Review: Snow accumulation and compaction…by Kreutzmann et al.

This paper reports on snow compaction measured with repeat GPR profiles. The exercise is thorough, the methodology well explained and the results are plausible. The exercise is well justified in relation to satellite measurements of snow accumulation. I am submitting a marked Manuscript (MMS), which has many suggestions and edits for improved writing. My technical comments are:

1. **Air waveform.** In Figure 2 you show an air wave waveform and say that is the waveform transmitted into the snow. In GPR, an antenna on the ground surface is "loaded" by the reaction fields induced near its surface, the result of which is usually an attenuation of higher frequencies and a dominant frequency lower than that specified by the manufacturer. Fortunately, new dry fluffy snow provides almost no loading and so what you see in air is likely what is transmitted. I have seen this many times with the GSSI "400 MHz" antenna unit. In your case you have found a dominant frequency of 620 MHz for a Sensors and Software "500 MHz" unit. You should look within your data for isolated wavelets and compare with your air wavelet. They are probably similar, given your excellent results with deconvolution.

2. The **Fourier spectrum** shown in Fig 2b needs to have the vertical axis labeled as to whether it is power (intensity) or amplitude. If it is intensity then your assessment of the (half power-3dB) bandwidth is correct.

3. The **theoretical resolution criterion** on p. 4 is nice but not practical. It is simpler to measure the time duration of the 3/2 cycle wavelet (about 2.25 ns), translate it into distance within the firn medium (pick a density) and then take ½ to account for round trip propagation. Applying the Kovacs formula to 500 kg/m^3 density, the resolution is 24 cm, not the 19 cm the formula gives. Practically, when looking at a GPR profile one can usually see horizons merging and follow the phase fronts to get even better resolution.

4. **Fig 2.** should show the resulting deconvolved waveform, which should show at least one half cycle removed, and the resulting Hilbert magnitude transformation.

5. The reflectivity series is also known as the **impulse response**.

6. The paper states that **dispersion and absorption** are the causes of variation in waveform. Not always true, especially in dry firn. Trace by trace examination of any dry firn GPR profile will show strong variations, and dispersion and absorption cannot be the cause. I think it is mainly caused by interference but this is not clear because interference cannot shift a frequency spectrum lower, yet we see it all the time in Antarctic GPR profiles, from 3 MHz pulses to 400 MHz pulses. The profiles seen in Arcone (1996) were recorded on the McMurdo Ice Shelf in January, when there was much water, and show much waveform variation. I doubt there was any melt in November, when you recorded. Your success with deterministic deconvolution is statistical; you apparently made a good average choice of waveform

7. There is much discussion regarding **causes of density variations**. A primary cause is hoar layers; read Alley's (1988) classic paper on firn stratification or your cited reference Arcone et al, 2004, and follow-on papers in Annals of Glaciology and Journal of Glaciology. Many of the wavelets you see may be thin layer responses to low density hoar. This is especially true on the West Antarctic plateau. Dust is likely not concentrated enough to make reflections, but it may have caused melt and subsequent freezing, or even metamorphosis. On the McMurdo Ice Shelf there are also melting and ice layers (see Arcone, Geophysics, 1996), so hoar is just one factor in this complex setting.

8. There is also discussion on **causes of horizons dipping**, as in Fig. 8. Generally the topographic effect is seen at a 1–10 km scale, with profiles oriented close to that of the katabatic wind (see Arcone at al, 2005, JG, Fig. 5) This is antidunal accumulation, whereby more snow accumulates on windward slopes than on leeward ones. In the dunefields of East Antarctica the differential accumulation is extreme. On the McMurdo ice shelf there is no significant undulating topography. Instead, there is compression, which becomes clear in long profiles of many km length, especially toward Williams Field and beyond, toward the Ross Ice Shelf. There is also shorter range compression, especially against Ross Island north of Scott Base, best exemplified by the buckling "rollers." See the Nobes et al reference below.

9. The highlights of the paper are **Figs. 10, 11**. I suggest adding a theoretical curve and some data of others (Arthern?) for comparison. In the Discussion, you try to reconcile your results with those of others. I think that that your results show the limitation of previous measurements.

References

Alley, R. B. 1988. Concerning the deposition and diagenesis of strata in polar firn. *J. Glaciol*., **34**(118), 283−290.

Arcone, S. A., Spikes, V. B., and Hamilton, G. S., 2005, Phase structure of radar stratigraphic horizons within Antarctic firn. *Ann. Glaciol.*, **41**, 10–16.

Arcone, S. A., Spikes, V. B., and Hamilton, G. S., 2005. Stratigraphic variation in polar firn caused by differential accumulation and ice flow: Interpretation of a 400-MHz short-pulse radar profile from West Antarctica, *J. Glaciology*, **51**(7), 407−422.

Arcone, S. A., Spikes, V. B., Hamilton, G. S., and Mayewski, P. A., 2004. Stratigraphic continuity in 400-MHz radar profiles in West Antarctica, *Annals of Glaciology*, **39**, 195–200.

Arcone, S.A., 1996. High resolution of glacial ice stratigraphy: A ground-penetrating radar study of Pegasus runway, McMurdo Station, Antarctica. *Geophysics*, **61**(6), 1653–1663.

Nobes, D. C., Davis, E. F., and Arcone, S. A., 2005, "Mirror-image" multiples in ground-penetrating radar. *Geophysics*, **70**(1), K20-K22.

Non technical comments

1. **Writing style.** This paper is verbose. Constructions like, “is probably an indicator of,” is better phrased as, “probably indicates.” Paragraphs use “However” too often, and first person constructions need to be used more. Eliminate phrases such as, “note that,” because providing the thought that follows implies that it *is* to be noted. And please don’t start a sentence by saying, “Incidentally,’ which suggests that what follows is not very important, or happened by chance. See my MMS.

2. **Organization.** The paper is well organized but the Discussion is too long. Some paragraphs in the Discussion should be in the Conclusions, and some can be eliminated. One section of paragraphs should be in an Appendix. See my MMS