Geophysical Research Abstracts
Vol. 21, EGU2019-9101-1, 2019
EGU General Assembly 2019

Study of measurement repeatability in vector-network-analyzer characterization of soil complex dielectric-spectrum

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In-field monitoring of soil moisture content and salinity requires good understanding of the relationship between soil complex dielectric-spectrum and soil physical and chemical properties, such as particle size distribution, density, mineralogy, organic matter content. In order to gain such understanding, much effort has been put by researchers into developing methods for wideband reference characterization of soil complex dielectric-spectrum. The state-of-the-art approach for such characterization employs vector-network-analyzer (VNA) scattering-parameters measurement of a soil sample inserted into a large-diameter coaxial-transmission-line cell. The complex dielectric spectrum is then determined from scattering parameters based on modeling the cell as a transmission-line section filled with an unknown dielectric.

In order to accurately model the relationship between the soil complex dielectric-spectrum and soils physical and chemical properties, it is necessary to measure reference samples of various soils and of various moisture, salinity and density. The fundamental problem in preparing such samples is the limited repeatability of soil properties. Obtaining soil samples with predefined properties requires careful mixing a well-defined (in terms of texture, mineralogy and organic matter content) air-dry soil material with a controlled amount of saline water. This process, however, has by its nature limited repeatability due to water evaporation and possible imperfect mixing. Moreover, when inserting a soil sample prepared in such a way into a measurement cell, it is difficult to control the sample density due to nonrepeatable nature of the packing process. Consequently, although the vector-network-analyzer measurements may be very accurate, the nonrepeatability of the soil material limits the resolution of the reference measurements.

In this work, we present a study of repeatability errors in VNA characterization of soil complex-dielectric spectrum. To this end, we first define different nominal soil moisture content and salinity levels. Next, for each defined moisture content and salinity, we repeat the soil-sample mixing and packing process, and then perform the VNA characterization of the resulting samples. Consequently, we obtain measurements of repeated realizations of samples with the same nominal properties, which allows us to investigated the repeatability of the sample preparation process. Results of our work may serve as a first step in the difficult task of establishing uncertainty analysis for soil moisture-content and salinity determination based on dielectric measurements.

The project is financed by the Polish National Agency for Academic Exchange.