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Small-scale soil moisture determination with GPR

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The knowledge of topsoil moisture distribution is an important input for modelling water flow and evapotranspiration which are essential processes in hydrology, meteorology, and agriculture. All these processes involve non-linear effects and thus the small-scale variability of input parameters play an important role. Using smoothed interpolations instead can cause significant biases. Lateral soil moisture distribution can be sensed by different techniques at various scales whereby geophysical methods provide spatial information which closes the gap between point measurements by classical soil scientific methods and measurements on the field or regional scale by remote sensing.

Ground-penetrating radar (GPR) can be used to explore soil moisture on the field scale as propagation of electromagnetic waves is correlated to soil water content. By determining the velocity of the ground wave, which is a guided wave travelling along the soil surface, we can sense soil water content. This method has been applied to determine topsoil moisture for several years. We present a new groundwave technique which determines the velocity in between two receiving antennas which enables a higher lateral resolution (approx. 10 cm) compared to classical groundwave technique (half meter and more). We present synthetic data from finite-differences (FD) calculations as well as data from a sandbox experiment carried out under controlled conditions to demonstrate the performance of this method.

Further, we carried out field measurements on two sites on a sandy soil which is used as grassland. The measurements were carried out in late summer at dry soil conditions. Soil moisture on the first site shows an isotropic pattern with correlation lengths of approx. 35 cm. We think this natural pattern is governed by rout distribution within the soil and the water uptake of vegetation. On the second site, soil moisture distribution shows a regular stripe pattern. As the land has been used as agricultural crop land until two years before the measurements were carried out, this anisotropy is obviously caused by the former cultivation of the land.

Finally, we present a second technique to determine moisture of the topsoil by GPR using the same principle as remote sensing: the reflection of electromagnetic waves at the soil surface and determination of reflection amplitude. We use a 1 GHz horn antenna that is operated 0.5 m above the ground surface. As this method is based on a completely different physical principle than the first one, it provides an independent revision of our results. Even though, lateral resolution is not that high as when using the groundwave technique and the depth of investigation is not exactly the same, we get similar results showing the same pattern and characteristics at both sites.