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Interactive comment on "Surface-Based Ku- and Ka-band Polarimetric Radar for Sea Ice Studies" *by* Julienne Stroeve et al.

Anonymous Referee #2

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Review of 'Surface-Based Ku- and Ka-band Polarimetric Radar for Sea Ice Studies' by Stroeve et al.

This work describes a novel ground-based dual-frequency radar used to evaluate interactions with snow on sea ice at frequencies common to CryoSat-2, AltiKa, and their follow-on mission CRISTAL. Microwave interactions with snow are discussed as a key uncertainty limiting accuracy of altimetry-based freeboard and a potential source of snow depth information leveraging frequency dependent interaction. Stationary scans and transect measurements completed as part of MOASiC highlight complex interactions and a multitude of causal mechanisms. An extensive set of snow measurements are introduced, which in the future, will be used to decompose variations in penetration and scattering. The work focuses on introducing dual-frequency theory, the KuKa

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radar system, and provides case-studies to evaluate spatial, temporal, and angular dependency of the observed environment.

Overall, the work contributes highly relevant results to the remote sensing of sea ice and the datasets described will to be critical to ongoing retrieval development. The case study examples provide a good variety of configuration and observed conditions, illustrating many of the complexities involved. However, I felt the system descriptions and quantitative backscatter analysis should be strengthened prior to publication. For the system description, the reader is directed to previous literature to establish methods for calibration and processing. Given advancements of the current system (larger bandwidth, transect profiling, multiple frequencies), additional information is needed to understand system uncertainty with respect to the relative backscatter and NRCS analysis:

(1) Calibration procedures for NRCS and relative backscatter: On lines 276 and 373 corner reflector calibration is mentioned and methods are attributed to those introduced in Geldsetzer et al. (2007) and King et al. (2013). The referenced studies indicate that external targets and background noise estimates were necessary for absolute calibration of NRCS. A factor for this is applied in Eqn (3) of the supplement but it is unclear what is used to accomplish the calibration. In depth analysis of system uncertainty is beyond scope, but an indication of system stability throughout the campaign or between scan types is needed if magnitudes are to be compared across extended temporal periods or between sites.

(2) Estimation of NRCS: Figure 11 introduces estimates of backscatter as a function of incidence angle, but I was unable to determine how the integrated impulse range was defined. I would expect a dynamic approach where the ground projected footprint is elongated with range and there is frequency / spatial dependency of penetration. How was impulse range addressed in determining NRCS and was it identical for both frequencies?

(3) Discussion of errors: Errors for NRCS are described briefly on line 485 as being plus minus 1.7 dB or greater. What sorts of challenges might this present in analysis and are these errors stable between configurations and deployments? I am also interested in understanding if the errors described for NRCS (Figure 11) are valid for the individual or mean waveform analysis given range dependent noise demonstrated in Figure 6.

With respect to backscatter analysis, the presented interpretations could be enhanced with additional quantitative analysis. For example, Figure 9 and the associated text describes a good agreement with the snow depth, but it is unclear how this agreement was determined. Extraction of relative backscatter at the identified interfaces might be useful when associating peaks identified in the mean profiles (Figure 8). Finally, the acknowledgements section indicates that data are available at the UK Polar Data Centre but I was unable to retrieve them using common terms from the paper. If the data are available a set of links would be helpful.

Thanks to the authors for their dedicated work to develop and deploy a novel radar system in this challenging environment. The datasets and analysis are valuable contributions to community and will improve understanding snow-radar interactions on sea ice. Please find my specific comments indicated below with page and line numbers.

Specific comments P5 L139 – The seasonal aspect is an important distinction from previous ground-based Ku-band studies on sea ice. Could a table 3 be amended or a description be added to inform the reader of how the preliminary dataset fits in the context of the larger seasonal acquisitions?

P7 L218 – Questions regarding calibration: Has absolute (external) calibration of the system been completed or is the calibration process solely internal? The supplementary materials state an absolute calibration was completed and P9 L275 mentions a corner reflector, but I had difficulty determining the process or how often it is required. Please include information on how external factors (changes in cabling or mounting structure) were accounted for in the calibration process.

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P7 L225 – Can you add a description of the physical separation between the two horns? This is needed to reproduce the overlap estimates.

P8 L244 – Given that the system is operated on drifting ice have steps have been taken to compensate for ice motion when applying velocity or displacement thresholds? Please include a statement on uncertainty associated with ice motion and properties of the GPS.

P9 L258 – On P12 L374 it is stated that a near-field correction is applied but this line states it was not necessary. Please clarify.

P9 L272 – Is the minimum threshold of $\frac{1}{2}$ the antenna diameter greater than the accuracy of the GPS?

P10 L295 – A statement on standard snow pit protocols would be a helpful addition here. I read this currently as the SMP being a primary tool. It should be noted that the SMP provides a profile of micromechanical properties and requires a statistical model to derive microstructure. Presumably, the snow castings for uCT are to be used as a high-quality reference but this is not clear.

P10 L 311: Sturm and Holmgren, 2017 can be used as a citation for the instead of the patent: Sturm, M., & Holmgren, J. (2017). An Automatic Snow Depth Probe for Field Validation Campaigns. Water Resources Research, 9695–9701. DOI: 10.1029/2018WR023559@10.1002/(ISSN)1944-7973.SNOWEX1

Figure 2 and P10 L312: I was not able to determine in Figure 2 where the North and South transects were completed. Could these be added?

Figure 5 and P11 Line 343: The snow depth distributions are shown as a frequency count. Are they exact repeats in terms of the number of observations and locations?

P12 L379: Does the internal calibration loop agreement with the metal plate suggest the system is well constrained and does not need external calibration? A clear statement on system stability would provide confidence that the measurements can be

compared between deployments and configurations. Alternatively a statement of why external calibration is not needed could be provided.

P13 L390 and P13 408 411: Can quantities be associated with the terms dominate and significant? For example, what % of the signal is coming from the AS interface at each frequency or what % of backscatter is observed at ranges beyond where the SI interface is presumed to be.

P14 L425: How are location of the peaks determined? Its hard to pick where the peaks are by eye beyond the main lobe in Figure 8.

P14 L434: Does the cross-pol ratio support the presence of increased multiple scattering for the Northern Transect?

P14 L441: Peak detection = greatest magnitude? This is a critical point of clarification as several studies have suggested that surface bedforms and/or roughness dictate where along the rising edge the AS interface can be found.

P14 P442 and Figure 9: What is used to define agreement between the Ku-band signal and snow depth? Please provide quantities to support.

P15 L463: There needs to be some explanation about how estimates of NRCS were generated. What impulse range is integrated? Is the same for both systems? Does it change with incidence angle?

P16 L510: There appears to be little or no difference at angles common to altimetry (near nadir figure 11e) between the two dates. How should this finding be interpreted for current and upcoming missions?

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