The impacts of model structure, parameter uncertainty and experimental design on Earth system model simulations of litter bag decomposition experiments

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Abstract

Accurate Earth system model simulations of the terrestrial carbon cycle and its feedbacks to climate critically depend on algorithms representing the decomposition of litter and soil organic matter. Litter bag studies, in which specific types of plant litter are subject to varying environmental conditions in the field and decomposition is measured, serve as valuable benchmarks for model performance. Here we test the Energy Exascale Earth System land model (ELM), which has two different structural representations of decomposition, using observations from the Long-term Intersite Decomposition Experiment (LIDET) over five different biomes and six different leaf litter types. We find that seasonal patterns in soil conditions and nutrient availability have large effects on decomposition rates, and that it is critical to include this in the simulation design. Despite widely differing base decomposition rates between the two different model structures, the models produce similar temporal patterns of decomposition when nitrogen is limiting. Both models overpredict the fraction of original nitrogen present as a function of carbon remaining when using default parameterizations. A parameter sensitivity analysis indicates strong dependence of model outputs on nitrogen limitation, carbon use efficiency and decomposition rates. A large spread in model predictions when considering an ensemble of possible parameter combinations strongly suggests parameter uncertainty may be more influential than model structural uncertainty, and that new measurement and modeling approaches may be necessary to constrain these uncertainties.