COMPARISONS OF VERTICAL SNOW HARDNESS PROFILES USING THE SNOWMICROPEN, SNOW SCOPE, AND MANUAL METHODS

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Spatial information on snow strength is difficult to collect, interpret, and display. Hardness is often used as a proxy for strength because it is relatively easy to measure. Recent advances in low-cost digital probes may make collection of three-dimensional hardness information approachable for a number of applications in snow safety, as well as research in trafficability, wildlife, remote sensing, and a variety of other applications. We test profiles taken with the SnowMicroPen (SMP), Snow Scope digital probe, standard ram penetrometer, and other instruments to compare and evaluate the ability to reconstruct detailed hardness profiles, maximum hardness, total depth, and other properties. We also look at the instrument's capability for reconstructing important stratigraphic features over space. Measurements were made in Colorado and Wyoming subalpine snowpacks, and Alaskan boreal forest and tundra snowpacks.

Snow hardness penetrometers have been used since nearly the beginning of avalanche research, starting with the analog Ramsonde probe, which remains the most widely used penetrometer. The first automatically recording penetrometer, the Snow Resistograph, was developed by Charles Bradley in the late 1960's, and recorded the penetration resistance on a roll of paper as the probe was pressed into the snow. In the 1990's, the SABRE probe was developed as the first digital snow penetrometer which recorded data on a Blackberry, and in the 2010's the Avatech SP2 became available, which integrated a microcontroller into the probe handle. These cost-effective probes all had a similar goal of measuring snow stratigraphy and hardness, but were challenged by the accuracy of the depth at which each measurement was made. More recently, the Snow Scope (Propagation Labs) and the Lyte probe (Real Adventure Data) have become available.

In parallel, starting in the 1990's, both the U.S. Army CRREL and the WSL Swiss Federal Institute for Snow and Avalanche Research SLF began development of a high-resolution penetrometer, and co-developed the SnowMicroPenetrometer (SMP). While this tool is much larger, heavier, and an order of magnitude more expensive than the other penetrometers, it has very accurate vertical positioning and makes 250 penetration force measurements per mm. SLF has continued to improve and develop this instrument, and it has been used in a wide range of

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research for both avalanche and remote sensing applications. While it is too expensive and heavy for most avalanche practitioners, it remains the most accurate validation tool for testing new penetrometers targeting the avalanche community.

In this work, we measured profiles with the Snow Scope and the SMP, taken in support of research in remote sensing (NASA SnowEx Alaska, and NASA JPL Signals of Opportunity), as well as wildlife studies. The variables of interest and possibly attainable from the digital probes are stratigraphy and bulk snowpack properties (density and snow water equivalent (SWE)) for remote sensing, and near-surface hardness of snow layers for raptors that access prey in the subnivean environment, sometimes impeded both by excessive depth and/or impenetrable layers such as crusts or ice lenses. These same physical properties and the ability to derive them from a digital probe profile are potentially useful to many snow applications including a variety of avalanche applications.

Jon Maakested(left) inserts a SnowScope, while Zach Keskinen (right) operates the SnowMicroPen north of the Brooks Range in Alaska during the 2023 SnowEx Alaska campaign.