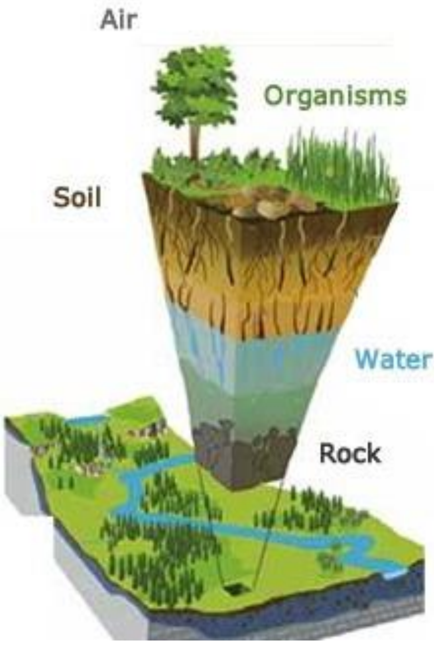
Hydro-geophysical monitoring of the Earth's Critical Zone

(Proposer: Prof. Giorgio Cassiani)



The Earth's Critical Zone (CZ) is the thin outer veneer of our planet from the top of the tree canopy to the bottom of our drinking water aquifers. Th CZ supports almost all human activity, is experiencing ever-increasing pressure from growth in human population and wealth. Understanding, predicting and managing intensification of land use and associated economic services, while mitigating and adapting to rapid climate change and biodiversity decline, is now one of the most pressing societal challenges of the 21st century. This project aims at developing, testing and validating an integrated approach solidly based onto non-invasive geophysical techniques, for the monitoring and modeling of the CZ. Particular attention will be devoted to the soil-plant-atmosphere (SPA) interactions, with particular attention to the spatial and temporal distribution of soil moisture as an effect of precipitation, irrigation, redistribution, infiltration and root uptake ("green water"). The SPA interactions play a critical role in the exchanges of mass and energy, that in turn control a number of environmental processes in the CZ, including those affecting and mitigating Climatic Changes (CC). Also of utmost importance is the understanding of the relevant processes taking place in agricultural practice, in order to optimize irrigation and plant resilience in face of expected climatic changes and growing population demands ("more crop per drop"). In spite of these challenges, our understanding of the complex CZ and SPA interactions is often limited by the lack of spatially extensive and time intensive data, particularly regarding the subsoil components, including root activities, and their changing states. 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 centimeters and their view of the subsurface is hindered by vegetation itself. Ground-based, non-invasive (geophysical) techniques such as Electrical Resistivity Tomography (ERT) 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 investigation at the root-zone scale is still in its infancy. In addition, the interpretation of the results in terms of soil moisture dynamics has important intricacies. This project aims at combining novel measurement approaches to advanced SPA modeling via sophisticated 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;
- testing and validating the capabilities of small-scale hydro-geophysics in monitoring eco-hydrological processes at the scale of interest for SPA interaction for CZ characterization;
- 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 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.

This integrated approach will be applied to a number of sites where existing traditional and innovative instrumentation has already been partly 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.

Collaborations

Active collaborations in the field of ECZ science include: the Hebrew University of Jerusalem (Israel), the University of Bonn (Germany), the UFZ (Germany), Lancaster University (UK), Rutgers University (USA), the Universities of Florence, Naples and Catania in Italy. Funding for research equipment comes from the Project of Excellence of the Department of Geosciences.

References

Banwart, S., Chorover, J., Gaillardet, J., Sparks, D., White, T., et al. (2013): Sustaining Earth's Critical Zone - Basic Science and Interdisciplinary Solutions for Global Challenges. The University of Sheffield, United Kingdom, ISBN: 978-0-9576890-0-8.

Busato L., J. Boaga, M.T. Perri, B. Majone, A. Bellin, G. Cassiani, 2019, Hydrogeophysical characterization and monitoring of the hyporheic and riparian zones: the Vermigliana Creek case study, Science of the Total Environment, 648 (2019), 1105–1120, doi: 10.1016/j.scitotenv.2018.08.179.

Cassiani G., N. Ursino, R. Deiana, G. Vignoli, J. Boaga, M. Rossi, M. T. Perri, M. Blaschek, R. Duttmann, S. Meyer, R. Ludwig, A. Soddu, P. Dietrich and U. Werban, 2012, Non-invasive monitoring of soil static characteristics and dynamic states: a case study highlighting vegetation effects, Vadose Zone Journal, Special Issue on SPAC - Soil-plant interactions from local to landscape scale, August 2012, V.11, vzj2011.0195, doi: 10.2136/2011.0195.

Cassiani G., J. Boaga, M. Rossi, G. Fadda, M. Putti, B. Majone, A. Bellin, 2016, Soil-plant interaction monitoring: small scale example of an apple orchard in Trentino, North-Eastern Italy, Science of the Total Environment, Vol. 543, Issue Pt B, pp. 851-861, doi: 10.1016/j.scitotenv.2015.03.113.

Cassiani G., J. Boaga, D. Vanella, M. T. Perri, S. Consoli, 2015, Monitoring and modelling of soil-plant interactions: the joint use of ERT, sap flow and Eddy Covariance data to characterize the volume of an orange tree root zone, Hydrol. Earth Syst. Sci., 19, 2213-2225, doi:10.5194/hess-19-2213-2015.

Chorover J., F.N. Scatena, T. White, S. Anderson, A.K. Aufdenkampe, R. Bales, S. Brantley, G. Tucker., 2012, Common Critical Zone Observatory (CZO) Infrastructure and Measurements; A Guide Prepared By CZO PIs, Sep. 27, 2012 and amended Dec. 5, 2012.

Javaux M., T. Schroder, J. Vanderborght, and H. Vereecken. 2008, Use of a Three-Dimensional Detailed Modeling Approach for Predicting Root Water Uptake Vadose Zone J.. Vadose Zone J. 7(3), 1079 - 1088.

Mary, B., Peruzzo, L., Boaga, J., Schmutz, M., Wu, Y., Hubbard, S. S., and Cassiani, G., 2018, Small scale characterization of vine plant root water uptake via 3D electrical resistivity tomography and Mise-à-la-Masse method, Hydrol. Earth Syst. Sci., doi: 10.5194/hess-22-5427-2018.

Mary B., D. Vanella, S. Consoli and G. Cassiani, 2019, Assessing the extent of citrus trees root apparatus under deficit irrigation via multi-method geo-electrical imaging, Scientific Reports, 9, 9913, doi: 10.1038/s41598-019-46107-w

Mary B., L. Peruzzo, J. Boaga, N. Cenni, M. Schmutz, Y. Wu, S.S. Hubbard and G. Cassiani, 2020, Time-lapse monitoring of root water uptake using electrical resistivity tomography and Mise-à-la-Masse: a vineyard infiltration experiment, SOIL, 6, 95–114, doi: 10.5194/soil-6-95-2020.

Mary B., L. Peruzzo, V. Iván, E. Facca, G. Manoli, M. Putti, M. Camporese, Y. Wu, G. Cassiani, 2021, Combining models of root-zone hydrology and geoelectrical measurements: recent advances and future prospects, Frontiers in Water, doi: 10.3389/frwa.2021.767910

Vanella D., G. Cassiani, L. Busato, J. Boaga, S. Barbagallo, A. Binley, S. Consoli, 2018, Use of small scale electrical resistivity tomography to identify soil-root interactions during deficit irrigation, Journal of Hydrology, 556, 310-324, doi: 10.1016/j.jhydrol.2017.11.025.

Vereecken H., A. Binley, G. Cassiani, I. Kharkhordin, A. Revil, K. Titov (eds), 2006, Applied Hydrogeophysics, Springer-Verlag, Berlin.