Modeling the oxygen isotope in the early Eocene hothouse climate using an isotope-enabled Earth system model

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The early Eocene (~56–48 Ma), a past hothouse climate, can help us better understand climate dynamics in a warm world including the climate sensitivity and variability, the hydrological cycle, and atmospheric/oceanic circulations. The early Eocene also provides a unique opportunity to test the climate models that are used extensively for climate change attribution and projection. However, most of our understanding of the early Eocene climate is based on proxies that are usually subject to large uncertainties resulting from calibration, preservation and dating issues. For example, the oxygen isotope ratio ($\delta^{18}O_c$) in calcite foraminiferal tests preserved in marine sediments has been used to infer past changes in ocean temperature and ice volume, although the $\delta^{18}O_c$ may also reflect local changes in the isotopic composition of seawater, carbonate ion concentrations, and the foraminiferal growing season and depth habit. Here, we use the water isotope-enabled Community Earth System Model to simulate climate conditions and water isotopes during the early Eocene, aiming to explore the paleoclimatic interpretation of $\delta^{18}O_c$ records. Our simulations can well simulate the reconstructed warm conditions at the early Eocene. We investigate the uncertainty in reconstructing the Eocene ocean temperature caused by the spatial and temporal variation of seawater $\delta^{18}O$, and show improved model-data agreement when proxy paleotemperatures are estimated using simulated seawater $\delta^{18}O$. We also examine how the foraminiferal growing season and calcification depth may complicate the interpretation of the $\delta^{18}O_c$ records and general model-data comparison.