

Moisture and humidity dependence of the above-ground cosmic-ray neutron intensity revised

30.04.2021 Markus Köhli^{1,2}, Jannis Weimar¹, Martin Schrön³ and Ulrich Schmidt¹

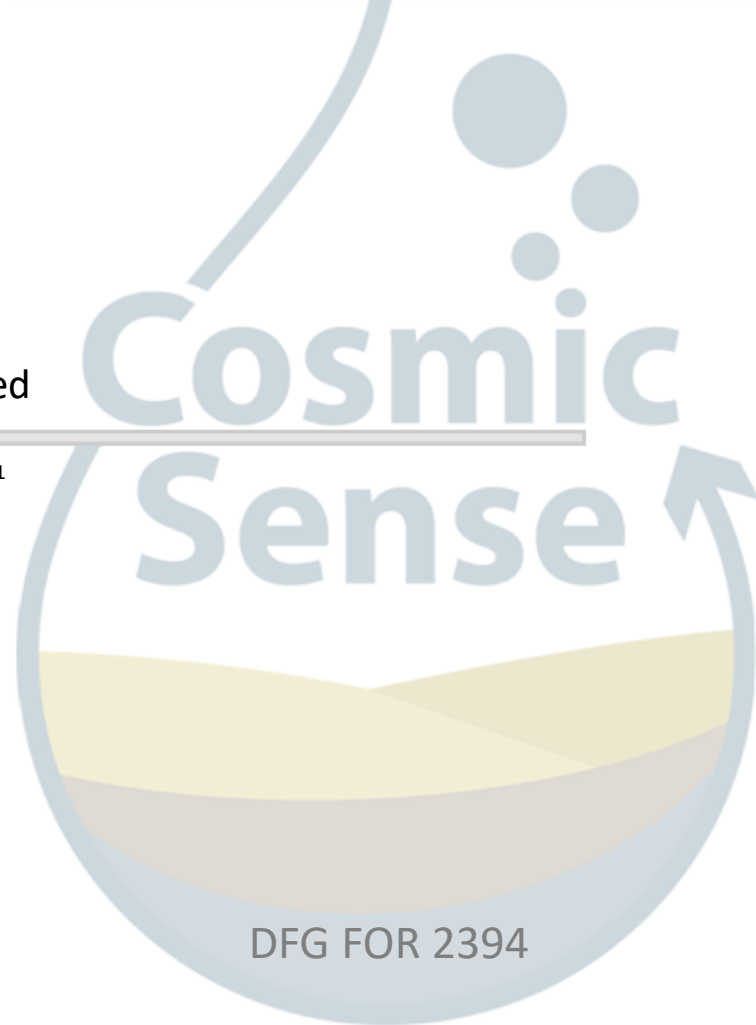
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Many studies were carried out for **finding a sensor calibration routine** and to compare the performance to conventional instruments

(Rivera Villarreyes et al., 2011; Franz et al., 2012; Hawdon et al., 2014; Almeida et al., 2014; Coopersmith et al., 2014)
with a good agreement between measured neutron flux and soil moisture values

However, unexplained features in the CRNS data could not be described by the Desilets equation

$$\theta(N) = \frac{0.0808}{\left(\frac{N}{N_0}\right) - 0.372} - 0.115$$

Then,

groups tried to **fit the parameters** of the hyperbola to their data

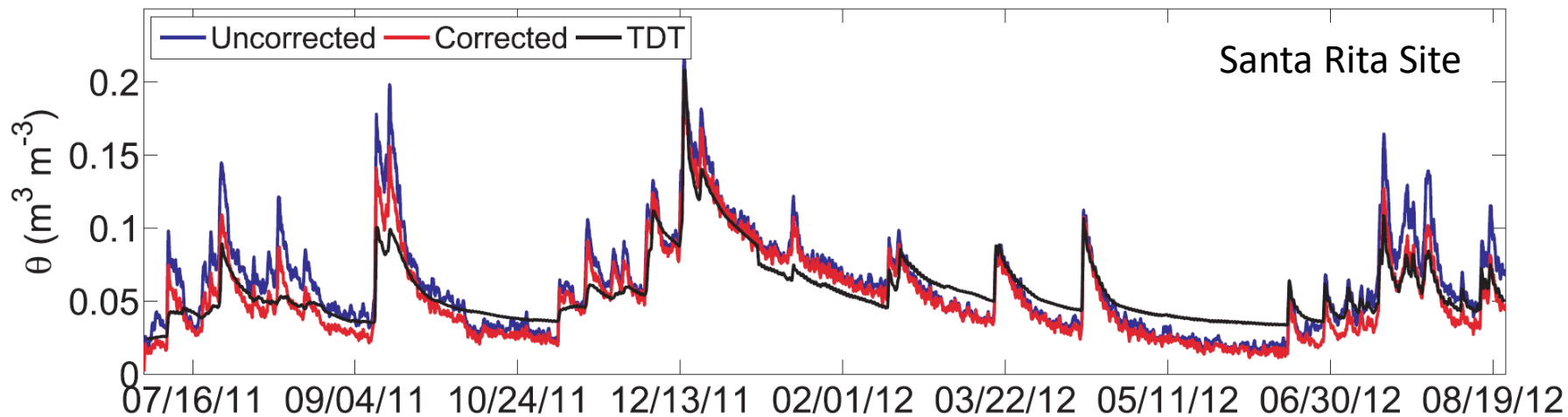
Rivera Villarreyes et al., 2011; Lv et al., 2014; Heidbüchel et al., 2016; Sigouin and Si, 2016

with a better correlation **at the cost of site-specific calibrations**

But still:

Desilets equation / N0 method: bad performance under dry conditions

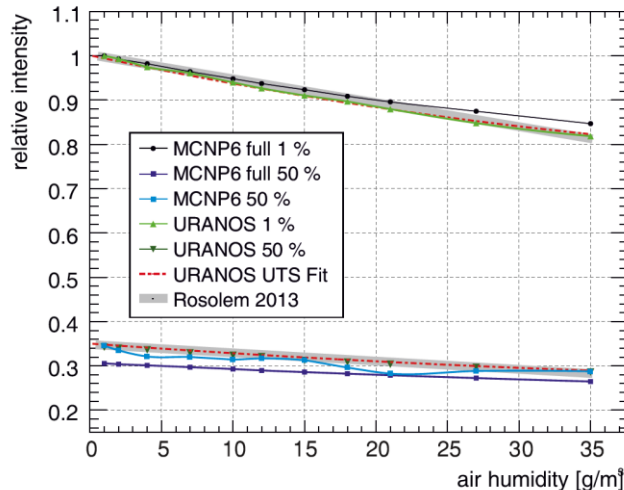
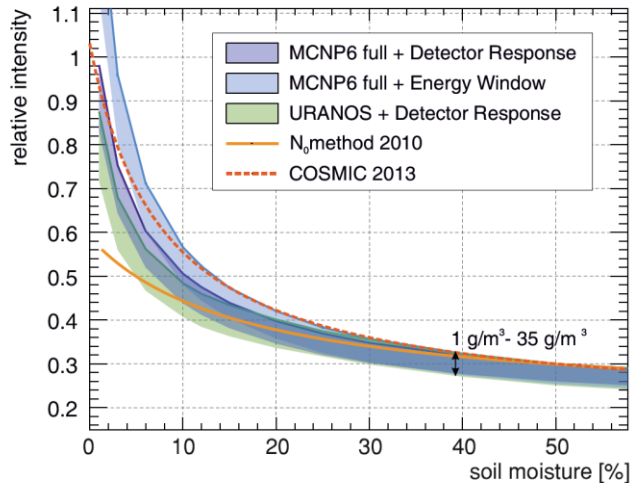
(b)



R. ROSOLEM, et al. "The Effect of Atmospheric Water Vapor on Neutron Count in the Cosmic-Ray Soil Moisture Observing System." *Journal of Hydrometeorology* 14(5), 2013, 1659–1671.

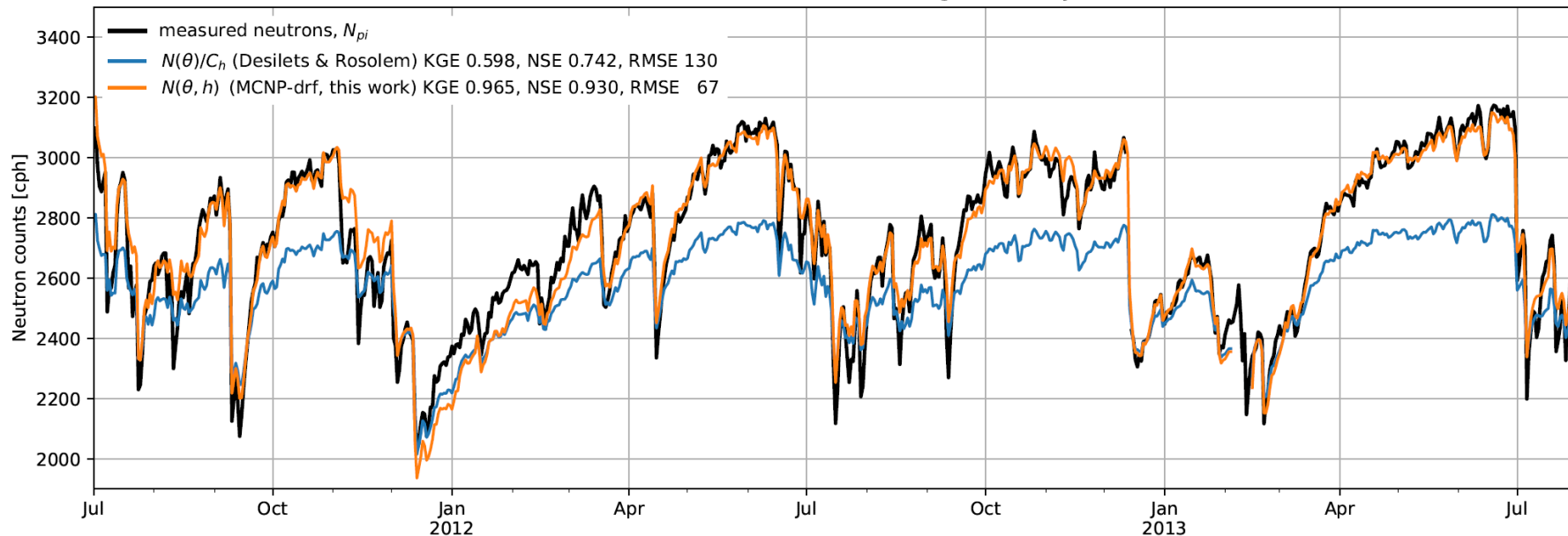
Our proposition: the universal transport solution (UTS)

$$I(\theta, h) = N_D \left(\underbrace{\frac{p_1 + p_2 \theta}{p_1 + \theta}}_{\text{Hyperbola}} \underbrace{(p_0 + p_6 h + p_7 h^2)}_{\substack{\uparrow \\ \text{air humidity} \\ \text{corrections}}} + \underbrace{e^{-p_3 \theta}}_{\text{Exponential}} \underbrace{(p_4 + p_5 h)}_{\substack{\uparrow \\ \text{air humidity} \\ \text{corrections}}} \right)$$



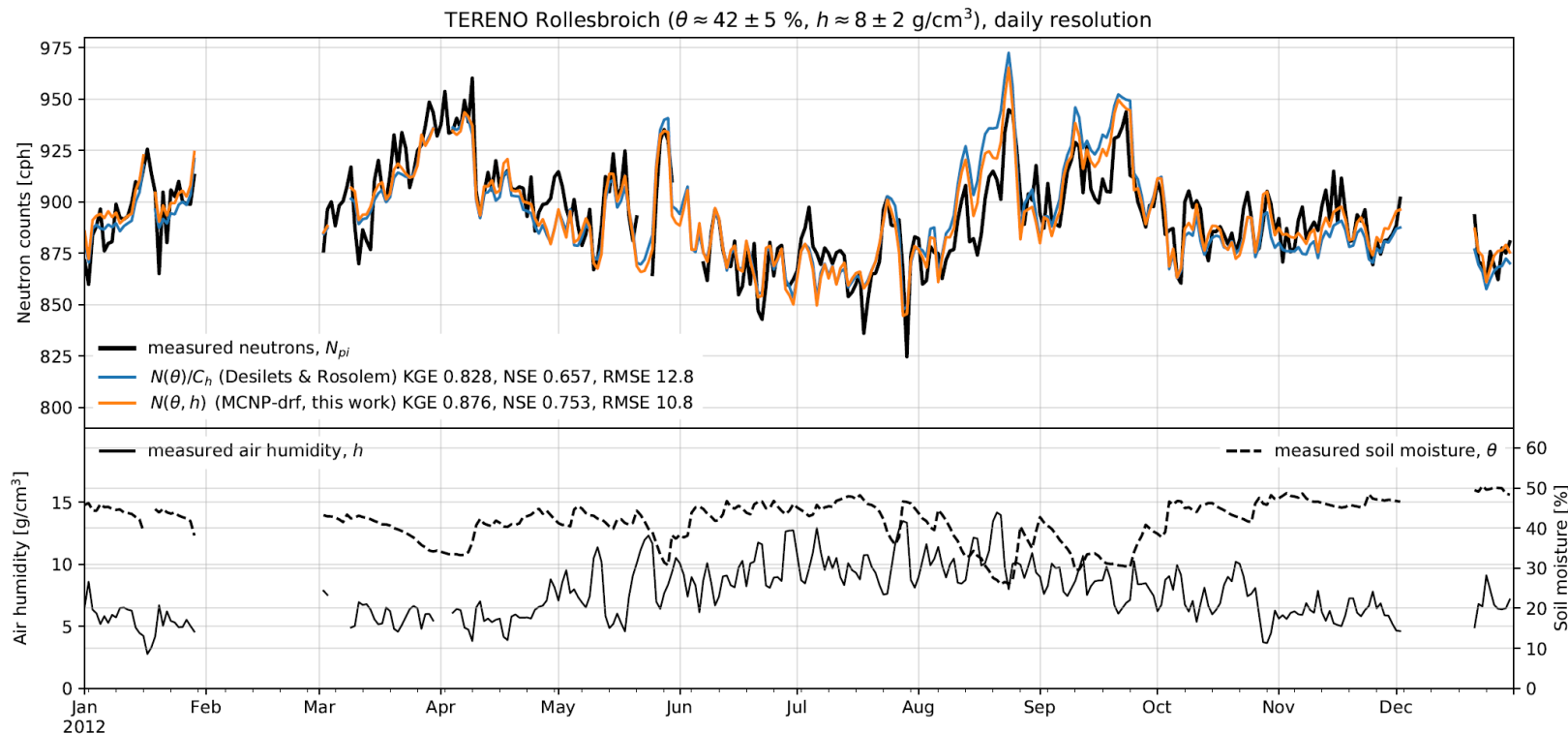
NS > Experimental evidence – dry conditions

COSMOS Santa Rita ($\theta \approx 7 \pm 3 \%$, $h \approx 7 \pm 4 \text{ g/cm}^3$), daily resolution



Caution! Here: soil moisture converted to neutron counts

Data from Santa Rita (T. Franz)

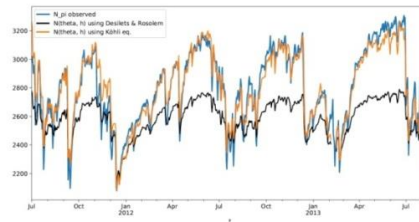


Data from Rollesbroich (R. Baatz)

- **Site-specific calibrations** are most probably a result of not optimal fit functions
- New **CRNS intensity function** found by **understanding the contributions** and **improving the corrections of CR neutrons to the signal**.

Combined function for soil moisture and humidity:

$$I(\theta, h) = N_D \left(\frac{p_1 + p_2 \theta}{p_1 + \theta} (p_0 + p_6 h + p_7 h^2) + e^{-p_3 \theta} (p_4 + p_5 h) \right)$$



- **First data blind validation very successful**
- Thermal shields can significantly improve the signal response



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