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Determination of the elastic modulus of snow via acoustic measurements

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The elastic modulus of snow is a key quantity from the viewpoint of avalanche research and forecasting, snow engineering or materials science in general. Since it is a fundamental property, many measurements have been reported in the literature. Due to differences in measurement methods, there is a lot of variation in the reported values. Especially values derived via computer tomography (CT) based numerical calculations using finite element methods are not corresponding to the results of other methods. The central issue is that CT based moduli are purely elastic whereas other methods may include viscoelastic deformation. In order to avoid this discrepancy we derived the elastic modulus of snow via wave propagation measurements and compared our results with CT based calculations. We measured the arrival times of acoustic pulses propagating through the snow samples to determine the P-wave velocity and in turn derive the elastic modulus along the direction of wave propagation. We performed a series of laboratory experiments to derive the P-wave modulus of snow in relation to density. The P-wave modulus ranged from 10 to 280 MPa for a snow density between 150 and 370 kg/m^3. The moduli derived from the acoustic measurements correlated well with the CT-based values and both exhibited a power law trend over the entire density range. Encouraged by these results we used the acoustic method to investigate the temporal evolution of the elastic modulus. The rate of increase was very close to values mentioned in literature on the sintering rate of snow. Overall, our results are a first but important step towards a new measurement method to attain the elastic properties of snow.