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Validation of two resistivity mixing models for porous media using in-situ time lapse electrical resistivity soundings and unfrozen water content measurements

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Thanks to highly contrasting electrical properties of liquid water and ice, ground resistivity measurements have been established as a useful proxy for imaging the freeze-thaw processes in the active layer and long-term ice content changes in permafrost. Quantitative interpretation of electrical resistivity changes in terms of liquid water or ice content changes relies on a valid resistivity mixing model that typically determines the ground phase composition based on specific resistivities of the ground components and the ground bulk resistivity response. To test the validity of two commonly used resistivity mixing models – the Archie's law, and the geometric mean model - we used time lapse ground resistivity data from three consecutive freeze-thaw periods to predict the unfrozen water content variation on a high-latitude permafrost site in Ilulissat (West Greenland).

We found that the resistivity measurements predicted the unfrozen water content decrease upon ground freezing very well, with Archie's law performing slightly better than the geometric mean model. In the thawing period, however, neither of the models was able to accurately predict the unfrozen water content increase. This is because of demonstrated non-unique relationship between the unfrozen water content and ground electrical resistivity, where the ground resistivity showed to be up to one order of magnitude higher during freezing than during thawing at the same unfrozen water content. In permafrost modeling applications, the thawing portion of the resistivity-water content relationship is typically of greater interest. However, our observations suggest that commonly used resistivity mixing models will require adjustment for the freeze-thaw hysteresis effects if quantitative predictions are sought.