B41E-0112

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

Michael M. Loranty[1], Logan T. Berner[2], Heather D. Alexander[3], and Sergei P. Davydov[4]

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

Colgate UNIVERSITY

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?

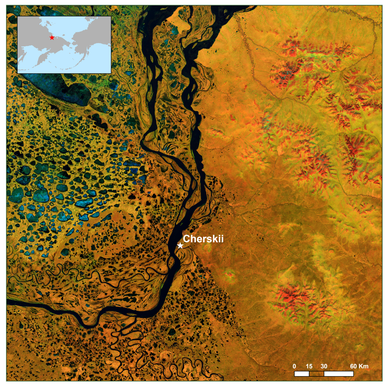

Figure 1. Map of the study region in northeastern Siberia. Landsat8 bands 4,5,6. Base image composed by G. Fiske

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 cjanderi*) 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).

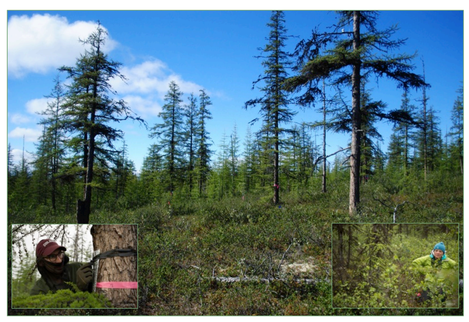

Figure 2. Boreal larch forest instrumented for sap flux in this study.

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 (J_S) was multiplied by the ratio of sapwood area (A_S) to leaf area (A_L) to determine transpiration per unit leaf area (E_L; Eq. 1).

•E_L was used in conjunction with D, T, the universal gas constant adjusted for water vapor (G_V), and the density of water (ρ) to calculate mean canopy stomatal conductance to water vapor (G_S; Eq. 2).

•Finally, G_S 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 (G_{sref}; Eq3).

Eq. 1 $$E_L = J_S A_S / A_L$$

Eq. 2 $$G_S = (G_V T \rho E_L) / D$$

Eq. 3 $$G_S = G_{Sref} - m \ln D$$

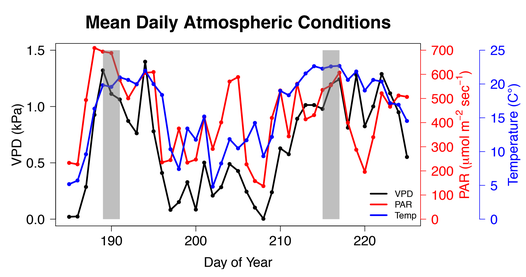

Figure 3. Mean daily VPD, PAR, and air temperature for the study site. Gray shaded areas indicate days used for analysis in this study.

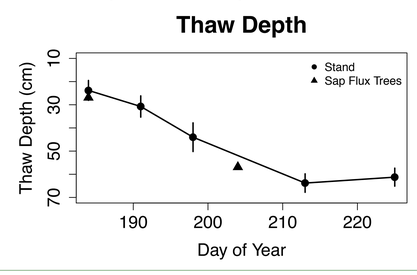

Figure 4. Means and standard errors for permafrost thaw depth during the study.

Results

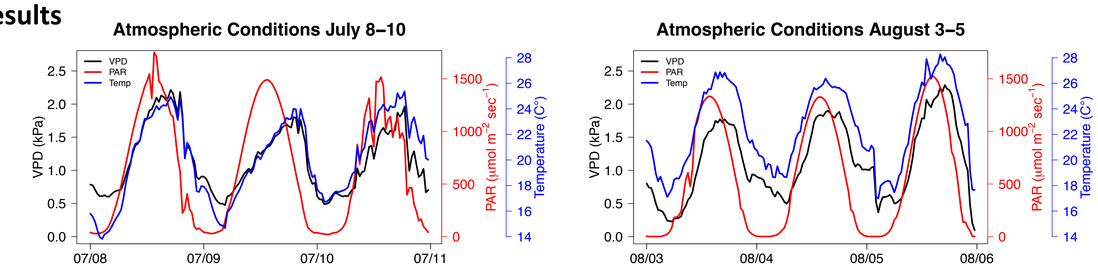

Figure 5. Diurnal patterns of VPD, PAR, and T at the study site for three days in early July (left) and August (right).

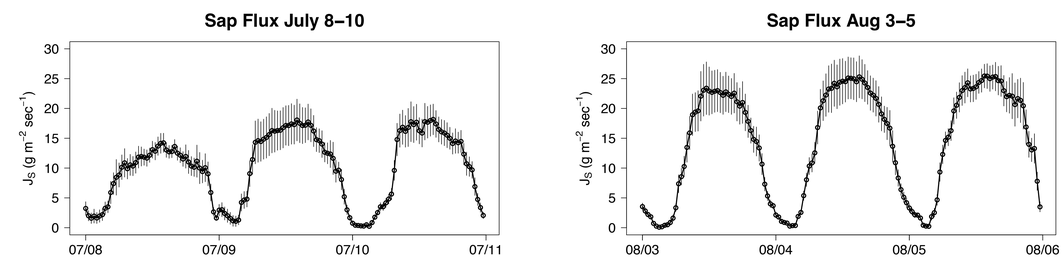

Figure 6. Diurnal patterns of sap flux at the study site for three days in early July (left) and August (right). Data are averages for all trees (n=9) and whiskers represent standard error of the mean.

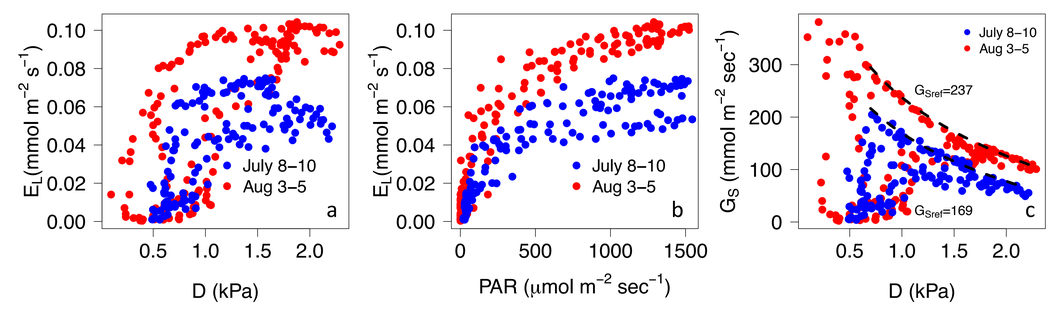

Figure 7. Response of E_L to (a) D and (b) PAR, and (c) G_S to D for three days in early July and August. Each point is a half-hourly mean (n=9) of E_L or G_S calculated using Eq1, and Eq2-3, respectively.

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 etal 2014).

•Remote sensing and model based estimates of evapotranspiration and photosynthesis that fail to account for permafrost dynamics may be inaccurate.

Literature Cited

Iijima, Y., Ohta, T., Kotani, A., Fedorov, A. N., Kodama, Y., & Maximov, T. C. (2014). Sap flow changes in relation to permafrost degradation under increasing precipitation in an eastern Siberian larch forest. *Ecohydrology*, *7*(2), 177-187.

Acknowledgments: This work was supported by funding from NSF 1044610,1304644, The Polaris Project, and Colgate University. We also thank personnel at the Northeast Science Station in Cherskii and Seth Spawn for field assistance, Greg Fiske for providing satellite data, and Chris Linder for photographs.