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Using paleoclimate data to constrain cloud parameterizations in GISS-E2.1

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Much of the inter-model spread in equilibrium climate sensitivity (ECS) estimates is attributed to cloud and convective parameterizations which model cloud and water vapor feedbacks. These parameterizations also directly influence water isotopes, which may be retrieved not only from modern observations, but also a plethora of paleoclimate archives that represent a much broader range of variability than is available in modern measurements. And thus, these water isotope tracers can be used to constrain ECS by flagging unrealistic parts of the parameterization phase space via model biases in a perturbed parameterization ensemble (PPE) of paleoclimate simulations. In this proof-of-concept study, we evaluate a suite of isotope-enabled atmosphere-only GISS-E2.1 simulations, each with varying cloud and convective perturbations, against speleothem and ice core $\delta^{18}O$ for the Last Glacial Maximum (LGM, 21000 years ago), mid-Holocene (MH, 6000 years ago) and pre-Industrial periods. The first-order spatial pattern of $\delta^{18}O$ of precipitation ($\delta^{18}O_p$) is in excellent agreement between proxy data and all parameterizations across all time periods. While the simulations generally capture large scale $\delta^{18}O_p$ patterns, the magnitude of change is consistently smaller in all simulations than those of the proxies, highlighting uncertainties in both models and proxies. Not a single set of parameterizations worked well in all climate states, indicating that improving future simulations requires determining all plausible parameter combinations critical in refining ECS. Further, it may be that certain parameterization choices represent certain types of variability better than others, and there may be a non-unique solution to ideal clouds/convection parameterization choices that is modulated by the question asked.