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Mapping and monitoring the spatiotemporal Evolution of Water Flow Patterns in Snow using the electrical Self Potential (SP) Method: a Feasibility Study

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Delineating and monitoring the spatiotemporal evolution of water flow pathways in snow packs is challenging and labour intensive using techniques applied traditionally in snow hydrological studies. The electrical self potential (SP) method is widely used in hydrogeophysics and hydrogeology to map natural or artificially modified water flow patterns in groundwater aquifers, and more recently also in the unsaturated zone above such aquifers. Using a controlled laboratory study combined with snow hydrological and SP modelling we assess the usefulness of SP monitoring in snow hydrological applications.

We injected controlled volumes of water at the top of a laboratory column filled with snow collected at selected plots outside Abisko Research Station in the Arctic Sweden. Water discharge from the base of the column was measured at regular intervals and electrical self potentials between two non-polarising electrodes placed at the top and bottom of the column were monitored continuously using a Campbell Scientific CR10 data logger. The injection experiment was repeated several times as the snow evolved from an initially fresh dry powder to a partially saturated wet mass. Strong SP anomalies of several tens of millivolts were measured during the injection experiments, and the discharge breakthrough curve was found to lag noticeably behind the SP breakthrough curve.

We model [a] the discharge breakthrough curves using a 1-D finite-difference scheme

based on Colbeck's (1972) model of melt evolution in unsaturated snow packs; and [b] the SP breakthrough curves by assuming that the natural electrical potential gradients measured between the two electrodes are a function of water flux and saturation. We find that a combined model of discharge and SP can satisfactorily reproduce the lagged breakthrough curves. An electrical voltage gradient is generated as soon as the injected water begins to percolate downwards from the top of the column, while discharge becomes measureable only when the injected water reaches, and begins to exit from, the base of the column. Since there is no measureable SP gradient in the absence of water flow we infer that the measured SP breakthrough curve represents entirely an electrical streaming potential caused by capacitive effects at the interface between pore water and the snow grains.

Our feasibility study suggests conclusively that the SP method holds great promise in the monitoring and modelling the hydrological evolution of snow packs.