4D ERT monitoring of subsurface water pipe leakage during a controlled field experiment

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Locating and delineating leakage from subsurface pipelines is an important task for civil engineers. In this study we assess the efficacy of automated 4D Electrical Resistivity Tomography (ERT) for pipe leakage monitoring by conducting two controlled leak experiments at a test site in Bristol, UK.

To simulate the leak a plastic pipe with a hole was buried below a flat, grassed area at a depth of 0.7 m, representing a standard UK mains water pipe installation. The water table at the site lies well below the surface meaning that the experiment took entirely place in the vadose zone, where changes in resistivity are primarily sensitive to water content variations. The ERT array covered an area of 6.5m x 6.5m around the leak location. Data acquisition was carried out with the BGS PRIME (Proactive Infrastructure Monitoring and Evaluation) system, which facilitates remote scheduling and autonomous data collection and transmission. To obtain the resistivity changes of the subsurface a 4D inversion was carried out using a Gauss-Newton approach with spatial and temporal smoothness constraints.

Even though a pronounced artificial anomaly (probably related to the presence of a cluster of metallic soil moisture sensors) is present in the center of all resistivity time steps, we were able to reliably observe the onset, spread and cessation of the leakage. In-situ measurements with soil sensors at several depths above and below the leak complemented the ERT data and allowed us to assess their reliability and directly relate them to hydrogeological processes.

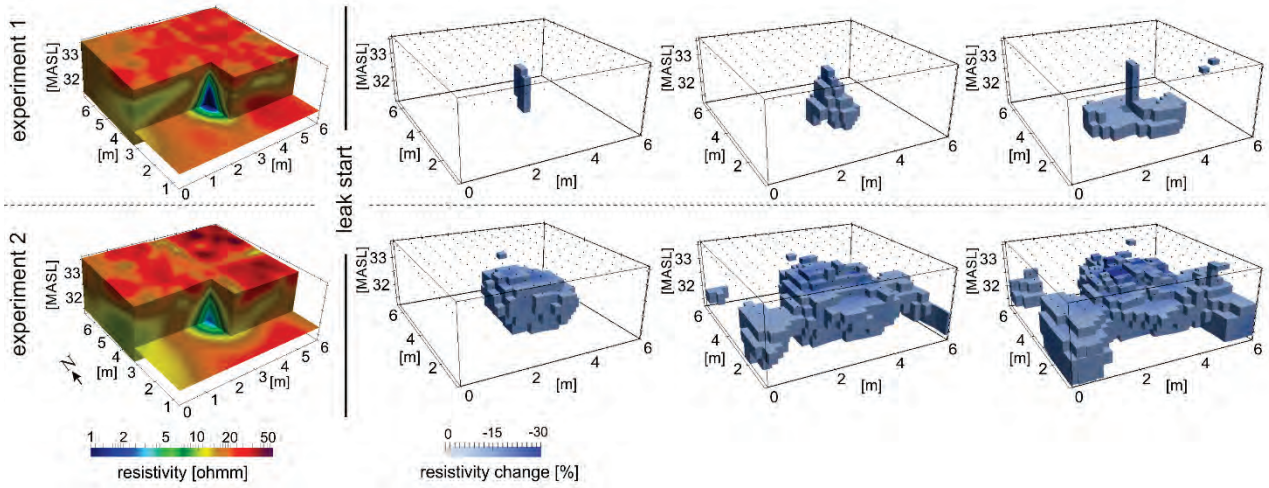

Figure: The pre-leak resistivity models indicate a pronounced artificial anomaly at the center (left subplots). Nevertheless, the evolution of the two leak experiments can be well resolved as resistivity changes with respect to the pre-leak conditions (right subplots, displayed are only model cells with a resistivity decrease of more than 10%). The plume for experiment 1 with a total leakage amount of 2.76 m³ is much smaller than the one for experiment 2 with a leakage amount of 20.7 m³.