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Time-lapse azimuthal resistivity data to detect preferential pathways in fractured rocks during infiltration test

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Karst and fractured environments are complex systems due to the high variability of the hydrological properties of the rocky subsurface.
In order to better understand the natural processes that govern these systems and to reduce uncertainty of the predictive modelling scenarios, the use of multidisciplinary approaches is strongly required. Among these approaches non-invasive geophysical techniques are widely used because of their capability to investigate large areas with high resolution. Particularly, electrical methods are suitable in karst and fractured systems because of the high sensitivity of the electrical resistivity to the presence of air, as well as to the main hydrological properties, such as soil moisture and hydraulic conductivity.
Resistivity measurements are commonly collected along profiles using electrical resistivity tomography (ERT) technique to detect karst macrostructures (channels or cavities).
At subcentimetric scale, such as that of the fractures aperture, ERT imaging could fail, the resolution being dependent on inter-electrode spacing. In this case, unconventional azimuthal resistivity measurements are very effective to detect preferential pathways in the fractured subsoil by estimating the apparent anisotropy, that is the ratio of apparent resistivity measured perpendicularly and transversally to fracture strike. Moreover azimuthal measurements are able to provide input parameters for numerical modelling, such as fracture strike and secondary porosity.
Azimuthal resistivity survey (ARS) is carried out by using square array, based on four-electrodes configuration, with the electrodes placed in the vertices of the square. ARS collects data by rotating the square array at regular angular intervals in order to detect resistivity variations with respect to the azimuth.
Two tests have been carried out in Altamura, Southern Italy, on outcropping fractured limestone with different fracturing degree. Time-lapse multiple square-array data have been collected during an infiltrometer test to detect the preferential pathways and to understand the evolution of the preferential flow over time.
The time-lapse monitoring lasted about 21 hours and for each test, more than 600 azimuthal resistivity measurements, have been collected.
Rosette diagrams at different depth slices have been plotted in order to highlight the behaviour of the fractured rock in the two test sites. Apparent anisotropy highlights preferential pathways, as confirmed by the changes of strike angles in depth.
The observed azimuthal resistivity variations over time suggested change in direction of preferential flow pathway triggered by the infiltration test conditions. These observations cannot be neglected in the development of a conceptual model of the fractured system and need to be considered as boundary conditions in numerical modelling.