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Snowpack energy balance and changes in the frequency and extremity of rain-on-snow events in the warming climate

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Seasonal snowpack significantly influences the catchment runoff and thus represents an important input for the hydrological cycle. Changes in the precipitation distribution and intensity, as well as a shift from snowfall to rain is expected in the future due to climate changes. As a result, rain-on-snow events, which are considered to be one of the main causes of floods in winter and spring, may occur more frequently. Heat from liquid precipitation constitutes one of the snowpack energy balance components. Consequently, snowmelt and runoff may be strongly affected by these temperature and precipitation changes.

The objective of this study is 1) to evaluate the frequency, inter-annual variability and extremity of rain-on-snow events in the past based on existing measurements together with an analysis of changes in the snowpack energy balance, and 2) to simulate the effect of predicted increase in air temperature on the occurrence of rain-on-snow events in the future. We selected 40 near-natural mountain catchments in Czechia with significant snow influence on runoff and with available long-time series (>35 years) of daily hydrological and meteorological variables. A semi-distributed conceptual model, HBV-light, was used to simulate the individual components of the water cycle at a catchment scale. The model was calibrated for each of study catchments by using 100 calibration trials which resulted in respective number of optimized parameter sets. The model performance was evaluated against observed runoff and snow water equivalent. Rain-on-snow events definition by threshold values for air temperature, snow depth, rain intensity and snow water equivalent decrease allowed us to analyze inter-annual variations and trends in rain-on-snow events during the study period 1965-2019 and to explain the role of different catchment attributes.

The preliminary results show that a significant change of rain-on-snow events related to increasing air temperature is not clearly evident. Since both air temperature and elevation seem to be an important rain-on-snow drivers, there is an increasing rain-on-snow events occurrence during winter season due to a decrease in snowfall fraction. In contrast, a decrease in total number of events was observed due to the shortening of the period with existing snow cover on the ground. Modelling approach also opened further questions related to model structure and parameterization, specifically how individual model procedures and parameters represent the real natural processes. To understand potential model artefacts might be important when using HBV or similar bucket-type models for impact studies, such as modelling the impact of climate change on catchment runoff.