

Improving Earth System Models through simulating past climate-carbon cycle feedbacks

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Considerable uncertainties exist in predicting future climate, carbon sinks, and the feedback between them. A primary cause is the simplification of processes and unconstrained model parameters. Particularly, constraining the ocean carbon sink, which dominates on centennial to millennial timescales, is challenging because present-day observations span only a few decades. Simulating the climate-carbon cycle system in past climates, for which a wealth of geological records are available to validate models, can advance our understanding of the Earth system and help reduce model uncertainties.

We use the Max Planck Institute Earth System Model to run a suite of transient simulations for the last deglaciation (21 ka to the present). When applying an ocean biogeochemical model tuned similarly to its CMIP6 version, the ocean contributes to an atmospheric CO₂ rise of only 30 ppm (a 90 ppm rise in ice core records), driven by the weakening of the solubility pump. After adjusting the model to address uncertainties related to the parameterisations of several biological processes, the model-data agreement for the present day is improved, and a larger deglacial ocean CO₂ outgassing of 40 ppm is achieved. When employing a physical model that produces a weaker glacial AMOC, the deglacial ocean CO₂ outgassing rises to about 60 ppm. Our results emphasise the crucial role of properly representing ocean circulation in the natural carbon cycle and highlight key areas for further development.