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Exploring Radiative Forcing from Pliocene Boundary Conditions and CO₂

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Past climate states hold valuable insights into future climate change. Among those states, mid-Pliocene (3.3 - 3.0 Ma) is often studied as an important analog to near future climate change following an intermediate warming pathway. This time interval featured topography and geography like present-day, yet with retreated polar ice sheets and expanded boreal forests, potentially reflecting equilibrium earth system responses to CO₂ forcing at a centennial to millennial time scale.

Despite the prolific research on Pliocene climate, little is known about the amount of radiative forcing, especially from changing boundary conditions, that drives the Pliocene climate. Existing constraints mainly focused on well-mixed greenhouse gases and aerosols. Here, we applied the methodology commonly used to quantify radiative forcing of future climate and its sources to constrain radiative forcing of the mid-Pliocene climate using three generations of Community Earth System Models (CCSM4, CESM1.2, and CESM2).

To calculate ERF, the difference in net top of the atmosphere radiative fluxes is computed between a pre-industrial control and a mid-Pliocene simulation. Both are carried out with prescribed pre-industrial sea surface temperature. The three mid-Pliocene simulations separately feature a 400 ppm CO₂ (the level of mid-Pliocene), mid-Pliocene geography and topography, and mid-Pliocene ice and vegetation. Changing atmospheric temperature, water vapor, surface albedo, and clear vs total sky radiative fluxes are further extracted from these simulations to calculate radiative adjustments with published radiative kernels for CESM.

In our preliminary results with CESM1.2, we found that ERF is 1.754 W m⁻² for CO₂ forcings, 1.143 W m⁻² for vegetation and ice sheet forcing, and -0.339 W m⁻² for geographic and topographic forcing. Further, ERF from boundary condition changes mostly arises from changing surface albedo with 1.626 W m⁻² for vegetation and ice sheet changes and -0.54 W m⁻² for geographic and topographic changes respectively. Radiative adjustments from water vapor responses tend to amplify the instantaneous forcing with the most profound effect induced by vegetation and ice sheet changes. These results underscore the importance of constraining radiative forcing from

changes in boundary conditions, which is potentially key to understanding drivers of past climate warmth and inter-model spread in simulated past climate states.