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Estimate of the Earth-system sensitivity across the early Eocene hyperthermals

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Earth-system sensitivity (ESS) is referred to as the long-term surface temperature change in response to an increase in atmospheric CO_2 concentration over geological timescale. This temperature response can be enhanced by positive feedbacks (e.g., changes in vegetation, ice) and diminished through negative feedbacks (e.g., changes in weathering, aerosols). These feedbacks can operate over different timescales, which can be fast (<10^2 years) or slow (>10^2 years). Although the interactions between these feedbacks are difficult to tease apart, ESS can be estimated directly using paleo-temperature and paleo-CO_2 data. The early Paleogene greenhouse period (56-53.5 Ma) provides a unique opportunity for such estimate. A series of extreme global warming events known as hyperthermals occurred during this time interval, each lasted less than 200 kyr. Changes in terrestrial carbon isotope discrimination calculated from published high-resolution marine and terrestrial carbon isotope records allows for a nearly continuous reconstruction of pCO_2 across these hyperthermals. Our calculation shows that the baseline pCO_2 is relatively stable (554 +500 -205 ppm) with significantly elevated values at each of the hyperthermals (i.e., PETM, H1, H2 and I1). By matching the new pCO_2 records with temperature data across these hyperthermals, we find that ESS is within the range of previous estimates for the early Eocene warm climate (1.6 to 3.5 K per doubling of CO_2) (Rohling et al., 2012) and the canonical range (1.5 to 4.5 K per doubling of CO_2). Future work is needed to quantify the uncertainty of the ESS estimates and to better understand the interactions between climate feedbacks.