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Disentangling the role of different sources of uncertainty and model structural error on predictions of water and carbon fluxes with CLM5 for European observation sites

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The Community Land Model version 5 (CLM5) integrates processes encompassing the water, energy, carbon, and nitrogen cycles, and ecosystem dynamics, including managed ecosystems like agriculture. Nevertheless, the intricacy of CLM5 introduces predictive uncertainties attributed to factors such as input data, process parameterizations, and parameter values. This study conducts a comparative analysis between CLM5 ensemble simulations and eddy covariance and in-situ measurements, focusing on the effects of uncertain model parameters and atmospheric forcings on the water, carbon, and energy cycles.
Ensemble simulations for 14 European experimental sites were performed with the CLM5-BGC model, integrating the biogeochemistry component. In four perturbation experiments, we explore uncertainties arising from atmospheric forcing data, soil parameters, vegetation parameters, and the combined effects of these factors. The contribution of different uncertainty sources to total simulation uncertainty was analyzed by comparing the 99% confidence
intervals from ensemble simulations with measured terrestrial states and fluxes, using a three-way analysis of variance.
The study identifies that soil parameters primarily influence the uncertainty in estimating surface soil moisture, while uncertain vegetation parameters control the uncertainty in estimating evapotranspiration and carbon fluxes. A combination of uncertainty in atmospheric forcings and vegetation parameters mostly explains the uncertainty in sensible heat flux estimation. On average, the 99% confidence intervals envelope >40% of the observed fluxes, but this varies greatly between sites, exceeding 95% in some cases. For some sites, we could identify model structural errors related to model spin-up assumptions or erroneous plant phenology. The study guides identifying factors causing underestimation or overestimation in the variability of fluxes, such as crop parameterization or spin-up, and potential structural errors in point-scale simulations in CLM5.