Hydrogeophysical techniques for SPAC (soil-plant-atmosphere continuum) characterization and monitoring of state and fluxes of mass and energy.

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This project aims at developing, testing and validating an integrated approach to the monitoring and modeling of soil-plant-atmosphere (SPA) interactions (Figure 1), with particular attention to the spatial and temporal distribution of soil moisture as an effect of precipitation, interception, stem flow, irrigation, redistribution, infiltration and root uptake ("green water"). The SPA interactions play a critical role in the exchanges of mass and energy, that control a number of key environmental processes, including those affecting and mitigating climatic changes. The bottom boundary condition of climatic General Circulation Models (GCMs) and Numerical Weather Prediction (NWP) models depends dramatically upon these poorly known processes, and this weakness largely explains the different predictions of models, and their inherent inadequacy. Also, of utmost importance is the understanding of the processes taking place in agriculture, in order to optimize irrigation and plant resilience in face of climatic changes and growing population demands ("more crop per drop"). In spite of these challenges, our understanding of the complex SPA interactions is often limited by the lack of spatially extensive and time intensive data, particularly regarding the soil/root component and its changing states. In particular, the investigation of subsoil distribution of the root structure and the consequent distribution of soil moisture content is troublesome. Common point-based methods do not allow the investigation of spatial distribution of state variables. Remote sensing generally penetrates the subsoil only by a few tens of centimeters and their view of the subsurface is hindered by vegetation itself. Ground-based, non-invasive (geophysical) techniques such as Electrical Resistivity Tomography (ERT), GPR, Electromagnetic Induction (EMI), cosmic ray detectors and micro-gravimetry can be applied at different scales to image static and dynamic characteristics of the subsoil, in response of hydrological stresses. However, the use of these techniques for investigations of the SPAC is still in its infancy. In addition, the interpretation of the results has important intricacies, and can provide fundamental information for the validation of novel models describing root growth and structure, and plant competition, in terms of optimality principles (optimal transport). Note that the concept of SPAC is largely superimposed onto that of the so-called Earth's Critical Zone (ECZ) that brackets the interface between soil and atmosphere, encompassing the vertical space between the top of the canopy above and the water table of the first aquifer below (Figure 2). The ECZ has been the objective of a number of studies and observatories in North America and Europe over the past two decades.

This project aims at combining novel measurement approaches to advanced SPAC modeling also using Data Assimilation techniques. Specifically, the project aims at:

- studying the small-scale dynamics of moisture content at a number of natural and agricultural systems applying a combination of traditional and innovative measurement tools, including non-invasive or minimally invasive techniques. Different environments are available in the Veneto Region itself, spanning from lagoon marshlands to agricultural land, and from urbanized areas to hilly and mountain regions;
- complementing the data concerning the dynamic soil moisture distribution with mass and energy flux data from sap flow, stem flow and eddy correlation measurements, in order to feed this essential information into mechanistic models that are, primarily, based upon mass and energy balance considerations;
- coupling the spatially extensive and time intensive data obtained from traditional and innovative minimally invasive techniques with mechanistic models representing the soil moisture dynamics

and root water uptake (RWU), whole plant transpiration, and leaf-level photosynthesis, using data assimilation (DA) techniques.

- assessing the value of the collected data towards the validation of predictive models based on fundamental principles (optimal transport).

This integrated approach will be applied to a number of sites where existing traditional and innovative instrumentation has already been put in place as part of funded projects and existing established collaborations at local, national and international levels. The project builds upon experience and expertise coming from a multidisciplinary set of researchers who will support the proponent in her two-year project plan, based in the Dept of Geoscience, UNIPD. All necessary equipment for site monitoring is available in the department, including advanced hydro-geophysical equipment (for ERT a Syscal Terra 96 channel resistivity meter, a Scintrex GC-5 relative micro-gravimeter; a Styx Neutronica Cosmic-Ray Neutron Detector System S2+; several EMI frequency domain electromagnetometers such as GF Instruments CMD explorer and miniexplorer and GEM2 multifrequency meter. Instruments to build a movable Eddy Correlation tower is also to be acquired. Secured funding for the research will come from a combination of existing projects including national and EU funded research programmes, lasting for the entire duration of the project.

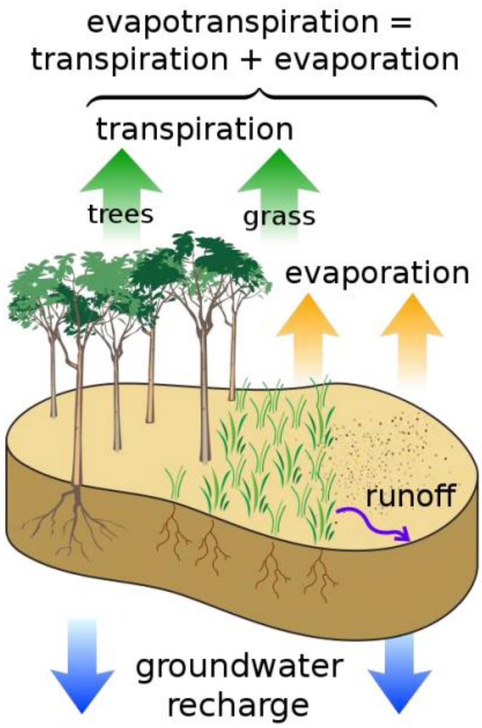

Figure 1*: the main components of the SPAC, with evidenced fluxes of mass (water) and energy (sensible and latent).*

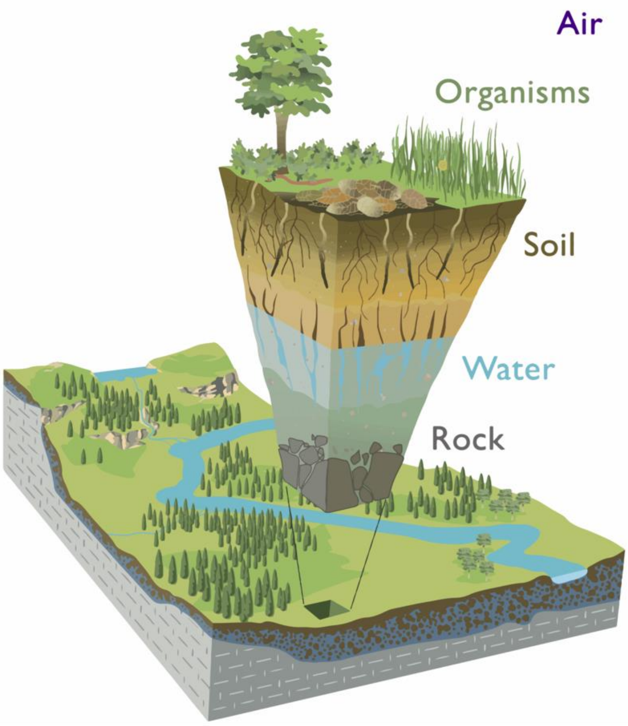

Figure 2*: the classical definition of the Earth's Critical Zone (ECZ): this essentially houses all processes and fluxes that are the SPAC's backbone.*