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Evaluation and Improvement of Global Carbon Cycle Models against Soil Carbon and Microbial Data Sets Using a Bayesian MCMC method

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Long-term land carbon-cycle feedback to climate change is largely determined by dynamics of soil organic carbon (SOC). However, most evaluation studies conducted so far indicate that global land models predict SOC poorly. We have developed new techniques to evaluate and improve global carbon cycle models against global datavases of soil carbon stock and microbial biomass carbon. We have evaluated and improved one conventional model and two microbial models. We evaluated predictions of SOC by the Community Land Model with Carnegie-Ames-Stanford Approach biogeochemistry module (CLM-CASA'), investigated underlying causes of mismatches between model predictions and observations, and calibrated model parameters to improve the prediction of SOC. We compared modeled SOC to observed soil C pools provided by IGBP-DIS globally gridded data product and found that CLM-CASA' on average underestimated SOC pools by 65% (r^2=0.28). We applied data assimilation to CLM-CASA' to estimate SOC residence times and C partitioning coefficients among the pools, as well as temperature sensitivity of C decomposition. The model with calibrated parameters explained 41% of the global variability in the observed SOC, which was substantial improvement from the initial 27%. The projections differed between models with original and calibrated parameters: over 96 years the calibrated model released 48 Pg C from soil pools and 6.5 Pg C from litter pools less than the original model. Thus, assimilating observed soil carbon data into the model improved fitness between modeled and observed SOC, and reduced the amount of C released under changing climate. We have constrained parameters of two soil microbial models; evaluated the improvements in performance of those calibrated models in predicting contemporary carbon stocks; and compared the SOC responses to climate change and their uncertainties between microbial and conventional models. Microbial models with calibrated parameters explained 51% of variability in the observed total SOC, whereas a calibrated conventional model explained 41%. The microbial models, when forced with climate and soil carbon input predictions from the 5th Coupled Model Intercomparison Project (CMIP5), produced stronger soil C responses to 95 years of climate change than any of the 11 CMIP5 models. The calibrated microbial models predicted between 8% (2-pool model) and 11% (4-pool model) soil C losses compared to CMIP5 model projections which ranged from a 7% loss to a 22.6% gain. Lastly, we observed unrealistic oscillatory SOC dynamics in the 2-pool microbial model. The 4-pool model also produced oscillations, but they were less prominent and could be avoided, depending on the parameter values. To further reduce the uncertainty in the soil carbon prediction, we need to explore alternative model structures, improve representation of ecosystems, and develop additional global datasets for constraining model parameters.