The Cryosphere Discuss., 6, C2766–C2771, 2013
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The Cryosphere Discussions

Interactive comment on "Radio-frequency probes of Antarctic ice birefringence at South Pole vs. East Antarctica; evidence for a changing ice fabric" *by* D. Besson et al.

Anonymous Referee #5

Received and published: 10 January 2013

General comments Besson et al. analyze wide-band radar data from the South Pole in order to characterize the ice in terms of birefringence. Basically they use a radar with a single linear polarization, but since the radar is stationary they can acquire polarimetric data by rotating the antenna. They observe the propagation delay and amplitude as a function of the polarization at five internal reflectors in the upper half of the ice sheet. The propagation delays of the reflectors do not vary with the polarization unlike the amplitudes. Also an oblique propagation experiment is described. The paper is interesting, but it lacks focus in the sense that some sections are not related to birefringence i.e. to the title. Observations are not always (attempted) explained or commented. Often details are provided where the relevance is not obvious (to me), and in some cases

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other details would have been valuable. Many symbols are not defined.

Specific comments Page 4695: The title indicates that the comparison of the South Pole and East Antarctica is a key issue, but it is not addressed until the conclusion on page 4707.

Page 4696, line 3: The precision is claimed to be 0.5 ns, but the band 0.2 GHz to 1 GHz mentioned page 4699 line 18 corresponds to 1.25 ns.

Page 4696, line 10: The correlation applies to the amplitude, not the birefringence just mentioned.

Page 4696, line 24: In practice the reflection types are not easily separated on the basis of the magnitude.

Page 4697, line 3: “publicatons” –> “publications”.

Page 4697, line 11: “Acid vs. density”: In practice there are shallow acidity contrasts too, i.e. the overlap of the two mechanisms complicates the discrimination.

Page 4697, line 18: A COF change over tens of meters hardly causes a strong reflection when the pulse length is 0.5 ns.

Page 4697, line 23: The baseline amplitude is not proportional to 1/r. It depends much more on the exponential attenuation caused by absorption and scattering than on the Friis dependency (except maybe at short ranges).

Page 4698, line 12: Fujita et al. 1996 is not found in the list of references.

Page 4698, line 19: The c-axis orient towards the direction of convergence (cf. Y. Wang et al., Annals of Glaciology, Vol. 35, pp. 515-520, 2002). Hence, the convergence/divergence determines the anisotropy not directly the flow direction, but in practice they might be interrelated to some extent.

Page 4698, line 24: No information is provided on the signal generator. How much

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power? Is it pulsed and if so does it generate a short pulse or a modulated pulse for subsequent pulse compression?

Page 4699, line 2: Each cable is connected to a horn. Please make it clear from the beginning that the two horns are for transmission and reception, and specify the distance between the two.

Page 4699, line 3: Probably many readers do not know what a TEM horn is. A typical reader would reader appreciate knowing that a linear polarization is transmitted.

Page 4696, line 3: Likewise, many readers are not familiar with the VSWR. If a plot of the antenna gain as a function of the frequency cannot be shown, please briefly explain why the VSWR tells about the antenna bandwidth, or simply omit the figure.

Page 4699, line 20: The receiver gain is not very interesting. The noise figure might be.

Page 4700, lines 4-9: What is the implication of the three differences?

Page 4700, line 15: How is the synchronization measured? Cross-correlation like on page 4705 line 4?

Page 4700, line 16: Please compare the one nanosecond with the difference in propagation that would be expected in case of a significant birefringence (e.g. as measured in East Antarctica).

Page 4700, line 21: Please write explicitly that a missing “x” means copol.

Page 4700, line 24: In all plots the yellow peaks is barely visible.

Page 4701, line 1: Why does the power of the cross-pol signal exceed that of the co-pol signal? Also on page 4707 line 24 this issue is mentioned without any attempt to explain it.

Page 4701, Section 2.3: A spectral analysis of time windows centered at the reflections

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would probably be more illustrative than this indirect time domain analysis.

Page 4701, line 20: Indeed, a longer reflection indicates a smaller bandwidth, which in turn could be a result of a frequency dependent reflection from a (deep) acidity contrast. Is the transmitted spectrum flat? If so please provide this information because otherwise the frequency response of the scattering could flatten the spectrum and have the opposite effect on the extent of the reflection.

Page 4701, line 23: "ice attenuation increases with frequency": So far the frequency dependence of the reflection (not the attenuation) has been addressed.

Page 4701, line 27: The choice of 500 MHz is unfortunate as it implies that the output of the highpass filter has a larger bandwidth than that of the lowpass filter (since according to page 4699 line 18 the center frequency is 600 MHz). Consequently, the resolution differs.

Page 4702, Section 2.4: This section does not seem to address the issue of birefringence. If I am right, please delete it, and otherwise clarify how it relates to birefringence.

Page 4702, line 20: According to the Friis equation alpha equals 2 (in the far field). Please consider referring to the radar equation (both the (2r)-2 and r-4 versions) instead of the Friis equation. I suppose most readers are more familiar with the radar equation.

Page 4702, line 15-19: Which temperature profile is used? How are the 6°K computed?

Page 4703, line 9-28: According to ND Hargreaves (J. Phys. D, 10(9), 1285–1304, 1977) a 90° period results from birefringence, while a 180° period results from anisotropic reflection. I recommend including a reference to this paper rather than the lengthy (and not easily understandable) explanation why the South Pole observations differ from those in East Antarctica. In addition, an explanation of the 180° period is missing. At least Hargreaves has one potential explanation (anisotropic reflection).

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Page 4704, line 5: The meaning of “three-dimensional” is not very clear to me. Is it the orientation of the preferred c-axis in 3D, not just in the horizontal plane?

Page 4705, line 5: The oblique scattering from the bedrock results in a long return waveform. Hence it makes sense to use the “onset”. Please explain that this is due to the rough surface and the geometry. Also, so far the signals polarizations have been quite similar (except for the amplitude and potentially the propagation delay). Now the polarizations are completely different. Please explain why.

Page 4705, line 12: Indeed the horizontal component of the V polarized return from the deep bedrock becomes very small when the RX-TX separation is small. In this case, is the experiment worth anything? If it is not, please delete this section.

Page 4705 Section 3.1: This section does not seem to address the issue of birefringence. If I am right, please delete it, and otherwise clarify how it relates to birefringence.

Page 4706, line 21: I understand that you compare with the BEDMAP grid points (not the radar sampling points on which the BEDMAP is based). If so, the comparison does not make sense in my view.

Page 4706 Section 3.2: This section does not seem to address the issue of birefringence. If I am right, please delete it, and otherwise clarify how it relates to birefringence.

Page 4707, line 14: In my view it does not make sense to compare radar measurements at Dome Fuji and South Pole without discussing the glaciological differences.

Page 4707, line 21: I am not sure “monolithic” is the correct word. Clearly the ice is polycrystalline. Maybe “uniform” is more correct?

Page 4708, line 5: Do you really mean that the results from the oblique propagation confirm the results obtained with the vertical propagation. The former addresses the entire ice thickness the latter only the upper half. Also, the former suggests birefrin-

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gence, while the latter does not.

Page 4708, line 11: “propagation perpendicular” –> “propagation parallel”

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