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3D time-lapse Electrical Resistivity Tomography (ERT) to monitor subsurface flow processes during a sprinkling and injection experiment on a mountain slope

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Understanding the relationships between precipitation volumes, surface runoff and subsurface storage, drainage and flow processes on mountain slopes is critical for flood management in alpine regions. In the Schächen catchment (central Switzerland) an unexpectedly delayed and heavy flood reaction to a long duration rainfall event was observed in 2005. It is believed that the steep creeping landmass slopes with thick soils were responsible for the delay. To better comprehend and visualise water infiltration and runoff formation we conducted a 3D time-lapse ERT experiment during a water sprinkling and injection experiment on the side of a hill in the Schächental region presumed representative of soil and other conditions associated with the delayed flood.

Constant sprinkling at a rate of about 10mm/h was applied to a plot of area 30m x 5m. The electrical conductivity of the sprinkled water was approximately that of the pore water (25mS/m). A total of 33 consecutive ERT data sets, each comprising 3521 measured electrode configurations, were recorded with a 96-electrode array over an area of 27.5m x 14m, which included two thirds of the sprinkled area. Each electrode configuration was measured at a repeat interval of 2 to 2.8 hours. The entire 3D ERT monitoring experiment was divided into two separate time intervals: (1) the initial 25 hour period involving only freshwater sprinkling, until steady state was reached, (2) the following 35 hour period during which, in addition to the sprinkling, salt water was injected in two boreholes at a depth of 1m (unsaturated zone). The salt water injections were separated by 17 hours, and monitored until 14 hours after sprinkling stopped. During the first interval all changes in the subsurface resistivity are caused by changes in the water saturation and the temperature of the fluid, whereas in the second interval they are mainly due to changes in salt concentration of the pore fluid. Supplementary measurements of water table elevation and fluid electric conductivity were made in several boreholes. To image the subsurface resistivity changes, we inverted the ratios of time-lapse resistances to their background (pre-sprinkling) values.

The sprinkling during time interval 1 allowed us to examine near-surface infiltration. Even from the first time window, the emergence of a shallow wetting front could be observed in the inverted depth sections as a decrease in bulk resistivity. Both salt water plumes during interval 2 were found to move laterally as well as vertically through the soil into a zone of fissured Flysch. Below the water table, the plume could be tracked further as a weaker ERT signal, which shows a flow component parallel to the water table in the downslope direction where it eventually breaks the surface.

3D ERT monitoring has proven to be a powerful tool to monitor water sprinkling and injection experiments. Due to its advantageous ability to resolve changes, both in time and in space, it captured most of the soil moisture and flow dynamics. Processes, such as infiltration and drainage, which are important for the understanding of runoff formation, could be readily visualized.