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Hydrological and biogeochemical constraints on terrestrial carbon cycle projections

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The terrestrial biosphere is currently acting as a sink for about a third of the total anthropogenic CO_2 emissions. However, the future fate of this sink in the coming decades is very uncertain, as current Earth System Models (ESMs) simulate diverging responses of the terrestrial carbon cycle to upcoming climate change. Here, we use observation-based constraints of water and carbon fluxes to reduce uncertainties in the projected terrestrial carbon cycle response derived from simulations of ESMs conducted as part of the 5th phase of the Coupled Model Intercomparison Project (CMIP5). We find in the ESMs a clear linear relationship between present-day Evapotranspiration (ET) and Gross Primary Productivity (GPP), as well as between these present-day fluxes and projected changes in GPP, thus providing an emergent constraint on projected GPP. Constraining the ESMs based on their ability to simulate present-day ET and GPP leads to a substantial decrease of the projected GPP and to a ca. 50% reduction of the associated model spread in GPP by the end of the century. Given the strong correlation between projected changes in GPP and in NBP in the ESMs, applying the constraints on Net Biome Productivity (NBP) reduces the model spread in the projected land sink by more than 30% by 2100. Also, the projected decline in the land sink is at least doubled in the constrained ensembles and the probability that the terrestrial biosphere is turned into a net carbon source by the end of the century is strongly increased. Moreover, a similar strategy is used to provide constraints on the feedbacks involving the terrestrial carbon cycle and the climate system. The findings indicate that the decline in the future land carbon uptake might be stronger than previously thought, which would have important implications for the rate of increase of the atmospheric CO_2 concentration and for future climate change.