Sap Flux Measurements at Virginia Tier III Site.

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What can we learn from half-hourly measurements of sap flux at Tier 3 Sites?

- Using a network of hundreds of sensors that measure water movement in the trunks of trees, or sap flux density (J^S), PINEMAP researchers can estimate how much water trees in each plot of the Tier III sites are using every half-hour.
- By scaling this water use by plot sapwood and leaf areas, we can get an estimate of transpiration per unit ground area (E^C) and per unit leaf area (E^L).
- We can also we estimate the conductance of the canopy to water vapor (G^S) by comparing E^L atmospheric evaporative demand determined by vapor pressure deficit (VPD).
- From these estimates of G^S, we can then estimate the stomatal response of these trees to VPD, volumetric soil moisture (VSM) and photosynthetically active radiation (PAR).

Overview of Approach

- Used data for 5 trees per plot in 4 plots each of control (CC), fertilization (FC), throughfall displacement (CD) and combined treatments (FD). Data were pooled across plots within each treatment.
- Sapwood and leaf area indices (SAI and LAI) was determined from DBH measurements and LAI-2200 readings in February of each year. SAI was assumed to change linearly from Mar. 1 to Oct. 31. LAI was assumed to follow the seasonal dynamics observed at a Tier II site near Plymouth, NC.
- Analysis was conducted in hierarchical Bayesian framework (Fig. 1), based on a state-space model of G^S response to VPD, PAR and VSM, fit to available (non-gap-filled) J^S data.
- Missing VSM readings were gap-filled using multiple imputation of working sensors, then averaged by throughfall displacement treatment, assuming 30% area under displacement benches (Fig. 2).

Bayesian State-Space Approach to Estimating Conductance

Features

- Consistent approach across sites to analyzing sap flux data
- Sets clear assumptions about missing data, scaling to stomatal conductance (G^S)
- Uncertainty associated with G^S and transpiration per unit LAI (E^L)
- Responses to environmental drivers (VSM, VPD, PAR)

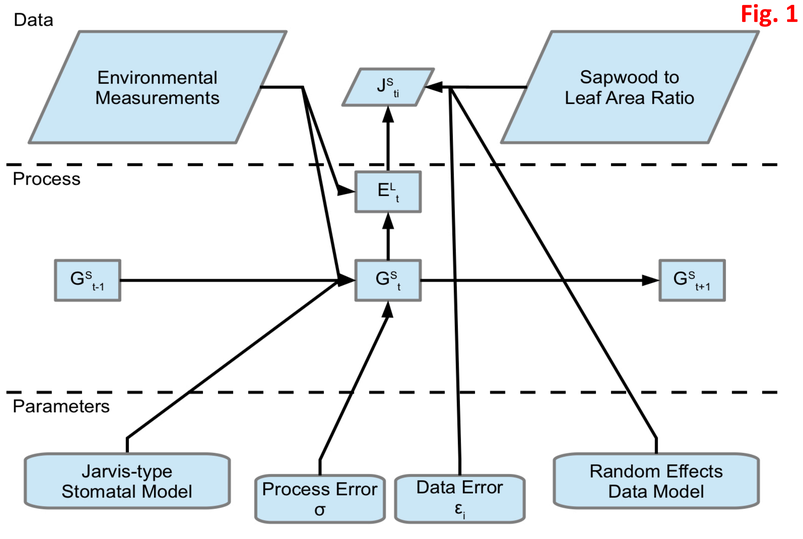
Inputs

- Clean (not gap-filled) sap flux estimates
- Vapor pressure deficit, incident PAR, soil moisture
- Plot sapwood and leaf area
- Priors for stomatal response of *P. taeda*

Outputs

- Posterior distribution of transpiration and stomatal conductance
- Multivariate distribution of stomatal response parameters
- NOT included: Radial variation in J^S, uncertainties in SAI/LAI, xylem hydraulics.

Fig. 1



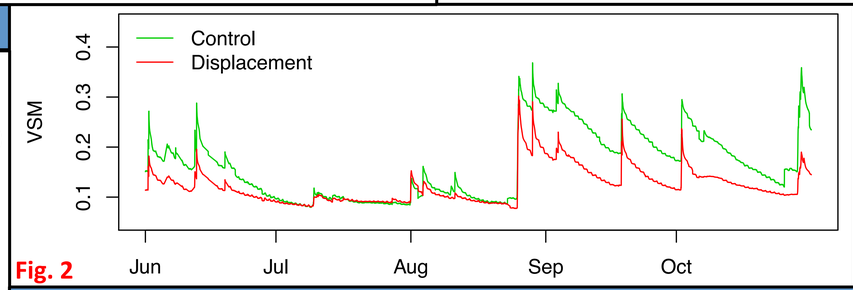
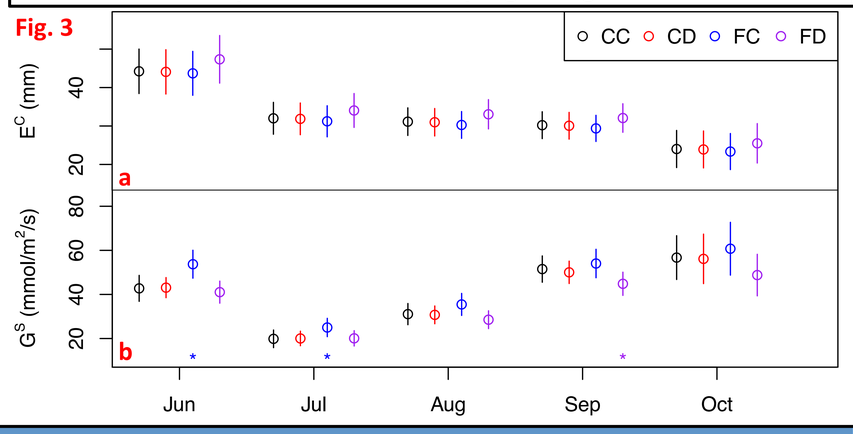


Fig. 2

Transpiration and Stomatal Conductance

- Treatment effects evaluated by parametric bootstrap using mean and standard deviation of mean monthly daytime G^S and sum of E^C as inferred by model from the J^S data. Bars indicate 95% credible interval.
- June and July values of G^S in FC treatment were significantly different from the CC value, while Sept. values in FD were lower than CC (Fig. 3b).
- Observed trends in other treatments are largely a function of small differences in the LAI of each treatment.
- Due to leaf longevity of *P. taeda* (18-24 months), treatment effects on leaf area are likely to occur over multiple growing seasons.

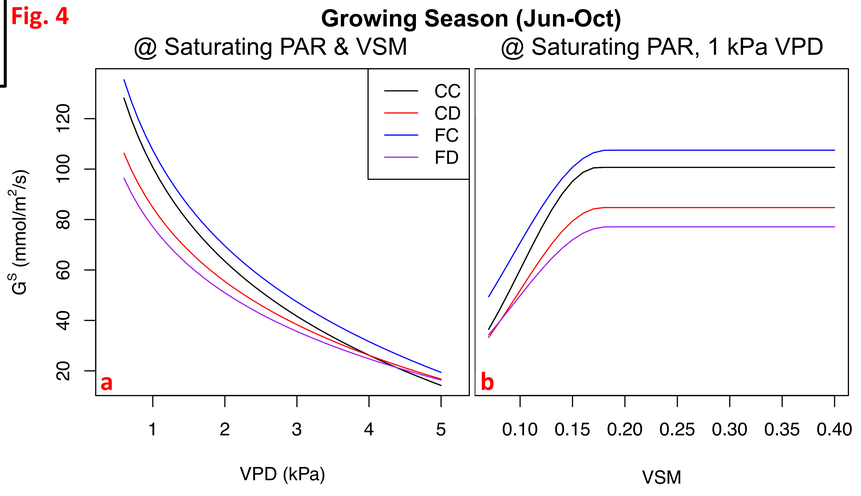
Fig. 3



Stomatal Response to Environmental Drivers

- Throughfall displacement reduced VSM an average of 4% from June to October. However, this difference was not constant (Fig. 2).
- At low VPD and high VSM, throughfall displacement reduced maximum G^S relative to the control (Fig. 4, CD and FD vs. CC).
- Throughout the VPD and VSM ranges, fertilization increased maximum G^S in plots without throughfall displacement (Fig. 4, FC vs. CC).
- Threshold VSM at which G^S decreased was similar across treatments (~0.18 m^3/m^3, Fig. 4b).
- Estimates of light-saturated G^S at high VPD and low VSM were similar across treatments, with FC slightly higher than other treatments.
- While parameters of these half-hourly responses are dependent on range of VPD and VSM at each site (thus not comparable across sites), it will be of interest if the relative pattern of G^S response between treatments is similar across sites.
- We would expect differences in development (such as changing SAI/LAI ratios) to impact results in future years of measurements.

Fig. 4



Possible Future Directions and Areas for Improvement in Models and Data

1. Measurements of J^S at multiple depths would permit quantification of uncertainty due to radial variation of sap flux at multiple depths.
2. More frequent measurements with LAI-2200 would permit more accurate representation of seasonal changes in LAI in model of G^S.
3. Measurements of J^S at multiple heights in the stem would permit estimates of hydraulic time constants to be included in model of G^S.
4. Litterfall data from each plot could be used to verify/correct LAI estimate, but only for LAI values ~2 years previous to litterfall.
5. Whole tree harvests could be used to verify LAI estimates at certain points in time, as well as improve sapwood area estimates from DBH.
6. Branch harvests could be used to estimate tree leaf areas from non-destructive branch measurements.
7. Any harvested woody material could be examined for treatment effects on hydraulic characteristics of xylem.

Conclusions

- Evidence for treatment effects on E^C and G^S in the first year of treatment is limited, but G^S was increased in FC and decreased in FD in some months.
- Treatments effects on LAI in following years may change these responses.
- Investment in further measurements may be worthwhile, especially regarding radial variation in J^S and temporal dynamics of LAI.

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