EGU22-10649
https://doi.org/10.5194/egusphere-egu22-10649
EGU General Assembly 2022

Combining nutrient competition, dynamic vegetation, and parameter calibration to improve boreal forest predictions to changing climate

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While climate change is impacting all parts of the globe, boreal forests are experiencing disproportionally higher rates of temperature increase, thus drastically impacting one of the largest biomes in the world. Changes in high-latitude forests have strong implications to the regional water and carbon cycling, and shifts in canopy cover (i.e., abundance and shifts between evergreen and deciduous species) will alter albedo, ecosystem productivity, and surface and canopy water fluxes. For example, high latitude warming may increase nutrient availability via a deepening of the soil active layer. Warming also induces permafrost degradation and loss, leading to strong interactions that alter the hydrology, and soil biological and physical processes. These climate-related interactions will affect plant competitive interactions, survival, and ultimately community distribution and carbon storage. In this study we explore how vegetation dynamics will be affected by changes in plant and microbial N competition, differences in nutrient demand due to shifts in PFTs (e.g., faster resource acquisition in deciduous plants), and ultimately carbon allocation. To be able to accurately predict and model these complex ecological processes we are using a new demographic vegetation model (FATES; Functionally-Assembled Terrestrial Ecosystem Simulator) that is coupled to ELMv1, the land surface model in the global Earth System Model - E3SM. We present here the newly implemented representation of nutrient competition, acquisition, and extensible approach of nutrient and carbon allocation within plants in the ELM-FATES model. This work has successfully coupled the interactions of nutrients between soil biogeochemistry (BGC) in ELM and plant productivity and carbon in FATES, with improved model hypothesis testing for plant's nutrient storage capacity. With the inclusion of nutrient cycling in the previously 'carbon-only' ELM-FATES where the largest competition was light driven, the productivity and biomass storage was significantly reduced for the simulated boreal forests. After conducting an uncertainty quantification experiment (i.e., using large ensembles to generate surrogate models) in order to test the model parameter sensitivity, we found that model parameters related to carbon storage and leaf economics had the largest sensitivity on plant processes. We then applied a Bayesian inference approach using neural networks to calibrate the model parameters against observational datasets, and greatly improved model predicts to match field inventory data. These newly represented ecological-based processes have helped to improve the representation of these vulnerable forests in an Earth System Model.