The theoretical basis for tree hydraulics

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Keck Institute for Space Studies
Sensing Forest Water Dynamics From Space: Towards Predicting the Earth System Response to Droughts
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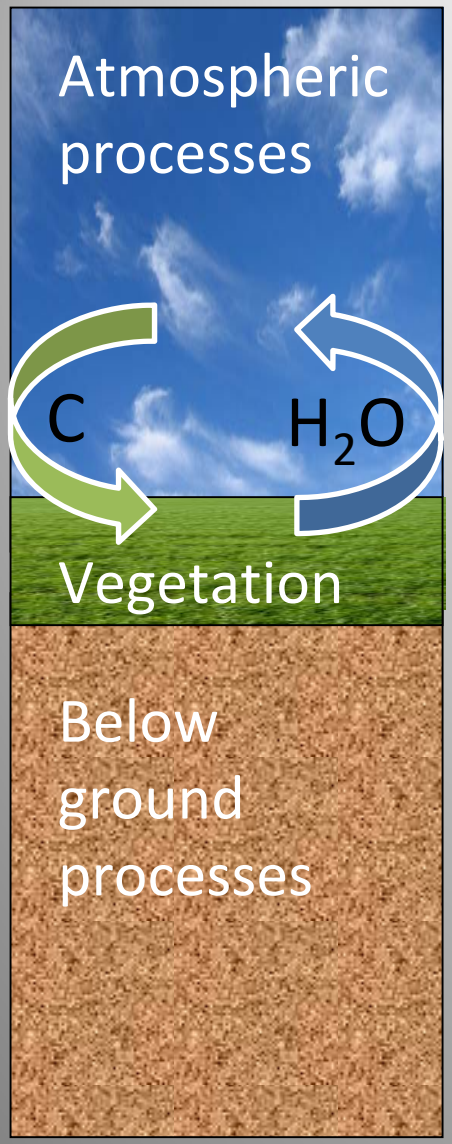
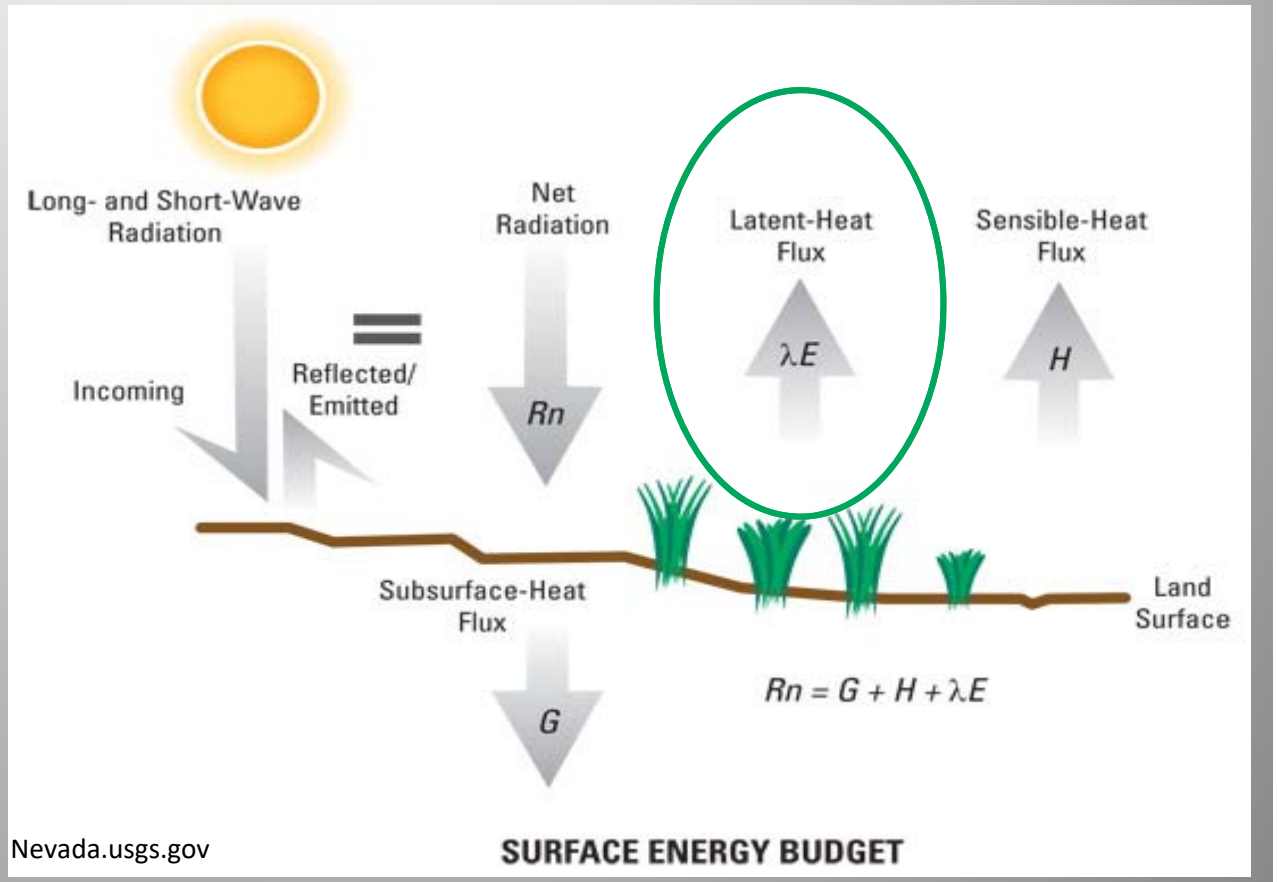
Vegetation-atmosphere feedbacks

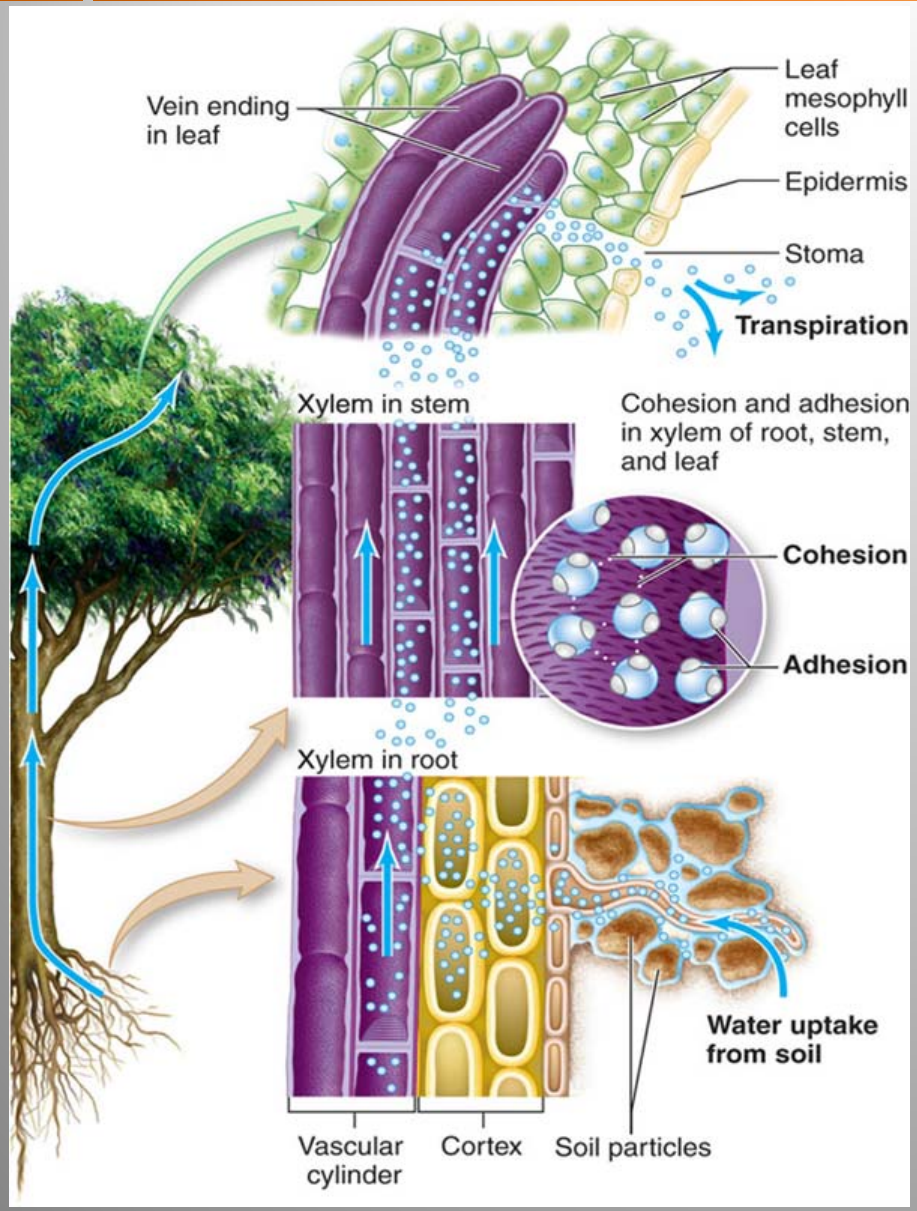


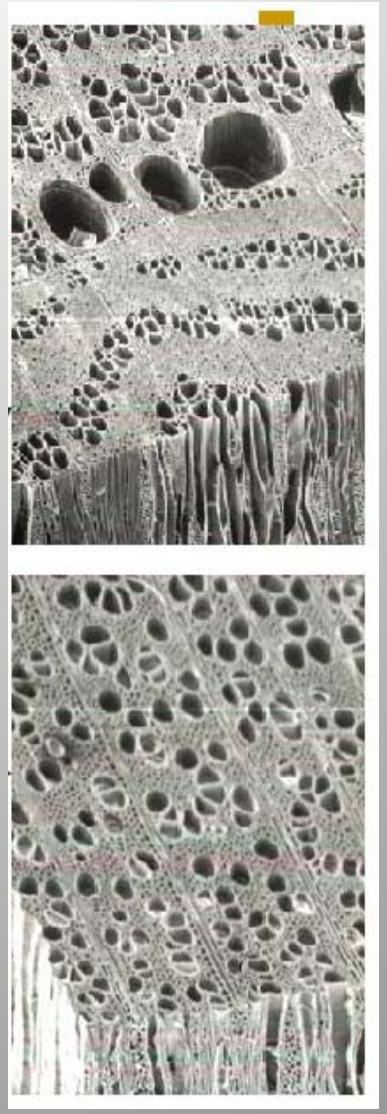


How much water is flowing?

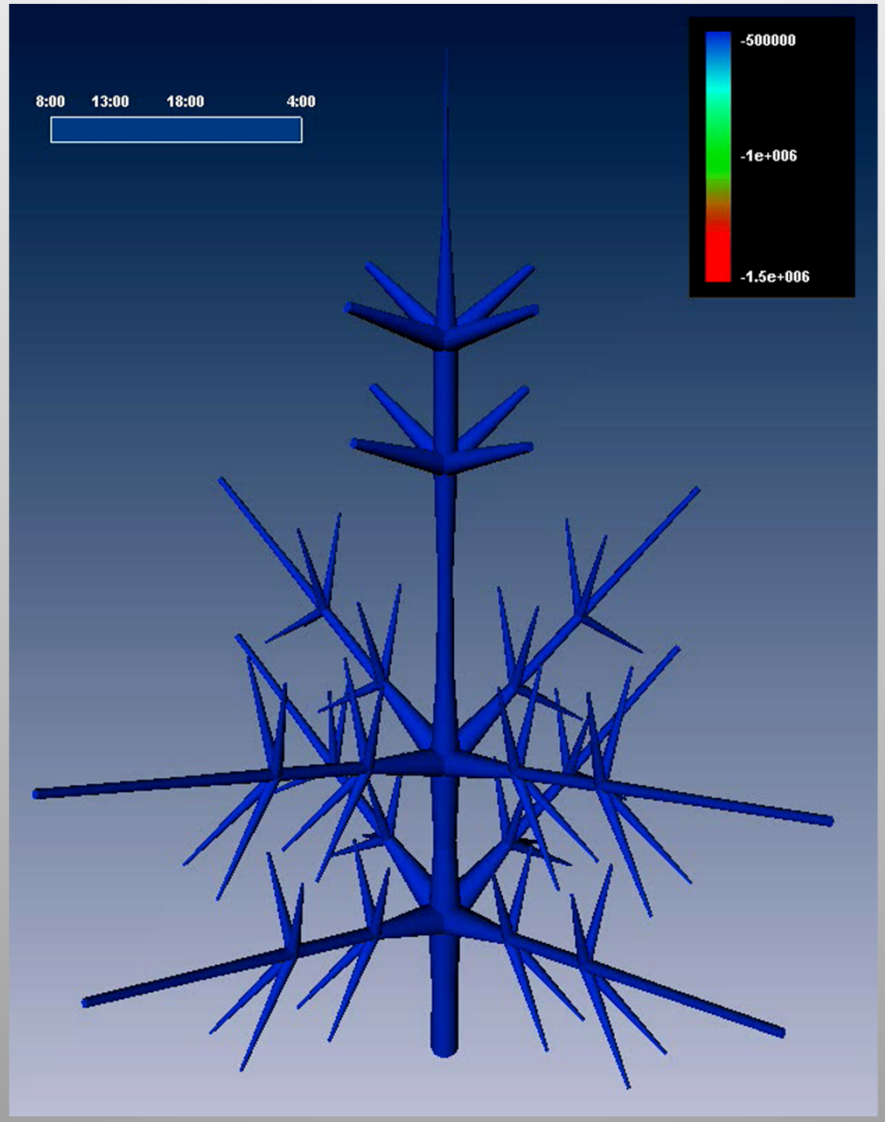
Sap leaks from a birch tree during sensor installation in real time

Water transport: the basics



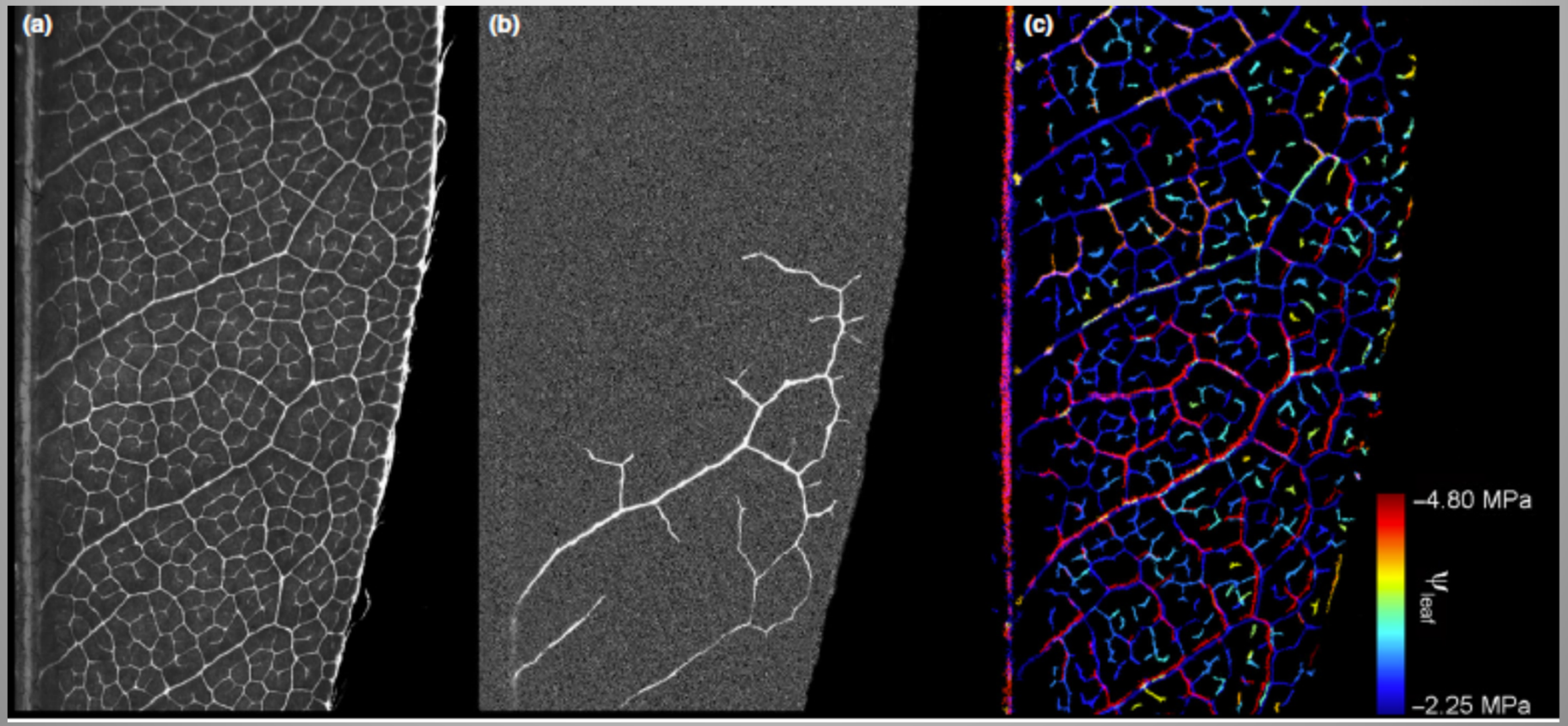


Water movement inside of a plant



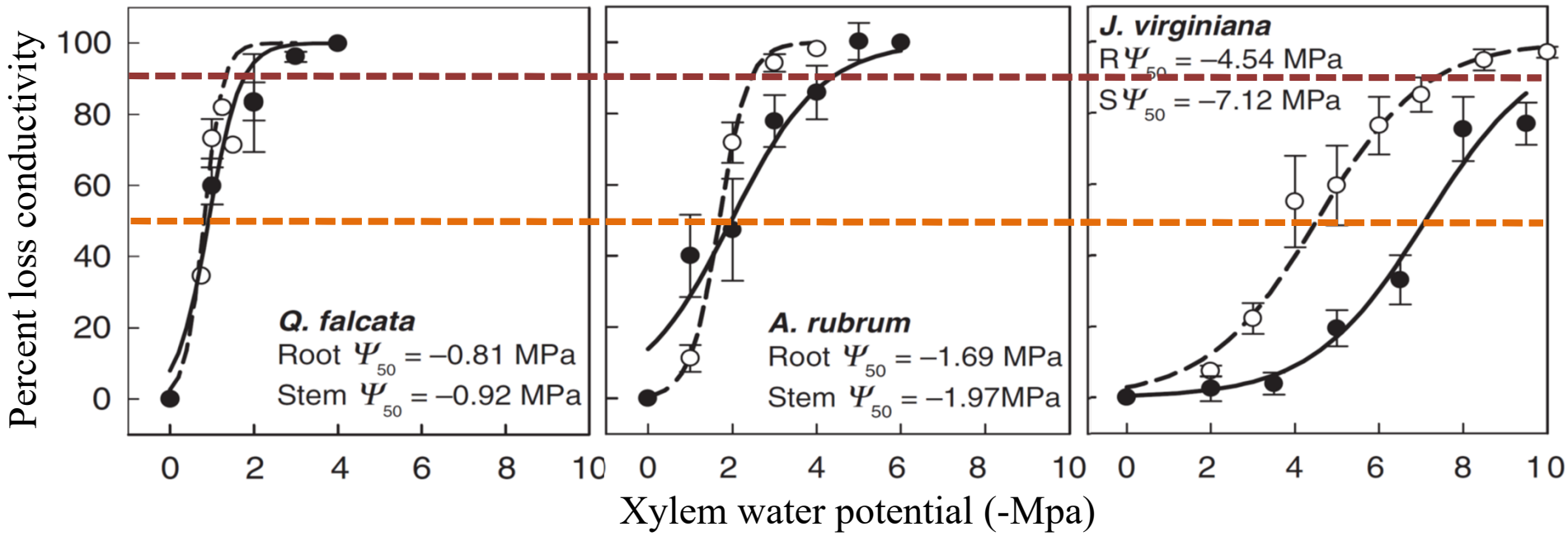
- From Bohrer et al 2005, WRR

The onset of hydraulic limitations



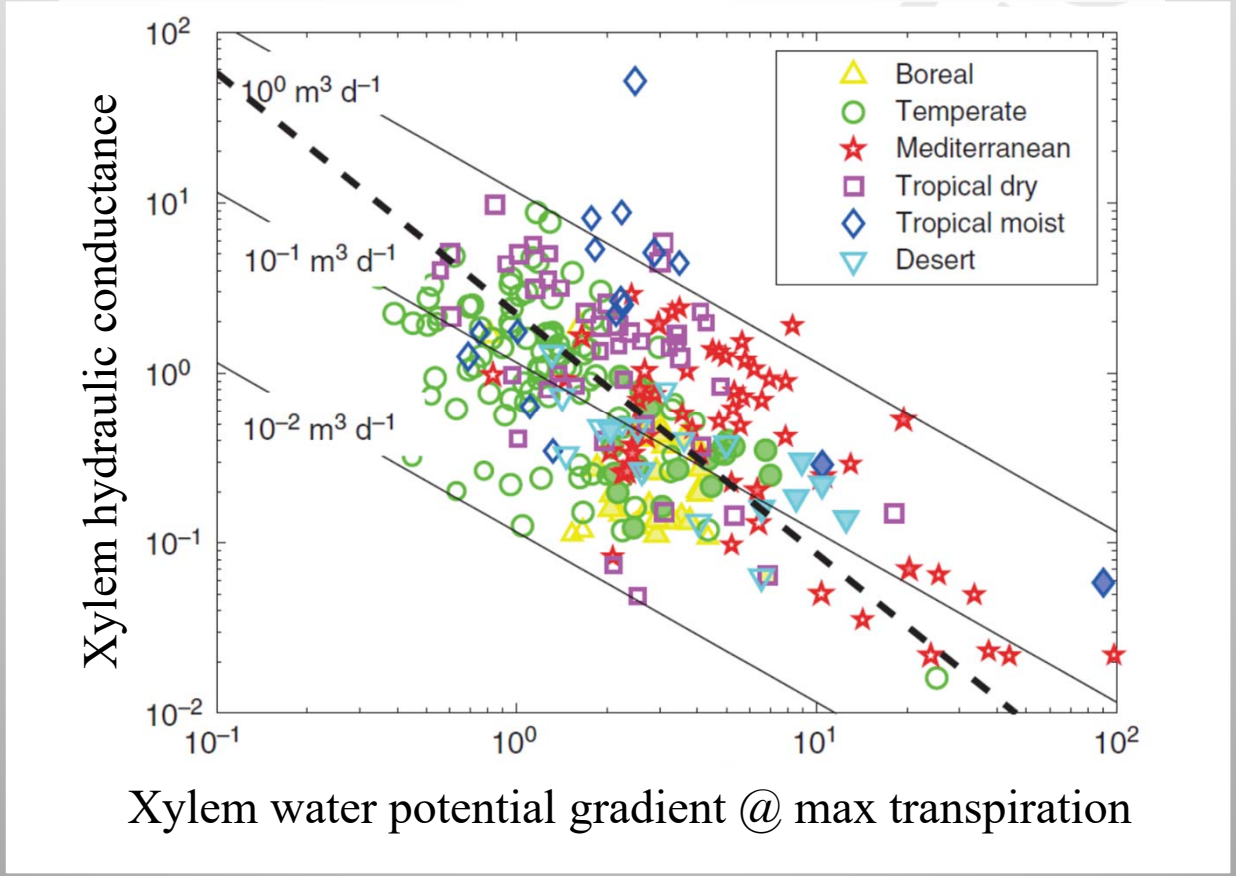
- From Brodribb et al. 2015, New Phytologist

Cavitation and hydraulic vulnerability



- From Maherali et al. 2006, PC&E

Trading safety for efficiency?



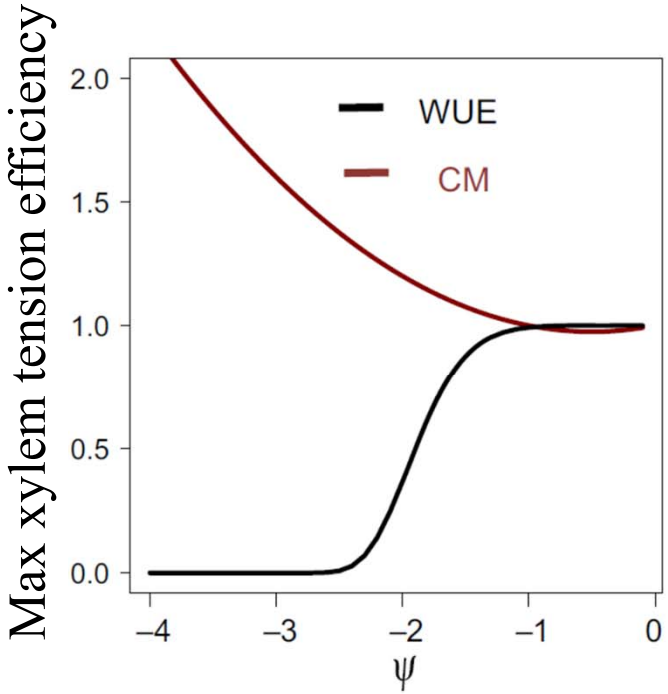
- From Manzoni 2013, New Phytologist

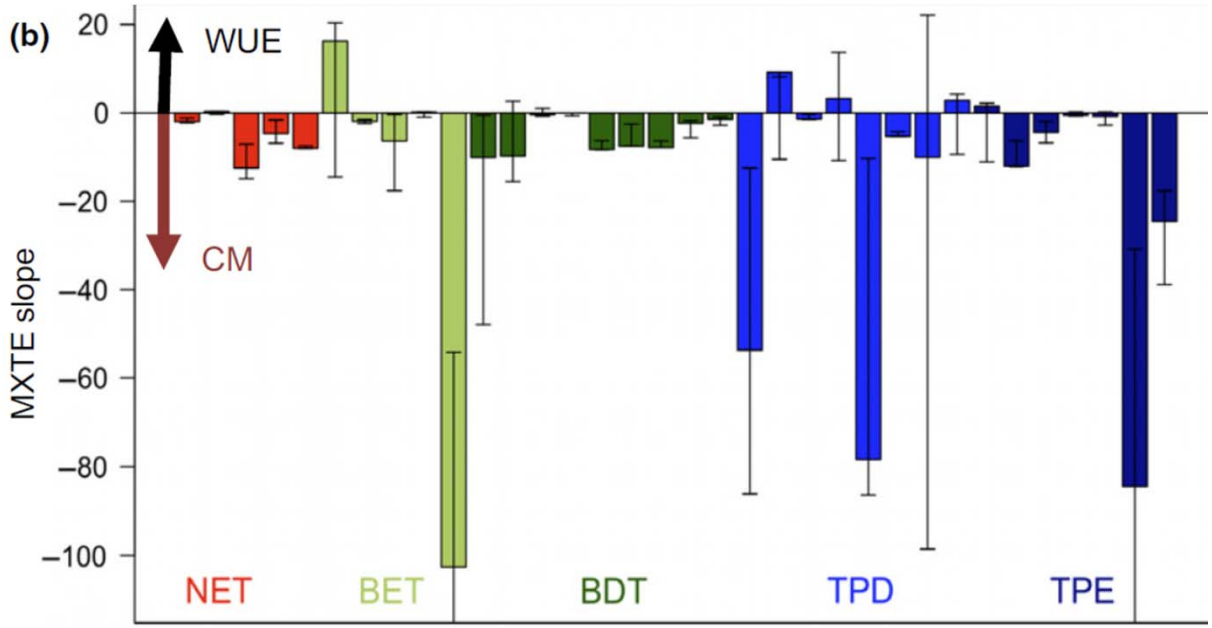
- A perfect tradeoff of safety and efficiency doesn't exist (Gleason 2016, New Phytologist), because compounding variables abound

Trading carbon for water:

Carbon maximization theory

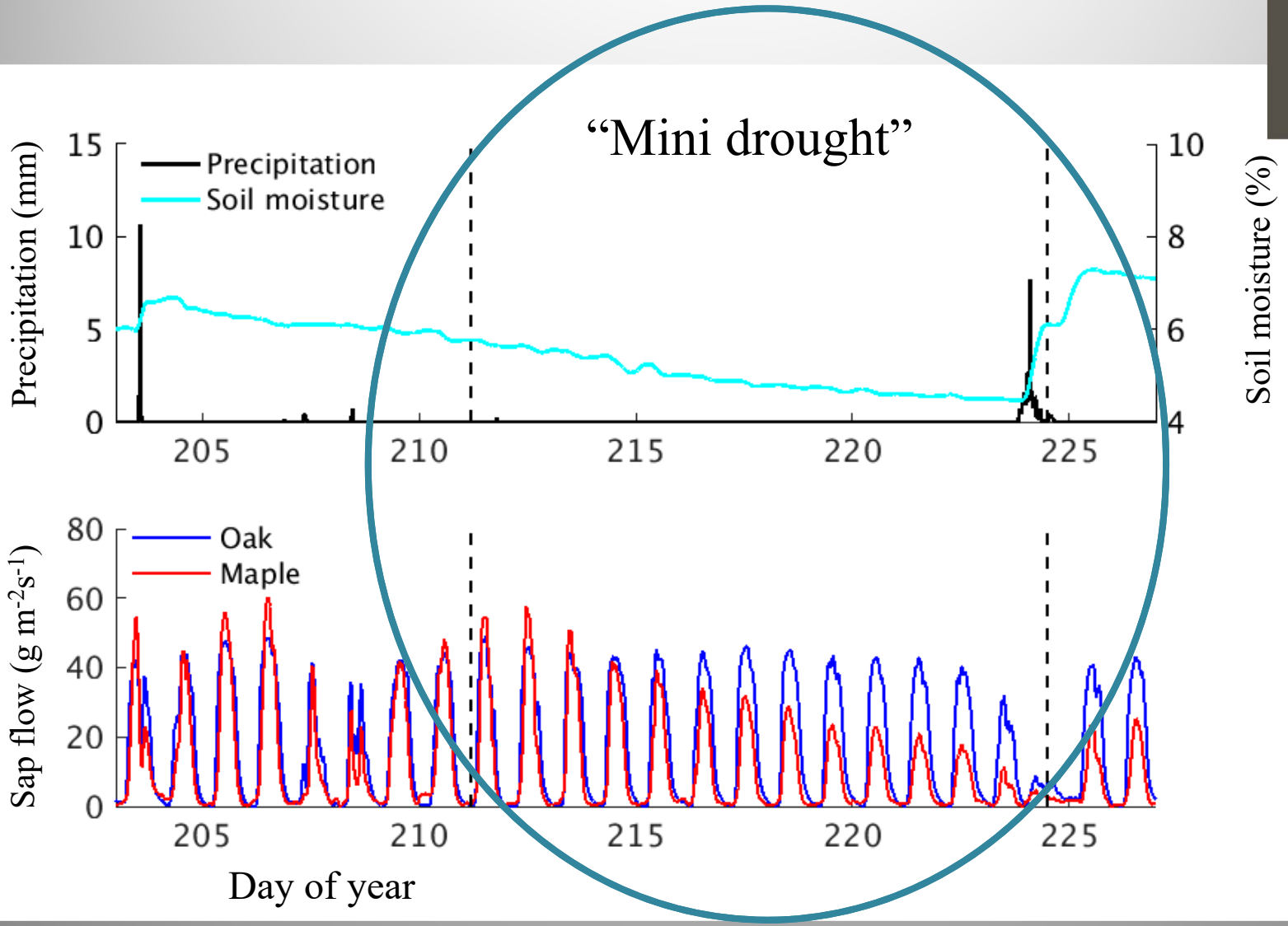
$$MXTE = \frac{\partial A_n}{\partial \psi_L}$$





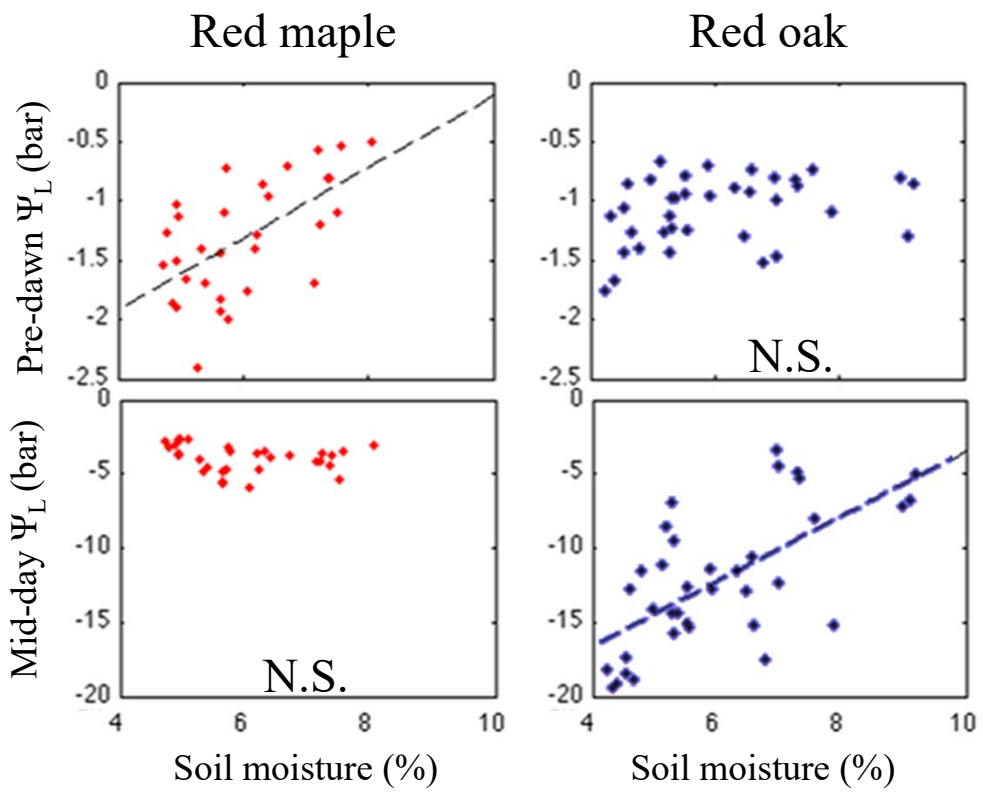
- From Anderegg et al. 2018, Ecology Letters

Consequences of hydraulic strategies

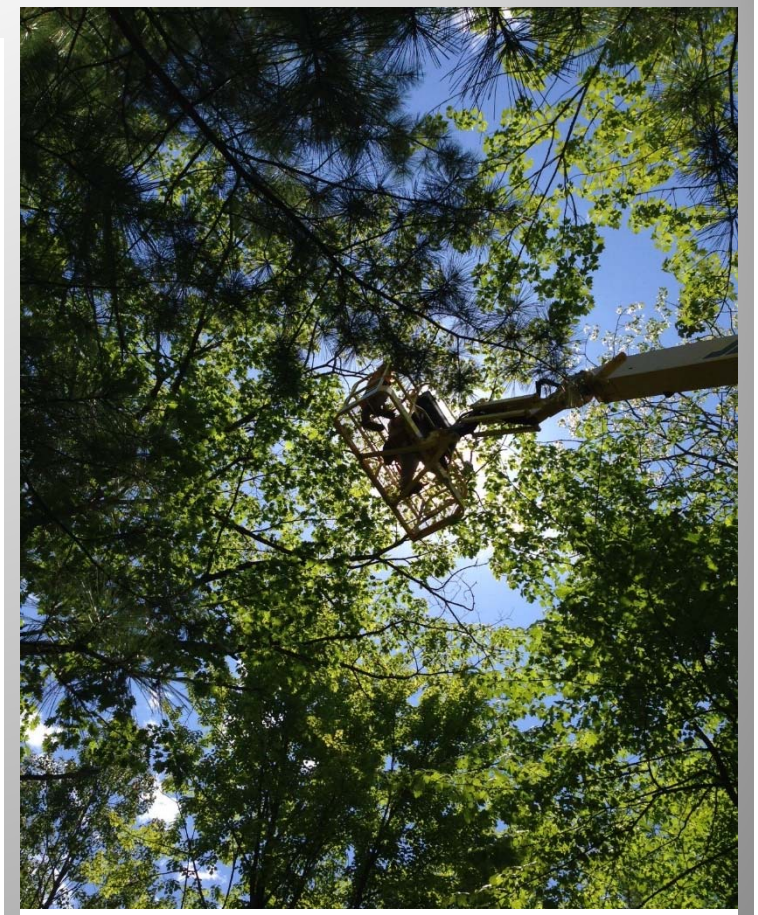


- Matheny et al. 2017, Ecohydrology

Diurnal leaf water dynamics



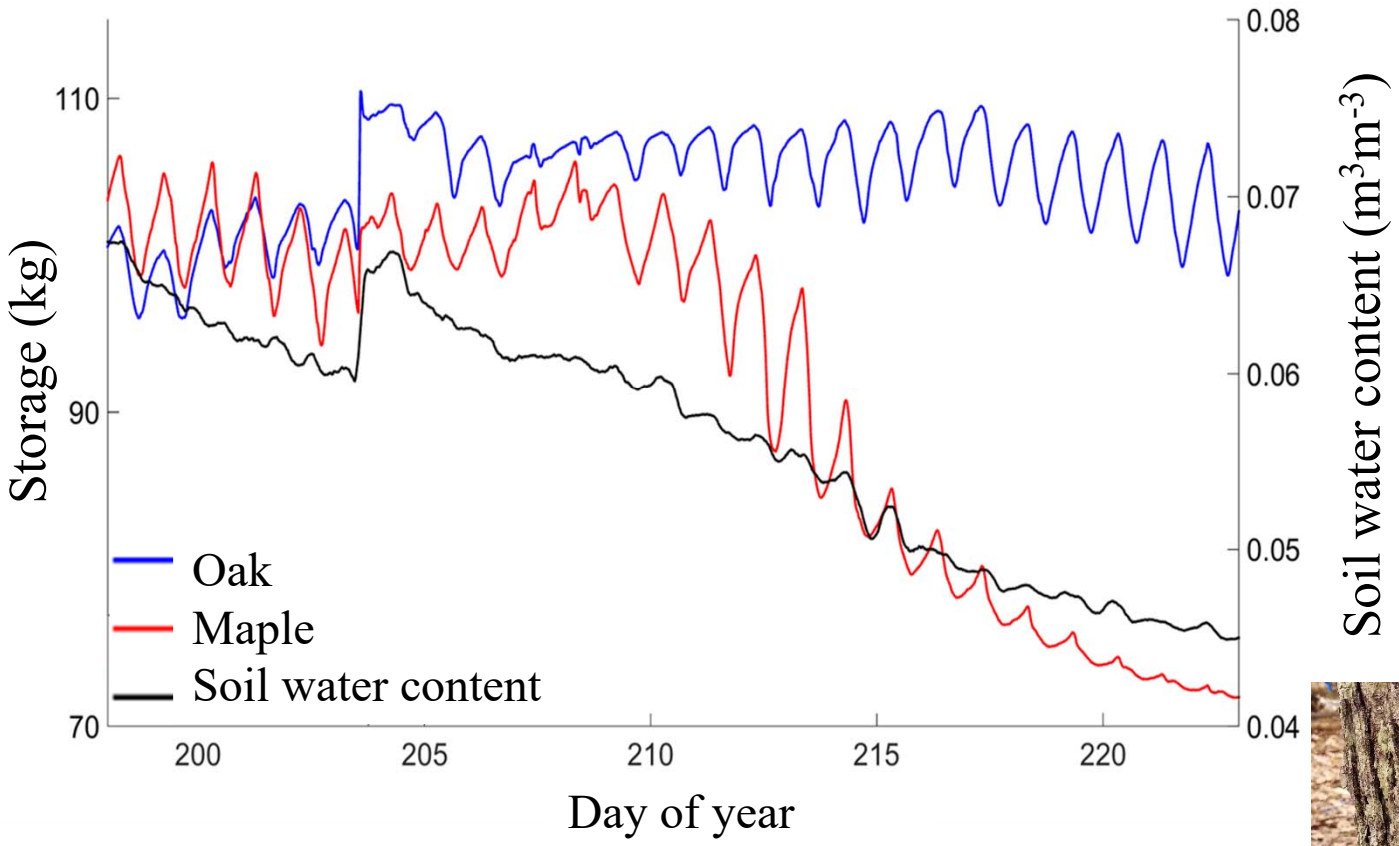
*Note: 10 bar = 1 MPa



Measuring leaf water potential with Alyssa Wunderlich (REU), summer 2014

- Thomsen et al. 2013, Forests

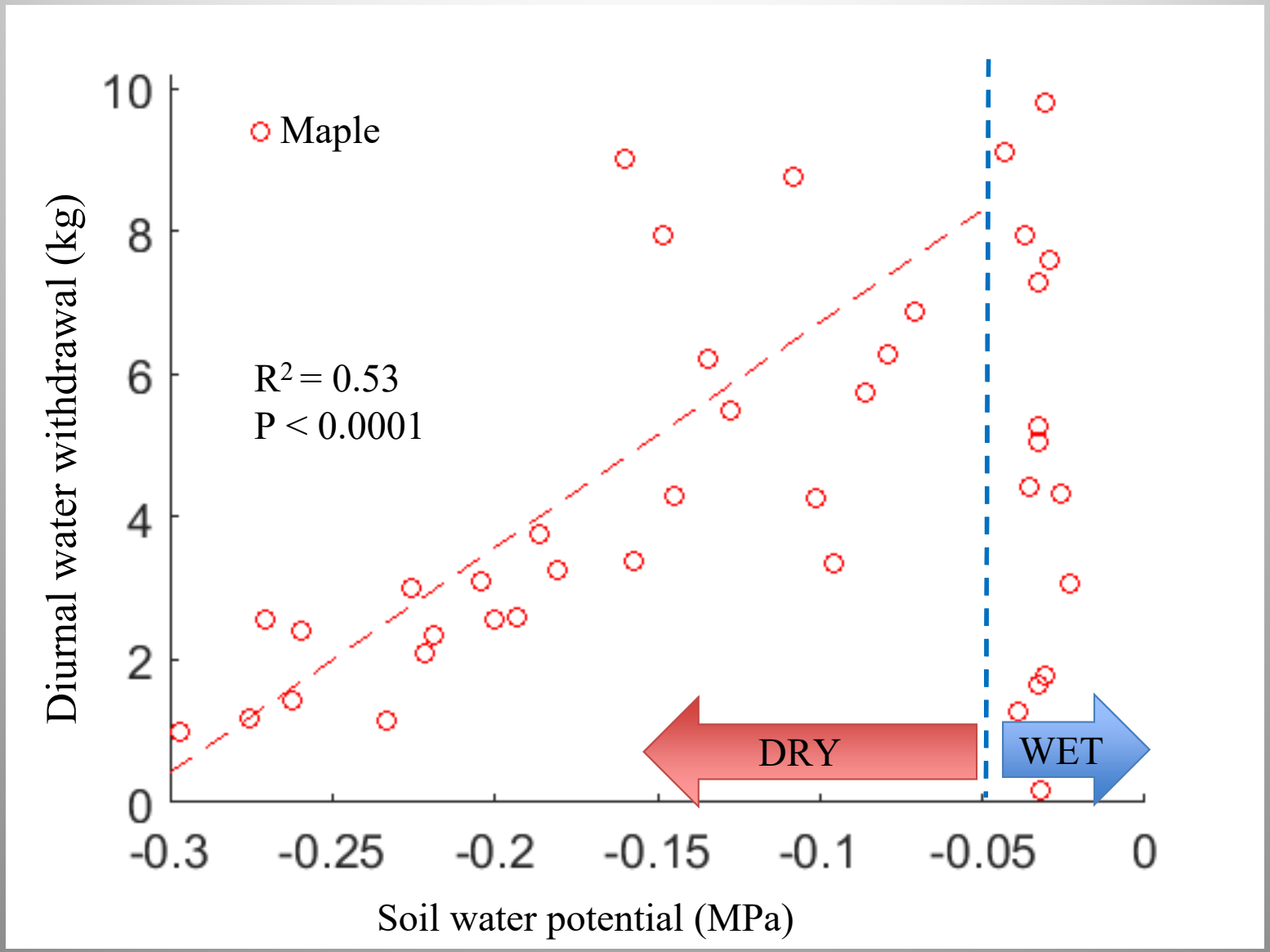
Reliance on biomass capacitance



Capacitance sensor in maple, 2016

- Matheny et al. 2015, Ecosphere

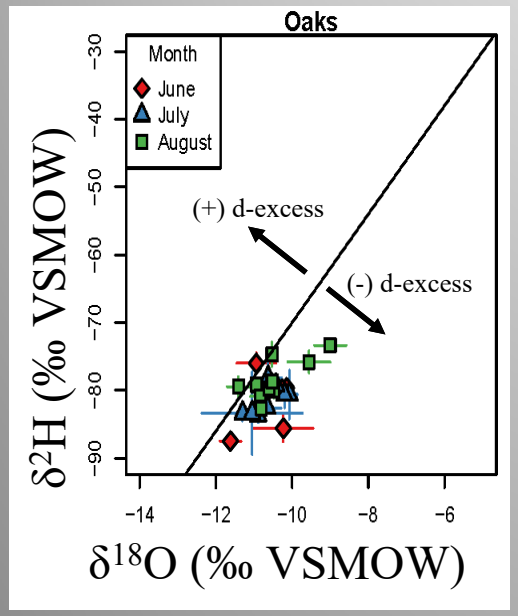
Water storage dynamics with declining soil water

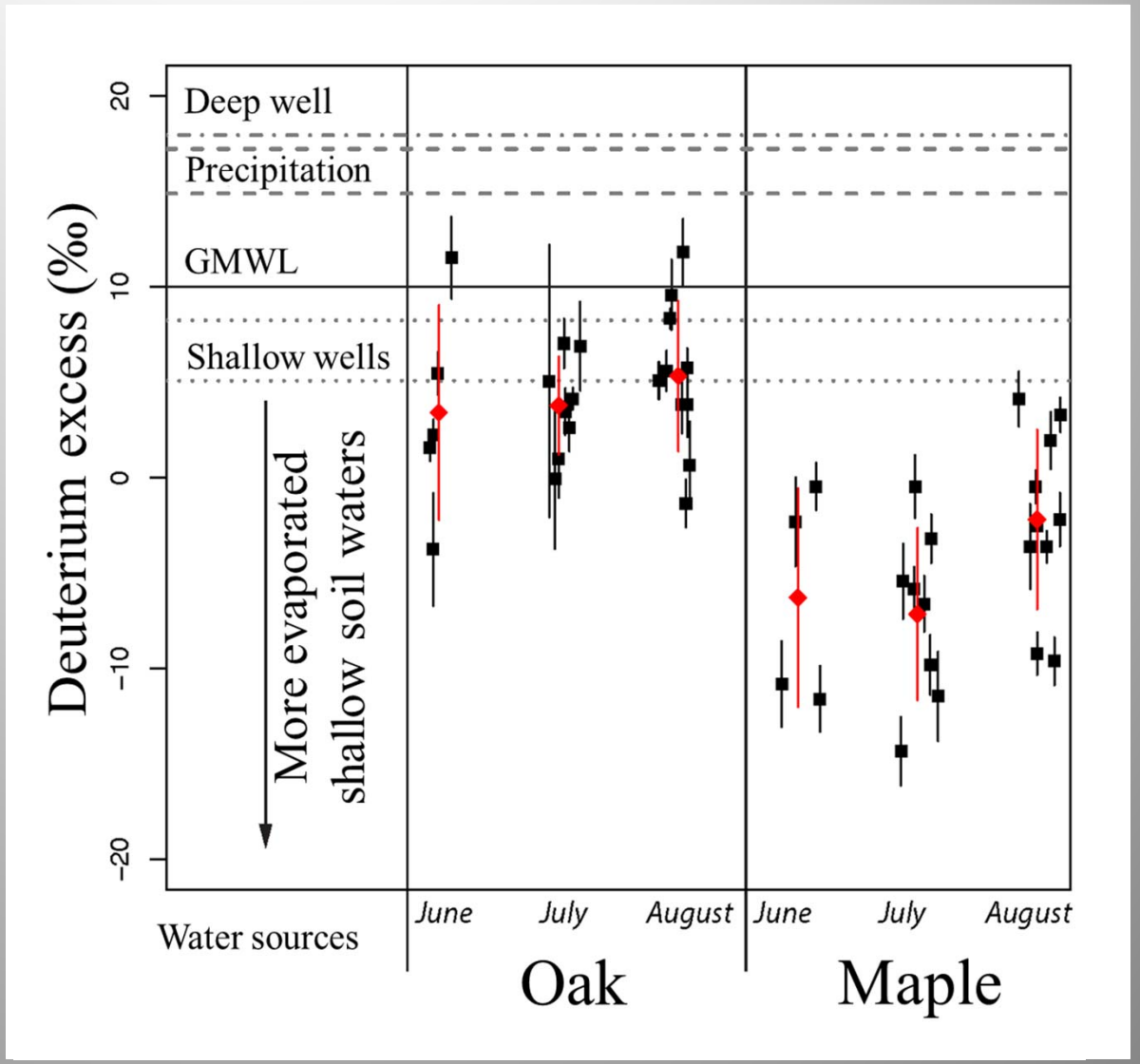


Differential access to water in the root-zone

- D-excess:

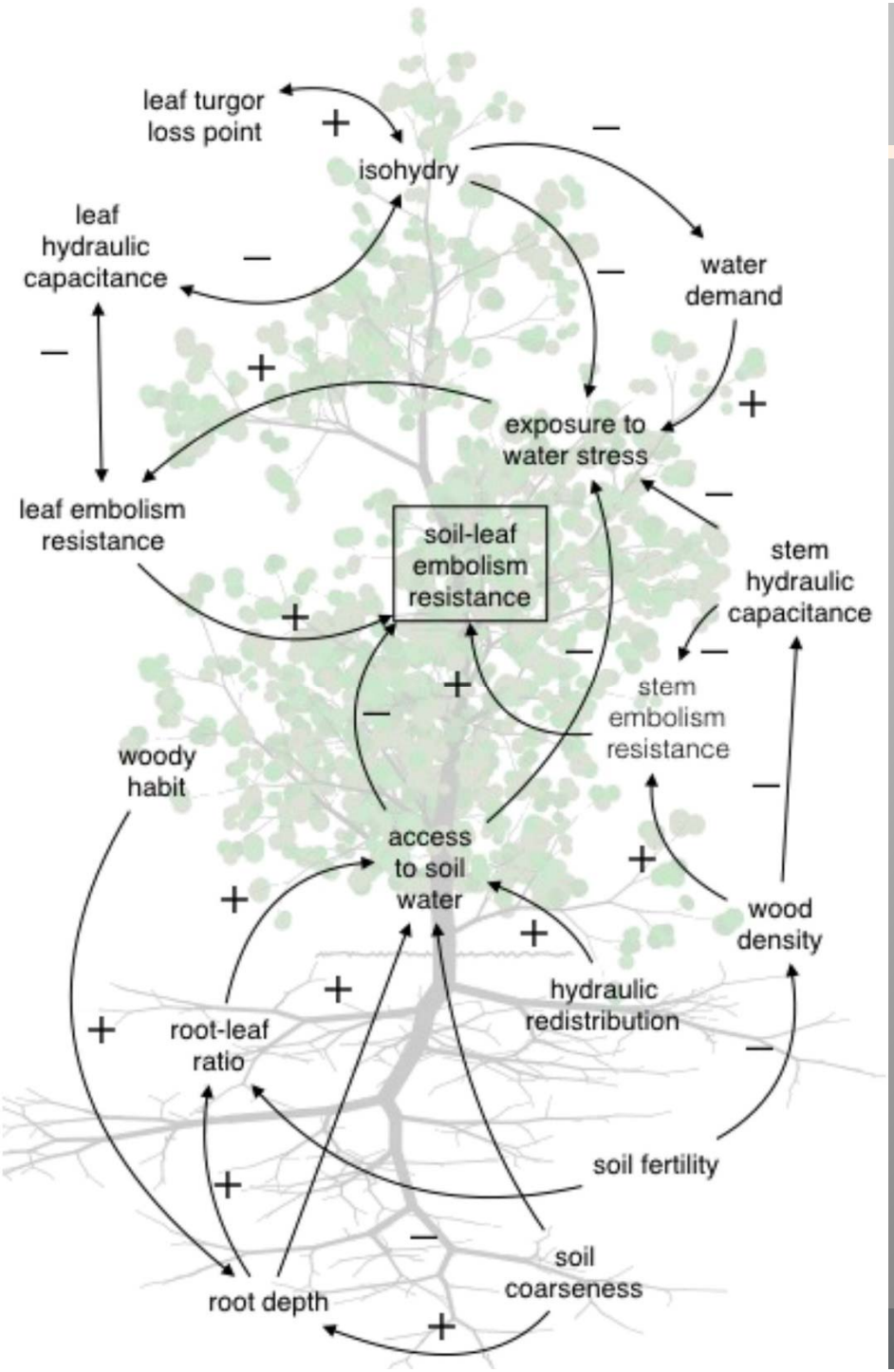
$$\delta D - 8^* \delta^{18}O$$





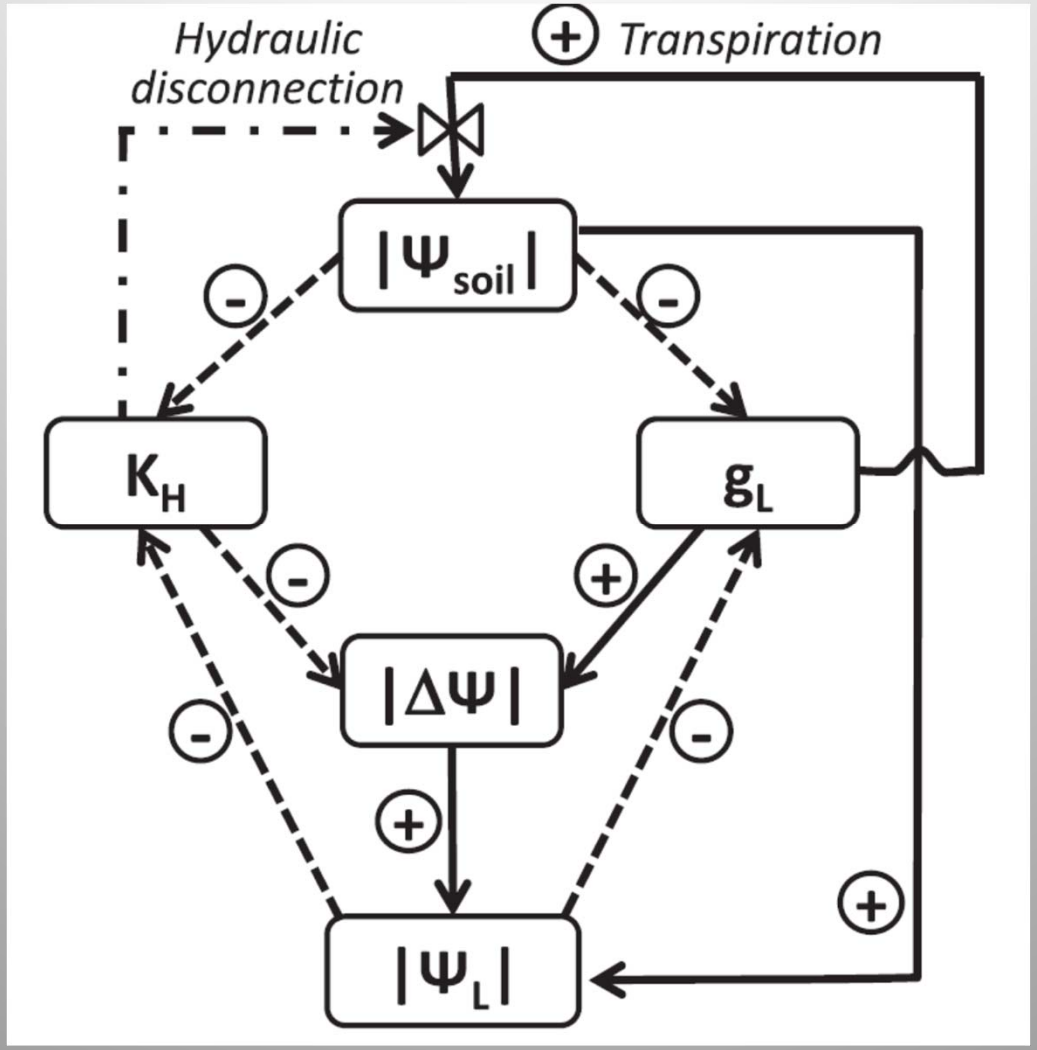
➢ Matheny et al. 2016, Ecohydrology

The framework for a whole plant hydraulic strategy



- McCulloh et al. 2019, PCE

Isohydricity as a whole plant response



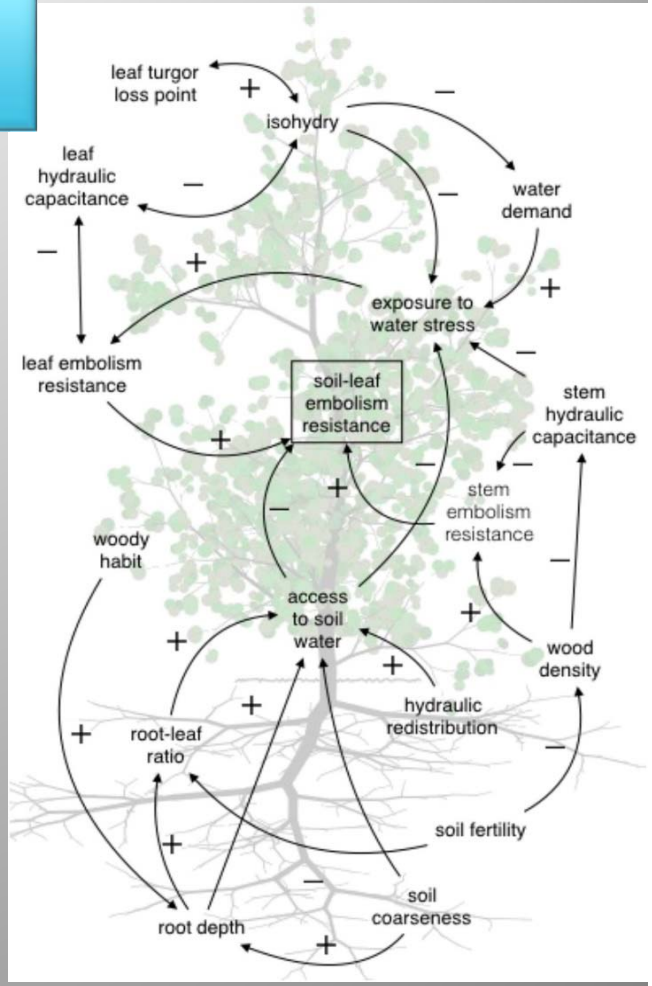
- Martinez-Vilalta & Garcia-Forner 2017, PCE

Isohydricity as a whole plant response

$$\frac{d\psi_L}{d\psi_s} = \frac{\delta\psi_L}{\delta\psi_s} + \frac{\delta\psi_L}{\delta VPD}\frac{\delta VPD}{\delta\psi_s} + \frac{\delta\psi_L}{\delta A_L}\frac{\delta A_L}{\delta\psi_s}$$

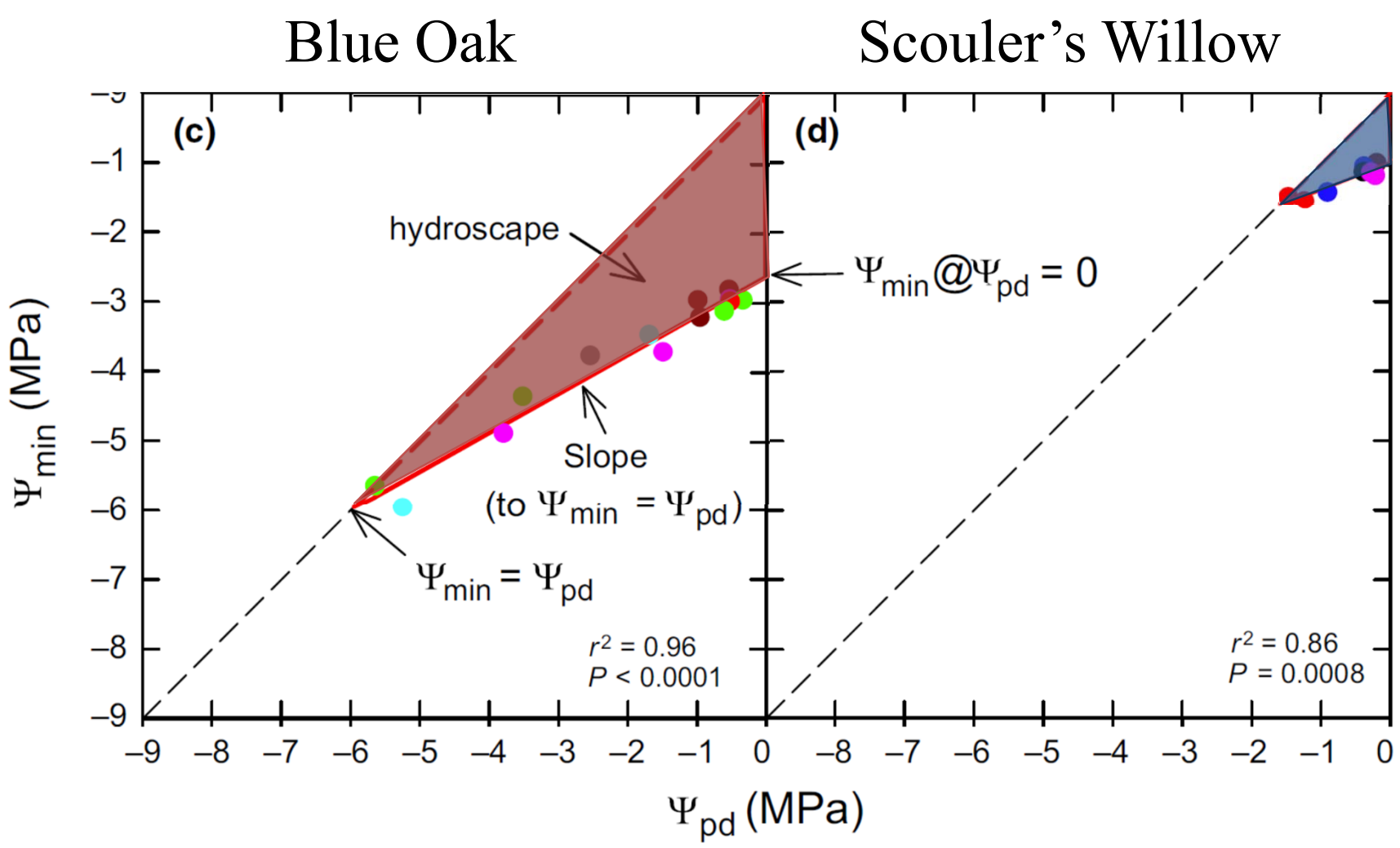
$$\frac{dg_s}{d\psi_s} = \frac{\delta g_s}{\delta\psi_s} + \frac{\delta g_s}{\delta VPD}\frac{\delta VPD}{\delta\psi_s}$$

- Novick et al. 2019, PCE



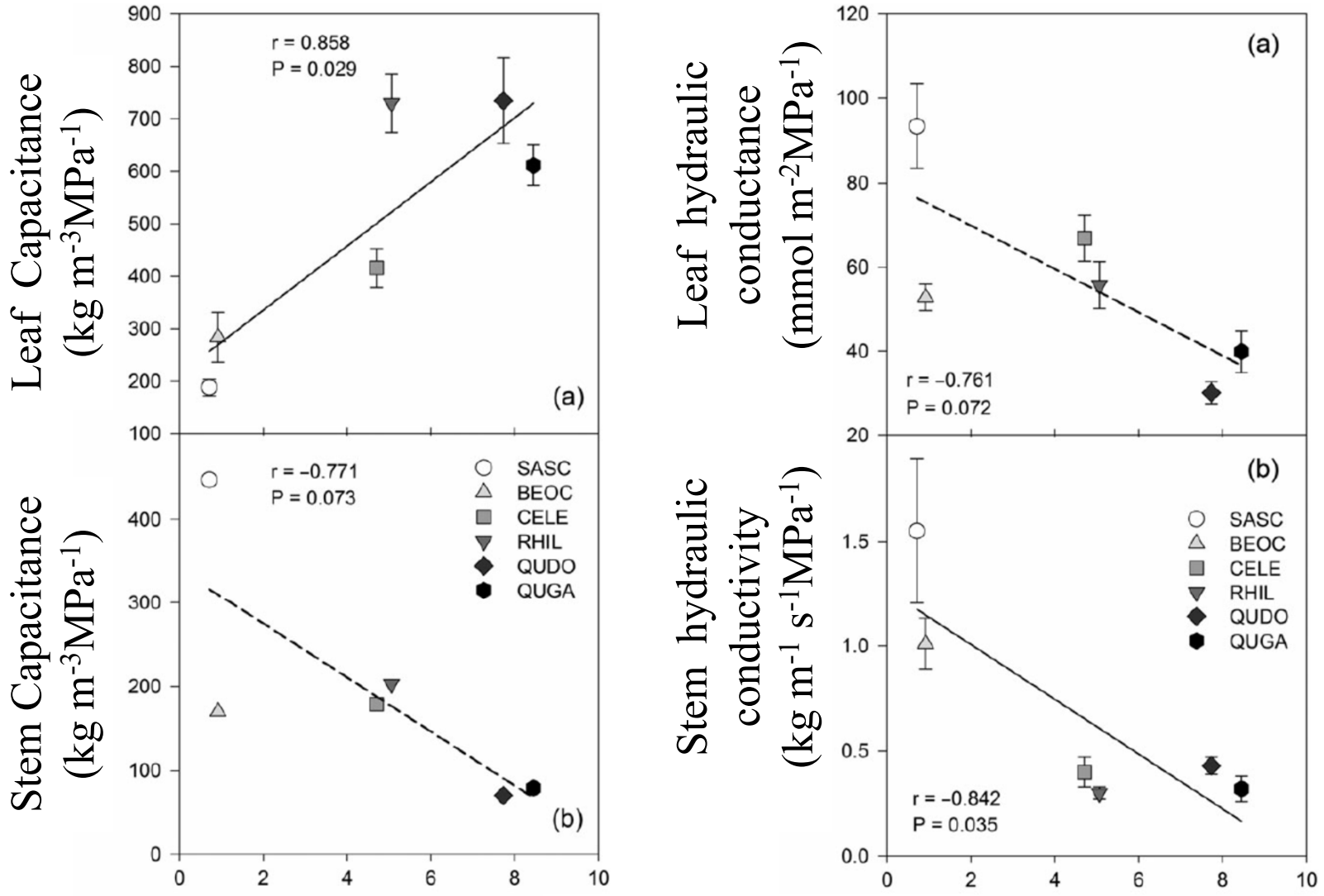
- McCulloh et al. 2019, PCE

Can we classify species based on hydraulics?



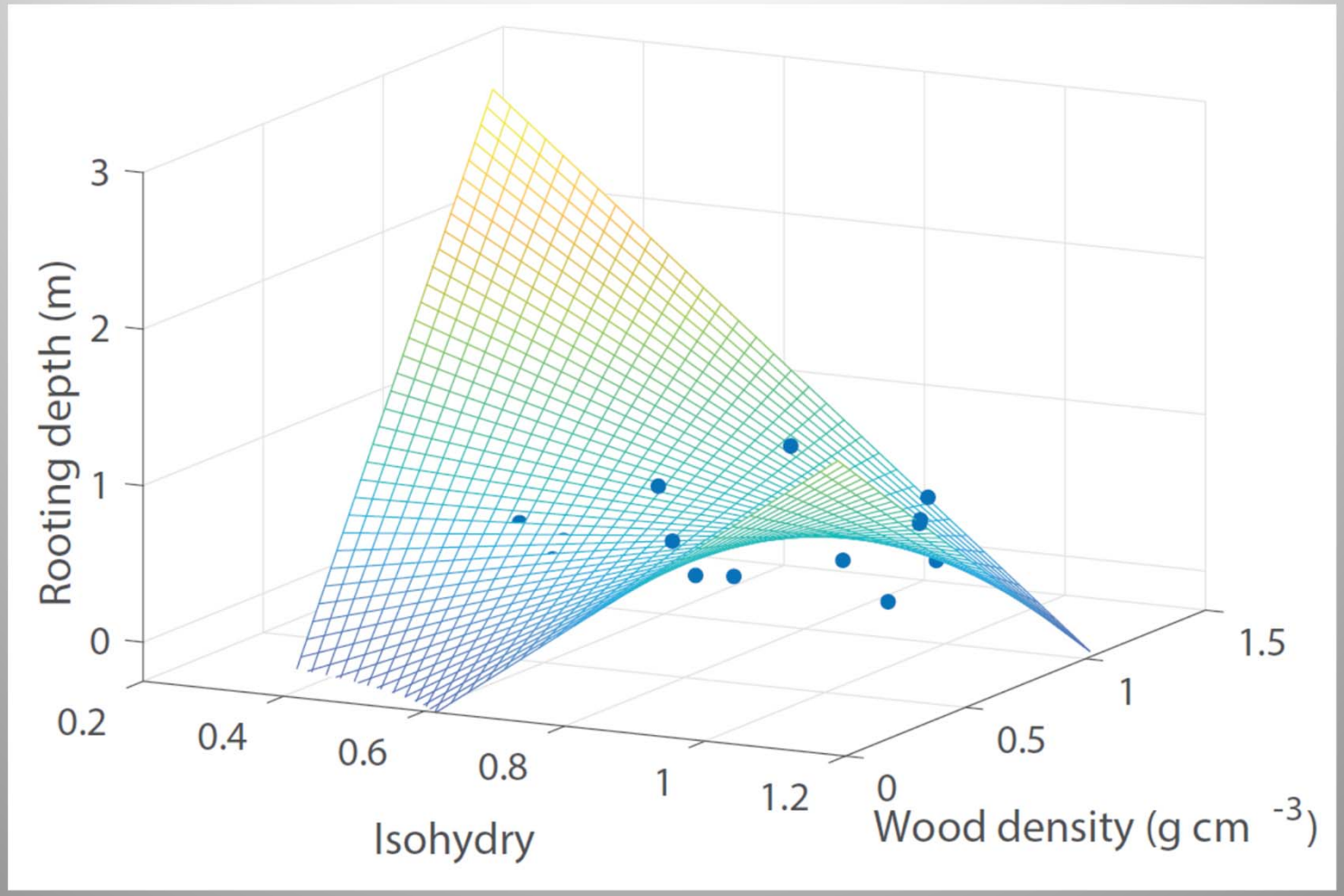
- Meinzer et al. 2016, Ecology Letters

Correlations among hydraulic traits?



- Fu et al. 2019, PCE

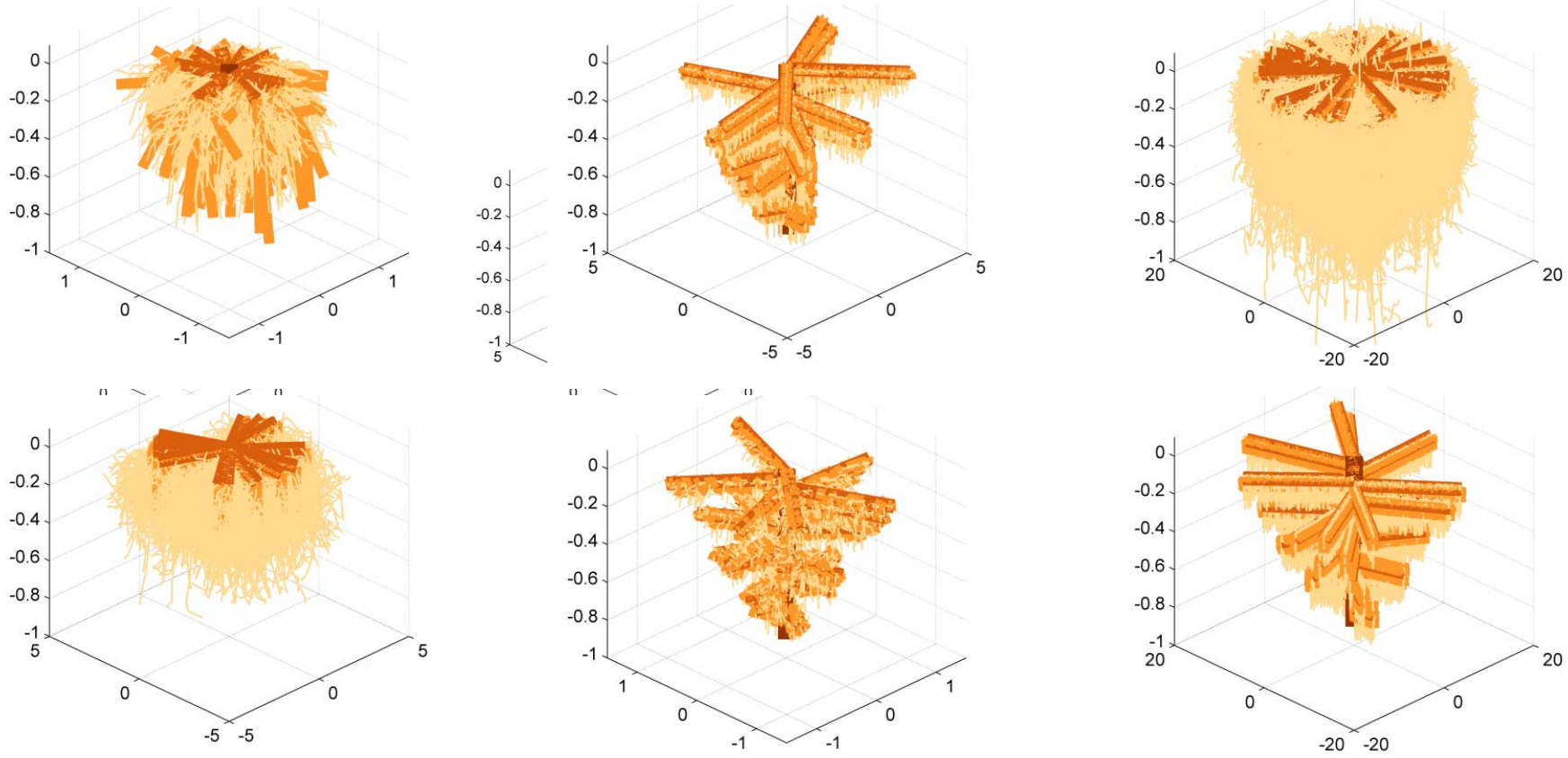
Hydraulic "trait spaces"



- Mursinna, et al. *Forests* 2018

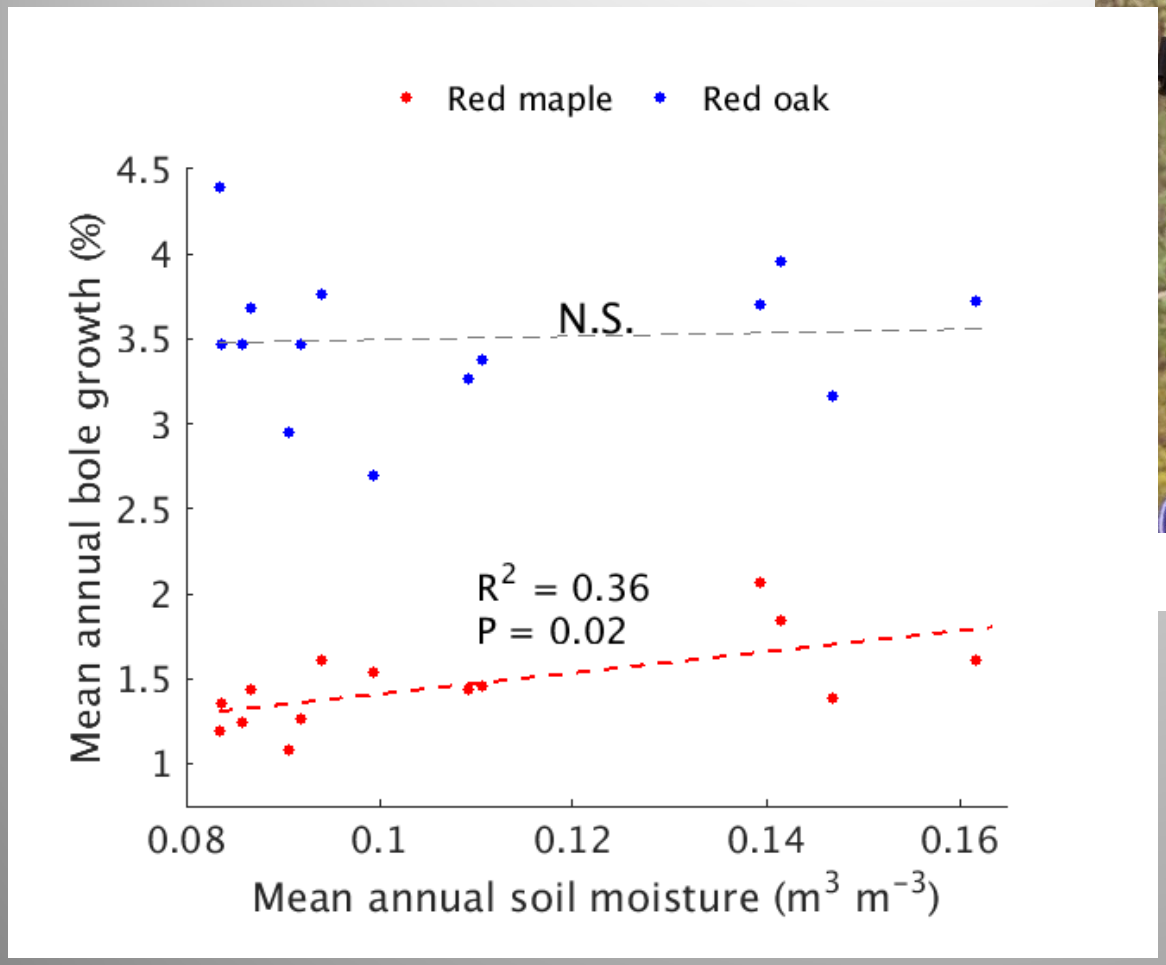
Underrepresented parameters: Roots

Its not just about depth anymore



- Agee, et al. In prep

Hydraulic strategy influences growth

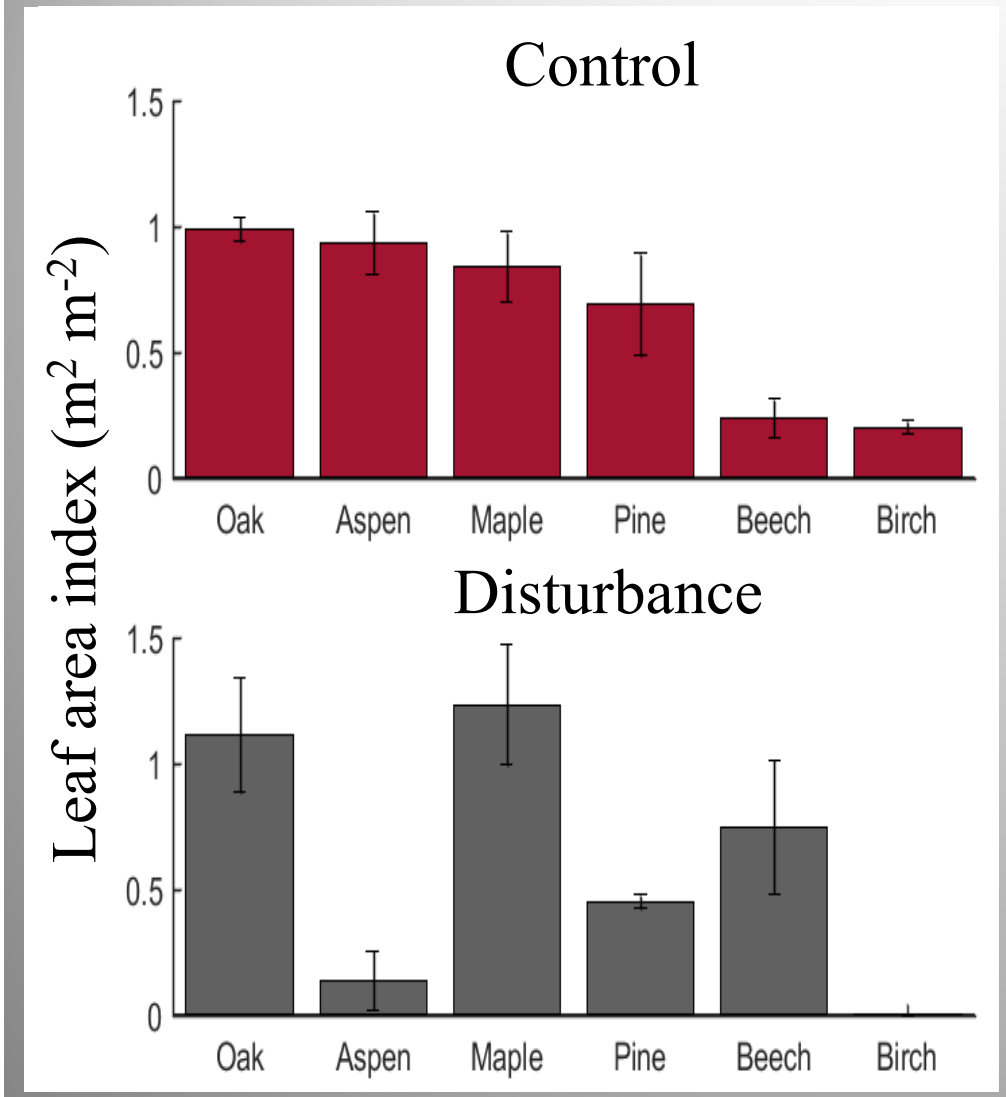


Dendrometer (Saskatchewan)

- 2001-2014
- Maple: n = 423
- Oak: n = 114

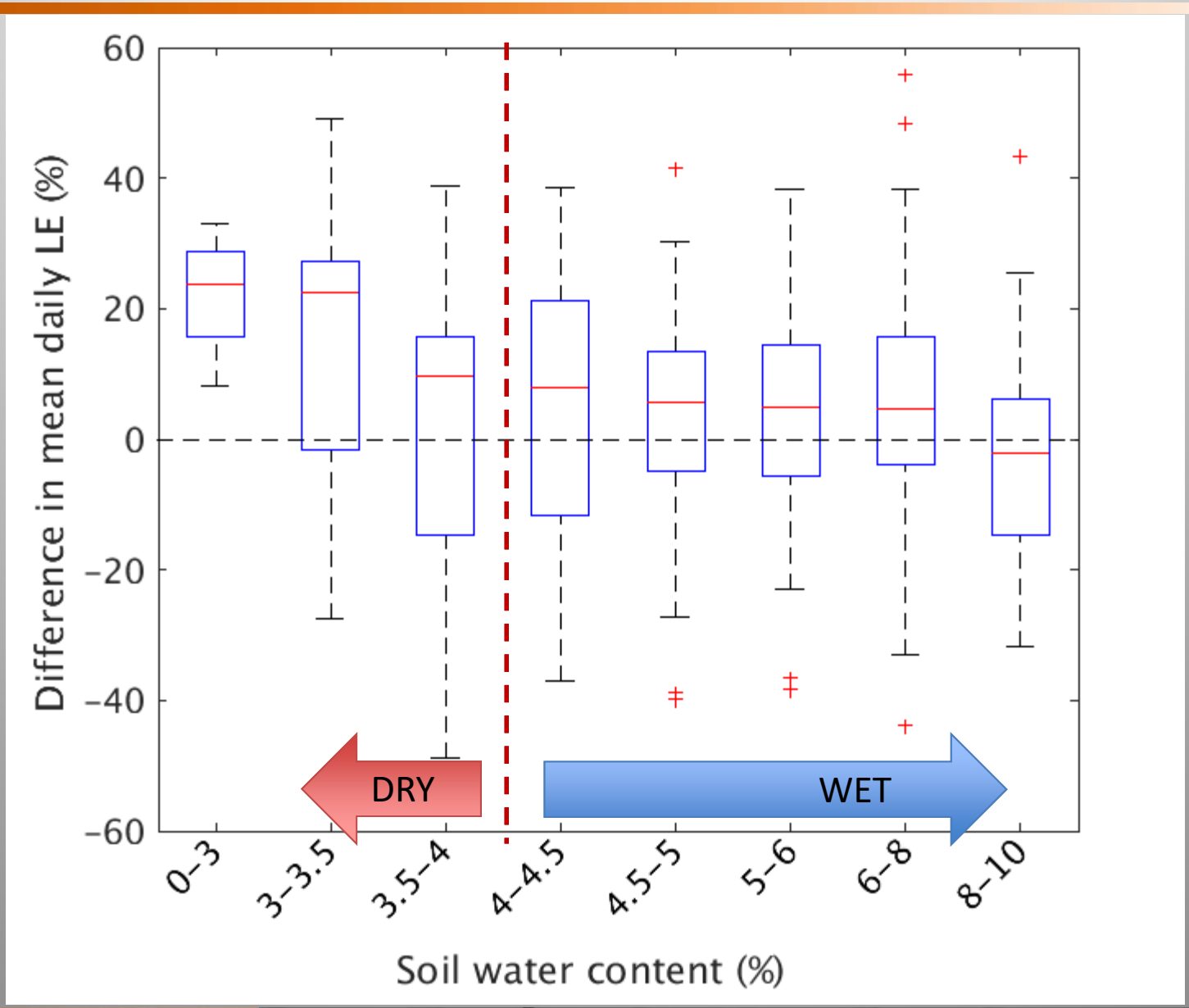
➢ Matheny et al. 2017, Ecohydrology

Changes to canopy structure and composition



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

Water limitation produces largest plot-scale differences



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*

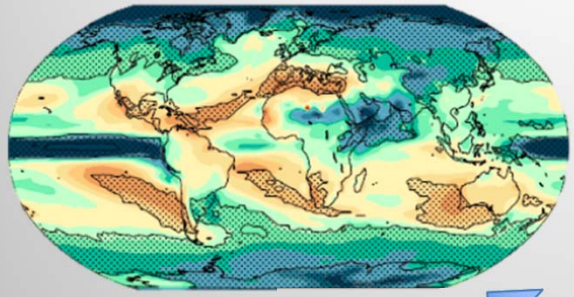
DAVID D. BRESHEARS, ORRIN B. MYERS, SUSAN R. JOHNSON, CLIFTON W. MEYER and SCOTT N. MARTENS*

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

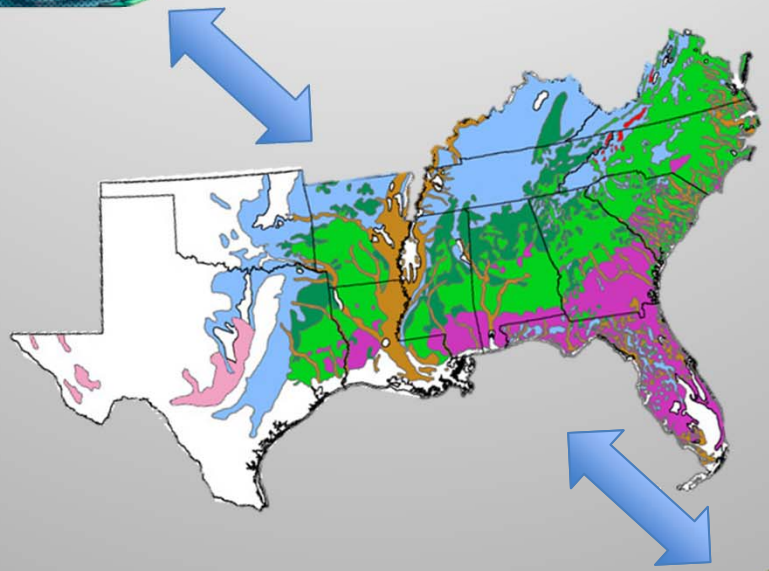
Boreal tree hydrodynamics: asynchronous, diverging, yet complementary

Christoforos Pappas[1,10], Ashley M. Matheny[2,3], Jennifer L. Baltzer[4], Alan G. 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]

The difficulties of scale

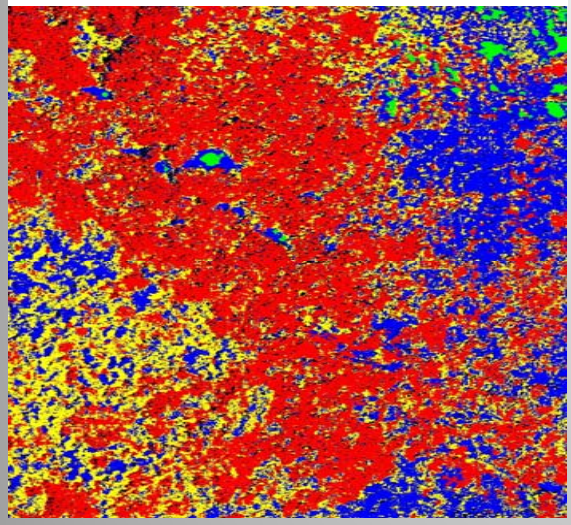


Can we connect hyper-local measurement to big-picture understandings of ecosystems?



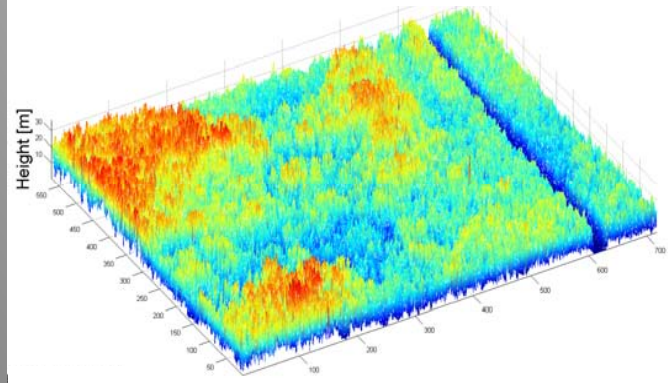
Scaling from tree to ecosystem level

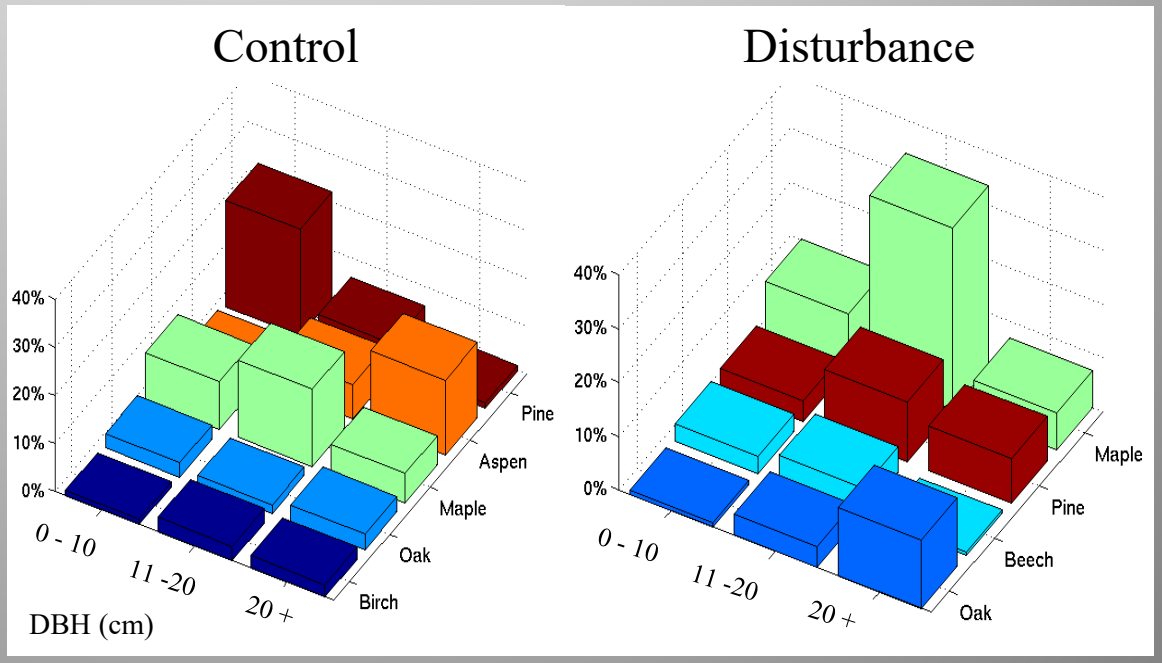
Multispectral imagery of UMBS



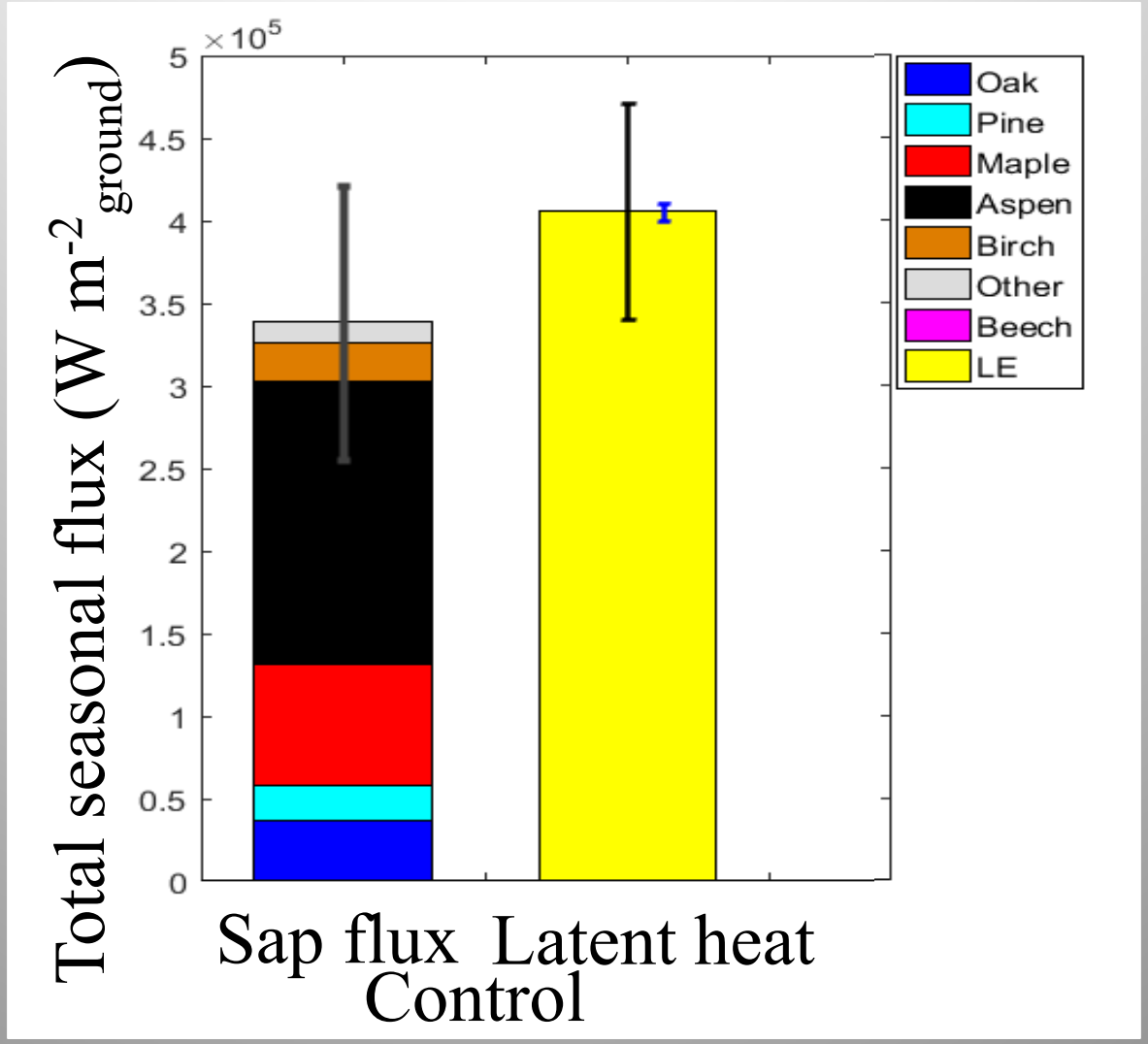
- Trees within the same histogram ‘bin’ are assumed to transpire similarly.

Aerial LiDAR of UMBS

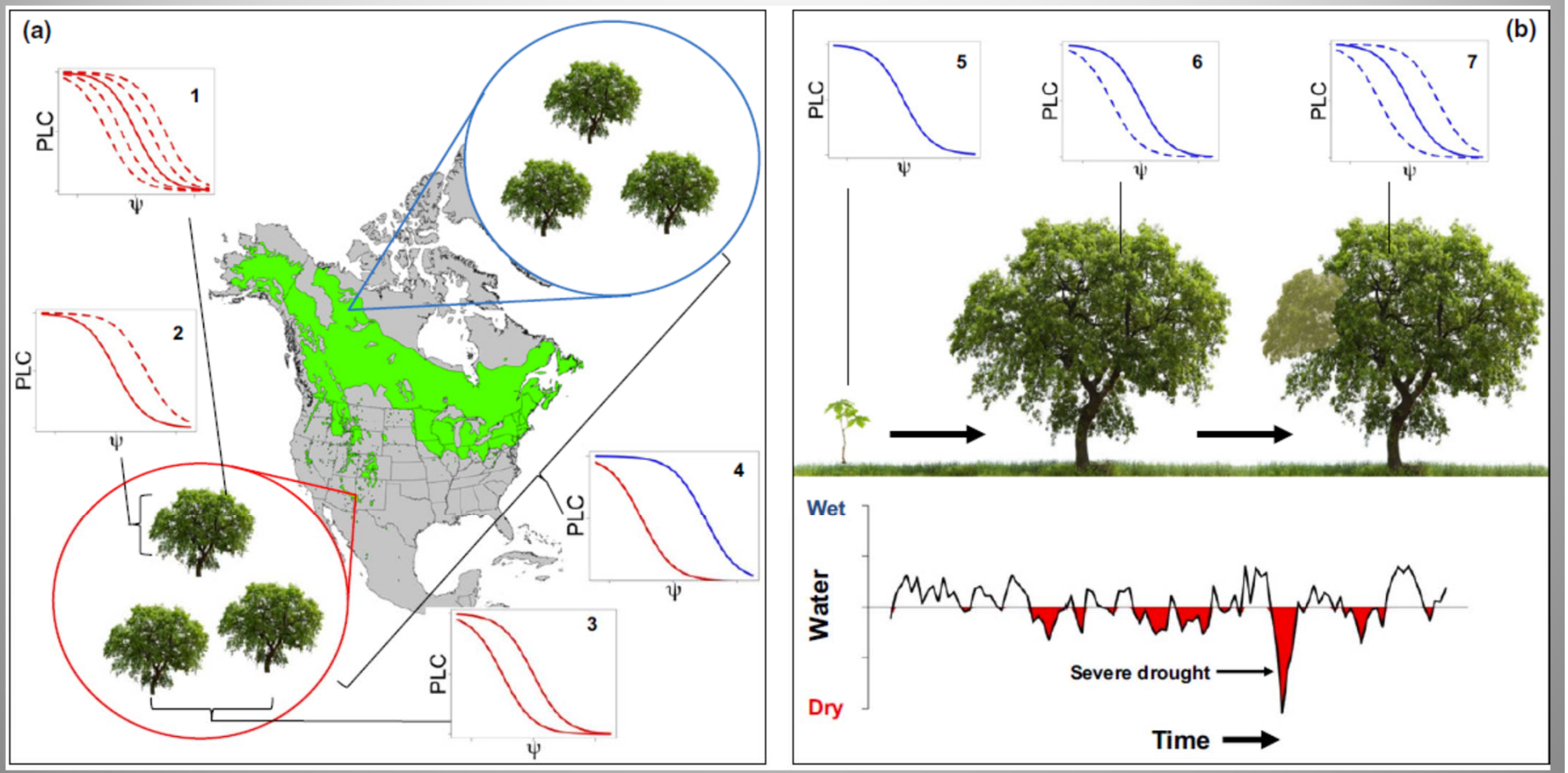




Scaling from tree to ecosystem level



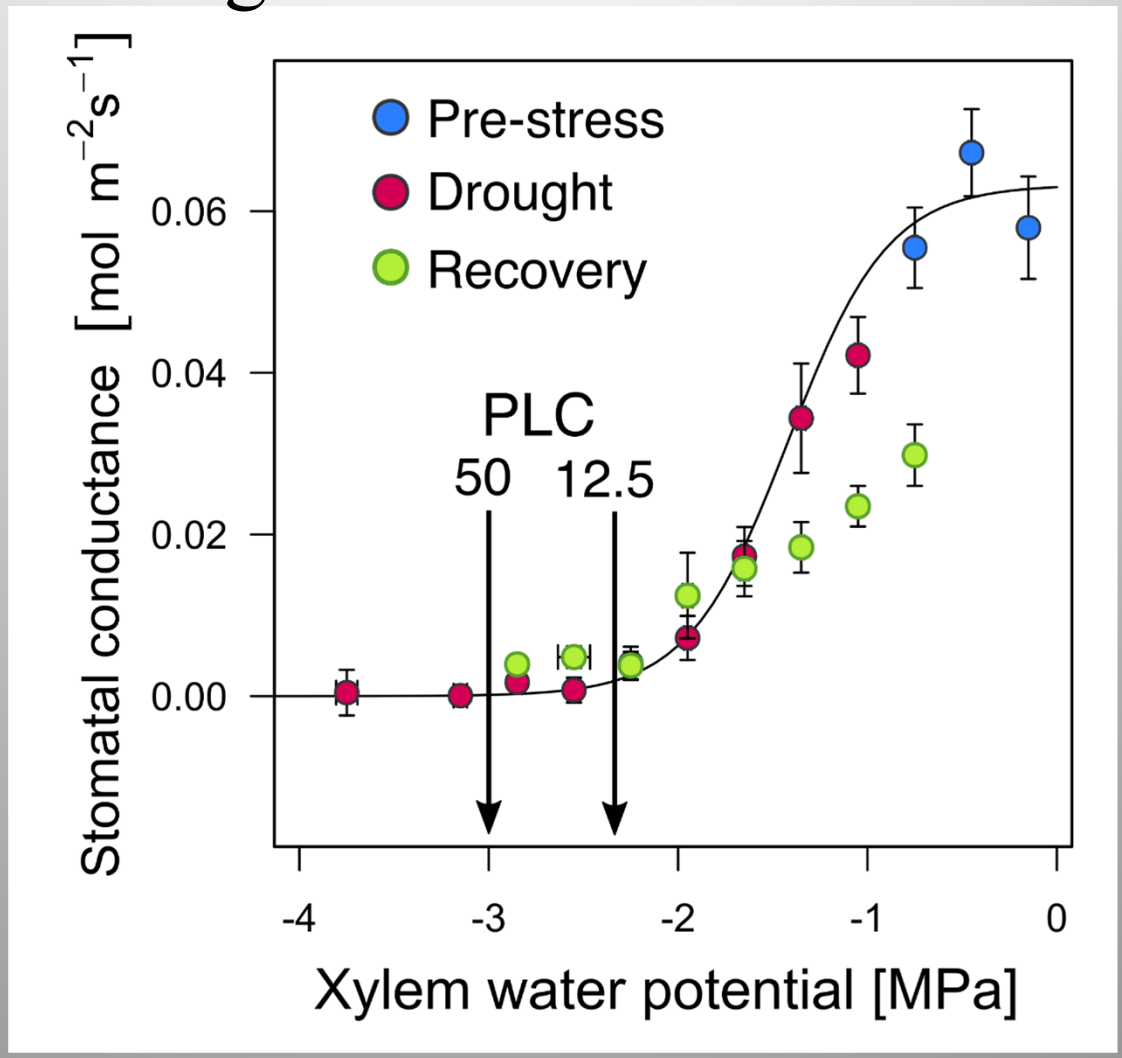
Intra-specific trait variation



- Anderegg 2015, New Phytologist

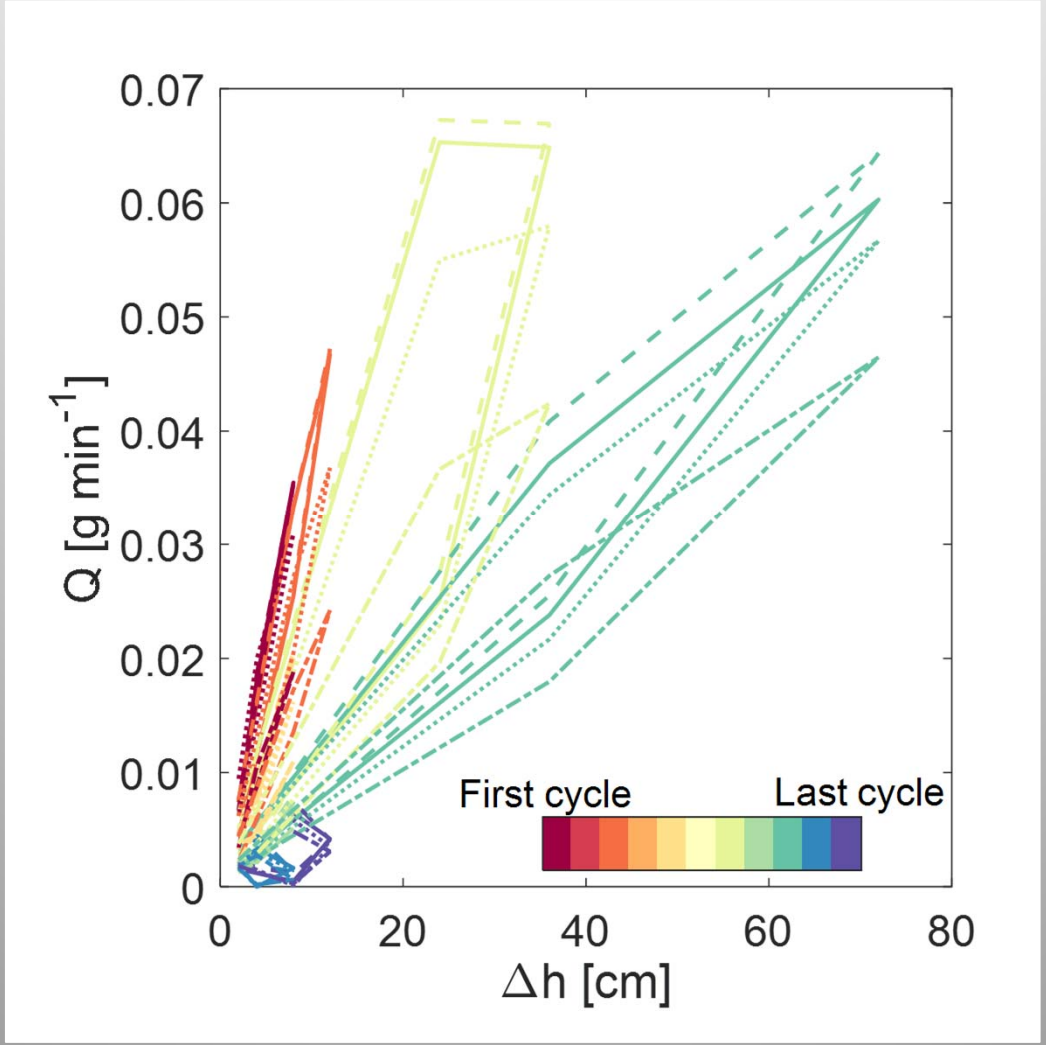
New challenges

How does drought effect the trees that live?



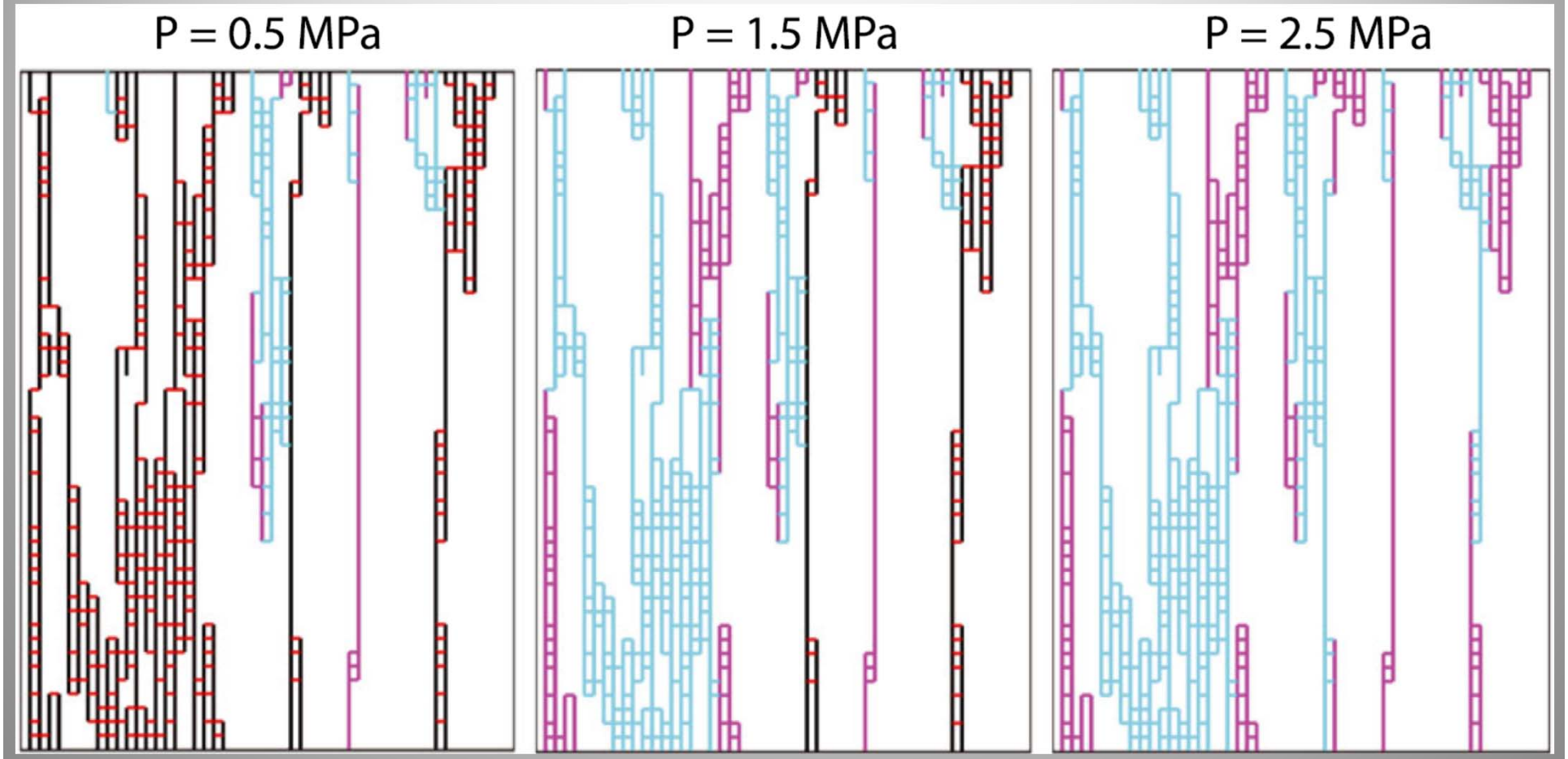
- Bohrer, et al. *AGU* 2018

Hysteretic responses to water stress



- Bohrer, et al. *AGU* 2018

A deeper perspective on xylem networks



- Mrad, et al. 2018 PCE

Acknowledgements

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Rich Fiorella, Chris Vogel, Tim Morin,
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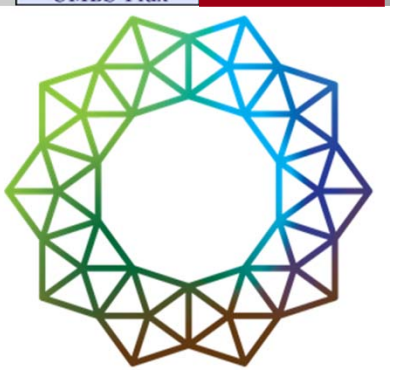
Gough, Luke Nave, Julia Thomsen,
Golnaz Mirfenderesgi, Ana Maria
Restrepo Acevedo, Austin Rechner, A. Rio
Mursinna, Airborne LiDAR – NCALM
(UMBS data)
P.E.O. Chapter AV



DOE National Institute for Climatic Change Research

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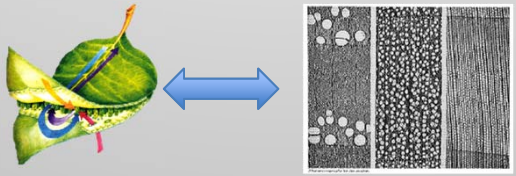
WHERE DISCOVERIES BEGIN

TEXAS

- Vegetation plays a central role in water, energy, and nutrient cycles

- Plants control hydraulic function dynamically!



- New measurements and models can improve our understanding of hydrosphere-biosphere-atmosphere exchange