Examination of Current and Future Permafrost Dynamics across the North American Taiga-Tundra Ecotone

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In the Arctic, the spatial distribution of boreal forest cover and soil profile transition characterizing the taiga-tundra ecological transition zone (TTE) is experiencing an alarming transformation. The SIBBORK-TTE model provides a unique opportunity to predict the spatiotemporal distribution patterns of vegetation heterogeneity, forest structure change, arctic-boreal forest interactions, and ecosystem transitions with high resolution scaling across broad domains. Within the TTE, evolving climatological and biogeochemical dynamics facilitate moisture signaling and nutrient cycle disruption, i.e. permafrost thaw and nutrient decomposition, thereby catalyzing land cover change and ecosystem instability. To demonstrate these trends, in situ ground measurements for active layer depth were collected to cross-validate below-ground-enhanced modeled simulations from 1996-2017. Shifting trends in permafrost variability (i.e. active layer depth) and seasonality were derived from model results and compared statistically to the in situ data. The SIBBORK-TTE model was then run to project future below-ground conditions utilizing CMIP6 scenarios. Upon visualization and curve-integrated analysis of the simulated freeze-thaw dynamics, the calculated performance metric associated with annual maximum active layer depth rate of change yielded 76.19%. Future climatic conditions indicate an increase in active layer depth and shifting seasonality across the TTE. With this novel approach, spatiotemporal variation of active layer depth provides an opportunity for identifying climate and topographic drivers and forecasting permafrost variability and earth system feedback mechanisms.