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What was the phase relationship between precession and sedimentation in the Mediterranean during the Late Miocene?

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The Messinian Salinity Crisis (MSC) drastically modified the environment of the Mediterranean Sea. The large signal-noise ratio preserved in the geological record for this extreme event makes it a perfect target for exploring the biogeochemical processes involved through palaeoclimate modelling. In addition, Late Miocene sequences in the Mediterranean have been astronomically tuned, providing a very high-resolution age model that resolves sediment data on a millennial timescale or shorter. Consequently it is possible to carry out robust model-data comparison where the precise orbital phasing is equivalent.

Sequences of laminated sapropelitic beds interbedded within homogeneous marls are frequently found in Late Miocene sections in the Mediterranean and have been associated with orbitally-driven climate responses. In fact, the deposition of these sediments has been linked to freshwater input causing both stratification of the water column and increased surface productivity, at times of high summer insolation. Most of the hypotheses relating the phasing of the sedimentary record to the orbital forcing are, however, still untested. Insight can therefore be gained by investigating the impact of varying orbital parameters on the Mediterranean's hydrologic budget using global climate models.

A series of 22 fully coupled atmosphere-ocean-vegetation snap-shot simulations have been run at evenly spaced intervals (1kyr) through an entire precession cycle during the pre-evaporite stage of the MSC ($\sim$6.5 Ma). In our simulations, the Mediterranean Sea's hydrologic budget exhibits high seasonal variability. Model results can be directly compared with high-resolution geological data that is available for our selected time slice; for instance, cyclic changes in microfaunal assemblages that have a strong seasonal bias can be compared with our model output. This allows us to test the biogeochemical phasing of Mediterranean successions in relation to orbital forcing.

Our simulations also show that at times of minimum precession and maximum insolation during the summer months, the hydrologic budget shifts to positive values, turning the Mediterranean Sea into a non-evaporative basin. This is triggered by dramatically increased precipitation over North Africa, linked to the local precession-driven monsoon system, specifically by runoff originating from the Chad-Eosahabi drainage basin. However, runoff appears to dominate the Mediterranean hydrologic budget only at a precession minimum and in the rest of the cycle it is mainly driven by local changes in precipitation and evaporation over the basin itself. This has important implications when interpreting the geological record and its links with orbital forcing, since this correlation is thought to be an expression of the changes in the hydrologic budget.