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Innovative methods for non-invasive monitoring of hydrological processes from field to catchment scale (HS1.1.3)

Long-Term Soil Moisture Observations Using Cosmic-Ray Neutron Sensing in Austria

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INTRODUCTION

A new soil water sensing technique, the Cosmic Ray Neutron Sensor (CRNS), capable of measuring landscape water content up to 20 ha in area, 30-40 cm deep was recently tested in the Soil and Water Management and Crop Nutrition (SWMCN) Subprogramme of Joint FAO/IAEA Division. This poster presents an overview of results achieved during the soil water monitoring period 2013-2019.

Objectives

Calibration and validation of CRNS
Use of backpack CRNS (footprint and effective depth)
Use of backpack CRNS for investigation of SWC spatial variability and temporal dynamics
Use of backpack CRNS in mountainous areas
Reducing noise of neutron counts

MATERIAL & METHODS

Studied sites (2013-2019)

SWMCN carried its CRNS measurements of soil water content (SWC) at two monitoring stations Petzenkirchen, footslope of Turnitzer Alpen and Rutzendorf, Machfeld, both in Lower Austria. The short term measurement campaigns were carried in Illmitz, Neusiedler See (Burgenland) and in Rauris, High Tauern (Salzburg) (Figure 1).

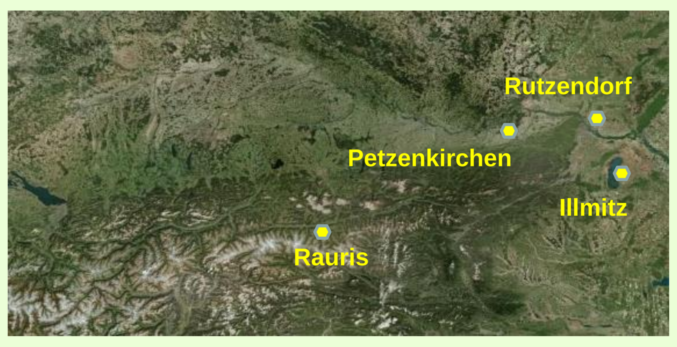

Figure 1. Studied sites for CRNS SWC measurements

Methods

Two CRNS devices are used: The stationary CRNS is installed in Petzenkirchen (since December 2013). The backpack CRNS was used for short term measurement campaigns in Illmitz and Rauris and since March 2019 it is installed at new monitoring station in Rutzendorf. Apart from CRNS, soil moisture was also measured by several conventional techniques such as gravimetric method, time domain reflectometry (TDR), time domain transmissivity (TDT) and Drill & Drop capacitance probes.

RESULTS

Calibration and validation

The calibration of CRNS data set from Petzenkirchen stationary site (Figure 2) was done in several campaigns during 2013-2016 (Wahbi et al., 2015, Franz et al., 2016) using N_0 method (Desilets et al., 2010, Bogena et al., 2013) which is site-specific and depends on the surroundings. The correlation of stationary CRNS data with gravimetric data (Fig. 3) is acceptable (R^2 = 0.642 for first calibration). With repetition of measurements (n = 6) it does not improve further (R^2 = 0.640 for six calibrations). The validation with gravimetric method, TDR and TDT (Fig. 4, 5, 6) confirms that CRNS produce reliable results.

Validating the footprint and effective depth of backpack CRNS

The validation of ackpack CRNS footprint and effective depth (Wahbi et al., 2017, 2019) involves 16 calibrations for 5 study sites at an altitude of 300 - 1700 m a.s.l. It showed similar outcomes for a 75-meter and 200 meter (Figure 7). The effective depth (Figure 8) was estimated to 10 cm for volumetric water contents of 30 - 60%.

SWC spatial variability and temporal dynamics investigated by backpack CRNS

The backpack CRNS measurements carried in Illmitz along a transect (7 sites) repeated for 7 times show example how SWC spatial variability and temporal dynamics can be investigate. (Fig. 9, 10).

Improving the CRNS signal by smoothening the noise of neutron counts

The neutron counts have a noisy appearance "up and down fluctuations around a mean value". Reducing the "noise" of CRNS signal was tested on Petzenkirchen data series (Franz et al., 2020) using the third order Savitzky-Golay (SG) filter (Savitzky, Golay, 1964). This procedure succeeded to considerably smoothen the signal (Fig. 11).

CONCLUSION

The research carried at Joint FAO/IAEA Division brought a lot of valuable information on the functioning and possible application of CRNS. This knowledge was used to produce three CRNS Guidebooks (IAEA, 2017, 2018, Wahbi et al., 2018). Recently a new coordinated research project (CRP) 'Enhancing Agricultural Resilience and Water Security Using Cosmic-Ray Neutron Sensor' was initiated. The CRP's major objective is to develop approaches of using CRNS and Gamma Ray spectrometer (GRS) for agricultural and environmental applications such as soil moisture monitoring, hydrological modelling, irrigation scheduling, drought management and flood prediction.

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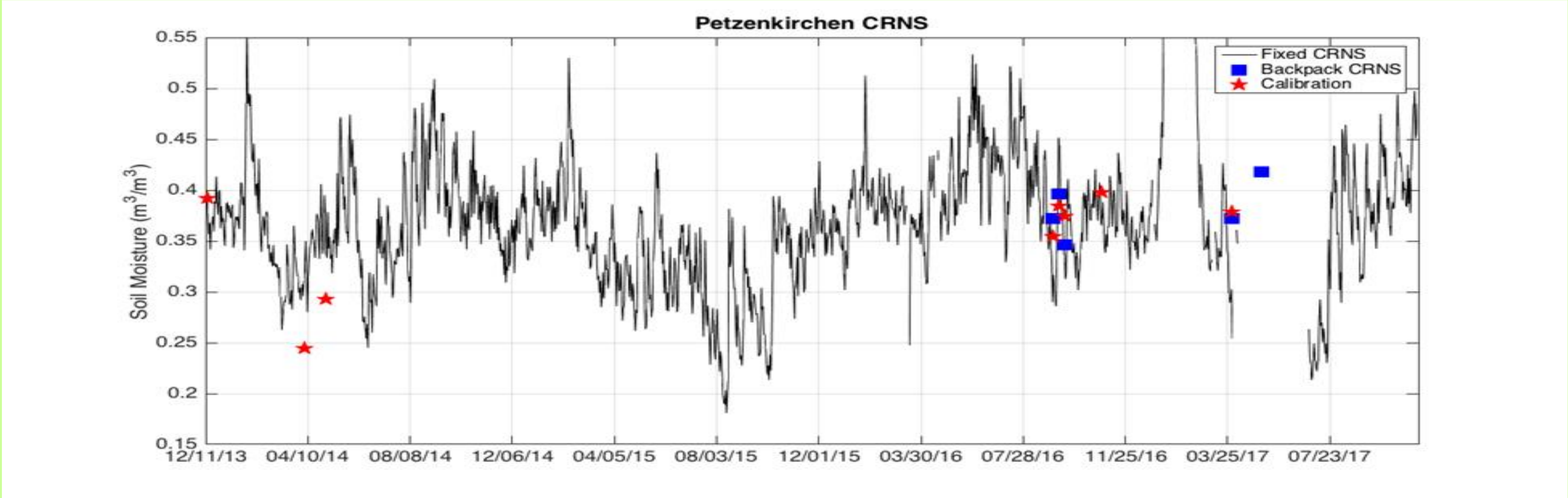

Figure 2. Volumetric SWC measured by CRNS at Petzenkirchen

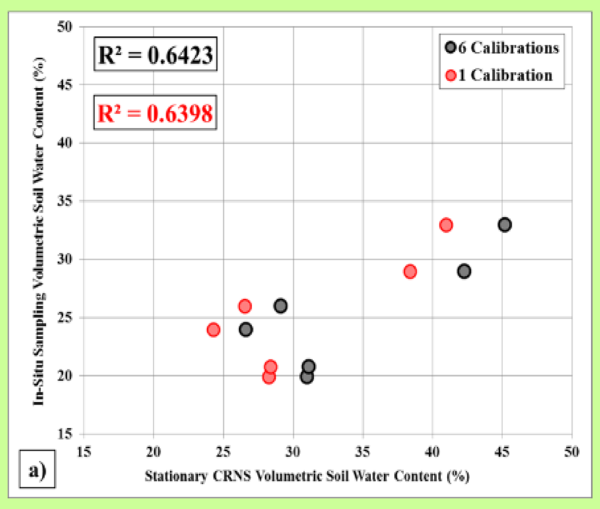

Figure 3. CRNS SWC versus SWC in-situ sampling of calibration campaigns at Petzenkirchen: red – 1st calibration, black – mean of 6 calibrations

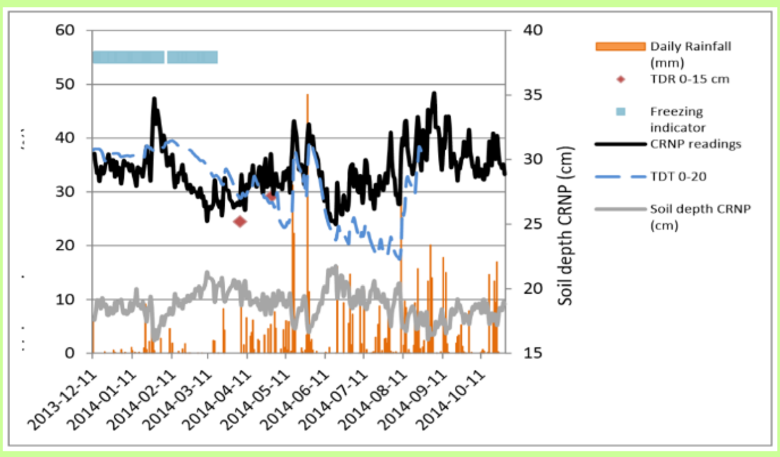
Figure 4. Validation of Cosmic Ray Neutron Sensor at Petzenkirchen station

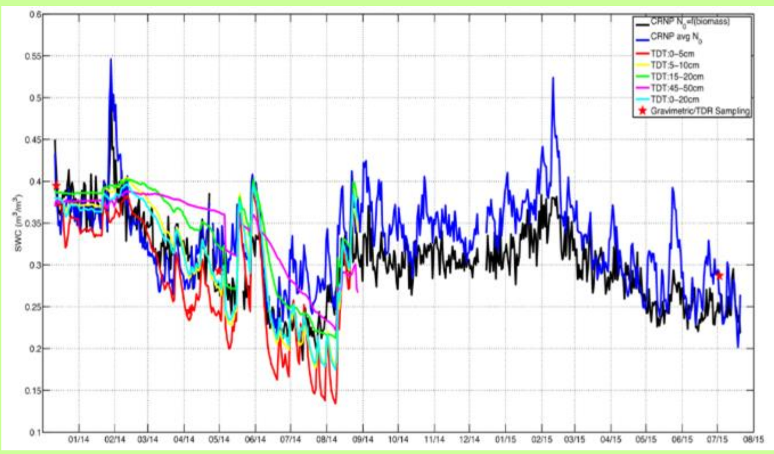
Figure 5. SWC by CRNS, TDT, TDR and gravimetric method at Petzenkirchen station

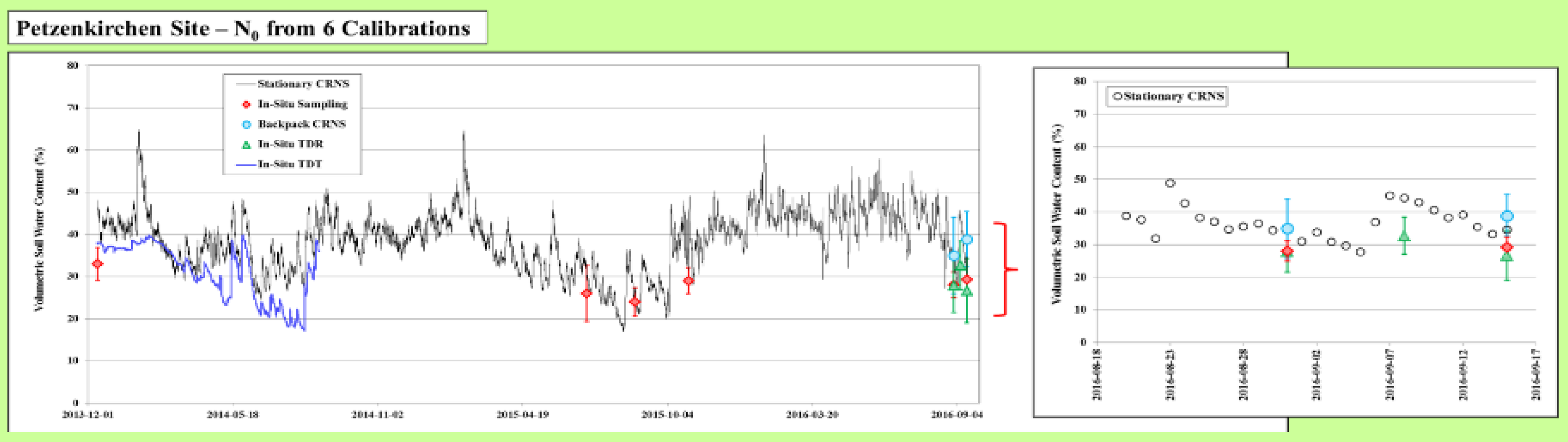

Figure 6. SWC by stationary and backpack CRNS, TDT (0-10 cm), TDR, and gravimetric method for the purpose of CRNS data validation (error bars represent standard deviation)

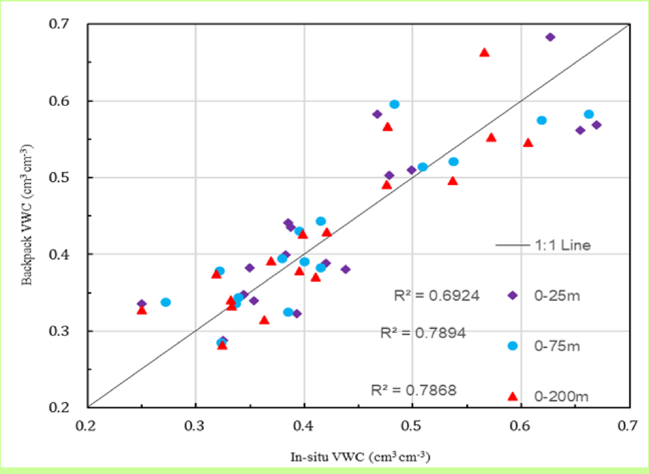
Figure 7. Relation between stationary and backpack CRNS SWC (three different footprints, altitudes from 300 to 1700 m a.s.l.)

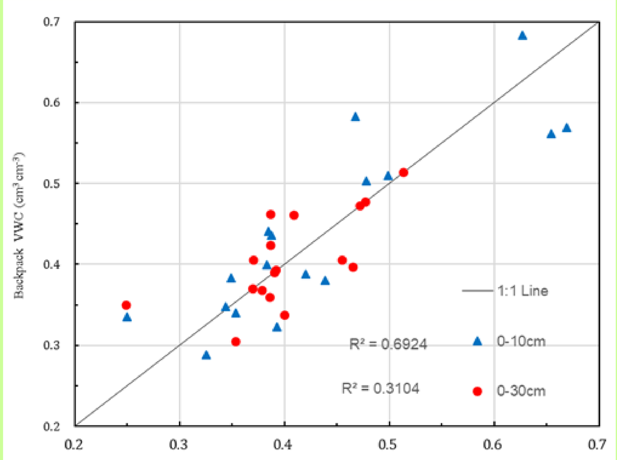
Figure 8. Relation between stationary and backpack CRNS SWC for two different soil depths at different altitudes (from 300 to 1700 m a.s.l.)


Figure 9. Location of measurement transect near Illmitz

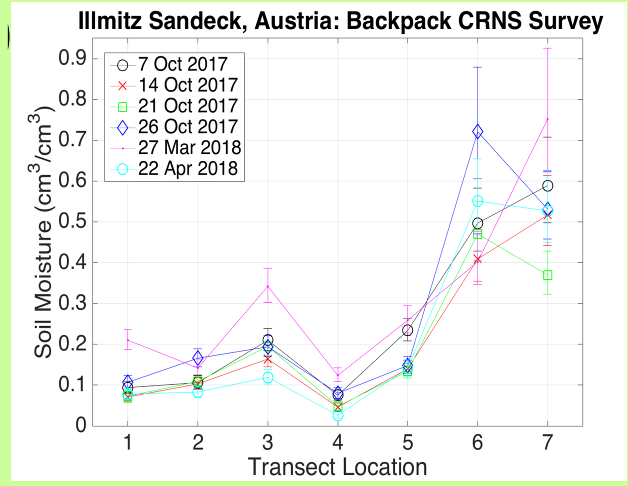

Figure 10. Backpack CRNS SWC of seven field surveys near Illmitz

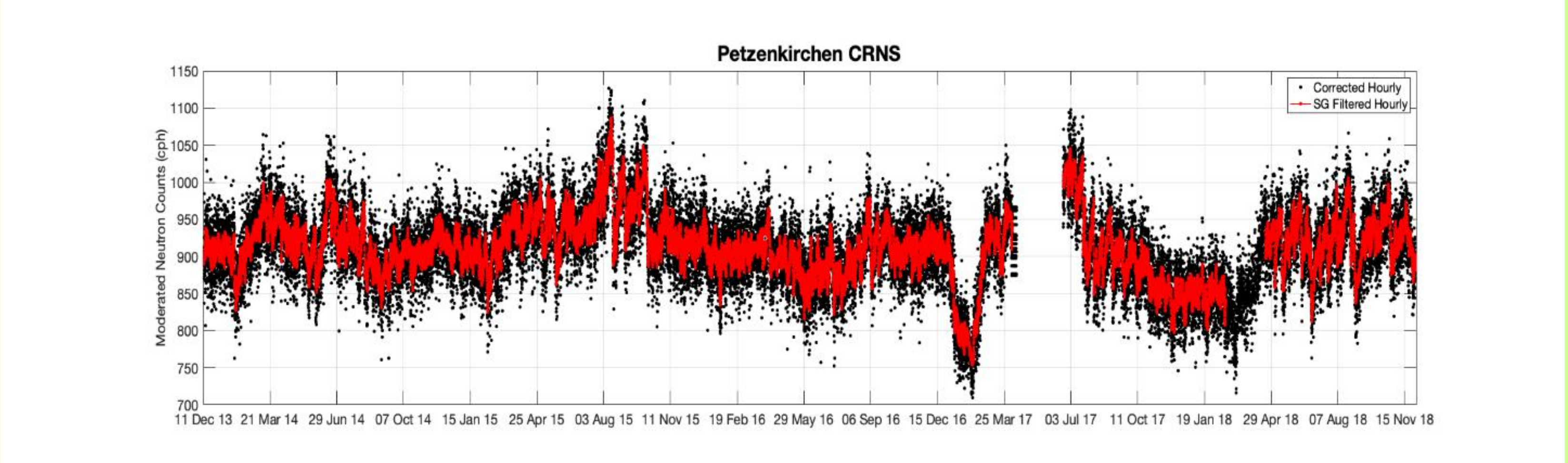

Figure 11. Time series of corrected neutron counts (black dots), SG filtered neutron counts (red line)