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The Cryosphere Discussions

Interactive comment on "Measuring snow water equivalent from common offset GPR records through migration velocity analysis" *by* James St. Clair and W. Steven Holbrook

Anonymous Referee #1

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General Comments:

In this paper, the authors attempt to apply established techniques from the exploration seismology literature to the problem of measuring Snow Water Equivalent (SWE) using constant offset GPR with the stated goal of simplifying that process while obtaining reliable results. The manuscript goes on to detail the application of these complicated methods to a few lines of field data with exceedingly limited success at producing results and processing flows that are either reliable or simple. Given these results (as presented and described in the body of the manuscript itself) the concluding statements that "the processing flow that we presented in this paper proved to be an efficient way

to measure radar velocities within seasonal snow" (Line 508) and "the method requires less processing time than visually scanning each migrated image and could make GPR a more attractive tool for estimating SWE at the watershed scale" (Line 509) are unsupported.

Specific Comments:

The paper states that the "primary purpose of this study is to simplify the process of measuring GPR velocity in seasonal snow and obtain reliable SWE estimates" (Line 444) yet it accomplishes neither:

In terms of processes, simplification, the adaptation of Fomel's seismic approach (Line 133) and the NSE metric (Line 477) are gratuitously complicated, fail due to data quality issues (Line 230), and are not justified given the limited data set. There is no case made that the claims of efficiency (e.g. Line 221, Line 508) address actual measurement and processing bottlenecks or are even accurate. Further, once implemented these techniques still require frequent and substantial manual interventions (Lines 230, 377, 447, 460, and 462) culminating in the authors' suggestion that wavelength scale "point diffractors suitable for this type of analysis can be scouted for ahead of time during summer months or on aerial photographs" (Lines 499). Traditional GPR methods are much simpler than this (e.g. do not require advance scouting or aerial observation).

In terms of reliable SWE estimation, the authors show that the presented approach "does not allow us to confidently differentiate between dry snow and moist snow" (Line 350). Further, authors show that the collected data does not exhibit the frequency dependent attenuation upon which the entire approach depend (Line 318 and Line 331) and even though "within uncertainty bounds there is no resolvable frequency change" (Line 440) the authors go on to use that uncertainty speculate that "there may be up to a 36 MHz shift" and then estimate a volumetric water content from it (Line 442) even though nothing suggests the existence of such a shift beyond the authors' assumption and assertion it should exist (Line 318). This is inappropriate and, as written, likely

invalidates the results and conclusions of the paper. Further, the lack of observed frequency dependence is likely due to an actual lack of frequency dependence in radar attenuation in ice for frequencies below 1 GHz (Gudmandsen, 1971). This must be addressed. At the very least, the authors' statement "averaging mean snow-densities from manual observations may be a better strategy" (Line 489) makes it clear that the stated goal to "obtain reliable SWE estimates" (line 144) was not met.

Technical Corrections:

Line 107: Add an explanation and citation for "targets that have lateral dimensions that approximate the wavelength of the signal".

Lines 122: Why mention the 800 MHz data if it's not used in the analysis? Consider removing.

Line 202: This entire paragraph has a level of detail that seems inappropriate for a journal manuscript. Consider dropping or revising.

Line 235: Provide a justification for the "equally likely" claim.

Line 251: The units of the left and right side of this equation do not match.

Line 318: Add an explanation and citation for "the coefficient increases with increased frequency" and address the fact that, in ice and below 1 GHz it does not (Gudmandsen, 1971).

Line 155, 404, and others: Justify uncertainties and provide basis throughout the manuscript for uncertainties that are currently just asserted.

References:

Gudmandsen, P. "Electromagnetic probing of ice."ÂăElectromagnetic probing in geophysics. Vol. 79. 1971.

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