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The relative role of orbital, CO2 and ice sheet forcing on Pleistocene climate

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During the last ~2.5 million years, the Quaternary period, Earth's climate fluctuated between a series of glacials and interglacials, driven by long-term internal forcings such as those in atmospheric CO_2 concentrations and ice sheet extent, and external forcings such as the orbital parameters of the Earth around the Sun. Climate models provide a useful tool for addressing questions concerning the driving mechanisms, dynamics, feedbacks, and sensitivity of the climate system associated with these variations. However, the structural complexity of such models means that they require significant computational resources, especially when running long (> one million year) transient simulations, and as such are not suitable for exploring orbital-scale variability on these timescales.

Instead, here we use a climate model to calibrate a faster statistical model, or emulator, and use this to simulate the evolution of long-term palaeoclimate during the Quaternary period; firstly during the late Pleistocene (the last 800 thousand years) and secondly the entire Quaternary (the last 2.58 million years). The emulator is driven by five forcing components: CO_2, ice volume, and three orbital parameters. We firstly compare the simulation with proxy records, and secondly investigate which forcing component is contributing the most to the simulation.

The results suggest that the emulator performs well and generally agrees with the proxy records available during the late Pleistocene, for both temperature and precipitation, especially concerning the timing and duration of the various glacial-interglacial cycles. There are, however, some instances of discrepancies, especially concerning the minima and maxima of the cycles. A factorial

experiment shows that CO_2 concentrations and ice volumes changes drive the most variability. The efficiency of the emulator approach also allows us to carry out a quasi-transient simulation through the entire Quaternary period, and allows projections of possible future drilling results from deep Antarctic ice cores.