Simulating ice sheets during Pleistocene glacial cycles: A dance of CO$_2$, ice and orbital cycles

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During the Mid Pleistocene Transition (MPT; 1.2-0.7 Ma) glacial cycle periodicity shifted from 40 thousand years (ka) to an average 100 ka. While orbital cycles have a large influence on glacial cycle periodicity, the MPT took place without any clear change in the power spectrum of the orbital forcing. This suggests that the MPT must have resulted from Earth system processes rather than a change in external forcing.

In this study, we use an ice-sheet model to simulate the evolution throughout the past 1.5 million years of the Laurentide, Eurasian, Greenland and Antarctic ice sheets. We force the model with last glacial maximum and pre-industrial climate time-slices from the PMIP4, which are interpolated according to prescribed CO$_2$ and insolation reconstructions, as well as modelled ice-sheet geometry, thereby implicitly including the temperature-albedo and precipitation-topography feedbacks.

We show that forcing the model with the combination of CO$_2$ and insolation can capture the 40 ka cycles before the MPT and the 100 ka cycles after the MPT, without requiring a change in the ice-sheet model set-up. Deglaciations are initiated when the combination of CO$_2$ and insolation creates a warm enough climate. Before the MPT, these conditions are met in almost all 40 ka cycles, as interglacial CO$_2$ levels are high enough to cause deglaciations. After the MPT, interstadial CO$_2$ levels tend to be low enough not to trigger a deglaciation during orbital maxima, resulting in longer glacial cycles. Results are most sensitive to the parameterization of the basal friction. Increased basal friction leads to more merged cycles before the MPT. Decreased basal friction will result in an increased likelihood for interstadial CO$_2$ and insolation levels to result in complete melt of the North American ice sheet.