Dear Prof. Conway,

Thank you very much for reviewing the manuscript and for your valuable comments to improve our manuscript. We would like to first address your comments/questions (in red), and then integrate them into the final manuscript:

Sections 2, 3.1 & 3.2 provide in-depth descriptions and details of a very impressive radar system, data collection and processing methods. You also note a power mismatch between the two transmitters when used in HH and VV orientations, and provide a simulation to estimate the influence of the truss on the antenna radiation pattern. Conclusion is that the power mismatch was likely caused by interference between the radiation patterns. The focus for the remaining part of the paper is on polarization measurements from just one of the transmitters, which includes HH and HV transmit-receive polarizations. In order to make the manuscript more accessible to readers who are not so interested in details of the radar system, I suggest you consider moving these detailed descriptions (together with Figs. 1, 2, 3, 4, 6, 7 & 8) into supplementary information.

We will move this into supplementary documents, as suggested.

In order to keep the manuscript accessible to readers, you might also consider moving the discussion of filtering data (together with Figs 11&12) to the supplementary section.

We will make this change.

Page 1 - line 29. I think this point should be the main emphasis of the abstract. It should be expanded to state details of the "very good agreement". The importance of the work is that it enables confidence in radar-detected polarimetry and it can be applied in places where there are not measurements from ice cores.

We expanded the abstract as follows (added text is marked in green):

Abstract. Ice properties inferred from multi-polarization measurements, such as birefringence and crystal orientation fabric (COF), can provide insight into ice strain, viscosity and ice flow. In 2008, the Center for Remote Sensing of Ice Sheets (CReSIS) used a ground-based VHF radar to take multi-channel and multi-polarization measurements around the NEEM (North Greenland Eemian Ice Drilling) site. The system operated with 30 MHz bandwidth at a center frequency of 150MHz. This paper describes the radar system, antenna configurations, data collection, and processing and analysis of this data set. In the area of 100 km^2 around the ice core site, ice birefringence dominates the power variation patterns of co-polarization and cross-polarization measurements. The phase shift between the ordinary and extraordinary waves increases nonlinearly with depth. The ice optic axis lies in planes that are close to the vertical plane and perpendicular or parallel to the ice divide depending on depth. The ice optic axis has an average tilt angle of about 11.6° vertically, and its plane may rotate either clockwise or counterclockwise by about 10° across the 100-km^2 area, and at a specific location the plane may rotate slightly counterclockwise as depth increases. Comparisons between the radar observations, simulations, and ice core fabric data are in very good agreement. We calculated the effective co-latitude at different depths by using azimuth and co-latitude measurements of the c-axis of ice crystals. We obtained an average effective c-axis tilt angle of 9.6° from the vertical axis, which is very comparable to the average optic axis tilt angle estimated from the radar polarization measurements. The comparisons give us confidence in applying this polarimetric radio echo sounding technique to infer profiles of ice fabric in locations where there are no ice core measurements.

Page 10 - line 5ff. Does this mean that you profiled along circle 3 twice, or something else?

No, we did not profile twice along Circle 3. The two coherent integrations means using the average of every two consecutive data records of complex values to replace the original two data records. It decimated the number of data records by a factor of two.

- line 9. In fig.9 it looks like the upper _125m is blank (rather than 250m expected from a 3us delay).

Yes, there is a factor of 2 after considering the two-way propagation. Thanks for the correction. We revised it as follows:

In Fig. 9, the top ~127 m is blank. This corresponds to the eclipsing time, which is equal to the duration of the 3-µs chirps that the radar has to wait before recording data for unambiguous range detection. … As seen in Fig. 9, the receive power level obtained for HH measurements is higher than that of HV measurements for shallow depths between 127 and 750 m, and the power level of HV measurements becomes comparable to that of HH measurements for depths of 750 to 1450 m.

- line 16. Do you mean signal "extinction" (rather than "distinction")?

Yes, it should be "extinction". We have corrected this typographic error.

Page 13 - line 21ff. Reference to Fig.10b -it would be helpful to also explain Fig. 10b in the figure caption (Page 34). Are dotted "measured" lines raw data or have they been filtered? Are they from Circle 3 or from some other circle?

Thanks for the suggestion. We revised the caption of Fig.10b as follows:

Figure 10: Effects of the angle α between TX1 and x-axis and birefringence phase shift ∅ on reflected power. The color bar in (a) gives the power scale in the range from 0 dB to -25 dB. The blue and red lines correspond to co-polarization and cross-polarization respectively. The solid lines are simulated and dotted lines are filtered measurements along Circle 3.

Page 15 - line 5ff. I have trouble interpreting Fig. 11. What do the different colors of power profiles represent? It is not clear to me what criteria has been used to assign the annotations in Fig. 11a. I see now that this is described on Page 17 line18ff. It would help if you pointed the reader to this explanation. Also, it would be helpful to include a note about the annotations in the caption rather than having to refer to Fig. 14.

The purpose of Fig. 11 is to show the bulk properties of the received power at different depths. In Fig. 11, there are 14 HH and VV power profiles, respectively, at 14 depths. The colors are automatically determined by MATLAB's plot command, which cycles through its default colors. To avoid ambiguity, we revised Fig. 11 by using four colors (blue, red, green and magenta) to distinguish the profiles that are close to each other and by labelling the different profiles with numbers (from 1 to 14 in increasing order) according to the depths from the top to the bottom. The updated plots are included below. To make it easier for readers to understand the annotations in Fig. 11a, we revised the caption as suggested.

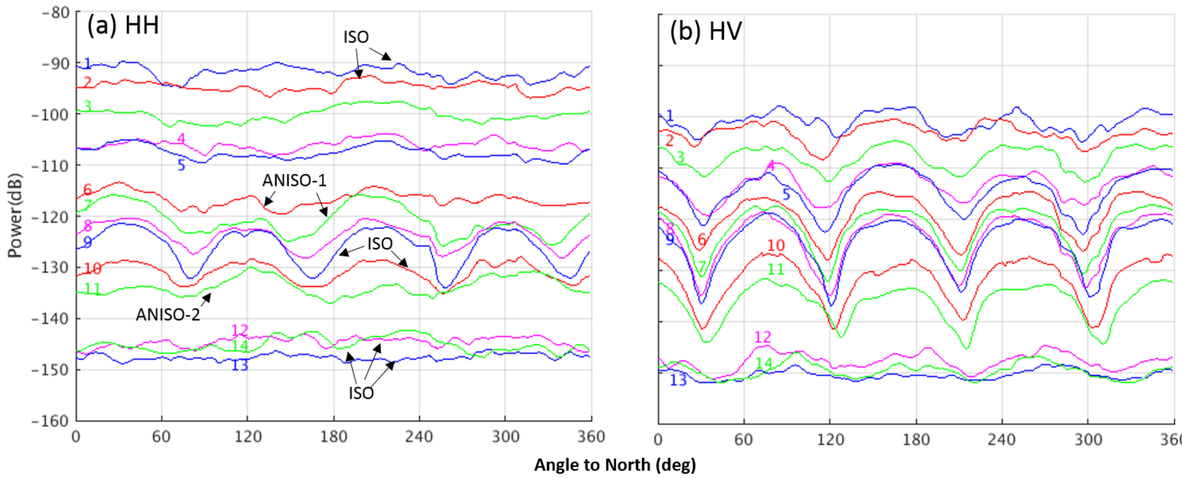

Figure 11: Power profiles with respect to the angle to North at different depths for HH and HV measurements. Four colors (blue, red, green and magenta) are cycled through for distinguishing close profiles and all the profiles are numbered from 1 to 14 in increasing order, according to their respective depths from the top to the bottom. The annotations in (a) illustrate the isotropic and anisotropic patterns discussed with Fig. 14 at the end of Section 3.3.

Page 18 - Concerning Figs 14b & 14d; how is normalized power determined in the upper 250m? Also, the depth scale in Fig. 14e needs to be clear; I am not sure – does it range from 1.34 to 1.5km?

Thanks for pointing out the ambiguities. In Fig. 14b & Fig. 14d, the power profiles parallel-to-ice-divide (in blue) and perpendicular-to-ice-divide (in red) were normalized by dividing them by the maximum of the parallel-to-ice-divide power profile, which appears at depth of ~327 m. In Fig. 14e, the depth scale ranges from 1.34 to 1.5 km. We revised Fig. 14e and its caption as shown below:

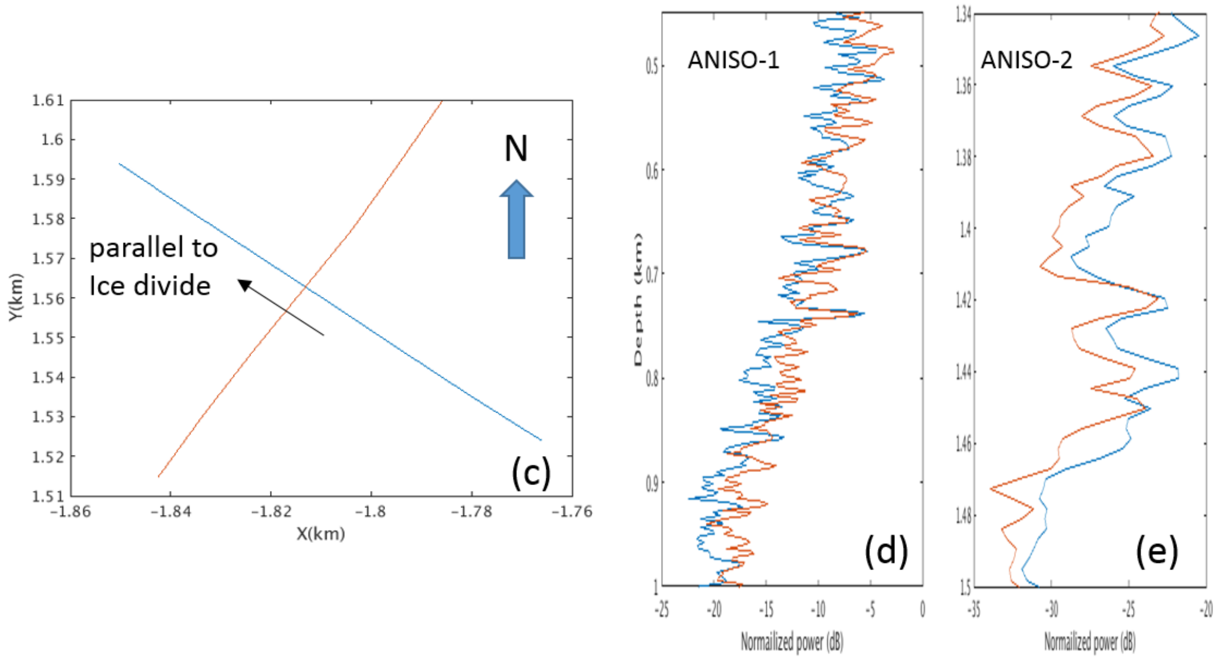

Figure 14: (a) Power variation patterns and their depth profiles for the HH polarimetric measurements at the four circles. ISO indicates no obvious anisotropy observed. ANISO-1/ANISO-2 are anisotropic patterns and indicate the ice optic axis is perpendicular/parallel to the ice divide. (b) Stacked normalized power-depth profiles and their differences at a crossover from non-polarimetric measurements with HH antenna configuration. The normalization is done by dividing both profiles by the maximum of the blue one at 327 m. The plot of the differences is area-filled. (c) Paths of the crossover (see the cross mark in Fig. 5a for its location relative to the four circles). (d) Anisotropic pattern ANISO-1 at the crossover. (e) Anisotropic pattern ANISO-2 at the crossover.

Page 19 - lines 11&14. What is meant by “at the internal ice layer interface”?

Because the power difference maxima appear at local peaks, when we said “at the internal ice layer interface” we meant “at the internal ice layer”. We revised the text as follows:

…with a maximum difference of 6.3 dB at the depth of ~462 m … with a maximum difference of 4.4 dB at the depth of ~1459 m.

It might also be instructive to plot a full-depth-profile of the power difference, which might help the reader to delineate regions of ISO/ANISO-1/ANISO-2.

We revised Fig. 14b to include the full-depth-profile of the power difference and the caption was updated accordingly, as follows:

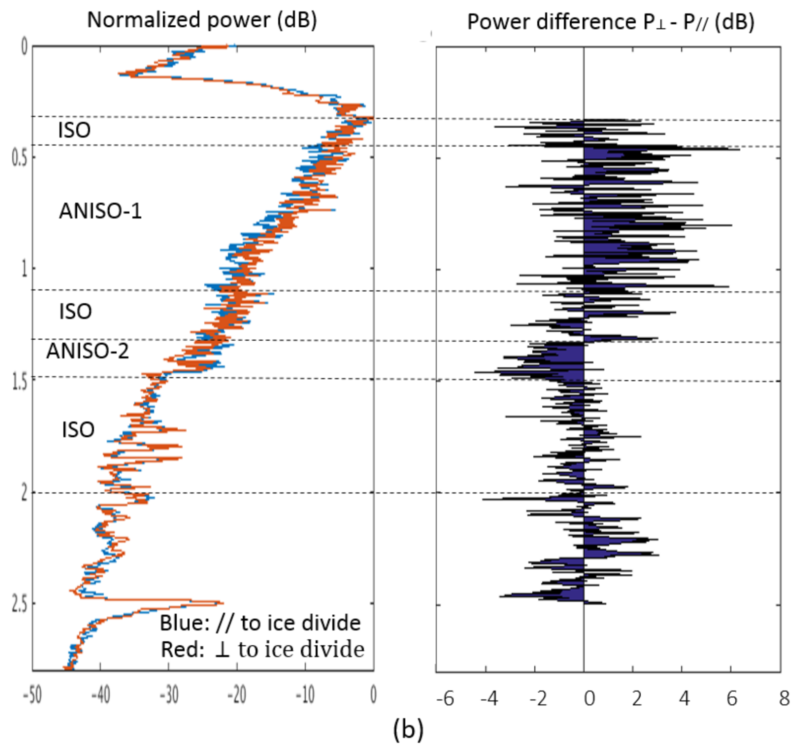

Figure 14: (a) Power variation patterns and their depth profiles for the HH polarimetric measurements at the four circles. ISO indicates no obvious anisotropy observed. ANISO-1/ANISO-2 are anisotropic patterns and indicate the ice optic axis is perpendicular/parallel to the ice divide. (b) Stacked normalized power-depth profiles and their differences at a crossover from non-polarimetric measurements with HH antenna configuration. The normalization is done by dividing both profiles by the maximum of the blue one at 327 m. The plot of the differences is area-filled. (c) Paths of the crossover (see the cross mark in Fig. 5a for its location relative to the four circles). (d) Anisotropic pattern ANISO-1 at the crossover. (e) Anisotropic pattern ANISO-2 at the crossover.

- line 21. Fig 15 – not 14.

We corrected this typo both at line 21 & 24. Thanks for pointing out it.

It might be a more instructive comparison to compare the measured profile of eigenvalues with a full-depth-profile of the power difference, calculated either from Fig.14b or from the cross-over measurements (Fig. 14d&e)

Please see above regarding revisions to Fig. 14b.

Page 20 - line 9. Presumably you observe “weak radar reflectors” (rather than “weak ice layers”)

We revised the text and changed “weak ice layers” to “weak reflectors”.

- line 18. Fig. 16 seems redundant; full-depth information is given in Fig 15a

We consider that that Fig. 16 may be supplementary, but not redundant, as it displays the raw ice core data from which the eigenvalues of Fig. 15a were derived. It is also a complement to Fig. 18 from which the effective co-latitude at different depths were calculated. We would be happy to change to supplementary material if recommended, but we would definitely like to keep it.

Page 24 - line 3. Is this correct? I suspect that the borehole measurements of fabric have already provided insight into the ice flow history. More important here is that the radar polarimetry measurements are closely similar to measurements from the borehole and can be used with confidence to extrapolate ice-flow histories spatially.

We argue that the orientation of the crystals in the core is only known relative to the vertical axis. The orientation of the core in the x-y plane after it was extracted is not known. Therefore, direct checks of ANISO-1 and ANISO-2, which provide insight to ice flow, are not possible with core data. We agree with the referee's statement that the radar polarimetry measurements can be used with confidence to extrapolate ice-flow histories spatially, therefore we add the following hereafter:

(6) The very good agreement between the radar observations, simulations, and ice core fabric data provides assurance as to the effectiveness of polarimetric radio echo sounding techniques to infer profiles of ice fabric in locations where no ice core data are available.

-line 5. Do you mean stresses rather than forces?

Yes. We revised "forces" as "stresses".