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Automated delineation of snowpack stratigraphy using a high-resolution snow penetrometer

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Slab avalanches require the presence of weak layers or interfaces within the snowpack. Determining the presence and character of these layers or interfaces is essential for avalanche hazard evaluation and forecasting. The SnowMicroPen (SMP) improves our ability to quickly identify stratigraphic properties, including weak layers, and to assess snow hardness, a proxy of snow strength. Recent research shows that this high-resolution penetrometer can identify thin weak layers and detect changes in the hardness of weak layers and their boundaries with adjacent strata. However, these techniques rely on the time-consuming procedure of manually delineating stratigraphic boundaries.

In this study, we develop SMP signal analysis techniques to automatically delineate stratigraphic boundaries within seasonal snowpacks. We utilize data collected between 2002 and 2005 in the eastern Swiss Alps and in the Rockies of Southwestern Montana, USA. To identify transitions in stratigraphic hardness, a moving-window regression calculates the first and second derivatives of the penetration hardness for each SMP profile. Transitions in the variance of micro-structural hardness were identified with a moving-window coefficient of variation function, as well as its derivatives. We ranked all transitions as a function of their acuteness and then compared them with manually delineated boundaries, as well as with boundaries observed in traditional manual snow profiles and stability tests.

Our automated signal analysis techniques detected most observed stratigraphic boundaries, including critical weak layer boundaries. High-ranking transitions often coincide with boundaries observed in traditional manual snow profiles and stability tests,

suggesting that the automated delineation technique works for the stratigraphic evaluation of the snowpack. This advance now allows the rapid analysis of large spatial datasets produced by the SMP. Analyzing these datasets, in turn, may prove useful for efficiently acquiring and analyzing stratigraphic information essential for accurate avalanche prediction.