21st Century Tundra Shrubification Controlled by Non-Growing Season Plant Nutrient Uptake

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The role of plant photosynthesis in controlling high-latitude tundra carbon stocks is strongly limited by nutrient availability and critical for centennial-scale climate interactions. However, global land model plant representations are uncertain and fared poorly in recent confrontations with high-latitude observations. We show here that tundra plant nutrient acquisition during the non-growing season (NGS), a widely observed process ignored by most large-scale land models, is substantial and affects modeled ecosystem vegetation composition and carbon budgets. We apply a well-tested mechanistic model of coupled plant, microbial, hydrological, and thermal dynamics that explicitly represents nutrient acquisition based on competitor traits. We further test the model against observed NGS plant nutrient uptake in a northern Alaskan tundra site and then demonstrate strong effects of NGS nutrient uptake on plant growth. Applying the model across the North America tundra indicates that NGS nutrient uptake is consistent with observations and ranges between ~5-50% of annual uptake, with large spatial variability and dependence on plant functional type. Finally, we show that NGS plant nutrient acquisition strongly enhances 21st century tundra shrubification rates. Our results highlight the importance of NGS plant and soil processes on high-latitude biogeochemistry and vegetation dynamics and motivates new observations and processes to represent these dynamics.