Editor's Remarks

Dear Authors,
thank you again for the revisions of your manuscript. I am glad that the reviewer agrees with your changes, and has provided more suggestions for further improvements and clarifications. Please consider them carefully in your next revisions.
Looking forward to receiving your manuscript, best regards
Christian Haas

Review by Helmut Rott

General Comment:
I wish to thank the authors for their efforts in revising the manuscript and preparing the detailed response to the reviews. The revised version thoroughly addresses and clarifies issues raised in the review. In particular the revisions and material added to the sections on radar signal interaction, the retrieval approach and on the test cases, as well as related discussions are essential contributions for comprehensive understanding and are enhancing the impact of the topic addressed in the article. However, there are a still some issues that need to be checked and clarified, as addressed below.

1. Line 362ff: The RMSE value and correlation coefficient are lacking statistical significance, being based on a very limited sample with only two different soil moisture values (Fig. 6a).

   We have removed the RMSE value and correlation coefficient.

2. Fig. 9 and related text: Rather than an example for wheat (which is usually harvested many weeks before the first snowfall) the readership of a review paper on snow remote sensing techniques would expect reference or discussion on the impact of vegetation as prevalent during the snow cover season.

   The example of wheat is shown to illustrate that RTE/DBA underestimates the transmission through vegetation and has a higher frequency dependence when compared to the hybrid method as shown in Gu et al., 2021, 2022. There are not many new published results using NMM3D for different types of vegetation to be shown in this review paper. However, there has been tremendous improvement recently in computational EM efficiency and we expect new NMM3D results in near future.

3. L552 and Fig 10: Only a short statement refers to this figure, lacking a message on the observed SnowSAR backscatter signatures. For example, as follow-up to the extensive discussion on the impact of forest on the backscatter signals and the sensitivity to SWE,

information on differences in sigma-0 between open land and forested areas would be of interest for the reader. The add-on of forest cover map along the track (e.g. forest density, as shown in the Appendix to ESA 2012), or an outline of the forested areas, would be useful.

In the revised paper, it is now stated on page 20: "The differences between open area and forested area has been addressed and illustrated in Montomoli et al., 2016 paper using the models of classical radiative transfer. Results of full wave simulations are currently being studied."

4. Fig, 15b: This figure was replaced by a less informative one (showing only binary scattering albedo values) whereas the original one shows observed and simulated values (which is of interest).

   The method to compute the "observed" single-scattering albedo is quite complex. After considering, we removed the observed values from the graph to avoid the need for a lengthy discussion of how they were computed. Thus, we have kept this graphic as is, even though it is possibly less informative, as we are more concerned with confusing readers than the information contained in this graph.

5. Fig. 16 and Fig. 17: The data base and message of these figures, which were not shown in the original version of the paper, are unclear. Besides, in Fig. 16 the assignment of the two point clouds at each frequency, displayed with the same symbol, is not obvious.

   The purpose of this figure is to visually illustrate that the backscatter is dependent on two variables, SWE and single-scattering albedo. However, we agree that the purpose of the figures was perhaps not as clearly explained as it might have been.

   We have revised this by removing one frequency, and producing plots only at Ku-band, and doing some analytical work to show that a linear fit based on both SWE and single-scattering albedo has less residual error than fitting on SWE alone. This helps visually and quantitatively illustrate the point that Ku is dependent on both SWE and single-scattering albedo.

6. Table 4: Please provide also the mean SWE values for each data set, in addition to the SWE range.

   We have updated Table 4 with mean SWE values.

7. L1040: Please provide a reference on observed difference in saturation between the co- and cross-polarized signals, and specify the Ku-band frequency, incidence angle and snow type for the 300 mm saturation limited quoted here. Depending on microstructure, the saturation limit may vary by one order of magnitude. NoSRex

Snowscat data show similar sensitivity in terms of SWE for co- and cross-polarized Ku-band data (e.g. Lemmetyinen et al., 2014), suggesting a similar saturation limit.

It is now stated on page 40: "The Ku band cross polarization saturation can be shown using bi-continuous DMRT. The data for deep snow cross polarization at Ku band is quite limited."

8. Section 5.2, C-band SAR: The revision of this section does not adequately address the issues mentioned in the comments to the first version of the paper. As motivation for including this section it is mentioned " that some recent studies have demonstrated the possibility of snow depth estimation for deep snow using C-band radar …". The material and reference presented in this section suggest that the snow microstructure does not play a role for deducing the depth of deep snow from C-band backscatter data. A balanced account, as to be expected for a review paper, should present a wider view, referring also to publications on the impact of snow microstructure. An in-depth study on this respect is reported by Naderpour et al. (2022), showing a dense time series on L- to K-band backscatter (including C-band and Ku-band) for Alpine snow and discussing the impact of microstructure on the observed signatures and SWE.
We agree that snow microstructure likely plays a role in the response of the C-band cross-polarized radar signal to SWE, and did not intend to imply otherwise. We have added a statement clarifying this at line X:

"Thus, we would expect that snow microstructure plays a role in governing C-band response to SWE."

Naderpour et al. (2022) uses ESA's WBSCAT instrument, which indeed has cross-pol measurement capability. However, Naderpour et al. (2022) analyze only the co-pol signals. We have added a citation of Naderpour et al.:

"This hypothesized mechanism may explain why cross-polarized C-band radar is sensitive to SWE (Lievens et al., 2019), while co-pol is relatively insensitive to SWE (Naderpour et al., 2022). Further field-based studies of the investigations of the effects of microstructure on C-band radar signals are ongoing."

9. Fig. 20A: Please check the equation for computing the height and the geometric properties of an interferometric baseline. The height above a reference surface is proportional to the wavelength, the phase difference, and the radar range times the sin of the incidence angle and inversely proportional to the perpendicular baseline. Besides, it is not obvious that this figure is needed, considering that similar graphics have been shown in many publications and textbooks over the years.

Good catch. We have revised the equation. Thank you.

10. L1203: Radarsat and Envisat (a multi-sensor mission) were not the first C-band SAR mission, ERS was years ahead.

    It is true that ERS was launched before Radarsat-1 and Envisat. We have changed the statement.

11. L2010: CryoSat-2 has a Ku-band sensor featuring a SAR mode and a SAR Interferomeric (SARIn) mode.

    We have removed the statement on page 46 "To date, however, there have been no SAR missions at Ku-band."

12. L1238 to 1241: " Based on the ground-based measurements and the airborne measurements, the Ku-band at 17.2 GHz has a dynamic range from -16 dB to -6 dB " , "The X-band at 9.6 GHz has co-polarization dynamic range from -20 dB to -14dB". I wonder where these numbers come from and to which snow type, background medium and incidence angle they refer. For example, at the snow-covered Alpine valley and the tundra site the SnowSAR data show at 40 deg. inc. angle KuVV sigma-0 values up to -4 dB, and X-VV up to -6 dB.

    This is a fair point. We have deleted these sentences.

13. L1239: " … Ku-band 17.2 GHz …. shows good correlation with SWE ". This is a simplified statement, can be omitted. For deep, fine-grained snow the sensitivity is rather low, as for example evident from the SnowSAR data of the Alpine tundra site.

    We have removed this statement.

14. L1247 -L1249: Please provide a reference to experimental data on the sensitivity of Ku-band cross-pol sigma-0 for snow depth below one meter.

    We have removed this statement.

15. L1284: " ….seasonal snow melt is a commodity of the utmost importance for human health and well-being, supports nearly all sectors of the economy …" This seems to be slightly exaggerated.

    We have revised "nearly all sectors" to "many sectors", and have added three citations that support the point.

    Naderpour, R., Schwank, M., Houtz, D., Werner, C. and Mätzler, C. 2022: Wideband backscattering from Alpine snow cover: A full-season study, IEEE Trans. Geosc. Rem. Sens., vol. 60, pp. 1-15, 2022, Art no. 4302215, doi: 10.1109/TGRS.2021.3112772, (date of publication October 5, 2021; date of current version January 21, 2022).