Geophysical Research Abstracts
Vol. 16, EGU2014-682, 2014
EGU General Assembly 2014

The integration of 3D electrical resistivity tomography and ET flux measurements to characterize water mass balance in the soil-plant-atmosphere continuum

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The system of soil, vegetation, and the adjacent atmosphere is characterized by complex patterns, structures, and processes that act on a wide range of time and space scales. While the exchange of energy and water is continuous between compartments, the pertinent fluxes are strongly heterogeneous and variable in space and time. Therefore, quantitatively predicting the systems' behaviour constitutes a major challenge. Traditionally, soil moisture beneath irrigated crops has been determined using point measurement methods such as neutron probes or capacitance systems. These approaches cannot measure soil moisture at depths beyond the root-zone of plants and have limited lateral coverage. Literature results show that electrical resistivity tomography (ERT) can be used to reliable map the spatial heterogeneity in soil moisture. Here we present the application of the time-lapse non-invasive 3D micro - electrical tomography (ERT) to monitor soil-plant interactions in the root zone of an orange tree located in the Mediterranean semi-arid Sicilian (South Italy) context. The subsoil dynamics, particularly influenced by irrigation and root uptake, has been characterized a 3D ERT apparatus consisting of 48 buried electrodes on 4 instrumented micro boreholes plus 24 mini-electrodes on the surface spaced 0.1 m on a square grid. During the monitoring, repeated ERT soil moisture measurements were collected, as well as laboratory characterization of the soil electrical properties as a function of moisture content and pore water electrical conductivity. Plant transpiration was continuously monitored during the ERT experiment by the sap flow heat pulse (HP) method for a quantitative analysis of the mass balance in the soil-plant-atmosphere system under observation. In addition, evapo-transpiration has been continuously monitored at the same site using an eddy-correlation tower. The integration of measurements regarding soil,plant and atmosphere allows a better understanding of subsoil interactions between biomass, hydrosphere and atmosphere. This case study demonstrates that 3D micro-ERT is capable of characterizing the pathways of water distribution, and provides spatial information on root zone suction regions. The reliability of the method may suggest its integration into farm water management surveys to delineate zones of excessive water loss due to deep drainage and to improve the positioning of point measurement methods for measuring soil moisture, thereby improving irrigation scheduling. The integration with plant transpiration and local evapo-transpiration makes available a full set of complementing data to constrain predictive models for the soil-plant-atmosphere continuum.