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Conference Abstract

Assessing soil moisture using cosmic-ray neutrons in three boreal forest stands in Northern Europe

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Abstract

Introduction

Cosmic-ray neutron sensors (CRNSs) have been used worldwide to assess soil moisture changes continuously and non-destructively at scales of less than kilometers. The method is based on inverse correlation between cosmic-ray neutron intensity and soil moisture, as low-energy neutron intensity above the soil depends greatly on the hydrogen content of the soil (Zreda 2008). On the field scale, the effective range of the sensor is from 130 to 240 m and penetration depth from 15 to 83 cm depending on soil moistness, decreasing exponentially with distance from the sensor (Köhli 2015).

CRNSs have been used in diverse environments, such as grasslands, agricultural fields and forest ecosystems, various climatic zones and more than ten years in Europe (Bogena 2022). Here we attempt to calibrate the CRNS soil moisture estimation process for three boreal coniferous forests stands in southern and northern Finland and compare the results with data from point measurements of soil moisture sensors. Since most of the CRNS research has been conducted further south in Europe, these will be novel results from CRNS measurements of boreal forests in northern Europe, partly even further north than the Arctic Circle.

Materials and methods

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Three CRNSs (StyX Neutronica Black Puppet SP; Fig. 1) were installed in 2022 at two University of Helsinki field sites, two at the Station for Measuring Ecosystem-Atmosphere Relations (SMEAR) II (61.51°N, 24.17°E, 181 a.s.l) near Hyytiälä forest station in southern Finland and one at SMEAR I (67°46’N, 29°35’E, 390 a.s.l) on Kotovaara hill, near Värriö subarctic research station in eastern Finnish Lapland. SMEAR II in southern Finland has two sensors, one located to call “hill” and other called “hollow” sites. The forest around CRNS “hill” is a 63-years-old Scots pine (*Pinus sylvestris* L.) stand with undergrowth of Norway spruce (*Picea abies* (L.) Karst.), and around “hollow” is dominated by 60–100-years-old Norway spruces (Kolari 2022). The soil above the bedrock around “hill” sensor is haplic podsol on glacial till (FAO 1988), and the soil depth is approximately 0.5–1.0 m. “Hollow” site has a small a stream flowing in wet seasons near the sensor. Forest around SMEAR I in northern Finland is naturally generated Scots pine stand, which has estimated to be on average approximately 70–80 years old (Matkala 2021). Soil type is haplic podsol on sandy till (FAO 1988), and the soil depth is approximately 0.5 m.

Figure 1. doi

Cosmic-ray neutron sensor in southern Finland on “hollow” site (Picture by Kira Ryhti-Laine).

Moisture calibration was conducted by taking volumetric soil samples from different directions, distances and various depths from the sensors, based on Schrön (2017). Moisture content of the samples was determined gravimetrically. Soil samples from SMEAR II “hill” were collected from six different directions at 7, 40 and 100 meters from the sensor in August 2022. Soil samples from SMEAR II “hollow” were collected from four different directions at 4, 24 and 70 meters from the sensor in August 2023. Humus layer was sampled, and soil samples were sampled from 5 or 6 different depths up to 30 cm. Soil samples from SMEAR I were collected from six different directions at 3.5, 49 and 114 meters from the sensor in June 2023. Humus layer height was measured, and soil samples were collected from 6 different depths up to 30 cm. Additionally, soil organic matter (SOM) and carbon (SOC) were determined for soil samples.

Calculations were conducted with an open-source Python tool “crspy” (Power 2021).

Results

Preliminary results from the assessment of soil moisture using CRNS from the first measurement years 2022–2024 are shown in the eLTER conference. We aim to evaluate the performance of CRNS in our measurement areas by comparing the results with environmental variables, such as, soil moisture measured continuously with soil sensors at different depths and different locations near the CRNSs, precipitation and snow depth in the area. The purpose is to detect whether the results of CRNS and point measurements are in line or if there are divergent patterns during the year(s) or discrepancies in some conditions that might affect the validity of either measurement method.

Keywords

cosmic-ray neutron, soil moisture, boreal forest

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Conflicts of interest

The authors have declared that no competing interests exist.
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