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Geoelectrical monitoring of water movement in the unsaturated zone

Susann Berthold and Tobias Geib
GFI Grundwasserforschungsinstitut GmbH Dresden, Germany (sberthold@gfi-dresden.de)

To continually track the water movement in the unsaturated zone and monitor groundwater recharge, two geoelectrical profiles were permanently installed in the catchment area of a waterworks. The geoelectrical profiles were set up in areas with different groundwater recharge. One profile was installed on a forest clearing, where the unsaturated zone is eight meters thick and dominated by sand. The second profile was installed in heathland, where the unsaturated zone is eleven meters thick and dominated by fine sand. The profile length for the geoelectrical measurements and the number of electrodes per profile were chosen depending on the depth of the groundwater table.

The geoelectrical measurements were carried out autonomously twice a day. Remote data transmission made the data instantaneously available for analysis and evaluation. During the entire period of investigation, that is August 2011 to December 2012, the geoelectrical profiles worked independently with low maintenance. During this period, approximately 800 data sets were recorded at each location. Each individual data set contained several thousand measuring points in the geoelectrical cross section.

To handle the large amounts of data and efficiently interpret them, a largely automatic algorithm, the so-called ELMON algorithm, was developed. The algorithm reads in the raw measurement values and allows fast acquisition of incorrect measurements and, where appropriate, initiation of maintenance (for example, to troubleshoot browsing by game). The detected erroneous measurements are automatically removed. Then, the change in soil electrical conductivity is determined via a physically founded calculation method developed in the framework of the project. The change in soil electrical conductivity is represented compared to a reference state, e.g. the day prior to a rain event.

Using the ELMON algorithm, the water movement through the unsaturated zone could be monitored over a period of more than a year. Clearly, the geoelectrical measurements reflect the spatially and temporarily differentiated water movement and changes in soil moisture, respectively. As expected, water movement is controlled by rainfall rate and water content of the soil. In the sand layers beneath the forest clearing, it takes about two days until the upper first meter of the soil is percolated by the seepage water after a rain event. Deeper regions show decreasing water content at the same time, indicating the drainage effect. Lateral variations in soil moisture could be clearly observed as a response to vegetation and soil inhomogeneities.

Using the geoelectrical measurements, it was also possible to track the ground frost progress over time and to determine its spatially different manifestation. The detection of ground frost is of great importance for groundwater recharge, as it determines times/zones of low or no groundwater recharge (when the ground is frozen) and times/zones of suddenly increasing groundwater recharge (when snow melts and the ground thaws).

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