Testing a land model in ecosystem functional space via a comparison of observed and modeled ecosystem flux responses to precipitation regimes and associated stresses in a central USA forest

Lianhong Gu[1*], Stephen G. Pallardy[2], Bai Yang[1], Kevin P. Hosman[2], Jiafu Mao[1], Daniel Ricciuto[1], Xiaoying Shi[1], Ying Sun[3]

[1] Environmental Sciences Division and Climate Change Science Institute, Oak Ridge National Laboratory, Oak Ridge, Tennessee, USA

[2] Department of Forestry, University of Missouri, Columbia, Missouri, USA

[3]Jackson School of Geosciences, University of Texas, Austin, Texas, USA

[*]Corresponding author:

Lianhong Gu

Environmental Sciences Division, Building 4500N

Oak Ridge National Laboratory

Oak Ridge, TN 37831-6335.

Email: lianhong-gu@ornl.gov

Abstract

Testing complex land surface models has often proceeded by asking the question: does the model prediction agree with the observation? Such an approach has yet to produce a solution to the 'spaghetti problem of terrestrial models'. Here we test the Community Land Model (CLM) by asking the question: does the model behave like an ecosystem? We pursue its answer by testing CLM in the ecosystem functional space (EFS) at the Missouri Ozark AmeriFlux (MOFLUX) forest site in the central USA, focusing on carbon and water flux responses to precipitation regimes and associated stresses. In the observed EFS, precipitation regimes and associated water and heat stresses controlled seasonal and interannual variations of carbon uptake and water use in this deciduous forest ecosystem. Such controls were exerted more strongly by precipitation variability than by the total precipitation amount per se. A few simply constructed climate variability indices captured these controls, suggesting a high degree of potential predictability. While the interannual fluctuation in carbon uptake was large, a net carbon sink was maintained even during an extreme drought year, suggesting a high degree of resilience of this forest ecosystem to environmental stresses. Although CLM predicted seasonal and interanual variations in evapotranspiration reasonably well, its predictions of carbon uptake were too small across the observed range of climate variability. Also, the model systematically underestimated the sensitivities of carbon uptake and evapotranspiration to climate variability and overestimated the coupling between carbon and water fluxes. Consequently, the modeled and observed trajectories of ecosystem fluxes did not overlap in the EFS and the model did not behave like the ecosystem it attempted to simulate. We suggest that future model improvements should focus on better representation and parameterization of process responses to environmental stresses and on more complete

and robust representations of carbon-specific processes so that adequate responses to climate variability and a proper degree of coupling between carbon and water exchanges are captured.

Key words: Ecosystem Functional Space, Carbon and Water Budgets, Climate Variability Indices, Land Surface Modeling, Eddy Covariance