Understanding the response of transpiration to variability in solar radiation and vapor pressure deficit in a pre-montane transitional forest

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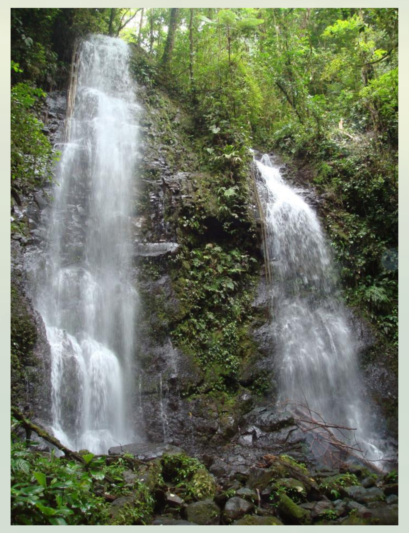
Introduction & Objective

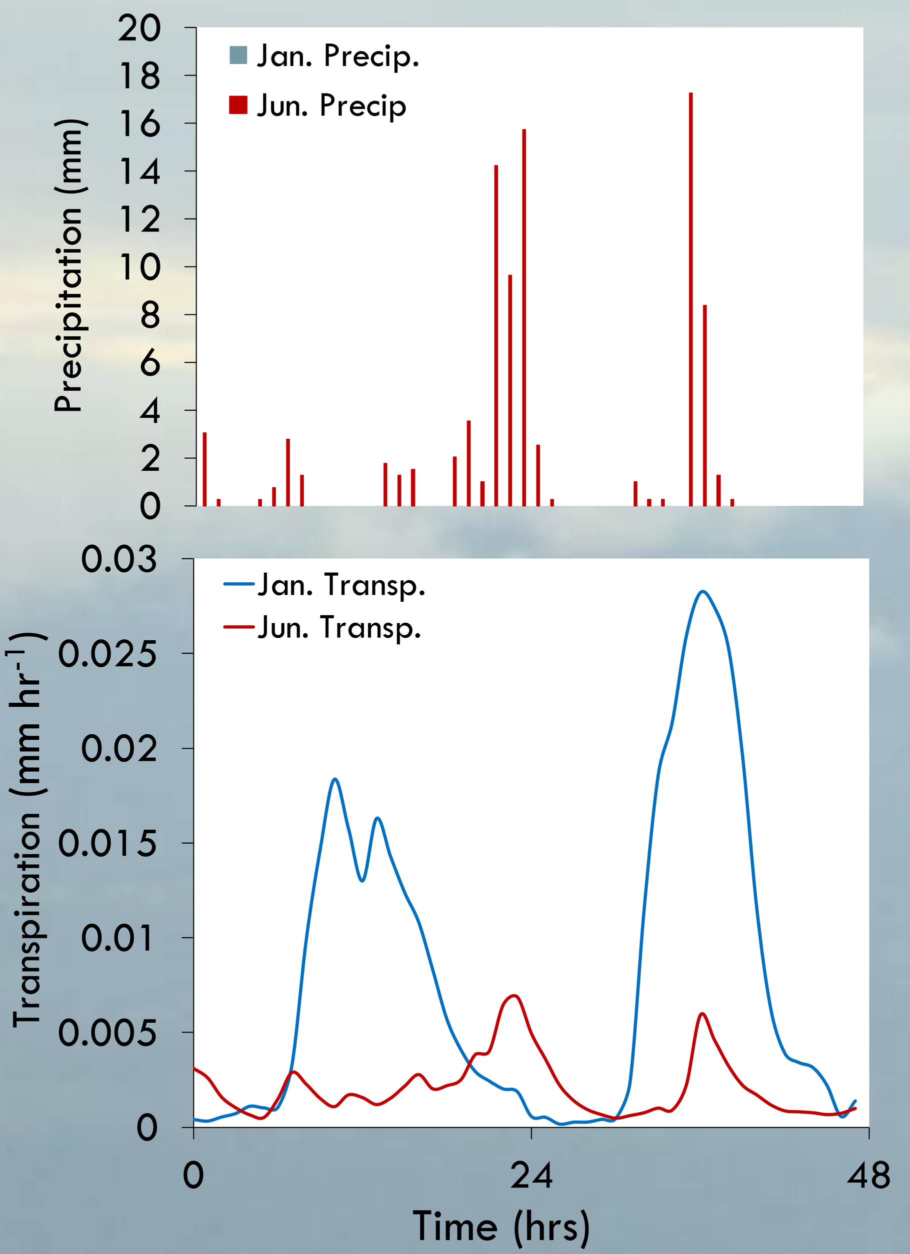
Physiological responses of pre-montane transitional forests to climate variability are not well understood. Solar radiation (I_s) and vapor pressure deficit (***D***) are primary drivers of transpiration in various ecosystems and typically used in models. And yet other factors such as soil water availability limit the success of simple climate-based models of transpiration. This study focuses on how transpiration responds to alterations in ***D*** and I_s. With a high annual rainfall, it was hypothesized that pre-montane transitional forests would not be limited by water availability except in isolated periods of the dry season. Instead ***D*** and I_s may best predict daily transpiration. These physiological responses to climatic variation are important in understanding terrestrial systems' contributions to local water budgets. Long-term monitoring of these closely-coupled processes will aid in further understanding long-term water balances (McJannet, Fitch et al. 2007) of tropical forests.



Methods

The study site is a pre-montane transitional forest located at the 96-ha Texas A&M University Soltis Center located in North Central San Ramón, Costa Rica. The center receives ~4500 mm of rainfall per year, and the site is comprised of primary and secondary forest due to selective logging. A 30-m diameter plot was established for monitoring transpiration within a 10-ha sub-watershed using 20mm heat dissipation sap flow sensors (Granier 1987). The study plot was primarily composed of secondary forest. 15 trees were selected for sap flow monitoring and categorized into 5 groups accoriding to sapwood area per unit ground area. Two probes were placed, one on top of the other, approximately 10 cm apart. The top probe was heated by a constant voltage. Temperature differences were recorded by a copper-constantan thermocouple placed in the center of the heating coil. The lower probe was unheated in order to serve as the reference probe (**Figure 4**). Measurements were taken every 30-s and recorded every 10-min. Climate data was measured every 5-min at a weather station near the study site. Sap velocities were calculated using MATLAB and simple linear regression and mixed effects models were used for data analysis.

Figure 1. *Transpiration can be quick to respond to precipitation events. Comparison of two 48-hr time periods (Jan. 25-26 & Jun. 12-13) show the variability in transpiration due to total rainfall during a dry period (Jan=0mm) and wet period (Jun=91mm).*



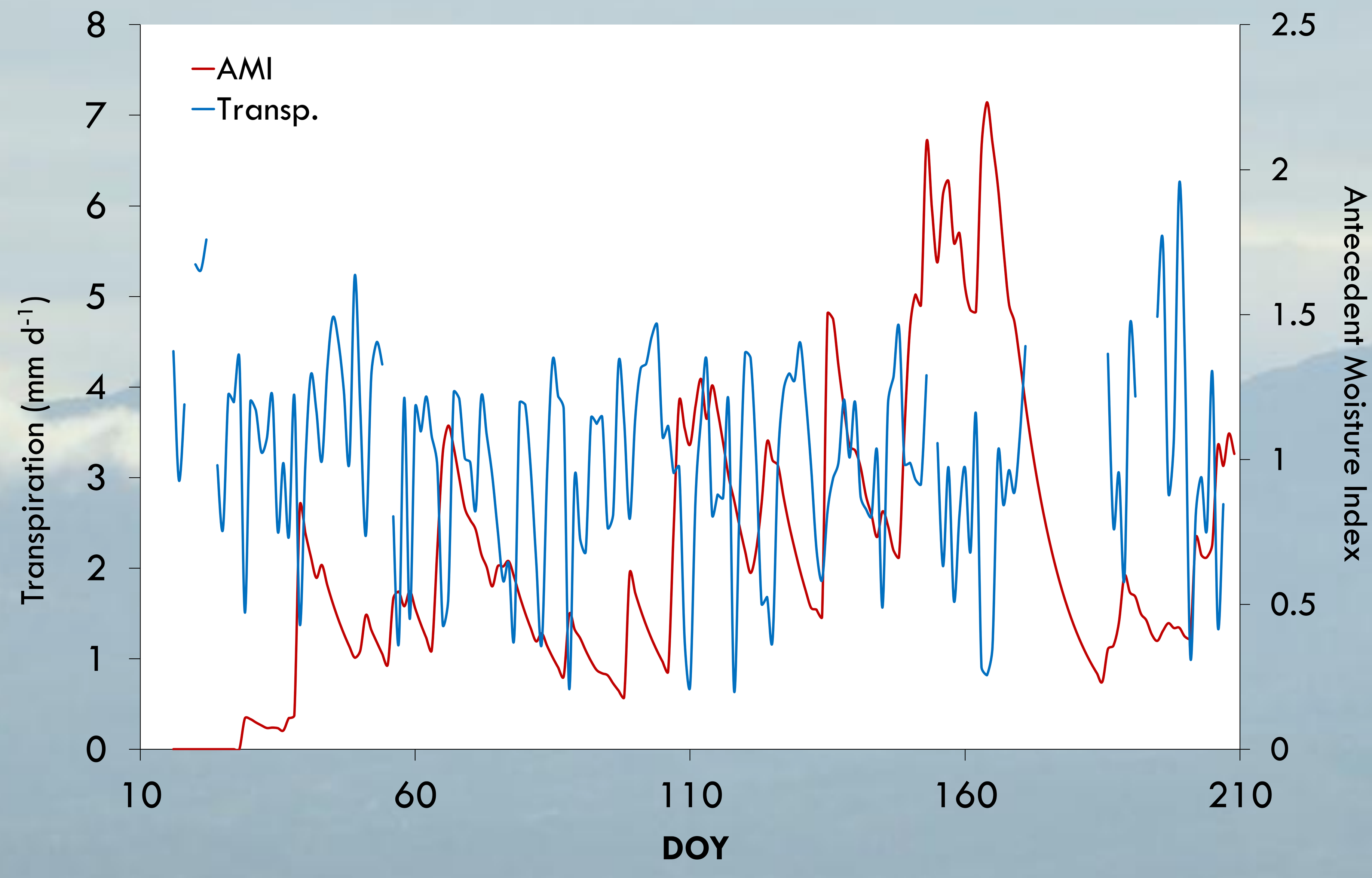


Figure 2. *Antecedent moisture index (AMI) indicates relative wetness of the soil based on preceding moisture conditions (rainfall). Long-term transpiration varies daily without any evident upward or downward trend with respect to the AMI profile from DOY 16-207. Gaps in transpiration data were a result of sensor installation/replacement and/or data logger configurations.*

Figure 3. *Daily stand transpiration in relation to solar radiation (I_s) and vapor pressure deficit (D) over the six month study period.*

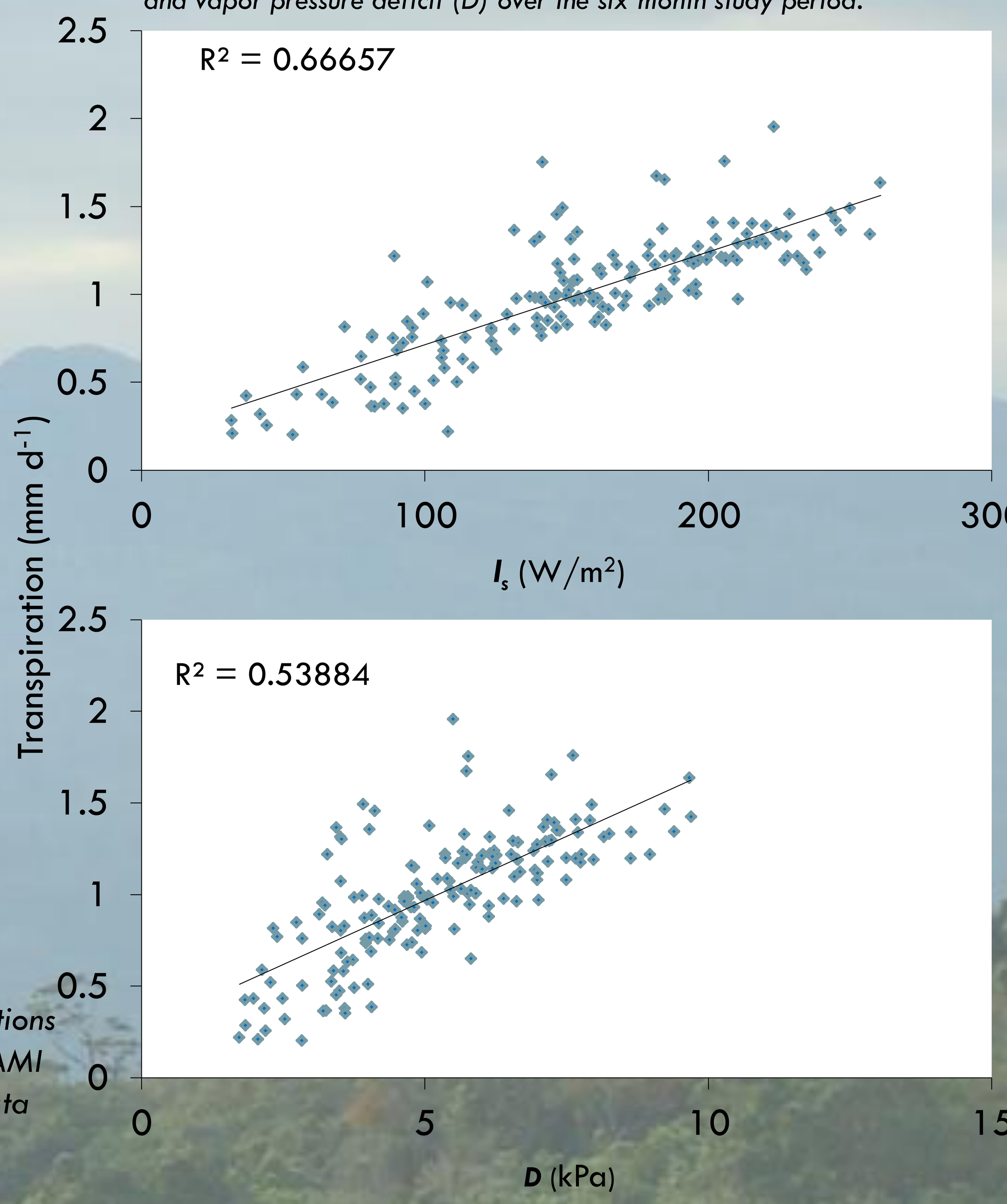
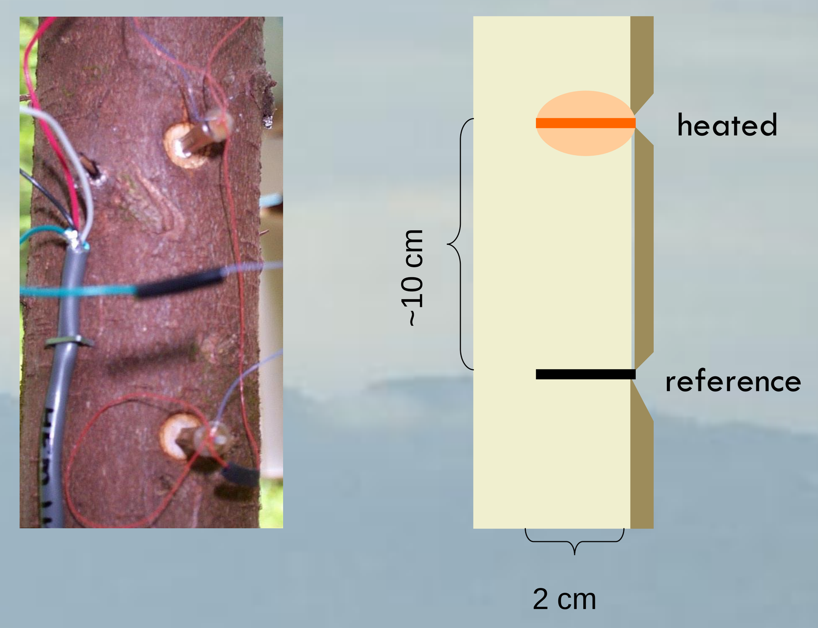


Figure 4. *Sap flow sensor diagram and explanation of Granier equation.*



At night, sap flow is assumed to be zero. This yields our max ΔT. *During the day, as water travels up the stem, temperature (ΔT) varies with flow rate.*

Granier Equation

Sap Flux velocity (v)

$$V = 0.119\left(\frac{\Delta T_{max} - \Delta T}{\Delta T}\right)^{1.231}$$

Results & Discussion

Transpiration can vary widely on a daily or monthly scale depending on climatic conditions. Typically forests exhibit a seasonal increase in transpiration, but our study site did not (**Figure 2**). Average stand transpiration was 0.999 mm d^{-1} ($\pm$0.340) over the six month study period with a cumulative rainfall of 1406 mm. Daily stand transpiration depended significantly on variations in *D* (r^2=0.54, $p<0.05$) and I_s (r^2=0.67, $p<0.01$) over the six month period with slight variability between individual trees (**Figure 3**). Coupling of *D* and I_s to transpiration was expected but with a lower degree of significance. Precipitation affected transpiration on an hourly basis (**Figure 1**); however, long-term transpiration was decoupled from rainfall events ($p>0.05$) indicating water is likely non-limiting. Instead the system may be light or "demand" limited due to no evidence of transpiration leveling off when *D* or I_s is high.

Conclusion

The results of this study illustrate the trees' physiological independence from rainfall over a six month period. Precipitation only significantly affects transpiration on an hourly time scale. Daily transpiration totals are minimal in this wet environment in comparison to dry environments that are frequently water-limited. Since water is non-limiting, trees in this system have no need for water adaptations. Transpiration is mainly a function of energy inputs and atmospheric water demand. These co-dependent processes are important in predicting the contributions of transpiration to the water budget. With predictions of global change, further quantification of climate-driven transpiration will become increasingly important in understanding site level ecohydrology.

References

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