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Astronomical Climate Pacing in a Model Framework for Late Triassic Lake Level Cycles

Jan Landwehrs[1,2], Michael Wagreich[1], Georg Feulner[2], Matteo Willeit[2], Jessica H. Whiteside[3], and Paul E. Olsen[4]
[1]Department of Geology, University of Vienna, Vienna, Austria
[2]Earth System Analysis, Potsdam Institute for Climate Impact Research, Potsdam, Germany
[3]Ocean and Earth Science, National Oceanography Centre, University of Southampton, Southampton, United Kingdom
[4]Lamont-Doherty Earth Observatory of Columbia University, Palisades, United States of America

Combining both detailed geological records and climate modeling provides exciting opportunities to understand orbital effects on the early Mesozoic greenhouse climate across the supercontinent Pangaea. Lake sediments from the Newark-Hartford Basins (NHB) of the eastern US record cyclic climate changes in the tropics of Pangaea during the Late Triassic and earliest Jurassic (~233–199 Ma). We explore how the combined climatic effect of orbital forcing, paleogeographic changes and atmospheric pCO_2 variations could have contributed to major features of this record.

For this, we assess results from an ensemble of transient, orbitally driven climate simulations for nine geologic timeslices, three atmospheric pCO_2 values and two paleogeographic reconstructions. Each simulation is run with an idealized orbital forcing, with precession, modulated by eccentricity, and obliquity oscillating over a 250 kyr interval. The long duration and large number of simulations is achieved by utilizing the fast CLIMBER-X Earth System Model.

A transition from tropical humid to more seasonal and ultimately semi-arid climates is associated with the tectonic drift of the NHB region from the equator to ~20°N. The orbital modulation of the precipitation-evaporation balance that could be recorded in the lake sediments is most pronounced during 220 to 200 Ma, while it is limited by weak seasonality and increasing aridity before and afterwards, respectively. Lower pCO_2 values around 205 Ma contribute to drier climates and could have led to the damping of sediment cyclicity observed at this time. Eccentricity-modulated precession dominates the orbital climate response in the NHB area, with maximum humidity associated to high spring-summer insolation and enhanced moisture import from the Tethys sea. High obliquity further amplifies summer precipitation through the seasonally shifting tropical rainfall belt.

We furthermore show how contemporaneous proxy localities, e.g. in the Germanic Basin, Junggar Basin or Colorado Plateau, can also be evaluated in this model framework. Studying the varying climate response in these different areas provides directions towards an integrated picture of global astronomical climate pacing in the Late Triassic. Furthermore, the presented approach is readily applicable to other periods in Earth history.