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# Reconstructions and predictions of the global carbon cycle with an emission-driven Earth System Model

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The global carbon budget including $CO_2$ fluxes among different reservoirs and atmospheric carbon growth rate vary substantially in interannual to decadal time-scales. Reconstructing and predicting the variable global carbon cycle is of essential value of tracing the fate of carbon and the corresponding climate and ecosystem changes. For the first time, we extend our prediction system based on the Max Planck Institute Earth system model (MPI-ESM) from concentration-driven to emission-driven taking into account the interactive carbon cycle and hence enabling prognostic atmospheric carbon increment.

By assimilating atmospheric and oceanic observational data products into MPI-ESM decadal prediction system, we can reproduce the observed variations of the historical global carbon cycle globally. The reconstruction from the fully coupled model enables quantification of global carbon budget within a close Earth system and therefore avoids the budget imbalance term of budgeting the carbon with standalone models. Our reconstructions of carbon budget provide a novel approach for supporting global carbon budget and understanding the dominating processes. Retrospective predictions based on the  emission-driven hindcasts, which are initiated from the reconstructions, show predictive skill in the atmospheric carbon growth rate, air-sea $CO_2$ fluxes, and air-land $CO_2$ fluxes. The air-sea $CO_2$ fluxes have higher predictive skill up to 5 years, and the air-land $CO_2$ fluxes and atmospheric carbon growth rate show predictive skill of 2 years. Our results also suggest predictions based on Earth system models enable reproducing and further predicting the evolution of atmospheric $CO_2$ concentration changes. The earth system predictions will provide valuable inputs for understanding the global carbon cycle and supporting climate relevant policy development.