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Early Eocene changes in the frequency and spatial distribution of extreme precipitation events

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Global warming over the next 100 years is likely to result not only in changes to the spatial distribution of mean annual precipitation, but also to the seasonality of precipitation and the frequency of hydrological extremes, with far-reaching socio-economic and ecological impacts. The study of the sensitivity of the hydrological cycle to episodes of global warmth in the geologic past is receiving increased attention from the paleoclimate community, but our understanding of the occurrence of hydrological extremes remains limited.

The warming associated with the Paleocene-Eocene Thermal Maximum (PETM) hyperthermal (∼56 Ma) has received widespread attention given its global nature, rapid onset and transient nature. A range of geomorphological, microfossil and biomarker proxies suggest significant hydrological changes occurred at the PETM which have traditionally been interpreted in terms of changes in mean annual precipitation; recently changes in the frequency of hydrological extremes at the PETM have also been suggested. In this work, we seek to better understand whether numerical climate models run with boundary conditions appropriate for the early Eocene (56 – 49 Ma) are capable of simulating changes in the frequency of intense precipitation ('storm') events by analysing GCM-simulated precipitation rates at an hourly frequency.

Our Eocene simulations are performed at x2 and x4 preindustrial CO_2 using a coupled atmosphere-ocean GCM, HadCM3L. Differences in climatology between high and low CO_2 may be considered analogous to the changes which occurred at the PETM. Our results indicate significant changes occur in the precipitation intensity-frequency relationships at locations which correspond to sites from which PETM proxies exist. The percentage of time during which precipitation occurs and the overall number of events lasting longer than an hour declines in the high-CO_2 model. These changes tend to occur with an associated increase in mean storm precipitation rate, such that hydrological extremes occur with a reduced return-period. We explore how these relationships vary spatially and show relative changes vary between sites in close geographic proximity.

Our results suggest that the interpretation of existing paleoclimatic proxies for hydrological change must consider both changes in mean annual precipitation rate, but also changes in the frequency of intense, high impact events.