

Rationale for the 750 m PRA Spacing: The authors mention placing Potential Release Areas (PRAs) along susceptible channels at a fixed interval of 750 m. While adopting a static disposition is well-justified for computational efficiency across a national domain, the rationale behind selecting 750 m specifically is not detailed. Please add a brief explanation or citation justifying this specific interval (e.g., balancing computational burden with typical initiation reach lengths).

Response: An interval between PRAs is indeed necessary to balance computational efficiency with the need to capture spatial heterogeneity in PRA properties along individual channels (e.g., channel curvature, catchment area, and lithology). Such heterogeneity can propagate through the model chain and ultimately affect simulated runout distances. The 750 m interval was selected empirically through sensitivity testing as a pragmatic compromise. We will clarify this rationale explicitly in the revised manuscript.

Justification Regarding Short-Duration Rainfall Intensities (5–10 min): The hydrograph volume parameterization uses 1-hour extreme precipitation. However, debris flow initiation and peak discharge in steep mountain channels are frequently governed by short-duration, high-intensity convective rainfall bursts (e.g., 5-minute or 10-minute peak intensity). While the authors state that 1-hour precipitation approximates concentration time and fits data availability, please add a discussion in the limitations section on why sub-hourly intensities were excluded and how this choice might impact modelled peak discharge.

Response: We agree that sub-hourly, high-intensity convective rainfall is an important trigger of alpine debris flows. For example, Iadanza et al. (2016) report critical rainfall durations as short as 10–20 minutes during summer. However, the characteristic rainfall duration associated with debris-flow initiation depends strongly on catchment characteristics, seasonality, rainfall-event structure, and antecedent moisture conditions. This variability is evident in Hirschberg et al. (2021), who identified triggering rainfall events for 67 debris flows in the Illgraben catchment with durations ranging from approximately 10 minutes to 24 hours.

For our national-scale analysis, we therefore selected the 1-hour rainfall intensity as a pragmatic compromise that provides a consistent reference duration across a wide range of environments and catchment characteristics. An additional advantage is the greater availability of 1-hour precipitation data at the national scale. We agree with the reviewer that this choice has limitations, particularly because short-duration rainfall peaks may be smoothed and the resulting peak discharges may therefore be underestimated for debris flows triggered by intense convective events. We will add a paragraph to the discussion explicitly addressing this choice and its implications for the modelled peak discharge.

Glaciers as Hazard-Amplifying Factors in Future Work: In the current hydrological parameterization, glacier accumulation areas are modelled as buffering zones that reduce runoff response (using an adjusted runoff coefficient of 0.0). Although the introduction and discussion acknowledge cryosphere hazards such as glacial lake outbursts and permafrost degradation, the current runout model treats glaciated terrain primarily as a runoff-attenuating factor. Please expand the future work section to explicitly discuss perspectives on incorporating glacial processes as potential hazard/risk amplifiers (e.g., GLOFs, thermokarst/glacier bed destabilization, or cascading ice-sediment surges).

Response: We agree with the reviewer that cryospheric processes can influence debris-flow hazards through multiple mechanisms, including processes that may amplify rather than attenuate hazards. Although such processes already represent an important component of alpine hazards, climate change may further increase the frequency or magnitude of specific extreme events, including glacial lake outburst floods (GLOFs; Zhang et al., 2024).

As the present study focuses specifically on rainfall-induced, bulking debris flows under current climatic conditions, we chose not to include additional cryospheric processes in the analysis. We will highlight this scope and its implications in a revised methodology. For future applications that explicitly consider climate-change effects on debris-flow runout, we recommend accounting for the cryosphere and their potential cascading effects. Accordingly, we propose to extend the outlook with a dedicated discussion of cryosphere evolution and its potential influence on Alpine debris-flow hazards under a changing climate.

References:

Hirschberg, J., Badoux, A., McArdell, B. W., Leonarduzzi, E., & Molnar, P. (2021). Evaluating methods for debris-flow prediction based on rainfall in an Alpine catchment. *Natural Hazards and Earth System Sciences*, 21, 2773–2789. <https://doi.org/10.5194/nhess-21-2773-2021>

Iadanza, C., Trigila, A., & Napolitano, F. (2016). Identification and characterization of rainfall events responsible for triggering of debris flows and shallow landslides. *Journal of Hydrology*, 541, 230–245. <https://doi.org/10.1016/j.jhydrol.2016.01.018>

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