Assessing The Underworld
An Integrated Performance Model of City Infrastructures
4D ERT monitoring of water pipe leakage during a controlled field experiment

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Introduction
Locating and delineating leakage from subsurface pipelines is an important task for civil engineers. Automated 4D Electrical Resistivity Tomography (ERT) allows changes in subsurface resistivity to be imaged at high spatial and temporal resolutions in a minimally invasive manner. It is therefore a promising tool to supplement conventional point-sensing techniques to monitor subsurface flow processes (e.g. Runn and Hubbard, 2005).

With the presented project we assess the efficacy of automated ERT for pipe leakage monitoring by conducting two controlled leak experiments. Critical issues concerning the measurement system include autonomous near-real-time functionality, measurement speed and data quality (Wilkinson et al., 2010). Methodological issues include detectability, delineation and quantification of the leak. For assessing the latter issues, supplementary in-situ point reference measurements of water content and electrical conductivity are used to judge the quality and to relate the measured bulk resistivity to hydrogeological properties.

Method (4D ERT)
4D ERT images spatial and temporal changes in bulk resistivity. In the vadose zone these changes are primarily sensitive to water content variations. Other influences include variation in temperature and ionic concentration of the pore fluid.

Data acquisition
Data are sampled on a rectangular grid of buried electrodes. By conducting a set of experiments with varying electrode combinaisons the whole volume below the electrode array is interrogated. Temporal resolution is obtained by repeatedly measuring an identical set of data (Kuras et al., 2016).

Measurement system
BGS PRIME (Productive Infrastructure Monitoring and Evaluation) system with capabilities for:
- remote scheduling
- autonomous data collection and telemetric transfer
- low power operation (10W, using solar panel)

Data processing
The final ground resistivities are obtained indirectly through a 4D inversion process, in which the observed data are matched to those calculated for a specific subsurface electrical model. The process is constrained by assuming smooth spatial and temporal resistivity changes (software: Res3DInv 3.09, Loke 2014).

Limitations:
- e.g. VWC measurements are required in order to significantly influence the bulk resistivity (supporting the assumption in the inversion).
- The artificial low resistivity anomaly at the centre of the array limits the direct conversion of resistivity into soil moisture content. This reinforces the assumption that compositional changes of the disturbed refill took place.

Experimental setup

The experiment is carried out on flat grassed area within the vadose zone.

Results and discussion

Leak experiment 1:
Percentage changes with respect to undisturbed pre-leak state: a) Model cells with more than 10% decrease in resistivity. b) Time-line with mean leakage amount. c) Vertical slice through middle of observed volume

Leak experiment 2:
After opening the leak, both tests show an immediate decrease in resistivity below the leak location indicating an increased volumetric water content and the spread of the leak. At the last timestep before closing the valve in exp. 2 water drained off the surface at the plume location. Drying out was immediate for exp. 1 with a much lower total leak volume.

Acquisition schedule
- Experiment time-line: activation mean flow total amount
  - Leak 1 1.24 days 1.496 l/min 2.76 m³
  - Leak 2 2.99 days 4.809 l/min 20.68 m³

Limitations:
- Temporal blurring occurred at depth where model resolution is limited (especially during rain events).
- In artificially disturbed soil compositional changes might significantly influence the bulk resistivity (supporting e.g. VWC measurements are required in order to understand the ERT picture).

References