Replies to Reviewer 1 (Blake P. Weissling) comments

We are very grateful for the very positive evaluation by this reviewer, and by the suggestions for further improvements, which we have considered carefully. Please find our replies (AC) to the specific reviewer comments (RC) below:

RC: In section 2.1.2 (line 167), the authors state that the conductivity of the consolidated ice in this layered model is set at 0 ms/m (infinite resistivity). Such a conductivity would assume that all entrained brine has been drained from the sea ice and I'm wondering if such an assumption is valid. Even with very cold first year ice, I would assume that some brine pockets remain albeit not necessarily connected in a significantly porous permeable network. Could the author's comment on this and if you considered a non-zero conductivity in your model (say at < 50 ms/m bulk ice conductivity)?

AC: The reviewer is right in stating that the conductivity of consolidated sea ice can be larger than zero due to connected brine residing within the ice. However, conductivities between 0 and 50 mS/m do not affect the EM thickness retrieval much (less than 10 cm). We have therefore added the likely range of consolidate ice conductivity to Section 2.1.2 "(~0-50 mS/m; Haas et al., 1997)" and have added a sentence to the end of the model description of Section 2.1.3:

"Note that we chose σ_i = 0 mS/m for simplicity, while in reality consolidated sea ice still contains some brine that can slightly raise its conductivity up to σ_i = 50 mS/m or so (Haas et al., 1997). However, those small variations have little effect on the EM retrieval of consolidated ice thickness (Haas et al., 1997; 2009)."

RC: In section 2.1.3, the author's present a mathematical model based on a continuous integration (Hankel transform). Is there a discrete version of this transform, and if so how was it computationally implemented? I'm not looking for an elaborate explanation, but just a short description of what the discrete transform looks like and if it was solved/applied in Matlab or some other software package. This would be useful for other researchers in applying the method. Perhaps an addenda describing the computational approach in more detail. Saves us from having to reinvent the wheel so to speak.

AC: We thought that the stated references provided enough information on the modeling, but agree that stating a few more details in our manuscript would clarify the modelling more immediately. Indeed the model cannot be computed analytically but requires a numerical method that uses digital filters. While we were using old software which I developed during my PhD and that was based on Anderson (1979), one of my former PhD students has indeed published a matlab based code on Pangaea:

Irvin, A.: One Dimensional Frequency domain Electromagnetic Model (ODFEM). PANGAEA, https://doi.org/10.1594/PANGAEA.897352, 2019.

Anderson, W. L: Computer Program. Numerical integration of related Hankel transforms of orders 0 and 1 by adaptive digital filtering, Geophysics, 44, 1287–1305, https://doi.org/10.1190/1.1441007, 1979.

In the manuscript we have added a sentence immediately below the first mention of the Hankel Transform:

“This equation can only be solved numerically using digital filters. Here we used the filter coefficients of Guptasarma and Singh (1997) that are, for example, implemented in a program by Irvin (2019).”

RC: In section 3.3, paragraph 2, the authors describe only the cementation factor in the application of Archie’s Law. There are 2 other factors or coefficients relevant to Archie’s Law ( )for brine saturated porous media, the tortuosity factor (a) and the saturation exponent (n). Could the author’s address this and if such coefficients/exponents have been formulated for ice media? Both numbers I suspect would be relevant in an ice matrix.

AC: These are good points. Honestly we are not sure what the latest studies about sea ice conductivity are, except for the work of Jones which we use later in our manuscript and that is less based on using Archie’s law. However, our approach largely follows the work by Haas and Hunkeler which we clearly cite. In that work tortuosity and saturation are assumed to be one, for a lack of better information. These assumptions also follow yet earlier work by Kovacs and Morey (1986). We have now added that reference and added the following comment:

Figure 8 shows the horizontal conductivity for Archie’s Law “with tortuosity factor and saturation exponent set to one (e.g. Kovacs and Morey, 1986)”, and cementation factor m=1.75 (Haas et al., 1997), and m=3 (Hunkeler et al., 2015b),

Kovacs, A., and Morey, R.M.: Electromagnetic measurements of multi-year sea ice using impulse radar, Cold Regions Science and Technology, 12(1), 67-93, https://doi.org/10.1016/0165-232X(86)90021-2, 1986.

RC: Technical comments: In section 2.1 (line 108-9), the sentence beginning “The surveys covered : : :” could be rephrased as it reads a bit awkward.

AC: OK

RC: In line 117, is “levelness” best word choice? AC: We reconsidered the word but find it quite suitable in this context.

RC: In that same line, could the author’s elaborate briefly on “occasional

noise” and what it entails?

AC: added: noise from EMI interference or episodic electronic drift

RC: In section 2.1.3 (line 254) do you mean to say “derived apparent conductivities” or “derived apparent thicknesses”? This possible typo is repeated in line 271, “from the apparent (conductivity) of the Q measurement”. Please check as I think you meant to say “thickness” in both cases.

AC: Thank you for your careful reading, yes these should be thicknesses.

RC: In section 2.2 (line 316), “we assume of typical” is strange wording. Maybe drop the “of”.

AC: thanks, yes the “of” has to go…;)