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Dependency of feedbacks on forcing and climate state in perturbed parameter ensembles

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Climate sensitivity is one of the most important metrics for future climate projections. In previous studies the climate of the last glacial maximum has been used to constrain the range of climate sensitivity, and similarities and differences of temperature response to the forcing of the last glacial maximum and to idealized future forcing have been investigated. The feedback processes behind the response have not, however, been fully explored in a large model parameter space. In this study, we first examine the performance of various feedback analysis methods that identify important feedbacks for a perturbed parameter ensemble in experiments simulating both past and future climates. The selected methods are then used to reveal the relationship between the different ensemble experiments in terms of individual feedback processes. We, for the first time, evaluate all the major feedback processes for an ensemble of paleoclimate simulations. It is shown that the feedback and climate sensitivity parameters depend on the nature of the forcing and background climate state. The forcing-dependency arises through the shortwave cloud feedback while the state-dependency arises through the combined water vapor and lapse-rate feedback. Despite this, past climate can still be used to provide a useful constraint on climate sensitivity as long as the limitation is properly taken into account, because the strength of each feedback correlates reasonably well between the ensembles. It is, however, shown that our perturbed parameter ensemble does not cover the range of results simulated by structurally different models, which suggests the need for further study exploring both structural and parameter uncertainties.