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Understanding the major transitions in Quaternary climate dynamics

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Climate dynamics over the past 3 million years was characterized by strong variability associated with glacial cycles and several distinct regime changes.
The Pliocene-Pleistocene Transition (PPT), which happened around 2.7 million years ago, was characterized by the appearance of the large continental ice sheets over Northern Eurasia and North America. For two million years after the PPT climate variability was dominated by relatively symmetric 40 kyr cycles. At around 1 million years ago the dominant mode of climate variability experienced a relatively rapid transition from 40 kyr to strongly asymmetric 100 kyr cycles of larger amplitude (Mid-Pleistocene Transition). Additionally, during the past 800 kyr there are clear differences between the earlier and the later glacial cycles with the last five cycles characterized by larger magnitude of variability (Mid-Brunhes Event).
Here, we use the Earth system model of intermediate complexity CLIMBER-2 to explore possible mechanisms that could explain these regime shifts.
CLIMBER-2 incorporates all major components of the Earth system – atmosphere, ocean, land surface, northern hemisphere ice sheets, terrestrial biota and soil carbon, marine biogeochemistry and aeolian dust. The model was optimally tuned to reproduce climate, ice volume and CO_2 variability over the last 400,000 years. Using the same model version, we performed a large set of simulations covering the entire Quaternary (3 million years) starting from identical initial conditions and using a parallelization in time technique which consists of starting the model at different times (every 100,000 years) and running each simulation for 500,000 years. The Earth's orbital variations are the only prescribed radiative forcing. Several sets of the Northern Hemisphere orography and sediment thickness representing different stages of landscape evolution during the Quaternary are prescribed as boundary conditions for the ice sheet model and volcanic CO_2 outgassing is used as the external forcing for the carbon cycle to allow for different background atmospheric CO_2 concentrations.
We show that by varying only these two model boundary conditions and volcanic forcing the model is able to reproduce the major regime changes of Quaternary long-term climate dynamics.