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# Exploring the role of model-data-fusion approaches in constraining the long term predictability of terrestrial ecosystem carbon fluxes with multi-model ensembles

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Discrepancies between future projections of land carbon fluxes originate from different process representations, but also from differences in model parameterization. Between model divergence stems mostly from different modeling structures, parameterizations and initial conditions. In addition to the known differences in the mean model behavior under future climate scenarios, there are likely also differences in model responses to increased climate variability, and extreme events, which have yet to be assessed. Here we present an in situ model data fusion experiment to explore the contribution of diverse long-term observations in addressing the divergence in responses to climate variability and extreme events between different modeled projections of ecosystem water and carbon fluxes until 2100.

We focus on two forest sites in France – Hesse and Le Bray. At these sites the carbon and water fluxes have been observed for more than ten years using eddy covariance. A consolidated set of flux observations and respective uncertainties is complemented with biometric information on aboveground biomass, biomass increments and soil carbon stocks. These datasets are used as constraints in the inverse parameter optimization of an ensemble of terrestrial biogeochemical models ranging from specific forest models to generic land surface schemes, namely: BASFOR, FöBAAR, JSBACH, LPJ and ORCHIDEE. The set of multiple constraints ensures that the models simulate the responses of ecosystem fluxes to environmental conditions in agreement with ecosystem pools.

Despite significant improvements in modeling performance, we observe modest improvements in estimating the interannual variability in carbon fluxes and pools. The divergence in long-term trends until 2100 between models is reduced after optimization. However, an increase in the variability of net ecosystem fluxes is observed, which results from the higher interannual variability in the climate scenarios, as well as the growing ecosystem carbon pools. These results suggest more frequent and amplified responses of ecosystem carbon cycle as present-day extreme conditions become more frequent. Overall, this study emphasizes the importance of long-term observations in assessing inter-model divergence and in addressing the future sensitivities of ecosystem carbon fluxes to changes in climate variability.