Response to the Reviewer #1

This is a well written paper which describes in-situ measurements from a Ku/Ka band radar during a portion of the MOSAiC field campaign. The results are highly relevant and represent a very good data set needed for better understanding of radar returns from sea ice and the snow layer. From a technical perspective I believe the methods and data are quite sound and thoroughly described in the paper. However, the paper stops short of providing information that would be of most use as a reference to understanding or improving retrieval techniques from satellite or airborne altimeters.

The authors thank the reviewer for their time and effort in reviewing our manuscript and for the constructive feedback. Please find our detailed point by point responses to the comments below.

What would be most useful here would be some results and discussion showing the observed difference in backscatter between the snow-air and snow-ice interfaces as well as the variability that was seen.

The primary objective of this paper was to a) introduce the instrument, and its deployment on sea ice during the MOSAiC expedition, both in the altimeter and scatterometer mode; and b) to demonstrate examples of radar signatures from both these modes, to ultimately demonstrate the potential of this instrument to retrieve snow depth on sea ice. Detailed analysis (including linking fully-polarimetric radar scattering, to snow/sea ice geophysical property measurements) will be further investigated in the upcoming manuscript, and including (as mentioned) relative contributions of the surfaces observed to backscatter in both bands. A quick look at the power vs range can be seen in Figure 8 where the relative power values are shown plotted against range (depth) at different locations along the transect and for both the northern and southern transects. This demonstrates some of the variability seen between transects.

Tying these to some of the physical properties measured in-situ such as salinity would also be useful. It is mentioned that this paper represents a first data set and that further studies will follow, from that perspective I do think the paper is indeed quite useful and should be published. But it would be nice to have the results placed in a bit better context towards how they could specifically be used in understanding satellite or airborne radar returns.

We agree with the reviewer comment to add ice salinity information to the analysis. In the revised version of the manuscript, we have added snow/sea ice salinity results for preliminary analysis (see lines 320-325; 450-452), as follows:

"During leg 1, sea ice thickness measurements made via drill holes ranged between 80 and 96 cm. At the start of leg 2, ice thickness at the third established RS site was 92cm, increasing to 135 cm (29 January). Measurements of sea ice freeboards during leg 2 ranged between 7 and 10cm. Ice cores revealed overall low salinity (< 1ppt), until the few centimetres above to the ice/water interface, where salinities increased between 6 and 8 ppt. The upper 20cm of the ice was relatively consistent in its low salinity (0 – 0.5 ppt), which was comprised of refrozen melt ponds."

"Snow and SYI properties from the northern transect were found to be similar to the three RS sites. Snow at the RS sites was consistently dry, cold (bulk snow temperature ~ -25°C from all RS sites), and brine-free."

Line 280: The MOSAiC floe description seems a bit simplistic with declarations about the floe properties which ignore some of the variability within the floe itself. I would suggest referencing the paper by Krumpen et al. on the floe description and history.

Krumpen, T., Birrien, F., Kauker, F., Rackow, T., von Albedyll, L., Angelopoulos, M., Belter, H. J., Bessonov, V., Damm, E., Dethloff, K., Haapala, J., Haas, C., Harris, C., Hendricks, S., Hoelemann, J., Hoppmann, M., Kaleschke, L., Karcher, M., Kolabutin, N., Lei, R., Lenz, J., Morgenstern, A., Nicolaus, M., Nixdorf, U., Petrovsky, T., Rabe, B., Rabenstein, L., Rex, M., Ricker, R., Rohde, J., Shimanchuk, E., Singha, S., Smolyanitsky, V., Sokolov, V., Stanton, T., Timofeeva, A., Tsamados, M., and Watkins, D.: The MOSAiC ice floe: sediment-laden survivor from the Siberian shelf, The Cryosphere, 14, 2173–2187, https://doi.org/10.5194/tc-14-2173-2020, 2020.

We have added Krumpen et al. (2020) reference describing the MOSAiC floe description and its history in the revised manuscript (see lines 289-293), as follows:

"The MOSAiC Central Observatory (CO) around the German research vessel R/V Polarstern was established on an oval shaped ice floe approximately 3.8 km by 2.8 km, located north of the Laptev Sea (85°N 136°E). The floe was formed north of New Siberian Islands, via a polynya event, in the beginning of December 2018 (Krumpen et al., 2020). This floe underwent extensive weathering and survived the 2019 summer melt, was heavily deformed, and consisted of predominantly remnant second-year ice (SYI)."

Some additional description of the ice properties beneath the radar site would also be helpful here and in other sections of the text such as Line 290 when it is brought up that the radar was moved.

We agree with the reviewer comment to add ice salinity information to the analysis. In the revised version of the manuscript, we have added snow/sea ice salinity results for preliminary analysis (see lines 317-325; 449-450), as follows:

"During leg 1, sea ice thickness measurements made via drill holes ranged between 80 and 96 cm. At the start of leg 2, ice thickness at the third established RS site was 92cm, increasing to 135 cm (29 January). Measurements of sea ice freeboards during leg 2 ranged between 7 and 10cm. Ice cores revealed overall low salinity (< 1ppt), until the few centimetres above to the ice/water interface, where salinities increased between 6 and 8 ppt. The upper 20cm of the ice was relatively consistent in its low salinity (0 – 0.5 ppt), which was comprised of refrozen melt ponds."

"Snow and SYI properties from the northern transect were found to be similar to the three RS sites. Snow at the RS sites was consistently dry, cold (bulk snow temperature ~ -25°C from all RS sites), and brine-free."

Line 900-905: What does it mean that "the power that comes from above the air/snow interface within a few cm of the peak is simply the impulse response of the radar"? I'm not sure why the peak is shifted several cm, and if it is the impulse response of the radar then why does it look so different than the metal plate and calibration examples? Perhaps instead it reflects the surface height distribution and scattering characteristics of the surface.

The peak in the calibration plot has been shifted in range and power to fit the peak observed from the metal plate (we have added text to explain this.) We would expect the peak from the exposed snow surface to be seen at an increased range for two reasons: 1) The plate will always sit on top of the highest topography and has a finite thickness of ~ 2 cm, so its top surface is closer to the antennas; and 2) the plate does not cover the radar footprint. Hence, the power returned from the plate, which dominates the return, is from closer to the nadir point than the exposed snow surface. We have added text in the revised manuscript (See lines 416-420) to explain this, as follows:

"We would expect this because the metal plate, approximately 15 × 55 cm in size, did not fill the entire footprints of the Ka- and Ku-band antennas, and the plate sits atop the highest points on the snow surface and has a finite thickness of ~ 2 cm. Therefore, its surface appears closer than the snow surface as it dominates the return: the measured peak range of the metal plate of 1.53 m; when the plate is removed, the air-snow peak appears at about 1.55 m at both frequencies. The relative power is also much lower because the snow scatters light in more heterogeneous directions than the metal plate"

Figure 7 and other figures: Does the Range from Antenna represent the range assuming a speed of light in free space or in snow?

Throughout the paper, the range is shown assuming a speed of light in free space, we have added text to clarify this on line 431-432, as follows:

"Results are shown as both the radar range from antenna (in meters) along with the VV power (in dB) along a short transect distance; all radar range data in this paper are shown scaled with radiation propagating at the velocity of light in free space."

Figure 9 and Line ~440: This figure and discussion are very interesting and is highly relevant for assumptions about the radar backscatter from the snow-air and snow-ice interfaces from altimeters. However, this is very qualitative and hard to put the results in a useful context as presented here. It would be useful to show at the least the backscatter difference between the snow-air interface from the algorithm and the value from the magnaprobe location.

We are pleased at the reviewer's comment about the relevance to altimetric data and are also very interested in exploring the potential for these data to provide perspectives for satellite radar altimetry – the results so far have been highly motivating and show exciting potential. However, as mentioned earlier, the primary objective of this paper was to a) introduce the instrument, and its deployment on sea ice during the MOSAiC expedition, both in the altimeter and scatterometer mode; and b) to demonstrate examples of radar signatures from both these modes, to ultimately demonstrate the potential of this instrument to retrieve snow depth on sea ice. Detailed analysis (including linking fully-polarimetric radar scattering, to snow/sea ice geophysical property measurements) will be further investigated in the upcoming manuscript. We have included plots to demonstrate this potential, but a separate publication will be required to explore the analysis in detail including combination of datasets, data processing and detailed results which are beyond the scope of this paper. Nevertheless, we have now added the numerical value of the backscatter from the snow-air interface as detected from the algorithm and also the value of the backscatter from where the magnaprobe hit the snow/ice interface. This is on Line 493-495 where we state:

“Overall, the mean power at the air/snow interface (as picked by the algorithm) is -31 and -20 dB for the Ka- and Ku-band, respectively, both with a standard deviation of 3 dB. The mean power at the MagnaProbe-derived snow depths is -45 and -30 dB for the Ka- and Ku-band, respectively, with standard deviation of 6 dB.”