The transient and asynchronous response of ice volume to orbital-driven climate changes of the Late Pliocene

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The contribution to sea-level rise of the Antarctic and Greenland ice sheets in a warming climate is uncertain. A better understanding is evidently needed to make more rigorous projections of the impact of regional sea-level rise. A warm interval within the Late Pliocene (3.264 to 3.025 million years before present) can be used to gain a better understanding of the response of the ice sheets to a warming climate with CO2 levels close to or higher than present. For this interval, the highest rise in sea level relative to the present might expected to be a combination of the smallest ice sheet on both Antarctica and Greenland. However, it has been hypothesised that an asynchronous response of ice sheets in the northern and southern hemisphere might be expected based on an analysis of insolation variability (Raymo et al., 2006; Dolan et al., 2011).
Here, we present results from transient experiments with ice-sheet models forced with multiple snapshot experiments of the HadCM3 climate model (Prescott et al., 2014). The HadCM3 simulations used Pliocene boundary conditions (Haywood et al., 2011) with an atmospheric CO2 level set to 405 ppm. Simulations 20 kyr on either side of two interglacial interval within the Late Pliocene, Marine Isotope Stage (MIS) KM5c (from 3.225 to 3.185 Myr ago) and K1 (from 3.080 to 3.040 Myr ago), have been carried out with different orbital parameters related to the specific time points. For the ice-sheet model we used the global combined ice-sheet model as described in De Boer et al. (2014). As a spin-up a global ice volume simulations (as in De Boer et al., 2014) was run starting from 3.5 Myr ago to the start of the KM5c interval (3.225 Myr ago) and for the intermediate time period from 3.185 to 3.080 Myr ago between MIS KM5c and K1. For the 40 kyr simulations for MIS KM5c and K1 the ice-sheet models for Antarctica and Greenland where run simultaneously forced by the HadCM3 climate every 2000 (KM5c) and 4000 years (K1).
The multiple snapshot HadCM3 simulations already show peak temperatures during the MIS KM5c and K1 intervals that were not globally synchronous (Prescott et al., 2014). Our simulations indicate that the hypothesis put forward by Raymo et al. (2006) of an asynchronous response of ice sheets combined with our transient modelling is indeed a key factor in simulating sea level. In particular, simply summing the maximum individual contribution of the Greenland and Antarctic ice sheets to sea-level rise during the MIS K1 interval is shown to be larger that then actual synchronous sum of the sea-level contributions. This is largely caused by the opposite signal of orbital driven insolation change over Greenland and Antarctica, hence leading to an asynchronous response of the ice sheets.

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