Replies to Editor (Ted Maksym) comments

AC: Thank you for your additional comments Ted, which help to clarify our manuscript further. Please find our replies (AC) to the specific editor comments (EC) below:

EC: In addition to the minor points raised by the two reviewers, I would like to add to the comment from RC2 about the accuracy in derived SIPL for different hi. I note that for the thicker SIPL layers (~4-8 m), assuming a conductivity in the middle of the estimated range (~1200 mS/m), that the behaviour upon which eq. 5a-c are based does not really hold. The decrease in I with increasing SIPL levels out, and Q shows a slight, increase, comparable to the variability in I (Fig 3). Hence, ha,I has a modest increase as SIPL increases between 4-8m that is comparable to the decrease in ha,Q over the same range. But Fig 6 is very convincing that eq 5b and 5c work. I think this is because the relationship between ha,Q and SIPL is roughly linear over this range, so that 5c remains linear, but would slightly modify the effective value of alpha. It might be that since the effect is modest, this relationship still works well enough over the range of SIPL. I do note that I'd expect this to reduce alpha for larger SIPL (if I have the direction of the effect correct), which is not consistent with the lower value used for 2013 and 2016, so it seems it is not a large enough effect to make much difference to the empirical fits. However, similar to RC2's question, I wonder if this effect may become important if the consolidated ice thickness varied significantly?

As noted, the effect seems to be unimportant, so I do not necessarily suggest any major changes need be made; ultimately eq. 5c is semi-empirical, and the effect of variability in ha,Q is not so important. However, for these ranges of SIPL and conductivity, neither I or Q vary much (figure 3). This would suggest that the derived SIPL values may have quite large uncertainty. Can you provide some estimate of uncertainty due to the precision and/or accuracy of the instrument for these SIPL thicknesses? Given figure 4a, it seems that for SIPL thicknesses above ~5-6m, that the SIPL estimate would be essentially indeterminate. Particularly since relatively slight variations in conductivity seem to have as great, or greater effect. Given this, it is perhaps somewhat surprising that the SIPL thicknesses match observations as well as they do (although many of the estimated SIPL thicknesses are well outside the drill hole error bars in Figs 9 and 10). Some further discussion of potential limitations of this method based on this may be helpful to add to the text.

AC: Thank you very much for your comments. Indeed, as already expressed in our reply to reviewer 2, these issue were high on our mind initially but were forgotten in the final stages of writing the discussion… Therefore we have added two paragraphs to the discussion that address your and that reviewer's comments as they are closely related. They concern both thick and thin consolidated ice as well as an increasingly thick SIPL thicker than approximately 6 m:

"Our validation data are limited to drill-hole measurements from first-year fast ice that is typically 2 m thick at the end of the winter. Therefore, most of our model results were also limited to 2 m thick consolidated ice. However, Figure 5 also includes results for 4 m and 6 m thick consolidated ice (dashed curves). From the behavior of those model curves it can be inferred that with thicker consolidated ice the ratio of ha,Q/hi decreases, which suggests that, in the presence of a typical SIPL, thicker consolidated ice can be retrieved more accurately than thinner ice from the quadrature measurements. Figure 5 also shows that the scaling factor α is hardly affected by consolidated ice thickness at all, i.e. the accuracy of retrieved SIPL thicknesses is independent of ice thickness. The thickness profiles in Figure 9a include surveys of multiyear fast ice in 2013 and 2017, which are visible by large steps towards thicker ice in the west. These are indications that the measurements are indeed quite sensitive to thicker consolidated ice and SIPL as well. We only attempted very few drill-hole measurements of the thick consolidated ice and thick SIPL, as they are very challenging and their accuracy is poor. Therefore we did not include them in our analysis here.

However, thick consolidated ice and a thick SIPL pose other challenges that are related to the decreasing sensitivity of EM measurements with increasing height above the water or conductive SIPL. Despite the better behavior of ha,Q/hi discussed above with regard to Figure 5, thicker consolidated ice results in weaker inphase and quadrature signals which eventually approach the EM noise level and are then insensitive to consolidated ice thickness changes (not shown here, see Haas et al., 2009). However, these limitations only apply to ice several tens or meters thick (e.g. Rack et al., 2013). More importantly, increasing SIPL thicknesses also lead to reduced sensitivities particularly of the inphase signals as has been discussed above with regard to results shown in Figure 3. That figure shows that for typical SIPL conductivities of 900 mS/m and more the inphase signal remains approximately constant for SIPL thickness of 6 m and more. This is due to the limited EM field depth penetration into conductive layers, which make the method insensitive to changes below the level of penetration. Therefore it is likely that the good results shown in Figure 7 benefited from the fact that most drill-hole SIPL thicknesses in the study region were not larger than 6 m (total thickness of 8 m). In fact, Figure 7 shows that the uncertainties of the thickest SIPL measurements which also have the largest drill-hole errors are considerably larger than those of smaller total thicknesses."

In addition, we have added error bars of +/-0.5 m thickness to the graphs in Figures 9 and 10 to illustrate the uncertainty of the AEM retrievals and to show that within that uncertainty the agreement with the drill-hole data is really good.

EC: A couple other suggestions (up to authors' discretion):

Figure 1: Might it be better for the green dots to show the total estimated thickness (consolidated + SIPL), or just the SIPL thickness, rather than the apparent thickness (which is not an actual thickness)? A casual reader might look carefully only at this figure, as it provides a clear geographical presentation of the results. I think it would be best if this showed the actual results.

AC: We have debated various options when we first compiled this figure, including your suggestion. However, we concluded and are still convinced that we should leave it as it is, for the following reasons: 1. In the context of the paper the figure shows the initial apparent thickness that would be obtained when carrying out the measurements. They already show the coherent apparent thickening in the region of the known ISW plume which is the key point of the figure. This was an important discovery/recognition for us when we looked at the data for the first time after our first surveys. 2. Showing the consolidated ice plus SIPL thicknesses would strongly increase the range of displayed values and more subtle details would be less clearly visible. Note also that we only show the surveys over the first-year ice, as the multiyear ice and its SIPL would be much thicker, again increasing the range of displayed values and decreasing their resolution.

However, we agree that it would also be useful to show the full range of measurements, and therefore we have implemented your other suggestion below.

EC: Figure 6: it might be useful to show the full drill hole thicknesses here as well (consolidate

+ SIPL) so that the scaling factor is more apparent.

AC: We agree that this looks interesting as well, and will replace the figures as shown below, even though the scales get much expanded and details of the blue and orange curves are less clearly visible than before.