REVIEW

This paper proposes a new method for identifying potential release areas (PRA) for snow avalanches based on terrain characteristics and validates the approach using a long-term avalanche cadaster dataset. The research is situated in France. and the study area includes three mountain massifs in the French Alps. Overall. the topic is interesting and relevant for the avalanche research community and the NHESS readership.

While I appreciate the authors' desire to create a practical. transparent. and computationally efficient algorithm for PRA identification that uses easily accessible datasets. there are several substantial weaknesses in the present study that. in my opinion. prevent this manuscript from being a meaningful contribution to the literature in its current form. Properly addressing several of my concerns would require a substantial redesign and/or expansion of the study. and I am unsure whether that can be accomplished within the current peer-review process. I hope that the following comments can help the authors to further develop their research.

Author's response: We deeply thank the referee for his/her meaningful suggestions and feedback. Even if some of the criticisms where for us a bit too strong, we took them as a challenge to clarify and improve our research and they certainly greatly helped us to improve the paper.
Let us just stress first that the main objective of the paper is to develop a PRA detection method that grounds on already existing developments (notably by Margherita Maggioni, Yves Bühler and their co-authors) and works reasonably well in the context of the French Alps. This is shown by performing an evaluation/validation exercise relying on an excellent data source regarding past avalanches, the CLPA in different massifs and areas of the French Alps (response Tables 1 and 2). However, in addition to the benefit for avalanche hazard assessment in the French context, there are also some slight methodological outcomes of the paper that may be of broad relevance for the topic:

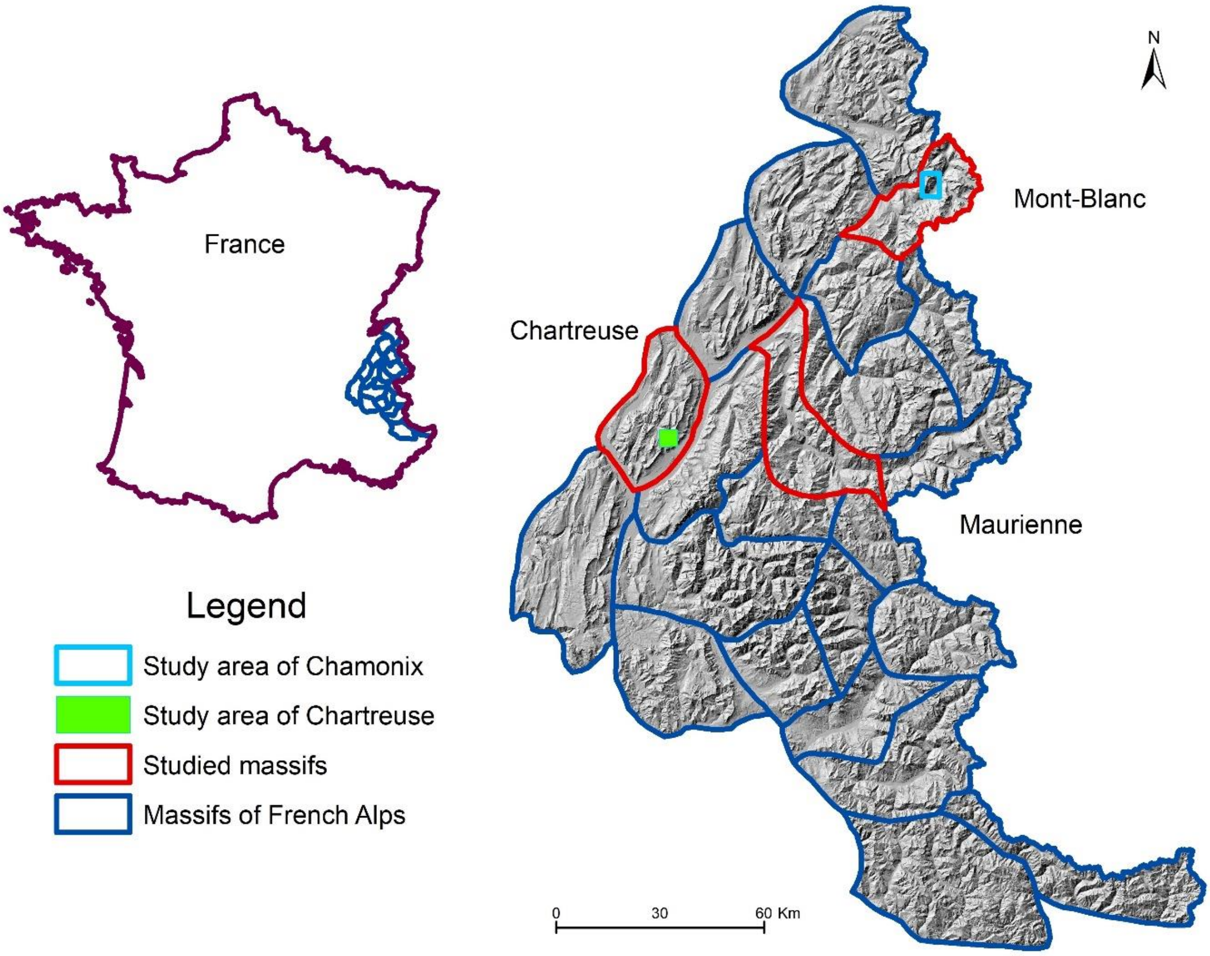
i) The determination of individual PRAs using a watershed delineation algorithm;
ii) A validation approach on the basis of accuracy scores computed using two metrics, PRA numbers and area;
iii) Broader findings and reflexions about how to validate a PRA detection method, notably how can a validation data sample be defined, and which scores can be interpreted.

None of these points are completely new in the community, but we find that they have not been fully answered so far in the literature, and we humbly hope that our paper will therefore bring some useful elements to the debate. The questions raised by both reviews however indicate that these objectives/questions were not clear enough in the first version of the paper. The paper will therefore be largely reworked to better introduce the research questions and discusses the findings and the approach with regards to these questions.
Eventually, let us note here that to make the validation and parametric study more convincing, we performed many additional analyses i) in terms of potential set of parameters, ii) by considering into the analysis the questions of the DEM resolution, iii) by performing the parametric study all over 3 entire massifs and not only over a small area, and iv) by investigating the relation between the determination of the validation sample and the accuracy scores. An additional small area within the massif of Chartreuse (Chartreuse study area / Dent de Crolles) is also considered to better highlight/illustrate some results (response Figure 1). However the matching between detected PRAs and validation sample should be checked first in terms of massif-scale scores, which provides a much more systematic assessment free of local effects and "cherry picking".
What follows provide a point-by-point answer to the referee's comments, questions and suggestions and introduces the results of these additional analyses that will be fully integrated in the reworked version of the paper.

N. Eckert. on belief of the co-authors

		Chamonix area	Chartreuse area (Dent de Crolles)	Chartreuse Massif	Mont-Blanc Massif	Maurienne Massif
Accuracy rate (Eq. 3)	In numbers	92.1	93.6	93.5	90	91.4
	In areas	98.3	90.2	96.2	96.8	97

Response Table 1: *Summary of accuracy scores for the different massifs and study areas (updates Table 3), including the new Chartreuse/Dent de Crolles study area (response Figure 1).*



Response Figure 1*: updated figure of the paper that includes the new Chartreuse/Dent de Crolles study area.*

	Chamonix area	Chartreuse area / Dent de Crolles	Chartreuse massif	Mont Blanc massif	Maurienne massif
Total area [km2]	34.3	7.6	847.0	578.0	917.1
Total area covered by CLPA [km2]	25.8	4.7	44.0	354.6	382.3
Fraction of area covered by CLPA (%)	75.3%	61.7%	5.2%	61.3%	41.7%
Total area of PRAs within CLPA extensions (validation sample) [km2]	3.6	0.5	1.6	58.3	55.7
Total number of PRAS withn CLPA extensions (validation sample)	85	28	85	1522	1884
Total area of detected PRAs [km2]	8.1	1.2	15.4	166.3	115.1
Total Number of detected PRAs	210	58	721	3676	3638
Total area of detected PRAs within area covered by CLPA [km2]	5.5	0.8	2.3	90.8	71.6
Total Number of detected PRAs within areas covered by CLPA	107	39	108	2003	2575
Aerial fraction of detected PRAs within the area	23.7%	15.3%	1.8%	28.8%	12.5%
Aerial fraction of PRAs within the area covered by CLPA	21.2%	17.0%	5.3%	25.6%	18.7%
Aerial fraction of PRAs within CLPA extensions with regards to total area of PRAs	67.2%	68.4%	15.3%	54.6%	62.3%
Fraction of PRAs numbers within CLPA extension with regards to total number of PRAs	40.5%	48.3%	11.8%	41.4%	51.8%

***Response Table 2**: Characteristics of studied massifs and areas.*

PRIMARY ISSUES

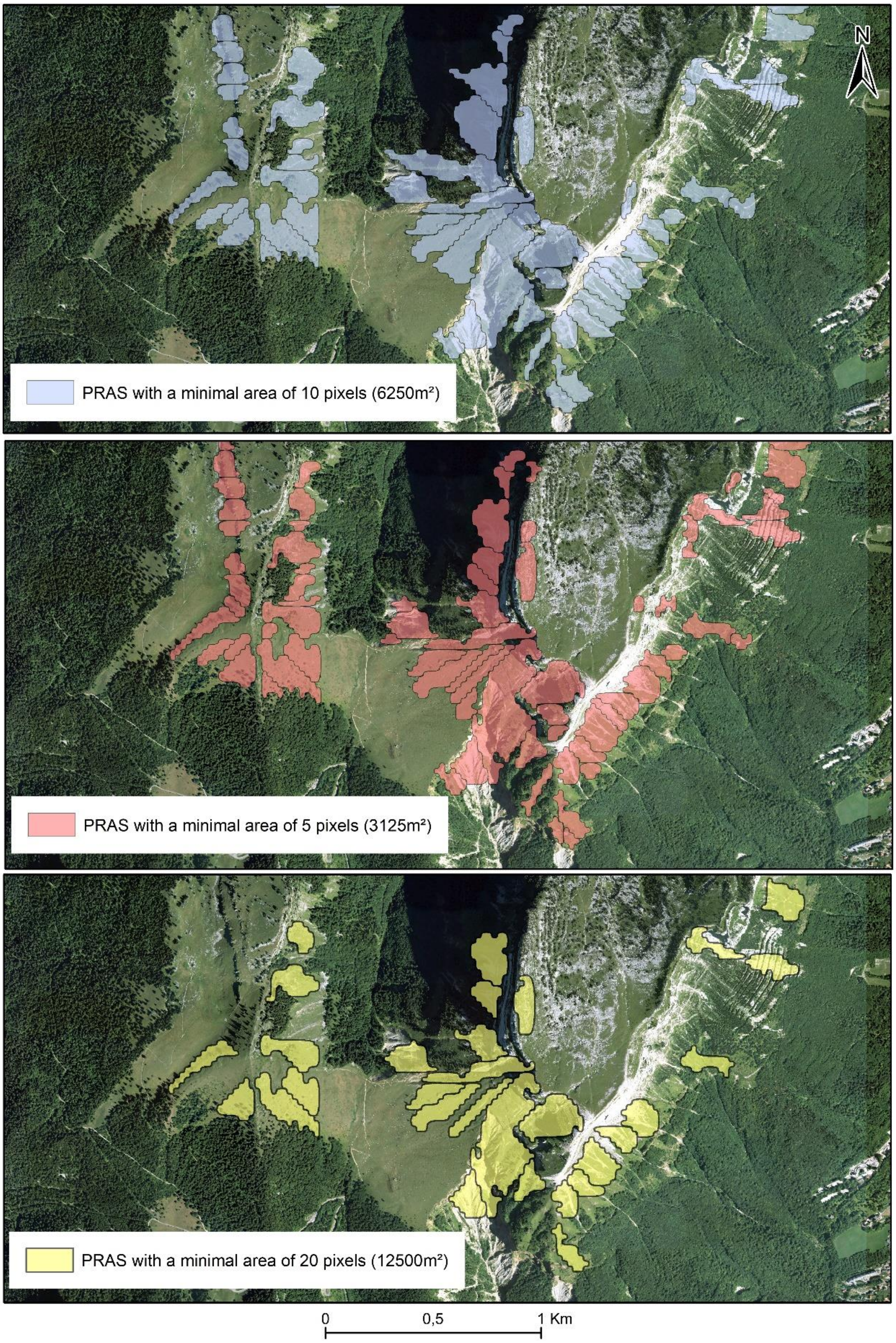
Selection of terrain characteristics and threshold for PRA identification

While the selection of terrain characteristics included in the PRA identification algorithm is based on existing literature. the reasons for their selection (or the refusal of other characteristics) are only discussed superficially. Furthermore. the selections of the parameter thresholds (e.g.. 1400 m elevation threshold. incline range) do not seem to be well grounded in evidence. I recommend that the authors conduct a proper grid search to determine the ideal parameter settings for their PRA identification algorithm. This is particularly important because they use a low-resolution DEM (25 m). which results in incline values that are biased towards lower values. This means that the thresholds described in the literature are not necessarily applicable. While the current sensitivity analysis might intend to do this. it is not done in a very rigorous and scientifically valid way. See additional comment on sensitivity analysis below.

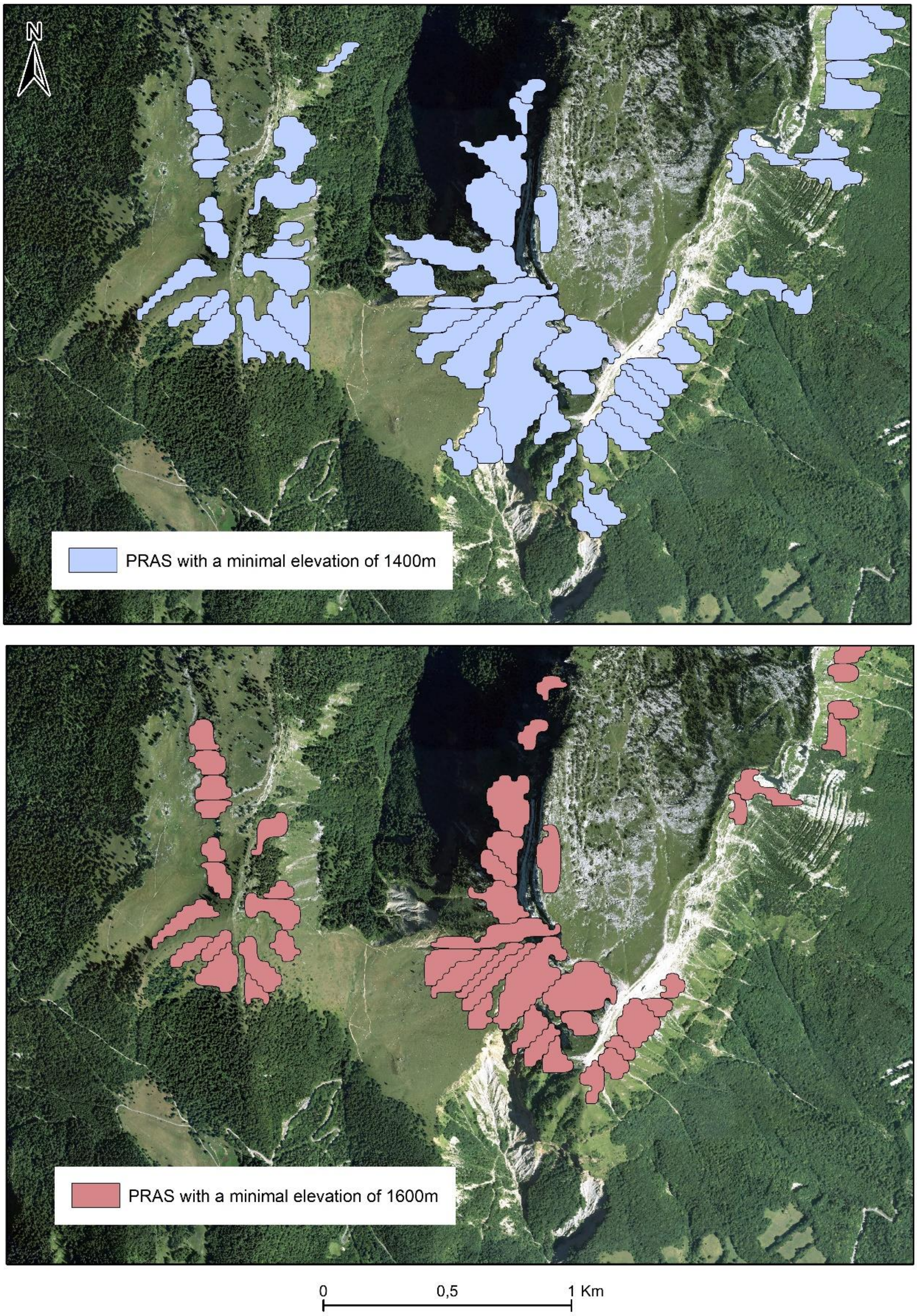
Author's response: As indicated before, we conducted many additional analyses to investigate how the choice of the different parameter values and thresholds affects the PRA detection in terms of PRA areas, numbers and accuracy scores (response Table 3). This systematic search was performed over the entire massif of Mont Blanc. Results overall appear as consistent, with globally decreasing accuracy rates as one leaves the default values determined from the literature and used for the identification of the validation sample. Overall, accuracy scores seem nevertheless rather stable over considered ranges of parameters/thresholds, with slope range being the most influential parameter over the tested range (up to a 10% decrease in accuracy for numbers). Also, specific areas have been analysed (response Figures 2-4). They, e.g., show that a too large minimal extension, a too high minimal elevation or a too restricted slope range logically misses release areas that an expert analysis would definitely consider as suitable location for an avalanche release. These results will be more deeply analysed in the revised version of the paper. See also our responses to the next comments, notably those related to data, validation and DEM resolution and related discussion regarding the dependency of the results on the validation set-up and the interpretation of the scores.

		With default values	Minimal area (m2)			Minimal elevation (m)			Slope range (°)				Maximal distance to ridge (m)			
			3125	9375	12500	1200	1600	1800	[26-60]	[30-60]	[32-60]	[34-60]	400	500	700	800
Total area of detected PRAs [km2]		90.80	93.8	88.2	85.2	90.7	88.9	88.7	90.8	64.5	58.9	51.8	81.0	88.5	94.3	95.0
Delta area with regards to default values [km2]		/	2.99	-2.57	-5.64	-0.05	-1.89	-2.14	0.00	-26.25	-31.89	-39.03	-9.80	-2.33	3.52	4.20
Delta area with regards to default values (%)		/	3.3%	-2.8%	-6.2%	-0.1%	-2.1%	-2.4%	0.0%	-28.9%	-35.1%	-43.0%	-10.8%	-2.6%	3.9%	4.6%
Total number of detected PRAs		2003	2632	1654	1369	2000	1979	1941	2002	1598	1582	1505	1877	2008	2088	2104
Delta numbers with regards to default values		/	629	-349	-634	-3	-24	-62	-1	-405	-421	-498	-126	5	85	101
Delta numbers with regards to default values (%)		/	31.4%	-17.4%	-31.7%	-0.1%	-1.2%	-3.1%	0.0%	-20.2%	-21.0%	-24.9%	-6.3%	0.2%	4.2%	5.0%
Total area of detected PRAs within CLPA extensions [km2]		84.9	85.7	83.3	81.2	84.7	83.1	76.6	84.8	61.9	56.3	49.6	75.3	82.3	87.5	87.5
Total number of detected PRAs within CLPA extensions		1601	1768	1391	1201	1590	1589	1520	1597	1409	1406	1349	1468	1576	1622	1621
Accuracy rates	In numbers	90	83.6	89.9	89.3	89.6	89.3	84.4	89.9	86.9	84.2	81.0	85.2	88.1	83.6	88.5
	In areas	96.8	95.7	96.8	96.7	96.7	96.5	91.3	96.7	96.0	94.7	92.6	95.0	96.2	92.6	96.1
Delta accuracy with regards to default values	In numbers	/	-6.4	-0.1	-0.7	-0.4	-0.7	-5.6	-0.1	-3.1	-5.8	-9.0	-4.8	-1.9	-6.4	-1.5
	In areas	/	-1.1	0.0	-0.1	-0.1	-0.3	-5.5	-0.1	-0.8	-2.1	-4.2	-1.8	-0.6	-4.2	-0.7

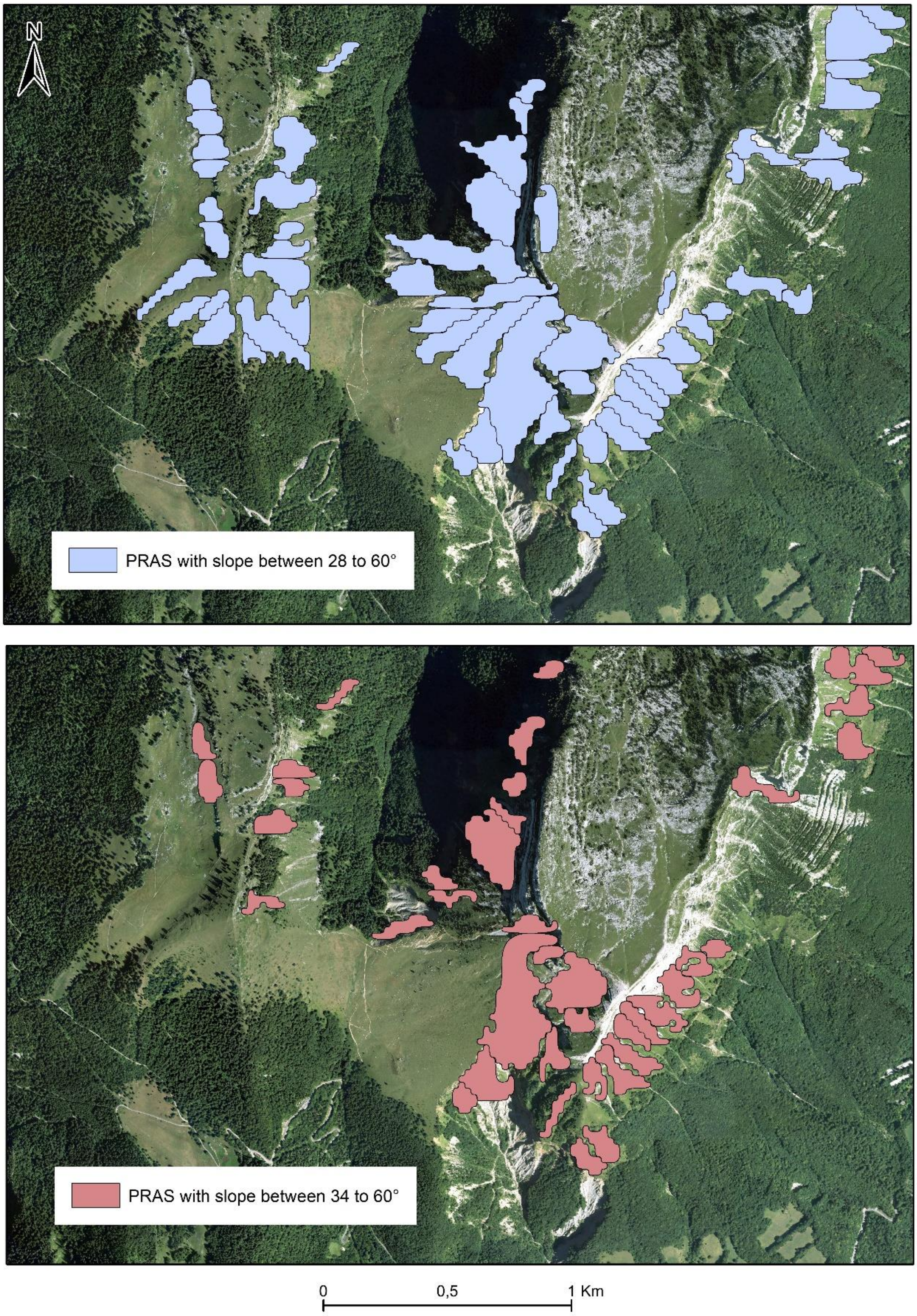
***Response Table 3**: Parametric study performed all over the Mont Blanc Massif. Total area of detected PRAs and total number of detected PRAs are those of the part of the massif covered by CLPA. The table expands information that was provided previously in Table 5 and 7 for the small Chamonix area only.*



***Response Figure 2**: Effect on PRA detection of the minimal area. Chartreuse/Dent de Crolles study area.*



***Response Figure 3**: Effect on PRA detection of the minimal elevation. Chartreuse/Dent de Crolles study area.*

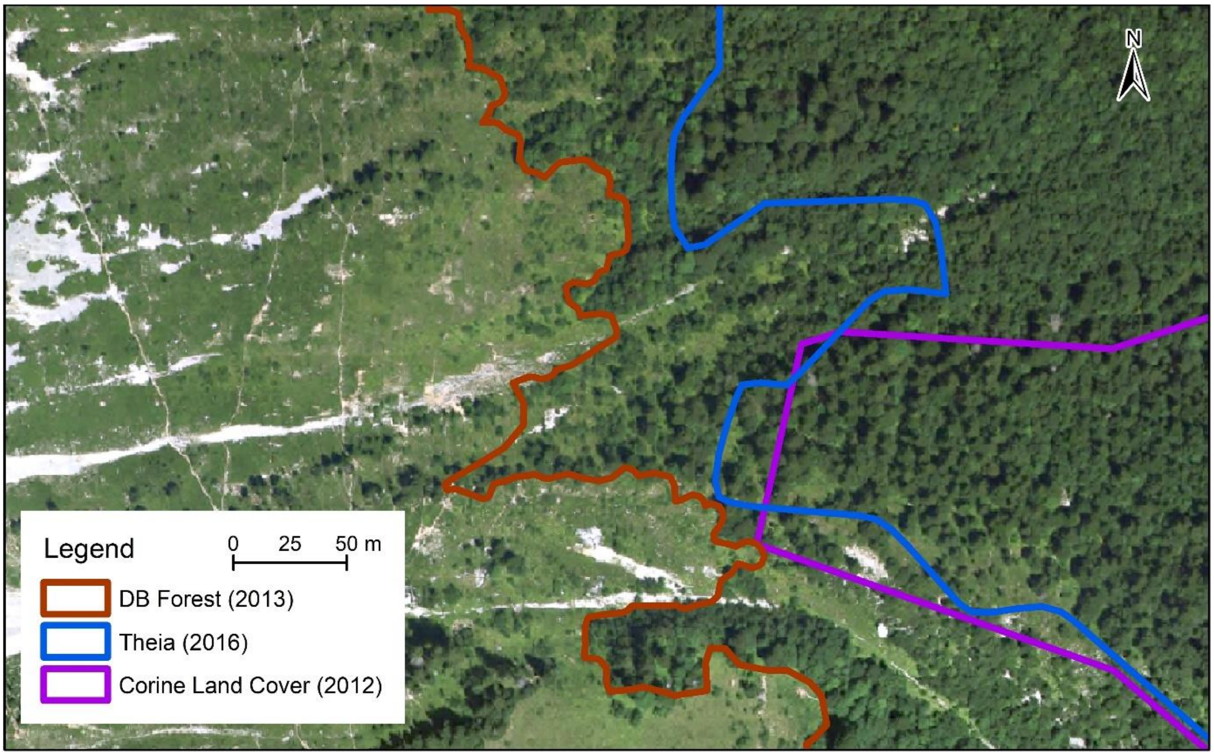


***Response Figure 4**: Effect on PRA detection of the slope range. Chartreuse/Dent de Crolles study area.*

Selection of datasets

Several datasets used in this study seem to be of lower data quality than established best practices in the field of PRA identification suggest. For example. the forest data set seems to have considerable limitations and the DEM is of much lower resolution than suggested in the literature. While I do not have a problem with a let's-do-the-best-we-can-with-what-we-have approach (not everybody has Swiss quality datasets available!). these choices need to be clearly explained and potential shortcomings evaluated and discussed.

Author's response: Regarding forest cover information, there are three main data sources available at the scale of the entire French Alps and we tested all three. None of them is perfect, and, certainly, Switzerland and other countries benefit from more precise systematic forest inventories. Detailed comparison with aerial photographs shows that, logically, main difficulty arises when the forest density is low, which makes the limit between forest and non-forest difficult to set (Response Figure 5). However, visual analyses in different configurations convinced us that at least the DB forest we eventually retained is clearly not that bad. And a systematic analysis over the three entire considered massifs showed that i it lead the highest accuracy both in numbers and areas with regard to the other available forest data sources (response Table 4). Yet, better forest data could lead to results that are even more reliable. Also, a less stringent PRA/NoPra rule as function of NoForest/Forest (e.g. a higher PRA susceptibility with decreasing forest density) would for sure be an interesting option for further developments. These points will be precised in the revised version of the paper.
See our next responses about the quality of CLPA and DEM resolution.



Response Figure 5:*Comparison of forest extensions from Theia, Corine land cover, and DB Forest from IGN with aerial photographs (©IGN) taken in 2012 within the municipality of Le Sappey-en-Chartreuse, Chartreuse / Dent de Crolles study area (updates Figure 2).*

Watershed delineation

While I appreciate the simplicity of the watershed delineation approach. delineating PRAs is not new. The OBIA approach described in Bühler et al. (2018) does the same thing in a more sophisticated way. In my opinion. Section 3.1.3 and Fig. 4 explain the calculation of the flow direction. but do not actually show how the watersheds are delineated. Since the authors' method uses standard tools available in open-source GIS software. it might be more useful for the reader to get a detailed description of how these calculations are done in freely available GIS software.

Author's response: The watershed algorithm we use is the one from ARCGIS that follows the references in text and the workflow of Figure 4. Following this suggestion we will detail the principle of the algorithm a bit more in text and move current Figure 4 to the supplements as is does not really belong to our results.
Also we agree that in essence the idea is similar to the OBIA approach of Bühler et al. (2018), even if we have to say that we were not able to fully understand its details from the paper (we tried hard!). We will add in the revised version of the paper that both approach follow more or less the same rationale.

Validation of PRA identification

I see several fundamental challenges in the current validation approach that. in my opinion. provides a very biased perspective on the performance of the PRA model.

1) The authors' choice to only evaluate the performance of the model within areas of documented avalanches means that they only test whether the PRA algorithm can identify start zones in known avalanche path (true positives). It does not provide any insight about the algorithms ability to ignore terrain where avalanche do not start outside of the known avalanche paths (true negatives). While the authors explain their approach when they introduce their modified confusion matrix (L290+). this does not seem to be very meaningful to me. As explained by the authors. avalanche cadaster datasets are not widely available and have limitations in many areas. The purpose of PRA models is to identify PRA in areas where direct observations are not available. In my opinion. a more meaningful approach would be to validate the model in areas with high confidence in the avalanche mapping record and include both avalanche terrain and non-avalanche terrain so that the complete confusion matrix can be properly evaluated. As can be seen in Fig. 3 and 7. there are considerable areas outside of the avalanche path areas that the algorithm incorrectly identifies as PRAs.

2) Applying the PRA model steps (e.g.. > 1400 m. slope incline between 28 and 60°. watershed delineation. etc.) to the CLPA dataset before conducting the validation completely defeats the purpose of a validation. Obviously. the model will perform well if the validation only includes terrain with the same characteristics. In the end. the authors only evaluate the steps in the PRA algorithm that are not included in the CLPA preprocessing (slope curvature?). This is a fundamental weakness of the paper.

3) The simplified confusion matrix and calculation of the accuracy and error rates derive directly from the authors' choice of only examining true positives and false positives. As pointed out above. I do not think this is meaningful. Simply assuming that the true negative is 100% is not meaningful and leads to inflated accuracy rates. It is also unclear to me why the authors use percentages in their confusion matrix calculations. Confusion matrices are general populated with counts. which is possible for evaluating both the identification of individual PRAs and the total area of PRAs.

4) Nowhere in the manuscript is explained how the author identify a match between a PRA identified by the algorithm and the validation dataset. Is 100% overlap required or do the authors use a different rule to distinguish true positives from false positives?

5) Only focusing on the accuracy rate is a very simple evaluation of performance. Furthermore. since the error rate is simply the complement to the accuracy rate. having the error rate in all the tables does not add any value. The use of this simple validation measure is very much at odds with the content of the paragraph on model evaluation in the introduction (L87+). where the authors seem to highlight the value of more advanced evaluation approaches. This seems a missed opportunity for contributing to the literature.

6) The repeated statement that the validation in this study is done over large areas of terrain (i.e.. entire massifs) is incorrect. The validation was conducted within documented avalanche paths within these massifs. which. as highlighted in Fig. 7. are generally very small areas.

Author's response: We fully agree that the validation is the crucial issue Even if, with the CLPA, we have a very valuable data support, it was for us the main source of questions and concern during the work. As said in our main comment, it is also the point on which, even if clearly we do not pretend to solve the problem, we may bring some methodological/generic outcomes/thoughts for the community. This is why we choose to focus on the validation at several points in the paper, and even in the title with the "ground truth" words. But we agree that our rationale was not clear enough and the review process helped us to formalize our thoughts as follows:

- Despite drawbacks inherent to any avalanche cadastre, the CLPA is an excellent source of information regarding past avalanches, possibly one of the finest worldwide (in terms of compromise between a very large extent and a high data quality over the area), due to its old history, its extremely regular update by devoted technicians, continuous financial support from the French ministry of the environment and because it includes various complementary sources of information (testimonies, landscape footprints, etc.). This makes it over the years closer and closer to the true maximal avalanche prone terrain. From that perspective, it is perfectly suited to evaluate a method that aims at automatically identify the maximal avalanche prone terrain as we aim at. Notably, as CLPA extension polygons are concatenations/unions of all observed avalanche extensions on a given avalanche path, CLPA is more likely to provide an accurate estimate of the entire "ground truth" than any observation of single avalanche events. See the CLPA extracts below that will be inserted in the paper as an additional supplementary figure (response Figure 1).
- Yet, visual results and scores must be interpreted with care due to the peculiarities of CLPA data. Within a given massif, some areas are covered by CLPA and some of them are not (response Table 2, response Figures 2, 7, 8 and 9). Accuracy scores are evaluated only over areas which are covered by CLPA, namely much larger areas in Mont Blanc and Maurienne Massifs than in Chartreuse massif (response Table 2). By contrast, in areas covered by CLPA, it is known that CLPA is very good on lower slopes and in forested terrain and more likely to miss avalanche prone terrain (and release areas) at high elevations, far from inhabitants and forests (response Figure 7). In such latter cases, "false positives" are likely to be often avalanche extents that are missing in CLPA.
- CLPA does not distinguish release areas from flow paths and runout zones, which implies that a pre-processing is required to isolate individual release areas within CLPA extensions that can be compared with our PRAs. Hence, for us, the issue is not that the CLPA validation data is not "ground truth" but that indeed the predicted PRAs and validation data are not independent (they are initially, but the pre-processing of the CLPA with the slope, forest, etc. filters introduces some dependency). However, let us say boldly that we are almost sure that obtaining a fully independent sample of "ground truth" PRA is simply not possible. Indeed, even "live", one never really observes a release area, but the full extension of an avalanche, and delineating the release area always involves some subjectivity (except, maybe, with high speed camera and films that can

be watched in slow motion to see the avalanche at its earliest stage…). Also, assuming one is able to observe a “true” release area, there is little chance that the entire PRA is observed. Consequently, the definition of any validation sample will always involve some partially subjective and more or less explicit choices, with possible use of some filters (slope, etc.) similar to those we use. Our choice was to do it and to say it explicitly in a transparent manner.

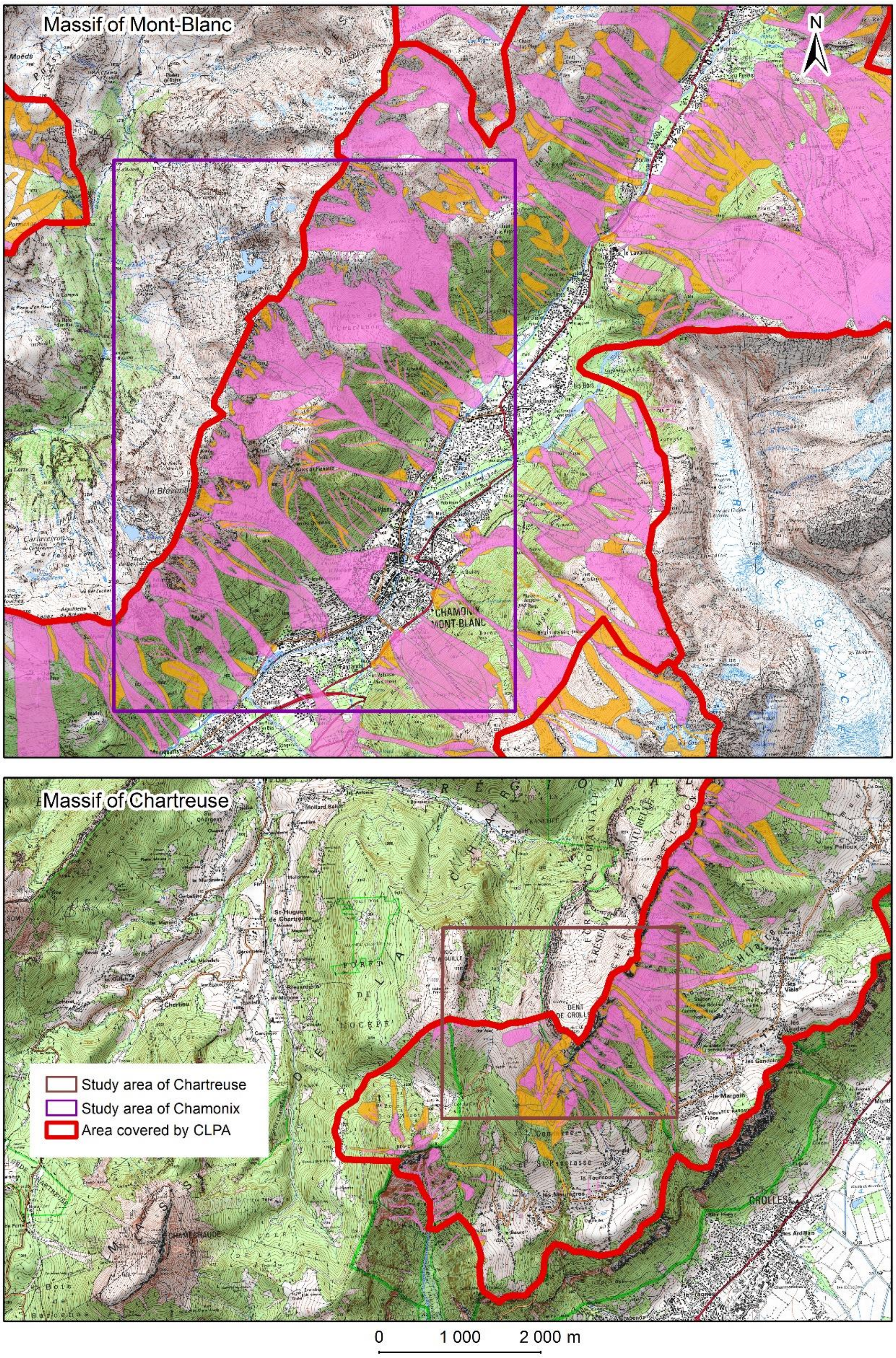
- Even with the best validation sample at hand, one will never be sure that i) all potential PRAs have been spotted, ii) the maximal potential extension that can be released under the most extreme conditions has been spotted for all PRAs (see our previous point about place where CLPA is good / less good). As a consequence, for us, only “true positives” can be trustfully validated, as it is never sure that a complete PRA or a part of a PRA automatically identified but not present in the validation sample is not simply missing from the validation sample. This is why we focus in our validation approach on accuracy scores/ true positives only.
- Accuracy scores (or other quantities related to confusion matrixes) were seldom used so far to evaluate PRA detection methods, to our knowledge, only in Bühler et al (2018) and with one single metric. Even if this is far from nothing, this is not much. Especially, we stress that one metric is not enough to judge the accuracy of a PRA detection method, as, e.g. the right number of PRAs can be identified but with wrong extents, and vice-versa. As a first step, we propose to evaluate accuracy scores both for PRA numbers and areas, which may cover the two most critical dimensions of the problem, but additional complementary metrics should probably be used as well in the future (focusing e.g. on the shape of PRAs, their elevation, etc.).
- Eventually let us state that focusing the PRA search and validation on terrain which are presumably favourable to avalanches is arguably not a bad idea. It is a rather standard approach in machine learning that is increasingly used in susceptibility mapping approaches outside the snow avalanche field in order to focus the detection on most suitable areas and thus increase the detection power. But we agree that this should be considered when interpreting the obtained scores.

In the reworked paper, we will reinforce these points in the discussion and justification of the research objectives and approach to highlight the limits and outcomes of our work on PRA validation for the community. Yet, we will remove “ground truth” from the title in order to avoid any misinterpretation. And we will even better explain the peculiarities of the CLPA data (we tried to do it already but we understand that this may be hard to understand from different countries with different ways of collecting, presenting and using avalanche data), and how they affect the results.

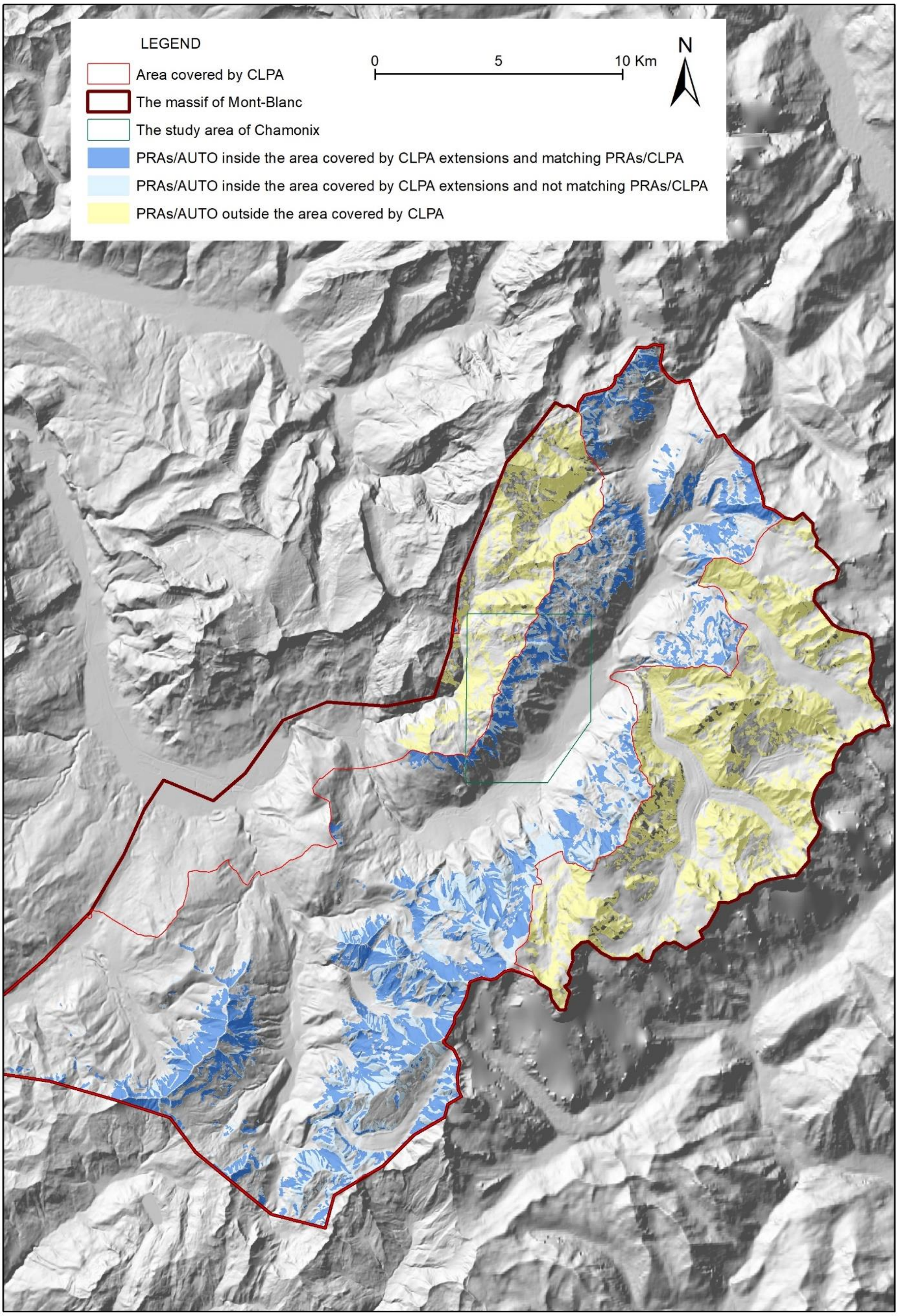
We will also remove unnecessary numbers in confusion matrixes and Tables, focusing only on accuracy scores on numbers and areas. These sum up all information related to true positives that we can decently evaluate (see response Tables).

We agree that how the matching between the detected PRA and the validation sample is done was not sufficiently clear. Detected PRAs and the validation sample are considered as polygons. In terms of numbers, a detected PRA and a validation polygon match as soon as their intersection is non-zero. The confusion matrix in area is computed by evaluating intersected areas. This will be added to the revised manuscript.

We will eventually further discuss the obtained scores and how they should be interpreted (see our response below about “sensitivity study”), with the support of the additional in-depth large scale parametric/sensitivity study that includes the effect of change on the validation sample.



Response Figure 6: *Extracts of the Official French avalanche cadastre "CLPA" (March 2022 edition). Magenta end orange polygons correspond to the extent of past avalanches from i) testimonies and documentary sources and ii) photo-interpretation of landscape footprints, respectively. Full legend at ;https://www.avalanches.fr/static/1public/epaclpa/CLPA_feuilles_carte/CLPA_legende_carte.pdf). Small study areas of Chamonix and Chartreuse/Dent de Crolles are located, as well as the limits of the areas covered by CLPA in both massif.*



Response Figure 7: *Result of the proposed PRA detection method (Fig. 5) for the entire Mont Blanc massif. Digital Elevation Model ©IGN.Updates Figure S2.*

Challenges in sensitivity analysis

As mentioned above. the sensitivity analysis does not seem sufficiently rigorous to provide meaningful insight. For example. the authors only compared the benefit of the 1400 m elevation threshold to not having an elevation threshold at all. Why not test other threshold values (1300 m. 1500 m. etc.)? The sensitivity analysis also only examines certain parameters and leaves out others without explanation. In my opinion. properly deriving the parameter selection and thresholds from the available data is a critical piece that needs to be included in this paper.

Given that the authors use a low-resolution DEM that is far below the quality recommended in the literature. it seems critical that this choice is justified with a proper sensitivity analysis. While the performance of the lower-resolution DEM will likely be lower. its use can still be justified based on a cost-benefit argument. but it will be important to have the comparison to better understand the consequences of this choice.

Some of the main results of the sensitivity analysis do not seem to match common sense. The fact that including slope incline increases the accuracy rate by less than 2% seems wrong as incline is one of the primary determining characteristics of avalanche terrain. In my understanding. this odd result is the direct consequence of only looking at terrain within documented avalanche paths and processing the validation dataset with PRA algorithm rules. which clearly highlights the limitations of the validation approach taken in this study.

Author's response: Let us first state that we do not really perform a sensitivity analysis, which would require a much more sophisticated approach that what we do. Such approaches have been introduced in the snow avalanche field only recently (e.g. Heredia et al., RESS 2021) and this remains probably to be done for the specific issue of PRA detection. So we prefer speak of a parametric study.

Regarding the different parameters / thresholds, we now provide systematic results all over the Mont Blanc Massif (response Tables 4 and 5). Table 4 is not a complete grid search, which is something numerically intensive and, to our opinion, not mandatory given our objectives and the ways our scores and results should be interpreted, see below. However, it is a systematic search moving each parameter one by one. Also, we expanded the results that were already in the paper by evaluating how accuracy scores evolve when applying the different steps/filters of the method successively, and with Theia and Corine land cover forest data instead of the IGN DB forest data. This could be done all over the Mont Blanc, Maurienne and Chartreuse Massif (response Table 4). We also investigated the effect of DEM resolution on i) scores (response Table 5) and ii) the visual aspect of detected PRAs (Response Figure 8). As already stated, results overall highlight i) decreasing accuracy rates as one leaves the default values determined from the literature and used for the identification of the validation sample, ii) rather stable accuracy. Yet, it can be noted that, when removed one by one, the watershed delineation step and the forest and minimal area filters appear as important, at least in terms of PRA numbers. Regarding the resolution issue, performing the PRA detection with higher resolution DEMs does not improve the results when the same validation sample is considered (i.e. determined with the 25 resolution DEM). Yet, more numerous PRAs of smaller areas are detected.

The effect of the DEM resolution was further studied by investigating how it affects the determination of the validation sample and the subsequent accuracy scores after the PRA detection (response Table 5, response Figure 9) highlighting again limited added value (and even a slight decrease in accuracy) with higher DEM accuracy.

Eventually we understand that our scores may appear as erroneously high. We want to remember that they concern the "true positives" only, and that we are fully aware that they are not independent of the way the validation set up is designed. As a consequence, they should not be directly compared with scores obtains with other approaches on other data sets. We simply consider them as probative enough to suggest that our approach performs rather well in the French context. Visual inspections on well-known areas confirmed that the PRA detection was indeed able to perform rather decently. In the same spirit, our parametric search should not be seen as a way to determine a truly optimal combination. We do not think we have the data that would allow this. Simply, we are able with it to determine a set of values, or different ranges of values, that perform rather well, and it is probably a good thing that the method is not too sensitive to very slight changes over reasonable ranges of most important parameters/thresholds.

These results will be inserted and more deeply analysed in the revised version of the paper. Also the discussion section will stress even more than in the current version how our scores and results should be interpreted.

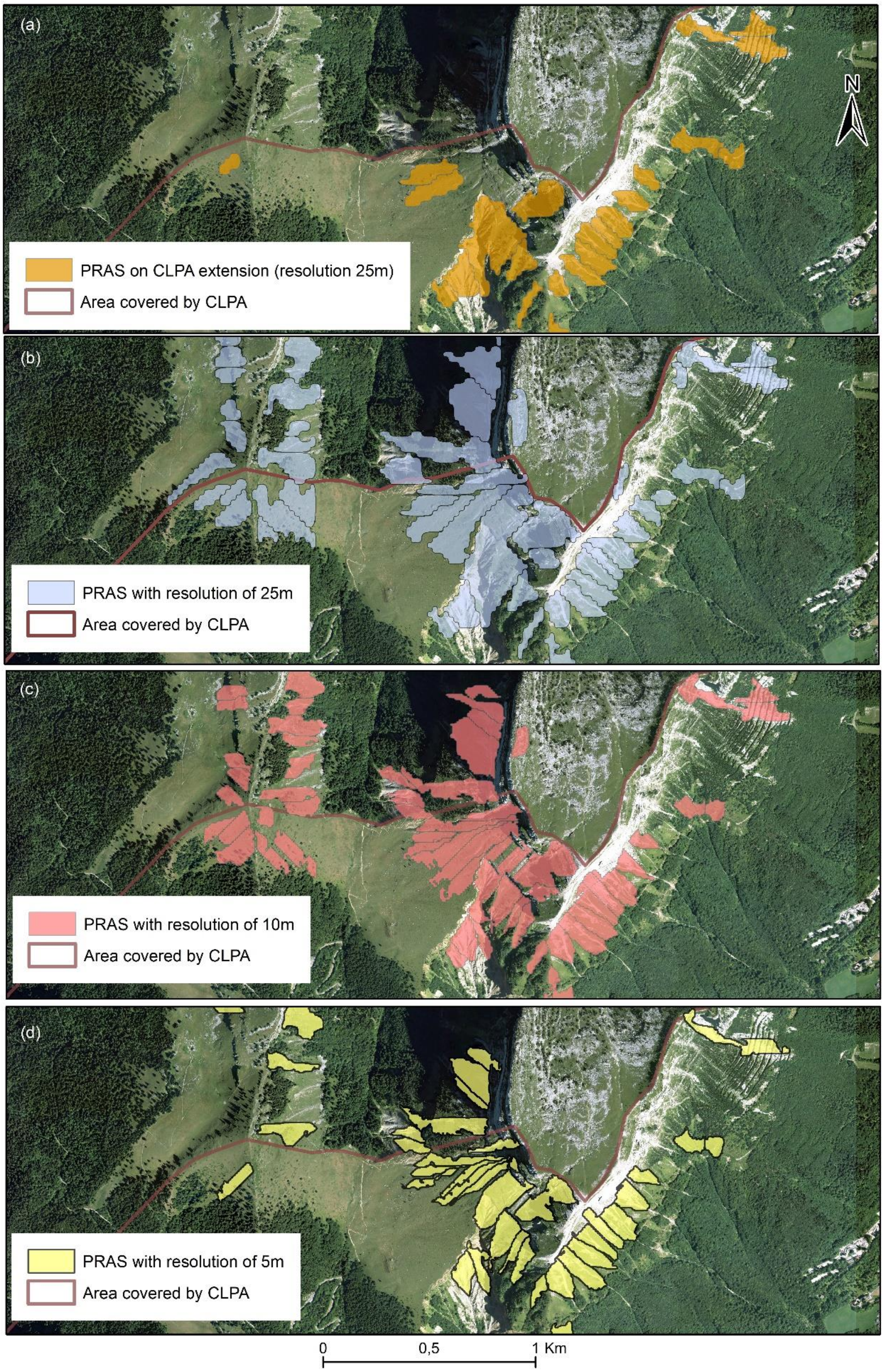
		With default values	Without Minimal elevation filter	Without slope filter	Without distance to ridge filter	Without minimal area filter	Without watershed delineation	Without forest filter	With Corine Land Cover forest	With Theia forest
Validation sample	Total area of PRAs within CLPA (validation sample)	58.3	58.3	58.3	58.3	58.3	58.3	58.3	58.3	58.3
Validation sample	Total number of PRAs within CLPA extensions (validation sample)	1522	1522	1522	1522	1522	1522	1522	1522	1522
Detected PRAs	Total area of detected PRAs	90.80	98.13	97.95	102.35	102.78	96.60	135.11	109.01	104.14
Detected PRAs	Delta area with regards to default values [km2]	/	7.33	7.15	11.55	11.98	5.80	44.31	18.21	13.34
Detected PRAs	Delta area with regards to default values (%)	/	8.1%	7.9%	12.7%	13.2%	6.4%	48.8%	20.1%	14.7%
Detected PRAs	Total number of detected PRAs	2003	2085	2074	2173	4315	262	2803	2170	2218
Detected PRAs	Delta numbers with regards to default values	/	82	71	170	2312	-1741	800	167	215
Detected PRAs	Delta numbers with regards to default values (%)	/	4.1%	3.5%	8.5%	115.4%	-86.9%	39.9%	8.3%	10.7%
Detected PRAs	Total area of detected PRAs within CLPA extensions	84.89	86.63	86.64	89.28	87.12	17.16	102.29	93.08	89.76
Detected PRAs	Total number of detected PRAs within CLPA extensions	1601	1622	1623	1626	2061	111	1597	1528	1607
Accuracy	Accuracy rate (Eq. 3) In numbers	90	88.9	89.1	87.4	73.9	71.1	78.5	83.3	85.9
Accuracy	Accuracy rate (Eq. 3) In areas	96.8	94.1	94.2	93.6	92.4	58.9	87.9	91.9	93

	Delta Accuracy with regards to default values	In numbers	/	-1.1	-0.9	-2.6	-16.1	-18.9	-11.5	-6.7	-4.1
		In areas	/	-2.7	-2.6	-3.2	-4.4	-37.9	-8.9	-4.9	-3.8

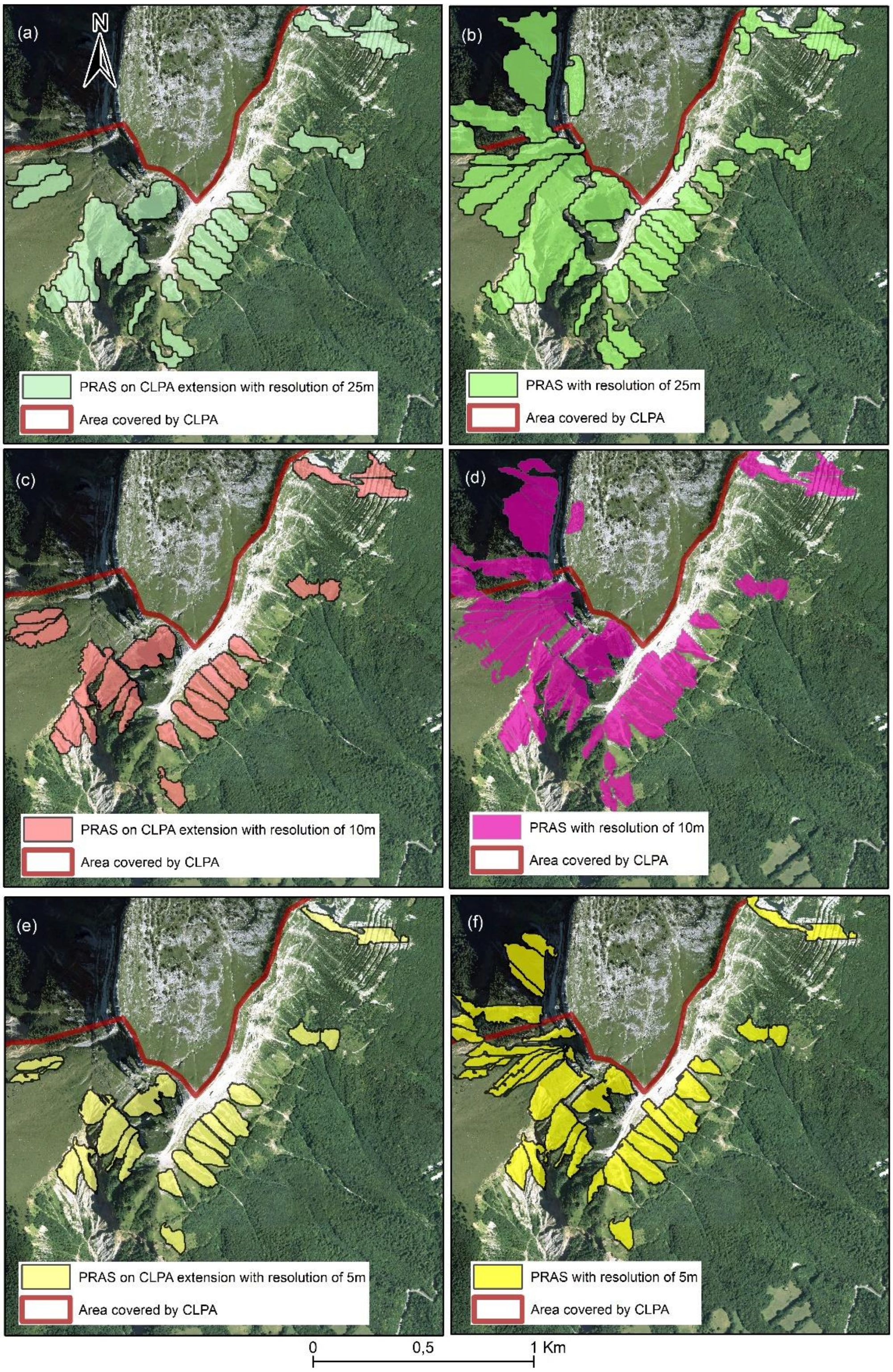
***Response Table 4**: Evolution of accuracy rates when applying the different steps/filters of the method successively, and with Theia and Corine land cover forest data instead of the IGN DB forest data **all over the Mont Blanc Massif**. Total area of detected PRAs and total number of detected PRAs are those of the part of the massif covered by CLPA. The table expands information that was provided previously in Table 4 and 6 for the small Chamonix area only. For the revised paper, similar Tables will be produced for the entire Maurienne and Chartreuse massif.*

			With default values	Resolution 10 m	Resolution 10m. adjusted validation sample	Resolution 5m	Resolution 5m. adjusted validation sample
Validation sample	Total area of PRAs within CLPA (validation sample)		58.3	58.3	53.5	58.3	45.9
	Delta area in validation sample with regards to default values		/	/	-4.8	/	-12.4
	Delta area in validation sample with regards to default values (%)		/	/	-8.3%	/	-21.2%
	Total number of PRAs within CLPA extensions (validation sample)		1522	1522	2061	1522	2181
	Delta numbers in validation sample with regards to default values		/	/	539	/	659
	Delta numbers in validation sample with regards to default values (%)		/	/	35.4%	/	43.3%
Detected PRAs	Total area of detected PRAs		90.8	84.0	88.9	71.8	71.7
	Delta area with regards to default values [km2]		/	-6.8	-1.9	-19.0	-19.1
	Delta area with regards to default values (%)		/	-7.5%	-2.0%	-20.9%	-21.0%
	Total Number of detected PRAs		2003	2989	3081	3131	3130
	Delta numbers with regards to default values		/	986	1078	1128	1127
	Delta numbers with regards to default values (%)		/	49.2%	53.8%	56.3%	56.3%
Accuracy	Total area of detected PRAs within CLPA extensions		84.9	76.8	76.6	66.8	64.1
	Total number of detected PRAs within CLPA extensions		1601	2420	2339	2694	2457
	Accuracy rates	In numbers	90	87.9	88	87	89.3
		In areas	96.8	95.1	93.1	94.9	94.7
	Delta Accuracy with regards to default values	In numbers	/	-2.1	-2	-3	-0.7
		In areas	/	-1.7	-3.7	-1.9	-2.1

***Response Table 5**: Evolution of accuracy rates with DEM resolution on PRA detection and selection of the validation sample for the entire Mont Blanc Massif.*



***Response Figure 8**: (b-d) Effect of DEM resolution on PRA detection. Chartreuse/Dent de Crolles study area. a) shows the validation sample obtained with the default setting. The absence of CLPA in the upper left corner is clearly visible.*



Response Figure 9: *Effect of DEM resolution on PRA detection (right) and selection of the validation sample (left). Chartreuse/Dent de Crolles study area. The absence of CLPA in the upper left corner is clearly visible.*

Comparison with other algorithms

In my opinion. comparing the algorithm introduced in this paper with some of the established methods would be very important for highlighting the value of the new approach. I think this should be included in this manuscript.

Author's response: We are sorry but this is where we simply cannot go at this stage. Doing so would imply having access to existing algorithms as open access codes/routines. which is currently not the case. Obviously, the principle of existing algorithm is published, but the description is not always very precise and easy to follow. And even when it is, following published guidelines/equations do not guarantee that what the different authors have done can be reproduced exactly, due toe, e.g.. differences introduced by different numerical implementation schemes. Therefore, the only comparison that can be done at this stage is the one regarding the choice of the different parameter values and/or steps of the approach. This was already done in the previous version of the paper but will be reinforced in the reworked discussion.
However, we really think that such an inter-comparison on different data sets (as results may be to some extent case-study dependent) would be beneficial for the community and we would be very happy to contribute. This is a reason why, as a first step, we provide the full data set corresponding to the paper in open access.

Limited discussion

In its current form. the discussion primarily repeats information from earlier sections of the manuscript (i.e.. introduction. methods and results) without adding much value. This is partially due to the fundamental limitations mentioned above. The tone of the discussion is also quite casual (e.g.. L529: "All in all. the validation data we use is certainly not perfect and our validation approach may potentially favour the comparison with our detected PRAs. …"). which does not seem appropriate for a scientific publication. See the technical comments section for additional comments. The outlook section does not seem to offer any novel ideas as it primarily discusses already existing application cases for PRA maps (e.g.. large scale mapping of avalanche hazard and risk) and existing research extensions (e.g.. PRAs conditional on snow and weather conditions. probabilistic detection rules).

Author's response: The whole discussion will be deeply reworked in the revised version of the paper to remove the unnecessary material, and, by contrast, to expand the discussion with respect to our answers to the different comments. See also our responses concerning the tone.

SECONDARY ISSUES

Set up of the research objective and expectations

To motivate their study. the authors provide a fairly comprehensive. even though not completely up-to-date. summary of the existing literature on PRA identification in the introduction. In this overview. they identify several limitations of the existing approaches (e.g.. disagreement about relevant terrain factors. delineation of individual PRAs. validation of PRA algorithms) to set the stage for their research objective on L103. This setup creates the expectation (explicitly or implicitly) that the algorithm introduced in this manuscript will address these issues. There are multiple issues with this. First. I do not agree with all the claims that are made in the introduction. The terrain parameters included in the various PRA algorithms do not differ from each other that much. Bühler et al. (2018) have presented an approach for meaningfully delineating PRAs. and the most cited algorithms have been validated with mapped avalanche datsets. Second. the paper does not deliver on these expectations due to the methodological issues mentioned above. This results in disappointment and sets the paper up for failure.

I think the manuscript would benefit from a more focused introduction that describes the research objective more honestly and positions the study within the existing literature more accurately. I have no problem with a study that aims to create a simple approach for PRA identification based on easily accessible datasets. but this objective should be clearly stated at the beginning of the paper to create meaningful expectations.

Author's response: We will rework the end of the introduction to better state the different research objectives of our work (see our previous answers, notably our first answer concerning the overall objective of the study). We will also delate the material unnecessary at this stage in the revised manuscript, but we think it is good for the reader to have a hint already at this stage of the paper of the workflow and the main outcomes with regards to these objectives.
Eventually, we fully agree that the approach and parameters we eventually retain is largely in accordance with the existing literature (except maybe for the resolution that we found less important than in other studies with regards to our chosen validation metrics and data), but we never intended to say something different. We will take extra-care in the revised manuscript to clarify this.

Language and tone

Overall. the quality of the English in this manuscript is not very high. and the text includes many terms that are not meaningful in this context (see partial list in technical comments). While the use of these terms might the result of a poor translation from French. it is important to check the manuscript for proper use of terminology before publication.

Furthermore. the tone of the writing is rather ambitious and glowing. Examples include "In this paper. a method that well identifies …" (L16 and L103). "… the CLPA is a very valuable source of information. … and. arguably. among the rare existing ones …" (L197). and "… the CLPA is almost surely a true avalanche extent." (L188). The further exasperates the reader's sense of unfulfilled expectations mentioned above.

Author's response: We agree that the English of the paper was largely improvable. In addition to changes in structures and of some sentences, the revised version of the paper will be proofread by a native English speaker.

Regarding the overall tone, we are really sorry if the referee has been exasperated by our limited skills in English, this was obviously really not our objective. We will try to improve with the help of the professional proofreader.

However, regarding the specific points mentioned by the referee, we accept that we said it badly or at least too casually, but we stick on the idea of the exceptional quality of the CLPA data (at least in terms of combination of a very large extent over which the data is of high quality). See our previous specific response about CLPA.

Figures and tables

The figures included in this paper are not of high quality. Several are hard to read (e.g.. Fig. 2). and the figure layout and formatting of the legends seem different in every figure. In my opinion. Fig. 5 and 6 do not add any value beyond what is already explained in the text. It is also unclear to me why the validation maps for the Mont-Blanc and Maurienne massifs are currently in the supplementary material and not included in the main manuscript.

Captions of tables are typically presented above tables. In all confusion matrix tables. the different components of the confusion matrix should be properly labelled.

Author's response: We produced high quality Figures for the first version of the paper already, and a loss of resolution simply occurred because the submission as a single pdf file was mandatory in the system (maybe we missed something). We are sorry but the resulting bad resolution of some of the Figures is not our fault. However, we worked hard to improve the quality of the figures even more in terms of Layout, resolution, scope, etc. Examples have been provided before and the new very high quality figures will be provided in the revision.
We also agree that the Figures corresponding to the Mont Blanc and Maurienne Massif should be moved to the paper core, the overall number of Figures is not that high.
And we will check the position and content of all Table labels.

TECHNICAL COMMENTS

Author's response: We again thank the referee for his/her careful reading of our paper. All edits will be corrected and all suggestions, when not specifically answered below, will also be fully integrated in the revised version of the manuscript.

Abstract

L10: 'lacunar' is not a meaningful word in this context.

L18: 'Confrontation' should be 'Comparison'.

Introduction

L30: Extremely convoluted sentence.

L64: 'Retained' should probably be 'included'.

L83: 'on the field' should probably be 'in reality'.

L98: I am not sure whether the existing PRA algorithms are 'competing'.

Author's response: Formulation will be amended.

L104: Should be '… where avalanches can occur'.

L108-120: This preview of the methods and results is not necessary in the introduction. It is best to finish the introduction with the statement of the research objective.

Author's response: We will rework the end of the introduction to even better state the different research objectives of our work (see our first answer). We will also delete the material unnecessary at this stage in the revised manuscript. However. we think it is good for the reader to have a hint already at this stage of the paper of the workflow and main outcomes with regards to these objectives.

Data

L134: ‘reputed’ should be ‘well known’.

L176: All abbreviation need to be properly introduced the first time they are used in the manuscript. There are additional abbreviations that have not been introduced.

L176: It should be ‘It consists of…’.

L179: I don’t not understand what is meant with ‘… is mainly produced at the destination of …’.

Author’s response: simply “the target audience is”. This will be corrected.

L192: ‘… near human stakes …’ should be ‘… near human assets or settlements.’

L225: ‘In order to …’ can be simplified to ‘To …’. There are several cases of this in the manuscript.

L241: The sentence that describes how the thresholds and parameters are chosen (reference to Sect 4.2) does not seem to belong here.

Author’s response: We will highlight in a specific place of the default value for the different thresholds and parameters have been fixed.

L245+: The description of the algorithm provided in this section does not seem consistent with the information presented in Fig. 5.

Author’s response: We will slightly rework the description to improve its clarity.

L261: The statement that PRA identification target primarily large avalanches needs to be stated much earlier in the manuscript as it is a fundamental assumption of the study.

Author’s response: It will be moved earlier in the paper (introduction).

L271+: The description of the CLPA seems repetitive as it discusses information that was mentioned previously already.

Author’s response: We will delete the unnecessary material.

L280: Typo: PRAS should be PRAs. There are several instances of this typo in the manuscript.

Results

L327+: The description of the confusion matrix provides exactly the same information that is shown in the table. Hence. it does not add any additional value.

Author's response: We will delete the unnecessary material.

L349: I do not know what you mean with 'probative'. There are several uses of this work in the manuscript.

Author's response: see our responses about validation and scores.

L350+: The explanation provided here seems rather speculative and not well grounded.

Author's response: We will ground our explanations on the characteristics of the massifs and of the CLPA in them.

L371: Not sure what you mean with 'parametric study'.

Author's response: see our responses about sensitivity analysis.

L380: In academic writing. the term 'significant' should only be used in the context of statistical significance. Use 'considerable' or substantial' instead.

L382: 'Use 'more substantially' instead of 'more largely'.

L406: The last sentence in this paragraph is too hand-wavy and not grounded in evidence.

Author's response: We will ground our conclusions on the results of the parametric studies.

L410: Table 6 does NOT show that not including the forest layer results in the worst performance. The accuracy rates without forest are higher than with the theia dataset.

Author's response: see Response Table 4 that confirm our results all over the Mont Blanc Massif.

L421: Delete 'eventually'.

L425: Use 'tower' instead of 'pylon'.

L435: Delete 'eventually'.

Discussion

L447+: There is no need to repeat the information from the intro at the beginning of the discussion section.

Author's response: The whole discussion will be deeply reworked in the revised version of the paper. Regarding this specific point, we will delete unnecessary repetitions, but we think it is important before starting the discussion to remember briefly the objectives of the work and what has been achieved.

L455+: I do not think these objectives have been achieved by this study.

Author's response: see our responses about paper objectives, validation and scores.

L469: I am not sure what is meant with 'probative'.

Author's response: see our responses about validation and scores.

L475+: This discussion primarily repeats information from the methods and results section without adding much value.

Author's response: The whole discussion will be deeply reworked in the revised version of the paper to remove the unnecessary material, and, by contrast expand the discussion with respect to our answers to the different comments. See also our responses concerning the tone.

L499: Reword this sentence. It should be '… by comparing X to the processes CLPA dataset.'.

L503+: This sentence seems like an excuse and is not very convincing. The readers' expectations should be managed by properly describing the research objective in the introduction.

Author's response: see our responses about paper objectives, validation, scores and comparison of existing algorithms.

L507: 'Envisaged' should be 'envisioned'.

L510: 'Confronted' is the wrong word here.

L529: Similar to the sentence on L503. this sounds like an excuse. Limitations should be discussed more seriously.

Author's response: see our responses about paper objectives, validation, scores and comparison of existing algorithms.