The missing drifts: Snow density heterogeneity from wind-packing exacerbates systematic underestimation of deep snow storage from the scale of nivation hollows to mountain ranges

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Response to Reviewers

We thank the reviewers and editors for their continued engagement with this study. We have made the technical correction. Additionally, we are generally willing to accommodate the second reviewer's points of disagreement, as follows.

Response to Reviewer Comments

I appreciate the listing of all the novel aspect of the study in the reply and recommend mentioning at least some of the points of this list in Conclusions.

We have added several of the points directly addressing novelty to the Conclusions, as follows:

"Although the challenge of capturing snowpack heterogeneity is widely recognized, the impacts of bulk density on spatial SWE are relatively unexplored due to a lack of representative data. In this study, we perform the first quantitative statistical tests of spatial SWE sensitivity to wind-packing drift effects (Sect. 3.5), develop new bulk density regression relationships with forest cover, elevation, and other variables (Sect. 3.4), and evaluate a new representativeness metric to explore why in-situ datasets (and SWE regressions based on in-situ measurements) fail to capture alpine snow drifts (Sect. 4.3). Our results show that drift-related snow density variations provide a salient control on watershed SWE distributions despite the first-order importance of drift-related snow depth variations (Fig. 11). Since in-situ monitoring sites (SNOTEL) are exclusively in forested areas, extrapolation from these in-situ measurements systematically fails to capture the spatial distribution of the WRR snowpack (Figs. 11-12)."

L 951: "by as much as 24% (Sect. 3.4)" – should be Sect. 3.5'

Fixed.

1) Meromy et al. 2012 is irrelevant for the study as you also deal in the scale of sub-grid variability since you use lidar data with 3 m resolution.

Good point—we understand how our high-resolution lidar data could be seen as "sub-grid" relative to kilometer-scale grids, even though the lidar data themselves define a (different) grid scale. We have added this citation with the following statement:

"Similar representativeness problems occur widely when comparing small-scale measurements (i.e., in-situ or lidar-derived) to kilometer-scale grids (Meromy et al. 2013)." (Sect. 4.3)

2) doi.org/10.1016/J.coldregions.2025.104435 “has minimal relevance” (reply to original comment to L291) as it contains a modern HS2SWE-model. In fact, you might rather cite this study instead of doi.org/10.5194/hess-25-1165-2021 as it is newer and contains the reference to the former study.

We have added this additional citation with a further explanation in Sect. 4.1:

“In another example, a recent intermediate-complexity layer-wise snow density model (H2SWE) also does not consider wind-packing, instead parameterizing exclusively the effects of metamorphism and deformation (Winkler et al. 2021), and this class of model is predominantly applied in wind-sheltered areas (Magnusson et al. 2025).”

3) the possible occurrence of permafrost should not be mentioned because it is purely speculative (reply to original comment to L562). It is just a possible explanation for the cold temperatures near the ground, which have already been observed below long-lasting snow avalanche deposits.

We have gone ahead and added a statement to this effect with citations to prior literature on snow-related permafrost:

“It is possible that the colder temperatures near the ground (Fig. 6) could be related to permafrost, which can be associated with patterns of snowpack redistribution in alpine environments (Luetschg et al. 2004, Kenner et al. 2017).” (Sect. 3.3)

4) a density measurement with SWE tubes through 6m of dense snow is impossible (reply to original comment of RC2). See “Determination of snow density” in “A Best Practice Guide for Long-term Glacier Monitoring in Switzerland” (https://doi.glamos.ch/pubs/intrep/intrep_5.pdf)

It is not the 6 m depth that is the primary challenge in the deep drift context; rather, it is the high density and thick ice layers combined with the depth. Nevertheless, of course it may be possible with enough effort. We note that nothing in the manuscript implies that it would be impossible, merely “not conducive.” We would be enthusiastic to see density data from future drift surveys using SWE coring tubes if anyone decides to test this method in a comparable environment.