Adapting Granier's sap flux probes for urban ash trees

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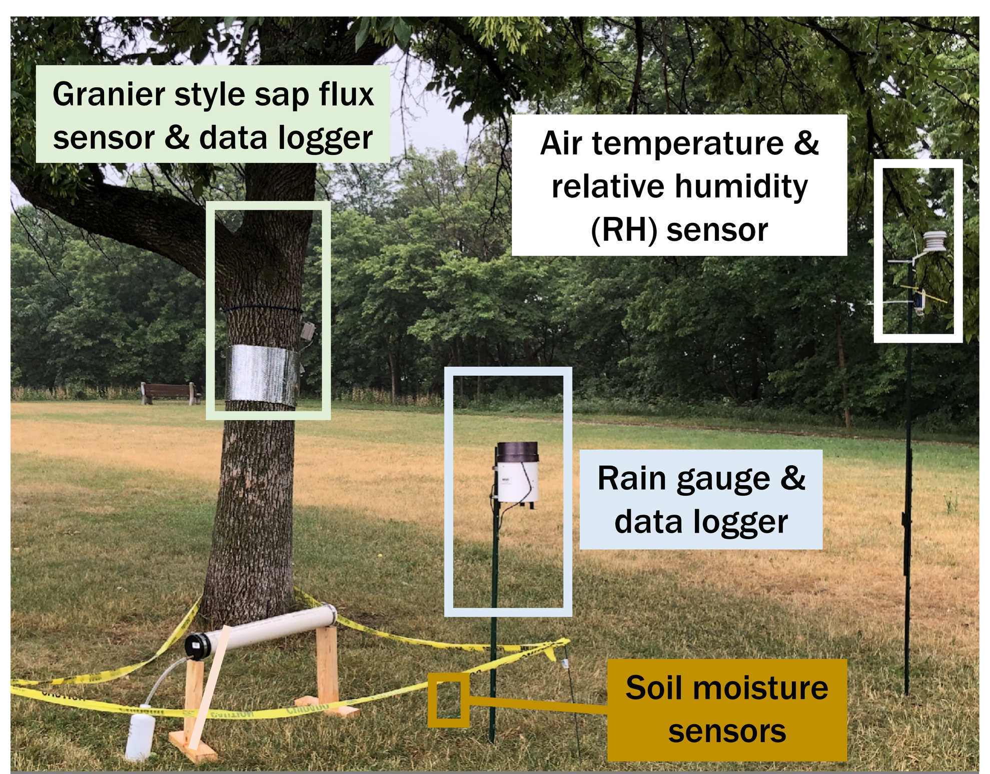
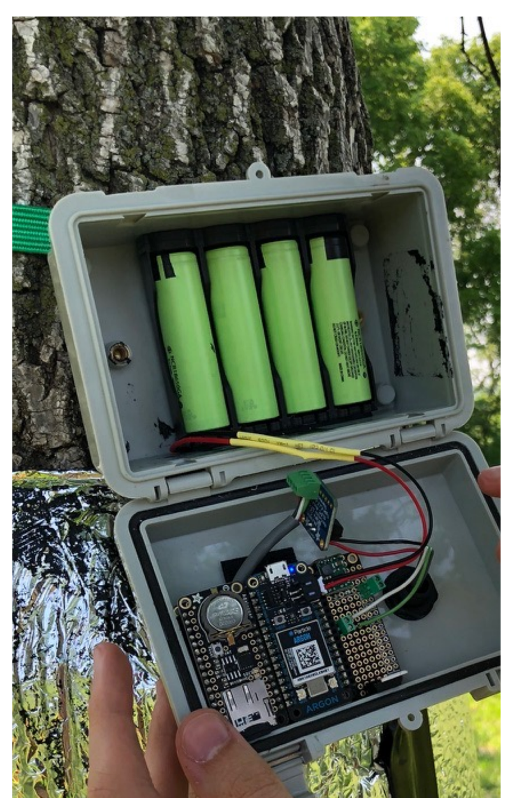
We want to quantify urban canopy's transpiration rates

Tree transpiration **reduces urban air temperature, but by how much?** With sap flux, soil moisture and air temperature and relative humidity measurement, we study how urban trees control the water and heat dynamics. Specifically, we are studying 18 ash trees in four urban parks in the City of St. Paul, MN, USA, using **the Granier style sap flux sensors adapted for urban research**.

To do so, we designed decentralized sensing systems

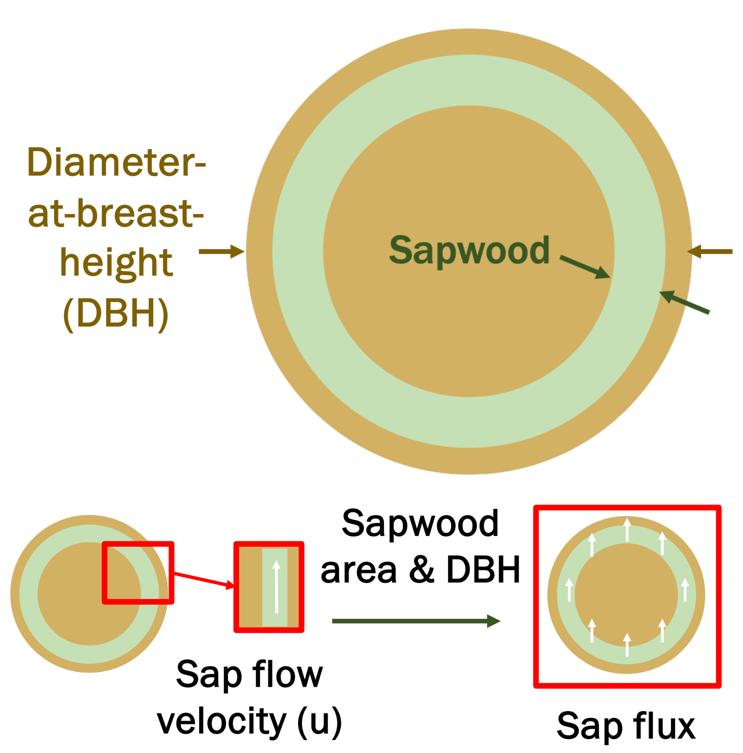


Paired, under-canopy and and open-air sensors are installed for air temperature & RH measurements.



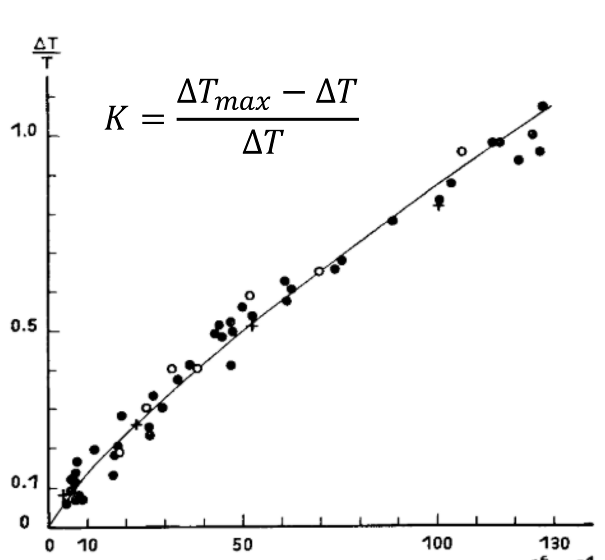
Datalogger design

What is transpiration and how is it measured with Granier style sensors?



Sap flows through the conductive vessels in trees, and acts as a proxy for transpiration and water uptake.

Sap flux sensors are developed and used for measuring the sap flow velocity (u) at a given part of the wood tissue. Then, with known tree diameter and sapwood width, we can calculate the sap flux of the trees.

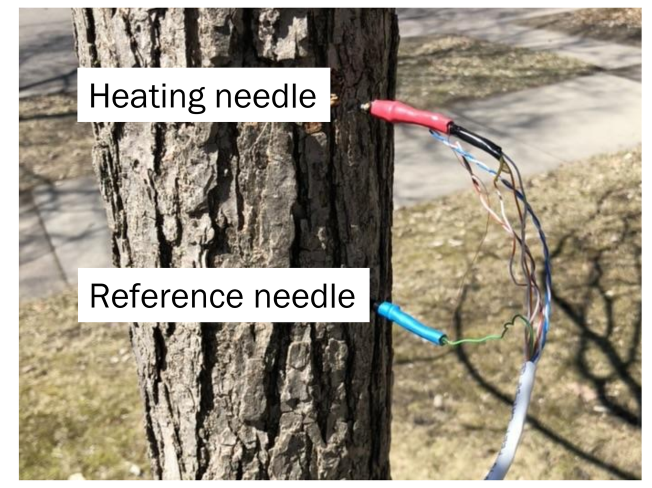


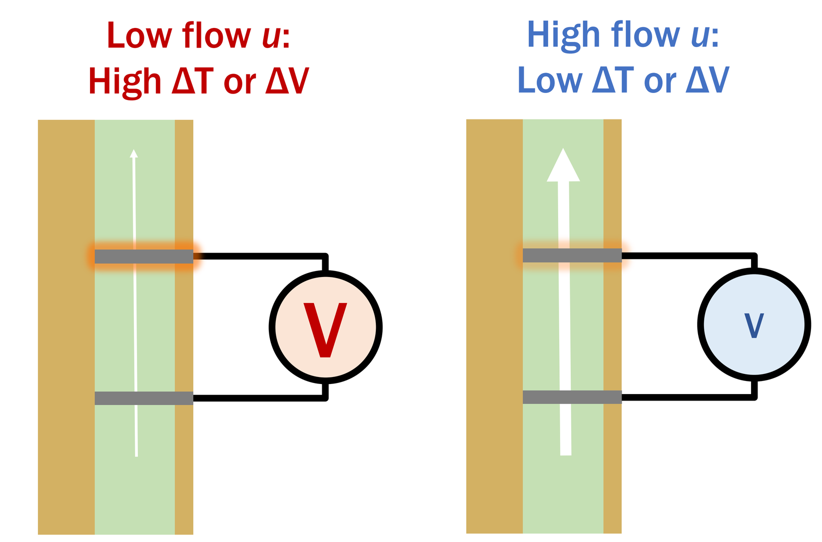
Granier (1985) showed that the relationship is assumed to be the same regardless of tree species.

Reference: GRANIER, A. (1985). Une nouvelle méthode pour la mesure du flux de sève brute dans le tronc des arbres. *Annales des sciences forestières*, 42(2), 193–200.

$$u = \left[\frac{1}{\alpha}\frac{\Delta T_{max} - \Delta T}{\Delta T}\right]^{1/\beta} = \left(\frac{1}{\alpha}K\right)^{1/\beta}$$

How do Granier style sap flux sensors work?





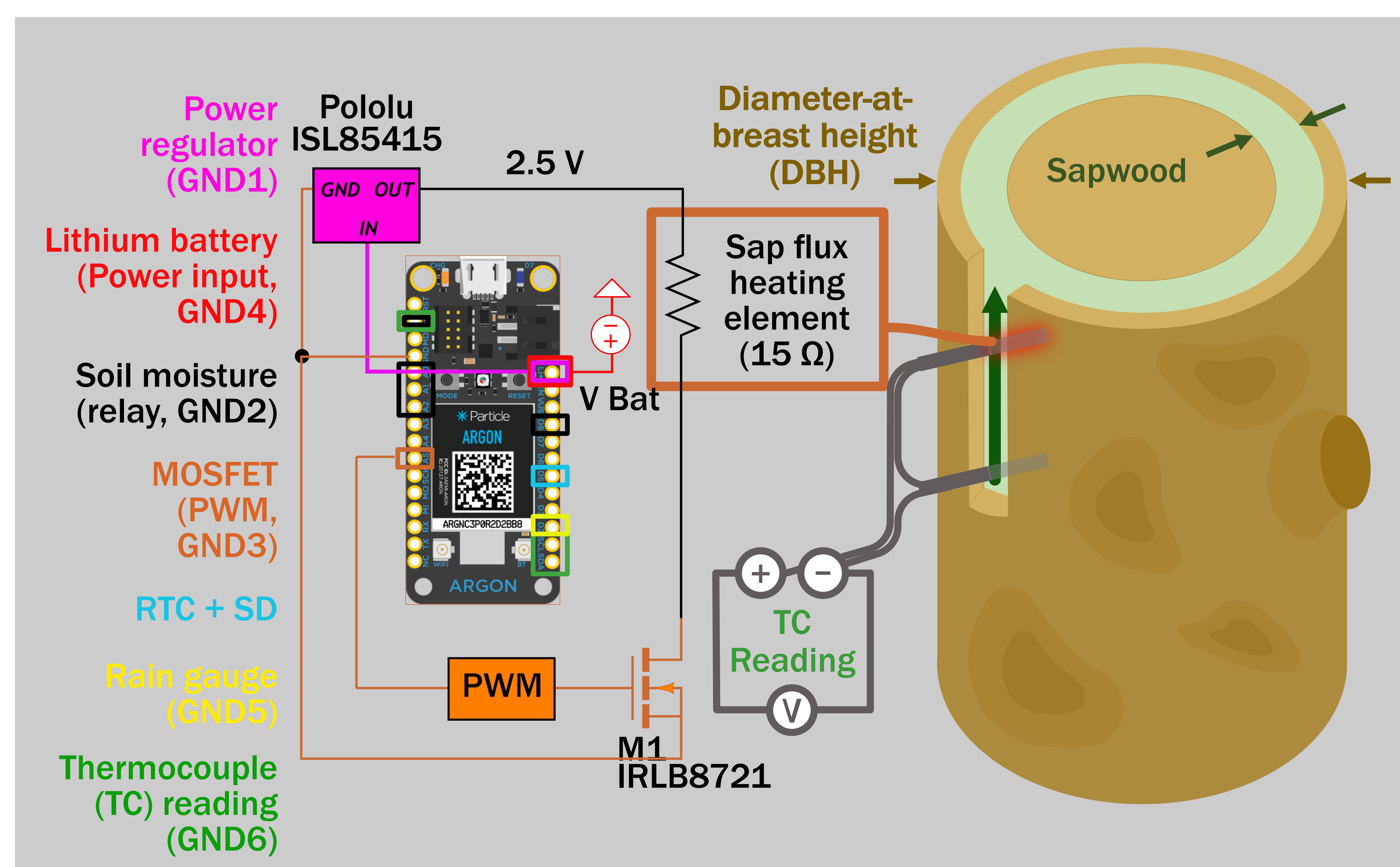
The sap flux sensors uses **two needles each with an encased thermocouple** to measure temperature differential between the two points (ΔT or ΔV).

The top needle is also heated constantly with a heating coil wrapped around the needle wall.

High flow → lower ΔT or ΔV
Low flow → high ΔT or ΔV

How do we power the sap flux sensors and log data?

The Granier style sap flux sensors require high heating power, and the typical forestry application with large battery packs needs to be **downsized and decentralized for urban research**. We used a Particle board to both regulate sap flux sensor's heating power and to log temperature differential readings from the sensor. With this compact setup, we collected reliable measurements on just a **weekly maintenance schedule**.



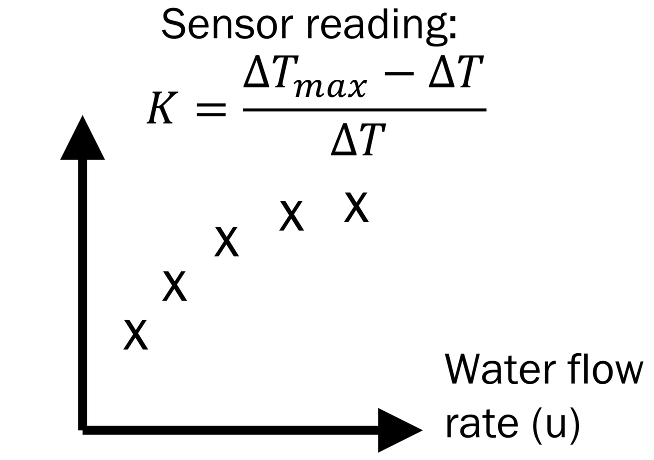
In this design, a **power regulator** is connected to the **power source** (four 18650 lithium ion batteries in parallel), and steps the voltage down to 2.5V, which then is connected to the **MOSFET** (IRLB8721). With a **pulse-width modulation (PWM)** from the Particle, the MOSFET acts as a switch and further reduces the average voltage to 2 V to supply constant power (0.2W) to the **sap flux heating element** (approximately 15 Ω). The duty cycle of PWM can be adjusted to the actual resistance of the heating element in each sap flux sensor.

The voltage differential can be read using a **thermocouple amplifier** (MCP9600). With an external **Adafruit FeatherWing module** with real time clock and SD reader, the Particle board can log data onto an SD card.

In progress: Calibrating the sap flux sensors for green ash trees (Fraxinus Pennsylvanica)

Urban ash trees around the Twin Cities metro have been removed due to region-wide emerald ash borers infestation. We opportunistically collected green ash tree stumps removed from local municipalities to calibrate sap flux sensors for our study species.

By measuring the flow rate of ionized solution through the tree trunk, we map the **sap flux sensor measurements (K)** with the **flow rate (u)** to derive a formula to interpret sap flow for Frax. Pennsylvanica. This work is currently in progress.



$$u = aK^b = a\left(\frac{\Delta T_{no\ flow} - \Delta T}{\Delta T}\right)^b$$

Conclusions

In **urban** settings, **decentralizing the sensing system** allows more flexibility for measuring the hydrological fluxes along the soil-plant-atmosphere continuum at the same site. Our research also synergizes with **municipal tree removal program,** which serves as a unique opportunity to quantify urban trees' effect on **water and heat dynamics**.

To see our preliminary results, please join **today at 4:20 pm (Moscone-2006-West)**:

GC44F-03: Estimating urban trees' transpiration and cooling benefits

or check out our project at our **MSP urban LTER** website: https://mspurbanlter.umn.edu/

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