Geophysical Research Abstracts
Vol. 16, EGU2014-13809, 2014
EGU General Assembly 2014

Joint inversion of multi-configuration electromagnetic induction measurements to estimate soil wetting patterns during surface drip irrigation

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In arid and semi-arid regions, development of precise information on the soil wetting pattern is important to optimize drip irrigation system design for sustainable agricultural water management. Usually mathematical models are commonly used to describe infiltration from a point source to design and manage drip irrigation systems. The extent to which water migrates laterally and vertically away from the drip emitter depends on many factors, including dripper discharge rate, the frequency of water application, duration of drip emission, the soil hydraulic characteristics, initial conditions, evaporation, root water uptake and root distribution patterns. However, several simplified assumptions in the mathematical models affect their utility to provide useful design information. In this respect, non-invasive geophysical methods, i.e. low frequency electromagnetic induction (EMI) systems are becoming powerful tools to map spatial and temporal soil moisture patterns due to fast measurement capability and sensitivity to soil water content and salinity.

In this research, a new electromagnetic system, the CMD mini-Explorer, is used for soil characterization to measure the wetting patterns of drip irrigation systems using joint inversion of multi-configuration EMI measurements. Six transects of EMI measurements were carried out in a farm where Acacia trees are irrigated with brackish water using a drip irrigation system. EMI reference data (ground-truths) were calculated using vertical soil electrical conductivity recorded in different trenches along one of the measurement transects. Reference data is used for calibration to minimize the instrumental shifts which often occur in EMI data. Global and local optimization algorithms are used sequentially, to minimize the misfit between the measured and modeled apparent electrical conductivity (δa) to reconstruct the vertical electrical conductivity profile. The electromagnetic forward model based on full solution of Maxwell's equation is used as the EMI measurements are performed under high induction number conditions (δa > 100 mS/m). Joint multi-configuration inversion of EMI data for all six transects allows for accurate retrieval of the subsurface electrical conductivity profiles under the high induction number condition. High values of soil electrical conductivity in the inversion results show the dimension of wetting front of brackish water. Furthermore, to appropriately infer the parameter uncertainty, a Bayesian approach was used in the framework of the DiffeRential Evolution Adaptive Metropolis (DREAM) algorithm. Initial result of the posterior distribution of parameters indicate that most of parameters were well constrained. The proposed approach allows for quantitative mapping and monitoring of the spatial electrical conductivity variations and can be utilized for proximal sensing of the subsurface properties with a wide variety of applications.