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Biomarkers from maar sediments reveal Eocene hyperthermal temperature dynamics

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The early to middle Eocene (~56-46 Ma) was characterized by a sequence of short-lived (10^4-10^5 yrs) perturbations of the global carbon cycle associated with global warming and ocean acidification. Although these 'hyperthermal events' are considered as geological analogues for current anthropogenic climate change, the amplitude and pacing of hyperthermal warming, particularly on the continents remains poorly constrained. This shortcoming limits not only our abilities to evaluate Earth system response to the massive release of greenhouse gases but also inhibits testing of climate model simulations of abrupt warming against proxy data. Here, we analyzed branched glycerol dialkyl glycerol tetraethers (brGDGTs) and carbon isotopes of bulk organic matter ($\delta^{13}C_{TOC}$) from the maar sediments of the mid-latitude Eocene UNESCO World heritage site 'Messel Fossil Pit' (Germany) in order to reconstruct a sub-millennial to millennial scale temperature and carbon isotope record through hyperthermal event C21n-H1 (47.2 Ma). Our temperature record reveals a maximum warming of 3.5°C during the body of the hyperthermal, accompanied by ~12 ka scale warming fluctuations that are likely associated with half-precession forcing. When comparing our biomarker-based temperatures to Eocene climate simulations from the Deep-Time Model Intercomparison Project (DeepMIP), hyperthermal warming is best reproduced by 4× to 6× preindustrial pCO_2 concentrations, while all other 3× simulations underestimate the warming. Finally, an abrupt negative carbon isotope excursion (CIE) of ~7‰ in the $\delta^{13}C_{TOC}$ during peak hyperthermal is associated with a turnover of the predominant algal community within the lake system indicating direct impact of the hyperthermal conditions on the lake carbon reservoir.