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Comment on tc-2021-74

Helmut Rott

Community comment on "Sentinel-1 snow depth retrieval at sub-kilometer resolution over theEuropean Alps" by Hans Lievens et al., The Cryosphere Discuss., https://doi.org/10.5194/tc-2021-74-CC2, 2021

The objective of the work, promoting the wider use of operational SAR data for snow monitoring, is a very relevant undertaking, in particular as the spatially detailed monitoring of snow depth and mass in areas of complex topography is an open issue. However, as mentioned by the reviewers, the physical basis of the presented method is not clear. On page 5, line 17, the authors explain that the method is based "on the physical principle of an increase in snow volume scattering with increase in snow depth". I am not aware of any physical principle relating the radar backscatter intensity of a snow-ground medium to snow depth. As thoroughly proven by theory and experimental studies, the magnitude of the volume scattering signal of snow is largely determined by the size, shape and distribution of the scattering elements and their relations to the radar wavelength (e.g. Tsang et al., 2013). For backscatter modelling the description of the complex microstructure of snow as a sintered medium is critical (Löwe and Picard, 2015). The diversity of snow microstructure is probably a reason for the large spread of the scaling factor for converting the snow index to snow depth, changing according to Figure 7 by about one order of magnitude from low to high elevations.

In order to learn about the impact of physical snow properties and microstructure on the backscatter signals and to test the retrieval algorithm, we tried to retrace the processing steps described in the manuscript, based on Sentinel-1 data and snow measurements in an Alpine test site. However, we could not proceed due to missing information, in particular regarding the procedures related to equations 2 and 5. Equation 2 describes the bias correction for sigma-0 of a particular orbit and date in which the average sigma-0 from different orbits and the temporal mean backscatter of the individual orbit are decisive factors. It is not specified to which time span the temporal mean refers. Regarding the calculation of the statistical numbers, I assume backscatter intensity values in linear scale are used, as required for statistical analysis.

Equation 5 describes the relation (CR ratio) between cross-and co-polarized sigma-0. The cross-polarized ratio in dB (logarithmic scale) is multiplied by a constant factor (A = 2.0) in linear scale. This would yield a very low value for the first term on the right hand side of Eq. 5 and thus result in a large difference between the cross- and co-polarized terms. Possibly there is a syntax error, and A should be specified in logarithmic scale, yielding a shift by 3 dB for the first term. However, it is unclear why a constant value of 3 dB should be added to the sigma-0-VH values, in particular as subsequently the temporal changes in the snow index are clipped or reduced in order to avoid impacts of large changes in CR.

Essential components of the retrieval algorithm are the bias corrections and the spatial and temporal averaging procedures. The assumptions and rules related to these processing steps are hard to capture. In order to improve the traceability it would be helpful getting a concise account on these procedures in tabular and graphic form. This should cover the technical or physical constraints for subdividing the observations into true and biased values, as well as the various temporal and spatial merging and averaging procedures applied in the subsequent processing steps.

Further comments:

Page 5, line 18: Hard to understand why the Sentinel-1 data are used for retrieving the snow depth but not for detecting the snow extent. If a reliable signal on snow depth is available, this implicitly should account for the presence of snow. Besides, the selected optical snow extent product has 1 km resolution, not suitable for capturing the complex pattern induced by topography.

Figure 2 (page 8): According to this figure most of the stations in the Eastern Alps of Austria are either in valleys or in lowlands, including many sites within inhabited areas. This impairs the comparison in Alpine terrain.

Figure 4 (page 12): In the plots (a, b, c, d) different scales are used for the y-axis in respect to sigma-0. For example, the scaling factor (delta y/ delta sigma-0 VH) in plot (b) is 0.6 times the factor used in plot (a), adjusted in order to achieve good visual agreement between sigma-0 and snow depth in both cases. Actually there is a major difference in the VH backscatter response to snow depth between both sites, though being located at similar altitude.

Sections 3.2 and 3.3, correlations: There are two issues calling for further explanations. (i) It is mentioned repeatedly that spatio-temporal correlations were computed. This implies multiple correlation in which one dependent variable is related to two predictive variables representing temporal, respectively spatial, components. Details on the individual relations and their weights regarding the combined prediction of the dependent variable should be provided. (ii) In particular for snow depth larger than 2 m the correlation with in situ snow depth (shown in Fig. 11) is very high whereas the density plots in Fig. 10 show large scatter and a substantial bias. Possibly the correlations shown in Fig. 10 are based on a different sample?

References:

Löwe, H., and Picard, G.: Microwave scattering coefficient of snow in MEMLS and DMRT-ML revisited: the relevance of sticky hard spheres and tomography-based estimates of stickiness, The Cryosphere, 9, 2101–2117, 2015.

Tsang, L., K. H. Ding, S. Huang, and Xu, X: Electromagnetic computation in scattering of electromagnetic waves by random rough surface and dense media in microwave remote sensing of land surfaces, Proc. IEEE, 101 (2), 255–279, 2013.