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Observation of flow processes in the vadose zone using ERT on different space and time scales: results, obstacles, and suggestions

Ursula Noell (1), Christina Ganz (2), Axel Lamparter (1), Wilhelmus Duijnisveld (1), and Jörg Bachmann (2)

(1) Federal Institute for Geosciences and Natural Resources, Stilleweg 2, 30655 Hannover, Germany (ursula.noell@bgr.de),
(2) University of Hannover, Institute for Soil Science, Herrenhäuser Str. 2, 30419 Hannover, Germany

Electrical resistivity tomography (ERT) observes the flow processes in the vadose zone indirectly. ERT has been used to estimate water flow in different soil types and under different flow conditions using active experiments or monitoring the natural process in many cases. Our experiments in sand and loess soil connected ERT with local soil probing using TDR devices and tensiometers in order to proof the reliability of the ERT inversion results in terms of infiltration velocity. Additionally, a colour tracer was used and sections through the infiltration zones were excavated in order to compare the shape of the dye -stained infiltration zone with the results of the ERT inversion. The data revealed the complicated infiltration pattern with a higher transport velocity in sand and a different shape than expected by classical soil hydraulic models. These results indicate the need for independent observations in order to correctly assess the water storage in the vadose zone with its hydrological consequences, the groundwater recharge and the contamination risk caused by rapid movement of water. ERT can be used for this purpose on different spatial- and time scales but for reliable results various obstacles need to be dealt with. Firstly, the ambiguity of the resistivity because soil resistivity depends on both, soil water content and electrical soil/water conductivity. This obstacle is less severe when the infiltration velocity is investigated, because then only the first onset of resistivity change is interpreted as the water arrival time. Our results show that the arrival of the water front as well as the final infiltration depth can be reliably detected. In contrast, this obstacle is very severe when the amount of water stored is observed using conductive tracer. The problem is not critical during a passive experiment when the natural rain fall and the waters fate through the vadose zone is monitored. The second obstacle is the limited resolution of ERT which deteriorates with depth. The resolution depends on the electrode distances and the depth resolution can be increased by using borehole electrodes. However, if one ha of land is to be observed with a reasonable number of electrodes (some 100) the resolution will be some 10 m. The structures, however, that influence the infiltration process, might be much smaller. Therefore, it is suggested to use ERT as the tool to observe and quantify the infiltration process with regard to time and space on a scale of some meters. For independent proof local TDR devices should be inserted within the investigated area for calibration. These results should then be used to establish a physical soil model that grasps the observed process correctly in time and space. The next step would then be to repeat these local measurements at different locations where the similarity of the processes is at doubt. Only when this is confirmed or discarded, further upscaling steps can be done reliably.