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The temporally varying roles of rainfall, snowmelt and soil moisture for debris flow initiation in an alpine region

Karin Mostbauer (1), Roland Kaitna (1), David Prenner (1), and Markus Hrachowitz (2)

(1) University of Natural Resources and Life Sciences, Vienna, Institute of Mountain Risk Engineering, Vienna, Wien, Austria (karin.mostbauer@students.boku.ac.at), (2) Water Resources Section, Faculty of Civil Engineering and Geosciences, Delft University of Technology, Netherlands

Debris flows are frequent hazards in mountain regions. Though significant effort has been made to predict such events, the trigger conditions as well as the hydrologic disposition of a watershed at the time of debris flow occurrence are not well understood. Traditional intensity-duration threshold techniques to establish trigger conditions generally do not account for distinct influences of rainfall, snowmelt, and antecedent moisture. To improve our knowledge on the connection between debris flow initiation and the hydrologic system at a regional scale, this study explores the use of a semi-distributed conceptual rainfall-runoff model, linking different system variables such as soil moisture, snowmelt, or runoff with documented debris flow events in the inner Pitztal watershed, western Austria. The model was run on a daily basis between 1953 and 2012. Analyzing a range of modelled system state and flux variables at days on which debris flows occurred, three distinct dominant trigger mechanisms could be clearly identified. While the results suggest that for 68% (17 out of 25) of the observed debris flow events during the study period high-intensity rainfall was the dominant trigger, snowmelt was identified as dominant trigger for 24% (6 out of 25) of the observed debris flow events. In addition, 8% (2 out of 25) of the debris flow events could be attributed to the combined effects of low-intensity, long-lasting rainfall and transient storage of this water, causing elevated antecedent soil moisture conditions. The results also suggest a relatively clear temporal separation between the distinct trigger mechanisms, with high-intensity rainfall as trigger being limited to mid- and late summer. The dominant trigger in late spring/early summer is snowmelt. Based on the discrimination between different modelled system states and fluxes and more specifically, their temporally varying importance relative to each other, this exploratory study demonstrates that already the use of a relatively simple hydrological model can prove useful to gain some more insight into the importance of distinct debris flow trigger mechanisms, highlighting in particular the relevance of snowmelt contributions and the switch between mechanisms in early- to mid-summer in snow dominated systems.