Spatial controls on boreal tree and soil carbon fluxes across a permafrost transition
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Motivation. Climate change is occurring relatively quickly at high latitudes, and understanding how ecosystem carbon fluxes will change is critically important for making predictions about the C cycle on local, regional, and global scales. In particular, as discontinuous permafrost shrinks and deepens, small-scale changes in soil hydrology, temperature, and microbial biota will feed back onto both tree net primary production (NPP) and soil respiration, the soil-to-atmosphere CO2 flux (Rso).

Methods. We used a suite of spatially explicit measurements across replicated transects spanning a permafrost (none to shallow) and species (paper birch to black spruce) gradient in the CPCRW (see box) research watershed in interior Alaska. Tree cores were used to reconstruct stand history and compute present-day tree NPP; Rs, temperature, and active layer depth (ALD) were measured on a fine spatial grid; and soil physical and biological properties were sampled across the study area.

Figure 1. Detrended tree ring chronology. Ring-width data from 1250 black spruce, white spruce, and paper birch cores. Shaded error bars, derived from k-10 fold random subsampling; show standard deviation (dark) and min/max (light). Point size indicates number of contributing cores.

Preliminary Results. The tree ring record revealed alternating periods of high and low growth, but fairly stable growth across the past two decades (Figure 1). NPP computed from the last 5 years’ growth and tree inventories showed strong spatial gradients across the transects, with low (<100 g C m⁻² yr⁻¹) production dominated by black spruce in the lowland areas, rising abruptly to 300-400 g C m⁻² yr⁻¹ with changes in ALD and species (Figures 2 and 3). Soil respiration fluxes showed stronger fine-scale spatial correlations in autumn (Figure 4) than in midsummer (not shown).

Next steps. We will couple microbial ecological theory to horizontally resolved CO2, NPP, ALD, and vegetation data as well as the 3D-resolved nutrient/moisture/soil structure data to evaluate linkages between the ecology of microbial communities and ecosystem processes/features.

Figure 2. NPP across the transects by tree species (2, below), and relative to active layer depth (3, right). Species include Alnus spp., Salix spp., Betula papyrifera (BPEA), Larix laricina (LALA), and Picea mariana (PIMA). Line in Figure 3 is a smoothed loess fit.

Figure 3. NPP (2, above) and active layer depth (3, right).

Figure 4. Spatial dependency of Rs fluxes. Data shown are from September 2014, measured on a cyclically repeating grid (far right, with shading indicating changes in dominant tree species) that maximizes sampling efficiency.

Experimental variogram and fitted variogram model

Caribou-Poker Creeks Research Watershed and study design

CPCRW is a Long Term Ecological Research watershed in the Yukon-Tanana Uplands northeast of Fairbanks, Alaska, centered on 65°13’N 147°12’W at 200-800 m a.s.l. Mean annual air temperature in the 10° basin is ~1°C. Soils are silt loams, with discontinuous to continuous permafrost. CPCRW is dominated by black spruce (Picea mariana) and white spruce (Picea glauca) spruce, paper birch (Betula papyrifera), and willow (Salix spp.); ground cover include Phacelia versicolor and Salix spp. The goal of this project was to examine how soil variability at fine spatial scales is linked with changes in above- and belowground carbon cycling. In particular NPP and Rs.

We established 4x6 east-west transects spanning a permafrost gradient, with the E end of each 75 m transect in continuous, valley-floor permafrost, and the W end upslope with no permafrost within 350 cm. In 2014 active layer depth (ALD), tree NPP, Rs, as well as soil thermal, structural, and biological properties were measured.