Functional unit testing of the Community Land Model at the PiTS-1 field experiment

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Observations of field experiments are often made at the level of the whole-plant, leaves, and fine roots. Classic examples include the photosynthesis response of individual leaves to CO_2 concentration and light, the A-Ci and light response curves, respectively. These and other experimental observations have considerable value for calibrating and testing the fundamental processes of land-surface schemes in earth system models. However, it is generally difficult, if not impossible, to obtain model results for these fundamental processes from the in situ context of fully integrated and coupled land surface and earth system models, particularly under the controlled environmental conditions of field experiments. Thus the productive interplay between model and experiment is hampered. In response, we have developed a framework for extracting individual process representations from the Community Land Model (CLM) of the Community Earth System Model (CESM) into modular units for functional testing. The results of these modules, under the controlled environmental conditions of experimental field measurements, can be generated quickly and compared directly with the experimental observations. Here we report on results for leaf-level observations of loblolly pine (*Pinus taeda*) at the Oak Ridge National Laboratory's Partitioning in Trees and Soils (PiTS-1) field experiment and results from the functional unit module for leaf photosynthesis from CLM parameterized for loblolly pine. Initial comparisons between observations and functional unit results show discrepancies between modeled and observed A-Ci curves, with the model underestimating the magnitude of net photosynthesis, especially at higher temperatures. There is, however, a good match between modeled and observed light response. We then calibrated the model against both observed A-Ci and light response curves using Monte Carlo-Markov Chain (MCMC) parameter optimization. MCMC parameter optimization requires tens of thousands of model runs, numbers made possible by our modular framework and isolation of individual functional units but nearly impossible with even the single-site implementation of CLM. The parameter optimization substantially improves model performance in simulating both A-Ci and light response curves, primarily through increasing the optimum temperature for photosynthesis. These results suggest a focus in subsequent experiments on photosynthetic temperature response at high temperatures and experimental determination of the temperature optimum. Our functional unit testing strengthens and refines the linkage between model and experimental observations as part of the model-experiment (ModEx) concept. The increased modularity of our functional unit testing also provides a platform for structured investigation and quantification of functional uncertainty.