The Cryosphere Discuss., referee comment RC1
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Comment on tc-2021-154

Anonymous Referee #1

Referee comment on "Broadband spectral induced polarization for the detection of Permafrost and an approach to ice content estimation – a case study from Yakutia, Russia" by Jan Mudler et al., The Cryosphere Discuss., https://doi.org/10.5194/tc-2021-154-RC1, 2021

General Comments

The paper by Mudler et al. is devoted to the problem of ice content estimation in the buried rocks using non-invasive geophysical techniques, namely, the high-frequency induced polarization (HFIP) method. The manuscript is well-structured, rather concise and supported with sufficient illustrative materials. It contains novel interesting results and clearly deserves publishing even without any significant corrections. However, below there are some comments and suggestions, which I believe may help the authors to further improve the scientific quality of the paper.

Specific comments

- The main idea of the manuscript is to estimate the ice content in the buried rocks by using the two-component weighted power mean (WPM) model for fitting measured broadband HFIP spectra. For this purpose the authors first invert the observed 2-D HFIP data by means of the conventional Cole-Cole model and then make separate additional inversions of the revealed Cole-Cole response within each model cell by means of the two-component WPM formula. This approach is vulnerable to criticism, since the WPM and Cole-Cole functions could not be generally converted to each other, hence application of the Cole-Cole inversion to the data complying with the WPM model may only introduce additional errors and thus appears to be rather undesirable. If the authors believe that the WPM model is the best choice for quantitative description of the observed HFIP data, then the most natural way of handling them would be direct 2-D inversion for the WPM model parameters, without unnecessary intermediate use of the Cole-Cole function. Consider trying this approach if there are technical capabilities to do so – it may probably yield better results, provided that the non-ice IP effects in rocks are relatively small (otherwise some combination of the Cole-Cole conductivity + WPM permittivity models could be required instead).

- The choice itself of the employed model and its variable parameters should be discussed in more detail, if possible. For quantitative description of the HFIP response of an ice-bearing rock one may use the 2-component (Zorin, Ageev, 2017), 3-component (Stillman et al., 2010) or 4-component (Bittelli et al., 2004) WPM formula, not to mention the other potentially applicable mixing models, such as that of Hanai and Bruggeman. Why did you choose to employ the 2-component WPM for your data set? Are the temperature and clay content in the frozen layer under study low enough to consider all non-ice sources of IP effect negligible? Is it legit to fix the relaxation time constant of ice as a known value (page 5 lines 27-29), while it could in general vary by several times depending on ice purity and temperature? To answer these and other related questions it should be useful to provide the inversion results for all parameters of the employed WPM model and discuss more thoroughly the quality of data fitting, especially within the ice-bearing cells: the reported average misfit of 20% for amplitude and 0.15 rad = 8.6 degrees for phase (page 16 lines 7-8) appears to be rather high, but there are no illustrations showing how exactly and at which frequencies the actual data diverge from the best-fit model, so it is difficult to understand how the employed model should be modified to achieve better results.

Technical corrections

- Page 3, line 11. Replace “City” with “city”.

- Page 5, line 8. Replace “polarizing” with “polarizable”.

- Page 5, lines 29-31. This part of the text leaves the reader with a feeling that in order to successfully fit the HFIP data represented by a 5-variable Cole-Cole model one must use only the 5-variable mixing models, which is not the case. Indeed, since there is no direct relation between Cole-Cole and WPM models, any such fitting would be performed in the least square sense by solving an overdetermined system of equations using all available frequencies, no matter how many independent variables has the employed WPM model – 3, 5, 7 or more. Consider revising/rephrasing.

- Page 8, line 14; Page 13, line 12 and many other places. The term “high resistive” sounds to me a bit awkward, consider replacing with “highly resistive” or “high-resistivity”.

- 4. Linear scaling is generally inappropriate for presenting resistivity data – please, redraw the resistivity plot on a log scale. Also consider replacing “Kohm*m” with “kΩ·m”.

- 4 capture, second line. Remove “are”.

- Page 12, line Remove “by”.

- 9 capture, first line. Replace “describe” with “described”.

- Page 16, line 3. Replace “HFIP estimated” with “HFIP-estimated”.

- Page 17, line 4, Replace “Sibirian” with “Siberian”

- Page 18, line 14. Replace “two component model” with “two-component model of”