Geophysical Research Abstracts
Vol. 19, EGU2017-14813, 2017
EGU General Assembly 2017

Ages and transit times as important diagnostics of model performance for predicting C allocation in ecosystem models

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The global carbon cycle is strongly controlled by the source/sink strength of vegetation as well as the capacity of terrestrial ecosystems to retain this carbon. However, it is uncertain how some vegetation dynamics such as the allocation of carbon to different ecosystem compartments should be represented in models. The assumptions behind model structures may result in highly divergent model predictions. Here, we asses model performance by calculating the age of the carbon in the system and in each compartment, and the overall transit time of C in the system. We used these diagnostics to assess the influence of three different carbon allocation schemes on the rates of C cycling in vegetation. First, we used published measurements of ecosystem C compartments from the Harvard Forest Environmental Measurement Site to find the best set of parameters for the different model structures. Second, we calculated C stocks, respiration fluxes, radiocarbon values, ages, and transit times. We found a good fit of the three model structures to the available data, but the time series of C in foliage and wood need to be complemented with other ecosystem compartments in order to reduce the high parameter collinearity that we observed and reduce model equifinality. Differences in model structures had a small impact on predicting ecosystem C compartments, but overall they resulted in very different predictions of age and transit time distributions. In particular, the inclusion of a storage compartment had an important impact on predicting system ages and transit times. In the case of the models with 1 or 2 storage compartments, the age of carbon in the system and in each of the compartments was distributed more towards younger ages than in the model that had no storage; the mean system age of these two models with storage was $\sim$80 years younger than in the model without storage. As expected from these age distributions, the mean transit time for the two models with storage compartments was $\sim$50 years faster than for the model without storage. These results suggest that ages and transit times, which can be indirectly measured using isotope tracers, serve as important diagnostics of model structure and could largely help to reduce uncertainties in model predictions. Furthermore, by considering age and transit times of C in vegetation compartments as distributions, not only their mean values, we obtain additional insights on the temporal dynamics of carbon use, storage, and allocation to plant parts, which not only depends on the rate at which this C is transferred in and out of the compartments, but also on the stochastic nature of the process itself.