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Reply on RC1

Natalie Brožová et al.

Author comment on "Multiscale analysis of surface roughness for the improvement of natural hazard modelling" by Natalie Brožová et al., Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-2021-85-AC1, 2021

Dear Manuel López-Vicente,

Thank you very much for your comments and suggestions to our paper. We answer your comments below.

- Abstract. Include the method/s used to generate the DSM and the DEM, e.g. LiDAR, SfM. The type of method influences the point density, and thus, the ability of the obtained models to accurately capture macro-, meso- and micro-features of the landscape.

We will add the following information to the abstract (new information **in bold**).

"... we tested seven roughness algorithms using **photogrammetric** digital surface models (DSM) with different resolutions …"

"We simulated avalanches on different elevation models (**LiDAR-based**) to observe a potential influence of a DSM and a digital terrain model (DTM)."

- Abstract. Authors compare the results of "surface roughness" based on DSM vs. those obtained from DTM. I have serious doubts that this is correct. In a DSM, all landscape features are included, and thus, the corresponding values of surface roughness are associated to those features. However, the information captured in a DTM is mainly controlled by the ground elevation, without most of the features included in the DSM. From a strict point of view, a DTM is the sum of the DEM and the main landscape geomorphic features like rivers, cliffs, crests, and breaking points. Therefore, the surface roughness derived from a DSM and a DTM of the same site is always qualitatively different. Besides, the digital height model (DHM=DSM-DTM) obtained in different land uses is different because of the distinct features that characterise each land use. All these aspects should be clarified in a revised version.

Thank you for this valuable point. We showcase the differences between the DSM and DTM in order to emphasize the importance of surface roughness in the avalanche simulation. Above treeline, the DSM is very similar to the DTM except for small bushes, young trees and man-made structures. As soon as we get into forested terrain, the differences are becoming greater. Forests are already implemented within the RAMMS simulations. However, the sparse vegetation or other surface roughness features above the treeline are not represented within the simulations, since the DTM is used. As surface features like sparse vegetation are removed from the DTM, we believe that there may be an overestimation of the simulated runout. When we simulate the snow avalanche on the DSM, it interacts with the surface features included in the model and therefore better represents the reality. In fact, hazard processes show different behaviours when they interact with surface features. Based on our study, we do thus not propose to simulate hazard processes using a DSM instead of the DTM, but we stress the importance of surface roughness on different simulations. For this reason, we propose to accurately select the adequate surface representation (DSM, DTM or a combination of them) for the calculation of surface roughness, which should be included in modelling of hazard processes.

- Abstract. What is the novel aspect of this study? I suggest highlighting the actual contribution of this study based on the available literature. To clearly present these aspects will make the article more attractive for potential readers.

As stated above, the importance of surface roughness for natural hazard modelling is great (shown on the example of a snow avalanche). We found that some widely used surface roughness algorithms based on the DSM could be used to assess the roughness in alpine terrain. Together with the directional roughness this is a promising approach for achieving better assessments of surface roughness, which should be included in the hazard modelling in the future.

In order to make this point clearer in the abstract, we rephrased the end of the abstract:

“We simulated avalanches on different elevation models to observe a potential influence of a DSM and a digital terrain model (DTM) using simulation tool RAMMS. In this way, we accounted for the surface roughness based on a DSM instead of a DTM, which resulted in shorter simulated avalanche runouts by 16–27% in the two study areas. Surface roughness above a treeline, which in comparison to the forest is not represented within the RAMMS, is therefore underestimated. We conclude that using DSM- in combination with DTM-based surface roughness and considering the directional roughness is promising for achieving better assessment of terrain in alpine landscape, which might improve the natural hazard modelling.‟

- L.33-34. Please, provide more information of the six cited studies or choose the three most relevant studies. In my opinion, it is not necessary to include six articles to support one statement. Do the same in L.42-43 with the 5 references: include more information of the modelling approaches

We kept the following cited studies as they represent the wide field of possible applications of surface roughness.

“Quantifying surface roughness is thus central for the estimation of various biophysical characteristics and ecosystem services (Koponen et al., 2004; Sappington et al., 2007; Wu et al., 2018).‟

We kept the following studies to support the statement since they represents two advanced model to simulate flow propagation. Furthermore, we included more information involving modelling approaches.

‟Approaches to modelling flow propagation are numerous (Frank et al., 2017; Pudasaini and Mergili, 2019). They can represent the flow as a single-phase or a multi-phase consisting of solid and water component propagating through a given topography (Christen et al., 2010; Rosatti and Begnudelli, 2013). Some of them include a spatial variability of the friction parameters and can even simulate erosion processes (Hungr and

McDougall, 2009; Mergili et al., 2017)."

- L.102-104. These two sentences are very interesting. I suggest authors extend the explanation of this approach.

We include the following paragraph in the revised manuscript:

"However, the investigated natural hazards have a predominant diffusion direction identified as the combination of terrain slope and curvature. Some studies implemented the surface roughness along a predefined direction (Michelini, 2016; Trevisani and Rocca, 2015). The direction for which roughness has been computed, usually derived through GIS algorithm (D8 or D-infinity), applied to the original or smoothed digital models. However, the direction derived through neighbourhood cells analysis could not be the same of the mass flow propagation. Such behaviours may be observed when the routing volumes are extreme and therefore in some particular situations the propagation direction may be defined by its inertia rather than the topography (Guo et al., 2020). In other cases, the particular mountain topography may force mass flows to affect the opposite hillside of the valley through a runup mechanism (Iverson et al., 2016). Furthermore, the flow direction of banks and channel sides features computed with GIS algorithms do not usually correspond to the mass flow direction. In this situation bank direction can be improved through a smoothing process of the DTM in order to remove gullies and channel from the basal topography. This technique can be easily applicable in case of regular channels but it could become more complex when the channel morphology is irregular, since it could oversimplify the basal topography. For such reasons in this study, we propose a novel approach to calculate surface roughness along user defined lines."

- L.134: Which features were included in the DTM? I assume that all landscape features were represented in the DSM. However, it is not clear which features were included in the DTM, apart from the DEM. This is an important aspect, because the derived products from the DSM and DTM -as the surface roughness and terrain roughness- are qualitatively different, and thus, it has no sense to compare them in a direct way.

As answered already in the second comment (related to the comment on the abstract), we compare the DTM and DSM in order to stress the importance of surface roughness and different manifestations of surface roughness in DTM and DSM for natural hazard modelling. The DSM represents all landscape features, while in the DTM the vegetation cover (represented by trees, deadwood and shrubs) and man-made structures are removed. By using these two surface models, we show how is the avalanche flow influenced by the surface features. The DSM derived roughness adequately captures such features which are filtered out and missing in the DTM.

- Section 2.1 and Figure 1. What is the criteria followed and the method used to draw the boundaries of the two study areas?

The boundaries depend on the availability on high quality drone data in the two study areas.

- L.156. Add the country of the SenseFly company, as you did it in line 171 with DJI.

The area of almost 1 km-2 was surveyed on 17 June 2019 using a senseFly eBee+ drone (Lausanne, Switzerland) equipped with an RTK GNSS system for accurate georeferencing (better than 5 cm).

- Discussion. I would like to know the average size of the landscape features included in the analysis of this study. Besides, authors should evaluate the relationship between the size of the features and the extension of each window area. Maybe, if some features are

much smaller than the window area, the information of those features is blurred. Maybe, the suitable window area may depends on the average dimensions of the features. This idea should be discussed.

We add the following paragraph to the revised manuscript:

"However, the performance did not increase with higher resolution. This is probably due to the scale of our features of interest. Features in our study areas like shrubs, rocks, standing or laying trees, but also gullies are usually in the scale of meters. These features are not that detailed as the higher resolutions of 0.1–0.5 m would be able to distinguish."

"In our study, we could not find a relationship between the size of the roughness features (in meter scale) and the size of the moving window area. The best performing moving window area was analysed as the largest tested – 49 m^{-2}, in combination with the 1 m resolution."

- Discussion. Did you establish the thresholds for distinguishing between the roughness categories before running the algorithms or after obtaining the results? This aspect has to be clearly explained, and the numerical criteria to propose those thresholds too.

Thank you for your observation, we have this information in the methods part and will point it out in the discussion as well.

We rephrased this in the methods part 2.3 Design and statistical analysis of roughness categories, line 250:

"In order to obtain a classification based on threshold values for a technical purpose, we analysed the kernel density distribution between the roughness categories (Table 2), after evaluating the best-performing algorithm, to determine the point of minimum overlap. We used the overlap function (overlapping package; Pastore, 2018; Pastore and Calcagnì, 2019) implemented in R (R Core Team, 2021). This intersection is the threshold between two roughness categories (*xpoints*)."

We also rephrased this in the discussion part, line 424:

"After finding the best-performing algorithm (*vector ruggedness measure*), we calculated thresholds for distinguishing between the roughness categories, which may be further used in roughness classifications of other areas. These categories are a novelty in the literature and they can be considered a preliminary proposal. However, these values must be applied carefully, as they were assigned using the vector ruggedness algorithm based on the 1 m-resolution DSM and moving window area of 49 m^{-2}. One should be as well cautious when defining the roughness categories as e.g. the surface of snow can be highly variable (Buhler et al., 2016). In our study, the snow surface consisted of remaining snow patches in summer and was very smooth, as shown with the lowest distribution of roughness values (Fig. 4). We therefore propose further validation of such values over larger areas and different landscapes."

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