

# Cosmic Ray Sensing on an irrigated citrus orchard in Morocco

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#### **Problem:**

- Significant growth of agriculture, tourism and urbanization in and around Marrakesh
- Overexploitation of the groundwater table
- Lowering up to 40m beneath the surface

#### **Objectives of the project:**

- Cooperation between University of Potsdam and University Cadi Ayyad (Marrakesh)
- Irrigation recharge for a drip irrigated citrus orchard
- Assessment of the soil water balance on field-scale
- Combination of CRS and eddy covariance technique



### **Location**





**CRS** 





• Additional installed were TDR, fluxmeter, meteorological station

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# **Calibration Campaign**



#### Standard sampling procedure<sup>1</sup>:

Modified sampling pattern:





#### 3 characteristical zones of soil moisture:

- 1 = between and around the trees
- 2= at the drip lines
- 3= between tree rows

<sup>1</sup> Franz, T. E., Zreda, M., Ferre, T. P. A., Rosolem, R., 2013. An assessment of the effect of horizontal soil moisture heterogeneity on the area-average measurement of cosmic-ray neutrons. Water Resources Research 49 (10), 64506458.



## **Calibration Data Set**





Soil moisture [cm<sup>3</sup>/cm<sup>3</sup>]



# **Spatial Weighting**





For each layer calculated:

$$\Theta_{\text{spatial}(z) = (0,13*} \overline{\Theta}_{\text{dripper}(z))+(0,23*} \overline{\Theta}_{\text{trees}(z))+(0,53*} \overline{\Theta}_{\text{rows}(z))}$$



# **Vertical Weighting**



$$Wt(z) = a\left(1 - \left(\frac{z}{z^*}\right)^b\right)^{-2}$$

 $\theta_{\text{vertical (z)}=} \theta_{\text{spatial (z)}} * Wt(z)$ 

- a = constant def. by the condition that weights are conserved
- b = controls the curvature of the weighting function
- z\*= effective depth of the sensor
- z = single depth layers

$$\theta_{w} = ((0.9 * \theta_{vertical(z))+} (0.1 *_{\theta roads})))$$

Taking dry roads into account

<sup>2</sup> Franz, T. E., Zreda, M., Ferre, T. P. A., Rosolem, R., Zweck, C., Stillman, S., Zeng, X., Shuttleworth, W. J., 2012a. Measurement depth of the cosmic ray soil moisture probe affected by hydrogen from various sources. Water Resources Research 48 (8), 19.







Calibration after Desilets et al. (2010)

$$\theta(N) = \frac{a_0}{\left(\frac{N}{N_0}\right) - a_1} - a_2$$



### **Soil Moisture**



#### -> 24-h-moving average





### **Seasonal Scale**







# **Eddy Covariance and CRS**









# Thank you!



### **Corrections**







### **Daily Scale**





Footprint: Sector 1 ~ 8 ha Sector 2 ~ 12 ha Sector 3 ~ 4 ha Other ~ 4.5 ha irrigated Irrigation: Sector 1 = green Sector 2 = red Sector 3 = yellow













Hours of day



## **Soil Water Balance**





~ 30 % of inputs percolate to the groundwater table