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Mapping soil moisture of a bare soil using L-band radiometer and advanced GPR

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We compared passive and active proximal sensing techniques to map surface soil moisture at the field scale (72 x 16 m^2) over a bare soil. In particular, we used a L-band radiometer at 1.4 GHz and a stepped frequency continues wave ground penetrating radar (GPR) operating in the range 0.2-2.0 GHz. The brightness temperature measured with the radiometer was used to derive the soil surface dielectric permittivity, which is correlated with the volumetric water content. For GPR, the dielectric permittivity was retrieved using full-waveform inversion of the radar data in the time domain, focusing on the surface reflection. Time domain reflectometry (TDR) was used as reference characterization technique. To obtain a wide range of water contents, the field was irrigated non-uniformly. The generated moisture patterns were reasonably well reproduced by the two proximal sensing techniques. However, significant differences in the absolute values were observed. These discrepancies were attributed to the different sensing depths and the different sensitivities with respect to soil surface roughness. For GPR, the effect of roughness was obviated by considering only the lower frequency range, namely 0.2-0.8 GHz, following Rayleigh's criterion. The root mean square (RMS) error of the water content retrievals performed with the off-ground GPR was 0.038 when compared with the TDR reference measurements. For the radiometer, roughness was first ignored and then accounted for based on the calibration of an empirical model, resulting in a significantly improved RMS error of the retrieved soil moisture (0.020) when compared with the reference measurements. Monte Carlo simulations showed that around 20 % of the ground-truth information is required to obtain a good roughness calibration to be applied to the entire field. This study highlighted key issues in the determination of surface soil moisture at the field scale, which are especially critical to the quality of air- and spaceborne remote sensing data products. The proposed GPR method appears to be highly valuable for bridging the spatial scale gap between traditional ground-truth measurements and remote sensing.