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Rain-on-snow: A process-based analysis of numerous events spanning a range of meteorological and snowpack boundary conditions

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Rain-on-snow events have caused severe flood events in Europe in the recent past. Due to the complex interactions of physical processes during rain-on-snow events, it is still difficult to accurately predict the effect of snow cover on runoff formation. Data analysis from past rain-on-snow events have shown that depending on snowpack properties, the snow cover can amplify, delay or dampen runoff. Prior rain-on-snow research has tended towards process oriented single event case studies and broad-based analyses spanning a range of events and conditions. In order to improve our understanding of processes during rain-on-snow, detailed analyses of a large number of events covering a broad range of snowpack and meteorological conditions would be beneficial.

In this study, an advanced physics-based snow cover model (SNOWPACK) is used to model snow cover processes during rain-on-snow events. SNOWPACK simulations detail the mass and energy balance and structural properties of the snowpack. Using 15 years of data from numerous stations throughout the Swiss Alps we investigated runoff formation during rain-on-snow events across a broad range of conditions. This enables us to identify critical meteorological boundary conditions capable of creating substantial runoff. Pre-event snow cover conditions have a significant influence on the meltwater release under different meteorological boundary conditions. With small pre-event liquid water content the snow cover is able to hold back rain in the snowpack and therefore lead to a delayed runoff release and lower runoff/rain ratio for an event. Furthermore, snow depth, total SWE, and energy inputs - factors oftentimes displaying seasonal dependencies - were also shown to strongly affect runoff generation.