Zusammenfassung einer Publikation: Time-Lapse Seismic and Electrical Monitoring of the Vadose Zone during a Controlled Infiltration Experiment at the Ploemeur Hydrological Observatory, France

Literaturangabe zur Publikation:

«Um welche Art von Grundwassersystem handelt es sich? Wie wurde das Grundwassersystem erkundet ? Welche Parameter wurden gemessen?»

The article investigates water infiltration in the vadose zone with geophysical methods (electrical resistivity tomography and seismic refraction). Before developing the article, it is important to mention that the vadose zone acts as an interface between the atmosphere and the groundwater table in the saturated zone. Pores in the vadose zone can be partially, or totally filled by water as in capillarity fringe, due to water adhesion and capillarity action. This water, which is used by plants, commonly have a pressure head bellow the atmospheric pressure, which explains why preliminary infiltrations are done to saturated the vadose zone prior infiltration tests. In addition to lower pressure heads, the vadose zone is also often anisotropic due to its different layers (soils with different horizons, heterogenous unconsolidated sediments, etc.), to biological activities (vegetal root networks, burrows, etc.), and potentially to sedimentation mechanisms (e.g., clays alignment due to gravity or to some flows). The complex dynamics of vadose water and its importance for the biosphere and groundwater resupply make vadose zone an important topic. For example, soils and unconsolidated sediments in the vadose zone can strongly influence the infiltration behaviors increasing filtering and fluid retention.

One of the issues with the vadose zone is that measuring water content within, which has strong spatiotemporal variability, is challenging and classically invasive. This is commonly done by sampling and measuring in labs, or digging and positioning remote sensors (Time or Frequency Domain Reflectometry). Unfortunately, invasive methods disturb the vadose zone and potentially create zones of preferential infiltration (i.e., an observer effect). To reduce this potential bias, the authors of this paper proposed to use electrical resistivity tomography (ERT), with a Wenner–Schlumberger setup, and seismic refraction to measure soil moisture. These methods are less intrusive. As ionically charged water is a good electrical conductor, ERT is a widespread method in hydrology. On the other hand, seismic refraction, which is based on waves propagation through materials and their refraction when changing mediums, is commonly used to determine geological structures.

To be able to compare ERT and seismic refraction to the real moisture content in soils, the authors selected a site equipped with time domain reflectometer, thermometer and tensiometer sensors at the Ploemeur Hydrological Observatory in northwest France. These sensors were installed in 2012 by students and researchers, eight years prior this study, along the wall of a previously dug pit. The ERT and seismic sensors (14-Hz vertical geophones) for this study were set parallel and perpendicular to this wall (Fig. 1). A 2.2 x 2,4 m^2 infiltration area was delimited on which 9 infiltration events were done over 2 days. 250 l were injected during the first two infiltrations and then 400 for the remaining infiltrations but always at a lower rate than the maximal infiltration rate of 18 $mm/h/m^2$ (Pochet method). Data acquisition were following these infiltration events, at the exception of a first measurement, each day, before infiltrations to get the background signals (i.e., total of 11 individual acquisition). This setting allows time-lapse application to monitor the infiltrations taking the first measurement before any infiltration as reference.

For ERT time laps, an initial background model was calculated using the initial acquisition before any infiltration. Then, inversion models were done for each acquisition after the infiltrations and compared to the initial model. These model comparisons support an incremental decrease of the electrical resistivity up to 90 % due to infiltrations (Fig. 2). On the NS transect (a), we can observe that the first infiltration (Acq. 2) shown accumulation in the south at 4 m which potentially results from surface runoff and water accumulation. In addition, vadose water seams to flow preferentially in the south direction along this profile which might be due to anisotropy in soils. On the WE transect (b), there is not comparable accumulation but the infiltration profile seems to be more extended up to ~6 m suggesting leaching from the infiltration area. One interesting feature of the WE transect is the preferential infiltration along the wall of the previously dug pit. We have to mention that comparisons of water saturations and electrical resistivities interpolated respectively from ERT model and from TDR sensors are relatively coherent on the first meter depth supporting the use of ERT model to investigated infiltration.

For seismic refraction time-laps, authors first identified temporal shifts in the seismic trace recording after the infiltrations; these changes confirm a consistent relation between seismic waver velocity and water moisture in soils. As for ERT time-laps, the initial seismic reflection acquisition was used as background to compare with other acquisitions after the infiltrations. These model comparisons support an incremental decrease of the P-Wave velocities up to 60 % due to the infiltrations (Fig. 3). Comparisons of water saturations and P-Wave velocities interpolated respectively from seismic refraction model and from TDR sensors are much less consistent suggesting that petrophysical modelling has to be investigated more in detail. Nevertheless, the decrease of P-Wave velocities inside the infiltration area coincides with the infiltrations, like the decrease in electrical resistivity.

To conclude, the time-lapse inversions of ERT and seismic data shown comparable trends. This demonstrates utility of geophysical methods to investigate hydrological processes.

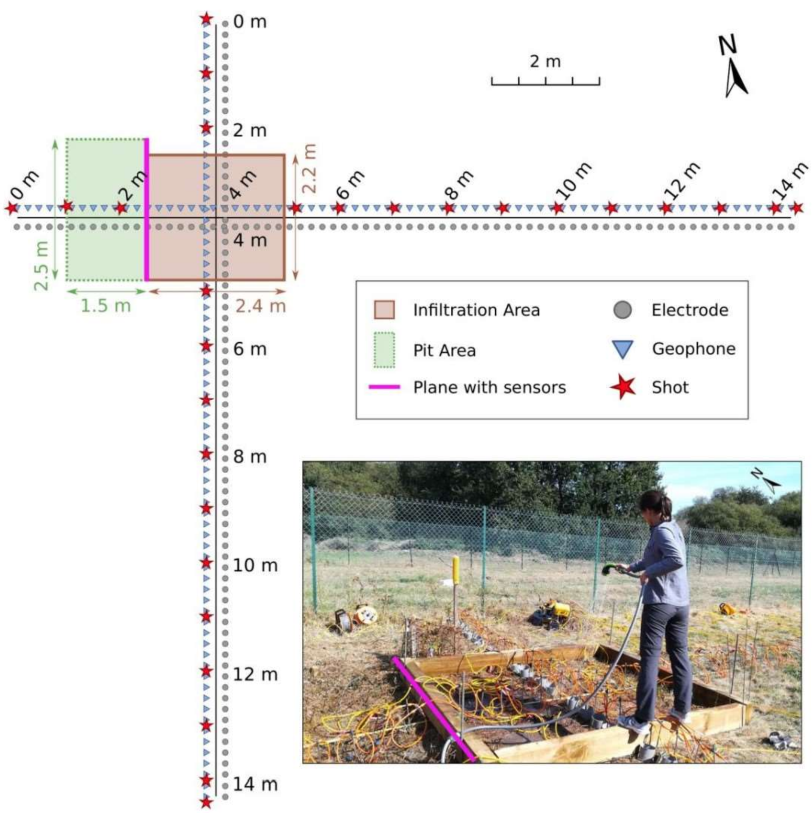

Figure 1. Setting of the experiment at the Ploemeur Hydrological Observatory. Infiltration area was set near a previously dug pit used to install sensors (with time domain reflectometer, thermometer and tensiometer). Geophones and electrodes for seismic refraction and electrical resistance tomography were set parallel and perpendicular to these sensors.

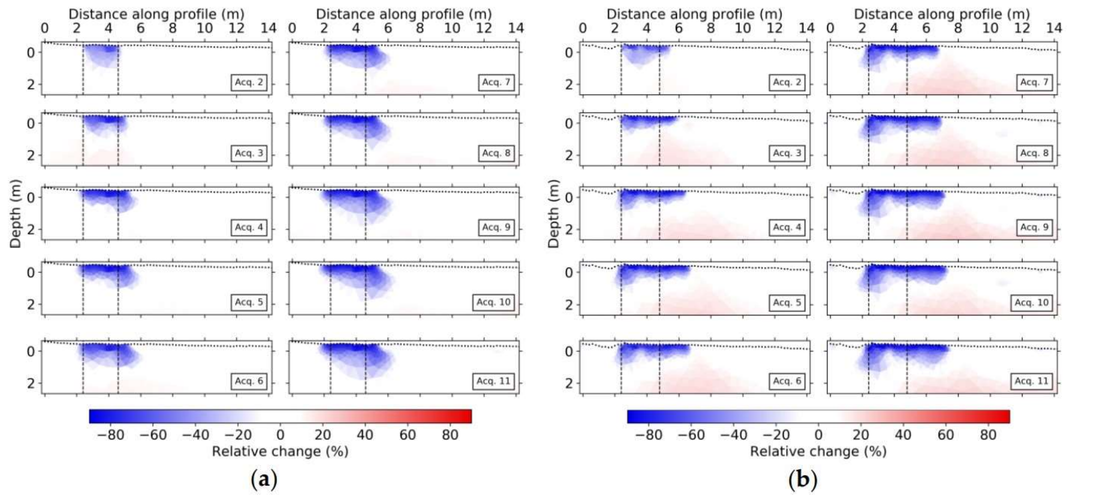

Figure 2. Time-lapse electrical resistivity tomography results. Through time, electrical conductivity increases where water is infiltrated. On the NS transect (a), the first infiltration (Acq. 2) shown accumulation in the south at 4 m which potentially result from surface runoff and water accumulation. Despite that, water seam to flow preferentially in the south direction along this profile which might be due to anisotropy in soils. On the WE transect (b), there is not comparable accumulation but the infiltration profile seems to be more extended up to ~6 m suggesting leaching from the infiltration area. One interesting feature of the WE transect is the preferential infiltration along the wall of the previously dug pit.

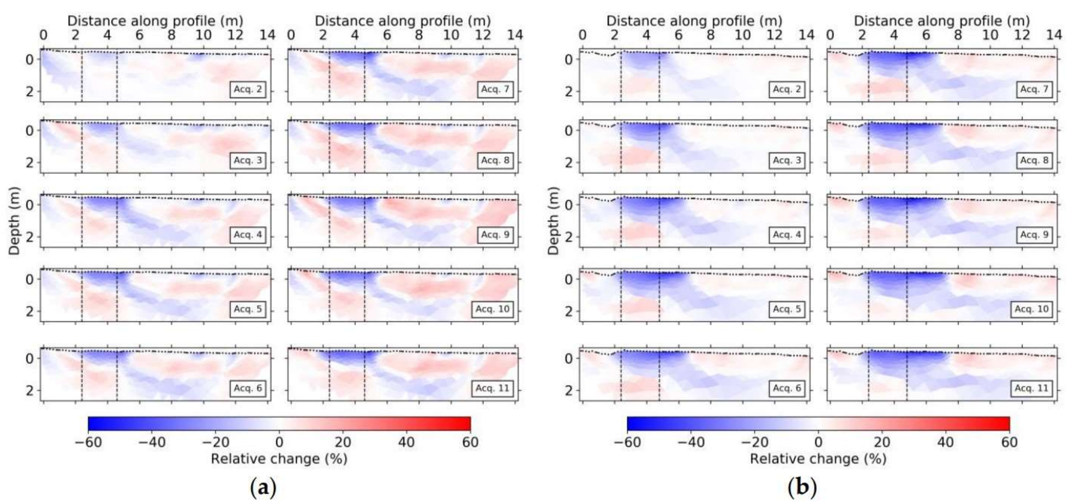

Figure 3. Time-lapse seismic results. On both transect, the P-Waves velocities decrease with incremental infiltrations.

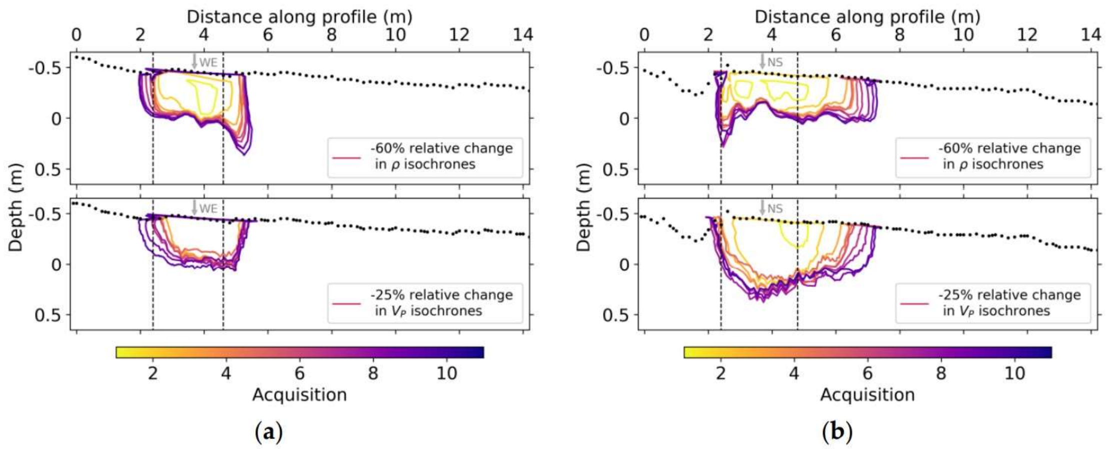

Figure 14. Isochrones showing a given percentage of relative change in electrical resistivity (ρ) and P-wave velocity (V_P) and their evolution with acquisition for (**a**) NS and (**b**) WE lines. The dashed black lines delimit the infiltration area and the gray arrows indicate line crossings.

Figure 4. Comparison between ERT and seismic refraction time-laps.