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Insights into the early Eocene hydrological cycle from an ensemble of atmosphere-ocean GCM simulations

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Recent studies utilising a range of geochemical proxies have indicated that a significant perturbation to global hydrology occurred at the Paleocene-Eocene Thermal Maximum (PETM; $\sim$56 Ma). An enhanced hydrological cycle for the warm early Eocene is also suggested to have played a key role in maintaining high-latitude warmth during this interval. Comparisons of proxy data to General Circulation Model (GCM) simulated hydrology have not widely been made however, and inter-model variability remains poorly characterised despite significant differences in simulated surface temperatures. In this work, we address this by undertaking an intercomparison of GCM-derived precipitation distributions within the EoMIP ensemble (Lunt et al., 2012), which includes previously-published early Eocene simulations performed using five GCMs differing in boundary conditions, model structure and precipitation-relevant parameterisation schemes.

We show that an intensified hydrological cycle is simulated for all Eocene simulations relative to preindustrial. This is primarily due to elevated atmospheric paleo-CO_2, although the effects of differences in paleogeography/ice sheets are also of importance in some models. For a given CO_2 level, globally-averaged precipitation rates vary widely between models, largely as a result of different climate sensitivities (dT/dCO_2) and differing parameterisation schemes. Despite this, models with similar global precipitation sensitivities (dP/dT) display different regional responses for a given temperature change. Regions which are particularly model sensitive include the South Pacific, tropical Africa and the Tethys and may represent targets for future proxy acquisition.

A comparison of leaf-fossil-derived precipitation estimates with GCM data illustrates that models tend to unanimously underestimate early Eocene precipitation rates at high latitudes. Models which warm these regions via elevated CO_2 or by utilising alternative parameterisations are most successful in simulating a match with geologic data. Further data from low-latitude regions and better constraints on early Eocene CO_2 are required to discriminate between these model simulations, given the large error bars on paleoprecipitation estimates. Given the clear differences apparent between simulated precipitation distributions within the ensemble, further interrogation of paleohydrological data may offer an independent means by which to evaluate model skill for warm climates.