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Water and Solute Release from a Subalpine Snow Cover

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Summary

In temperate and cold regions, a considerable portion of precipitation is stored as snow. In spring, release of chemical trace species from the snow pack in melt water is a significant input to soil, vegetation and surface waters. Accumulation and release of water and ions in the snow pack is complex. Preferential flow paths extensively configure the spatial distribution of the water and ion release from snow. Several authors reported from laboratory experiments that ionic concentrations in melt water were influenced by ion redistribution at the grain scale during previous snow metamorphism.

This thesis aimed at determining timing, heterogeneity, and regulating mechanisms of water and ion release from a melting snow cover in a subalpine environment. The main objectives were (i) to quantify the spatial and temporal variability of the ion and water release of a melting subalpine snow pack, (ii) to identify and characterize the most important processes leading to this variability, and (iii) to investigate the interaction between snow microstructure and water flow and the persistence of preferential flow paths. Field and laboratory experiments and numerical simulations were conducted.

Non-destructive continuous measurement of the liquid water content with a time domain reflectometry (TDR) system provided valuable insight into flow processes in snow. We adapted the evaluation routine of the system by defining the thresholds of the used algorithm relative to the maximum of the TDR signal. This improved the flexibility of the algorithm and automatically yielded water content between dry and saturated conditions.

On a marshy meadow in the Northern Swiss subalpine area, we took water samples at the snow pack bottom with a set-up consisting of 32 melt water samplers having a ground section of 0.4 x 0.7 m. The observed spatial and temporal heterogeneity of the melt release was enormous and more complex than expected. Ion redistribution at grain scale had no major effect on the nitrate concentrations in melt water, which we explained by the fact that the nitrate concentrations were in the range of its solubility in ice.

The formation of preferential flow paths was identified to be the main cause for the heterogeneity of the water and ion release from the subalpine field snow pack. In slight local depressions, vertical flow paths seemed to

be more frequent when the snow pack was strongly layered. More than 90% of the melt and rain water was routed to less than 50% of the horizontal area. Furthermore, the role of saturated flow at the snow pack base was larger than expected. The height of this saturated zone exceeded the capillary rise in snow and the water, that was in contact with the soil, contained dissolved minerals.

In cold laboratory, we investigated water and dye tracer movement through microstructurally different snow pack horizons. Naturally rounded snow of varying grain size was sieved into rectangular bins and infrared lamps were used to induced surface melt. The capillary barrier effect at the boundary between a fine over a coarse textured layer on matrix flow was confirmed. In contrast to matrix flow, preferential flow appeared as well-defined flow fingers that advance from 0.1 to 1 cm s^{-1}. During a melt phase, the advancing flow fingers enlarged and were only partially time invariant. This is in line with the field experiment, where the preferential flow paths gradually and sporadically translocated.

The development of the snow pack monitored in the field was simulated using two 1-dimensional physically based numerical models. Snow depth and water equivalent were simulated with high accuracy, whereas the model was not able to reproduce the observed strong layering of the snow pack. A sensitivity analyses was carried out: The model disregards capillary barrier effects, preferential flow, and lateral water flow, which is a major limitation for a more realistic simulation of the snow pack layering.

In conclusion, the distribution of plant nutrients contained in a snow cover onto a field during melt is heterogeneous and varilar59056cy0 pl