Estimation of shallow soil water content during evaporation by using full-waveform inversion of off-ground zero-offset ground penetrating radar

Davood Moghadas[(1)], Khan Z. Jadoon[(2,1)], Sébastien Lambot[(3,1)], Harry Vereecken[(1)], and Jan Vanderborght[(1)]

[(1)] Agrosphere (IBG-3), Institute of Bio- and Geosciences, Forschungszentrum Jülich GmbH, 52425 Jülich, Germany (d.moghadas@fz-juelich.de; h.vereecken@fz-juelich.de; j.vanderborght@fz-juelich.de).

[(2)] Water Desalination and Reuse Center, King Abudllah University of Science and Technology (KAUST), Thuwal, 239556900, Saudi Arabia (khan.jadoon@kaust.edu.sa).

[(3)] Earth and Life Institute, Université catholique de Louvain, Croix du Sud 2 Box L7.05.02, B-1348 Louvain-la-Neuve, Belgium (sebastien.lambot@uclouvain.be).

Study of soil water evaporation is crucial as it involves processes like the loss of water and also increasing the danger of soil salinization. The soil evaporation rates follow a three-stage procedure: the first stage in which evaporation rate is only affected by the amount of energy available to vaporize soil water content in the upper layer of the soil. During the second phase, the evaporation rate is determined by the soil hydraulic properties and the last stage is influenced mostly by the soil physical characteristics. In order to monitor soil moister content (θ) variations during the evaporation, non-invasive geophysical methods like ground-penetrating radar (GPR) play an important role in a digisoil mapping context.

Laboratory experiment was conducted to monitor the two-first-stages of soil evaporation rate. In this respect, an off-ground zero-offset GPR system was mounted on a sand box filled with the very fine sand. At the bottom of the sand box a copper sheet was placed to control the boundary condition in the electromagnetic model. The surface of the sand was exposed to evaporation for a period of twenty three days starting from fully saturated sand. The time-lapse GPR signal, temperature and weight of the setup was constantly measured to monitor the upward water flow. We inverted the GPR data using full-waveform hydrogeophysical inversion approach to retrieve sand water content variation during the evaporation phases. The inversion was carried out using the Complex Refractive Index Model (CRIM) to take into account the frequency dependency of both conductivity and permittivity. The global and local optimization algorithms were used sequentially to retrieve the sand bulk water content. To ensure proper retrieval of the moisture content, the reference water content values were obtained from the setup weight.

Figure 1(a) and (b) shows the amplitude of the measured and modeled time lapse Green's function in the frequency-domain. The modeled GPR signal is in good agreement with the measured time-lapse GPR signal, specially at the low frequencies. Figure 1(c) shows the estimated moisture content values derived using the full-waveform inversion scheme in comparison with the reference data (measured values). According to the results, the measured and estimated values agree very well for different phases of the evaporation (RSME=0.0076). This experiment shows that the proposed approach is promising for monitoring water content variations during the evaporation at shallow depths subject to considering the frequency dependency of both conductivity and permittivity in the inversion process.

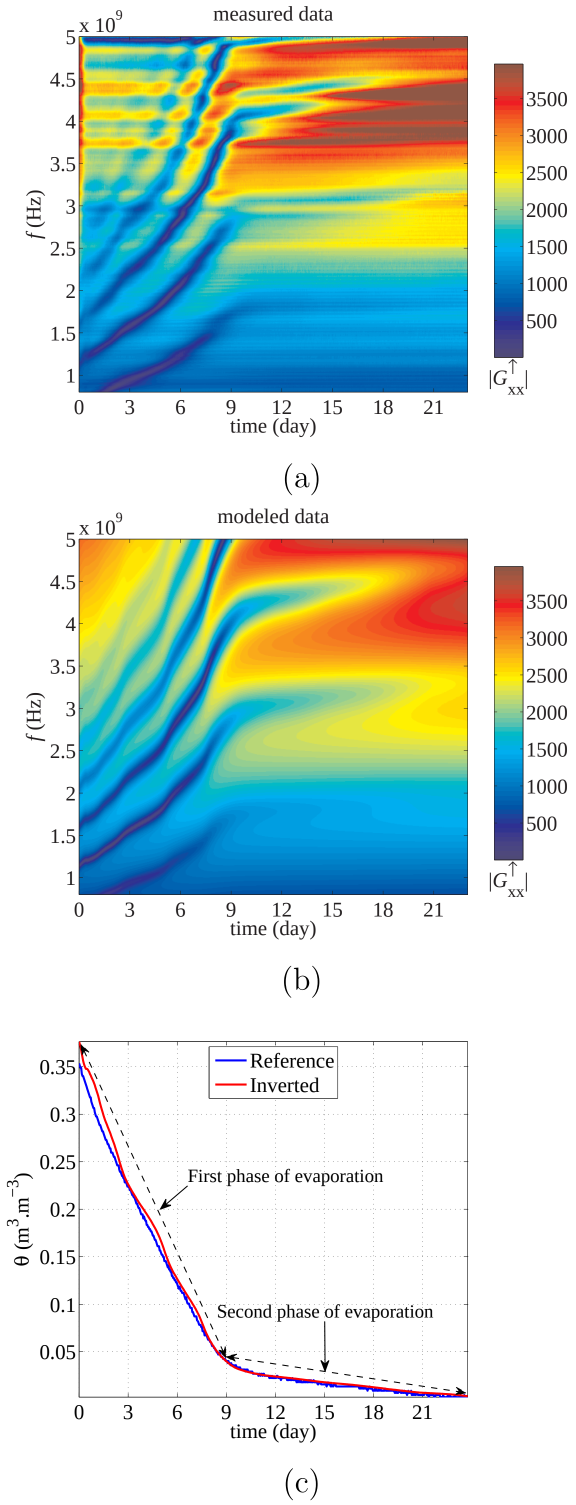

Figure 1: Sandbox measurement: The amplitude of the (a) measured and (b) modeled time-lapse Green's function in the frequency-domain. In sub-figure (c) the red and blue lines represent, respectively the GPR estimated and reference measured water content values.