The Cryosphere Discussions

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Reply on RC1

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Author comment on "Snow Avalanche Frequency Estimation (SAFE): 32 years of monitoring remote avalanche depositional zones in high mountains of Afghanistan" by Arnaud Caiserman et al., The Cryosphere Discuss., https://doi.org/10.5194/tc-2022-15-AC1, 2022

Dear Reviewer,

We are very thankful for your review and comments on our paper about snow avalanche deposition zones in Afghanistan. For now, we have decided to formulate an initial reply to your comments and then will wait for other reviews before submitting a comprehensive response to all review comments along with the revised version of the paper. Nevertheless, we are already working on your suggestions to effectively address your key comments.

1.The state of the art is incomplete. Several publications, very relevant for this topic have to be considered and discussed. In particular the optical mapping with SPOT6 over the Swiss Alps is important (Bühler et al., 2019). But also, several mappings with Sentinel-1 are missing (Leinss et al., 2020; Karas et al., 2021; Vickers et al., 2016). Considering hazard indication mapping new developments allow for applications over very large areas (Maggioni and Gruber, 2003; Barbolini et al., 2011; Bühler et al., 2022) and was even already conducted in Afghanistan (Bühler et al., 2018). Therefore, the introduction has to be overworked including the relevant publications.

Thank you very much for suggesting those relevant references. We will definitely add those references in the Introduction that contribute to the focus of our paper. Regarding Afghanistan, we have not found any published papers that include results of snow avalanches including the paper you noted. Very few, if any, studies have been conducted there on avalanche hazards at a detailed scale.

2. It is essential to clearly communicate what can be expected from the presented approach in terms of accuracy and reliability. First of all, only very large avalanche debris can be mapped. Throughout the paper the authors should

use this term and not the term avalanche to be clear. An avalanche consists of a release, a transition and a deposition zone. Only the deposition zone can be partially mapped. There are several problems for example if the avalanche debris is covered by soil / rock or wood (The NDSI is reduced and the deposit is not mapped as avalanche). There is now information on how many avalanches deposited onto one mapped deposit. Typically, this happens several times a year. In the river basins there is often complex terrain with a lot of cast shadow leading to missed avalanche debris. All these uncertainties lead to a very limited reliability of the presented approach. Therefore, it is not eligible to draw all the statistics from the mapped debris as the authors do in the results. These statistics are strongly biased and not reliable. Applying them for hazard mapping or the planning of mitigation measures could be very dangerous.

We thank you for your comment related to the terminology used in our paper. Moving forward, we will use the term 'deposition' or 'deposits' to better characterize the focus of our hazard assessment. The term 'debris' is widely used in geomorphology and often denotes the dynamic part of geomorphic processes (e.g., debris avalanches, debris flows); we prefer to use the more appropriate term "deposition" to characterize the 'static' portion of the snow avalanche hazard, which is what we mapped. As for avalanche structure, it was already explicitly articulated that SAFE only maps the deposition zone: "The avalanches are indeed detectable by delineating their depositional zones (not their release or transition zones)" lines 155-156. Although we feel this was already rather clear, we will add other caveats to clarify that were are not dealing with initiation or runout zone – only depositional zone – as this seems to have caused confusion.

As for snow avalanche deposits that may have been missed using NDSI, we agree that SAFE can omit snow avalanche deposits as already acknowledged in line 268: "Another source of error arises when SAFE cannot detect avalanches due to a dark color on the snow surface associated with surface debris or a debris flow on top of the avalanche." However, because of the advantage of our long-term data base, if SAFE misses an event in one year, the model systematically looks at each pixel in every year – in our case, 32 times (i.e., 32 years of data). Thus, frequently impacted areas will be identified even if events in a few years are missed due to shadows or debris flows. Thus, we disagree that our statistics are 'not reliable'.

Regarding the comment that the application of this model 'could be very dangerous', we completely disagree with this value judgement. SAFE is one model, if not the first attempt, to map areas at avalanche risk across large scales and on over long time periods in that region. As specifically mentioned in the paper, we looked at avalanche deposits on foot slopes where human settlements are most vulnerable to snow avalanches. SAFE does not examine mid- to upper-slope terrain because in mountainous Central Asia, as well as proximate mountain regions, these upper slope areas are not occupied by humans or their activities during winter. Only foot slopes represent an area at risk; high mountain winter recreational activities – e.g., skiing, and other winter tourism activities – are virtually nonexistent in this vast mountain region. What matters in our region, such as Badakhshan, is the location and frequency of avalanche deposits on villages, roads and, to some extent, streams. SAFE is the kind of model that we need here since it can be freely replicated and used with minimal resources to determine which villages and roads are at frequent risk. This is the advantage of our long-term (albeit less accurate than SPOT) database. In our work here on the border of Afghanistan, we frequently experience road blockages and the isolation of villages for several days because of avalanche deposits. This issue is a higher priority in Central Asia and the surrounding mountain regions than detailed mapping of avalanches on upper slopes.

3. To assess the mentioned uncertainties and potential biases we recommend to test the algorithm with the most complete and accurate avalanche dataset mapped with SPOT6 imagery over the swiss Alps in 2018 and 2019 (Bühler et al., 2019; Hafner and Bühler, 2019) https://www.envidat.ch/dataset/spot6-avalanche-outlines-24-january-2018;https://www.envidat.ch/dataset/spot6-avalanche-outlines-16-january-2019. This exercise could bring clarity into very important questions and help to assess the potential of the presented approach.

We would like to thank the reviewer for this recommendation and for sharing these relevant data with us. We will compare the outlined avalanches in 2018-19 with SAFE results on the same area of Switzerland as suggested. Given that the purpose of SAFE is not to map upper slope avalanches, it must be understood that the approaches in these two studies were quite different. However, we can still conduct a comparison between SAFE outputs and the outlined avalanche deposits at the foot slopes only, using the mask we developed for SAFE. Then only, can the two datasets be appropriately compared.

4. The snow avalanche size classification is totally flawed with respect to reality/ methodology. According to the definition of the EAWS (https://www.avalanches.org/standards/avalanche-size/#largeavalanche) size is mostly defined by volume, runout-length and destruction potential: so basically only avalanches larger than size 3 (large to extremely large) have potential to even reach those places where they are later detected with enough snow for it to remain until summer, Additionally, as the authors state they cannot separate single events, a size classification with the same classes as assigned to whole avalanches shortly after their release is nonsensical also as the area covered in gullies usually means a lot more volume than one would think. This makes methodologically no sense as well as everything derived from this (whether as category or as size).

We understand and appreciate your comment about avalanche size classification. Indeed, we unfortunately do not have any data on avalanche volume, and we admit that our terminology 'avalanches size' is confusing. We however believe that the classification of the cumulated avalanches deposits could be relevant information to highlight and rank the most vulnerable areas. Valleys with large 'size' events represent more vulnerable areas impacted by repetitive avalanches than 'small size' events. And if one valley bottom is affected by only one, but a very large avalanche, SAFE will still be able to identify it as a single large event, since SAFE maps the cumulated avalanche deposits. Therefore, we will change 'avalanches sizes' to 'avalanches surface area' in the text and figures.

5. It is not clear why only Landsat is used. Sentinel-2 imagery would also be a big help for the presented approach (even though only available from 2015).

What about the potential of other systems such as PLANET? This should be discussed.

It would be indeed interesting to run SAFE with other products such as S2 or other products from PLANET. This could be an area to explore in a future paper. For the objective of this study (i.e., a long-term assessment of hazards in valley bottoms related to avalanches), SAFE uses Landsat archives for two clear reasons: (1) those data are open access, which suits the economic context of local research institutes who cannot afford expensive images such as SPOT; and (2) as noted, the objective of this paper was to look at a long term – 32 years – period of avalanches debris and only Landsat archives can achieve this.

Please also note the supplement to this comment:
https://tc.copernicus.org/preprints/tc-2022-15/tc-2022-15-AC1-supplement.pdf