FETCH3: A Tree-Level Hydrodynamic Modeling Approach for Examining Species-Specific Stomatal Regulation at AmeriFlux Sites

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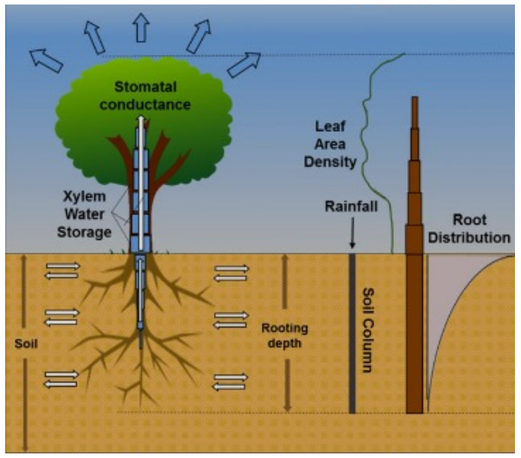
BACKGROUND

- Improving the representation of plant hydraulic behavior in vegetation and land-surface models is critical for improving our predictions of the impacts of drought stress on ecosystem carbon and water fluxes.
- Species-specific hydraulic traits play an important role in determining the response of ecosystem carbon and water fluxes to water stress

APPROACH

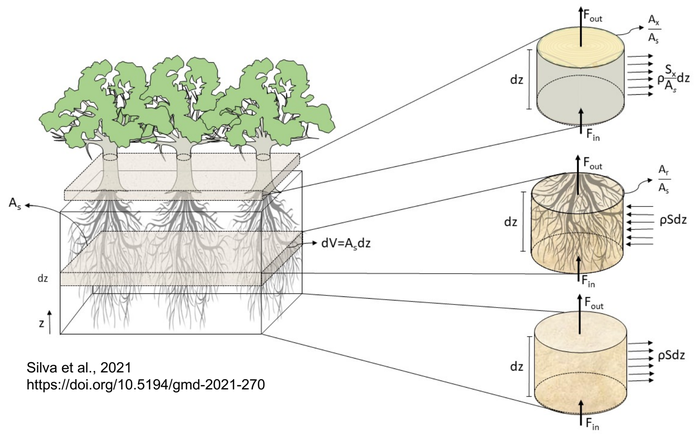
Finite-difference Ecosystem-scale Tree Crown Hydrodynamics model version 3 (FETCH3)



Mirfenderesgi et al., 2019

- Tree represented as simplified 1-D conduit with realistic vertical leaf area distribution
- Stomatal response is linked to xylem water potential (rather than directly to soil moisture)

Water transport through soil, roots, and xylem as porous media flow



Silva et al., 2021
https://doi.org/10.5194/gmd-2021-270

- Resolves water potentials along the vertical dimension
- Accounts for water storage in plant

water potential; hydraulic conductivity

$$C_s \frac{\partial \Phi_s}{\partial t} = \frac{d\theta_s}{d\Phi_s}\frac{\partial \Phi_s}{\partial t} = \frac{\partial}{\partial z}\left[K_s\left(\frac{\partial \Phi_s}{\partial z} + \rho g\right)\right] - S \quad \text{Soil}$$

root water uptake

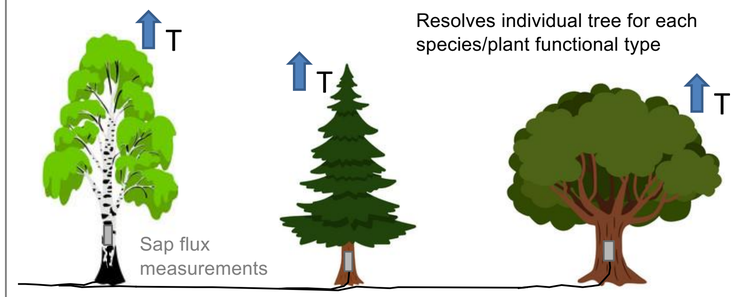
$$C_r \frac{\partial \Phi_r}{\partial t} = \frac{d}{d\Phi_r}\left(\frac{\theta_r A_r}{A_s}\right)\frac{\partial \Phi_r}{\partial t} = \frac{\partial}{\partial z}\left[K_r \frac{A_r}{A_s}\left(\frac{\partial \Phi_r}{\partial z} + \rho g\right)\right] + S \quad \text{Roots}$$

root cross-sectional area index

$$C_x \frac{\partial \Phi_x}{\partial t} = \frac{d}{d\Phi_x}\left(\frac{\theta_x A_x}{A_s}\right)\frac{\partial \Phi_x}{\partial t} = \frac{\partial}{\partial z}\left[K_x \frac{A_x}{A_s}\left(\frac{\partial \Phi_x}{\partial z} + \rho g\right)\right] - \frac{S_x}{A_s} \quad \text{Xylem}$$

capacitance; volumetric water content; hydroactive stem xylem cross-sectional area index; transpiration

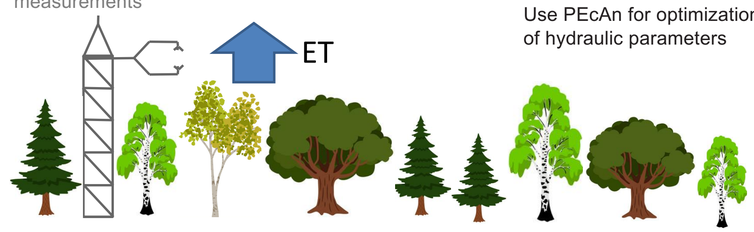
Scaling



Resolves individual tree for each species/plant functional type

Scale representative single trees to plot scale based on species composition and canopy structure

Can be validated using both tree-level observations (sap flow) and plot-level observations (eddy covariance)



PEcAn

Use PEcAn for optimization of hydraulic parameters

PLANS

- Use FETCH3 to examine interactions among water stress, species-specific hydraulic strategies, and stomatal regulation across different species and ecosystem types
- Use multiple sites that have both sap flux and eddy covariance data

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AMERIFLUX