Variability of snow thickness changes in steep rock faces based on Terrestrial Laser Scanning

**Motivation & Objectives**
The knowledge of the distribution of snow in very steep alpine terrain is important for hydrology, avalanche forecasting, slope stability (rock fall), ecology and climatology.
The goal of the project was to better understand what processes and parameters influence the snow cover in rock faces, especially during snowfall events. Terrestrial Laser Scanning (TLS) was used to measure snow thickness changes in two different rock faces.

**Variability of the Snow Distribution**
In previous studies, the variability of snow thickness was observed to be high. Dominant processes are a spatially variable snowfall (preferential deposition) and redistribution of snow by wind and avalanches.
Important terrain parameters are slope angle, roughness, exposition and wind exposure. Most studies treated gentle terrain, not much is known about snow in rock faces.

**Terrestrial Laser Scanning (TLS)**
TLS is a remote sensing technology to measure surfaces. The target surface is discretized as a point cloud. The range for each point is determined by measuring the time of flight of a laser signal.
Advantages of TLS is the high point density, precision and a large measurement range (6 km).

**Acquisition and Processing of Data**
Measurements were made at two different locations (Schiahorn and Sattelhorn) with two different laser scanners (Riegl LPM-321 and YZ-6000). The rock faces were scanned before and after snowfall events. By comparing these two scans, snow thickness changes can be computed. The scans must first be transformed to a common coordinate system. This process is called registration and is the most important step during postprocessing.

**Precision of snow thickness changes**
The main source of error is an imprecise registration. A process called Multi Station Adjustment (MSA) can correct registration errors. After MSA, reproducibility measurements showed an absolute mean deviation < 4 cm.
The figures show deviations between repeat measurements.

**Snow Accumulation in very steep terrain**
Schiahorn - In contrast to assumptions in previous studies, snow was observed to be accumulated and stored for at least 10 days in terrain up to 70° steep. The figure shows averaged transects of snow accumulation and slope angle across the slope toe boundary (transition from moderately steep to very steep terrain, vertical blue line).

**Snow redistribution by Wind and Avalanches**
Sattelhorn - Results showed clear evidence of snow redistribution by wind and avalanches. The left images show snow thickness changes, the right images shaded reliefs.
The top pair shows snow dunes (bright lines). These are surface features created by moderate winds. The lower pair shows an avalanche sliding surface and avalanche deposits.
At the Schiahorn location, small avalanches and sloughs redistributed snow from extremely steep to moderately steep terrain.

**Conclusions**
The main results are that TLS is only a viable experimental method if the registration is corrected with MSA and that a considerable amount of snow is accumulated and stored in very steep terrain.

**Selected Bibliography**