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Comparison of measurement accuracy of different soil moisture sensors in the field and implications for validation of remote sensing products

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Soil moisture is one of the key components in hydrological, climate and ecological systems. Continuous measurements are necessary to investigate its temporal and spatial variability, which is constrained by soil characteristics, topography, vegetation and meteorological conditions. Furthermore, these measurements are essential to parameterize models and to calibrate and validate remote sensing-derived soil water products. To investigate the spatial and temporal variability of soil moisture, dense networks of in-situ measurements are essential. Such networks regularly make use of sensors of lower costs. However, lower costs often imply less measurement accuracy.

In this study three soil moisture sensors are compared based on field measurements: TRIME-IT/EZ (IMKO GmbH, Germany), 10HS (Decagon Devices Inc., USA), and CS616 (Campbell Scientific, USA). All three sensor types make use of the dependency of soil permittivity on soil moisture. The low cost sensor 10HS is based on capacitance method and is widely used in measurement networks. The CS616 is of higher costs than 10HS and also widely used. The TRIME-IT/-EZ, based on the time domain reflectrometry (TDR) technique, is used as reference sensor. Several laboratory measurements have shown a high performance of this high-cost sensor (e.g. Mittelbach et al. 2011, in press). The field measurements consists of parallel measurements of the three sensor types at the Rietholzbach site (www.iac.ethz.ch/url/rietholzbach), which is included in the SwissSMEX/-Veg soil moisture measurement network (www.iac.ethz.ch/url/SwissSMEX). The installation was realized in May 2009 with seven different depths down to 110 cm with parallel measurements of soil temperature. With this profile, not only the land surface-atmosphere interactions but also root water uptake and surface-subsurface interactions of soil moisture can be determined. With a time period of more than one year, the data set includes a wide range of soil water conditions.

The focus of this comparison is on the soil moisture [Vol.%] derived with the calibration function provided by the manufacturers, its anomalies and its temporal evolution for all measurement depths. Furthermore, the dependency of soil moisture on temperature is analyzed. Using the TRIME-IT/EZ sensor as reference we find for the Rietholzbach site that the 10HS sensor underestimates the soil moisture up to 20 Vol.% at high soil moisture contents. In addition, the 10HS sensor measurements are limited to 30-40 Vol.%. In contrast, the CS616 shows a strong overestimation of water content up to 30 Vol.% mainly in measurement depths with low soil moisture variability. Both, the 10HS and CS616, show a decreasing sensitivity in sensor reading with increasing soil moisture. This suggests that care should be taken in the evaluation of remote sensing approaches with networks using these sensors with applied manufacturer calibration functions.

Reference:
Mittelbach, H., F. Casini, I. Lehner, A. J. Teuling, and S. I. Seneviratne (2011): Soil moisture monitoring for climate research: Evaluation of a low cost sensor in the framework of the SwissSMEX campaign, J. Geophys. Res., doi:10.1029/2010JD014907, in press.