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Spatio-temporal variability of snowmelt and runoff generation during rain-on-snow events in a forested mountain environment

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A network consisting of 81 standalone snow monitoring stations (SnoMoS), precipitation measurements, and streamflow data was used to analyze the observed snowcover distribution and melt dynamics during mid-winter rain-on-snow (ROS) events generating flooding in three study catchments with differing elevations, topographic characteristics, and areal extent in the Black Forest region of south-western Germany.
The crucial importance of the initial snowcover distribution prior to the event became evident. The contribution of snowmelt to total runoff was on average about 60%, highlighting the significance of snowmelt for the flood generation during ROS. The catchment with the most distinct topography was selected to further investigate the drivers of the spatio-temporal variability of snowmelt and the water available for stormflow runoff. A multiple linear regression analysis using elevation, aspect, and land cover as predictors for the SWE distribution within the catchment was applied on an hourly time-step using the observed dynamic at the SnoMoS locations. Based on this analysis the spatial distribution of the initial snowcover and the snowmelt occurring in different parts of the study basin during two ROS events in December 2012 was calculated. The amount and the spatial distribution of water potentially being available for the generation of runoff at the interface between the snowpack and the surface below was calculated considering spatially variable melt rates, water retention capacity of the snow cover and the input of liquid precipitation. Elevation was found to be the most important terrain feature having the biggest influence on the water release from the snowpack. Even though the highest total amounts of water from precipitation and snowmelt were potentially available for runoff in the higher elevations, the snowpack released reduced amounts of water to runoff in these regions. South-facing terrain contributed more to runoff than north facing slopes and more water was available at the surface of forested compared to open areas in the study basin. This behavior can be attributed to the snowpack itself having a higher storage capacity for water retention due to deeper, colder snowpack in the high elevations, north facing terrain, and open areas.
Finally, the number and location of monitoring stations necessary to simulate an accurate initial SWE distribution prior to the ROS conditions was analyzed. Results showed that by using 5 observation sites distributed over all elevation ranges and located at open and forested areas it was possible to calculate a comparable SWE distribution in the study basin. The findings of the study are especially important for the design of future observation networks in catchments. Furthermore, the results are valuable for operational applications and modelling studies of snowmelt and runoff generation during ROS conditions.