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Permafrost thaw and fire history: implications of boreal tree cover changes on land surface properties and turbulent energy fluxes in the Taiga Plains, Canada

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Given their large areal coverage, high carbon densities, and unique land surface properties and disturbance regimes (e.g., wildfires), the world's boreal forests are integral components of the global and regional climate systems. A large portion of boreal forests contain permafrost, i.e. perennially cryotic ground. In the Taiga Plains ecozone in northwestern Canada, the northernmost boreal forests grow on cold (<-1.5 °C) and thick (>100 m) continuous permafrost (>90 % in areal extent). More southerly boreal forests occur in areas with discontinuous (>50 - 90 % in areal extent), sporadic (>10 - 50 % in areal extent) and isolated permafrost (<10 % in areal extent). Using annual MODIS Percent Tree Cover (PTC) data from the MOD44B product in combination with spatial information on fire history, and permafrost and drainage characteristics, we show that in low-lying, poorly-drained areas along the southern fringe of permafrost, thawing induces widespread decreases in PTC and dominates over PTC increases due to post-fire regrowth. In contrast, PTC appears to be slightly increasing in the central and northern Taiga Plains with more stable discontinuous and continuous permafrost, respectively. While these increases are partly explained by post-fire regrowth, more favourable growing conditions may also contribute to increasing PTC. To better understand the implications of permafrost thaw on land surface properties (e.g., aerodynamic conductance for heat [ga] and surface conductance for water vapour [gs]), and the turbulent fluxes of latent (LE) and sensible heat (H) along the southern fringe of permafrost, we examined nested eddy covariance flux measurements made at two nearby locations at Scotty Creek (61º18' N; 121º18' W) starting May 2013. The low-lying, poorly-drained southern portion of this 152 km2-watershed contains rapidly thawing sporadic permafrost resulting in a highly dynamic mosaic dominated by decreasing forested permafrost peat plateaus, and increasing permafrost-free wetlands. The spatial heterogeneities within the eddy covariance flux footprints (forest/wetland vs. wetland) were resolved with a two-dimensional footprint model parameterized with various remote sensing data sets. Our results suggest that an increasing coverage of wetlands at the expense of forests reduces ga and thus the efficiency of the land surface to transfer heat to the atmosphere. At the same time gs is increased and thus more moisture is lost to the atmosphere from saturated wetland surfaces. The alteration of bulk transfer land surface properties lead to drastic decreases in Bowen ratios by reducing H and increasing LE with increasing coverage of wetlands. The most pronounced contrasts between forests and wetlands are observed in H during the late snow cover period in April. We used a similar set of eddy covariance flux measurements made concurrently at Havikpak Creek (68º19' N; 133º31' W) and Trail Valley Creek (68º44' N; 133º26' W), a boreal forest and a nearby tundra site in the boreal-tundra ecotone, respectively, as a first-order proxy for potentially increasing PTC under more stable permafrost conditions in contrast to Scotty Creek. Preliminary results indicate trends in ga, gs, H and LE opposite to those observed at Scotty Creek between forests and wetlands. Our study demonstrates diverging implications of boreal tree cover changes on land surface properties and turbulent energy fluxes, thus on regional climate system feedback directions and strengths, as a function of permafrost conditions and fire history.