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Sensitivity of Simulated Peatland Carbon and Energy Flux Warming Responses to Biogeochemistry Process Uncertainty

Daniel Ricciuto[1], Dan Lu[1], Jiafu Mao[1], Xiaoying Shi[1], Anthony King[1], and Paul J. Hanson[1]

[1]Environmental Sciences Division and Climate Change Science Institute, Oak Ridge, TN

Contact: ricciutodm@ornl.gov

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Uncertainty about land surface processes contributes to a large spread in model predictions about the magnitude and timing of climate change within the 21st century. Land surface models incorporate a diverse array of processes across various temporal and spatial scales, and include dozens of uncertain parameters. As components of complex Earth system models, such as the Energy Exascale Earth System Model (E3SM), these land-surface models provide crucial information about fluxes of water, energy, and greenhouse gases to the atmosphere and oceans. However, the signs and magnitudes of these fluxes depend on multiple competing feedbacks, and model projections diverge in the latter half of this century. Much of the current understanding about land-surface process uncertainties at regional to global scales derives from model intercomparison projects. However, such MIPs conflate structural and parametric uncertainty, so that combining models or drawing conclusions is difficult. Improved understanding about the sensitivity of model outputs to specific parameters and processes, and the contribution of parametric uncertainty to overall prediction uncertainty, is of critical importance for directing future model development and measurements, and for increasing the accuracy of future projections. One method to quantify model parameter uncertainty is global sensitivity analysis (GSA). A large number of GSA methods exist, and different approaches are selected depending on the computational demands of the model simulation, the dimensionality of the problem, and the desired accuracy of the result.

Here we perform a GSA for a peatland version of the E3SM land model (ELM-SPRUCE) at the SPRUCE experiment site. We analyze the sensitivity of hydrologic cycling, soil C cycling, and the growth of multiple plant functional types response to moderate (+4.5 °C) and high (+9 °C) warming scenarios. We find that the model is especially sensitive to autotrophic and photosynthesis temperature response functions, including parameters related to acclimation. To the degree that this parametric uncertainty can be reduced by observations, we can constrain predictions of responses to warming. This uncertainty is then compared to initial simulations from the SPRUCE model intercomparison, providing additional constraints on model structural uncertainty.