

## **Review of “Automated snow avalanche release area delineation in data sparse, remote, and forested regions” by Sykes et al.**

In this study, the authors use an existing potential avalanche release area (PRA) model and, with important modifications, apply it to forested avalanche terrain for a remote portion of the Columbia Mountains, British Columbia, Canada. They develop a relatively low-cost workflow using satellite imagery and a land cover dataset to generate high resolution DSMs that are used as the foundation of the PRA model along with a validation dataset derived from collaboration with experienced guides in the study area.

The manuscript is generally well written and organized. However, there are a few areas where clarification is necessary (see Specific Comments). The workflow and methods are sufficiently technical and sound and build off other well-established methods of DEM/DSM generation and PRA modelling. The interpretation is well supported by the data and results.

Overall, this work is very interesting and novel, shows promise for potential widespread application in other regions, and is a worthy contribution to avalanche mapping and risk management in remote or data sparse regions. The authors obviously understand the implications of avalanche terrain mapping and chose to bias an overestimation of PRAs, which is appropriate for this attempt at mapping PRAs in forested areas.

I recommend publication with minor revisions and ask the authors to address my questions/comments and consider the suggestions below.

### General Comments

As presented, the two major sources of error in the model are a function of uncertainty in forest characteristics and validation polygons. The authors provide a nice assessment of forest characteristics and uncertainty of validation polygons, but these are treated independently and separate. Is it possible to quantify the proportion of error due to each? I'm not necessarily suggesting additional analysis of this but think some comment based on available data might be useful and could help inform future work by suggesting potential directions to improve the model in forested terrain (e.g. should we focus on better validation data or input forest layer data?).

The validated polygons are a critical and interesting component of this study. The data are from a remote part of the Columbia Mountains and the authors are fortunate to have tenured guides provide input for this dataset. The authors suggest these tools could be used in other regions, but how can these tools be applied in other remote regions where operations are just getting started or expanding into new terrain but without the validation of long-term local knowledge or observations?

### Specific Comments

#### *Abstract*

Line 9: Can you briefly define high resolution by simply adding ( $\leq x$  meters)?

#### *Introduction*

Lines 64-71: Thank you for clearly and concisely laying out the objectives and contributions of this work for the reader.

## *Methods*

Sec. 3.2.2: How did you account for forest that may be classified as forest (e.g. “trees with rigid trunks” (line 420)) based on spectral signatures, but where the canopy height is small and subsequently buried by snowpack, or where the forest density (from Sec. 3.3.1) may change depending on snowpack height throughout the season or interannually? Would this (mis)classification contribute to the uncertainty in forest characteristics?

Lines 264, Sec. 3.3.1: Does the focal point function account for 5x5 cell neighborhood where the forested pixels are clustered mostly toward one quadrant of the 5x5? In other words, if 9 cells are forested in a 5x5, is it considered Sparse or are the non-forested cells already accounted for as PRAs from the original (non-forested) model? Please clarify in the manuscript.

Lines 285-294, Sec. 3.3.2: It was not immediately clear to me in this section how the forest slope scalar value was eventually selected, and I see that this is described in more detail in Sec. 3.4.2. Consider describing this earlier in the manuscript when you first introduce this parameter.

Line 309-311: These runs were familiar to the guides, but were they representative of the variable nature of the terrain/PRAs throughout the study area?

Line 314-316: It’s not clear to me what you mean by “consistent character?” Did they simply draw polygons around a sub-sample of similar terrain from the five selected runs? If so, how does this help with validation of variable terrain/PRAs throughout the entire study area if they are of “consistent character”? Please explain.

Line 320-321: What do you mean by “were minimized”?

Lines 322-326: These two sentences would be more helpful earlier in this paragraph to help the reader understand the collection/workflow before diving into how the confidence of PRAs and other terrain were incorporated.

Lines 346-352: Does this mean that *PRA error* for PRA proportions of 0% and 100% are 0? Please clarify.

Line 356-358: I’m a bit confused here. Were the polygons drawn by the guides not all contained within (or very adjacent to) the run polygons? Am I correct in assuming that the run polygons are all, by default, 0% (as per Figure 5)? This wasn’t immediately clear to me earlier on. I had assumed that the run polygons were simply meant as a physical boundary to constrain the areas the guides had to map until I looked more closely at Figure 5. Additionally, it’s also a bit confusing since 0% and 100% PRAs are considered areas with high confidence, yet here (line 357), you state that the run polygons have the greatest uncertainty despite them being categorized as 0%. Please clarify.

## *Results/Discussion*

Line 340: What are the samples sizes of validated polygons (n=167) for each category of release area proportions (e.g. 0, 25, 50, 75, 100%)?

Lines 417-422: See comment above re: classification of “trees with rigid trunks”. Would small height trees be classified as forest (not shrubs) and subsequently present as forested areas, when in fact they might eventually be buried mid-winter and affect the land type classification and ultimately the character/result of the PRA?

Line 562-563: Overestimation of PRA extent in all terrain (e.g. wind/sun affected alpine terrain) not conducive to SH development or do you mean forested terrain not conducive to SH development?

Lines 586-590: Are the forest descriptions here (e.g. “The forest is very dense”) characterizations by the guides or based on the forest layer you derived? I assume it is guides’ characterizations because you address canopy height which isn’t a part of the forest layer. Additionally, how well does the mapped forest layer align with guides’ characterization of forested terrain? Do you think forest density, independent of the forest slope scalar, has a greater influence than your results suggest?

Lines 612-619/Figure 13: Consider making Figure 13 a two-panel figure to show the distributions of forest density as well since you mention it here. This would also provide the reader with context of forest density. Also, can you elaborate on how forest density may or may not be more influential in estimating PRA than percent of forested area (or are they collinear)?

Lines 657-660: This is a very important point that highlights the importance of human use/mitigation and snowpack structure. While you mention the influence of snowpack structure on PRAs (vs. just more frequent release areas) in several places throughout the manuscript, consider emphasizing in the abstract and the conclusions that the model identifies PRAs for all potential release areas under a broad range of snowpack conditions rather than potentially frequent release areas.

### *Conclusions*

This section summarizes the work quite well and highlights the appropriate results and limitations.

### *Figures and Tables*

Figure 1: Please include an inset/overview map to provide context of where the study area is located in Canada.

Figure 4: Consider making the axis labels and tick mark labels larger.

Figure 7: Nice visualization of the comparison of different resolutions.

Figure 11: Can you show a square on the larger (zoomed out) map that designates the area of the zoomed inset map? Also, the purple is difficult to differentiate from the pink because of the green background forest layer. Consider using a higher contrast shading scheme, if possible.

Figure 13: In addition to making it a two-panel figure (see comment above), consider making the axis and tick mark labels larger.

Table 1: Please define “Optimized” in Table caption or somewhere in the manuscript body. I understand it as the 3 parameters were optimized and default values were used for the rest (lines 446-448), but then paragraph 360-366 implies that all parameters were optimized. Consider moving lines 446-448 into the Methods (~lines 360-366) for clarification.

### Technical Corrections

Lines 73-75: This is sort of implied in this section. Probably not necessary.

Line 449: add “.” after et al