Ensemble-based data assimilation improves hyperresolution snowpack simulations in forests.

This exploratory manuscript addresses an important problem in snow hydrology, using ensemble-based data assimilation to improve snowpack simulations in forests. The work is technically rigorous; however, it would benefit from streamlining, particularly the Introduction, detailed methods, and the interpretation in Results/Discussion. My specific comments follow.

General Comments:

The introduction is comprehensive, but it is too long and repetitive, particularly in describing snowpack importance, canopy effects, observation challenges, and data assimilation (DA). Several paragraphs could be merged or trimmed without losing key context. Below are suggested line-numbered edits.

1. **Comment on Section 2.2:** This section is technically detailed and demonstrates careful implementation of the MuSA framework. However, it is very dense and at times reads more like a technical manual than part of a research article. For example, lines 272–322 (DES-MDA algorithm) provide a step-by-step explanation that is overly detailed for the main text; a shorter summary with reference to Alonso-González et al. (2022, 2023) would suffice. The description of MuSA v2.2 modifications (lines 392–426) is useful but reads like release notes, condensed to emphasize only the improvements directly relevant to this study or move it to supplement.

2. The authors should provide more detail on FSM2 parameterization under canopy (e.g., snow interception, sublimation, and radiation partitioning). Was the snow–canopy energy balance scheme modified from Essery et al. (2024)? Without this, it's difficult to judge whether the ensemble spread fully represents canopy–snow uncertainties.

3. Comment on Sections 3 and 4:
The results section clearly reports validation metrics, but it is heavy on numbers with limited interpretation. The discussion of Euclidean vs. Mahalanobis distance could be strengthened by explicitly linking improvements to spatial pattern representation. The evaluation also relies mainly on the posterior mean, which should be stated earlier, as it limits the interpretation of uncertainty-aware metrics (e.g., CRPS).

The discussion provides a thoughtful interpretation of the findings, but is dense and occasionally reads more like Methods. Details on computational cost and jitter regularization could be shortened or moved to a supplement. The PCA vs. Mahalanobis comparison is valuable but somewhat speculative; supporting diagnostics would add rigor. The key contribution that ensemble DA can propagate clearing observations under the canopy should be highlighted more prominently, with reduced repetition. Finally, the broader implications for operational snow monitoring and multi-source assimilation could be emphasized to connect more directly with the study's goal of improving under-canopy SWE estimates.

Line to Line Comments:

Lines 54–83: This section is informative but could be reduced by ~30–40% without losing clarity. The canopy–snow processes (lines 54–70) are somewhat repetitive; for instance, lines 60–66 (interception/unloading) and 67–70 (radiation effects) can be merged into a single concise description of the main mechanisms. Similarly, the discussion of monitoring challenges (lines 71–83) repeats the same idea across multiple sentences, lines 71–77 (direct observation challenges and harsh conditions) and lines 78–83 (lack of representativity, SWE vs. snow depth difficulty) could be combined into one tighter paragraph. Condensing these will improve readability.

Lines 84–106:
This section gives a thorough overview of remote sensing advances, but could be shortened by ~25–30% to avoid redundancy. Lines 84–90 (general remote sensing role and snow depth retrievals) and lines 91–94 (limitations in open terrain/temporal coverage) could be merged into one streamlined paragraph introducing both the capabilities and constraints of current methods. Similarly, lines 95–97 (SAR potential) and 98–99 (limitations in dense forests) can be combined into one sentence to avoid repeating "unfortunately." Finally, lines 100–106 (lidar under canopy) contain overlapping ideas: lines 100–103 (lidar partial penetration and validation) and 104–106 (refinements and future promise) could be merged into a single concluding paragraph on lidar as a partial solution.

Lines 107–134: This section is informative and relevant, but can use some massaging for improved readability. Lines 107–116 (model complexity and parameter uncertainty) and 117–125 (forcing and downscaling challenges) could be merged into a single concise discussion, while lines 126–134 (simplified downscaling and uncertainty propagation) could be shortened to avoid repeating the theme of uncertainty. I also recommend citing Raleigh et al. (2015) to emphasize how uncertainties from meteorological data propagate into snowpack simulations.

135-136: Good sentence!

137-138: Check for the font size and type.

Lines 146–201: This section is clear and well structured, but a few points could be tightened. The discussion of canopy-related observation challenges (lines 146–152 and 193–197) and DA limitations in forests (176–183 and 193–197) partly repeats the same idea and could be merged.

2017-2018: Details on how you improved the method would help readers.

218-220: Use correct citation format "Based on nearby SNOTEL at a similar elevation (SNOTEL Site: 539, Independence Camp, https://wcc.sc.egov.usda.gov/nwcc/site? sitenum=539, last accessed: 11-Nov-2024)"

Figure 1: Use (a),(b) … and improve the figure description for clarity.

255: Mention the section number instead of saying aforementioned

270-271: remove thanks to instead say something “due to model physics”

275: Mention the downscaled resolution of forcing (if they were forced after downscaling)

Figure 2: Adjust legend (place it outside of main figure for clarity).