Variability in Canopy Transpiration with Atmospheric Drivers and Permafrost Thaw Depth in an Arctic Siberian Larch Forest

Michael M. Loranty1, Logan T. Berner2, Heather D. Alexander3, and Sergei P. Davydov4

1Department of Geography, Colgate University; 2Department of Forest Ecosystems and Society, Oregon State University; 3Department of Biological Science, University of Texas at Brownsville; 4North-East Scientific Station, Pacific Institute for Geography, Russian Academy of Sciences

Background

• Satellite data indicate increasing terrestrial ecosystem productivity in Arctic tundra, while boreal forests exhibit both increases and declines in productivity. It is hypothesized that hydrologic stress is responsible for declines in productivity. In the absence of hydrologic stress longer and warmer growing seasons result in increased productivity.
• A large proportion of the boreal biome is located in Siberia, and is underlain by continuous permafrost. Permafrost exerts strong control on groundwater dynamics; deep thaw can make ground water inaccessible to plants while shallow water can saturate soils (Iijima et al, 2013).

How does high latitude boreal forest transpiration respond to changing atmospheric and permafrost conditions?

Study Site & Methods

• The study was conducted in a mature, late-successional low-density boreal forest in northeastern Siberia (Figure 1-2). Mean January and June temperatures are -33°C and 12°C respectively. The area is underlain by continuous permafrost. Cajander larch (Larix cajanderi) is the only tree species in the region.
• We instrumented 9 trees with thermal dissipation sap-flux sensors from July 3 – August 14, 2014. Concurrent measurements of Vapor Pressure Deficit (D), Photosynthetically Active Radiation (PAR), and air temperature (T) were made at the site (Figure 3).
• Permafrost thaw depth was measured 1m from the base of each instrumented tree in each of the four cardinal directions on July 3 and 23. Additional stand level measurements characterized the permafrost conditions more generally (Figure 4).

Sap Flow Calculations

• The following calculations were performed on half-hourly data for each tree from three days in July and August (Figure 3). Results shown are mean values for all 9 trees.
• Sap flow velocity per unit sapwood area (Iv) was multiplied by the ratio of sapwood area (A) to leaf area (A) to determine transpiration per unit leaf area (E; Eq. 1).
• E was used in conjunction with D, T, the universal gas constant adjusted for water vapor (Gw), and the density of water (g) to calculate mean stomatal conductance to water vapor (G, Eq. 2).
• Finally, Gw was divided into 0.1 kPa bins of D and a boundary line was fit to the maximum value in each bin to calculate reference stomatal conductance at D=1kPa (Gref; Eq.3).

Results

• Diurnal patterns of VPD, PAR, and T at the study site for three days in early July (left) and August (right).
• Diurnal patterns of sap flux at the study site for three days in early July (left) and August (right). Data are averages for all trees (n=9) and whiskers represent standard error of the mean.

Discussion

• Why is canopy transpiration suppressed in July?
• Fine root development inhibited by shallow permafrost thaw depth?
• Partially developed canopy (e.g. not full leaf area)?
• Partially developed physiological (e.g. photosynthetic) capacity?

• Several other studies indicate the permafrost thaw depth inhibits root development which suppresses canopy processes (Dolman et al 2004; Iijima et al 2014).
• Remote sensing and model based estimates of evapotranspiration and photosynthesis that fail to account for permafrost dynamics may be inaccurate.

Literature Cited


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