Evaluation and Improvement of Terrestrial Carbon Cycle Models With Observations

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Terrestrial carbon cycle is a critical component of global carbon cycle in response and feedback to climate change. Yet most model evaluation studies conducted so far all indicate that Earth system models predict terrestrial carbon cycle poorly. Research in my lab has focused on evaluating and improving terrestrial carbon cycle models with observations.

We have improved the modeled turnover rates of the surface leaf litter against a global observed dataset of litter turnover rates using a Bayesian Markov Chain Monte Carlo (MCMC) approach to calibrate the model. After data assimilation, the model explained 43% of spatial variability in the observed litter turnover rates, which was better than the initial 15%. Data assimilation selects litter quality limitation function to be dependent on litter lignin-to-nitrogen ratio instead of the structural lignin content. The new model structure explained 61% of variability in the observations.

We improved the simulation of soil organic carbon (SOC) storage in CLM-CASA'. The original 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, C partitioning coefficients among the pools, and temperature sensitivity of C decomposition. The model with calibrated parameters explained 41% of the global variability in the observed SOC, which was substantially better than the initial 27%. The projections differed between models with original and calibrated parameters: over 95 years the amount of C released from soils reduced by 48 Pg C.

We also calibrated two microbial model formulations to global total soil organic carbon and microbial biomass pools, and compared the models' performance to that of CLM-CASA'. Once calibrated, both microbial models explained 51% of variability in the observed soil carbon. Maximum likelihood magnitude of SOC decrease after 95 years of climate change was almost 5-fold higher in the microbial models than in CLM-CASA'.

We applied a data assimilation approach to extract information from soil incubation data to constrain earth system models. A three-pool C-cycling model was optimally fitted with data from a 588-day long soil incubation experiment conducted at two temperatures (25 and 35 oC) for 12 soils collected from six sites arrayed across a mean annual temperature gradient from 2.0 to 25.6 oC. Initial C pool fractions were well constrained. Q10 values increased with recalcitrance of soil fraction. Higher Q10 for decades-old C fractions implies that a major portion of soil C may become a source of atmospheric CO₂ under global warming.