Supplementary Material for:
Potential and challenges of depth-resolved three-dimensional MPM simulations: A case study of the 2019 "Salezer" snow avalanche in Davos

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I SENSITIVITY OF THE SIMULATED FRONT APPROACH VELOCITY ON THE AVERAGING PERIOD

Figure I shows a sensitivity analysis of the avalanche front approach velocity extracted from the simulation presented in section 4.1 in the main article. The extracted front approach velocity is calculated from the displacement of detected front position over a time period Δt divided by the time period itself. While we visualize the calculated approach velocity for $\Delta t = 2.0$ s and the fluctuation errorbars for $\Delta t = 0.25$ s in Fig. 5 in the main article, in Fig. I we vary Δt between 0.25 s, which corresponds to the maximum output frequency of our model, and 32.0 s.

Fig. I shows that for $\Delta t = 8.0$ s the maximum approach velocity plateau between ≈ 55 s and ≈ 75 s, representative of the flow in the gully, is still visible but is decreasing due to averaging for higher Δt. Hence, to avoid this Δt should be chosen smaller or equal to 8 s.

For a choice of small Δt more detailed features such as the velocity decrease due to the secondary releases between $\approx$ 20 s and $\approx$ 50 s, but also large fluctuations are visible. For our analysis the short-lived peak values are only of little relevance, as the smallest time period of the velocity from the eyewitness video is 7 s and does therefore not allow for a comparison of intermittent flow features with the field data.

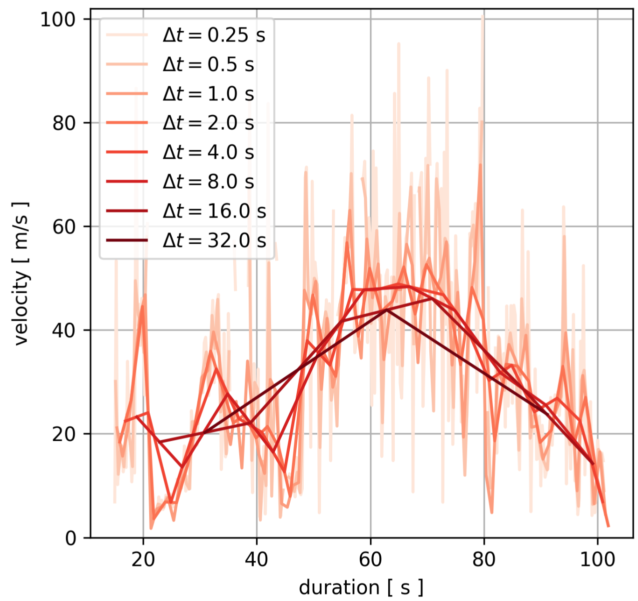

Fig. I. Sensitivity study on the effect of the averaging period Δt on v_{front}.

II SENSITIVITY OF THE SIMULATED FLOW OUTLINE AND RUNOUT FOR DIFFERENT SNOW COVER AND RELEASE SCENARIO DEFINITIONS

In order to investigate on the influence of i) the release scenario and ii) the snow cover definition on the simulation re-

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sults, we perform additional simulations where we make the following changes compared to the simulation presented in the main article:

i) Release scenario: We distinguish two different scenarios. First, the “sequential” release reported for the real event, which is presented in the article, where the flow of the primary release destabilizes the meta-stable secondary release areas one after the other as the avalanche flows down the slope. Second, we artificially enforce all release areas to release at the same time (simultaneous release).

ii) Snow cover definition: To study the influence of the snow cover definition, we perform a simulation identical as the one presented in the article, but with an even more simplified snow cover definition with a constant thickness of 2 m, which corresponds to the average snow thickness between 1.4 m and 2.8 m in the simulation in the article, distributed over the whole terrain irrespective of the elevation, and using the mechanical snow properties of the lower layer (1).

The simulations are illustrated in Figure II, and they are compared with the flow outline extracted from the drone measurements:

i) The simulation shows that a simultaneous release would result in a slightly smaller run-out compared to the sequential release. While in the case of the sequential release observed in the real event the secondary releases feed directly into the front of the already flowing avalanche, in the simultaneous release, three avalanche fronts form, which run into the same flow path, but remain separate flow fronts. Hence, the sequential release simulated in the article and observed in the real event can be considered as a worst case scenario. However, one should be careful generalizing this result. A simultaneous release may be the worst case scenario, if the terrain configuration is such that the different release fronts feed into a merged front at the same time.

ii) In contrast to the original scenario with two layers, Fig. II shows that the simulation with constant 2 m snow thickness has a shorter run-out. Given that the snow volume on the terrain remains constant, the likely reason for the shorter run-out can be attributed to the reduced erodability of the snow with the properties of layer (1) (Table 1 in the article). Compared to the fresh snow layer (2), layer (1) is characterized by a higher density and compressive strength, which reduces erodability. Hence, the good agreement of the run-out from the actual event and the simulated avalanche discussed in the main article can also be attributed to the presence of the more easily erodible layer (2).

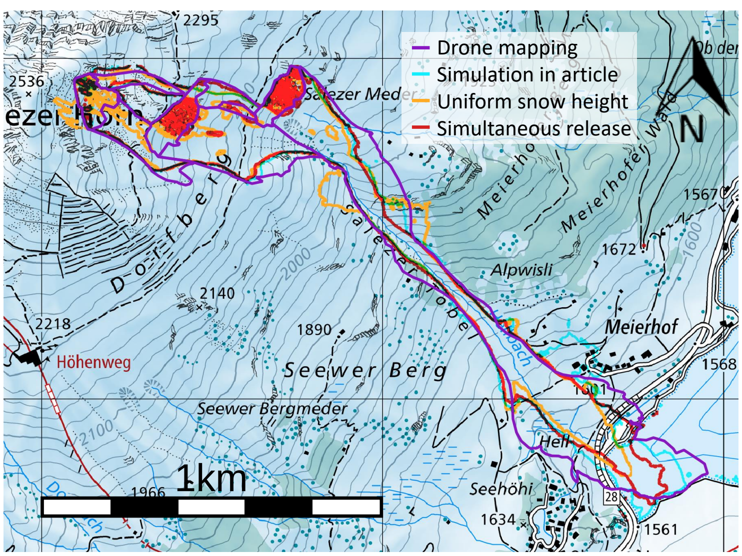

Fig. II. Sensitivity study on the effect of the snow cover definition and the release scenario on the run-out of the simulated avalanche. Map source: Swiss Federal Office of Topography.