Editor Comment

Dear authors,
the paper was again reviewed by 2 reviewers - both are in general happy with the new version of the manuscript. However, a couple of comments by reviewer #1 need to be considered before I can consider the manuscript to be published in HESS. Please make sure that you carefully address these points and provide a new version with changes marked so I can easily see what you did and make a decision based on your revised version.
Best regards
Markus Weiler

We sincerely thank you for your continued evaluation of our revised manuscript. We appreciate the opportunity to further improve our work and believe the manuscript has benefited significantly from this round of feedback. Below, we provide detailed responses to each of the remaining points, with changes clearly marked in the revised manuscript.

Reviewer #1

General Feedback:

Overall, the authors have carefully revised the manuscript, incorporating the feedback from the reviewers, which is greatly appreciated. The result is an improved manuscript that, along with the dataset and results, will make a valuable contribution. However, I have a few comments that I would like to see addressed before final approval:

Thank you again for your constructive feedback with specific comments on our manuscript. We have carefully revised our manuscript based on each of your comments.

Major Comments

The co-registration of your SfM and LiDAR products is still unclear. In your answer, you say that you used Ground Control Points to do so:

"All of the surveys were co-registered using ground control points(..). Linear, horizontal, and vertical shifts were applied to align all digital elevation models to these GCPs."

In the text you say that:

"GCPs surveyed using the base/rover equipment were used to co-register the UAS data. Linear, horizontal, and vertical shifts were applied to align all SfM and lidar DEMs to the GCPs."

I would be interested in what GCPs were used? If only optical GCPs were used, how were they identified in the LiDAR point clouds? What were the magnitudes of applied shifts for sfm vs lidar? I think this could be another advantage of LiDAR sensors that could be discussed with your data: Were the GCPs really needed for the LiDAR data? What is the benefit of the additional effort?

Response:
Thank you for this important clarification request. Conventional optical GCPs were surveyed-in using ground based GNSS RTK equipment prior to each successive UAS lidar and optical flight. UAS lidar trajectories and ground based GNSS positions were corrected using the same GNSS base station. Because of system limitations with our optical UAS, a separate base station had to be used to apply RTK corrections to the UAS imagery geotags. A constant linear shift was therefore apparent when comparing the GCP positions in the optical orthomosaics to the measured positions, as the base station used to correct the UAS imagery geotags was not surveyed-in to a high degree of accuracy. A total linear shift of ~2.5m was generally required to ensure that the photogrammetry products aligned with Lidar products.

Although UAS lidar data often require fewer GCPs due to higher onboard geolocation accuracy, we chose to use the same set of GCPs across both systems to maintain consistency and ensure the comparability of SfM and lidar products. This additional effort provided a common geospatial reference for both datasets and improved the reliability of relative difference analyses between sensor types.

Minor Comments

L16: Add a sentence on why a better understanding is needed for your specific environment.

Response: We added a sentence to the introduction to clarify the relevance of our study environment:
"This is particularly critical in mixed vegetation environments like ours, where both forest canopy and open areas influence snow accumulation and melt patterns."

L23: Avoid saying 0 cm.

To avoid that, we revised the sentence as below.
"Snow depth maps from SfM and lidar were fairly consistent in the field, with only marginal differences on most dates."

L24: Remove "also"

"Also" has been removed.

L39: Add examples to static and dynamic fluxes/variables

Response: We now state:
"The spatial variability of a snowpack is a function of static (e.g., slope, aspect, vegetation type, soil properties) and dynamic variables (e.g., solar radiation, wind direction and speed, temperature) and fluxes over a range of spatial scales"

L47: Numerous… various.. This sentence needs to be revised.

Response: Rephrased for clarity and conciseness.

"Previous studies have proposed diverse approaches to characterize snow distribution patterns and their temporal evolution across a range of climatic and topographic settings."

L78: This reasoning is not very convincing. "Growing need for understanding of UAS sensor's strengths and weaknesses". I would agree, but I don't see the link to the next sentence: "However, it is challenging to measure shallow snowpacks". As this is the key motivation of this work, I suggest rephrasing. Suggestion: 1) Need for new, multi-temporal data sets. 2) This is specifically the case for transition periods and shallow snowpacks (consider citing https://doi.org/10.1016/j.earscirev.2024.104751) 3) Various sensors exists with strengths and weaknesses that need to be investigated for your specific hardware and environment.

Response: Thank you for your suggestion. We revised this paragraph using your suggested structure and cited the recommended paper (López-Moreno et al., 2024):
"There is a growing need for new, multi-temporal snow datasets, especially during transition periods such as shallow and patchy snow conditions. These periods pose measurement challenges but are key for understanding snowpack dynamics (López-Moreno et al., 2024). Different UAS-based sensors offer complementary strengths and weaknesses that warrant further investigation in various environments."

L91: are discussed in Sections 4.3 and 4.4…. this should be your result section!

Response: To clearly say, the sentence has been revised as below.

"Sections 4.3 and 4.4 further examine the spatial patterns and temporal dynamics of snow depth, along with the physical variables influencing these patterns."

L110: Great! I missed that in your introduction/motivation. Maybe add a sentence on: https://doi.org/10.1016/j.earscirev.2024.104751

Response: Added a sentence here.

"López-Moreno et al. (2024) also emphasized the importance of studying these transient snow conditions, highlighting their sensitivity to climate variability and their implications for hydrological and ecological processes."

L270: (Figure 3) Section 4.3: I found it confusing to see Figure 6 ("Mean relative difference" – exploring the snow distribution) right after Figure 5 ("lidar and sfm difference"- exploring the system differences). It was not directly clear what difference you are talking about in this section. Maybe you could use more easy to follow acronyms or write one additional introduction sentence in this section.

Response: We have added an introductory sentence to Section 4.3 to provide clearer context for the subsequent analysis of MRD patterns.

"Understanding and quantifying the spatio-temporal variability—or stability—of snowpack is essential for identifying the physical drivers that influence snow accumulation and ablation across heterogeneous landscapes. To explore these dynamics in detail, MRD values were mapped to reveal spatial patterns in snow depth across survey dates (Figure 6)."

L335: Not easy to follow. I can see in Figure 5 that relative difference maps are similar during accumulation period. During ablation (March?), I can see more white areas, but not the "consistent spatial patterns" that you are talking about. Maybe add some numbers/letters to guide the reader to the individual features you are talking about/comparing? Are the white areas with no snow? Please add to the caption/legend what white areas are.

Response: To aid reader interpretation, we included more detailed descriptions referencing specific regions (e.g., northern/eastern field and forest areas). Additionally, figure captions now clarify that white areas represent locations with no snow cover (i.e., bare ground).

During the ablation period, consistent spatial patterns of the relative difference were still observed, particularly in the northern/eastern field where snow remained relatively deep, in contrast to the forest areas which continued to show shallow snow or exposed ground. These patterns persisted despite the increased presence of patchy snow cover in some regions.

Caption: Figure 7 Relative difference maps generated from the UAS lidar-based snow depth maps from February 4th to March 7th. The white areas in the figures indicate either masked areas (e.g., ponds and facilities) or areas with no snow.

L398ff: Are these your values or the literature values? I suggest providing your RMSE values and the ranges suggested by the literature.

Response: Thank you for the suggestion. We have clarified that the reported values include both our observed RMSD results and the ranges from previous literature.

SfM-derived error values from our study were 4.0 cm MAD and 6.8 cm RMSD for the field, and 31 cm MAD and 71 cm RMSD for forested areas, highlighting a clear vegetation-dependent variation in accuracy. These findings are consistent with previous studies comparing UAS SfM and snow probe measurements, which report RMSD values typically below 31 cm in sparsely vegetated or alpine environments, increasing up to 37 cm in areas with denser vegetation such as bushes, tall grass, or forests (De Michele et al., 2016; Bühler et al., 2016; Avanzi et al., 2018; Belmonte et al., 2021).

L432: Similar to comment above, I would recommend to be more precise: "By comparing maps of snow depth change…" You compared MRD not maps of snow depth change, right? Shouldn't this paragraph be included into the next section?

Response: Thank you for the clarification. We revised the sentence to accurately reflect the analysis performed. The updated sentence now reads:
"By comparing maps of mean relative difference (MRD) with maps of physical variables at the site, specific factors influencing snowpack dynamics over the winter season were identified."

The paragraph was combined to the following section for better alignment.

"With limited wind redistribution in the study area, the time stability analysis indicated that relative differences in the snowpack were generally consistent throughout both the accumulation and ablation periods.In addition to the previous findings that snowpack patterns are relatively consistent from year to year (Pflug and Lundquist, 2020; Revuelto et al., 2014), this study demonstrates that fixed physical variables such as vegetation, topography, and soil characteristics can sufficiently control the spatial variations of snowpack throughout a winter period. By comparing maps of mean relative difference (MRD) with maps of physical variables at the site, specific factors influencing snowpack dynamics over the winter season were identified. Our findings highlighted that vegetation type is a dominant factor shaping snow depth patterns. In both combined and field-only areas, SOM showed a statistically significant relationship, with snow depth decreasing as SOM increased. Furthermore, shadow hours and slope were found to contribute to the spatial variability of snowpack, even though the study area features relatively gentle slopes. The findings regarding the influence of vegetation and topographical factors on the snowpack's spatial variability align with previous studies conducted (Currier and Lundquist, 2018; Deems et al., 2006; Trujillo et al., 2007)."

L440: This first sentence could be rephrased.

Response: Sentence has been revised for clarity and flow.

"With limited wind redistribution in the study area, the time stability analysis indicated that relative differences in the snowpack were generally consistent throughout both the accumulation and ablation periods."

Figure S2: Legend and scale bar are missing

Response: We have updated Figure S2 in the Supplementary Material to include both a legend and scale bar.