The FETCH2 plant hydrodynamic model and biomass hydraulic capacitance

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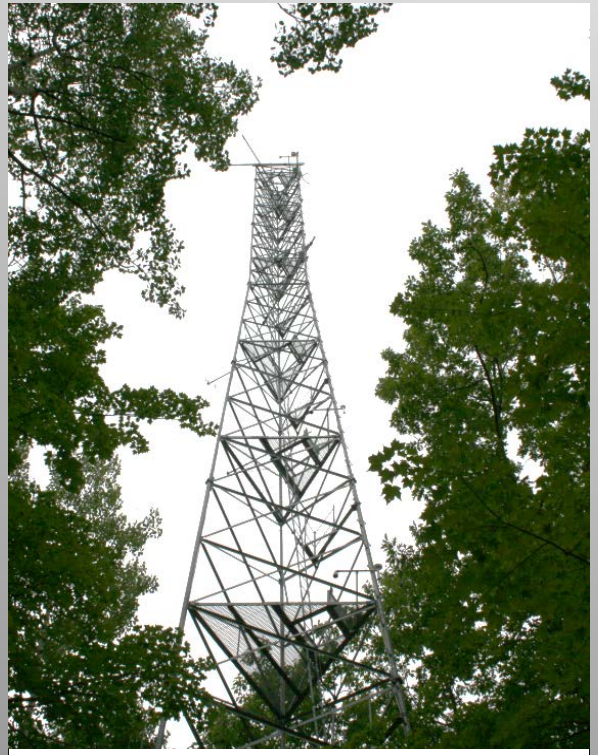
National Science Foundation
WHERE DISCOVERIES BEGIN

University of Michigan Biological Station (UMBS)

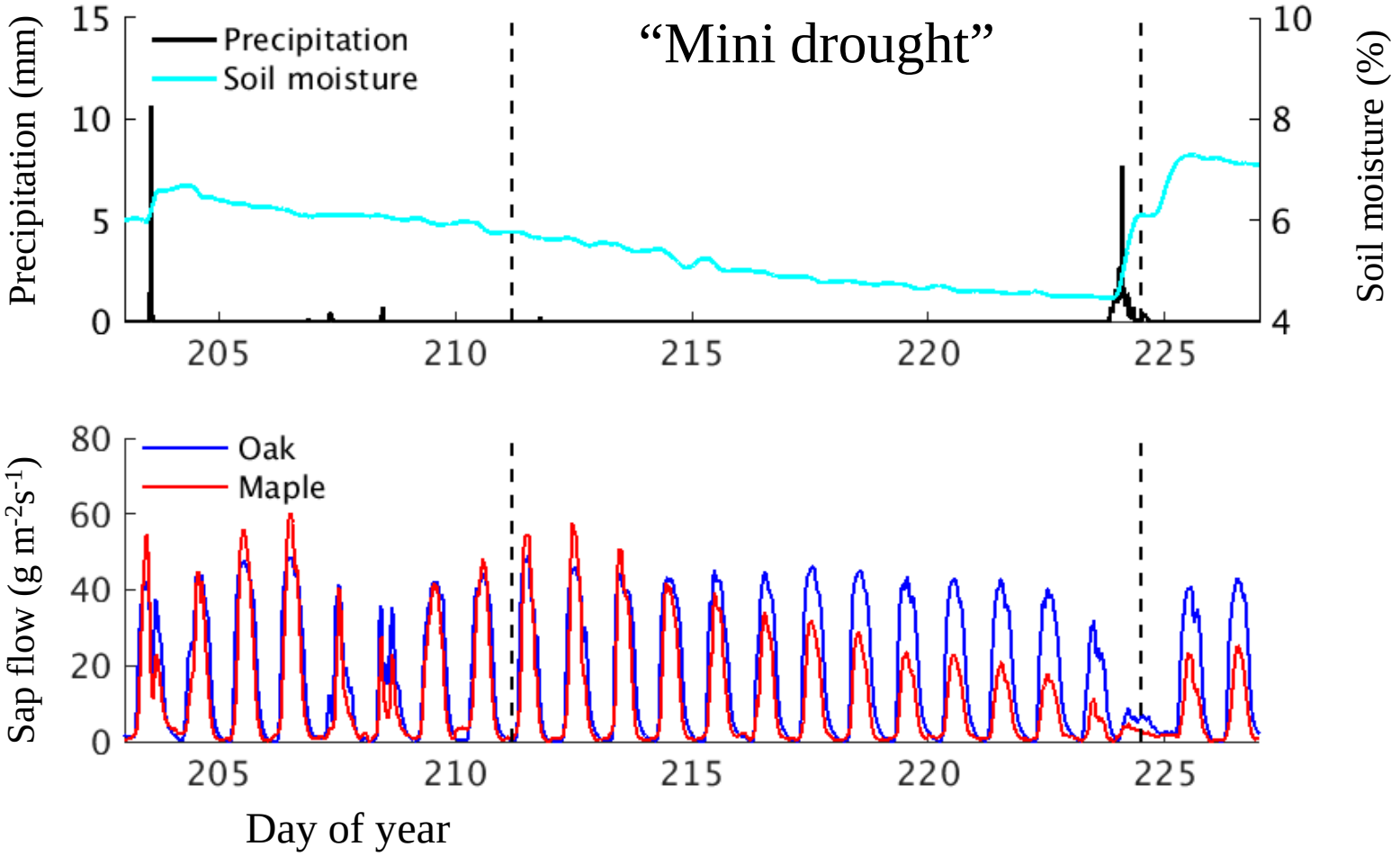
Temperate deciduous broadleaf forest (US-UMB, US-UMd)



Eddy covariance tower, UMBS

UMBS research forest

Species-specific regulation of water use



- Matheny et al. 2017, Ecohydrology

Within ecosystem divergent hydraulic function is common!

WILEY

RESEARCH ARTICLE

Contrasting strategies of hydraulic control in two codominant temperate tree species

Ashley M. Matheny[1] | Richard P. Fiorella[2,3] | Gil Bohrer[1] | Christopher J. Poulsen[2] | Timothy H. Morin[1] | Alyssa Wunde

Hydraulic architecture of two species differing in wood density: opposing strategies in co-occurring tropical pioneer trees

KATHERINE A. MCCULLOH[1], DANIEL M. JOHNSON[2], FREDERICK C. MEINZER[3], STEVEN L. VOELKER[4], BARBARA LACHENBRUCH[1] & JEAN-CHRISTOPHE DOMEC[2,5]

Differential use of spatially heterogeneous soil moisture by two semiarid woody species: *Pinus edulis* and *Juniperus monosperma*

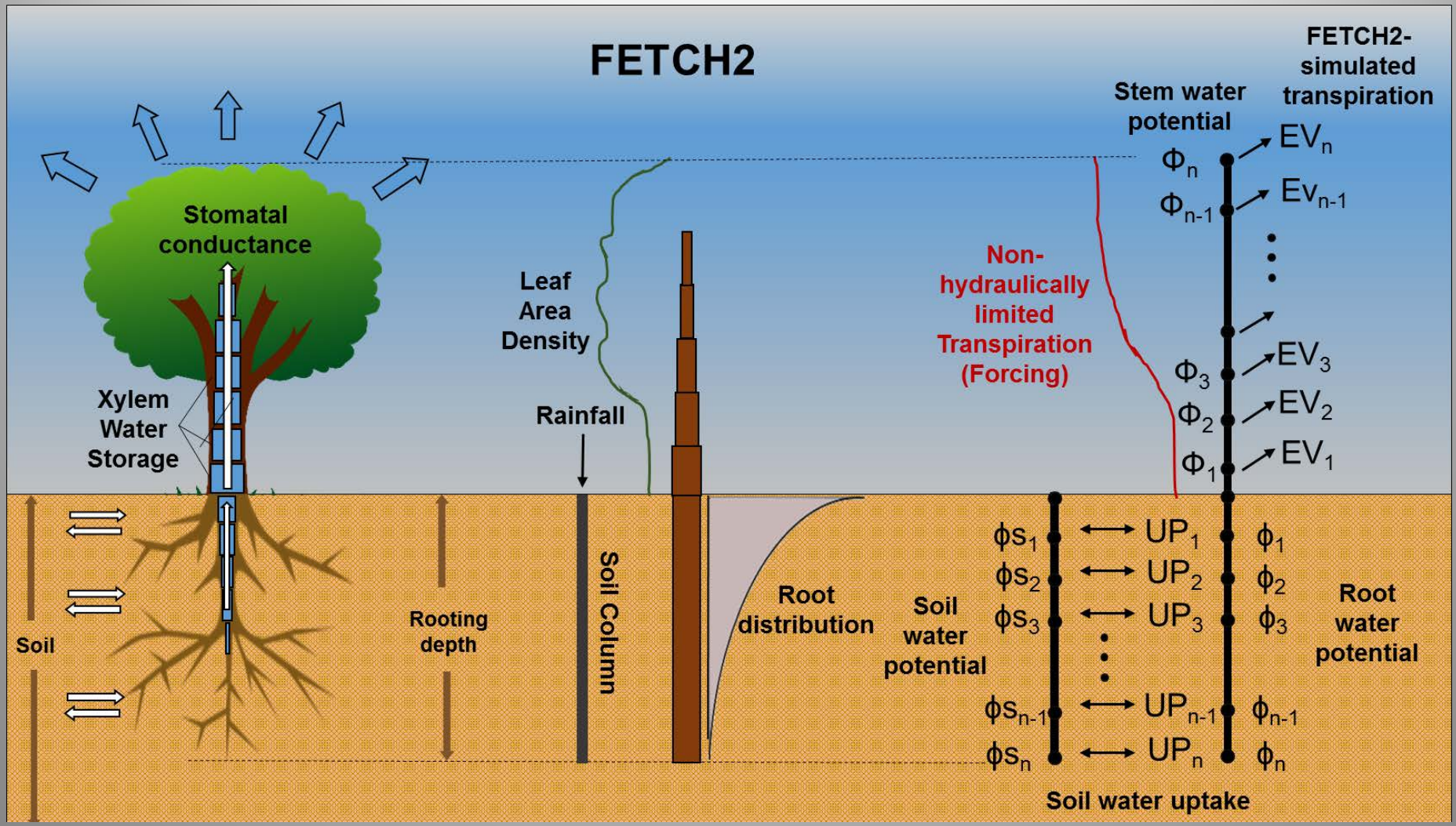
DAVID D. BRESHEARS, ORRIN B. MYERS, SUSAN R. JOHNSON, CLIFTON W. MEYER and SCOTT N. MARTENS*

Environmental Science Group, Mail Stop J495, Los Alamos National Laboratory, Los Alamos, NM 87545, USA

Boreal tree hydrodynamics: asynchronous, diverging, yet complementary

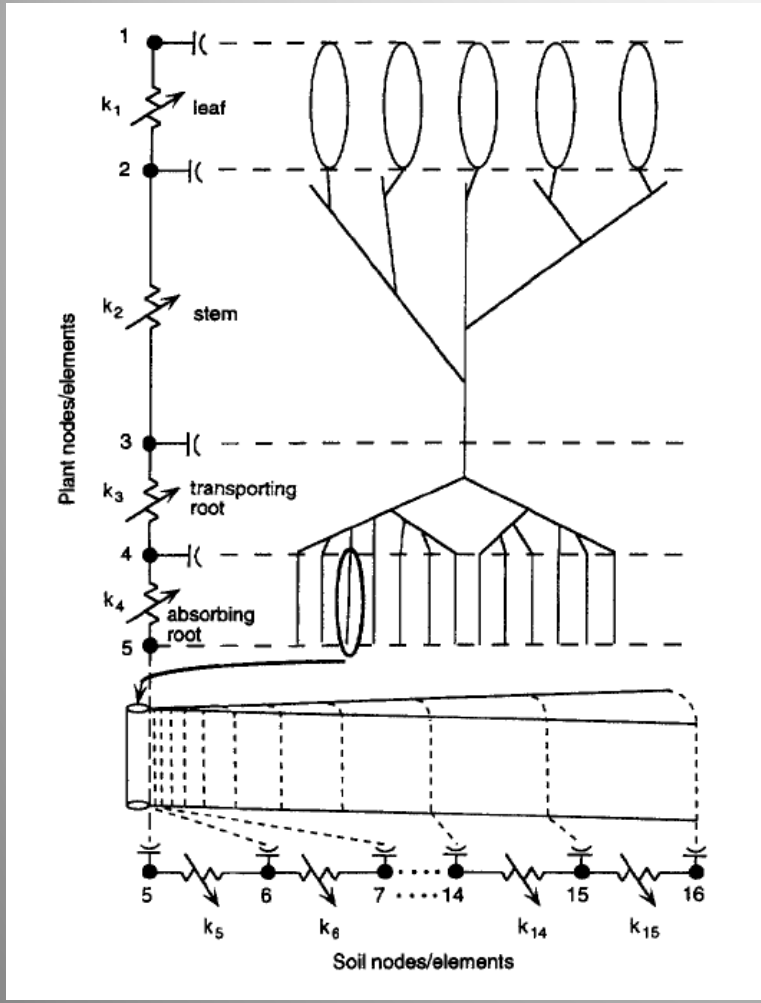
Christoforos Pappas[1*], Ashley M. Matheny[2,3], Jennifer L. Baltzer[4], Alan Barr[5], T. Andrew Black[6], Gil Bohrer[3], Matteo Detto[7,8], Jason Maillet[9], Alexandre Roy[1], Oliver Sonnentag[1], and Jilmarie Stephens[6]

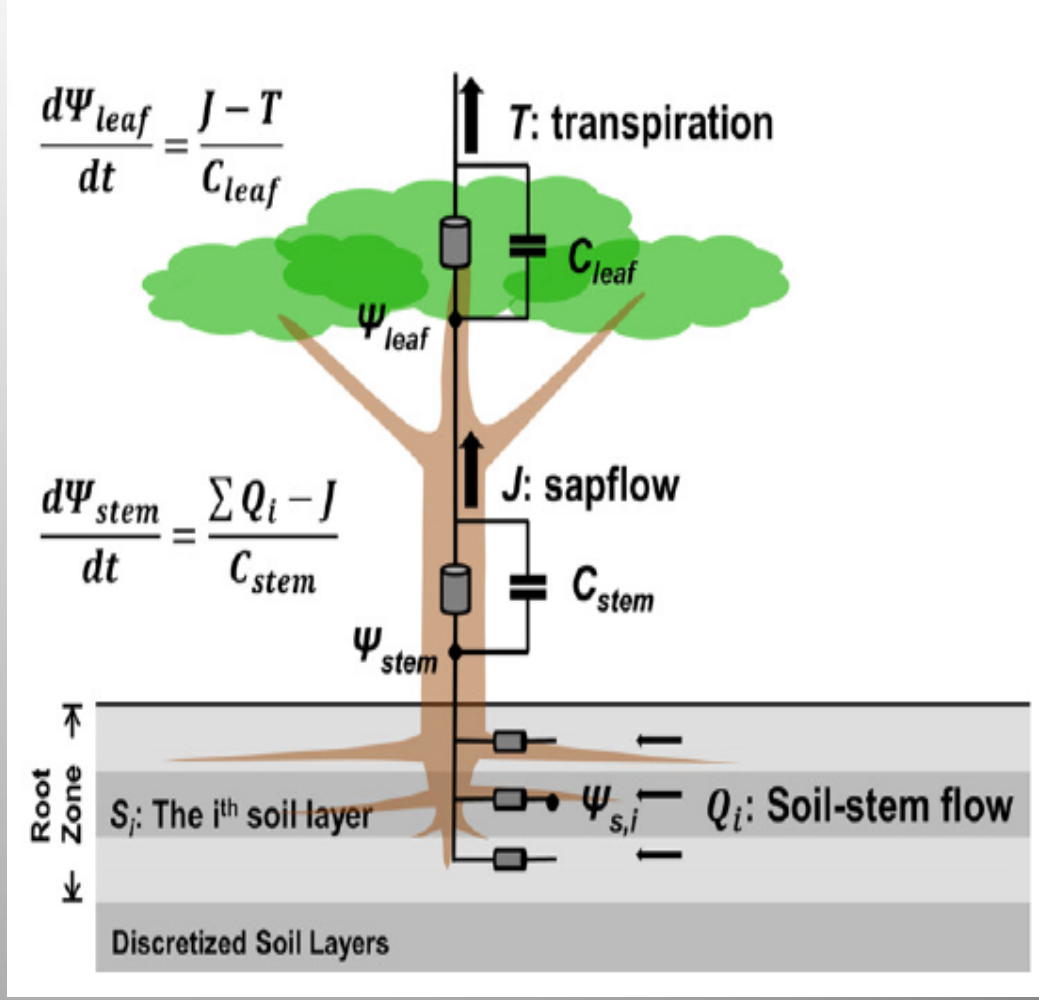
FETCH2 plant hydrodynamics model



- Mirfenderesgi, Bohrer, Matheny et al. 2016, JGR Biogeosciences

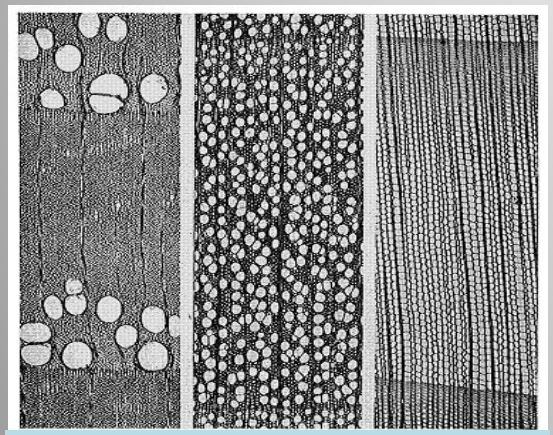
Plant hydraulics models





- Sperry et al. 1998 SPA model
- Xu et al. 2016 New Phytologist (ED2-Hydro)

Porous media analogy



Oak, maple, and pine wood cross sections

- 1-D Richards equation along hydraulic path length *l*:

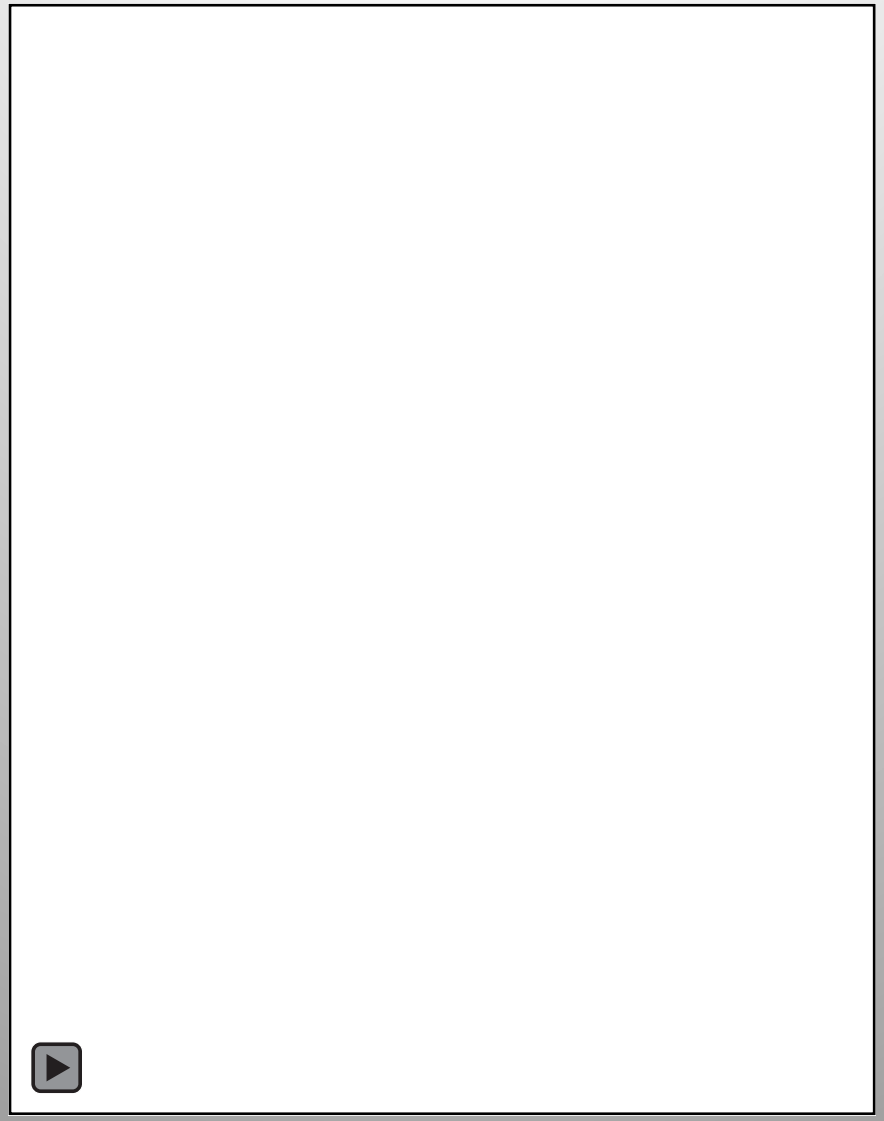
$$C(\Phi)\frac{\partial \Phi}{\partial t} = \frac{\partial}{\partial l}\left[K(\Phi)\left(\frac{\partial \psi}{\partial l}\right)\right] - Sink$$

- A modified 1-D Richards equation for flow in a tree:

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

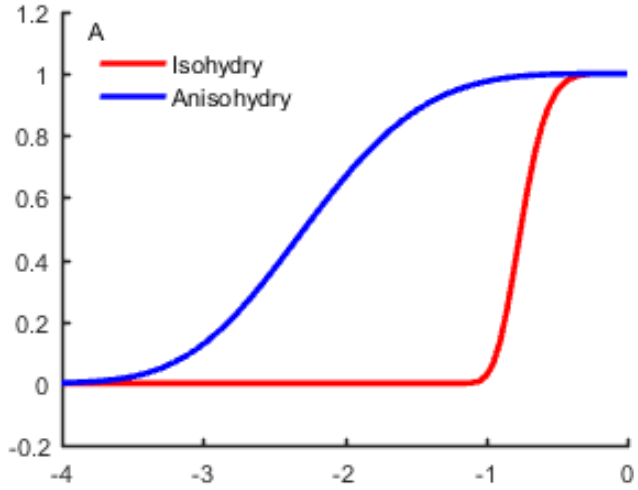
Capacitance | Conductance | Pressure gradient | Transpiration

FETCH2



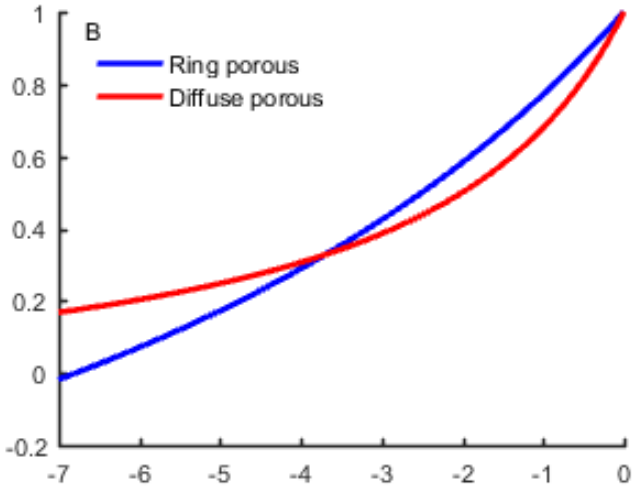
Hydraulic trait parameterization

Stomatal response (β)



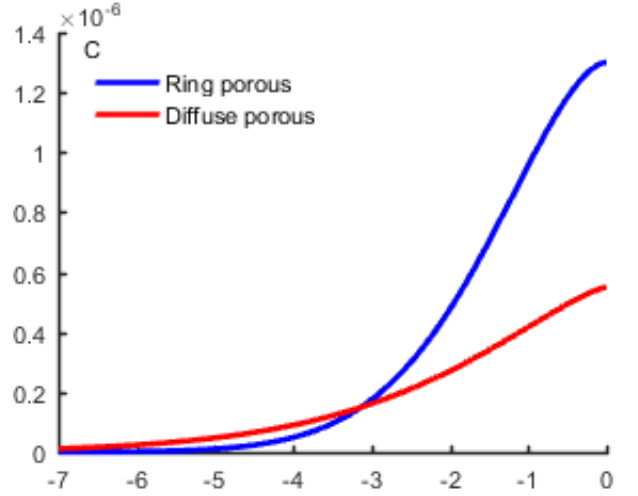
Leaf water potential (MPa)

Capacitance response

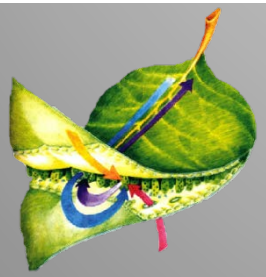


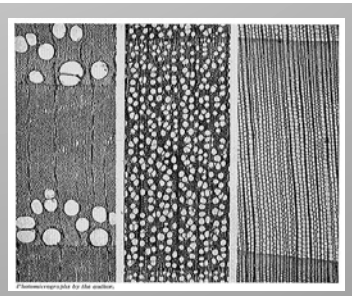
Xylem water potential (MPa)

Conductance (kg $m^{-1}s^{-1}MPa^{-1}$)



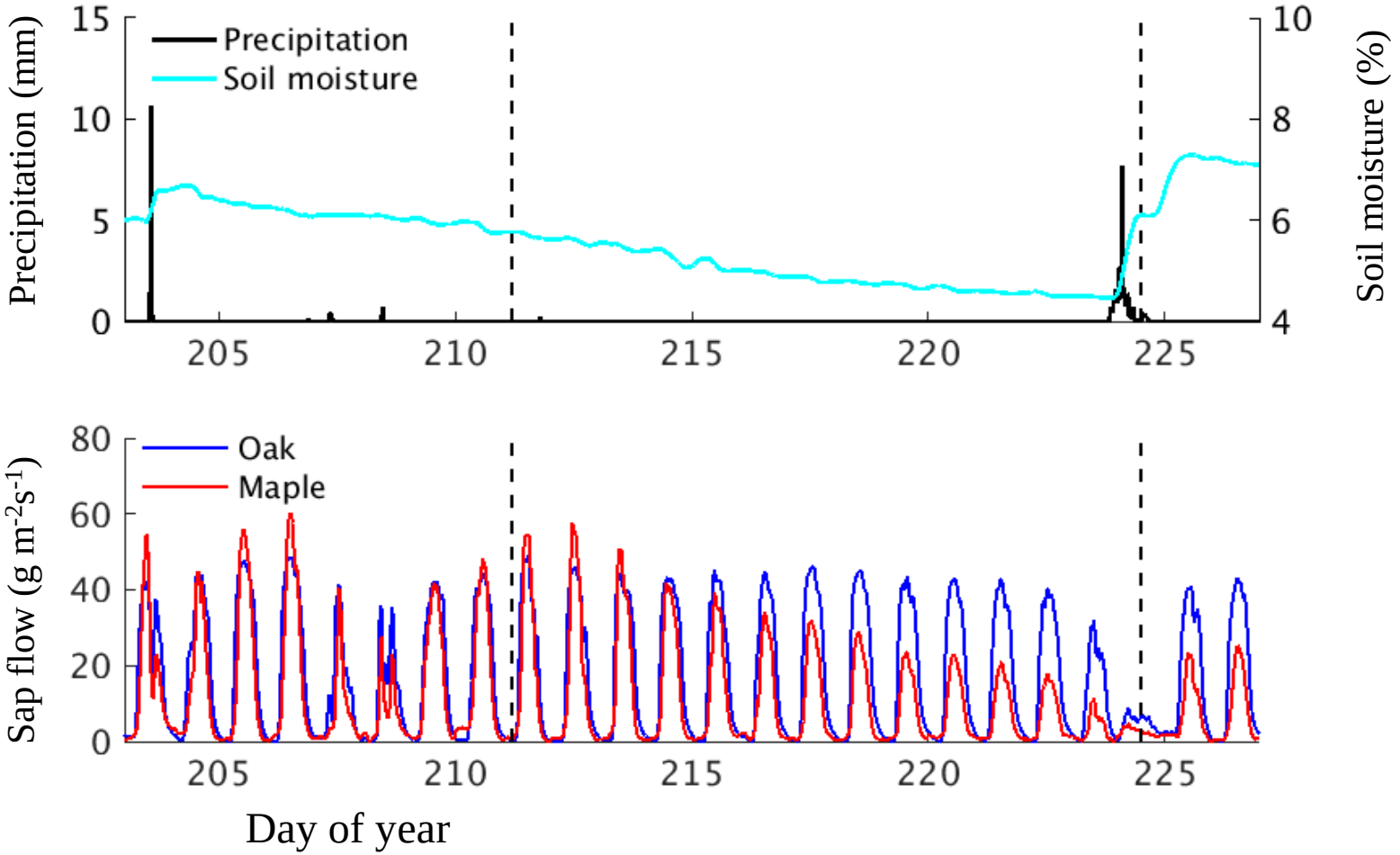
Xylem water potential (MPa)



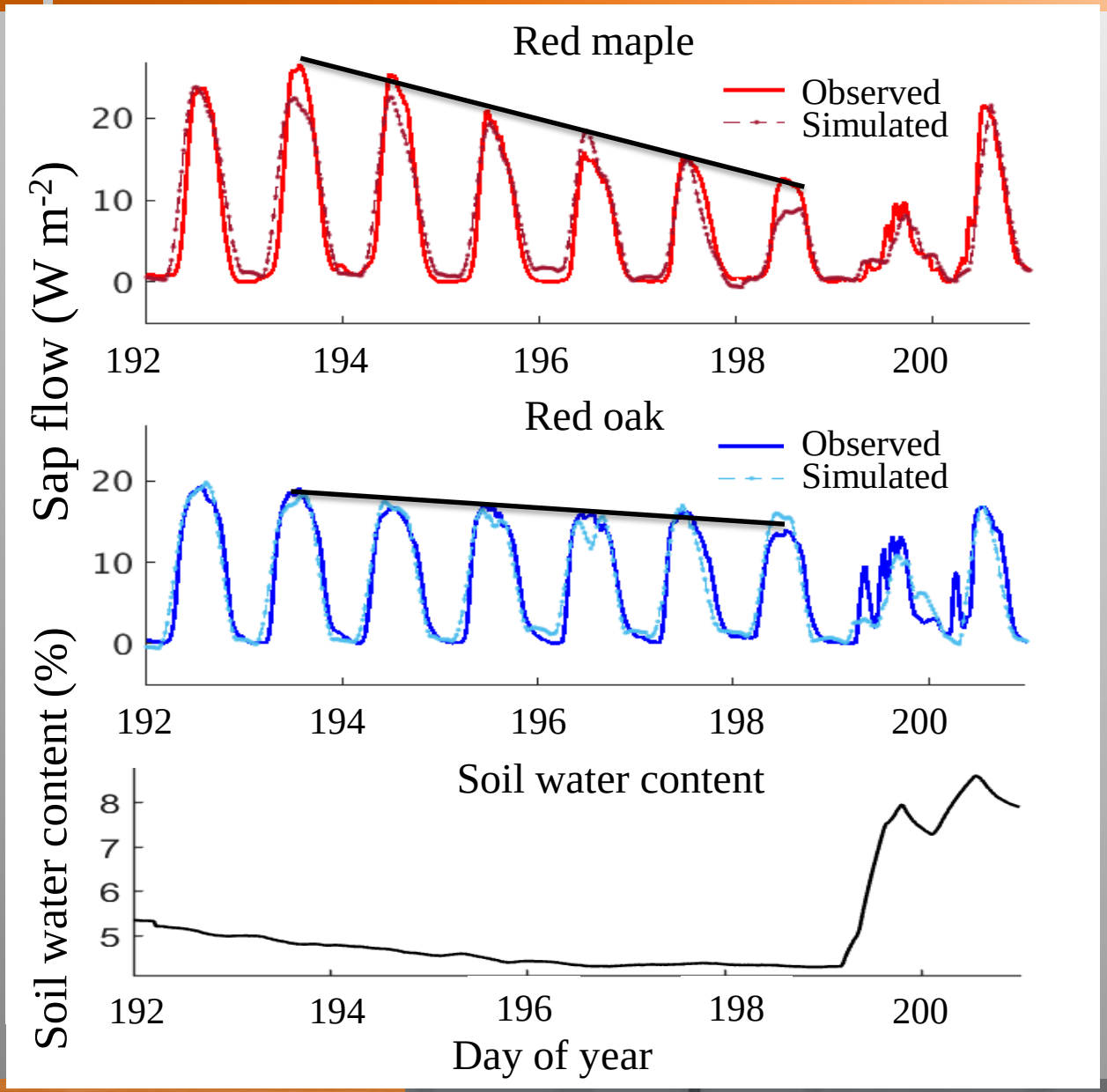


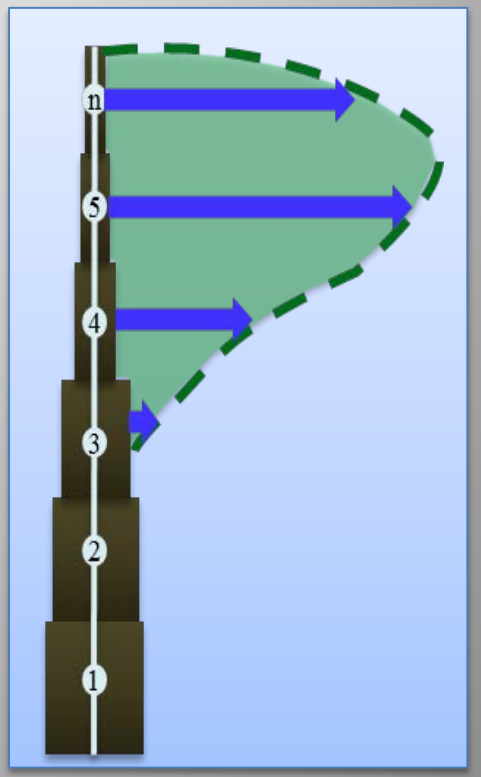
- Matheny et al. 2016, Ecohydrology

Can the FETCH2 model replicate behavior?

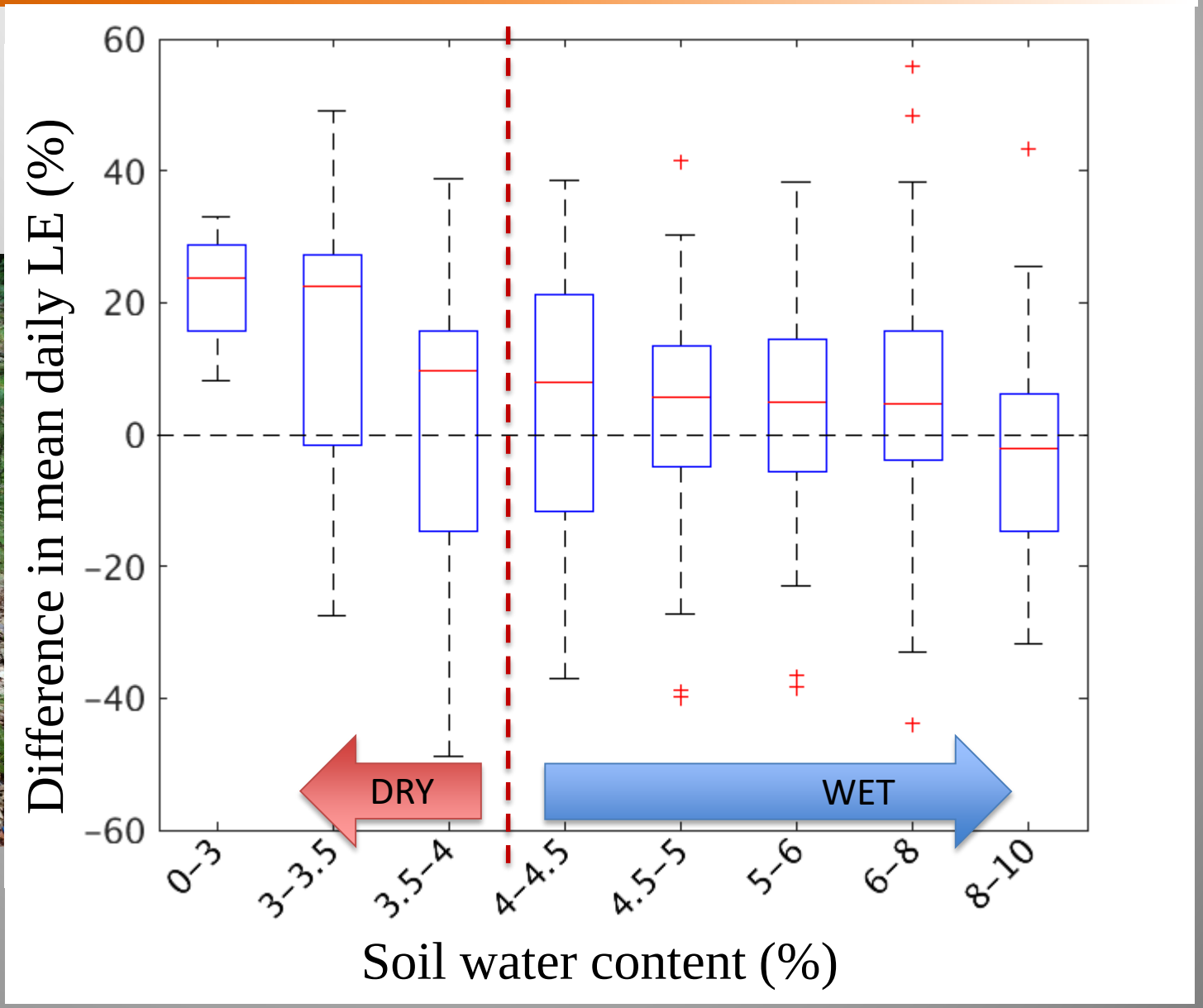


FETCH2 simulation of the ‘mini drought’

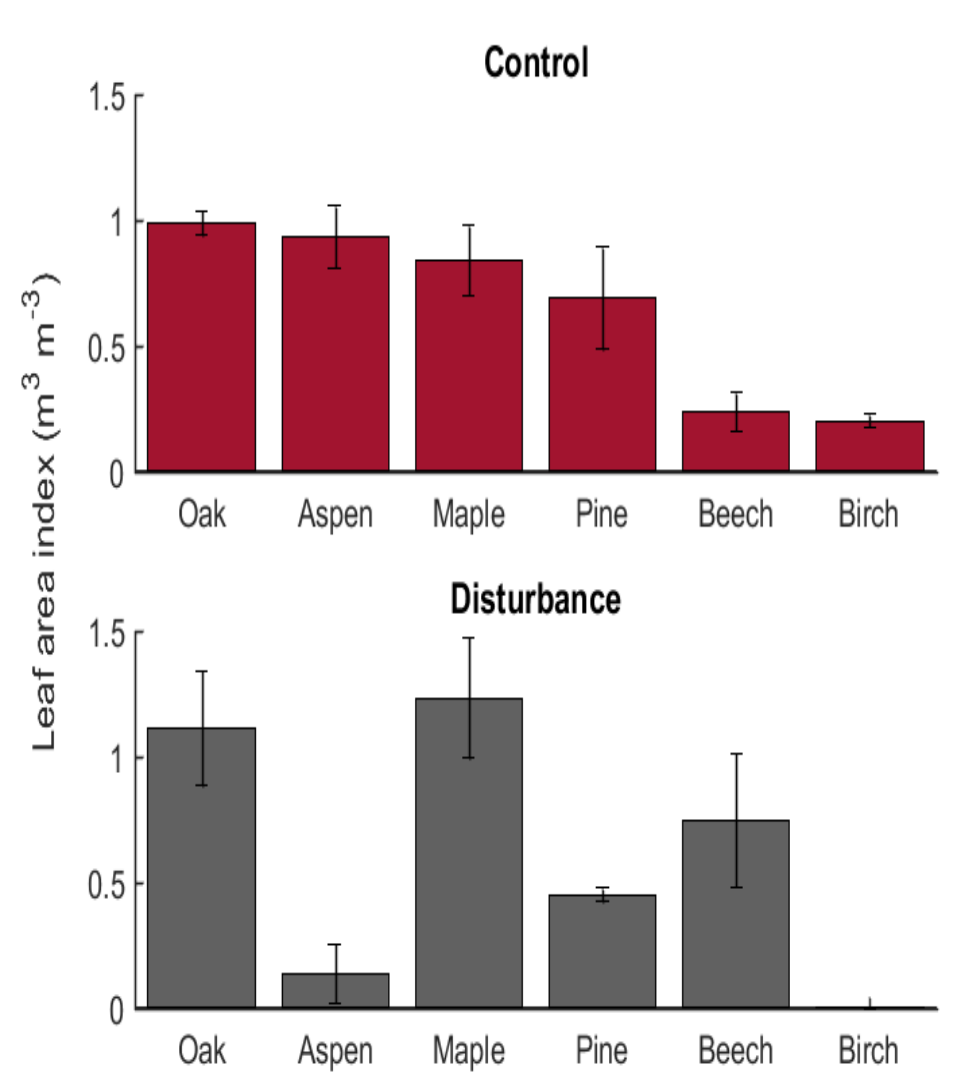




Forest response to disturbance – a first test



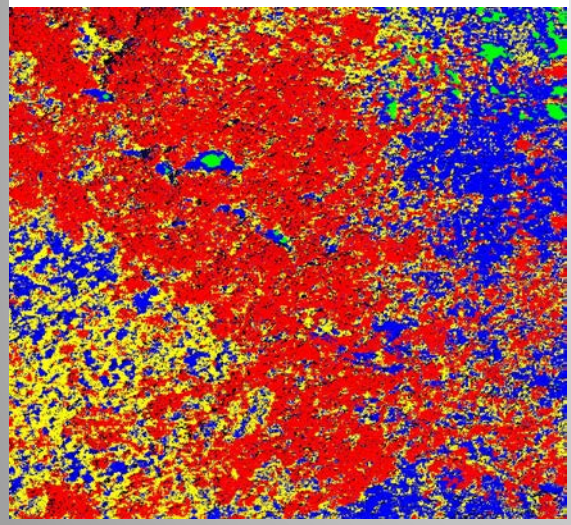
Changes to LAI



- Control LAI ≈ 3.89 m^2m^{-2}
- Disturbance LAI ≈ 3.68 m^2m^{-2}

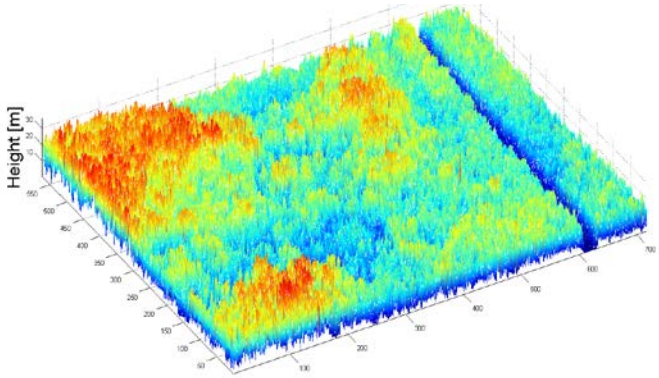
Scaling from trees to ecosystems

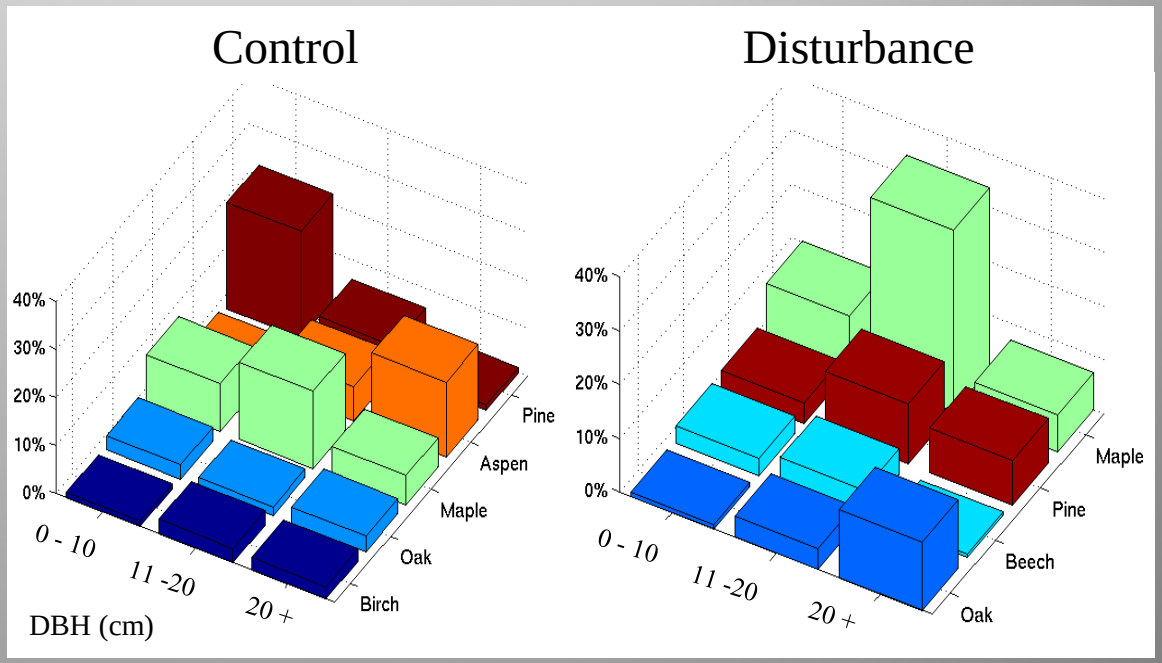
Multispectral imagery of UMBS



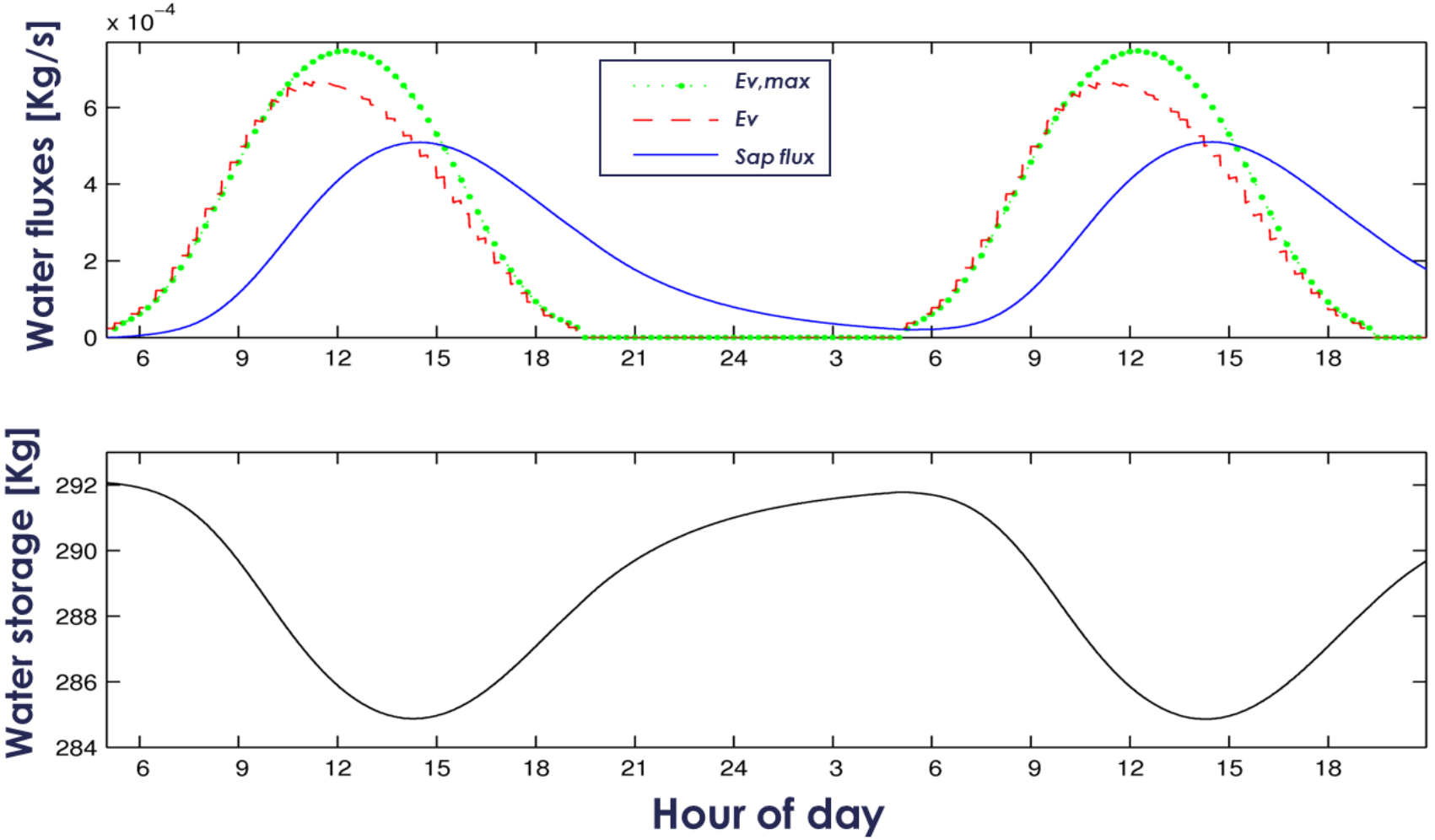
- Trees within the same histogram ‘bin’ are assumed to transpire similarly.

Aerial LiDAR of UMBS

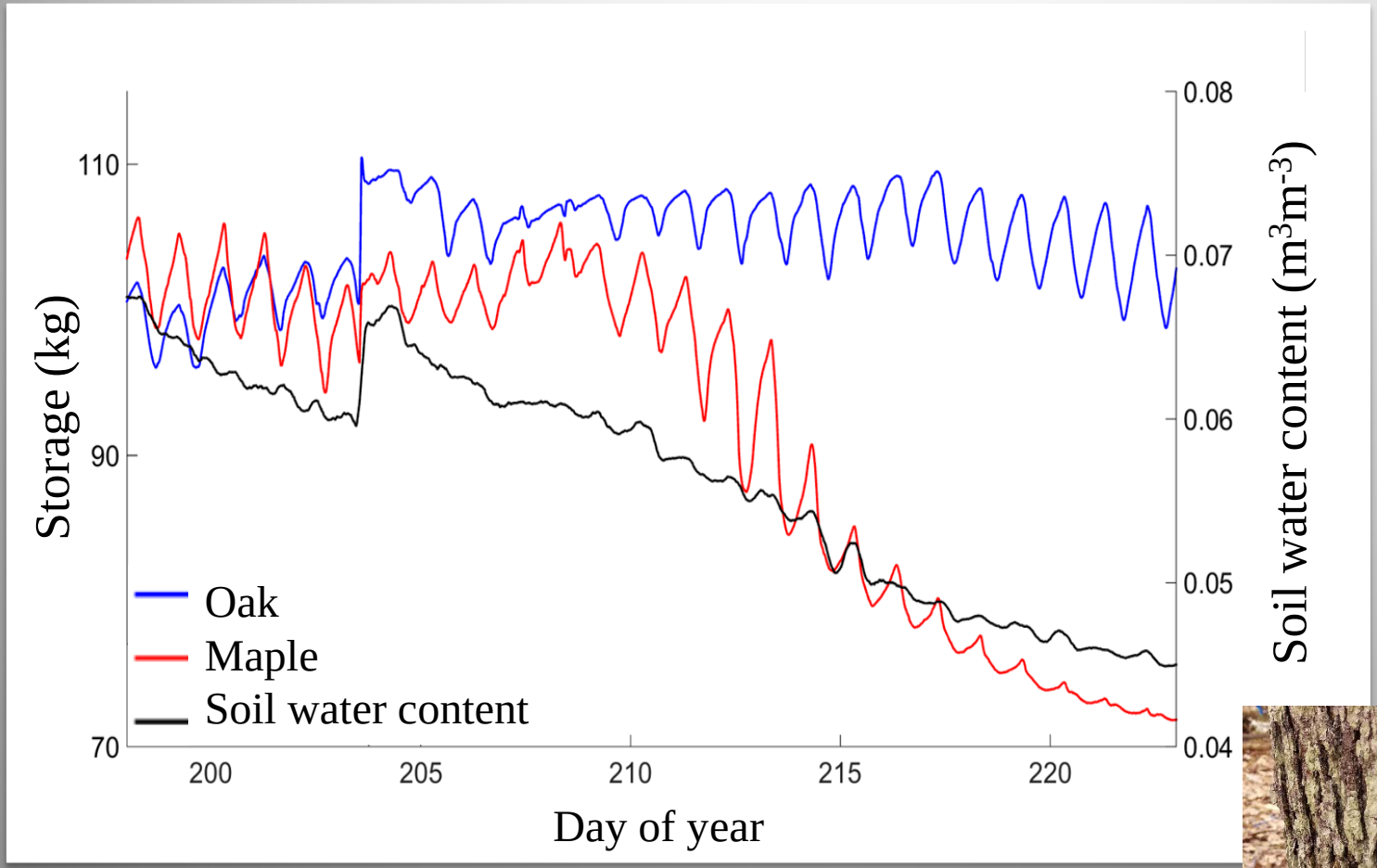




FETCH2 Outputs



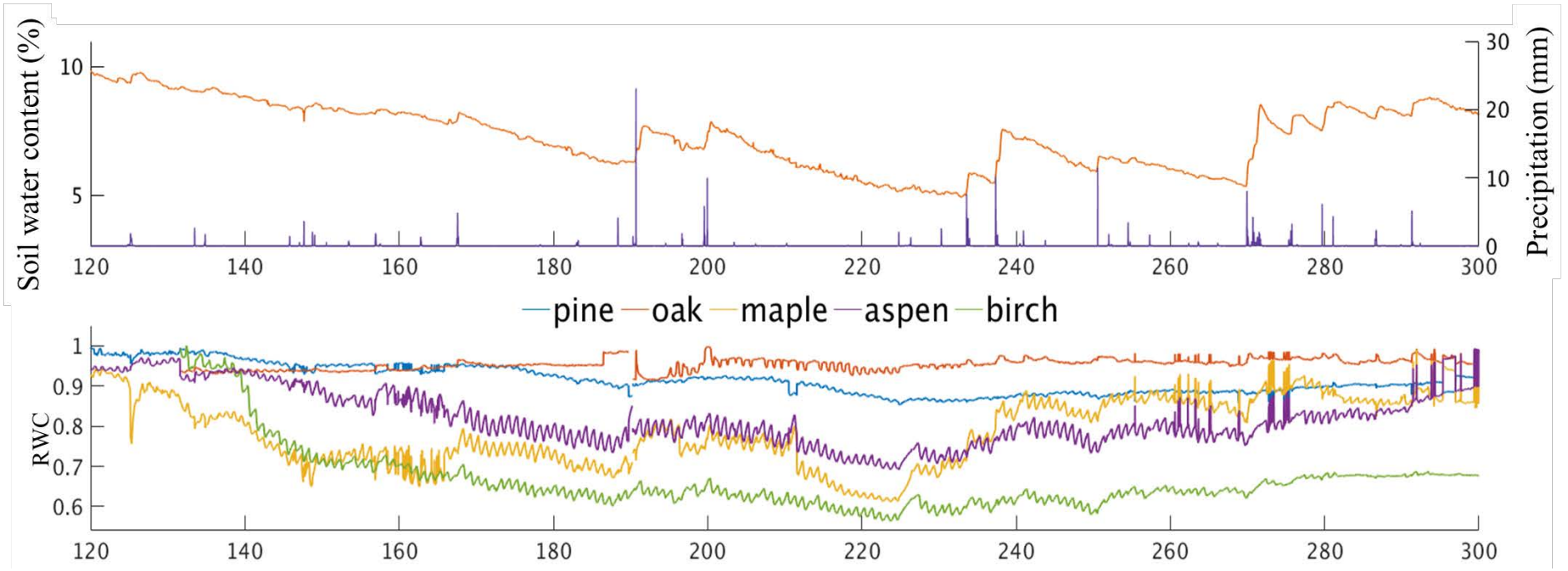
Opposing reliance on capacitance



GS-3 in maple, 2016

- Matheny et al. 2015, Ecosphere

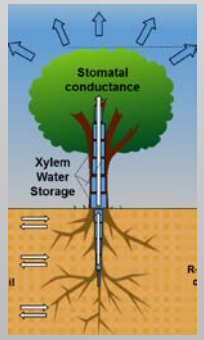
Biomass water content data – Available for use!



Julian day

- Plant hydraulics models capture different drought responses

- Interchangeable modules coming to a CLM-FATES near you… eventually



- Data available for test cases: sap flux (9 years), biomass water content (3 years) ashley.matheny@jsg.utexas.edu