Impact of Adverse Weather Conditions on Snow Depth Monitoring with Automated Terrestrial Laser Scanning

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Overview

Automated Terrestrial Laser Scanning (ATLS) allows high spatio-temporal monitoring of snow depth changes at several kilometres distance. However, ATLS observations may be **hampered by poor visibility** (e.g. due to snowfall, blowing snow or fog). In this contribution we present results from a **systematic analysis** of the impact of **adverse weather conditions on ATLS snow depth retrievals**.

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Methodology

From single scan snow depth mapping…

Terrestrial Laser Scanning is a ground-based, close-range sensing technique. It allows dense sampling of a surface by converting distance ($\mathbf{r}$) and angle measurements ($\boldsymbol{\theta}$ and $\boldsymbol{\varphi}$) to **3D point clouds** (Fig 1).

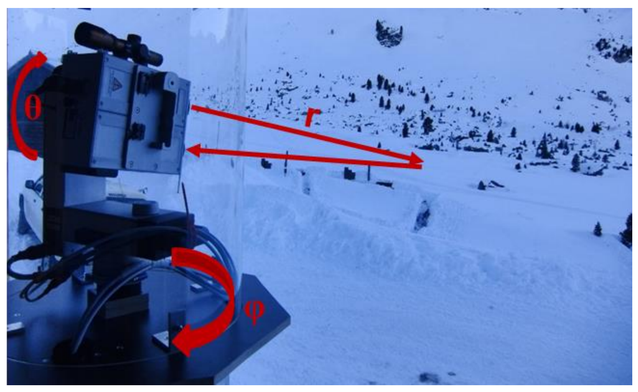

Fig 1: Measurement principle

Snow depth is not measured directly, but calculated by comparison of the snow surface measurements with previously recorded snow-free terrain heights (Fig 2).

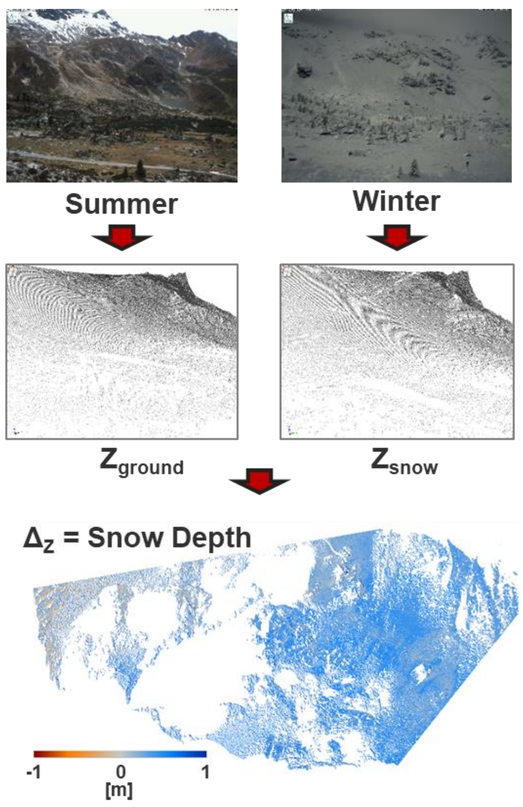

Fig 2: Snow depth map

…to multitemporal snow depth monitoring

Fig 3: ATLS setup on-site

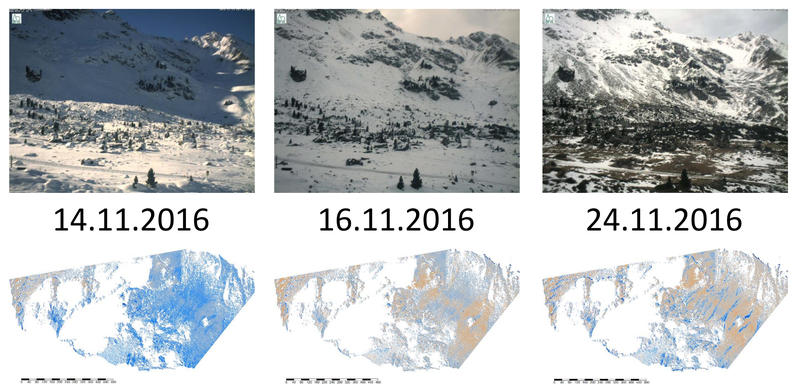

Fig 4: Exemplary ATLS time series (webcam image and snow depth map)

The **ATLS** instrument (Riegl LPM-321) was installed in a weatherproof, transparent glass fibre enclosure (Fig 3). It was **setup to automatically acquire data** at defined intervals, according to a task list (Fig 4). A remote connection allowed changing its settings and defining tasks. All measurements were fed into a **database** to be **checked, referenced and visualized** (Fig 5).

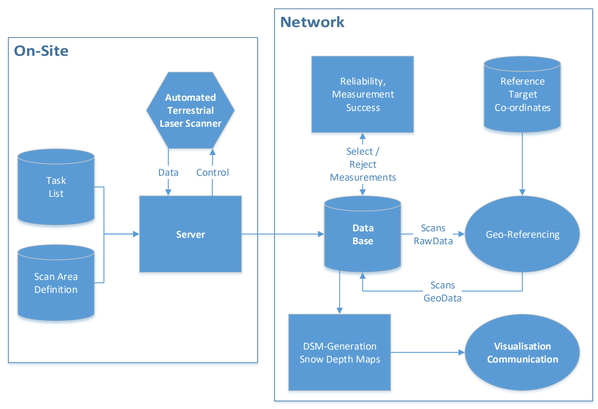

Fig 5: ATLS workflow

Data Acquisition and Analysis

Study Site

Our high-Alpine **study site** was located in the Tuxer Alps of Western Austria, approx. 30km from Innsbruck (Fig 6). During the winter 2016/17, our **ATLS-setup** located there, **recorded 1,057 scans** over a **6-month period**.

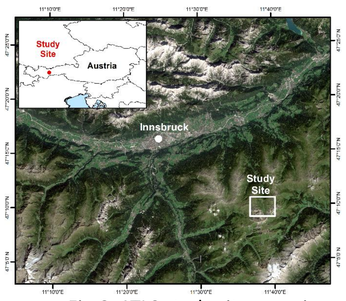

Fig 6: ATLS study site overview

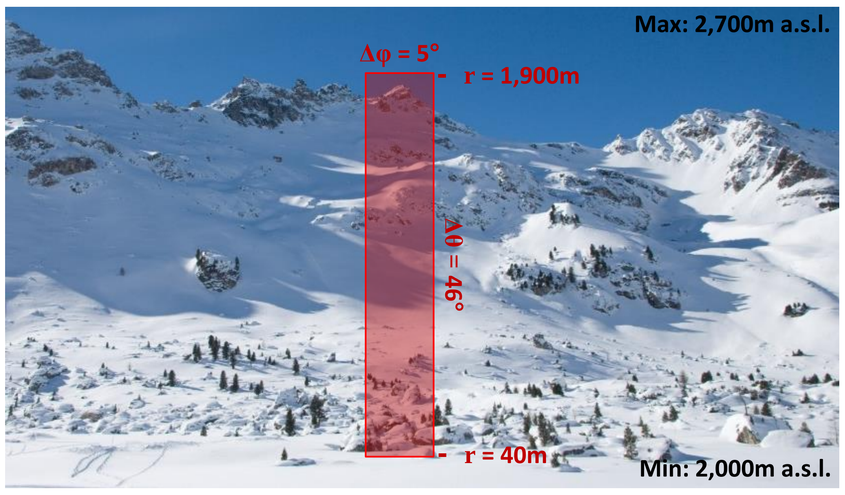

Fig 7: Scan area location and properties on investigated slope

Each scan mapped the same section of an **east-facing slope** along a **narrow, vertical strip** (approx**. 250,000 point measurements**). This was done to minimise the **duration** of data acquisition (**8-10 min**), while covering **distances** of **40 to 1,900 m** from the scanner location (Fig 7).

Results

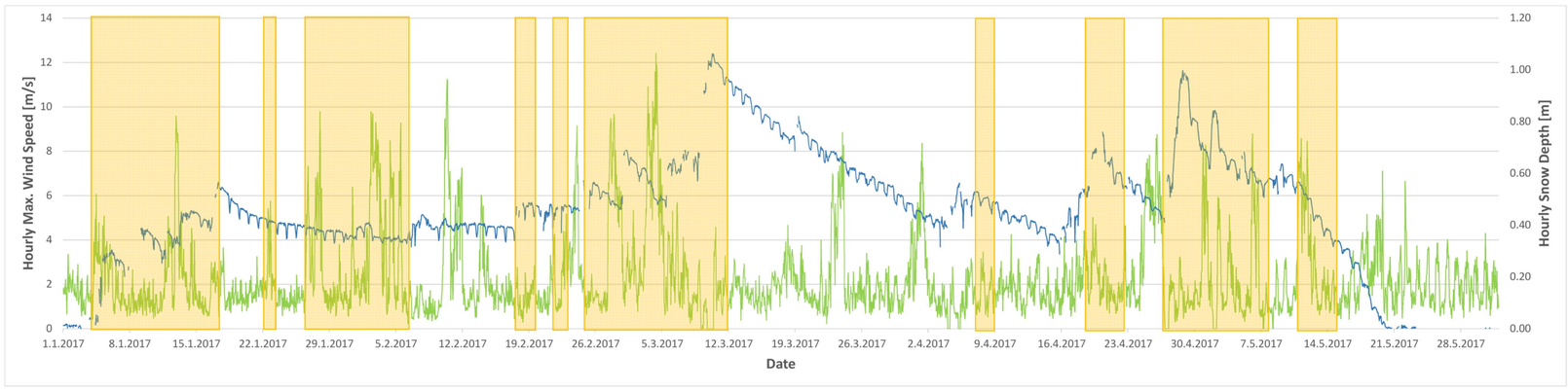

Fig 8: Automatic weather station data recorded near the ATLS (wind speeds & snow depth); scan periods are highlighted in orange.

The quality of the scans was analysed regarding completeness (data vs. no data / air vs. surface point) and precision (repeatability of measurements classified as 'surface point'). This quality indicator was then correlated with different meteorological variables and their intensity during the measurement period (Fig 8).

The results indicated that the meteorological factor with the strongest impact on scan quality was intense snow fall. It resulted in up to 60% of scans performed during a snow fall period being incomplete (Fig 9). Although the study site is very exposed to Föhn, high wind speeds resulted in very few incomplete scans.

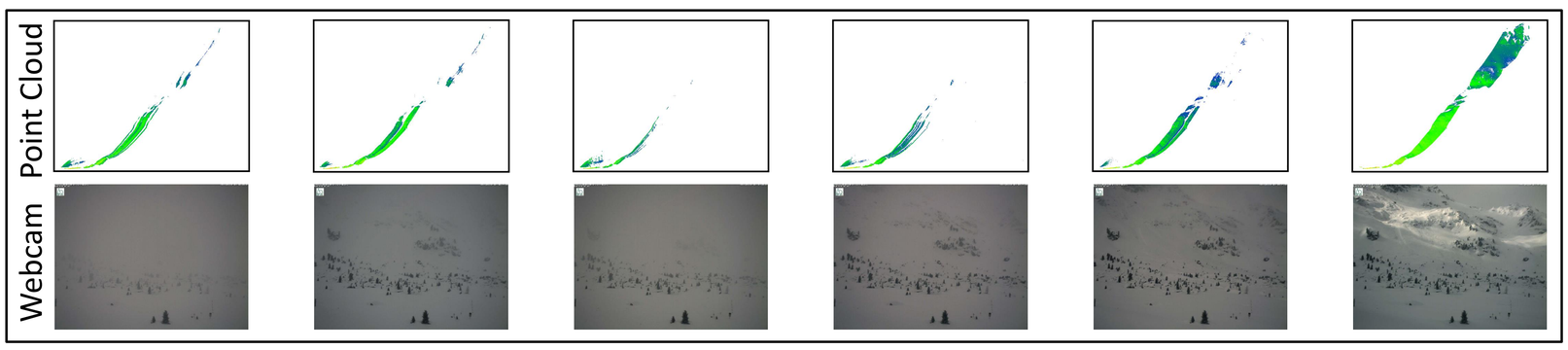

Fig 9: ATLS point clouds retrieved every 30 minutes on 10th March 2017 between 9:00 and 11:30 (upper row); corresponding webcam images (bottom row).

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