Linkage between root competitive traits and tundra nitrogen uptake patterns

Abstract

The Arctic tundra carbon dynamics are strongly limited by nitrogen availability, due to slow mineralization, slow nitrogen fixation, and trivial nitrogen deposition. Ongoing climate warming will likely perturb vertical distributions of nitrogen availability in tundra ecosystems through enhancing nitrogen mineralization and releasing frozen nitrogen from permafrost soil. However, arctic tundra responses to such changes are unclear, because of both the lack of vertically explicit nitrogen perturbation field experiments and untested hypotheses of root nitrogen uptake implemented in land models. In contrast to N uptake data in other ecosystems (*e.g.*, grasslands, agro-ecosystems), our vertically explicit ^{15}N tracer experiment (for three dominant tundra species: *Carex aquatilis*, *Eriophorum angustifolium*, and *Salix rotundifolia*) showed that plant nitrogen uptake profiles were not consistently related to profiles of soil available nitrogen or root biomass density. These results challenge both the prevailing hypothesis that root density always exerts first order control on nitrogen uptake and the model structures that apply this hypothesis. Applying a recently developed model of nutrient competition based on the Equilibrium Chemistry Approximation (ECA), we explained the paradoxical observations with: (1) highly competitive but shallow rooting plant species that obtain most of their nitrogen from topsoil under the stress of microbial nutrient competition and (2) poorly competitive species that absorb more nitrogen from deeper mineral soils, where microbial nutrient demand is low. Sensitivity analyses revealed that plant nutrient affinity (a proxy for competitiveness) could surpass the effect of root biomass density and exert a first-order control on nitrogen uptake patterns. Currently applied methods to resolve nutrient competition (*e.g.*, relative demand, microbes outcompete plants) were unable to explain the diversity of observed plant N uptake profiles. Our results (1) cast doubt on current climate-scale model predictions of arctic plant responses to elevated nitrogen supply under changing climate and (2) highlight the importance of considering essential root functional traits in large-scale Earth System Models (ESMs).