Reply to reviewer #2

We thank the reviewer for their time and constructive comments on the manuscript. We take all the comments and suggestions into account. Our replies are written in italic font.

General comment:

The Results section is somewhat confusing and its structure should be revised. I suggest first discussing the temporal evolution of the bias and then its spatial heterogeneity. Then I suggest comparing the original and updated versions of the GlobSnow V3.0 and finally compare with the SCv3.1 bias field. Perhaps, it would also be helpful to present a table in the Methods section with the different products you are comparing.

We agree that the Results section was a bit cumbersome. In our current structure, we first analyze the effects of updating the snow course data applied to GSv3.0, then the effects of changes in the retrieval algorithm (GSv3.0 vs SCv3.1), and finally we validate and evaluate the new daily bias-corrected SCv3.1 product. To make it easier for readers to follow this structure, we have added an explanation in Methods Section 2.6 and renamed one subsection in the Results section. We have also included a table in Section 2.6 listing the different products compared in the study, which we hope will clarify the differences between them.

Specific comments:

1. l. 34-35 Could you rephrase this sentence for clarity?

   Revised for clarity as follows: "The latter wavelength is similar in size to the snow grains, which induces significant volume scattering and attenuates the signal (Chang et al., 1987; Kelly et al., 2003; Mätzler, 1994)."

2. l. 38 It would be good to give explicit examples of "other SWE products".

   Following examples added:

   " the NASA Global Land Data Assimilation System version 2 – GLDAS-2; the European Centre for Medium-Range Weather Forecasts (ECMWF) interim land surface reanalysis – ERA-Interim/Land and ECMWF Reanalysis version 5 – ERA5 and the Crocus snow model driven by ERA-Interim meteorology"

3. l. 44-45 This may be trivial, but I think some readers would appreciate a sentence or two explaining the physics behind this method limitation.

   Following explanation added to text:
   "This occurs because, at higher frequencies (~37 GHz), snowpack transitions from a scattering medium to an emitter when SWE exceeds ~150 mm, reducing sensitivity to further SWE increases."

4. l. 52 Can you briefly explain why only the March SWE time series has been thoroughly evaluated by this method?

   March is commonly evaluated due to peak snow mass and data availability, as noted in Pulliainen et al. (2020) and Luojus et al. (2021). This rationale is now explicitly stated.

5. l. 68-92. This should be included in a new subsection of its own.

   Created new subsection titled "2.1 SWE retrieval".

6. l.70 Can you expand on the source of the snow depth measurements.

   Sources specified and text edited as follows:
   "SD measurements are collected from multiple sources. The main sources for Eurasia are the European Centre for Medium-Range Weather Forecasts (ECMWF) and the All-Russia Research Institute of Hydrometeorological Information - World Data Cente (RIHMI-WDC) (Bulygina and Razuvaev, 2012). Global Historical Climatology Network daily (GHCNd) (Menne et al., 2012) by National Oceanic and Atmospheric Administration (NOAA) is used as the main dataset for North America."

7. l. 83. Can you explain why the average of the 6 closest snow depth measurements is calculated and what effect this would have on the variance if the measurement points were sparsely distributed?

   The average of the 6 closest stations is calculated to smooth the results. Using single values creates a "bull's eye effect". Sparsely distributed points often mean a bigger difference between estimations (snow conditions are often more different when the distance between points is larger) which increases the variance of snow grain size estimates. This in turn reduces the weight given to the radiometer data in the final SWE estimate.

8. l. 90 (and l. 106) How was this constant value of snow density defined?

   The constant of 240 kg m^{-3} is used based on Sturm et al (2010)., added mention of this to text.

   Sturm, M., Taras, B., Liston, G., Derksen, C., Jonas, T., Lea, J.: Estimating snow water equivalent using snow depth data and climate classes. J. Hydrometeorol. 11, 1380–1394, https://doi.org/10.1175/2010JHM1202.1, 2010.

9. l. 111-114. Please state the difference between the new and original threshold detection values.

   Added differences between threshold values to text: "The threshold for SD was decreased from 80 mm to 30 mm, the brightness temperature thresholds were changed from 250 K to 255 K for Tb37V and from 240 K to 250 K for Tb37H."

10. l. 121. Consider "spatial interpolation and assimilation" as a subsection of the first part of the method (see. Specific comment 5.).

    See answer to comment 5.

11. l. 130-132. Snow courses may not be evenly distributed throughout the winter neither.

    That's true, temporal distribution is not even. However, Figure 1 shows temporal distribution of reference SWE dataset, and the average date of observation is relatively close to middle of the month.

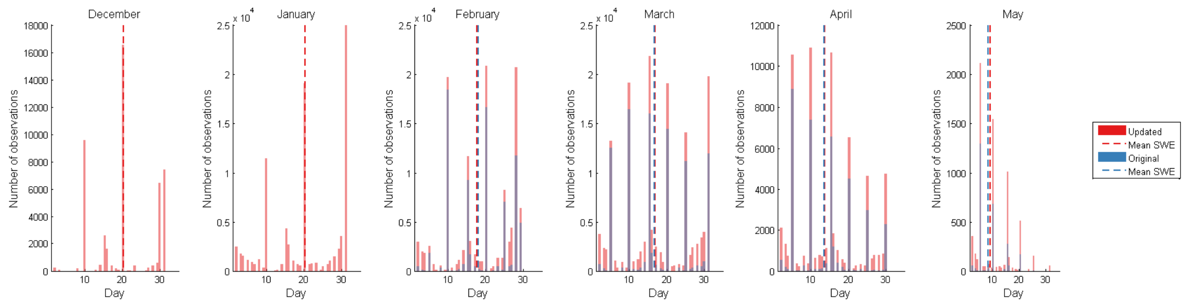

Figure 1 Temporal distribution of reference SWE estimates.

12. l. 132-133. Is the bias really stable over time? Please explain the implications of this assumption.

    As discussed in Sect. 2.5 (old Sect. 2.4) the monthly bias is relatively stable over the long term. In North America there's no trend in the bias. In Eurasia, there is a small trend in bias over the 40-year period (Appendix A), but it is not statistically significant. We have added P-values to Appendix A to support this statement.

    A small trend in bias (in Eurasia) is worth examining more closely in future studies. One potential approach could be to evaluate bias in separate time periods (e.g., by decade). If large enough, a trend in bias can act to reduce or reinforce intrinsic trends in long-term SWE estimates (e,g, due to climate change).

13. l. 171. I suggest to expand on the source of snow depth, SWE and snow density measurements.

    New information about sources of snow depth added, see comment 6. Sources of SWE/snow density measurements are listed in section 2.5 'Summary of changes in the refence snow course data'. For the SWE/snow density data we tried to limit the duplication from other papers and instead reference the publicly available NorSWE dataset (Mortimer and Vionnet, 2025) which contains a detailed description of the data used here.

    Mortimer, C., and Vionnet, V.: Northern Hemisphere in situ snow water equivalent dataset (NorSWE,1979-2021), ESSD Discussions,https://doi.org/10.5194/essd-2024-602, 2025.

14. l. 211. Figure 1:

1. The figure can be enlarged to make it easier for the reader to read and interpret.
2. I am struggling with the black and gray colors on the figure. What are these colors supposed to represent?

Figure enlarged and legend added to the figure.

15. l. 227-228: Can you elaborate?

    We use the same in situ data to compute the bias fields for two different SWE products (GSv3.0 and SCv3.1). Differences in the resultant bias fields are therefore a reflection of differences in the products rather than differences in the in situ data used to derive the bias correction fields. The main differences between these two products (retrieval and input data) are the Tb data, the use of spatially and temporally varying snow densities instead of a constant value, and updated snow masks. These changes are outlined in Sect. 2.2. We have added reference to that section in this sentence.

16. l. 256. Figure 2. Same comment as Figure 1 regarding the colors.

    Legend added to Figure 3 as well.

17. l. 268. Original = old and updated = new? Please be consistent throughout the manuscript.

    Standardized terminology to "original" and "updated" throughout.

18. l. 278-279. What would cause this negative bias in spring? Is it related to density assumption? Please elaborate.

    The negative bias during spring is partially due to constant density which tends to be too small during the spring season. This was demonstrated in Mortimer et al. (2022) which compared the difference in observed snow density from the reference snow courses (using an older reference dataset) versus the static value. They showed (Figure 11 in Mortimer et al. 2022) that the static value overestimates until about February and then underestimates. Additionally, wet snow is common during spring which makes retrieval challenging as only the top most layer above water layer is seen by the radiometer.

19. l. 282; l. 361; Table 1. SCv3.1 instead of SCv3.0?

    Yes, it should be SCv.3.1

20. l. 293-294. This sentence is redundant. Can you please rephrase it?

    Rephased as follows:

In April and May, the magnitude of the negative bias is larger in the updated fields, whereas in March, it is lower.

21. l. 304. "*...where the snow mass from the updated bias correction (blue line) is > 100 Gt larger than when calculated **with** the original reference data (black line).*"

    Rephrased for clarity as suggested.

22. l. 307. Figure 5: Do you also see a similar difference between the products for April snow mass?

    Yes, differences in snow mass between products are similar in April (shown below in Figure 2) and because of this we didn't include figure for April in the manuscript.

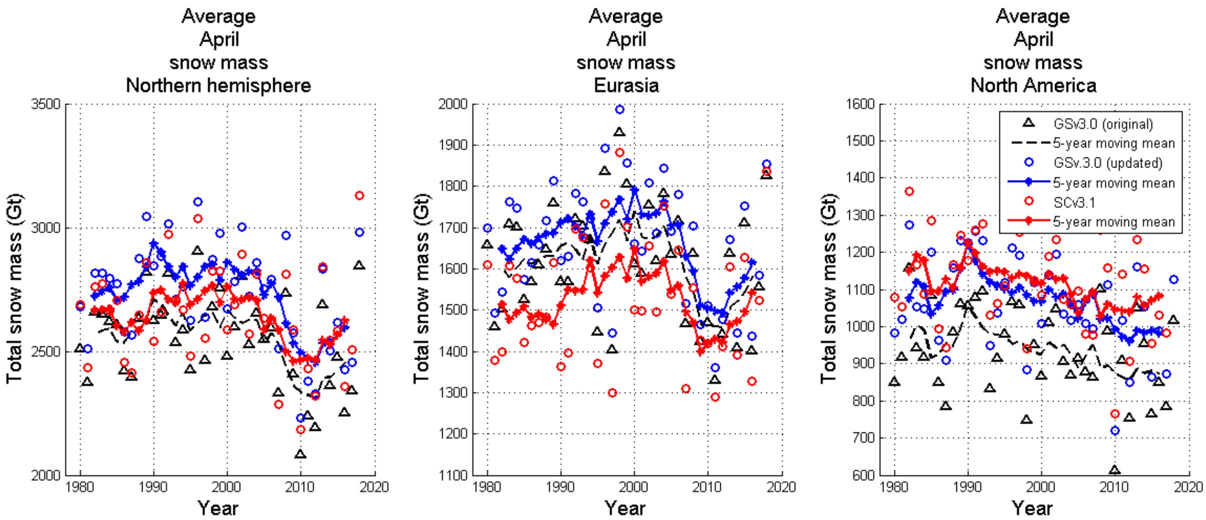

Figure 2 Average April snow mass

23. l. 313. Names can be somewhat confusing (see Specific comment 19).

    Changed "Snow CCI" to "SC" throughout.

24. l. 327-328. It would be interesting to discuss why the addition of new snow courses increases the negative bias between the two GS data products.

    The new sites are in regions (e.g. Alaska, Quebec) where SWE can exceed the retrieval algorithm's saturation limit (~150 mm). When this occurs, the bias will be negative because the retrieval algorithm cannot estimate these higher SWE values observed in-situ. Even when the retrieval relies solely on the interpolated SD field (e.g. wet snow), an upper limit is placed on the allowable maximum SD to ensure convergence during assimilation. By adding sites where the SWE often exceeds the method's upper limit we introduce more instances of *negative biases. Further, because SWE can be large at these locations the negative biases can be large.*

25. l. 332. Are the differences really most pronounced in May compared to other months? It is not possible to tell from Figure 6 alone.

    Yes, differences are most pronounced in May. We acknowledge it is a bit challenging to see on Figure 6 because we limit the colormap to +/-100mm to highlight the smaller differences. However, many of the differences are near these +/-100mm values whereas there are much fewer areas with such large differences in the other months shown. This can be seen also in the (new) figure 7 (old figure 8), where differences between monthly bias corrected snow mass estimates are largest in May.

26. l. 342. Figure 5 instead of Figure 4?

    Yes, should be Figure 5.

27. l. 352. Here you refer to figure 8 before figure 7, which makes it confusing. I think that reorganising section 3 (see General comment) would make it easier to refer to figures in the order in which they appear in the text.

    Figure 7 and 8 have been reordered so they appear in order they are mentioned in text.

28. l. 371. Table D1 (instead of Table B1).

    Fixed

29. l. 412 Figure 7:

    1. For consistency, I suggest using hemispherical maps as shown in the previous figures.
    2. What do the gray areas represent on the maps? Complex topography? Please state this clearly in the caption.
    3. The style of the caption for Figure 7 does not follow the requirements of the journal. Please revise.

Added explanation of complex terrain to caption and reformatted caption to follow requirements of the journal.

30. l. 425-433. Consider adding a supplementary figure showing the locations of SWE > 150 mm and SWE > 200 mm. This would help the reader in interpreting your results.

Large SWE values are present in different locations depending on the time of year and the year in question, so showing their locations might not help readers that much. Appendix E shows the percentage of large SWE values in different reference datasets.

31. l. 452. Typo. SWE instead of SEW.

    Fixed

32. l. 457-464. It would be interesting to further discuss how the new GSv3.0 and SCv3.1 data products may increase the bias in Quebec and Alaska (which are high snow locations).

    The products themselves do not increase the bias in Quebec and Alaska. Rather, adding new sites to the reference data used to evaluate the products altered the bias.

    The bias calculated with the updated reference dataset more appropriately captures the true bias in both the GSv3.0 and the SCv3.1 products. However, we acknowledge there are still many gaps in the reference dataset so some regions (e.g. arctic tundra) may not be fully capture in our validation. As discussed in response 24, adding sites in high SWE areas adds negative bias because SWE in these areas often exceeds the method's detection limit, when this occurs GS/SC will underestimate SWE compared to what is measured in-situ.

33. l. 466-468. Is it the opposite in April and May (snow density higher than 240 kg m^{-3}). It seems so from the bottom row of Figure 4. Please expand on that.

    Yes, the constant snow density tends to be too small in April and May which contributes to the underestimation of SWE seen in GSv3.0 product (see response 18). Changing to the spatially and temporally varying snow density (SCv3.1) has reduced the negative bias during these months. Added explanation of this to text.

34. l. 480. It would be interesting to further discuss the role of spatial resolution and how it affects the bias fields compared to the effect of other factors (such as a constant density assumption).

    We have added more information about the effects of spatial resolution to the text. More detailed analysis of the change in PMW input data can be found from the Mortimer et al. (2022).

    Overall, a finer grid spacing provides some improvements to the correlation, RMSE and bias of the SWE retrieval but has minimal effect on northern hemispheric snow mass (differing from snow density which has significant effect in snow mass).

35. l. 502-504. As North America is presented before Eurasia throughout the manuscript, I suggest that this order be maintained in the conclusion.

    Order changed in conclusion.