The Cryosphere
Discussions

Open Access

Interactive
Comment

Interactive comment on "Annual Greenland accumulation rates (2009–2012) from airborne Snow Radar" *by* L. S. Koenig et al.

Anonymous Referee #2

Review comments for Koenig et al, 2015, TCD under review for TC.
===

1 General comments

This is a nice study using the Snow Radar from Operation IceBridge (OIB) to determine accumulation over large portions of the Greenland Ice Sheet. The authors determine accumulation rates using the depth to internal reflecting horizons and a "hybrid" modeled/measured density profile. They compare the radar-derived accumulations with modeled accumulations from the MAR regional climate model. One of the major conclusions of this work is that the density profile in the shallowest meter is of

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

great importance, and the source of significant uncertainty.

This manuscript represents a great first step in using the OIB radars for determining accumulation, and definitely deserves to be published in TC. There are, however, a few things that need to be resolved, most of which are listed in my 'specific comments' below.

A more general comment is one of setting/context. The manuscript never mentions the other instrumentation on the OIB flights, and as such the reader could be left with the impression that the Snow Radar is the only instrument being flown. A natural question a novice reader might ask, knowing the names of the other instruments on OIB, would be- "if you are measuring accumulation, why not use the Accumulation radar?" You've answered that question in my mind with this manuscript, but not directly. While the Accumulation Radar shines in the interior of the ice sheet, it likely does not have the depth resolution to pull out the shallow layering that you get near the margins. One of the strengths of the snow radar is that it can resolve that single layer of accumulation in the percolation and ablation zones. In these zones the accumulation radar will not be able to see the interface between fresh snow and percolation facies, or fresh snow and ablation facies. For this reason alone it's well worth continuing this kind of analysis using the OIB snow radar. For deeper measurements, using non-annual layering, why not use the accumulation radar, as it's able to identify and trace layers far deeper than the snow radar is designed to do. Note that I don't think you need to do anything with the accumulation radar, but it would be good to at least acknowledge its existence, particularly as its flown on the same airplane, on the same flights.

2 Specific Comments

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

2.1 Modeled density bias
===========================

From inspection of figure 2, it appears that in addition to underestimating the shallowest meter of firn density, MAR also consistently overestimates density at depths greater than about 2.5 meters. Though this is still within the range of the 1-sigma area indicated in the plot, it is still a bias, and should be treated and discussed as such. I don't think it should change your results much, but this bias is clearly there and should be acknowledged.

Additionally, as figure 6 shows, for most of the ice sheet only 1-3 layers were seen, meaning that the majority of this analysis uses only the shallowest portion of this density profile. This heightens the importance of that shallowest part of the density profile, yet it only occupies 10or line on this plot identifying the depth to which 90analysis was carried might help the reader focus in on this issue.

2.2 Deriving accumulation rates from Snow Radar
=======================================

Section 4.2 introduces equation 1, described as a "standard equation" for converting depth from a radar profile to accumulation rates. This reviewer has not seen this expression before, though certain pieces of it make sense. If it is indeed a standard equation, there should be an easy way to reference it. Dimensionally it makes sense, but given the complexity of the expression and lack of a reference, I think it makes sense to show here at least a few steps of the derivation. In particular, it is not clear what the physical meaning of a 'cumulative snow/firn density', though many authors make use of a cumulative mass in such calculations. More clarity is required for this section.

2.3 Semi automated layer picker

==================================
There are several important details missing in this section:
- When aligning the surface, outliers in alignment (25 cm out) are discarded. This is fine, but you should state what portion of the data are discarded in this process. Were there 1like this? 10- Why stack to 50 meters in one 2011 and 2012, and 10 meters in 2009 and 2010? I assume there is a good reason, but it's not stated here and thus can't be ascertained.
- 4.3.2 and 4.3.3 layer detection- these paragraphs are not entirely clear to someone who isn't already familiar with the scheme. Is the spatial dimension to which you refer the depth dimension, or the along-track dimension? Often authors refer to 'spatial variability' to mean in the along-track dimension. When you define a 'segment' is this along the travel-time dimension or the spatial dimension? It is not clear that a detailed explanation of the layer picking routine is required for this publication, but if it is to be included, it needs to be more clear. One or more figures illustrating the process may make this more clear.
- Section 4.3.4 should either be eliminated or vastly expanded (if a detailed description of the algorithm is to be included, which is not really necessary). As it is, it does not really add to the paper. One way to make it more relevant would be to discuss the error rate of the autopicker- essentially the question is how often did the analyst have to correct the autopicked layers? In the conclusions the point is made that 10s of 1000s of kilometers were processed for this work- in what kind of time savings for the analyst did this autopicker result?

2.4 Results
============
- In section 5.1, when referring to figure 4, a full paragraph is devoted to the point that the "annual" accumulations are actually representative of only 10 months, due to the timing of the flights and the assumption of layer formation in high summer. Why not normalize this number to a 12-month year, and call it annual accumulation? You still

need to include caveats, but then the number reported in the figure will be comparable to other studies more readily.

- It is not clear to me that figure 5 needs to be included, as the MAR model results are not the focus of this study. One could combine figures 4 and 5 if the accumulation were normalized, and then it's a direct comparison between measured and modeled accumulation.

- Section 5.2, comparing radar-derived accumulations to MAR: expanding the radar footprint to the scale of MAR grid-cells may not be the best way to do this. Why not interpolate MAR to a smaller grid-scale, using whatever interp scheme is appropriate, and then compare? It may be more fair to MAR, since the support footprint of the radar measurements is pretty small. Also in this section- it appears that 2010 is a particularly difficult year for MAR measurements (from figure 10). Why might that be?

- Page 6731, figure 11: These accumulation rates are averages for each year, it might be beneficial to illustrate them as "stair step" plots, in which the horizontal bar is the duration over which the accumulation is averaged. The way they are presented it appears to the eye to be a point measurement at Jan 1 for each year. Furthermore, it would make sense for the spans in each case to be representative of the actual dates- you have the space on the x-axis to have the radar-derived measurements span from July to July, while having the NEEM core measurements span Jan to Jan (assuming that is what they are reporting). Then your phase-relationship argument in section 5.3 may be validated. Also, more important for the comparison with Camp Century, you should report your 11will actually probably make your result look in better agreement...

- On the same figure, it is confusing how the Camp Century OIB radar-derived accumulation rate from 2011 could possibly have only a SINGLE accumulation estimate for 2001? If you've dated a layer as 2001, it was dated (per the methods section) by counting other layers back in time. Thus there should be an accumulation estimate up through 2011, right? Similar argument for the 2009 and 2012 measurements, but it is most glaring for the 2001 measurement. I assume that there is some legitimate reason for there being only a single (2001) point for accumulation from the 2011 data,

but we need to know what it is.

3 Technical corrections (Specific (line-level) small things)

- Page 6699, lines 21-24: This sentence is awkward and not entirely clear. Clarify.
- Page 7600, line 3: "here after" should be "hereafter"
- Page 7601, line 6: "to monitor decadal-scale..." monitor is not really appropriate here- change to "measure"
- Page 7601, line 27: GCM is more frequently a "General Circulation Model" as opposed to "Global Climate Model". However, since you only are using RCMs here, why not just eliminate the mention of GCM?
- Page 6703, line 25: "an additionally" should be "an additional"
- Page 6704, line 5: this sentence is awkward- the phrase "that cover and vary" in particular is kind of confusing. Suggest just removing "and vary" since the statement that there are multiple profiles implies variability.
- Page 6704, line 6: "from the MAR model" is redundant- just use "from MAR" which is what you use elsewhere.
- Page 6706, line 4-6" The sentence "Equation (1) is written to show the relationship between the density profile, which is used for ... This is not a "between" situation, as we're talking about one thing. I suspect this is a copy/paste error.
- Page 6706, line 16: No need to mention the Onana et al layer picker, as you don't use it! Remove this sentence.
- Page 6706, line 13 and throughout: Active voice is much easier to read than passive voice, though this is a style thing and should be left to the discretion of the editor.
- Page 6707, line 1: "minimize data noise" eliminate 'data' from this, not a useful word here. It's all data...
- Page 6711, line 4: "whereas as the" delete 'as'.
- Page 6712, line 24: "filled to broaden with" delete 'to broaden'
- Page 6726, Caption to figure 6: English usage- "less than three layers" should be

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

"fewer than three layers" since we cannot have a fraction of a layer.

Interactive comment on The Cryosphere Discuss., 9, 6697, 2015.

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper