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A comparison of soil moisture sensors in clay-shale soils for long-term observation

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Many environmental applications require knowledge about soil moisture, which can be measured and monitored over long periods only by indirect techniques using proxies such as soil permittivity or soil temperature. The accuracy of the sensor depends on the soil properties such as grain size, temperature, bulk density and salinity, and on the calibration functions which are, most of the time, developed for laboratory controlled field conditions.
Assessing the accuracy of the sensors in real field conditions is rarely carried out. A number of sensors were installed to measure soil moisture changes at the Draix-Bléone hydrological observatory (South French Alps, Réseau de Basins-Versants / RBV) developed in clay-shale soils. The soil moisture sensors consist of commercial ECH_2O EC-5 (Decagon, US), PR2 Profile probe (Delta-T Devices, UK), CS-616 (Campbell Scientific, US), and the prototype Hymenet (IPGP, France) sensor. The sensors were installed at several depth along vertical and horizontal profiles of temperature observation measured by fiber optic DTS.
The basic principle of EC Decagon measures dielectric constant of the soil in order to find its volume water content (VWC). The PR2 Profile probe measure electrical soil permittivity based on polarization in an electromagnetic field with frequency 100 MHz (water has a permittivity $\approx$ 81 F/m, depending on environment temperature, compared to soil $\approx$ 4 F/m and air $\approx$ 1 F/m). The CS-161 works based on dielectric permittivity polarized because of impulse frequency about 70 MHz (in free air) around the probe. Then, Prototype of Hymenet works based on permittivity, conductivity and temperature measurement on signal frequency 20 MHz. We compare all of the sensors side-by-side to investigate the accuracy and variability of the soil moisture time series and propose an intercomparison of the sensors.
In this paper, the shallow profile of soil moisture down to 5 cm until 85 cm are evaluated over some time periods at different time scales. The sensors are evaluated in terms of calibration functions, sensitivity to soil properties, and to soil temperature. Some periods were also monitored with TDR-based 6050X1 Trase System (Soilmoisture, USA). The experiment was held by artificial infiltration and drainage on 17-19 July 2017. Site-specific derived calibration functions for the soils observed along the slopes are also presented.
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