REVIEW OF MANUSCRIPT TC-2023-19: SEISMIC ATTENUATION IN ANTARCTIC FIRN

The study derives phase velocities and attenuation of P- and S-waves in polar firn from seismic experiments using an inversion algorithm. The basic model of the inversion is a stack of homogeneous layers. The attenuation of each layer is obtained from the phase shift between the reference wavelet and the first break wavelet at the corresponding offset. The reference e.g. source wavelet is obtained from receivers placed close to the source.

Parameters for the Biot model are derived from the density model using functions of the porosity that have been shown to be functional in snow.

The study shows, that wave velocities in firn can not be explained by a basic porous model consisting of a rigid ice structure and a pore space consisting simply of air. Such a basic ice-air model underestimates the P-wave attenuation by at least two orders of magnitude.

The authors therefore use a porous model with the pore space filled with so called 'fluidized snow'. Fluidized snow is a mixture of snow particles and air. The difference between the soft air and the relatively rigid snow leads to higher attenuation as of higher friction of the rigid phase and the larger slip due to the soft phase being squeezed. The mechanism and the orders of magnitude of the attenuation is similar to a pore fluid consisting of air and water in melting snow. To my knowledge, the concept of fluidized snow as a pore fluid in Biot-theory to express wave velocity and attenuation in firn is new and has not been applied before this study.

As described in the introduction of the manuscript, only little information of wave velocity and attenuation of firn is present today. Such information is important as it could be used, for example, to obtain porosity of firn with seismic borehole experiments. As such, borehole logging in cheap hot water drill holes could replace costly core drills. Knowledge of the wave attenuation in the firn layer of ice sheets is also important to seismic surveys obtaining geological information of the underlying geological structures.

1. Comments

Figure Attenuation versus density: In the manuscript the attenuation and velocities are only shown versus depth in the firn deposits. For the use in further investigation and to compare with alternative theoretical models it is crucial to have the velocities and attenuation as a function of density and/or porosity. I would therefore highly recommend to add such figures to the manuscript.

Physical model of fluidized snow: For the theoretical model, fluidized snow is assumed to fill half the available pore space. Where the available pore space is a function of density. Given the results of the study this is a good approximation. It is, however, not so clear, how the fluidized snow phase can be measured in firn samples as for example in drilled ice cores. This is not a flaw of the study, but rather a question, that arrises from the results of the study.

Date: March 5, 2023.

2. Technical corrections

Technical corrections:

- Line 250: "depth depth"