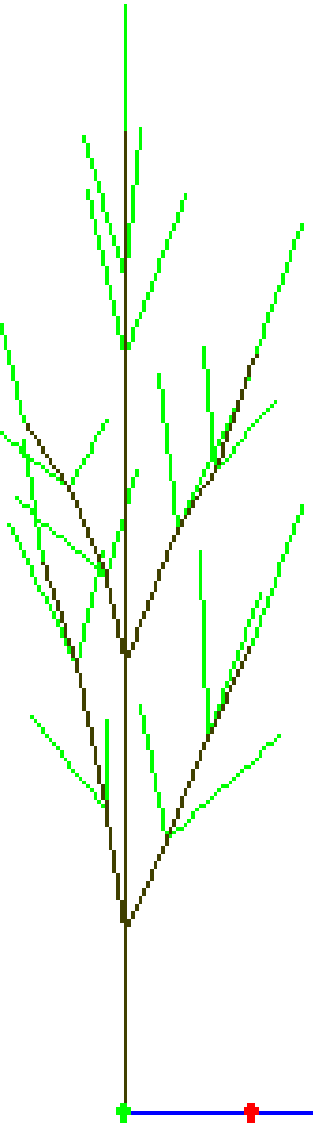

Assessing the effects of hydrodynamic stresses on stomatal conductance in forest patches with trees of difference structures, sizes and species

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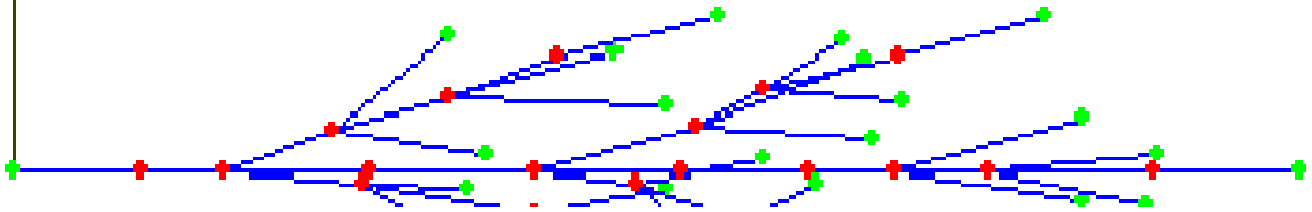
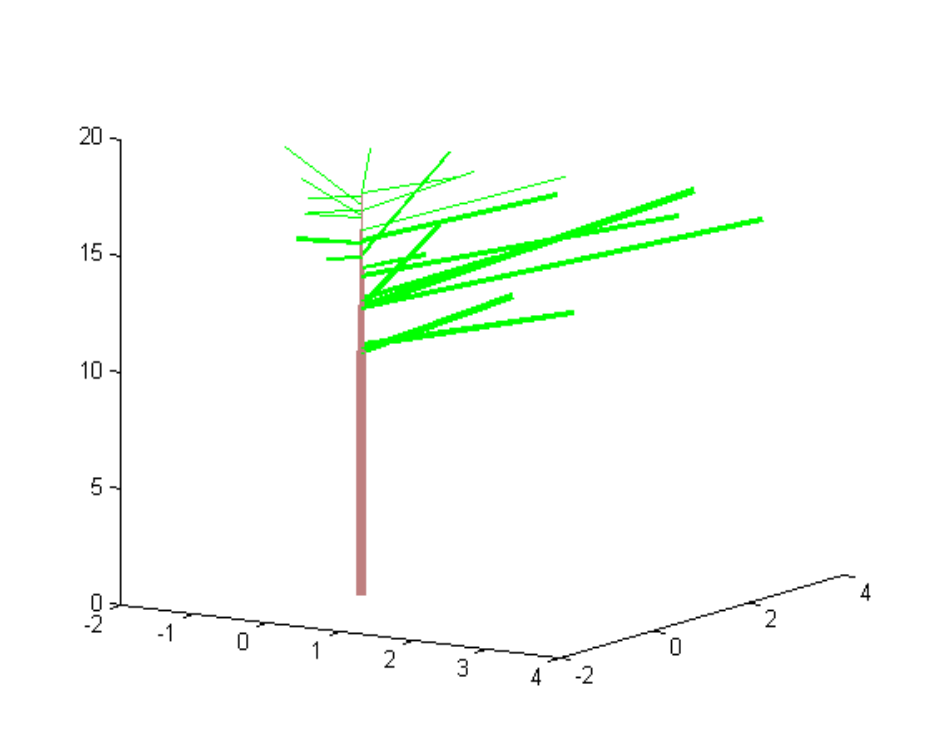
Ashley Matheny, Steven Garrity, Kyle Maurer, Kevin Meyer, Valeriy Ivanov

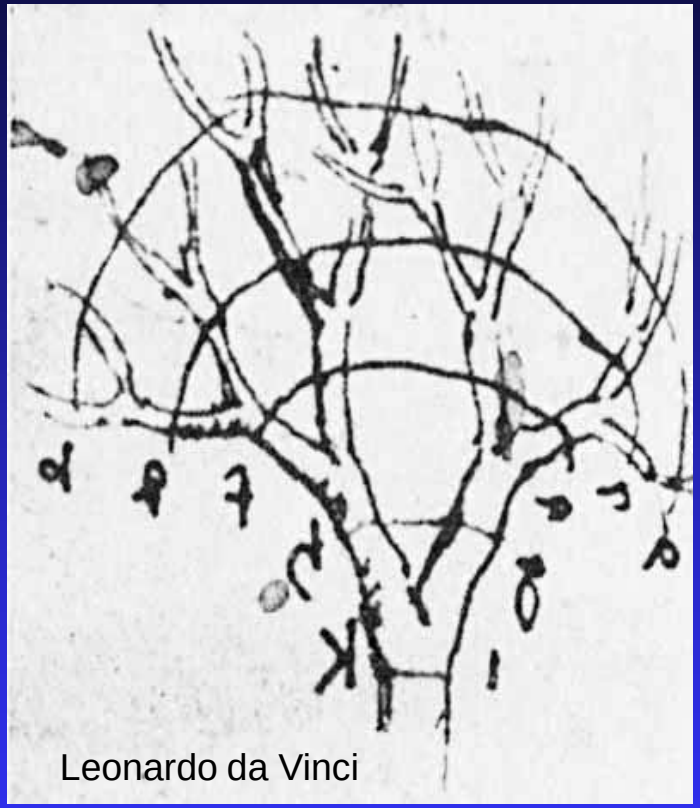


Incorporating the hydraulic structure of trees



Big-tooth Aspen

University of Michigan Biological Station Forest in Transition Experiment

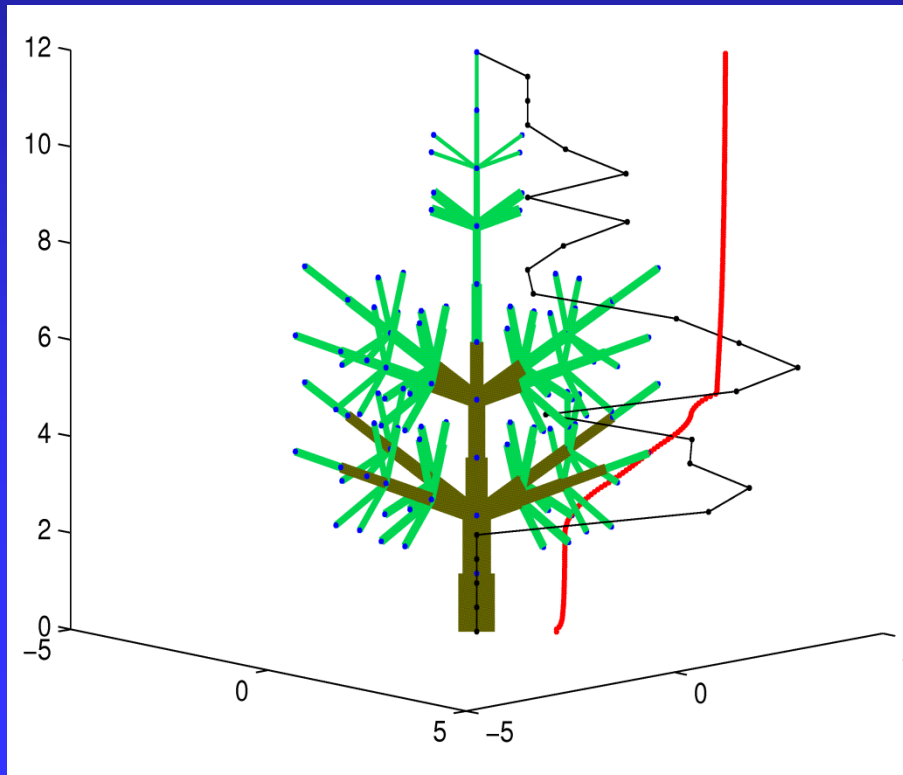


Leonardo da Vinci

Finite Elements Tree-Crown Hydrology (FETCH) model

- Advantages:
  - Accounts for trees' structure
  - Physical sense of hydraulics
  - 3-D sub-tree-scale solution of fluxes
  - Improved representation of fast temporal dynamics
  - Ability to forecast the effects of tree growth and structure on transpiration

Bohrer et al. 2005 WRR



1-D Richards equation in Pressure form

$$C(\Phi)\frac{\partial \Phi}{\partial t} = -\frac{\partial(K(\Phi)[\partial\Phi/\partial z + \rho g \cos(\alpha)])}{\partial z} - Ev$$

Capacitance | Conductance | Pressure gradient | Gravitational term | Transpiration

- Mass conservation of water in a porous media
- Describes change of Φ (water pressure) in space and time

New "tricks":

- Maximal potential transpiration restricted by stomatal response to water potential in branches
- 3D→1D coordinate conversion
- $C(\Phi)$ derived from empirical cavitation curves $\theta = f(\Phi)$
- $E_{V,max}$ based on atmospheric conditions within-above canopy

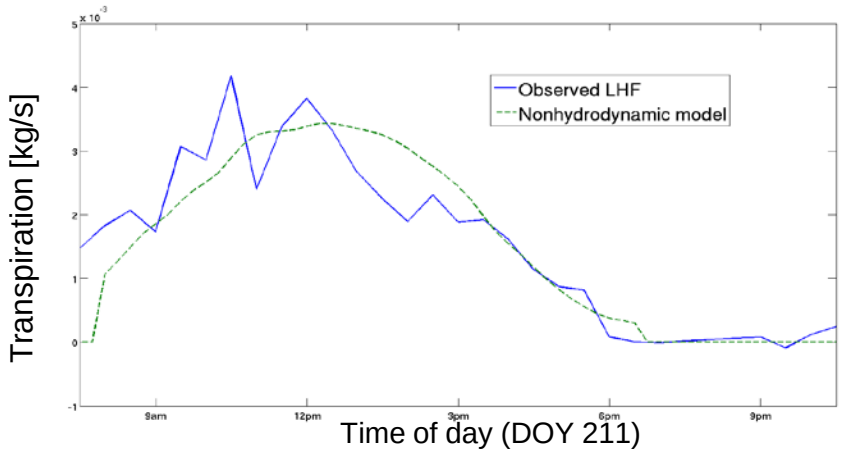
$$C(\Phi) = \frac{\partial \theta}{\partial \Phi} = p\theta_{sat}\frac{1}{\Phi_0}\left(\frac{\Phi_0 - \Phi}{\Phi_0}\right)^{-(p+1)}$$

$$K(\Phi) = f(A_z)K_{\max}e^{-(-\Phi/d)^{c1}}$$

$$E_V = E_{V,\max} \times \exp\left[-\left(\frac{-\Phi^{(n-1)}}{\Phi_\sigma}\right)^{c_3}\right]$$

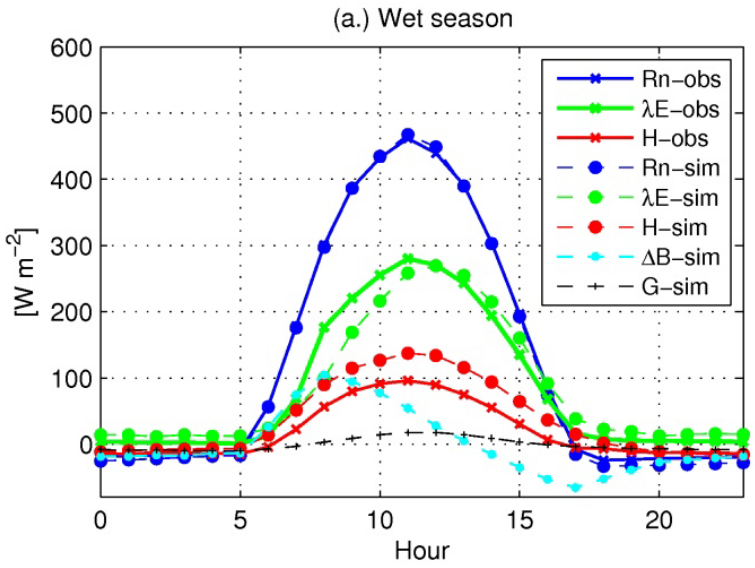
Hydrodynamic stress is everywhere !

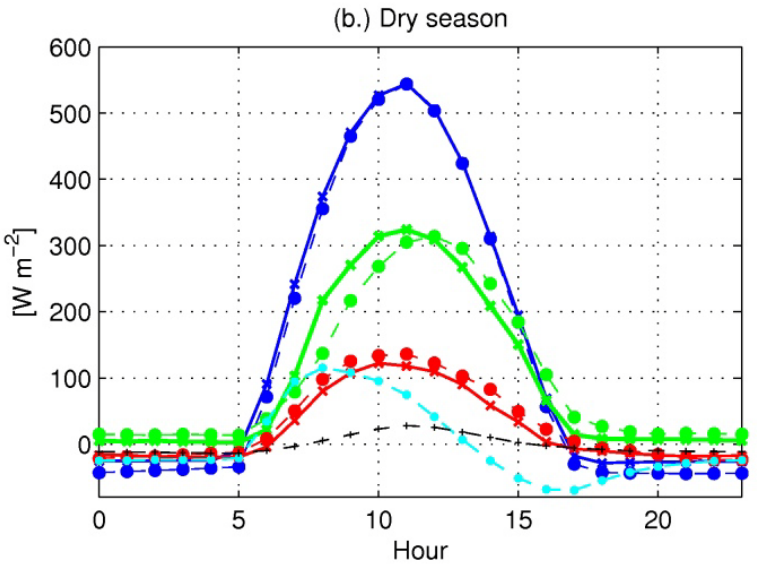
Non-hydrodynamic transpiration models produce a light-dependent transpiration curve, symmetric around noon



Observation – DOY 211.UMBS
Model – Poggi et al 2004+Leuning et al. 1995

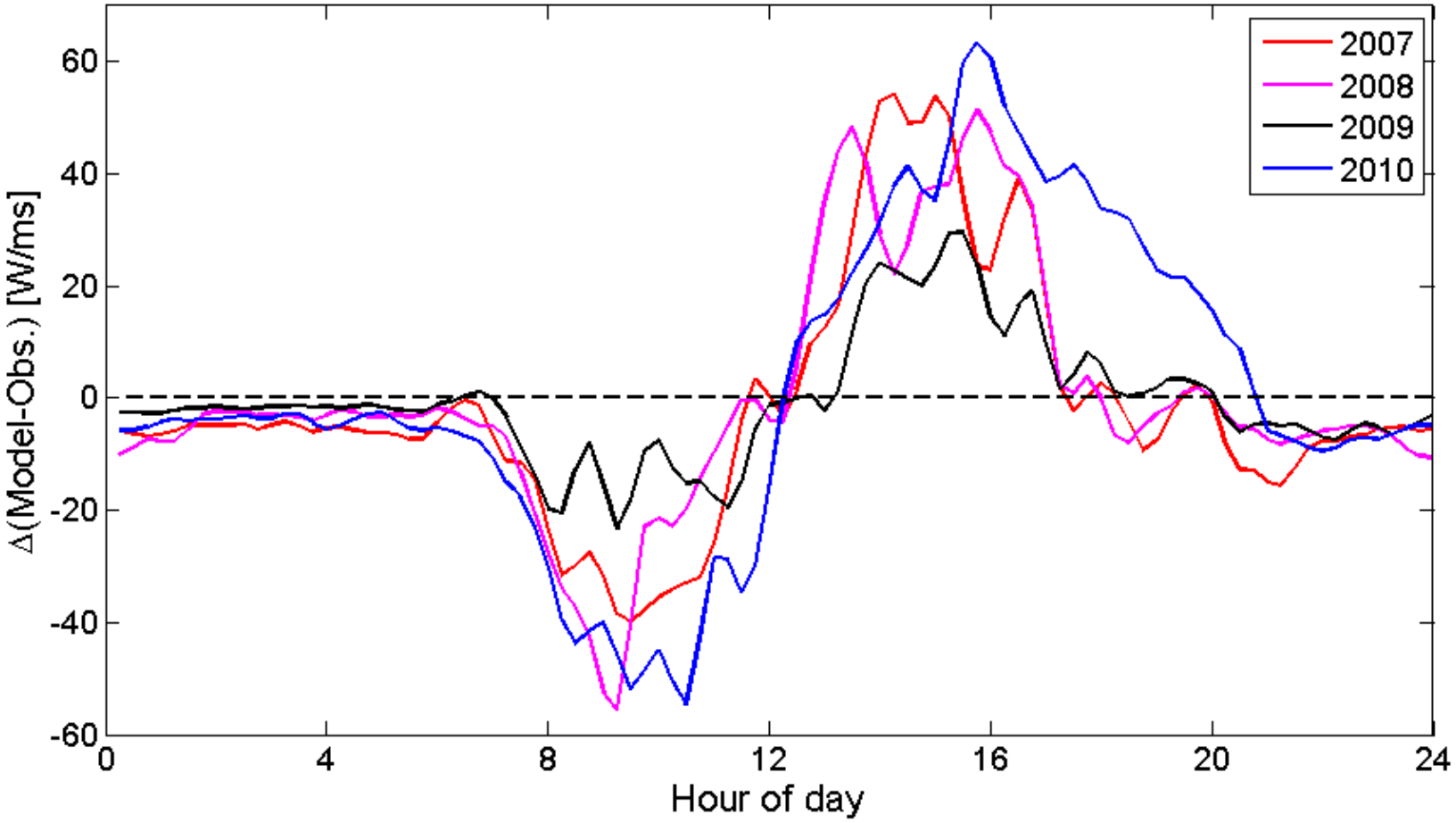
Observations - Harvard Forest, summer
Model – VEGGIE (Ivanov et al 2008)





Hydrodynamic stress is everywhere !

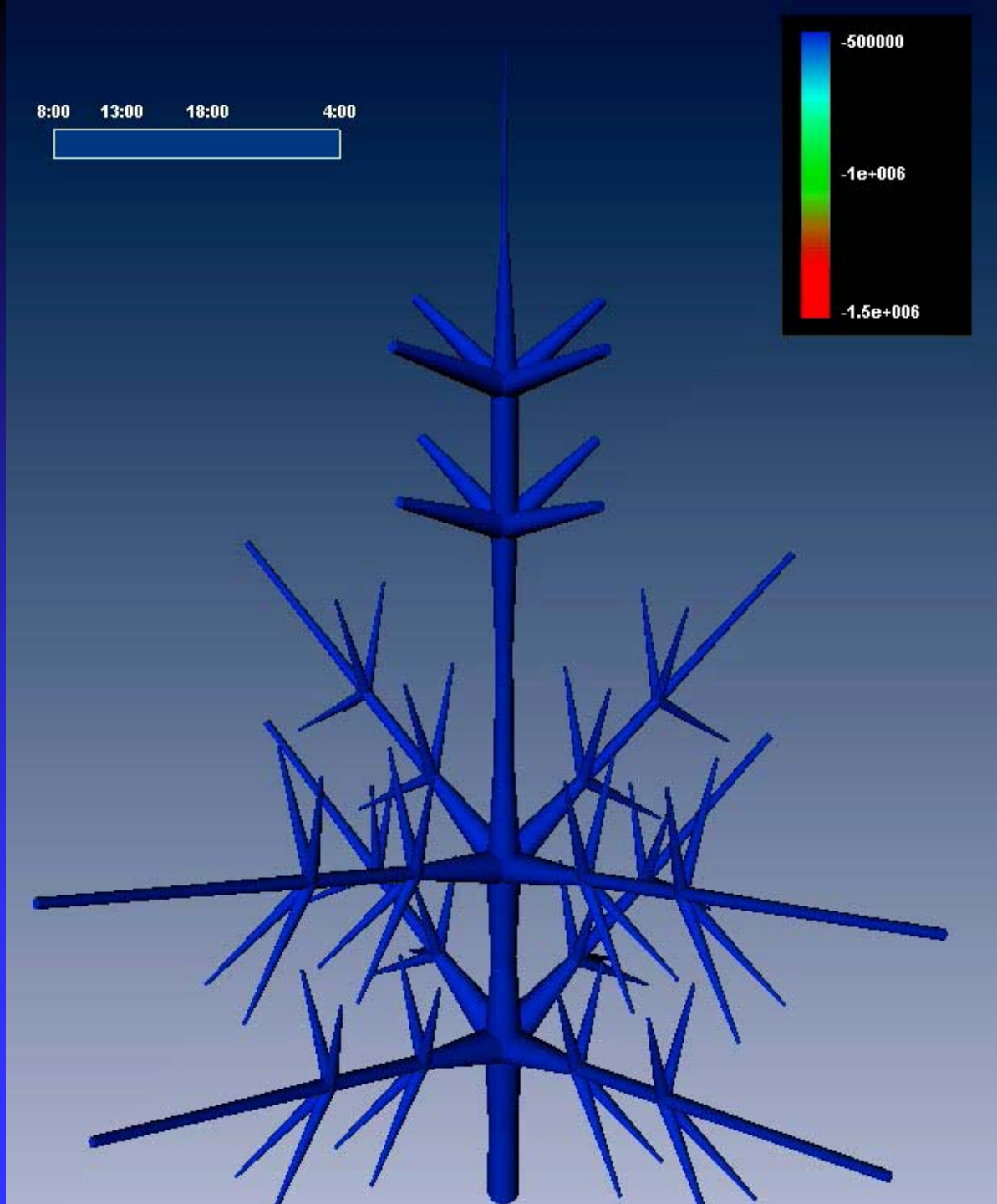
4 summers model vs. observation comparison in UMBS



What can FETCH do?

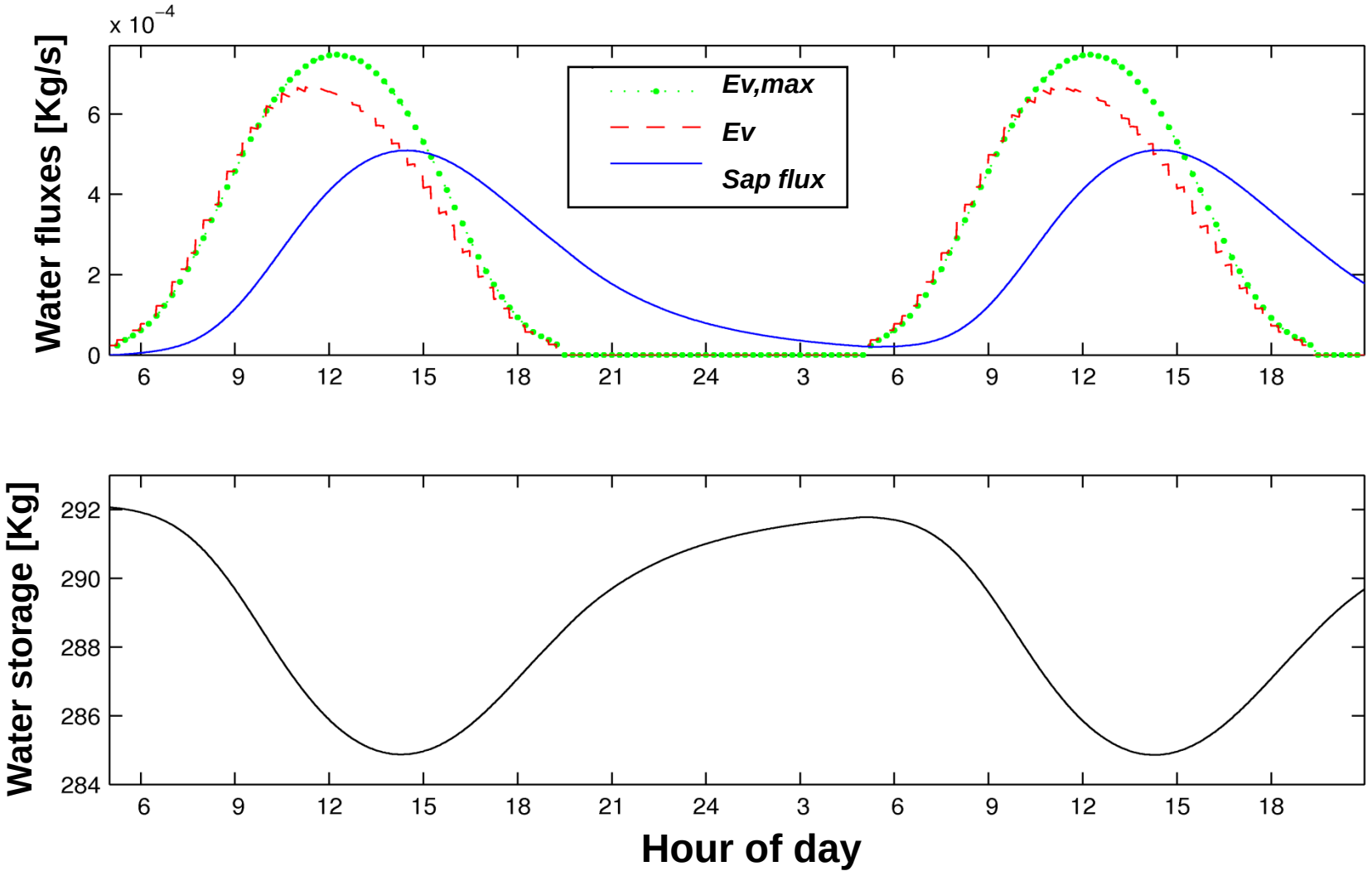
Daily dynamics

Pressure [Pa]
in model tree



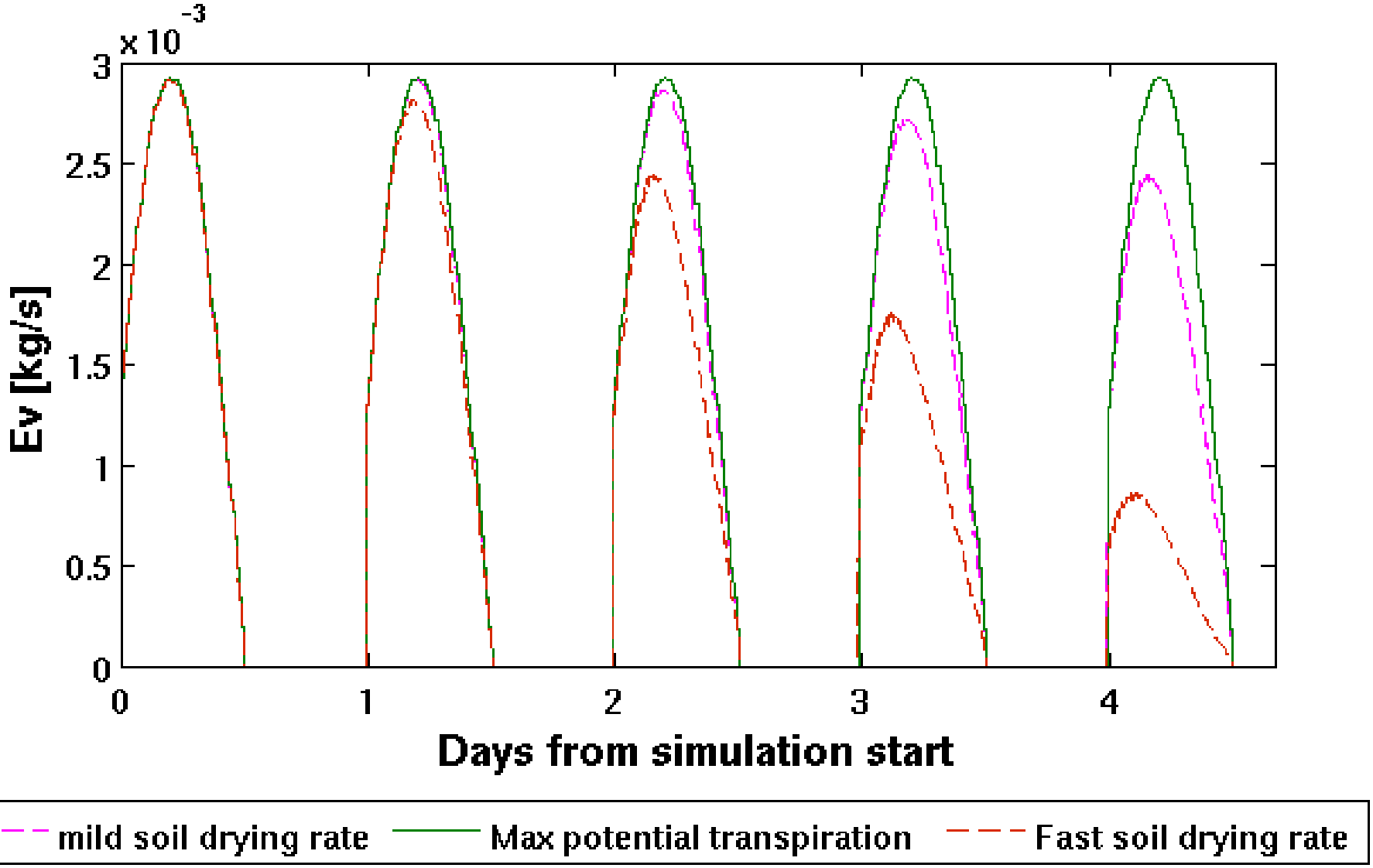
Daily dynamics from FETCH

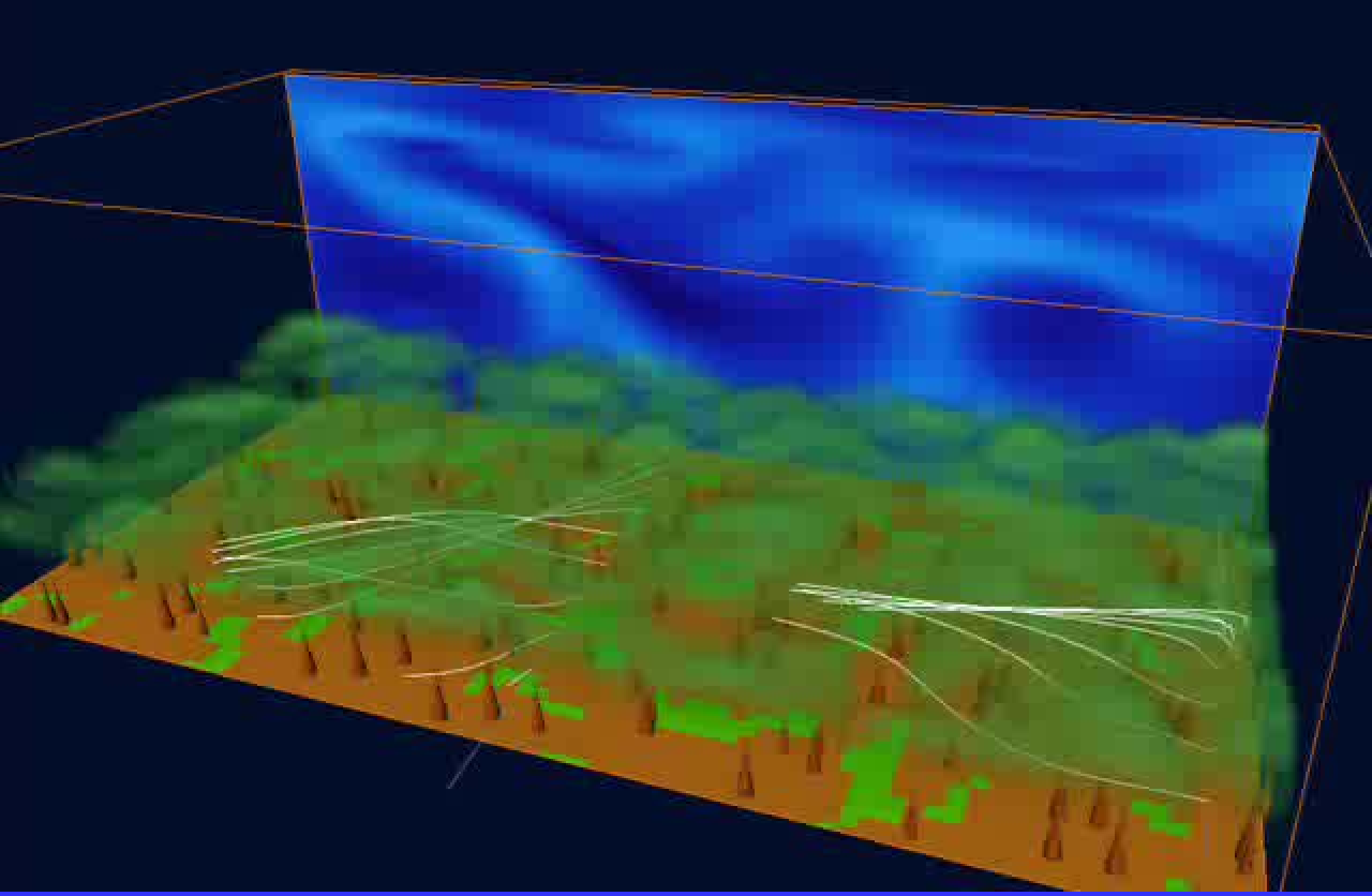
Non-restrictive soil moisture



Daily dynamics from FETCH

Drought sequence

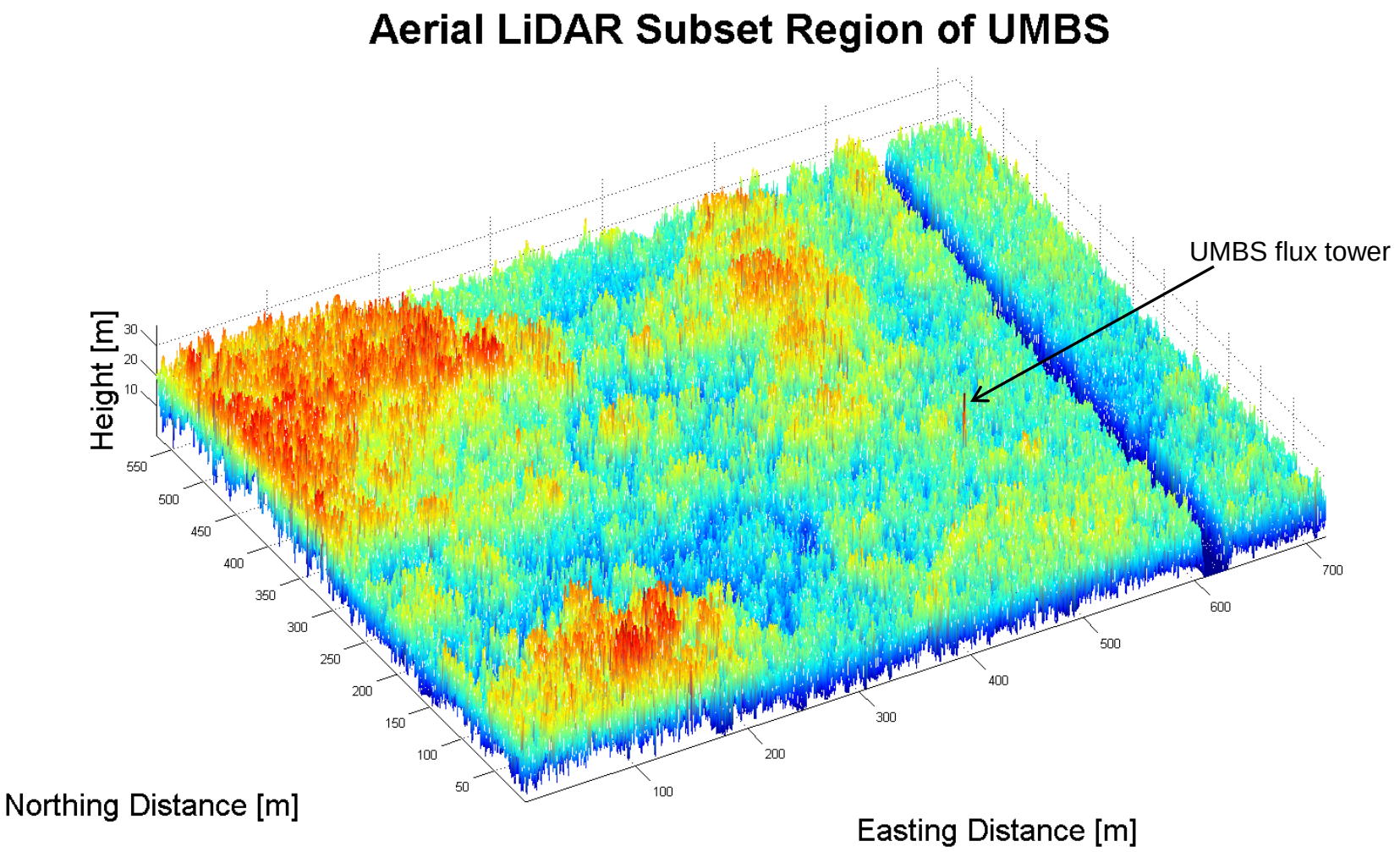




Application for ecological-atmospheric modeling

Accounting for within tree hydrological processes

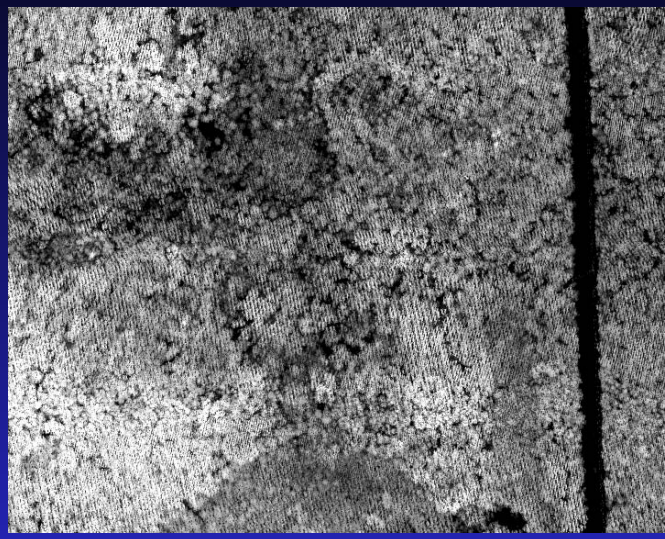
How to get branch-level explicit description of canopy structure?



Airborne LIDAR (example sub-domain, 0.55 x 0.7 km^2)

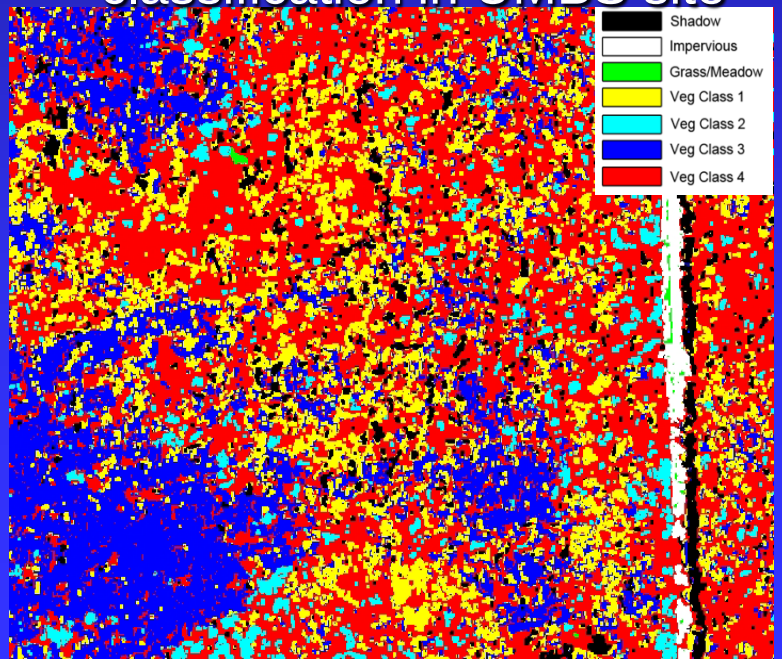
How to get branch-level explicit description of canopy structure?

Airborne hyperspectral image

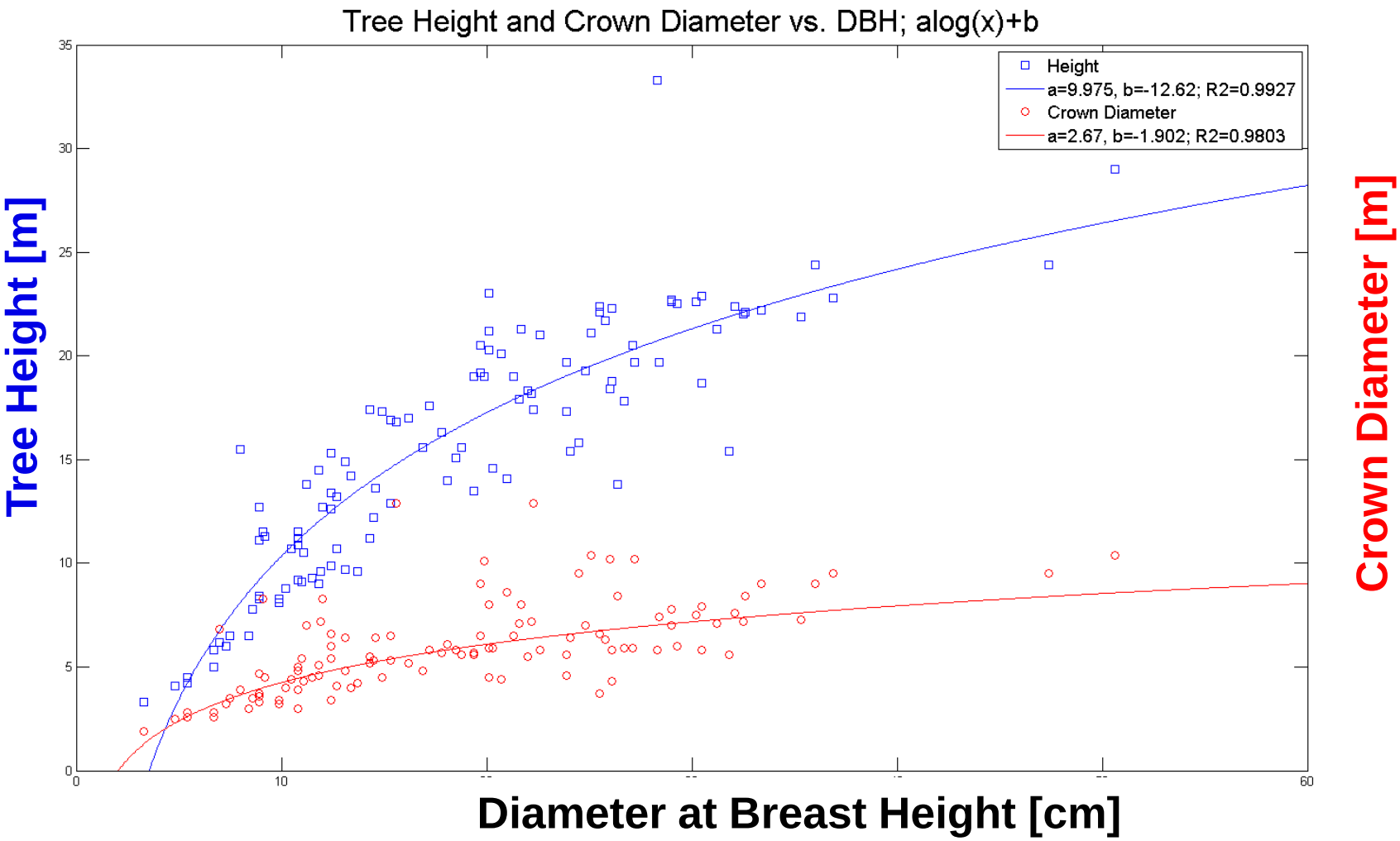


Airborne LIDAR

Combined to tree-type classification in UMBS site

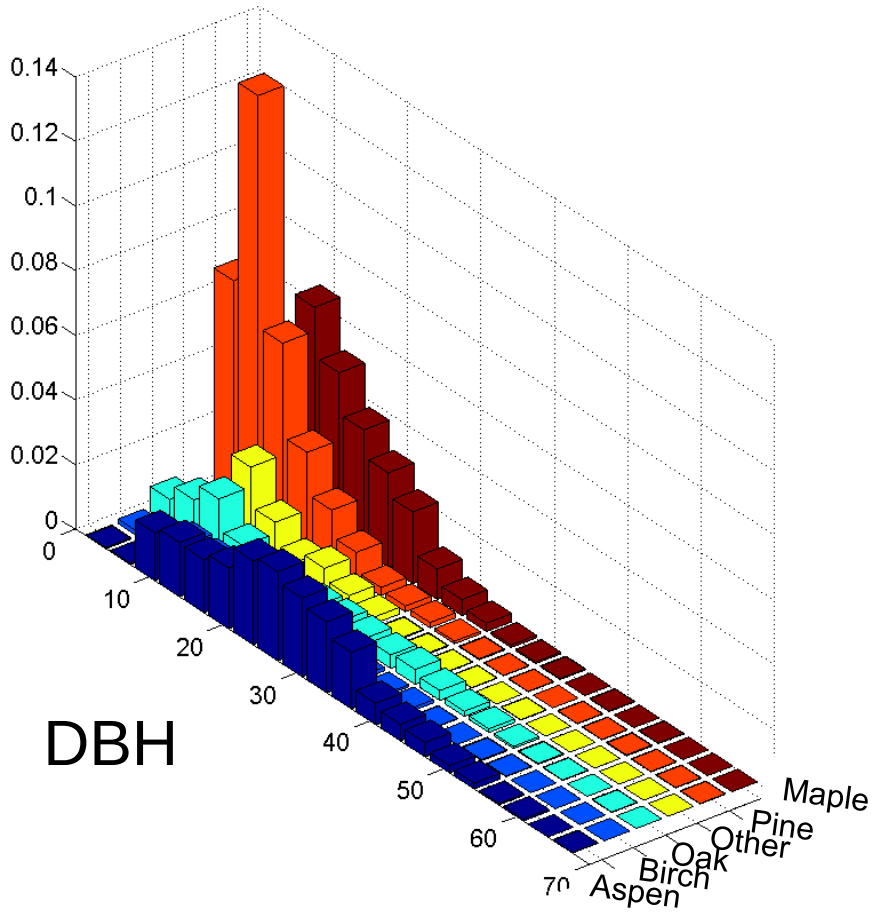


Use allometry to translate height-crown size data to DBH

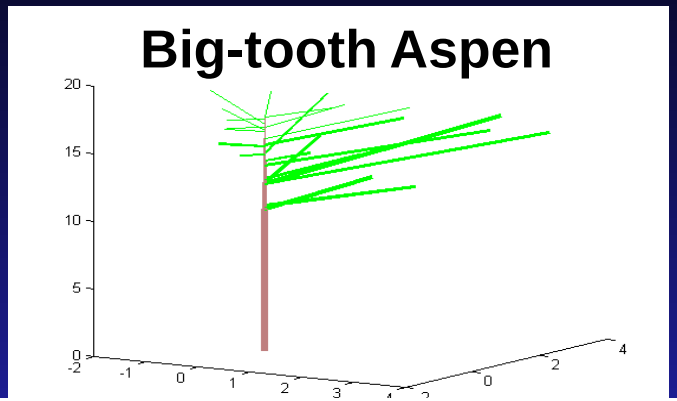


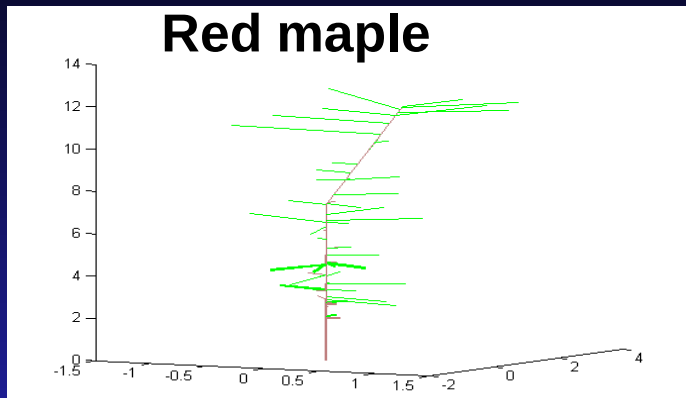
Decompose the forest to representative size/species DBH bins

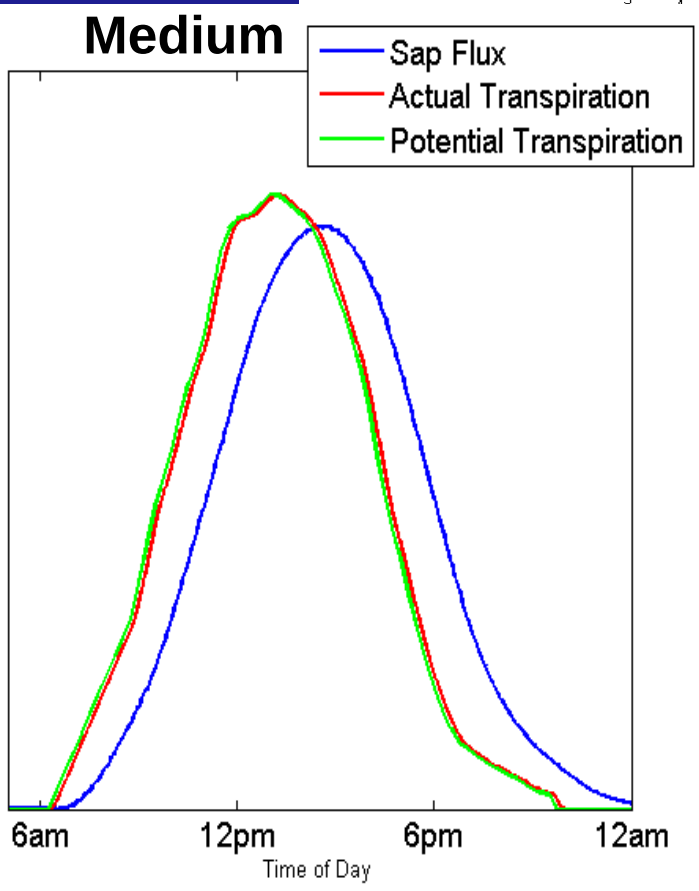
Distribution

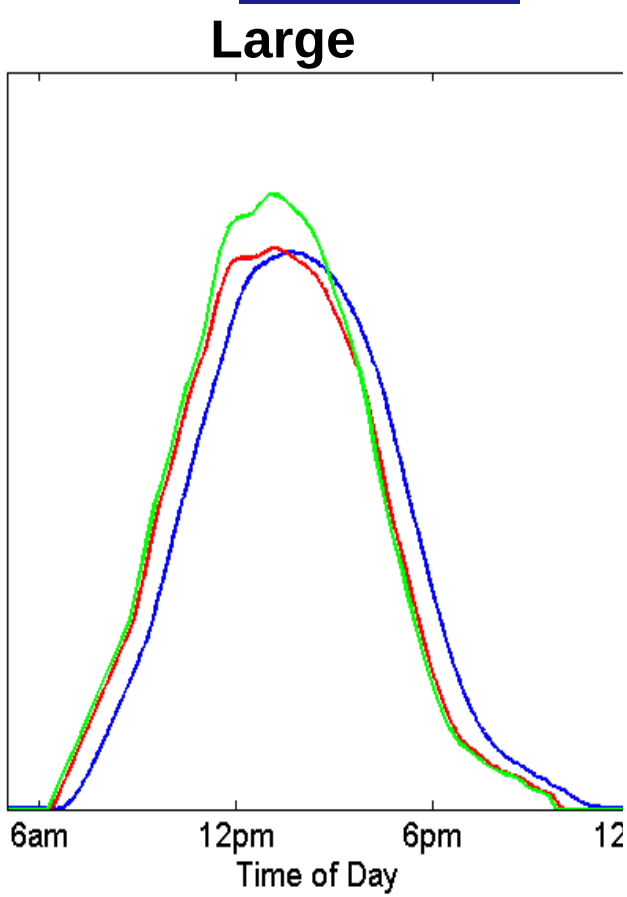


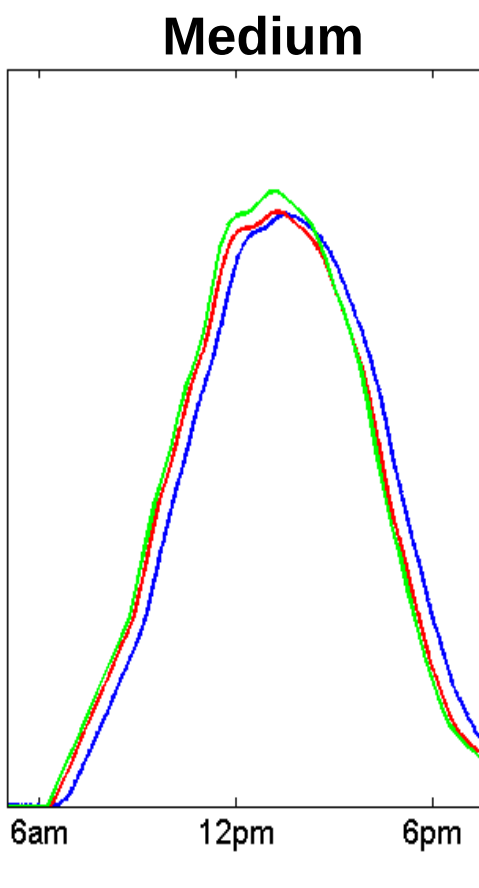
Will changes in structure also affect water demand?











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Sap-flux measurements: Karina Schafer (Rutgers U)

Eddy flux processing: Matteo Detto (STRI)

Airborne LIDAR – NCALM (UMBS data)

USDA United States Department of Agriculture National Institute of Food and Agriculture

NSF National Science Foundation WHERE DISCOVERIES BEGIN

BART Biosphere • Atmosphere Research and Training

NASA

DOE National Institute for Climatic Change Research

AmeriFlux

Ohio Supercomputer Center
Empower. Partner. Lead.

Forest Service US Department of Agriculture