## Integrated Geophysics and Data Science for Soil Moisture Characterization and Hydrogeological Risk Assessment in Urban and Peri-Urban Areas

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Extreme events such as prolonged drought periods and high-intensity rainfall episodes intensify a cascade of hydrological problems. These range from difficulties in securing agricultural water supplies and managing water in urbanized areas, to the critical domain of hydrogeological risk, where ensuring slope stability and preventing landslides become particularly tricky challenges. Effectively addressing these hydrological problems hinges on understanding soil moisture behavior across various soil types, a task for which hydrogeophysics is essential, particularly as its effectiveness is amplified by detailed hydrological and environmental analyses.

A multiparametric strategy using longitudinal multisensory monitoring systems is highly effective for modeling soil moisture. Recent advancements have optimized these systems to include time-lapse Electrical Resistivity Tomography (ERT) alongside various hydrologic and environmental sensors. This combination allows for sophisticated 2-3D dynamic thermo-hydro-geomechanical modeling of the subsurface, providing unique insights into soil moisture and landslides mechanisms.

Our work focuses on a slow-moving peri-urban landslide in the southern Apennines of Basilicata (Italy), an area historically affected by hydrogeological issues. We are setting up an open-air laboratory with a monitoring station that combines a time-lapse ERT system with an array of hydrological sensors (tensiometers, soil moisture sensors, piezometers) and meteorological sensors (thermometers, hygrometers, anemometers, pyranometers). In parallel we've developed a complementary laboratory methodology that unifies and adapts specific instruments to create a customized experimental environment for integrated data acquisition that replicates the coupled ERT plus hydrological field measurements.

Substantial data will undergo innovative processing, including advanced machine learning. These techniques will facilitate efficient analysis and integration of geophysical, hydrogeological, and environmental datasets across laboratory and landslide scales, significantly improving our ability to model and understand soil moisture behavior. Results will not only provide reliable insights for hydrological risk management but will also offer broader applications across the entire spectrum of water resource challenges.

**Keywords: soil moisture, hydrogephysics, landslides.**