmth. Furthermore, the length of the model integration was insufficient to allow an equilibrium condition to be reached.

Here we present the results from an ensemble of fully coupled OAGCM simulations using the HadCM3 GCM. Our mid Pliocene control run, incorporating a full suite of palaeo-boundary conditions has now been integrated for more than 850 simulated years. An additional four simulations have been performed which track the principal environmental changes that occurred between the mid Pliocene and pre-industrial (simulation 1. mid Pliocene but with pre-industrial CO_2; simulation 2. mid Pliocene with pre-industrial CO_2 and modern ice sheets; simulation 3. mid Pliocene with pre-industrial CO_2, modern ice sheets and soils but retaining mid Pliocene vegetation in non-glaciated regions; simulation 4. pre-industrial). Results from this ensemble of experiments broadly support the conclusions of the 2004 study indicating that elevated

CO_2 and the smaller Greenland and Antarctic ice sheet provide the largest contribution to mid Pliocene warmth. Changes in orography, soils and vegetation provide additional important contributions. Our control mid Pliocene simulation continues to indicate no increase relative to the pre-industrial in ocean heat transport from the tropics to high latitudes and no enhancement in thermohaline circulation.