The missing drifts: Widespread and systematic underestimation of heterogeneity in mountain snow density and SWE across scales

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Response to Reviewer Comment RC2

We appreciate the reviewer's engagement with our study, and we largely agree with the requested revisions. Our main takeaway from the reviewer's comments is that the text should be tightened and clarified where possible to improve the readability and more concisely report the key findings.

The manuscript addresses spatial variability in snow properties, particularly snow density, which has been relatively understudied in mountainous environments. Most existing measurements are conducted at lower elevations, where snow characteristics differ substantially; therefore, such observations are not representative of high-altitude conditions. At higher elevations, snow density is typically modeled, but these models often fail to capture highest densities.

This is a correct summary of the motivation for our summary. In fact, the reviewer's concise wording motivates us to further improve the language in our manuscript abstract and introduction to make sure that this key motivation (lack of representative snow density measurements) is easily apparent.

In situ observations from wind-drifted locations with several meters of snow accumulation in high mountains are very rare, mainly due to difficult access and the effort required for excavation and measurement of deep snowpacks. In this context, the study presents a unique dataset, including an exceptionally deep snow pit (5.9 m), which reveals very high snow density, as well as another 4 m deep pit with higher-than-average density compared to surrounding sites.

This is similarly a correct summary of one key component of our study's novelty. We also note that the vertical profiling within these snow pits is a further novel contribution, beyond just the bulk density of each location.

The study is further strengthened by the inclusion of a spatial snow depth survey using airborne lidar, allowing analysis at larger scales in addition to point-based measurements. The manuscript includes also comparisons with three other snow products. The model with 36 snow pits and lidar data demonstrates that other models without lidar data and SWE products underestimate SWE by approximately 2–17% at the watershed scale. Wind speed is simulated to identify wind-drift areas and incorporated into the analysis, showing that snow density is higher in these areas, which contributes to the underestimation of SWE at the watershed scale. Areas influenced by avalanches show particularly high densities, which is consistent with expectations. Overall, the watershed-scale comparisons with models and existing products are a valuable aspect of the study.

Again, we thank the reviewer for this concise summary of our basin-scale extension to the snow density and heterogeneity analysis.

The figures are generally clear and of good quality, effectively supporting the presented results.

Some additional comments and suggestions:

- It is unfortunate that only one very deep snow pit is presented. However, I acknowledge the difficulty of such measurements, and even a single profile is valuable. Since the deep pit was already excavated, it would be beneficial to include multiple detailed density profiles from this location.

We agree that multiple profiles from a single deep pit could be informative and help reduce uncertainty. Unfortunately, we had to prioritize a single profile given the limited time available in the field. We can add a sentence to the manuscript suggesting that parallel profiles may be worth considering for future investigators.

- It would be interesting to include a comparison with SWE tube measurements. Based on my experience, a soil plug is not always necessary when using a Federal sampler, as dense snow can remain in the tube without it. If future measurements are conducted, SWE tube sampling at snow pit sites could help confirm ground contact.

We agree that comparisons between SWE tube and snow pit density measurements are important. However, this topic has already been addressed quite extensively, e.g., (https://doi.org/10.1002/hyp.9317, https://doi.org/10.1007/s11629-023-8018-5, https://doi.org/10.3390/geosciences13070205, https://doi.org/10.1002/hyp.13785, https://doi.org/10.1029/2018WR024146). Throughout most of these studies, snow pits are used as the "gold standard" or validation metric against which other SWE or density estimates are compared. Thus, since we are primarily concerned with the natural variability of the snowpack, instead of the artificial variability across different instrument types, we prefer to rely solely on the snow pit approach.

Our current wording related to a soil plug is primarily applicable in shallow soft snow, and the reviewer is correct that dense snow would likely remain in the tube. However, the challenge then becomes driving the tube sufficiently deep into the hard, dense snow. For example, it would likely be impossible for unaided humans to drive a SWE coring tube through 6 m of very dense snow (including thick ice layers) in the deep nivation hollow, and even if this were possible, the amount of force required (from a sledge hammer or post driver?) would likely damage the tube.

We will extend our discussion of the snow pit vs. SWE tube section in the manuscript methods to clarify these points.

- The text is very long could be shortened for better focus

We agree, and we will work towards tightening the text and clarifying the key points throughout.

- Figure 1 would benefit from a scale bar

This map figure already effectively has a scale bar since it has 1 km tick marks around the edges, and we will clarify this in the figure caption.

- Please clarify whether the density cutter was used vertically or horizontally. Also, how many profiles were measured?

The density cutter is used vertically, so that a representative section of the vertical layering structure is obtained. (If the cutter were horizontal, we would under-sample the upper half and over-sample the lower half of each 10 cm interval due to the triangular geometry.) A total of 36 profiles were measured during this campaign (1 per snow pit).

- The accuracy and type of scale used for density measurements should be reported.

Agreed—we will add this.

- The opening of the Results section contains material that could be moved to the Introduction.

We agree that the arrangement of this information can be flexible, and we will move the background text on the Wind River Range snowpack evolution into the Introduction.

- Line 501: revise "Consequentially, we there" by removing "we"

Thanks for catching this typo—will be fixed.