Gauging leaf-level contributions to landscape-level water loss within a Western US dryland forest

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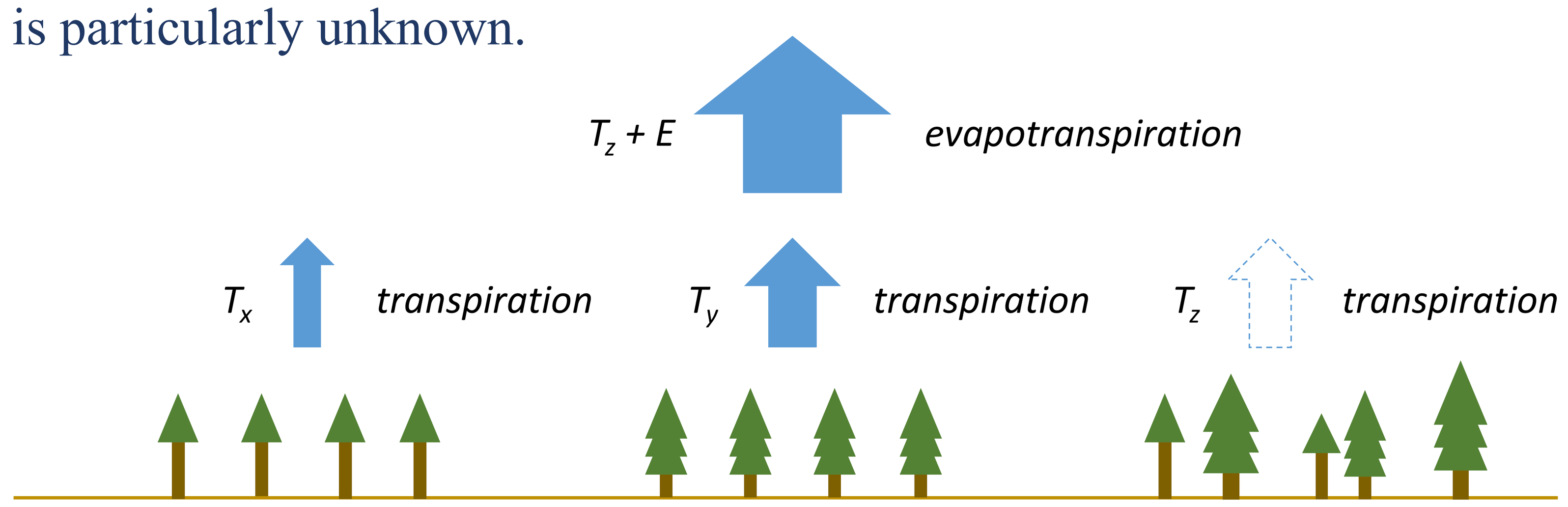
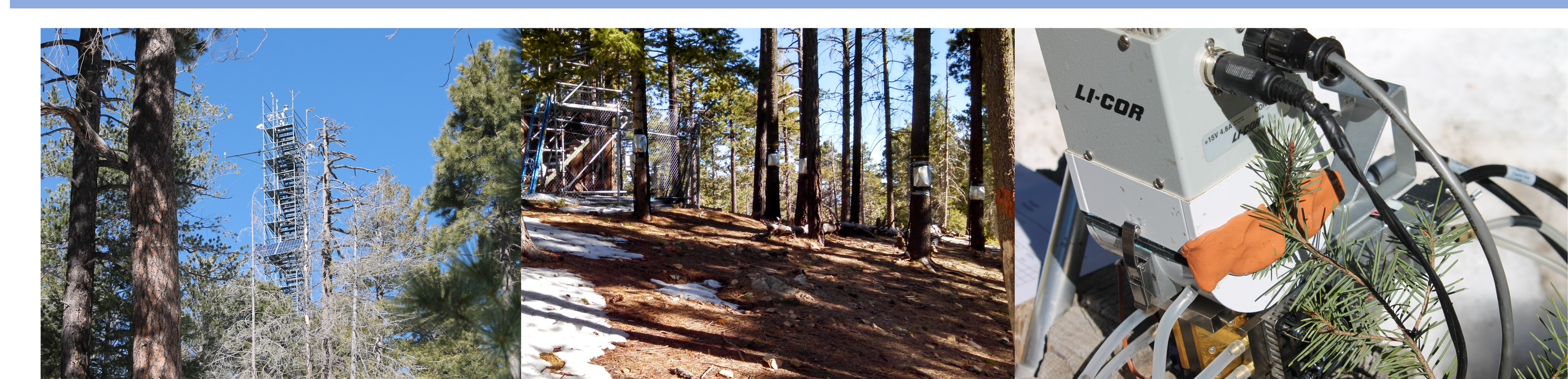
Introduction and Questions

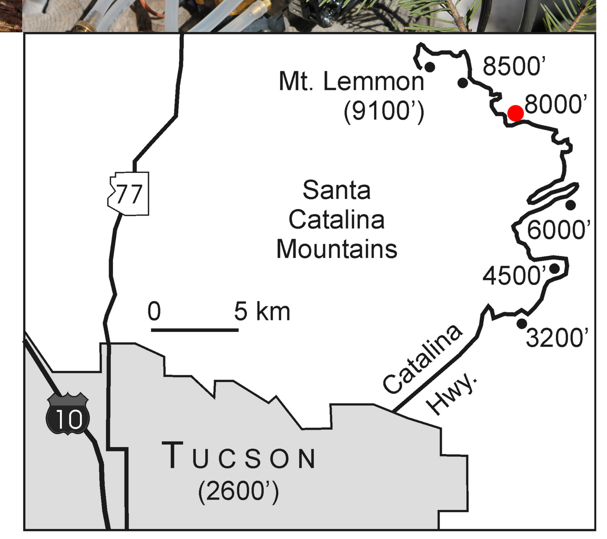
Dryland forests remain an understudied ecosystem in terms of water cycling. One unresolved problem in these systems is understanding the controls on transpiration (T) and its relationship to total ecosystem evapotranspiration (ET). T based on species composition of a landscape is particularly unknown.



- **What is the relative contribution of transpiration to total ecosystem evapotranspiration (*z* in relation to *E*)?**
- **What meteorological variables control transpiration (and when)?**
- **To what extent is transpiration controlled by the mix of conifer species that compose this landscape – what relationship do T_x and T_y have to T_z – at the needle- and tree-scale?**

Methods





Top left: an eddy covariance tower situated 15m above the canopy measured water vapor flux across the landscape, along with associated micrometeorological variables.
Top middle: sap flow measurements for three species within the footprint of the EC tower.
Top right: leaf level transpiration measurements for three species sampled at the site.
Far right: the study site (red) situated in the Santa Catalina Mountains, north of Tucson AZ.

- Data collected in 2015 and 2016 at the Mt. Bigelow CZO site (2550m elevation), the primary species found here are *P. menziesii, P. ponderosa,* and *P. strobiformis.*
- Latent energy flux from the tower was used as a measurement of ET.
- Trees within the footprint of the tower provided total tree sap flow, giving a measurement of tree-level T.
- Time series data are presented as a 5-day moving average.
- Needle-level measurements of T were also collected during 4 distinct periods in 2016 (spring, summer (dry), summer (monsoon), fall) using a Li-Cor 6400 XT.
- Data processed with R 3.4.2.

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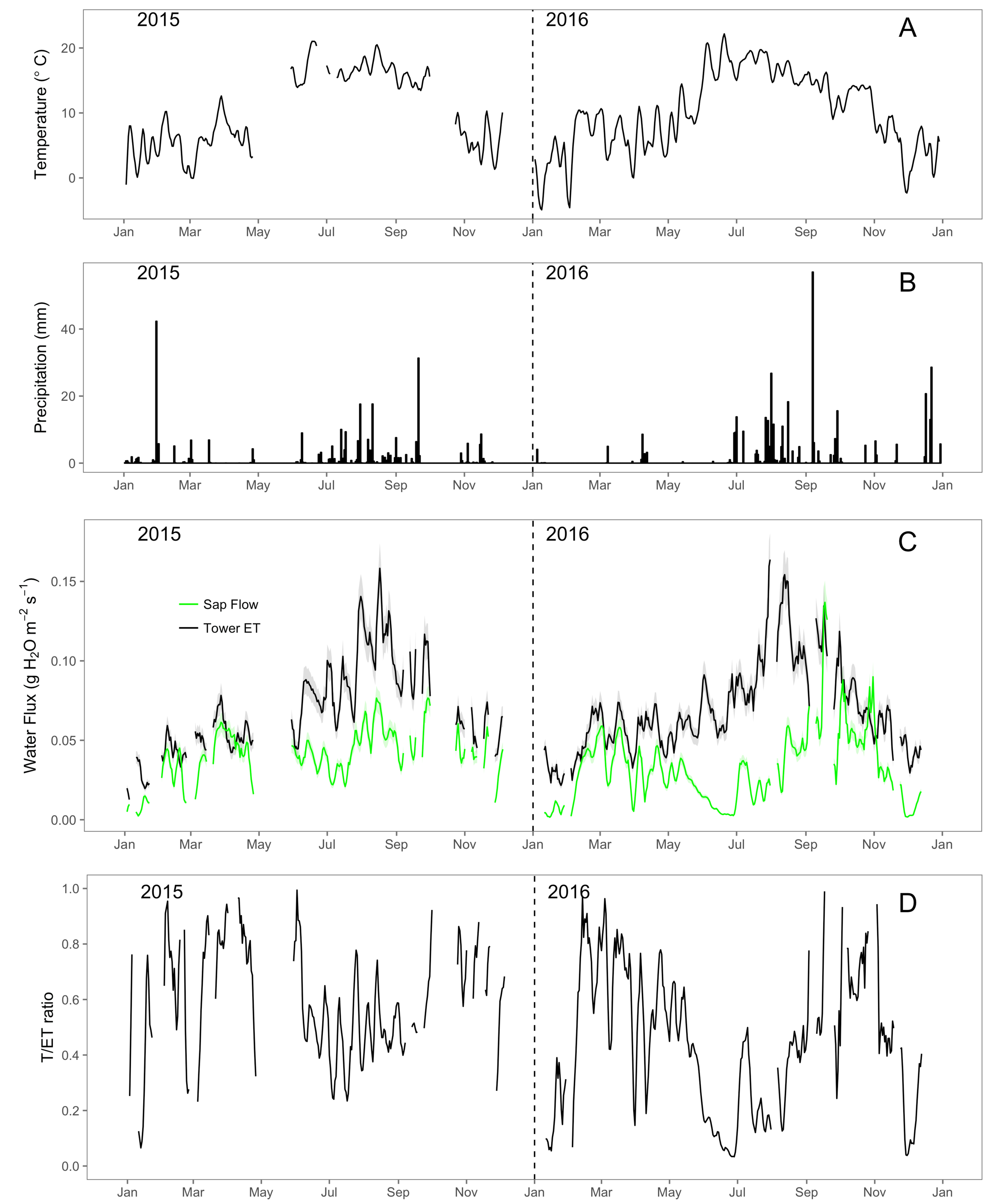
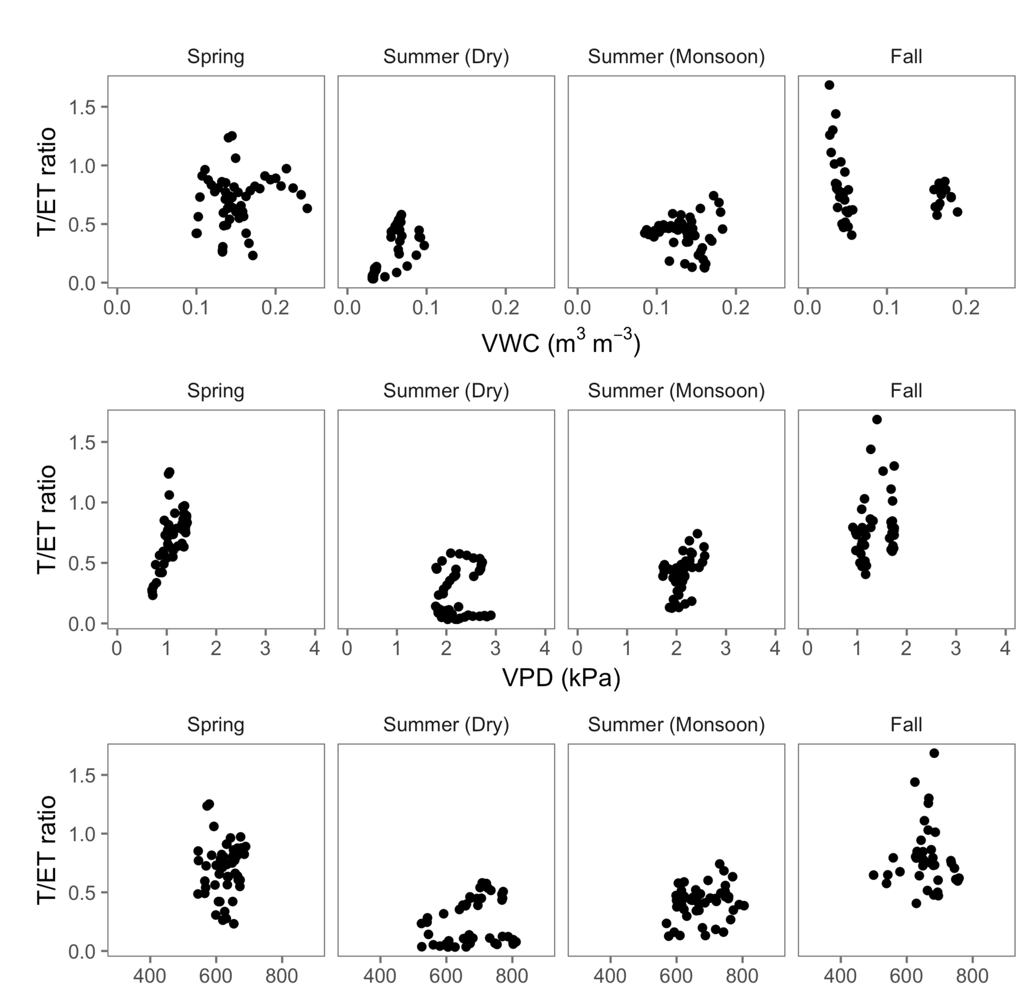
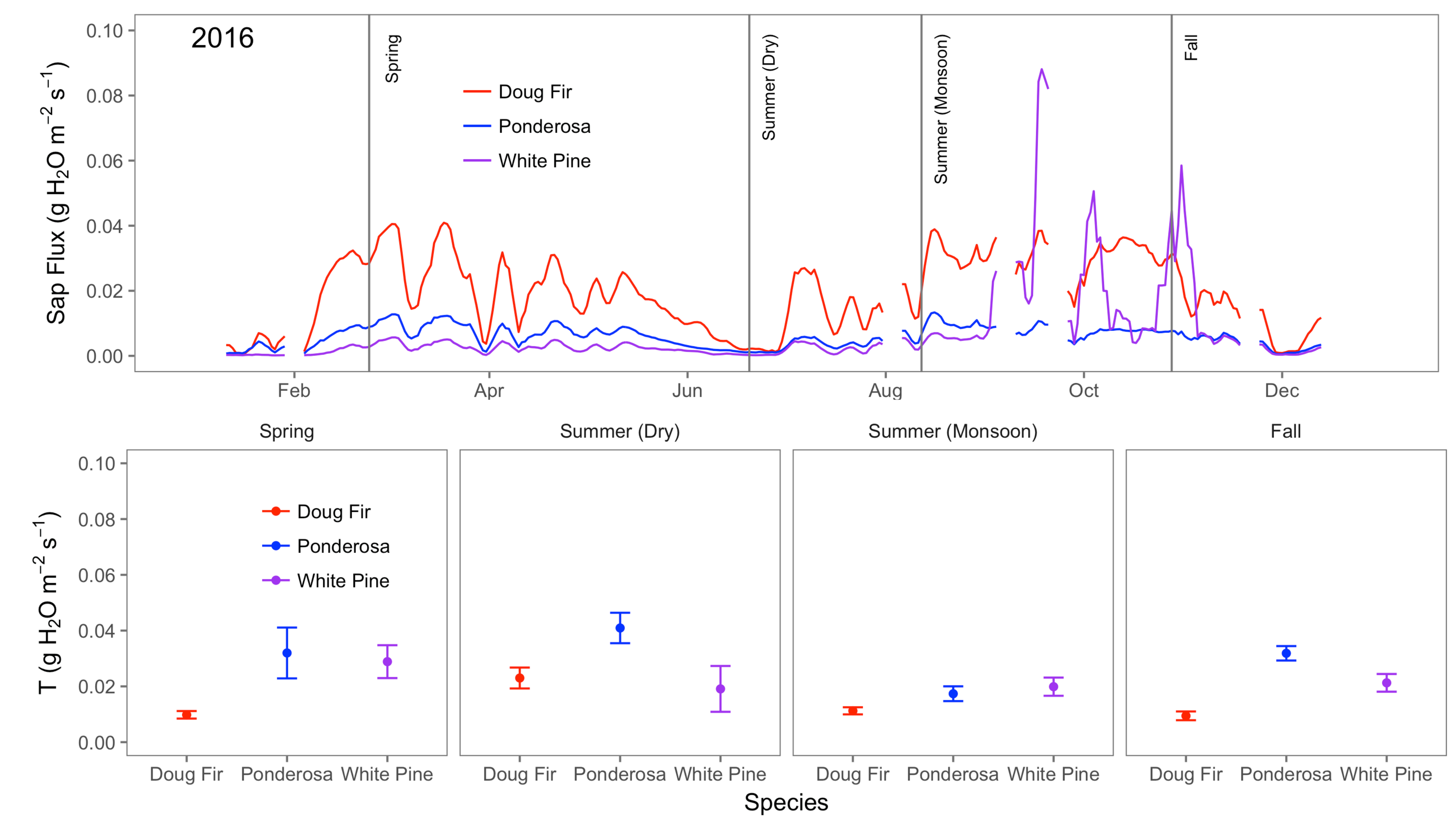
Results



A: Air temperature above the canopy for the two study years.
B: Precipitation below the canopy for the two study years.
C: Water flux as evapotranspiration (ET; EC tower data) and as transpiration (T; sap flow data) adjusted to the same units. Uncertainty (shading) is ±10% for both variables.
D: ratio of transpiration at the tree-scale to total evapotranspiration at the landscape-scale.



Regressions between the T/ET ratio and volumetric water content **(top)**, vapor pressure deficit **(middle)**, and incoming solar radiation **(bottom)**. A strong relationship is seen between T/ET and VWC in the dry summer, when water availability is low. However, the relationship to VPD is stronger in spring and fall when temperatures at this high elevation are lower and moisture availability is higher. Despite expectations that energy limitations would exist in spring or fall, weak relationships exist between the T/ET ratio and insolation.



Top: Sap flux redrawn for 2016 only, shown as relative contribution to landscape-scale transpiration for each species based on species density (sapwood area index).
Bottom: Needle-level transpiration from cuvette measurements during 4 periods in 2016. These data are corrected by leaf area, so magnitudes do not necessarily align to the time series. Dates the measurements were taken are shown by vertical lines on the time series plot.

Conclusions

What is the relative contribution of transpiration to total ecosystem evapotranspiration?

- Needle- and tree-scale T corresponded well to the magnitude of ET measured by the EC tower in 2016.
- Ratio of T/ET (46% average) aligned closely to previous literature.
- Differences in water loss rates at the needle- and tree-scale explained by species composition.

What meteorological variables control transpiration throughout the year?

- Both VPD and VWC stood out as having strong relationships with transpiration at the site (depending on season).

To what extent is transpiration controlled by the variety of conifer species that dominate this landscape?

- The species effect on T at the landscape scale is statistically significant depending on season (Fall: *F:19.6, p<0.001*).
- Ponderosa Pine at the needle-scale generally released water at a higher rate, but it only represented 32% of the species composition.
- Douglas Fir, at 57% of the stand, dominated landscape-level water flux, but maintained relatively low water release per needle area.

- The makeup of species across the landscape has a strong influence on the ratio of T to ET and the total magnitude of ET.
- Needle-level measurements of T adds valuable perspective on the magnitude of T measured via more common methods.
- Assessing the ratio of T to ET requires consideration of data from a variety of scales, from soil collars and leaf cuvettes (cm^2), to individual trees (m^2), to complex landscapes (km^2).