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Estimating structural and parametric uncertainties in the simulated early Eocene surface warming

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Simulating the proxy-derived surface warming and reduced meridional temperature gradient of the early Eocene greenhouse climate still represents a challenge for most atmosphere-ocean general circulation models. A profound understanding of uncertainties associated with the respective model results is thereby essential to reliably identify any similarities or misfits to the proxy record. Besides incomplete knowledge of past greenhouse gas concentrations and other boundary conditions, structural and parametric uncertainties are the main factors that determine our confidence in paleoclimate simulation results.

The recent publication of coordinated model experiments that apply identical paleogeographic boundary conditions for key time periods of the early Eocene (DeepMIP) allows a systematic analysis of inter-model differences and therefore of structural uncertainties in the simulated surface warming. Here we additionally explore the parametric uncertainty of the early Eocene climatic optimum (EECO) surface warming within one DeepMIP model. For this we performed perturbed parameter ensemble (PPE) simulations with HadCM3B at different atmospheric CO_2 concentrations following the DeepMIP protocol. Twenty-one parameter sets based on changes in six atmospheric parameters, a sea-ice parameter and the ocean background diffusivity were branched off from the respective DeepMIP control simulations and integrated for a further 1500 model years. The selected parameter sets are based on previous results demonstrating their ability to simulate a pre-industrial global-mean surface temperature within ±2 °C of the standard configuration.

Preliminary results indicate a large spread of the simulated low-latitude surface warming in the PPE and therefore significant changes of the large-scale meridional temperature gradient for the EECO. Some ensemble members develop numerical instabilities at CO_2 concentrations of 840 ppmv and above, most likely in consequence of high temperatures in the tropical troposphere. We further compare the magnitude of the parametric uncertainty of the HadCM3B perturbation experiments with the structural differences found in the DeepMIP multi-model ensemble and explore the sensitivity of the results to the strength of the applied greenhouse gas forcing. Model skill of the PPE members is tested against the most recent DeepMIP compilations of marine and terrestrial proxy temperatures.