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Interactive comment on “Mapping avalanches with satellites – evaluation of performance and completeness” *by* Elisabeth D. et al.

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Dear Markus Eckerstorfer,

thank you very much for your constructive and careful review of our paper. We totally agree that it's only three or four groups of independent scientists reviewing each other's papers about avalanche detection. We also agree with you that reviewers with another focus in remote sensing or avalanche experts would enrich the discussion and help the topic make progress with new ideas. However, in our point of view it is essential that the review is performed by someone who have the necessary technical skills but also a background in application to judge the full value of the new findings. Unfortunately, there are not so many specialists available today that fulfill these prerequisites. Please

find in the following our answers to the issues and questions you raised:

1) Limitations of this study:

We are aware that drawing conclusions about the overall accuracy of a method our “small” investigation has certain limitations that we attempted to carefully lay out in 5.3. In optical data, of course given a cloud-free image, illumination seems to be the most important factor for accuracy (4.2.1). Calculations have shown that 65% (61%) of the investigated perimeter were illuminated at the time of SPOT image acquisition in 2018 (2019). In order to do the effects of illumination conditions in optical data justice, we will add a small section to 4.2.1 and the discussion debating the implications of changing illumination conditions on the area affected by cast shadow over the course of the winter and its expected effects on the mapping accuracy.

As for radar data, the orbits were chosen because the far- range minimizes layover and improve avalanche visibility (see Leinss et al., 2020), we were not thinking about SAR signal change due to snow conditions as we selected images. But, we have pointed out in 5.1 that we observed that pre-and post-event radar backscatter images show much stronger overall changes of the snow conditions from mixed (pre-event) to wet-snow conditions (post-event) in 2018, whereas in 2019 with stable dry-snow conditions-avalanches were the most prominent changes of the backscatter signal. Additionally, we have pointed to the investigation of a series of SAR images exploring snow conditions in Eckerstorfer et al.(2019). We believe elaborating the effects of snow conditions on SAR imagery is beyond the scope of this paper, as the paper's objective is the comparison of different sensors rather than an in-depth study of radar-specific properties. As you pointed out, a detailed evaluation has been due, and we hope that more such investigations will follow. Therefor we have carefully described the applied data and methods and believe that with further comparison it will be possible to better assess the accuracy under varying conditions, in different regions and in diverse terrain.

2) Ground truth clarification:

As our ground truth was not comprehensive (Figure 5) we could not join avalanches identified in ground truth with those mapped in the different methods and automatically declare those without a match a false detection. We therefor had to examine our ground truth twice: first to identify avalanches and create validation points which we continued to match with the mapped avalanches. Second to check whether for the remaining unmatched avalanches (from our examined methods) we had ground truth and could proof a false detection or if the validity of that mapping would have to be declared unknown (which is where the remaining validation points come from).

Therefore, after identifying avalanches (i.e. validation points in ground truth), matching them with our avalanches from the satellite and ground based mapping methods, and backchecking for false detections, we had 550 points with valid information from our ground truth images. As mentioned, this includes confirmed avalanches as well as confirmed false detections. 48 of those 550 validation points where identified as representing avalanches outside our validation period, therefor only the remaining 502 went into analysis. The number of avalanches mapped in either method that could not be evaluated is 181, which together with 48 avalanches outside the validation period accounts for 229 avalanches that were not considered for analysis. We will attempt to make the above procedure even more clear in the final version of our paper.

Validation points:

The validation points were manually created in a location overflown by the avalanche based on the ground truth photo. We did not follow a pattern in which fraction (release, track, deposit) of the avalanche the validation point was placed. In Figure 4 the validation points are already shown in 4d. The validation points are actually points, but as we wanted to illustrate the relationship between the avalanches in the ground truth photographs with the mapped avalanches we chose to show joins with polygons in Figure 6. The location of our validation points did not have an effect on the results of joining

as we always went back to the corresponding ground truth photograph for clarification in case of ambiguity.

Figure 3:

The numbers to the left represent a sequence of steps, in that sense an x-axis. As noted in the legend, the orange arrow symbolizes the link between ground truth imagery and visually detected avalanches for validation.

Figure 4:

We will add aspect to Figure 4d in the final version of this paper, but not for Figure 4a-c as we are convinced it would considerably worsen the readability. Additionally, we will indicate the time of acquisition for the imagery in 4a-c in the legend of Figure 4. Whether or not multiple features belong to the same avalanche was decided relying on the ground truth photographs. We cannot show release, track and deposit as we do not know the exact dimensions of those avalanche parts (UAV data could provide that). If you are referring to 4.2.2 with this request, release, track and deposit were defined as upper, middle and lower third of the avalanche shown on ground truth imagery. As for the backscatter of SAR in 4c: red represents the post-event image, green/blue the pre-event image. The image is composed by LRW using the four Terrain-Corrected images from 2019 as listed in Table 2. We never used single-backscatter images. We did the detection based on the backscatter ratio (not shown) and looked at the shown LRW/TC corrected image in unsure cases. We will add the explanation of the colors shown in 4c to the legend in the final version.

Figure 6:

We tried to show spatial joins with respect to “reality” which is why we decided to picture outlines for ground truth avalanches. The spatial joining of validation points to avalanches mapped by either of the methods was done manually. As we could always go back to the original ground truth photographs depicting the avalanches on which our validation points were based on, proximity of points was never a deciding factor for joins. The avalanche from either mapping method had to overlap with the avalanche visible in the ground truth in order to be joined to the corresponding validation point. Hence, joining Sentinel 2 to the validation points did not pose a problem. Summarizing, because we looked at the underlying ground truth photographs in unclear situations, the position of the validation points did not have an effect on the joining procedure.

Table 5:

Based on your request we calculated POD and PPV neglecting joins. For the computation we treated multiple mapped avalanche patches which were originally joined to one validation point as separate avalanches (one-to-many) and one avalanche patch as just one avalanche even though it was joined to two validation points because of avalanches on ground truth (many-to-one). In order to make the effects of either join better visible we have calculated them both separately and together. The results are depicted in Figure 1 at the end of this document.

It can be seen that treating several avalanche patches as several avalanches (using no one-to-many joins), overestimates the number of avalanches, leading to a higher POD and PPV. Compared to the numbers in Table 4, the increase in POD for S1 is more pronounced as the percentage of one-to-many joins is higher (Table 5). If we are neglecting many-to-one joins and treating one avalanche polygon as one avalanche (even though ground truth showed two or more corresponding avalanches) the POD decreases as well as PPV. If both one-to-many and many-to-one joins are neglected, for SPOT the POD and PPV are slightly lower than the results in Table 4, whereas the opposite is true for S1. This is due to one-to-many joins being more relevant for S1 and many-to-one joins for SPOT. We will add this explanation to the Appendix of the final paper and add a few sentences to the section referring to joins in 4.2.

4.2.1

We think there is a misunderstanding about avalanches in partly illuminated terrain:

the category means that part of the avalanche (at least one 5th) is located in shaded and the remains in illuminated terrain (at least one 5th). As mentioned in 1. we will add a section discussing the change in shaded and illuminated areas over the course of the winter and its implications for the results in the final version of our paper.

Eckerstorfer, M., Vickers, H., Malnes, E., and Grahn, J.: Near-Real Time Automatic Snow Avalanche Activity Monitoring System Using Sentinel-1 SAR Data in Norway, Remote Sensing, 11, 2863, doi:10.3390/rs11232863, 201

Leinss, S., Wicki, R., Holenstein, S., Baffelli, S., and Bühler, Y.: Snow Avalanche Detection and Mapping in single, multitemporal, and multiorbital Radar Images from TerraSAR-X and Sentinel-1, doi:10.5194/nhess-2019-373, 2020.

Interactive comment on The Cryosphere Discuss., https://doi.org/10.5194/tc-2020-272, 2020.

	no one-to-many joins		no many-to-one joins		no joins at all	
	SPOT	S1	SPOT	S1	SPOT	S1
POD	0.75	0.31	0.70	0.25	0.72	0.29
PPV	0.89	0.89	0.86	0.86	0.87	0.88

Fig. 1. POD and PPV calculated neglecting one-to-many, many-to-one and both joins.