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Characterization of Near Surface Soil Moisture Variability Using Ground Wave of Surface GPR

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Knowledge of soil moisture content is an important character for irrigation management. In general surface moisture content is highly variable in space and is difficult to characterize from the conventional methods. As these methods (e.g. sensors, gravimetric column, theta probe, disc infiltrometer etc.) provide information at a 'point' scale, which is not always enough for proper agricultural management and collecting more data points is tedious at field scale. Ground penetrating radar (GPR) is now a well established geophysical technique for high-resolution spatial imaging of the moisture content in the shallow subsurface at intermediate scales. The noninvasive character, large data density volume and rapid data collection from GPR, makes it a promising field tool. The ground wave velocity of GPR is used for mapping the spatial distribution of near surface soil moisture content.

The objective of the study was to examine the spatial influence of ground wave depending on the varying anomaly size with different antenna separation relatively. The spatial heterogeneity was established by placing shallow water filled boxes at the surface of the homogeneous sand lysimeter. Boxes having varying width (12 cm, 24 cm and 48 cm) with constant length (32 cm) and thickness (2.5 cm) were used for measurement. The GPR survey was conducted with a pulseEKKO pro 250 system, which has 250 MHz central frequency. Initially GPR measurements were collected for lysimeter sand using profiling/common offset (CO) survey with three different antenna separations (0.38, 0.50 & 0.70 m). Then measurements were conducted with water boxes using the same separation to evaluate the effect of the varying subsoil properties on the early radar response of GPR. One of the variable offset surveys, common mid-point (CMP) was also measured for velocity analysis. CMP calibrated travel time was used to estimate the true ground wave travel time (GWTT) for the CO survey.

After calibrating the GWTT of sand, same calibration was applied to the sand with different water boxes. The estimated true GWTT (CMP calibrated) was used to demonstrate the velocity, dielectric constant, and moisture content. The result at 0.38 m separation shows, as the dimension of the anomaly increases the velocity decreases and hence the moisture content increases from the background soil, except for the smaller box. A responsible cause of no change in velocity may be due to the small surface area than other boxes. While at larger separations (0.50 m & 0.70 m) ground wave velocity was found same as of background sand for all three boxes. The findings signify that the spatial resolution of ground wave becomes weaker with wider antenna separation.

The overall result reveals that the CO survey of GPR with smaller antenna separation can predict the moisture content variability more accurately. In particular, travel time calibration is the most significant parameter with this CO survey mode and the accurate time shift correction (obtained by CMP survey) is essential for more precise investigation of moisture content. Altogether, present study demonstrates that ground wave can be used to map surface moisture content with a lot of flexibility in spatial scales with good accuracy. Of course, the use of GPR is restricted when the information range is much smaller than the used antenna separation.