Potential of X-band polarimetric SAR co-polar phase difference for Arctic snow depth estimation
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Revisions

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Reviewer's comments
Answers to reviewer
Modification to text

Dear Reviewer,

Thank you very much for the useful comments and suggestions regarding our work. This is highly appreciated. For a better readability of our response, the corrections in the manuscript are shown in orange.

Reviewer comments 1: Line 58: "The main challenge related to the use of SAR is the lack of a reliable method to relate satellite data to physical measurements in snow impacted environments." Would the authors be able to expand on why they see other SAR based methods unreliable? Some studies to provide examples:

Lievens, H. et al. (2019) 'Snow depth variability in the Northern Hemisphere mountains observed from space', Nature communications, 10(1), p. 4629.
Eppler, J. and Rabus, B. T. (2021) 'The Effects of Dry Snow on the SAR Impulse Response and Feasibility for Single Channel Snow Water Equivalent Estimation', IEEE transactions on geoscience and remote sensing: a publication of the IEEE Geoscience and Remote Sensing Society, pp. 1–23.

Alternatively, the sentence can be reworded to clarify the intended meaning.

The sentence will be removed.

Lievens et al. (2019) found a method to derive globally the snow depth in alpine areas at 1km^2 resolution. Our research focused more on snow characterization in arctic snowpack with consideration to the landscape scale (hence, at higher resolution).

Eppler and Rabus (2021) show the feasibility of the L-band VV polarization in L-band to estimate the SWE. Eppler and Rabus's paper was published last summer and seems to have gone under our radar while we finished this manuscript. This is indeed an interesting method which need to be studied further with spaceborne as their experiments come from airborne data. They actually addressed this point in this paper under review:

Eppler, J., Rabus, B. T., and Morse, P.: Snow Water Equivalent Change Mapping from Slope Correlated InSAR Phase Variations, The Cryosphere Discuss. [preprint], https://doi.org/10.5194/tc-2021-359, in review, 2021.

Reviewer comments 2: Line 185, Figure 3: Please consider adding a map of the TWI to give the readers that are unfamiliar with the area an understanding of how it varies

over the study area.

Thank you. We suggest to add a TWI map from our study site in the appendix so the reader will have access to the figure if needed. Here the map of the TWI and its legend added in appendix B.

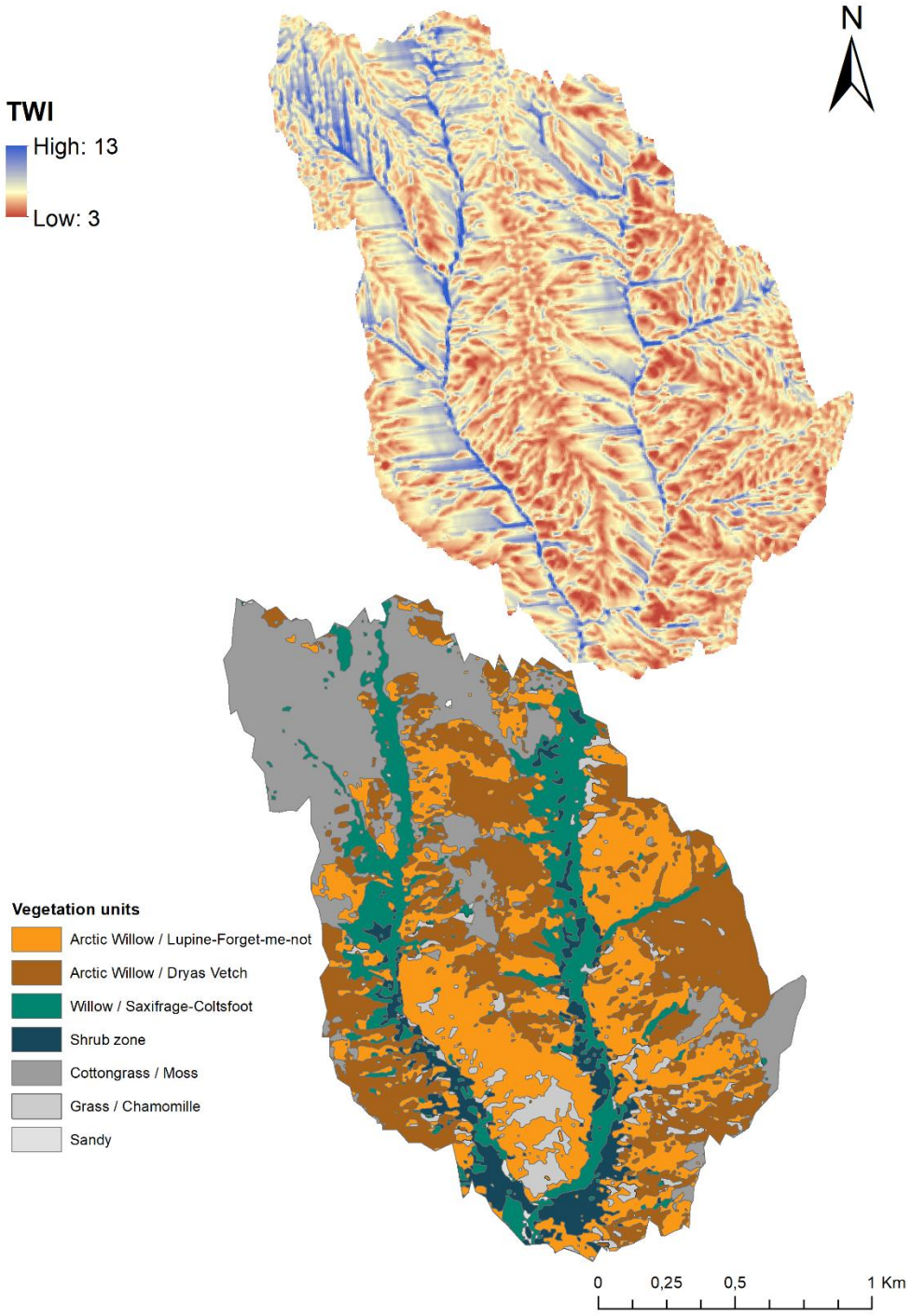

Figure B2: Topographic wetness index (TWI) map compared to vegetation units located on Qikiqtaruk-Herschel island.

Reviewer comments 3: Line 210: Were the CCOH calculated directly from the 5m resolution Kennaugh elements?
If so, isn't it a biased estimator at that resolution? For reference Leinss et al. 2014, was using an averaging window of about 75m.

The reviewer is right, Silvan Leinss smoothed the SAR signal using filter sizes of 75 m. We discussed that point with him and his recommendation was to try different filter sizes and to analyze which filter size fits the best. We have chosen a smaller window size to better reflect the heterogeneity of the snow surface which could alter within a few meters. Regarding the smoothing, the original spatial resolution of 2.5 m was resampled to 5 m before geocoding. Additionally, the SAR images were smoothed after geocoding with an enhancement approach called multi-scale multi-looking which adapts the local number of looks to the image content.

Reviewer comments 4: No-Line: Given that the CPD = 2*pi*SD/wavelength*birefringent_refractive_index, and that the birefringent_refreactive_index is about 1deg/cm of snow per Leinss et al., 2014, wouldn't there be cases where phase unwrapping may be needed for deep snow (~ >180cm)? If so, how was this handled? If not, why was it not needed?

Phase unwrapping is applied in case of continuous gradients which, for example, is the case for the generation of elevation models using InSAR. Though, the seasonal evolution of snow is not continuous as the CPD depends not only on the snow height but also on snow metamorphism. An indication when phase unwrapping should be applied is the existence of fringes in the diagram which is not the case (neither in our analyses nor in those of Silvan Leinss).

Reviewer comment 5: No-Line: Have the authors considered the phase noise of TanDEM-X sensor (+/-3.5 deg Leinss et al., 2014) in their uncertainty analysis? If not, why was it not needed?

Good point! The phase noise refers to absolute measurements. Our analyses are based on relative phase measurements. Therefore, there is no need to consider the phase noise.

Reviewer comment 6: Minor:
L93: "randomly phase shifts"
Consider "randomly shifting phase"
After verifications, we corrected it to “random phase shift”.

L122: "reach over a 110 cm"
Consider "reach over 110cm"
L412: " hummocky area "
consider "hummocky areas"

Thank you. All changes were made.