Author Response to Reviewer #2 (Reviewer's comments are in black and author responses are highlighted in blue).

The paper provides a comprehensive evaluation of wet snow dielectric constant models and their application in L-band radiometry of liquid water content in Greenland. While I agree that it is of vital importance to have this type of evaluation, as many people underestimate the influence of the dielectric constant models, there are several issues needed to be resolved before it can be considered for publication:

- The authors thank the reviewer for comprehensive review and insightful comments. Below is our point-by-point response to the reviewer's comments.

1. I am concerned about your assumption for the middle-layer in the MEMLS - highly reflective firn layers. You assume that ε_r varies from 5-26 while the imaginary part is fixed to 0.0002. This doesn't make much physical sense to me. For ice-firn mixture it is very unlikely to reach this high real part. If you assume some melting, then the imaginary part should also significantly increase. Please consider to either change the parameterization or justify this parameterization in the paper.

   - The near-surface density profile in the percolation zone is highly variable and characterized by multi-scale fluctuations (Johnson et al., 2014 and the references therein). Moreover, seasonal melting and refreezing lead to the formation of complex features such as random ice layers and ice pipes. Accurately modeling these effects across the percolation zone remains a significant challenge and is the subject of ongoing research.
     These sub-grid-scale structural variabilities contribute to the significant scattering of L-band brightness temperatures, particularly during the frozen season (Hossan et al., 2024). To account for these effects without introducing multiple uncertain parameters, we chose to model the combined reflective impact of the complex firn stratigraphy using an equivalent dielectric slab with a tuned permittivity (real part), following the approach already introduced in Mousavi et al., (2022).

     This equivalent layer is located beneath the seasonal dry/wet snowpack (top layer) and is defined by a real permittivity value that varies spatially (at each grid point) but remains constant temporally throughout the year. We acknowledge that, for typical ice-firn mixtures, such high values of the real part may seem unrealistic; however, it is important to note that this layer does not contain liquid water; its purpose is to simulate equivalent dielectric contrasts (for combined reflectivity) beneath the seasonal dry/wet snow rather than to represent physical dry or wet snow structures. Therefore, we maintain a low and fixed value for the imaginary part of the permittivity (0.0002), consistent with dry snow or ice. For a fixed location, the same characteristics of this layer were applied to all the models. As such, this layer has a negligible impact on liquid water retrievals, which are

governed by the top-layer that explicitly accounts for varying water volume fraction and thickness.
We will add this explanation to the revised manuscript to better justify our parameterization choice.

2. The paper has inconsistency in notations and some typos in equations:
- I could not find the definition of "v" in eq. (14.1) and "W" in eq. (16.1).

- "v" in Eq. (14.1) was meant to represent the volume fraction of liquid water (v_w). But we notice it was mixed with "W" in Eq. (16.1), and with f at some other places (Eq. 17-19). We replaced it with a single parameter (v_w) to represent the volume fraction of liquid water throughout the revised manuscript.

- Eqs. (17) and (18), β should be replaced by "1/2" and "0.4" respectively.

- β has been replaced with "1/2" and "0.4" in Eqs. (17) and (18) respectively.

- The equation numbering is wrong, e.g, there are two eq. (8) and eq. (20) in the paper and eq. (15) has "(15)" and "(15.1)" while other equations start directly with (num.num), e.g. "(16.1)" and "(16.2)".

- The numbering of the equations has been corrected, and format has been ensured consistent.

- eq. (20), there is often no “-“ sign before k_0 in the definition of alpha.

- We agree some authors do not follow the negative sign convention for the attenuation coefficient. Here, we followed the Ulaby and Long, (2014) convention to ensure the attenuation constant α is positive, given that the imaginary part of the complex square root can be negative in a lossy medium.

3. I am not sure whether it is a good idea to have so many sections for different models - some sections only have 2-3 lines. I suggest either put all the models in one section, or the authors can group the models and put them in different sections, for instance, 2.3.1 - 2.3.3 can formulate a section named, for instance, “Debye-form models” and sections 2.3.8 – 2.3.10 can form a section named “Power-law models”.

- We will consider possible reorganization of the contents of this subsection while ensuring coherence in the revised manuscript.

4. I recommend changing the name of the dielectric mixing model "MEMLS3" to "Matzler model" as the current name can cause some confusions to distinguish with the microwave emission model MEMLS3.

- We will change the name of the dielectric mixing model "MEMLS3" to "Matzler model" in the revised manuscript as recommended.

5. Notation consistency also needs to be improved. Examples are given:
- I am particularly concerned about LWA, LWC and volume fraction of liquid water vw. Is LWC the same as vw? If so, please keep them the same everywhere in the paper. Furthermore, in Fig. 6, is the notation mv same as vw?

- The liquid water content (LWC) and volume fraction of liquid water ($\boldsymbol{v_w}$) are the same, both indicating volumetric liquid water inclusion in percent. On the other hand, liquid water amount (LWA) is the product of $\boldsymbol{v_w}$ and the thickness of the wet layer $\boldsymbol{t_{wet}}$ and expressed in $\mathrm{m.w.e}$ unit (defined in Eq. 23 in the revised manuscript). In the revised manuscript, we will merge LWC/$\boldsymbol{v_w}$ into a single parameter $\boldsymbol{v_w}$ to avoid confusion and make it consistent throughout the manuscript.
- In Fig. 6, $\boldsymbol{m_v}$ will be replaced by $\boldsymbol{v_w}$ as well.

- This also occurs in Fig. 4, does the notation twet mean twet? Please revise them.

- Yes, "twet" was used to mean $\boldsymbol{t_{wet}}$ in Fig. 4. It will be corrected to $\boldsymbol{t_{wet}}$.

- line 413, the percent is written in "percent" and later it is "%", please keep consistency.

- All "%"s has been replaced with "percent" in the revised manuscript.

6. The authors can consider using different colors to represent the values shown in the blocks for selected tables (e.g. Tables 3,4,5 and 6). This colormap + number approach will greatly enhance the readability of these tables.

- We will test using different colors to represent the columns of the recommended tables.

7. Caption of Fig. 9 – what is EBM? Perhaps you want to say SAMIMI?

- Yes, we referred to the SAMIMI energy balance mode by 'EBM'. In the revised manuscript, we added SAMIMI before it (SAMIMI EBM).

8 . It is a bit surprise to see how big the impact of different dielectric mixing-model is on the retrieved LWA. Could it be associated with other parameterizations? For instance, the dielectric constant of middle layers? It would be good to briefly discuss this in the paper.

- The choice of dielectric models significantly impacts the LWA retrieval as the manuscript concludes. It can be associated with the other parametrizations, but the dielectric constant of the middle layer has little impact as mentioned in response 1. One of the crucial factors was the density of dry snow background. To minimize the uncertainty from density, we used the average measured density from the top 3 meters of snow, and it was fixed for all the models for a particular AWS. Other retrieval issues such as assumption of simplistic stratigraphy, and liquid water distributions may affect the absolute LWA estimates, and it should impact all the models in similar proportion. But we believe the relative differences between the estimates come from the respective model formulations and their assumptions. We will revise the discussion of the revised manuscript to better clarify it and consider other potential factors.

9. Line 716: please elaborate "forcing", e.g. weather and environmental conditions?

- The 'forcing' in line 716 indicated the in situ meteorological measurements from the automatic weather stations (AWS) (air temperature, air pressure, upwelling and downwelling short and longwave radiation fluxes, snow-surface height, wind speeds). To clarify, we replaced 'forcing' with 'in situ meteorological measurements.

10. Line 722: "except KAN_U…models seemed to refreeze" -> "except the retrievals using KAN_U…seemed to indicate the sites refreeze slowly…"

- Except for the average density of 3 m, the retrievals are independent of any site-specific in-situ data. We intended to indicate the retrieval (the SMAP measurement indirectly) at KAN_U site.

References:

Hossan, A., Colliander, A., Vandecrux, B., Schlegel, N.-J., Harper, J., Marshall, S., and Miller, J. Z.: Retrieval and Validation of Total Seasonal Liquid Water Amounts in the Percolation Zone of Greenland Ice Sheet Using L-band Radiometry, EGUsphere, 2024, 1–33, https://doi.org/10.5194/egusphere-2024-2563, 2024.

Johnson, J. T., Jezek, K. C., and Tsang, L.: UWBRAD : Ultra-Wideband Software-Defined Microwave Radiometer for Ice Sheet Subsurface Temperature Sensing, 2014.

Mousavi, M., Colliander, A., Miller, J., and Kimball, J. S.: A Novel Approach to Map the Intensity of Surface Melting on the Antarctica Ice Sheet Using SMAP L-Band Microwave Radiometry, IEEE J. Sel. Top. Appl. Earth Obs. Remote Sens., 15, 1724–1743, https://doi.org/10.1109/JSTARS.2022.3147430, 2022.

Ulaby, F. and Long, D.: Microwave Radar and Radiometric Remote Sensing, Microw. Radar Radiom. Remote Sens., https://doi.org/10.3998/0472119356, 2014.