Estimating Soil Hydrogeophysical Properties Using Radiometer and Ground-Penetrating Radar

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1 Objective

Soil hydrogeophysical properties are of major interest for estimating water and energy fluxes at the land surface. The objective of this study was to compare estimated soil hydraulic properties of a sand box from L-band radiometer, ground-penetrating radar (GPR), and in-situ measurements and analyze the uncertainty related to these estimations. The objective was also to determine the sensing depth for the radiometer and radar instruments.

2 Experimental Setup

The experiment was conducted at the TERENO test site Selhausen near Jülich (Germany). L-band radiometer and off-ground GPR measurements were performed over a rectangular wooden box (2.00 x 2.00 m^2 area and 1.00 m height) homogeneously filled with sand. The radiometer was fixed on an arc of 5 m radius with an observation angle of 35° while the GPR was fixed above the sand box at nadir position.

Figure 1. View of the experimental setup with the radiometer fixed on an arc and the sand box in the middle of the mesh grid at the TERENO test site Selhausen (Germany).

3 Experiment

From September to December 2011, the water level of the sand box was increased slowly every week. Six days after each increase of the water level, radar and radiometer measurements were performed above the sand box. Between the measurements, the sand box was covered in order to avoid any precipitation or evaporation from the sand.

4 In-situ Measurements

Ground-truth soil moisture data were obtained by using time-domain reflectometry (TDR) and capacitance sensors located at 7 different depths (from 5 to 80 cm). Soil temperature and soil electrical conductivity data were collected as well. A piezometer and 5 tensiometers were used to monitor the water level.

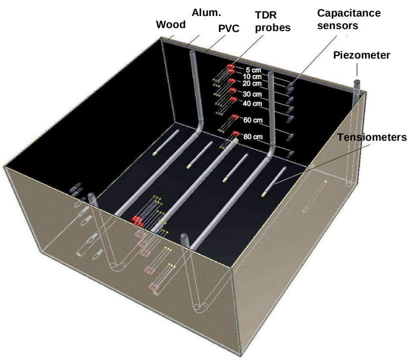

Figure 2. Detailed view of the sand box with the location of the TDR probes, capacitance sensors, and tensiometers.

5 Geophysical Measurements

We used the L-band radiometer ELBARA II working at the central frequency of 1.4 GHz and an off-ground GPR which consists of an UWB stepped-frequency continuous-wave radar operating over the frequency range of 1-3 GHz [1], [2].

Figure 3. L-band radiometer ELBARA II mounted on the arc (top) and off-ground GPR antenna fixed above the sand box (bottom).

6 Setup Calibration

To avoid the brightness temperatures measured being affected by radiance originating from areas outside the sand box, the surrounding of the sand box was covered with a reflector (mesh grid). In order to derive the contribution of the sand box to the total radiometer antenna temperature, we covered the sand box by a perfect absorber and then by a perfect reflector.

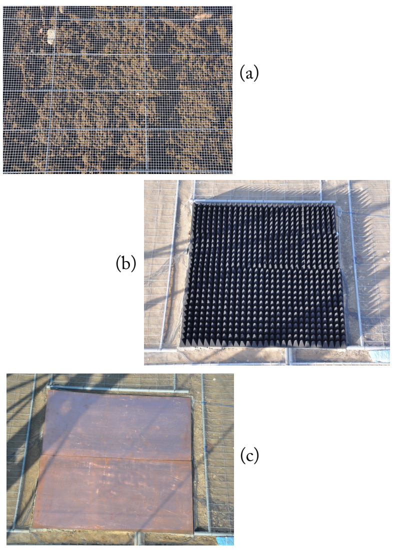

Figure 4. (a) Mesh grid used to cover the surroundings of the sand box with a mesh-size smaller than the wavelength of the radiometer, (b) perfect absorber, and (c) perfect reflector (copper) placed on the top of the sand box.

7 Preliminary Results

In general, the used mesh grid worked very well, with brightness temperature (T_B) measured above the entirely mesh covered setup (including the sand box) close to the sky brightness temperature (below 15 K for both polarizations). Additionally, T_B measured above the perfect reflector and perfect absorber stayed constant during the measurement period.

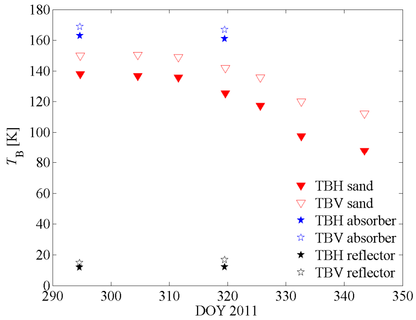

Figure 5. Brightness temperature measured by the L-band radiometer above the sand box (i) covered with a perfect absorber, (ii) covered with a perfect reflector, and (iii) not covered.

First results proved that the size of the sand box (2.00 x 2.00 m^2 area) was large enough to see differences in the radiometer signal obtained from measurements using a perfect reflector, perfect absorber, and the dry sand.

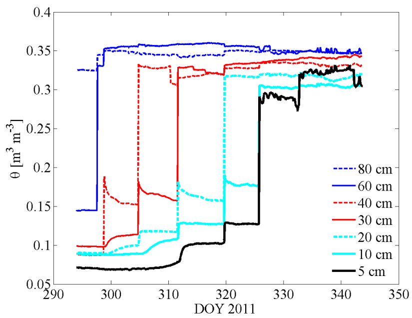

Figure 6. Soil water content monitored by capacitance sensors inserted at different depths in the sand box.

These results show that the soil water content at 5 cm depth mainly influences the measured brightness temperature by the radiometer.

8 Conclusions and Perspectives

Both methods were able to detect the slowly increasing of the water level in the sand box and provided relatively good agreement with reference measurements. In a second step, soil hydraulic properties will be estimated using integrated hydrogeophysical techniques. Known soil surface roughnesses will also be generated and the water level changes will be repeated to compare the results from rough to smooth surface and to test various empirical and physically based roughness modeling approaches.

References

[1] Jonard, F., Weihermüller, L., Jadoon, K. Z., Schwank, M., Vereecken, H. and Lambot, S. (2011). *Mapping Field-Scale Soil Moisture With L-Band Radiometer and Ground-Penetrating Radar Over Bare Soil*. IEEE Trans. on Geosci. Remote Sensing 49, 2863-2875.

[2] Lambot, S., Rhebergen, J., van den Bosch, I., Slob, E. C. and Vanclooster, M. (2004). *Measuring the Soil Water Content Profile of a Sandy Soil with an Off-Ground Monostatic Ground Penetrating Radar*. Vadose Zone Journal 3, 1063-1071.