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Characterization of snow mechanical properties using laser ultrasound: Role of snow crystal type

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Quantifying the mechanical properties of snow is crucial for various applications, including the assessment of slope stability, vehicle mobility on snow-covered terrain, and the understanding of snowpack evolution. To build our understanding of snowpack evolution, we utilize a novel non-contacting laser ultrasound system (LUS). This system collects ultrasonic wavefield data from tens to hundreds of kilohertz in a controlled cold lab environment, allowing us to interpret acoustic measurements and measure mechanical properties on a microscale and upscale this to the field scale.

We investigated the relationship between P-wave velocity changes and snow properties such as density, snow crystal type, and metamorphism through sintering. We controlled the density of the snow samples by adjusting the volume while maintaining the same mass. We controlled the microstructure by manipulating the supersaturation and temperature (controlling air and water temperatures within an artificial snow maker) within a cold lab to make artificial snow of a specific crystal type (i.e., Dendritic, plate, column, and needle snow crystals). Homogeneous snow samples, each composed of their own single crystal type, were created and compacted to a density of 250 kilograms per cubic meter.

Over a period of 72 hours, we measured acoustic wave propagation through these artificial snow samples to periodically observe changes in waves peed during metamorphism. This allowed us to monitor changes in mechanical properties as sintering occurred, for different snow crystal types. We also measured snow microstructure and micromechanical properties with destructive techniques, using the SnowMicroPen and MicroCT. Finally, we examined the relationship between velocity changes and snow crystal types, specifically in terms of sintering time. Our findings suggest that the crystal type, as influenced by time under isothermal temperature conditions, affects the observed bulk mechanical properties and their rate of change. Observations of ultrasonic wavefields show that snow strengthened by a factor of 1 to 2 within 72 hours, depending on the snow crystal type.