Water Isotopic Signature of Transpiration

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Water Isotopes and Climate Workshop

Oct 2 2019

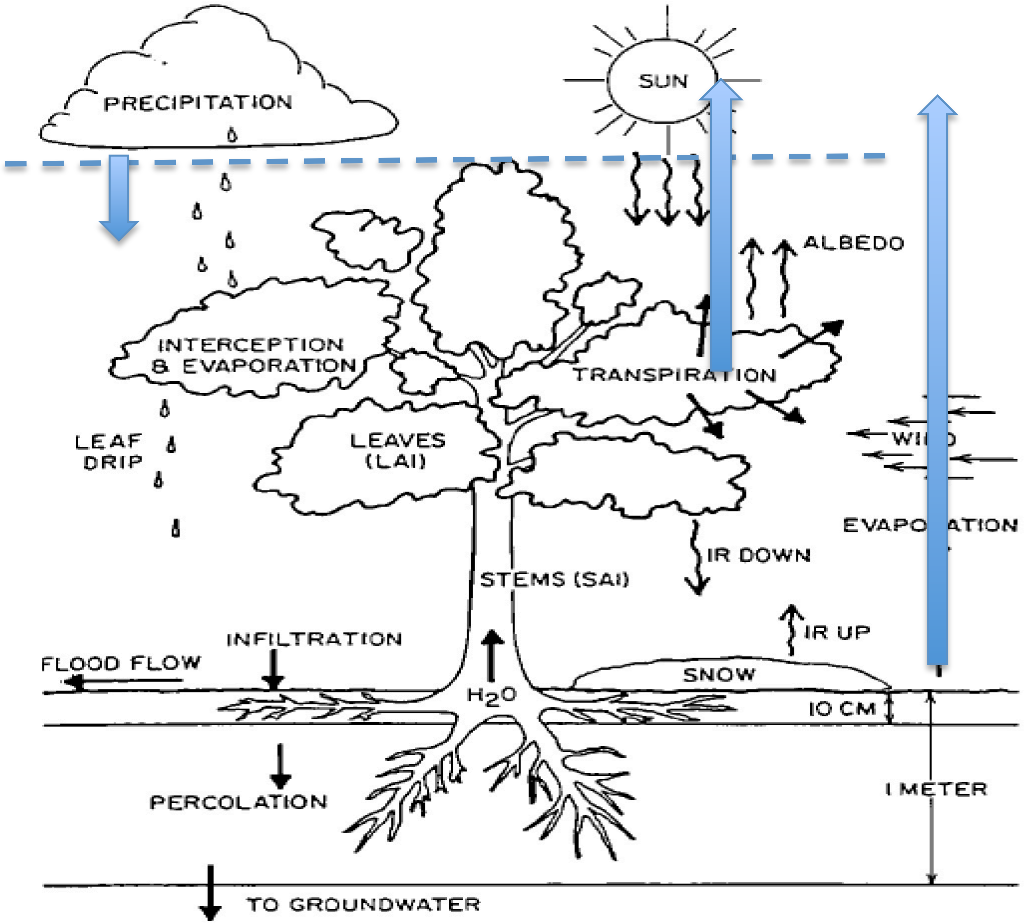


Fig. 1. Schematic of processes involved in surface physics parameterization.

On time scales >decades:

$$\delta D_{ET} = \delta D_{PRECIP}$$

Modeling Evapotranspiration for Three-dimensional Global Climate Models. Dickinson (Geophysical Monograph Series 1984)

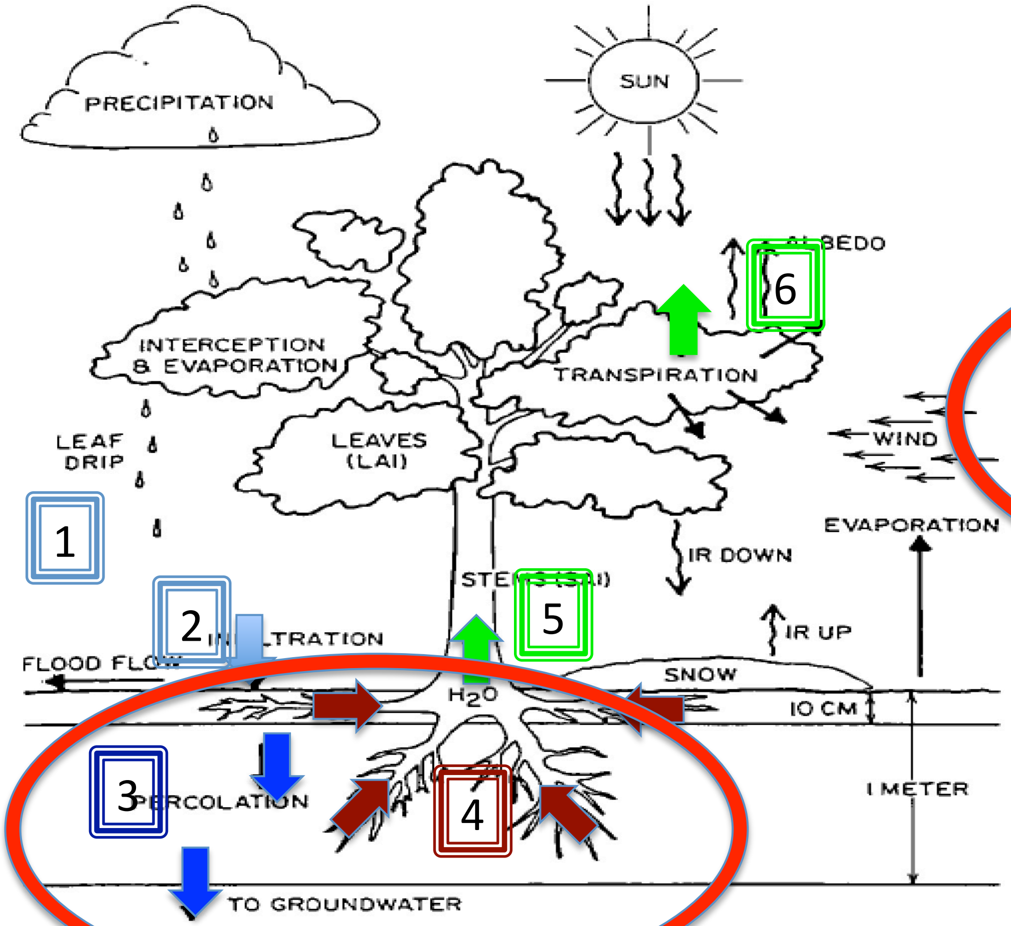


Fig. 1. Schematic of processes involved in surface physics parameterization.

1. Leaf drip – ignore evap of interception
2. Infiltration – assume δD same as precip
3. Percolation – to grdwater
4. Root uptake – assume δD same as water source, no fractionation
5. Stem flow– assume xylem δD same as root
6. Transpiration – assume time scale >days to ignore fractionation effects

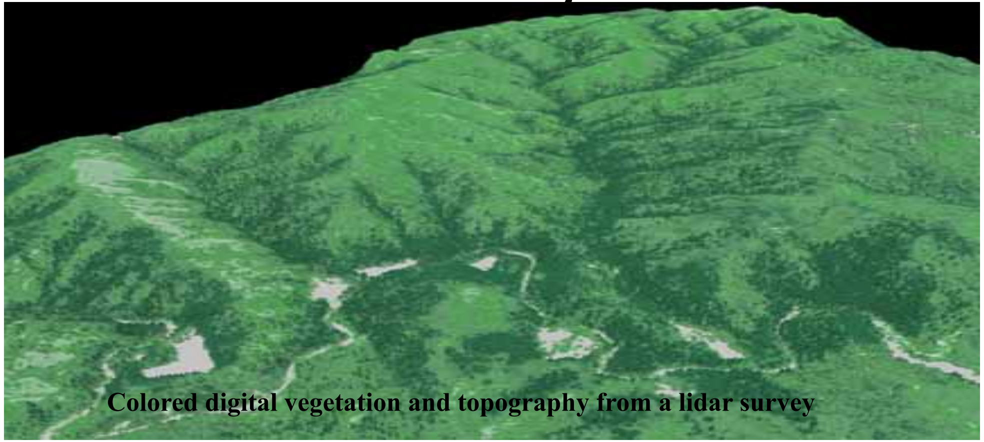
Modeling Evapotranspiration for Three-dimensional Global Climate Models. Dickinson (Geophysical Monograph Series 1984)

Eel River Watershed
Angelo Coast Range Reserve

UNIVERSITY OF CALIFORNIA
Natural Reserve System

Elder Creek Watershed

- Winter rain, summer dry
- Sedimentary bedrock
- Steep, no floodplain
- Old growth forest

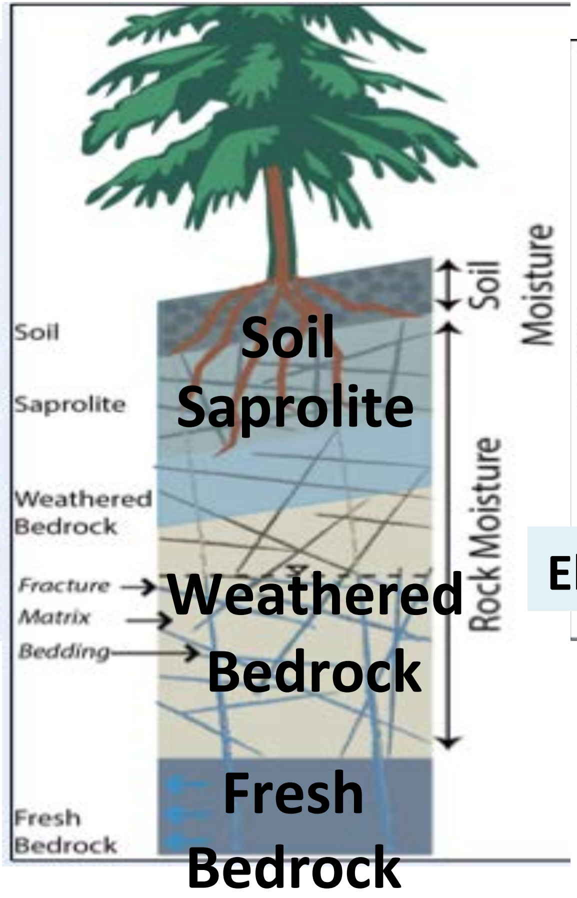

Colored digital vegetation and topography from a lidar survey

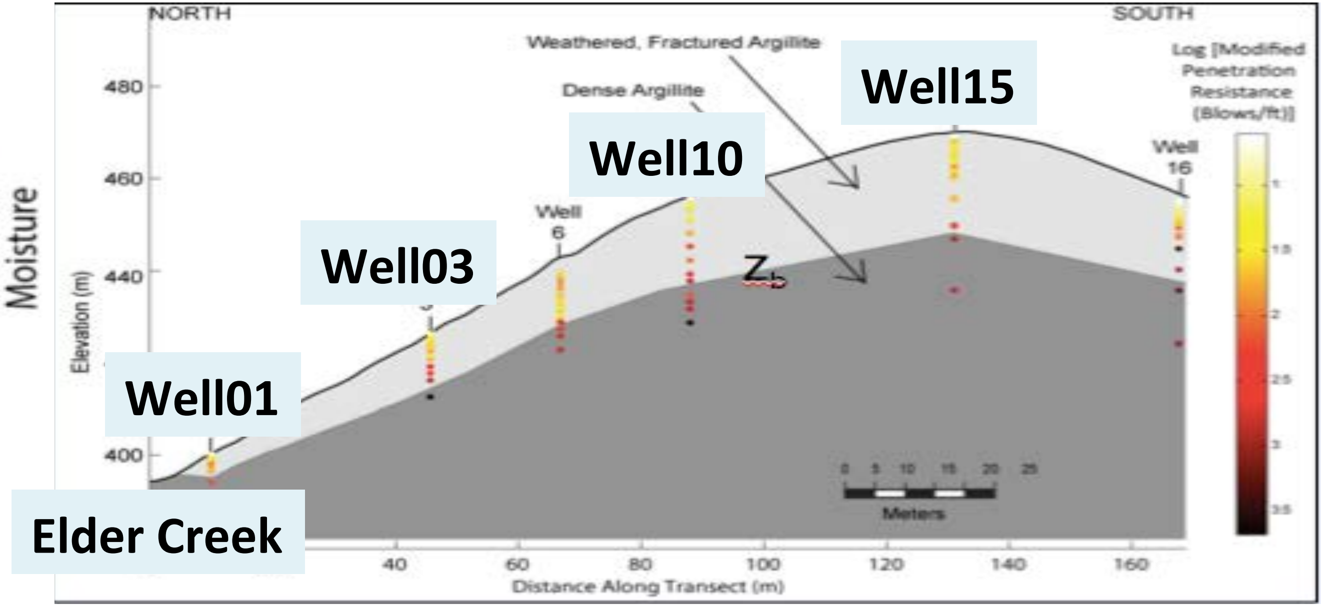
2007-2013: Keck HydroWatch Project (PI: Fung)

2013-2018: NSF Critical Zone Observatory (PI: Dietrich)

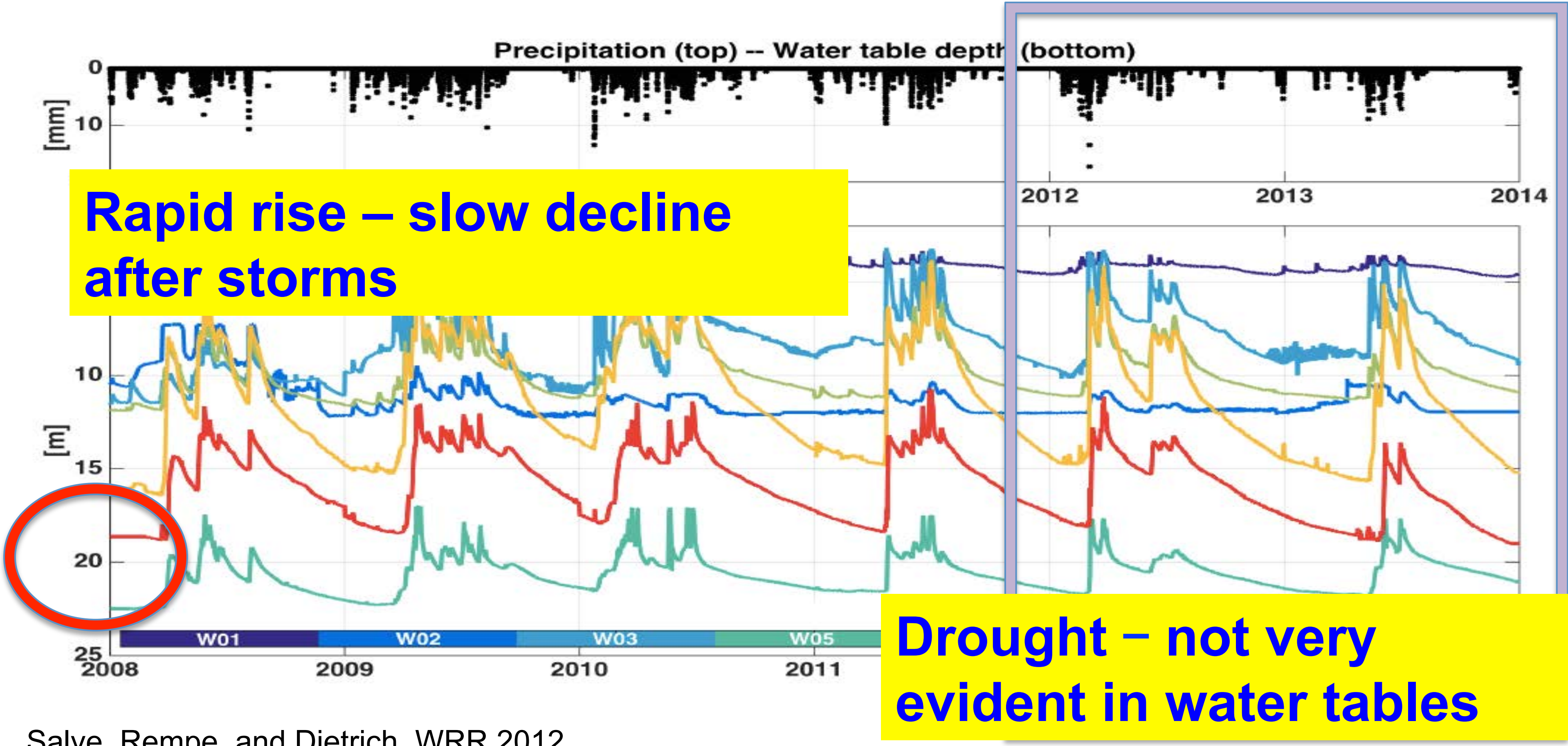
WELLS: GROUND WATER

What is underfoot?





Water table fluctuations at 7 wells over 6 years



Rapid rise – slow decline after storms

Drought – not very evident in water tables

Salve, Rempe, and Dietrich, WRR 2012

Modeling of flow in the vadose zone

Richard's Equation; y=pressure head (suction)

$$\underbrace{C(\psi)}_{\text{specific mositure capacity}} \frac{\partial \psi}{\partial t} = \frac{\partial}{\partial z}\left[\underbrace{K(\psi)}_{\text{hydraulic conductivity}} \left(\frac{\partial \psi}{\partial z} - 1 \right) \right] + \underbrace{S(z,\psi)}_{\text{sink}}$$

$$\underbrace{\theta(\psi)}_{\text{soil water content}} = \underbrace{\theta_{res}}_{\text{wilting point}} + \frac{\theta_{sat}(z) - \theta_{res}}{\left(1 + (\alpha|\psi|^{n})\right)^{m}}$$

$$\underbrace{\Theta(z,t)}_{\text{saturation}} = \frac{\theta(z,t) - \theta_{res}}{\theta_{sat}(z) - \theta_{res}}$$

saturation $0 \le \Theta \le 1$

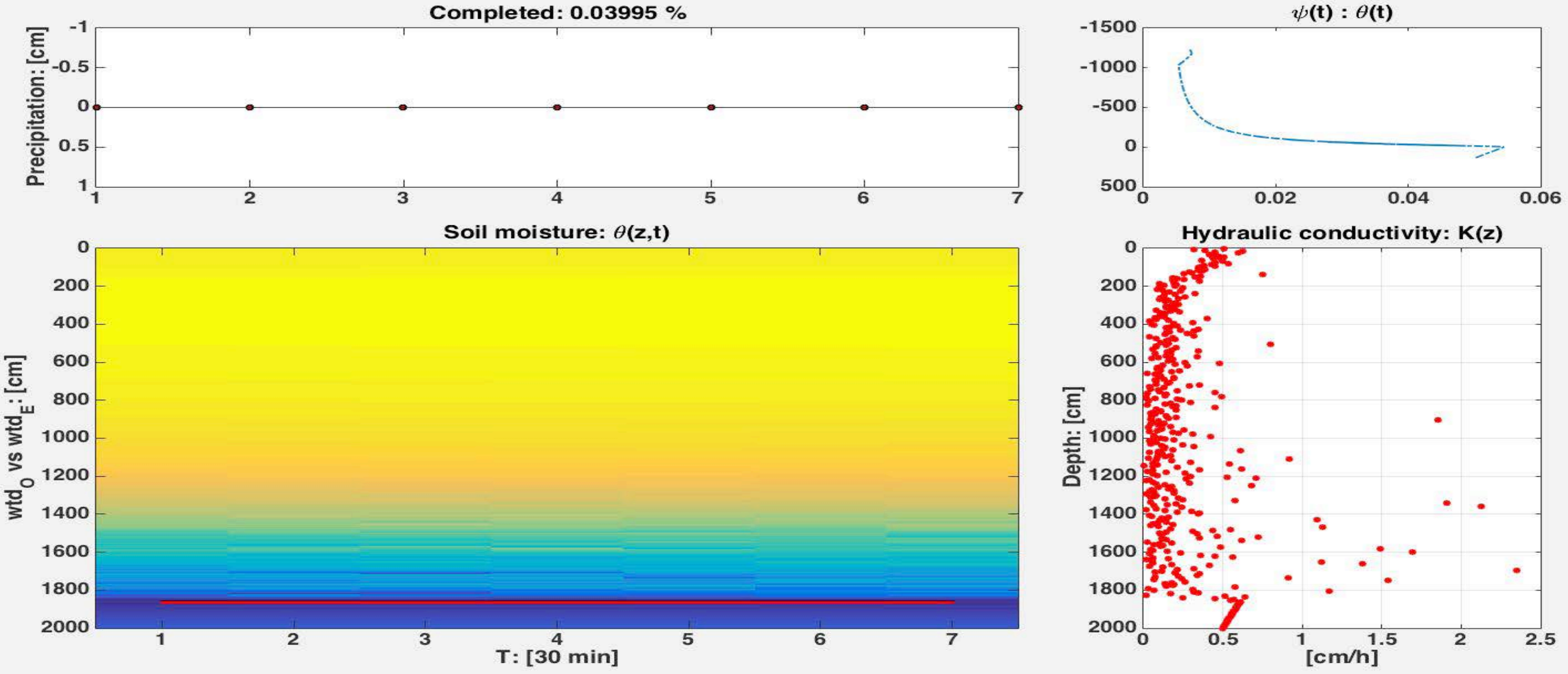
Pressure head is related to the amount of moisture present and hence to the degree of saturation

A new parameterization of Hydraulic Conductivity

$$K(\Theta) = \Theta^{\lambda} K_{bkg}$$

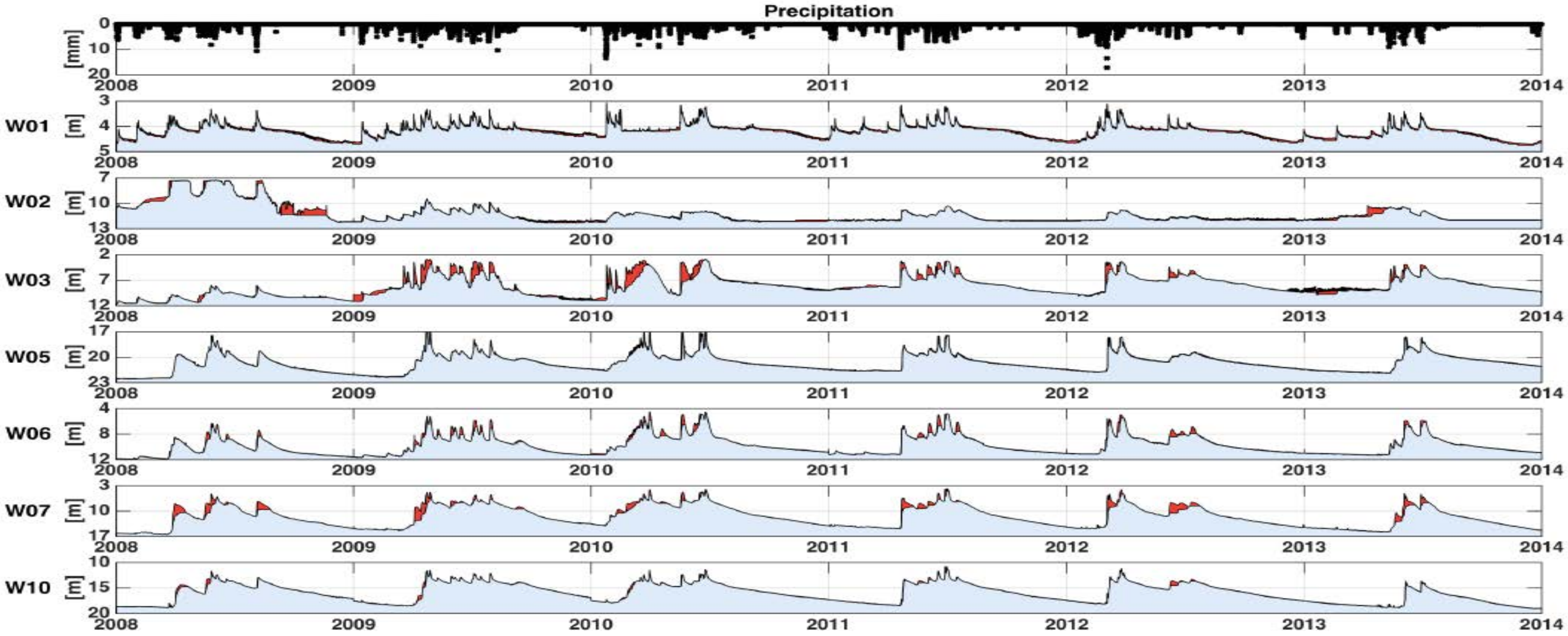
$$K_{bkg}(\Theta;\mu,\Lambda^2) = \frac{1}{\Theta\sqrt{2\pi}\Lambda}\exp\left(-\frac{(\ln\Theta-\mu)^2}{2\Lambda^2}\right) \quad \text{lognormal}$$

$$\langle K_{bkg}\rangle = \mu(z) \sim \exp(-z\cdot b_e); \qquad \mathrm{var}(K_{bkg}) = \Lambda^2 = \eta(1-\Theta)$$



Vrettas and Fung (JAMES 2016)

Simulation of the well water tables at Rivendell…



Vrettas and Fung (JAMES, 2016)

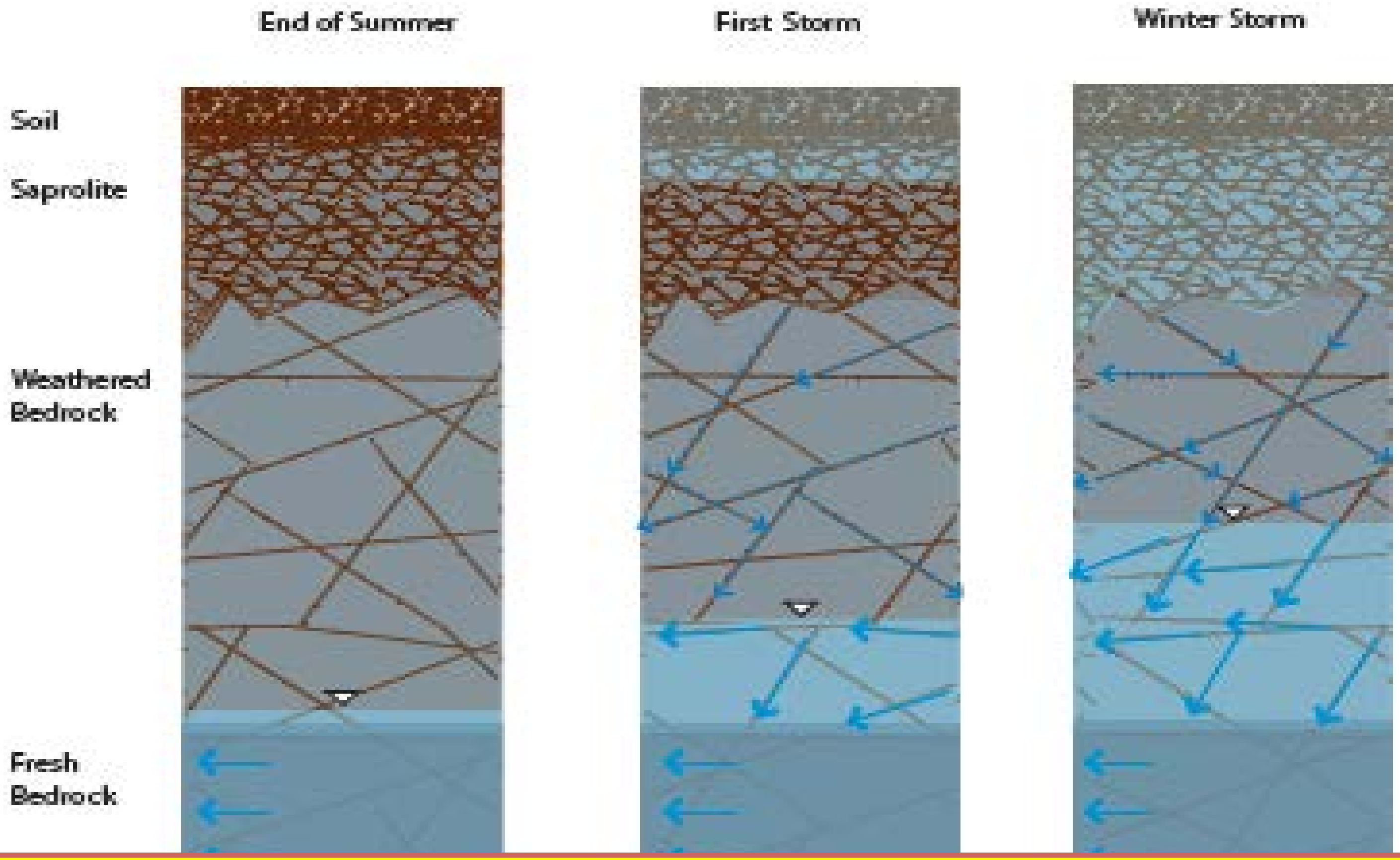
Hydraulic Conductivity increases with saturation

$$K(\Theta) = \Theta^{\lambda} K_{bkg}$$

$$K_{bkg}(\Theta;\mu,\Lambda^2) = \frac{1}{\Theta\sqrt{2\pi}\Lambda}\exp\left(-\frac{(\ln\Theta-\mu)^2}{2\Lambda^2}\right) \quad \text{lognormal}$$

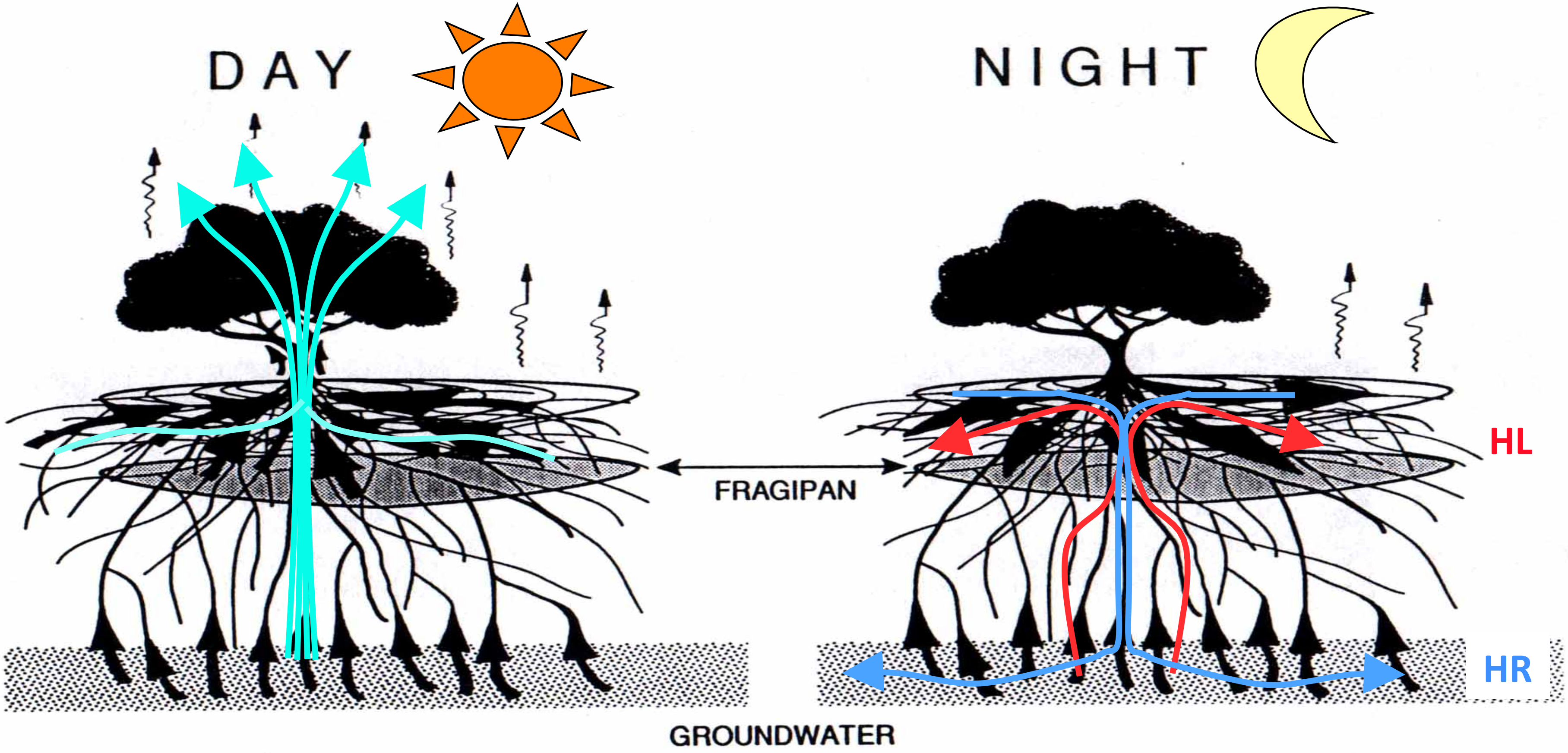
$$\langle K_{bkg} \rangle = \mu(z) \sim \exp(-z \cdot b_e); \qquad \mathrm{var}(K_{bkg}) = \Lambda^2 = \eta(1-\Theta)$$

Intense storms → faster penetration to depth



Rock Moisture:
~30% of water storage above water table

"Hydraulic Lift (HL) or Redistribution (HR)"



Todd Dawson

Where do trees get their water?

Isotope measurements Sept 2012-Feb 2013

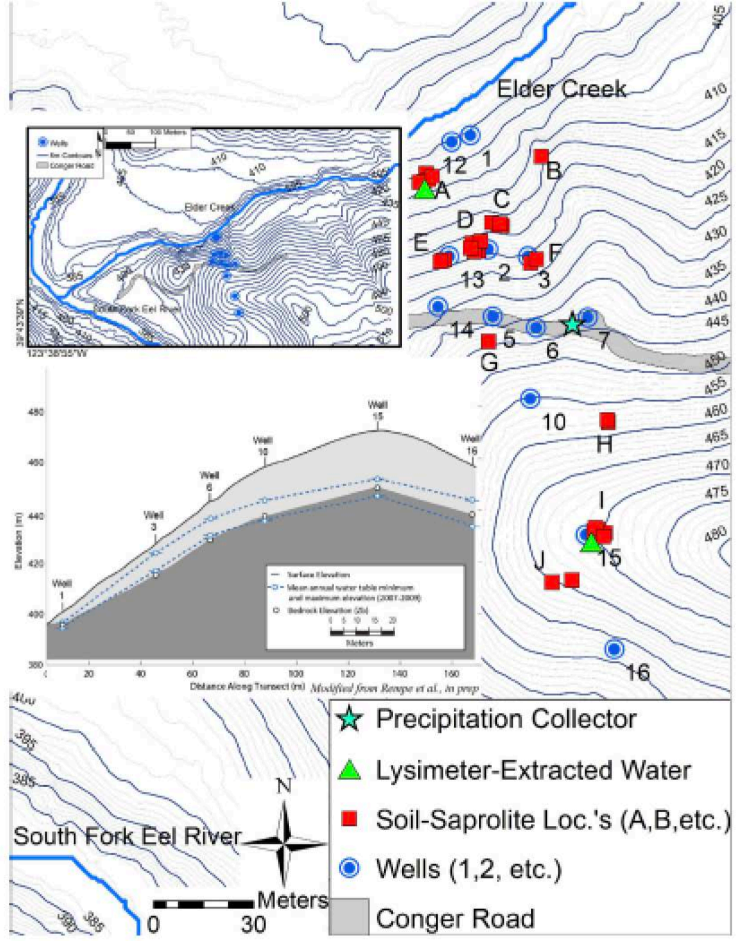
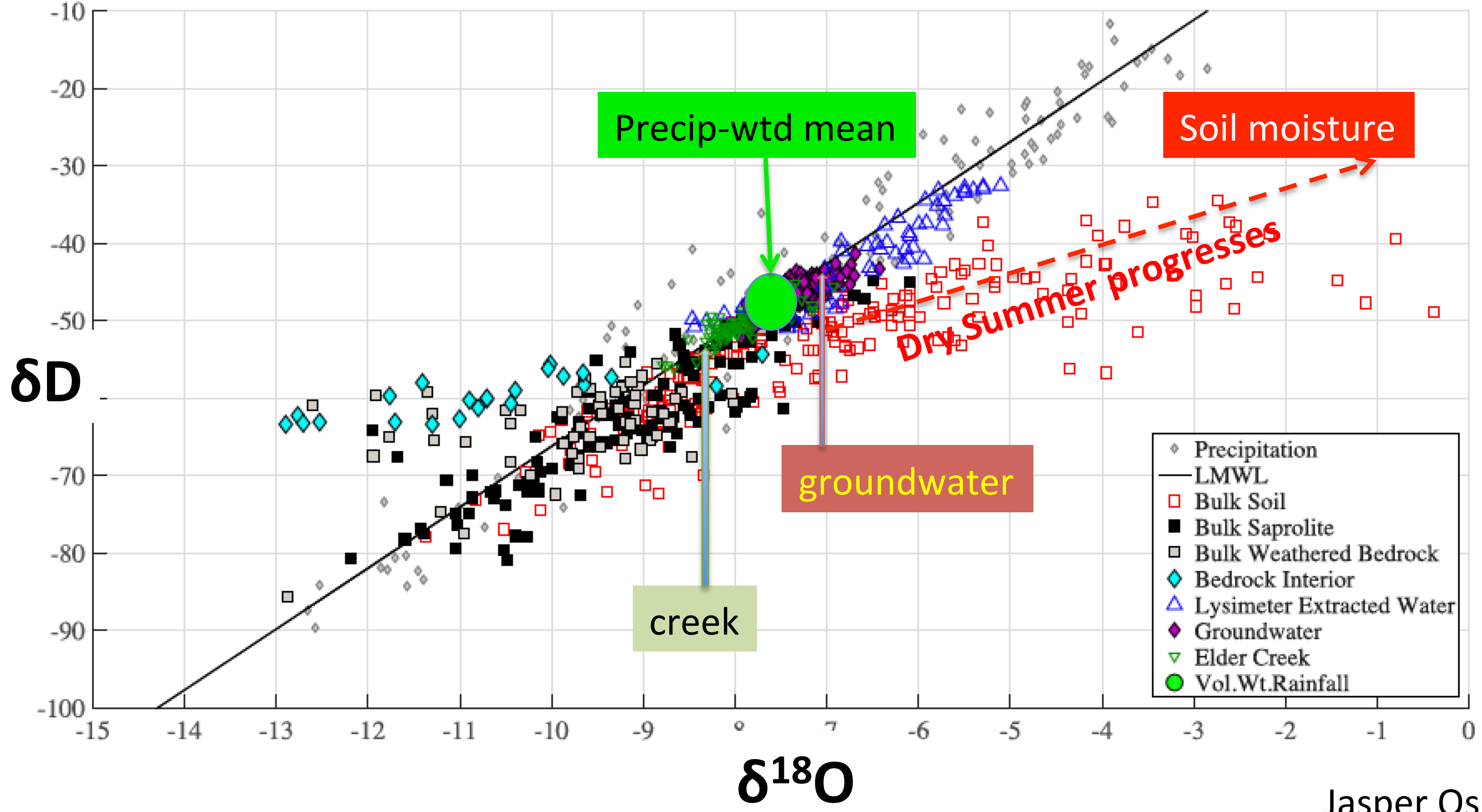
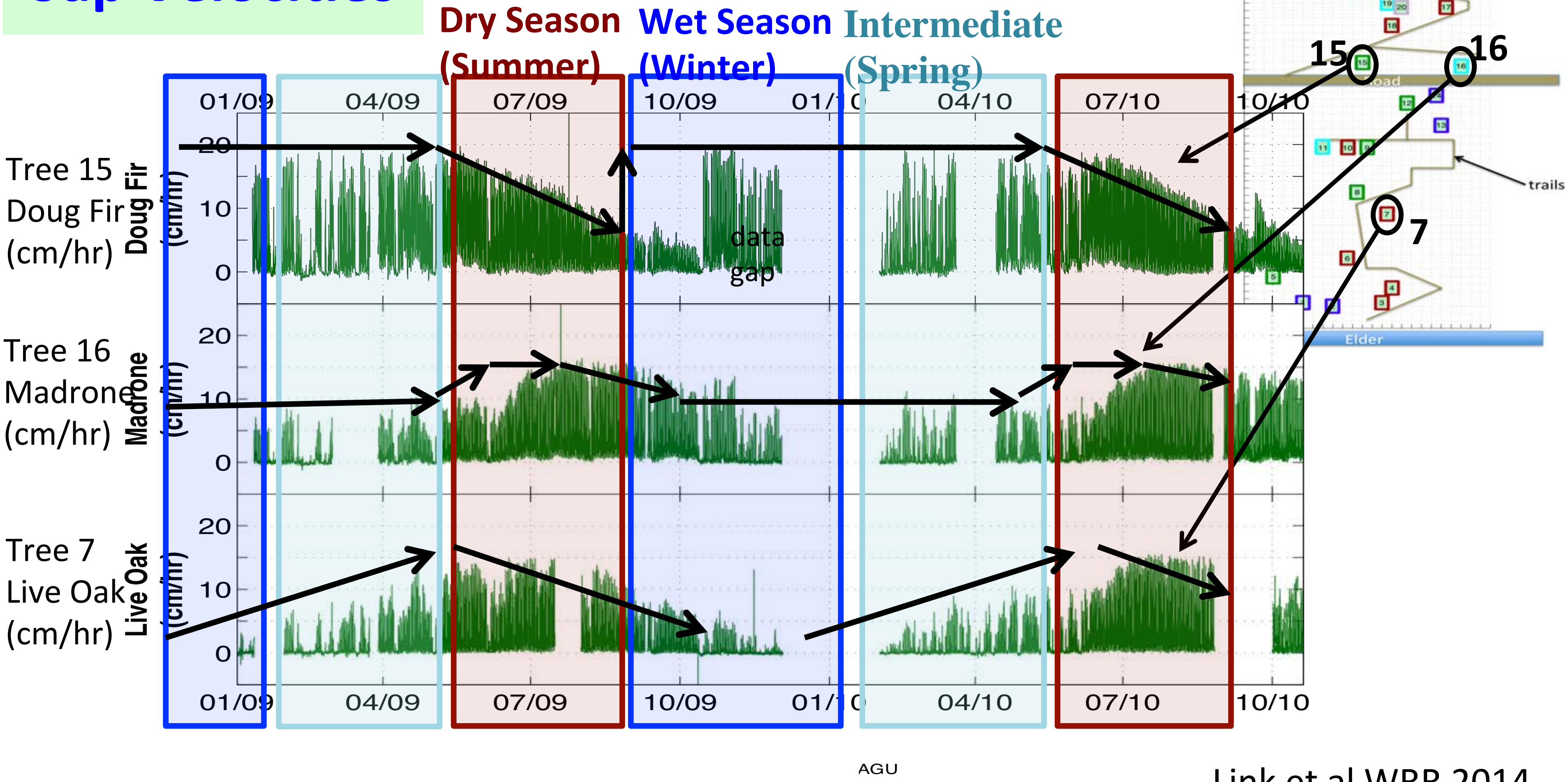


Figure 2. The Rivendell study site (39.729 N, 123.644 W), which lies within the Angelo Coast Range Reserve, in Northern California. Elder Creek lies at the base of the hillslope, and flows west, toward the South Fork of the Eel River, approximately 400 m downstream. The map shows 1 m contour LiDAR generated by the National Center for Airborne Laser Mapping. Blue dots show the location of deep groundwater monitoring wells. Red squares show the location of bulk soil and saprolite sampling sites. Green triangles show the location of mobile water sampling. The cyan star indicates the location of precipitation collection.

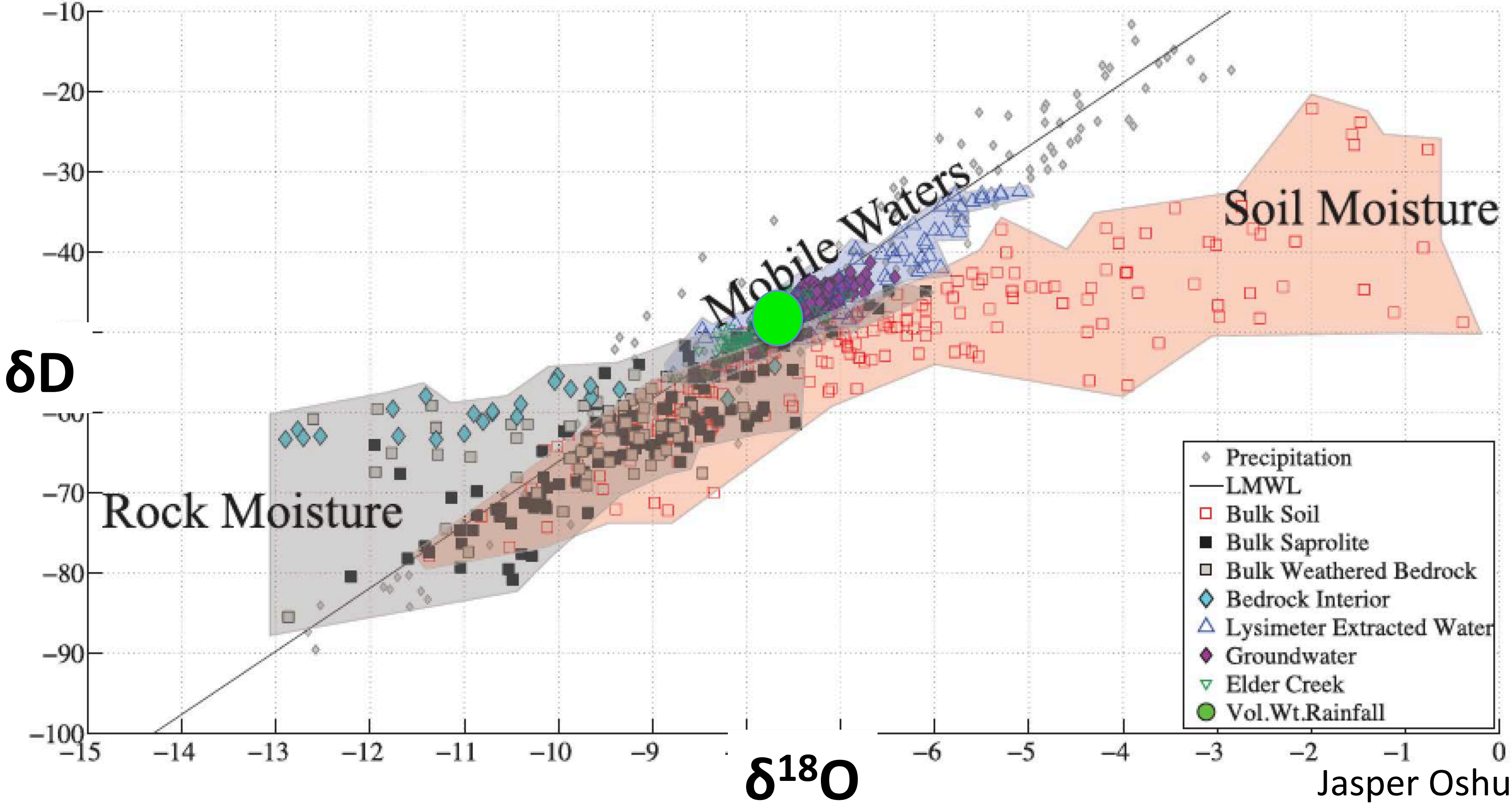


Jasper Oshun

Sap Velocities



Link et al WRR 2014



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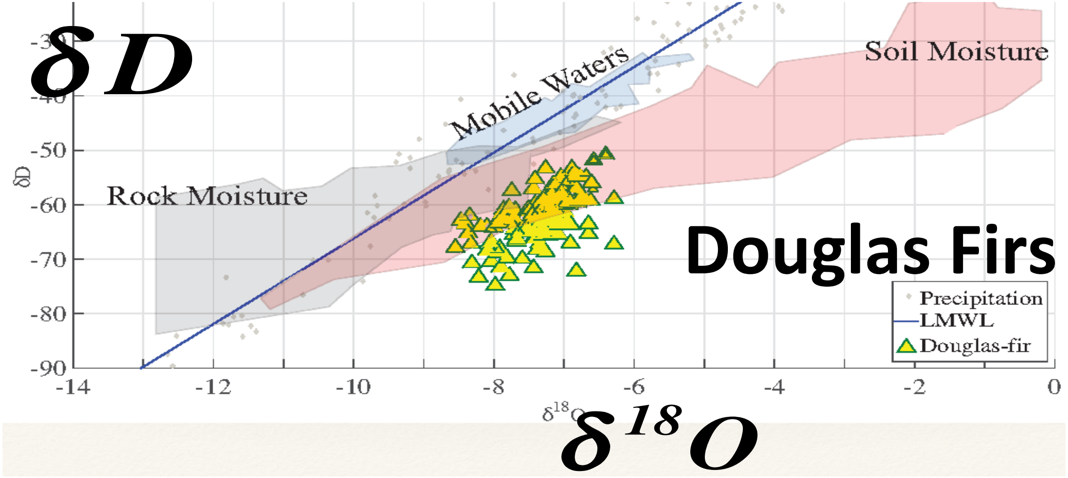

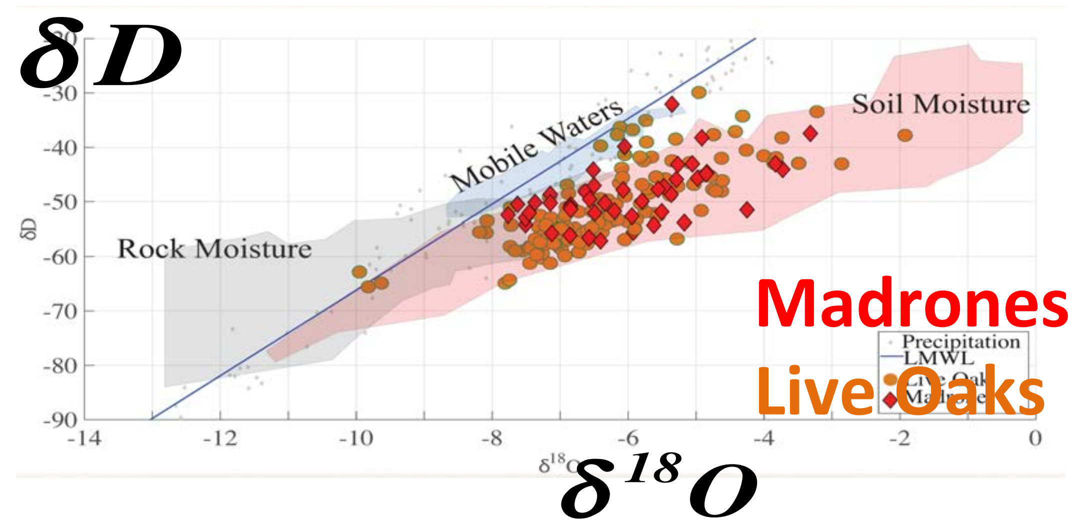

Isotopic Signatures in xylem

Douglas firs

- Hydraulic redistribution
- Deep roots
- Max daily transpiration in rainy winter

Madrones

- Deep roots
- Max daily transpiration in dry summer

J. Oshun

Summary

- In areas with weathered bedrock
- Rapid movement of water down (preferential flow) and up (hydraulic redistribution by roots)
- Xylem δD reflect seasonality of transpiration and the mixture of deep and shallow moisture at the time of transpiration

Outlook: Need for observations

- Near-surface δD of vapor from satellite
- Root architecture of different tree species
- Geologic substrate → reservoirs of rock moisture