Orbital driven Late Pliocene climate changes and their relation to ice volume and relative sea-level change

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Abstract

The contribution to sea-level rise of the Antarctic and Greenland ice sheets in a warming climate is uncertain. A better understanding of the physical mechanisms driving these changes is therefore 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 CO_2 levels close to or higher than present. Here, we present results from transient experiments with a coupled ice-sheet sea-level model solving the gravitational self-consistent sea level across the Late Pliocene.

The full transient experiment runs from 3.5 to 3.08 Myr ago. At particular time points during the full transient simulation, namely for Marine Isotope Stage (MIS) KM5c (from 3.225 to 3.185 Myr ago) and K1 (from 3.080 to 3.040 Myr ago), the ice-sheet model is forced with multiple snapshot experiments of the HadCM3 climate model. The HadCM3 simulations used Pliocene boundary conditions with an atmospheric CO_2 level set to 405 ppm. A sequence of climate model simulations covering 20 kyr on either side of MIS KM5c and K1 have been carried out with varying orbital parameters related to the specific time points. The full transient experiment starts with a global ice-volume simulation of four ice sheets regions (Antarctica, Greenland, Eurasia and North America) 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 MIS KM5c and K1, the ice-sheet models for Antarctica and Greenland were run simultaneously forced by the HadCM3 climate every 2000 (KM5c) and 4000 years (K1), respectively.

Our simulations indicate that the contribution during particular warm intervals to global-mean sea level from the Antarctic and Greenland ice sheets are of similar magnitude. In cases of high eccentricity and thus large variations in climatic precession an asynchronous response in hemispheric ice volume to orbital variations is observed. Sensitivity tests are performed with different ice-sheet and Earth model parameters providing an uncertainty estimate of simulated relative sea level. We show the distinct fingerprint of the sea-level contributions of each ice sheet during this interval and perform a comparison with global relative sea level data to constrain the specific ice-volume contributions to regional sea level during warm intervals of the Late Pliocene.

Keywords: Pliocene, ice sheet, sea level, orbital variations