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Causes of the weak relationship between modeled Last Glacial Maximum cooling and climate sensitivity, with consequences for emergent constraints

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The use of paleoclimates to constrain the equilibrium climate sensitivity (ECS) has seen a growing interest. In particular, the Last Glacial Maximum (LGM) and the mid-Pliocene Warm Period have been used in emergent constraint approaches using simulations from the Paleoclimate Modelling Intercomparison Project (PMIP). Despite lower uncertainties regarding geological proxy data for the LGM in comparison with the Pliocene, the robustness of the emergent constraint between LGM temperature and ECS is weaker at both global and regional scales. Here, we investigate the climate of the LGM in models through different PMIP generations, and how various factors contribute to the spread of the model ensemble. Certain factors have large impact on an emergent constraint, such as state-dependency in climate feedbacks or model-dependency on ice sheet forcing. Other factors, such as models being out of energetic balance and sea-surface temperature not responding below -1.8°C in polar regions have a restricted influence. We quantify some of the contributions and show they mostly have extratropical origins, which contribute to a weak global constraint, and remotely impact tropical temperatures. Statistically, PMIP model generations do not differ substantially, unlike what has been previously suggested. Furthermore, we find that the lack of high or low ECS models in the ensembles critically limits the strength and reliability of the emergent constraints.