Root-zone "Periscope" And Its Applications For Investigating Plant-Water Relations

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Presentation at EGU 2022

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inspiring achievement

NATIONAL CENTRE FOR GROUNDWATER RESEARCH AND TRAINING

sustaining a vital water resource

Water transfer in the soil-plant-atmosphere continuum (SPAC)

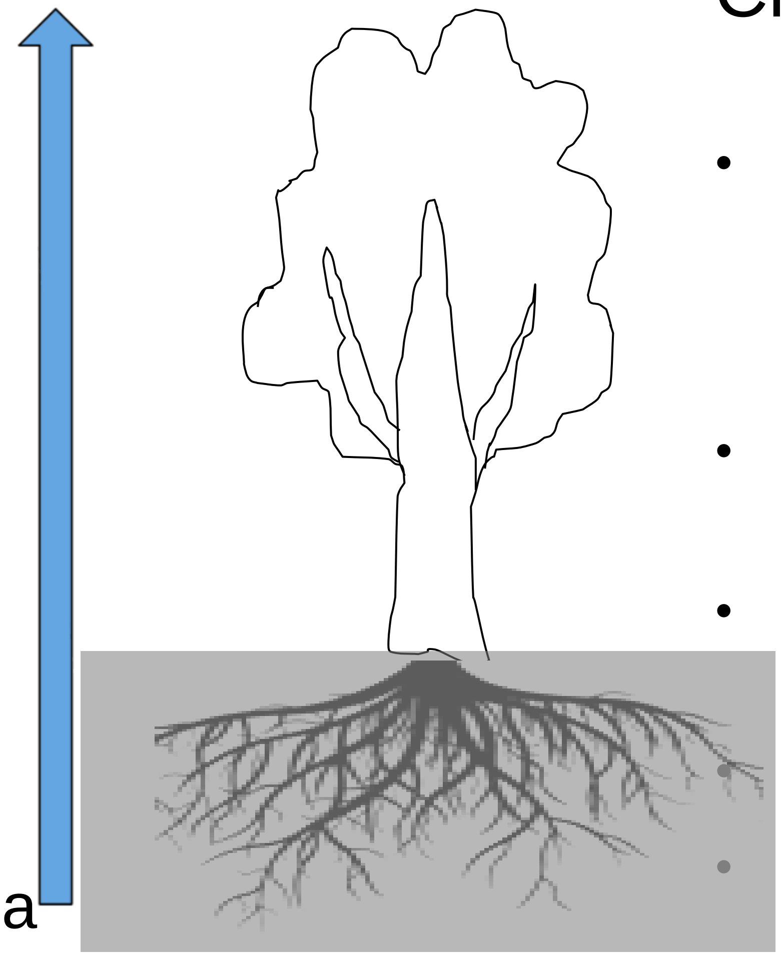
Air WP= -60 MPa

Leaf WP= -1.5

Stem WP= -0.9

Root WP= -0.8

Soil WP= -0.5 MPa



Challenges:

- Unknown root distribution (RZ moisture storage capacity)
- Difficulty in measuring hydraulic states
- State-dependent hydraulic conductivity
- RWU compensation
- Hydraulic redistribution

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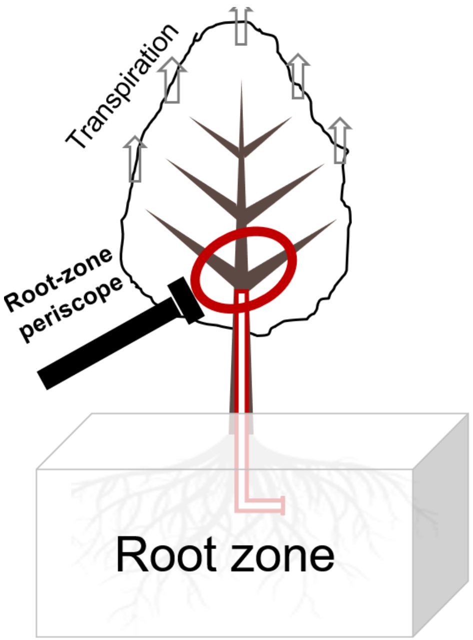
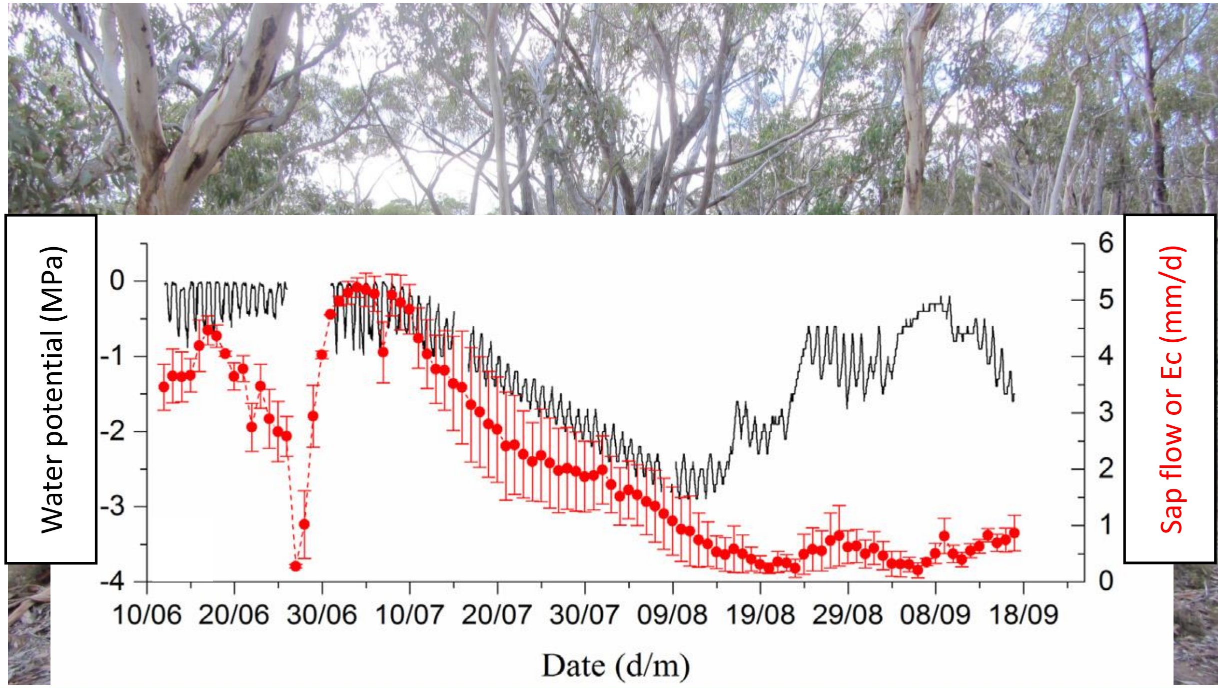
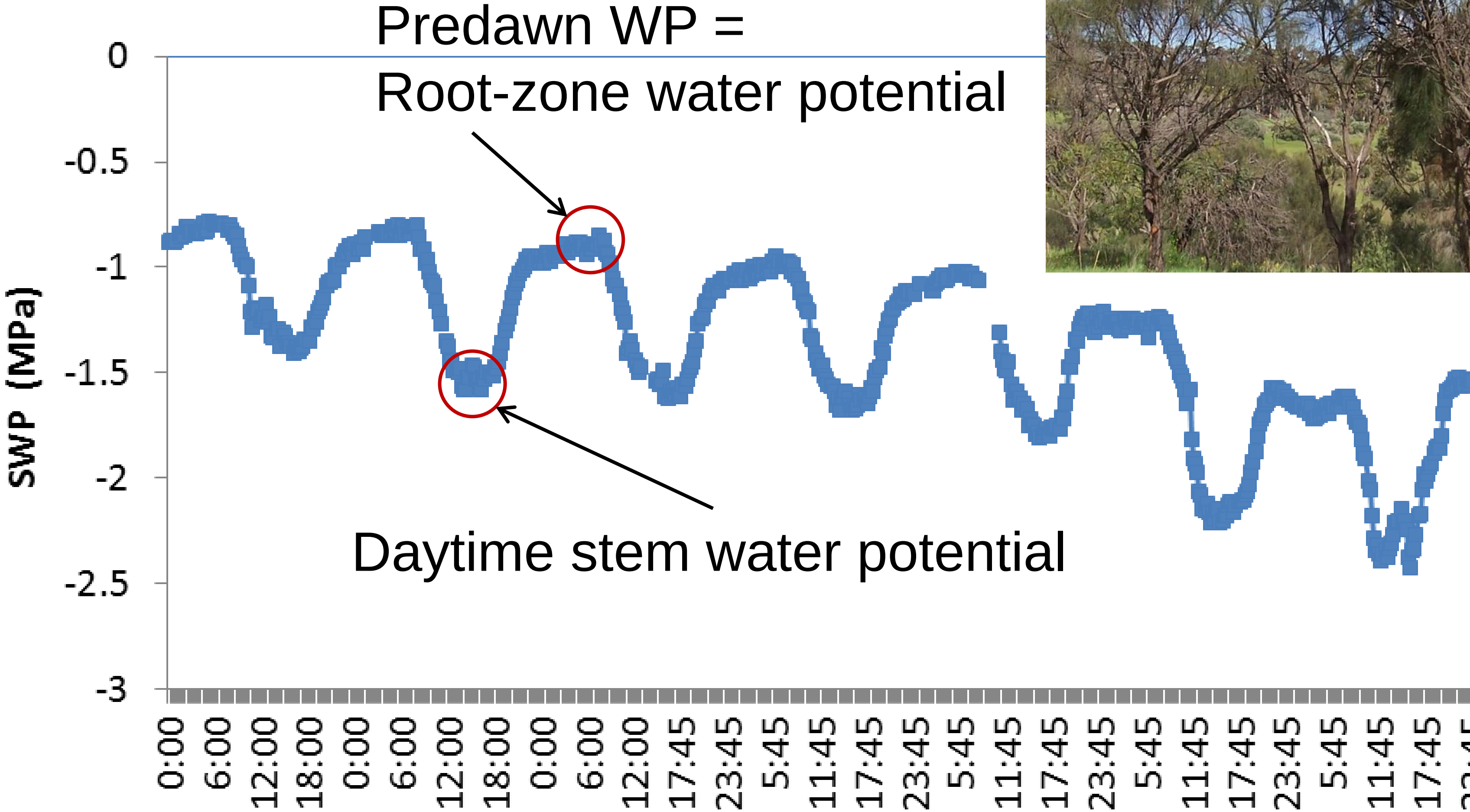
Using Trees as “hydraulic periscopes” to monitor and characterise SPAC

- “Observation wells” to monitor root zone hydraulic states
- “Pumping test” to estimate soil-plant continuum hydraulic properties





“Observation wells” at Predawn



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Yang et al., 2013

Testing SPAC models: an example on the Jarvis-Stewart Model

$$E_c = \frac{\Delta(R_n - G) + \frac{\rho_a c_p}{r_a}(e_s - e_a)}{\Delta + \gamma\left(1 + \frac{r_c}{r_a}\right)}$$

$$g_c = g_{max} LAI . f(R_s) f(D) f(T) f(\psi)$$

≤ 1

solar radiation

VPD

temper-ature

soil moisture

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Experiments at two sites of different climates

Drooping sheoak
Mediterranean climate

Guihua
Subtropical monsoon

Optimised parameters for two species in different climate zones

A. verticillata

$$g_c = 0.0076 \cdot LAI \cdot \left(\frac{R_s}{R_s + 4.6} \cdot \frac{350 + 4.6}{350} \right) \cdot$$

$$\left\{ e^{-0.75D} \cdot \left[1 - (-0.0128)(20 - T)^2 \right] \right\} \cdot$$

$$\frac{1}{1 + \left(\frac{\psi}{-0.87} \right)^{0.74}}$$

O. fragrans

$$g_c = 0.0042 \cdot LAI \cdot f(R_s) \cdot$$

$$\left\{ e^{-0.50D} \cdot \left[1 - (-0.0024)(24.5 - T)^2 \right] \right\} \cdot$$

$$\left[1 - e^{-0.61(\psi + 3.39)} \right]$$

$$f(T) > 1$$

Wang et al. 2014, Luo et al. 2016

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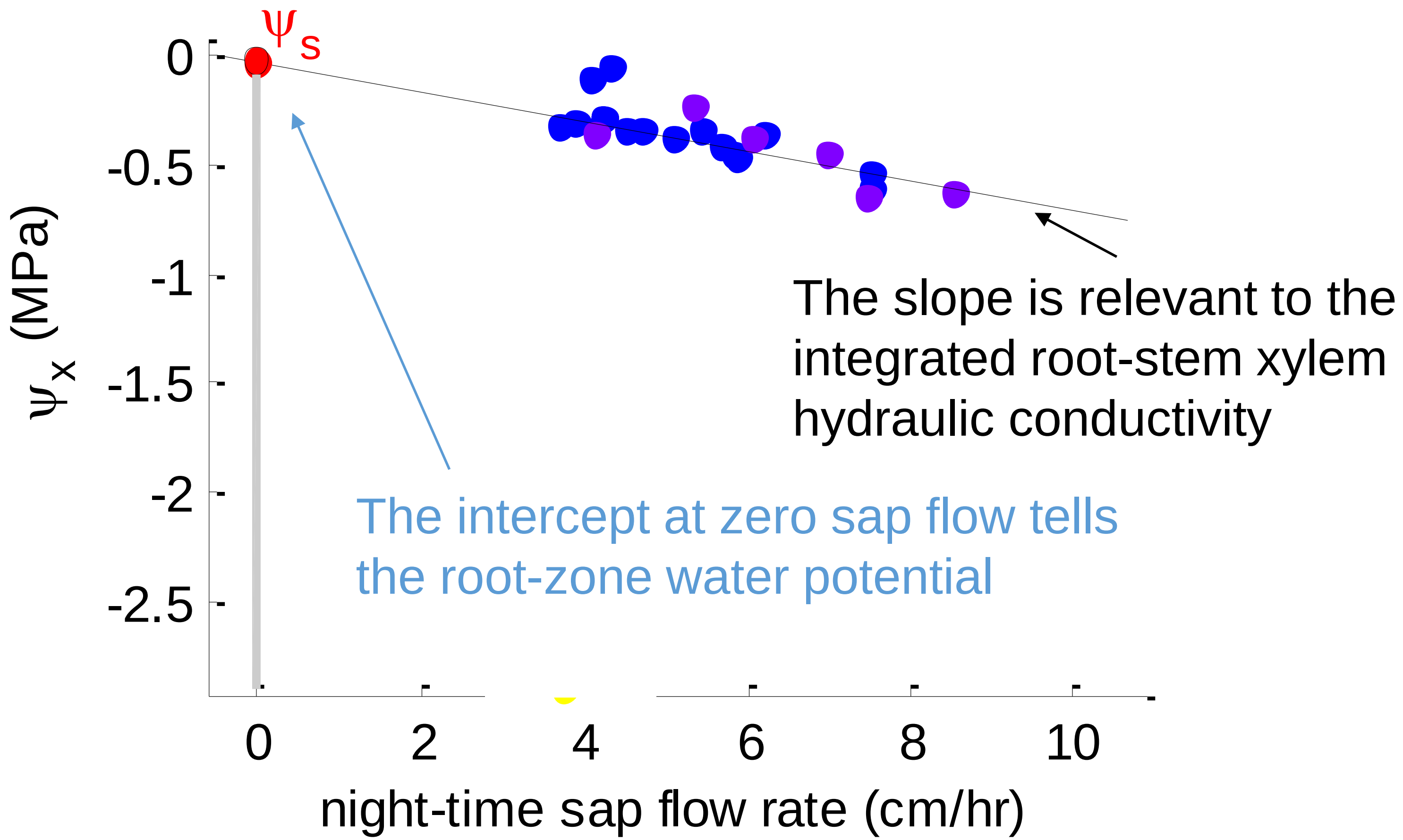
“Pumping test” when (e.g., night-time) the boundary condition is stable



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Deng et al., 2017

A vegetation-focused SPAC model (v-SPAC)

- **Sap flow** and **plant water potential**
- **Plant water storage** as a function of water potential
- Plant hydraulic conductance as a function of water potential (**integrated vulnerability curve**)

- Root-zone water storage and hydrological processes, based on LEACHM
- Parameterisation of vulnerability curve from night-time sap flow.

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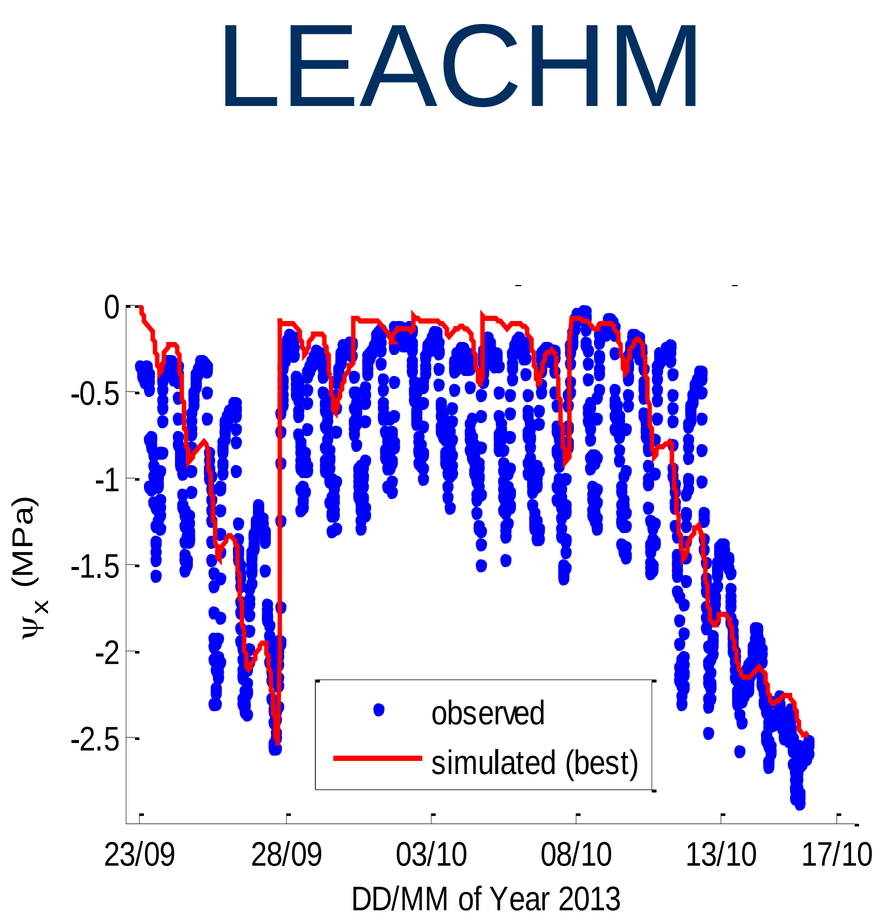

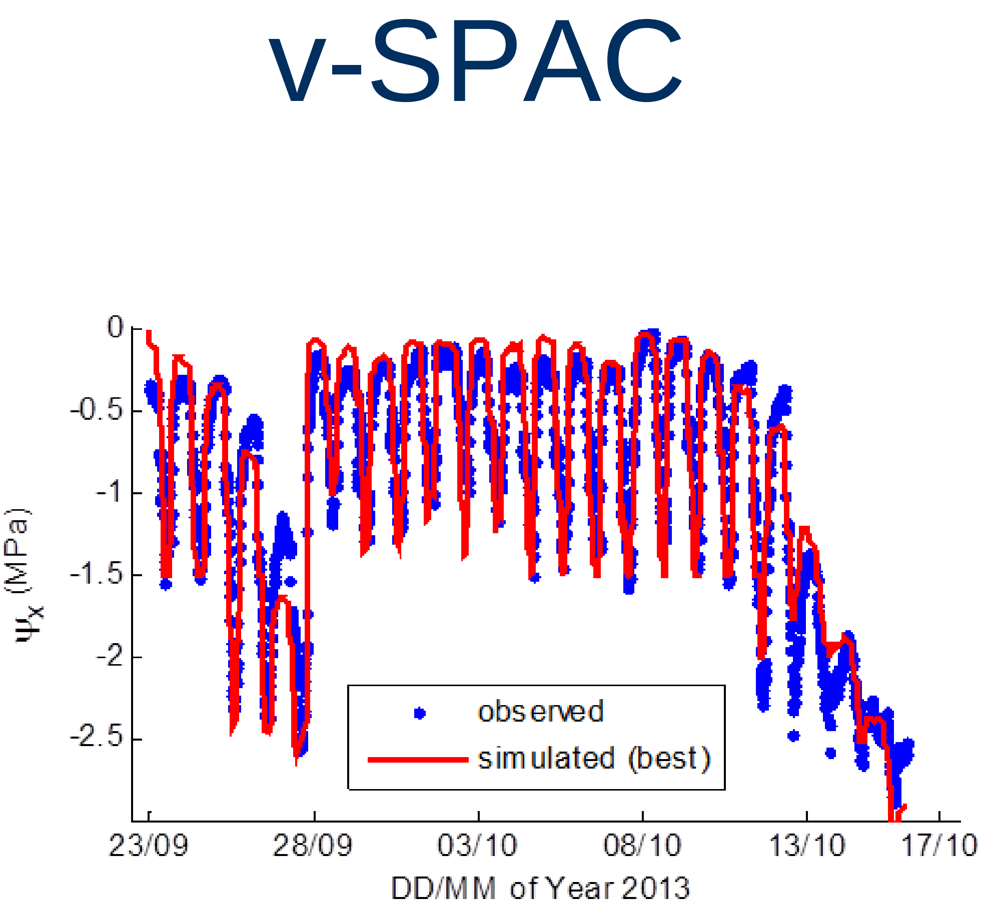

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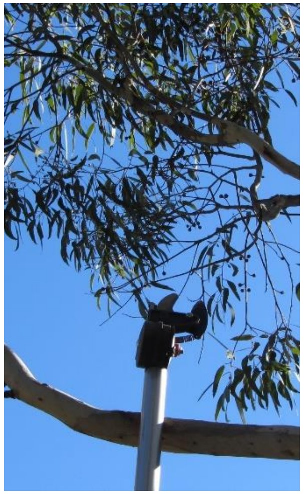
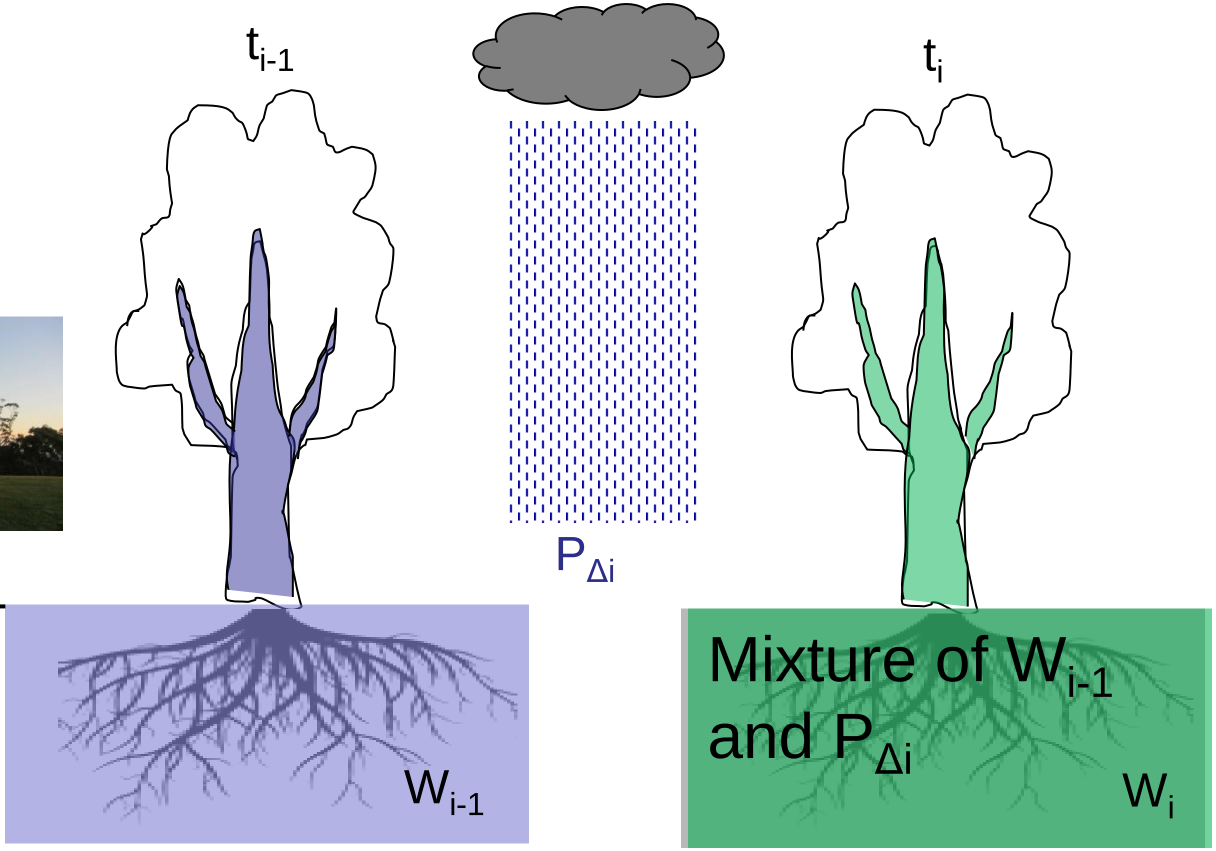
Deng et al., 2017

Isotopic Periscope: using trees for "tracer tests"

$$\delta_i = \delta_P \times \beta + \delta_{i-1} \times (1 - \beta)$$





***β*: moisture replenishment**

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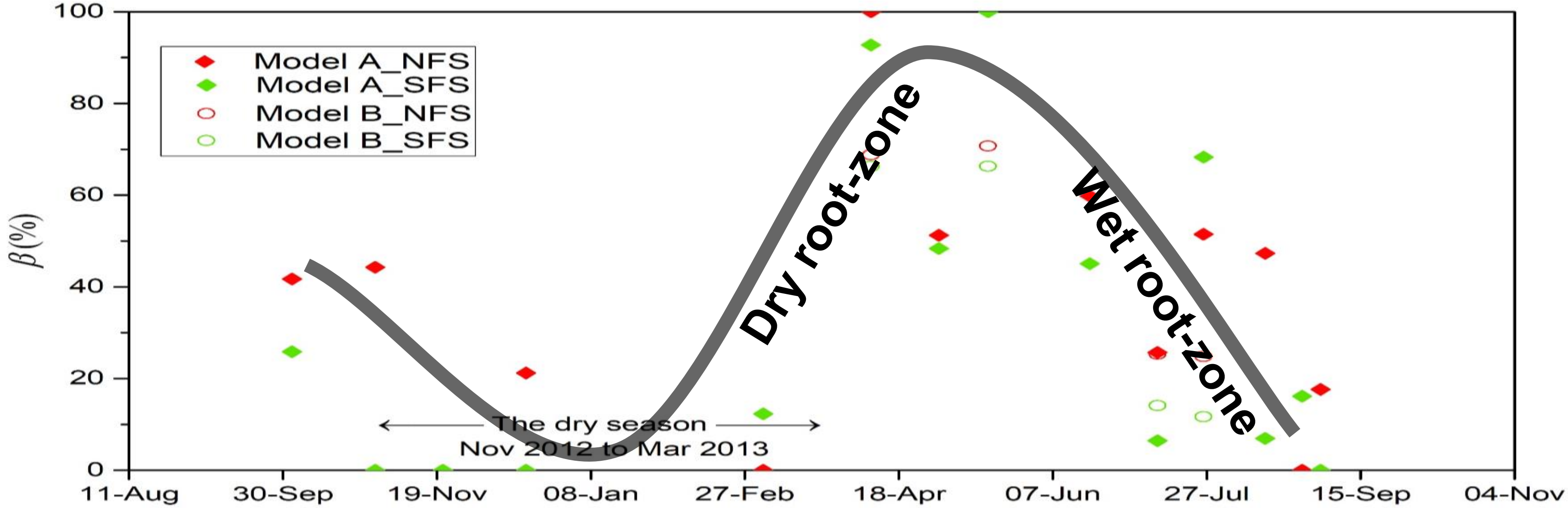
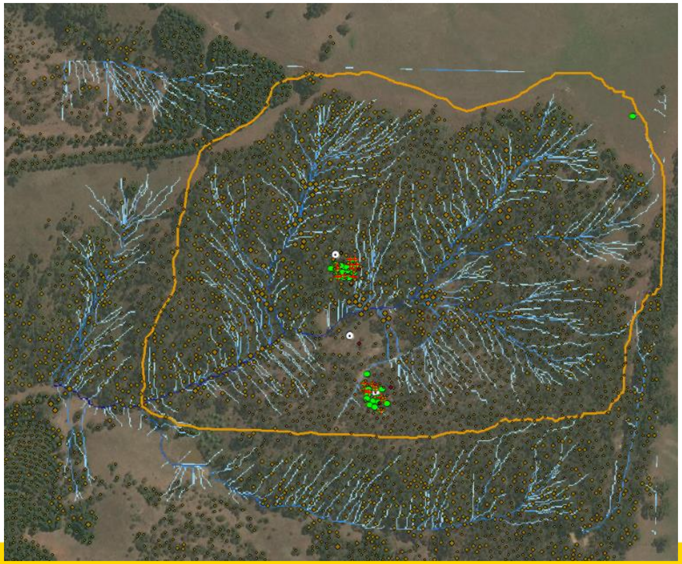
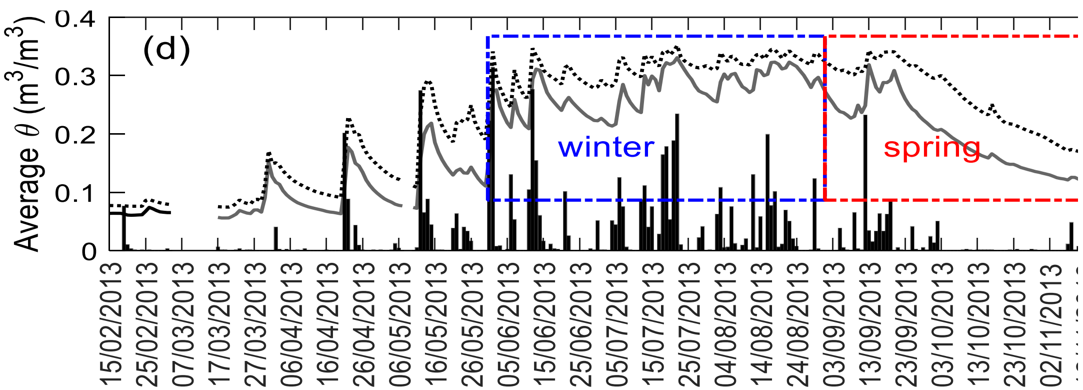
Seasonal variation of root-zone moisture replenishment







Xiang et al., 2019

Root-zone periscope → new opportunities in ecohydrological research

- **Hydraulic periscope**
  - Requirement: Stem water potential and sap flow
  - Dynamics of lumped root-zone hydraulic states
  - Root-stem hydraulic properties
  - Testing and developing SPAC models

- **Isotopic periscope**
  - Requirement: $\delta^{18}O$ of twig water and rain
  - Root-zone moisture replenishment

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Relevant articles

1. Liu, N., Deng, Z., Wang, H., Luo, Z., Gutierrez-Jurado, H., He, X., Guan, H. (2020). Thermal remote sensing of plant water stress in natural ecosystems. *Forest Ecology and Management*. 476, 118433. 10.1016/j.foreco.2020.118433
2. Liu, N., Wang, H., He, X., Deng, Z., Zhang, C., Zhang, X. & Guan, H. (2019) A hybrid transpiration model for water-limited conditions. *Journal of Hydrology*. 578, 124104.
3. Xu, X., Guan, H., Skrzypek, G. & Simmons, C. T. (2019). Root-zone moisture replenishment in a native vegetated catchment under Mediterranean climate. *Hydrological Processes*, 33, 18, p. 2394-2407.
4. Luo, Z., Guan, H., Zhang, X. and Xu, X. (2019). Examination of the ecohydrological separation hypothesis in a humid subtropical area: Comparison of three methods. *Journal of Hydrology*, 571 pp. 642-650.
5. Liu, N., Guan, H., Buckley, T., He, X., Zhang, X., Zhang, C., et al. (2019). Improvement of a simplified process-based model for estimating transpiration under water-limited conditions. *Hydrological Processes*.
6. Deng, Z., Guan, H., Hutson, J.L., Forster, M., Wang, Y. and Simmons, C.T. (2017). A vegetation focused soil-plant-atmosphere continuum model to study hydrodynamic soil-plant water relations. *Water Resources Research*, 53 pp. 4965-4983. DOI:10.1002/2017WR020467
7. Liu, N., Guan, H., Luo, Z., Zhang, C., Wang, H. and Zhang, X. (2017). Examination of a coupled supply- and demand-induced stress function for root water uptake modeling. *Hydrology Research*, 48(1) pp. 66-76.
8. Luo, Z., Guan, H., Zhang, X., Zhang, C., Liu, N. and Li, G. (2016). Responses of plant water use to a severe summer drought for two subtropical tree species in the central southern China. *Journal of Hydrology: Regional Studies*, 8 pp. 1-9.
9. Wang, H., Guan, H. and Simmons, C.T. (2016). Modeling the environmental controls on tree water use at different temporal scales. *Agricultural and Forest Meteorology*, 225 pp. 24-35.
10. *Wang, H., Guan, H., Deng, Z. and Simmons, C. (2014). Optimization of canopy conductance models from concurrent measurements of sap flow and stem water potential on Drooping Sheoak in South Australia. *Water Resources Research*, 50(7) pp. 6154-6167.
11. Yang, Y., Guan, H., Hutson, J., Wang, H., Ewenz, C., Shang, S., et al. (2012). Examination and parameterization of the root water uptake model from stem water potential and sap flow measurements. *Hydrological Processes*, [10.1002/hyp.9406]

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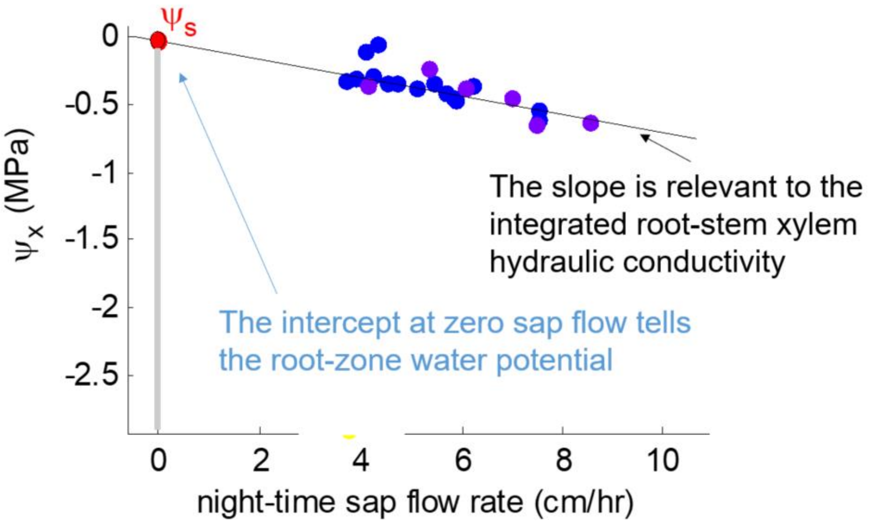
Ongoing:
Zhechen (Oliver) Zhang's PhD research



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Acknowledgement

Grzegorz Skrzypek co-supervised Xiang Xu's PhD research.
Hugo Gutierrez, Robert Andrew, Yunquan Wang, Nasrin Sterling, Kelsey Lees assisted with the field work

NCGRT (funded by ARC + NWC), Australia
China Scholarship Council

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