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Millennial scale climatic responses through a Late Miocene precession cycle

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Late Miocene (11.61–5.33 Ma) climate is thought to have been warmer and wetter than the present, with nearly ice-free conditions over the Northern Hemisphere, and significant differences in vegetation distribution. There still is considerable uncertainty in the reconstructed CO_2 levels for this time period, fostered by the temporally and spatially biased distribution of the available proxy record. Previous model-data comparison studies (i.e. Bradshaw et al., 2012; Pound et al., 2011) highlighted the mismatch between model results and proxy data for this time period. Here, we investigate how taking into account the variability due to changes in orbital forcing can account for some of these differences. We also explore the orbital control on the monsoonal systems at millennial scale resolution, as well as the impact of background CO_2 on orbital sensitivity.

Long-term changes in seasonal and latitudinal solar insolation are generated by periodic oscillations in the Earth's orbit and tilt relative to the Sun. These cycles have a modulating effect on climate and ocean circulation patterns. A record of this signal can be found in a number of terrestrial and marine sedimentary sequences.

A series of 22 fully coupled atmosphere-ocean-vegetation simulations has been run through an entire precession cycle during the Late Miocene ($\sim$6.5 Ma). These experiments were performed using HadCM3L (Hadley Centre Coupled Model, Version 3 - Low resolution ocean) with TRIFFID (Top-down Representation of Interactive Foliage and Flora Including Dynamics) to test the climatic response to changes in orbital forcing.

The Mediterranean Sea provides a remarkable geological record for this time slice. Several sequences around the basin margins have been astronomically tuned so that high resolution geological data can be directly compared with our model results. However, this is not the case for the rest of the world, where the distribution of climate proxy data for the Late Miocene is sparse, patchy and is typically constrained by a low-resolution age model.

Model results show the effect of different orbital configurations on the North African summer monsoon, with highly intensified precipitation patterns over these regions at times of minimum precession (maximum insolation), triggering significant changes in vegetation belts. Our simulations are compared quantitatively with the palaeorecord and show that orbital forcing could explain some, but not all, of the published model-data mismatch.

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