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Monitoring near surface soil moisture profiles during evaporation using off-ground zero-offset ground-penetrating radar

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Soil evaporation is important as it controls many processes in the physics of land-surface, including the mass and energy flows between the ground and the atmosphere, and fundamental biological processes such as seed sprouting and plant growth. In order to associate soil surface states to subsurface states and properties, it is important to have a perception about the vertical profiles of subsurface soil water contents and temperatures. However, the derivation of these profiles from local scale measurements would demand interpolation and may overlook variations that are at a smaller scale than the distance between the local soil sensors. In particular, for the detection of non-uniform and unstable infiltration and drying, it is questionable whether the wetting and drying front instabilities can be obtained from local scale measurements. In this respect, resorting to the geophysical methods like ground-penetrating radar (GPR) is vital as a continuous image of the subsurface states can be obtained by applying these techniques. In this study, we investigated the potentiality of the off-ground GPR data to monitor drying front of soil evaporation at the lysimeter scale. We simulated evaporation of near surface soil layers by using a sand box filled with the very fine sand. The bottom of tank was covered by a planar copper sheet playing the role of complete reflector. The room temperature was kept constant and the surface of the sand was exposed to evaporation. The time-lapse GPR, temperature and weight of the setup was constantly measured for a period of thirty days to monitor the upward water flow. The effect of the evaporation can be visualized in the high frequencies of the GPR signal. The full-waveform GPR model was integrated with hydrological model to estimate the soil hydraulic properties. Since the GPR method is sensitive to the soil moisture profile close to the soil surface, interpretation of the measured GPR signals with a water flow model in the soil requires the description of vapor flow since models that consider only liquid water flow are not capable of predicting drying fronts that correspond with S-shaped soil moisture profiles. Preliminary results show that the proposed method is promising for monitoring the effect of evaporation at shallow depths.