Five Years of Monitoring the Front Slope of the Highly Active Hinteres Langtalkar Rock Glacier Using Terrestrial Laser Scanning: A Case Study in the Central Alps, Austria

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Measurement System

Terrestrial long-range laser scanning is a quite new technique for glacier and rock glacier monitoring. The ability to acquire high-resolution 3D data of surface structures makes laser scanners a very interesting instrument for measuring glacier dynamics. Single time-of-flight measurements are automatically combined to a measurement grid.

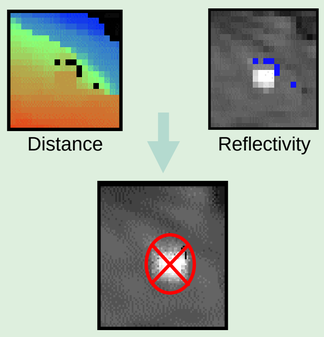
The integrated system is capable of describing 3D motion and deformations of glacier surfaces within a single day's measurement campaign, including logistics and evaluation.

Riegl LPM-2k Long Range Laser Scanner	
Scanner parameter	*Value (range)*
Measuring range for	
- good diffusely reflective targets	Up to 2500m
- bad diffusely reflective targets	> 800m
Ranging accuracy	± 50mm
Positioning accuracy	± 0.01gon
Measuring time / point	0.25s to 1s
Measuring beam divergence	1.2mrad
Laser wavelength	900nm
Scanning range hor. / vert.	400gon / 180gon
Laser safety class	3B, EN 60825-1
Power supply	11-18V DC, 10VA
Operation temperature range	-10 to +50°C

Sensor Orientation

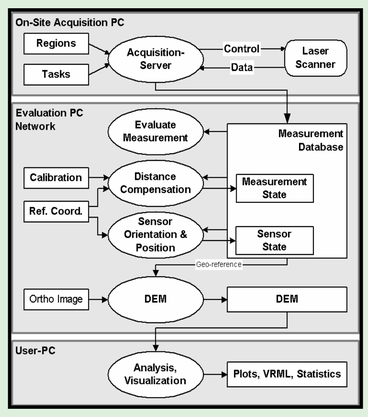
To guarantee the comparability of measurements:
- compensate orientation (due to new scanner positioning or slight misalignments)
- compensate distance measurements (due to atmospheric influences)

Use circular reflecting point targets fixed on stable surfaces somewhere in the spherical field-of-view of the sensor.



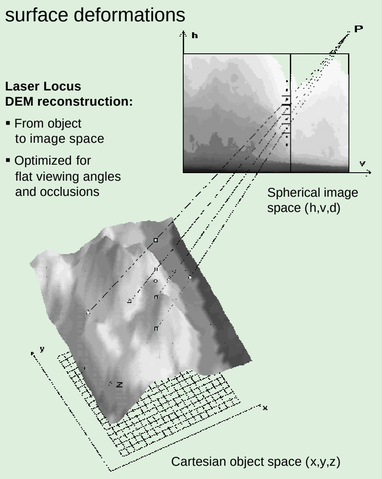
Data Acquisition and Analysis

Software GeoServer:
- Project definition: regions-of-interest, measuring sequence, starting time and repetitions, different acquisition strategies
- Fully automated data acquisition
- Semi-automatic data analysis



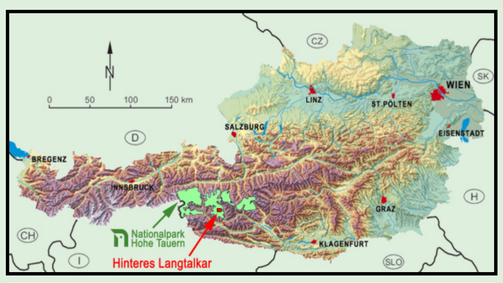
Data Analysis:
- Generate a Digital Elevation Map (DEM) using Laser Locus Method
- Differences between DEMs describe 3D surface deformations

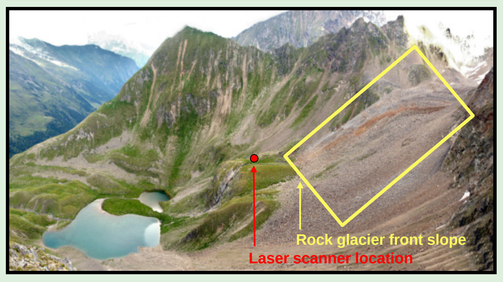
Laser Locus DEM reconstruction:
- From object to image space
- Optimized for flat viewing angles and occlusions



Hinteres Langtalkar Rock Glacier

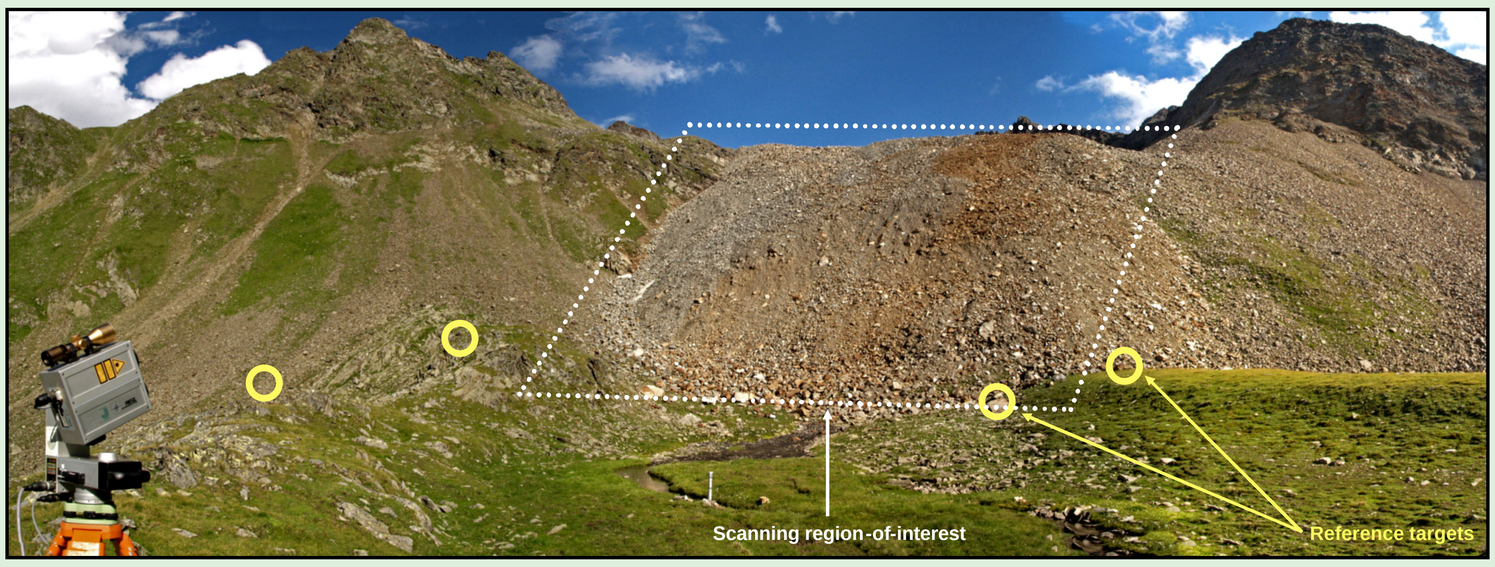
Location of Hinteres Langtalkar rock glacier:
part of Hohe Tauern National Park
(Schober group, Central Alps, Austria)





Measurement campaigns:
- July 12, 2000
- August 21, 2000
- July 26, 2001
- August 24, 2001
- August 19, 2004

- Measurement expenditure: 5 to 6 hours
- Orientation accuracy: 0.2 to 0.5m
- Geodetic network of 5 reference points.
- Sensor orientation: before & after main measurement.
- Sensor location: at a distance of about 100m to the foot of the rock glacier front slope.
- Angular resolution: about 0.5m at the center of the front slope (mainly limited by acquisition time), totally 140x200 single measurements.
- Valid measuring points: about 94%



Results

Laser scanner measurement:

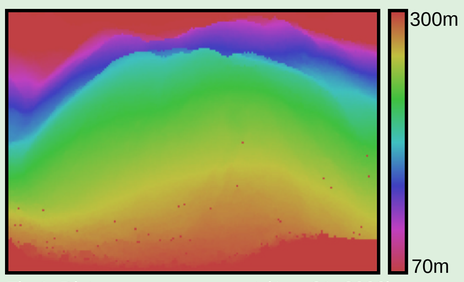


Fig.1: Distance measurement (Aug 21, 2000)

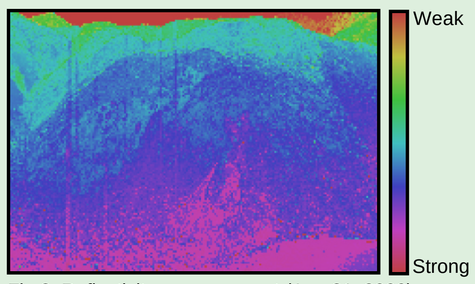


Fig.2: Reflectivity measurement (Aug 21, 2000)

Digital Elevation Map:

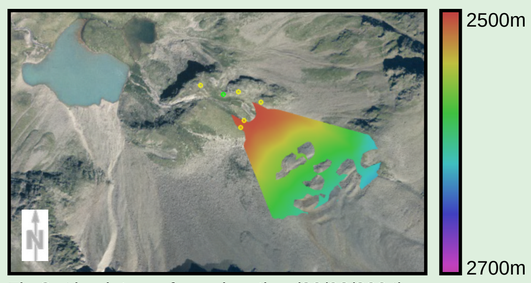


Fig.3: Absolute surface elevation (20/08/2004)

- Accuracy of difference measurements: Stable areas outside the rock glacier show an RSME of 11cm and a systematic difference of 3cm in height.

- Fig.4 and 5 shows a debris flow event. The flow has been caused by subsurface drainage after heavy rainfall. The spatial distribution of the observed mass movement can be identified and numerically evaluated.

Difference Digital Elevation Maps:

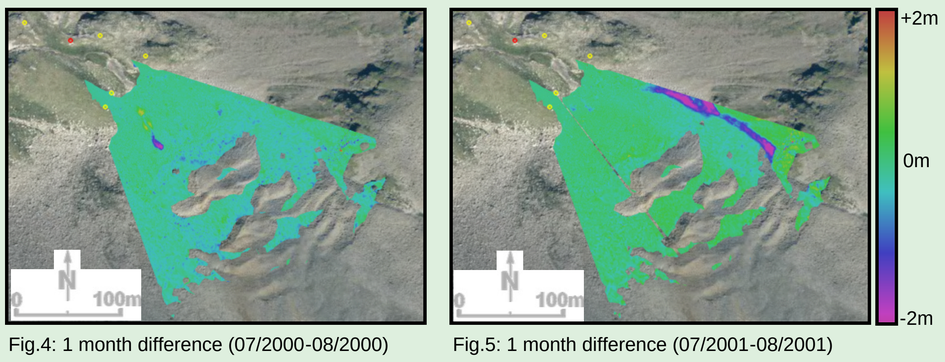


Fig.4: 1 month difference (07/2000-08/2000)

Fig.5: 1 month difference (07/2001-08/2001)

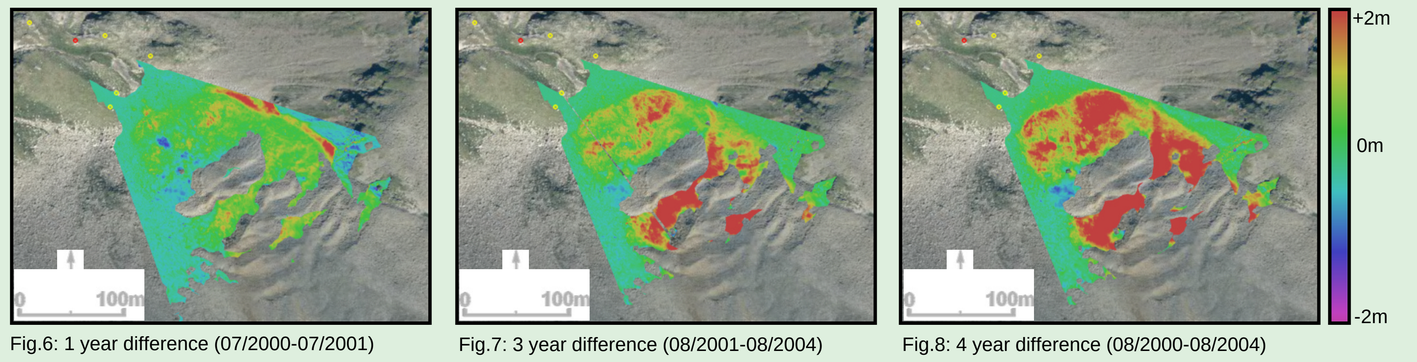


Fig.6: 1 year difference (07/2000-07/2001)

Fig.7: 3 year difference (08/2001-08/2004)

Fig.8: 4 year difference (08/2000-08/2004)

Surface structure velocity field:

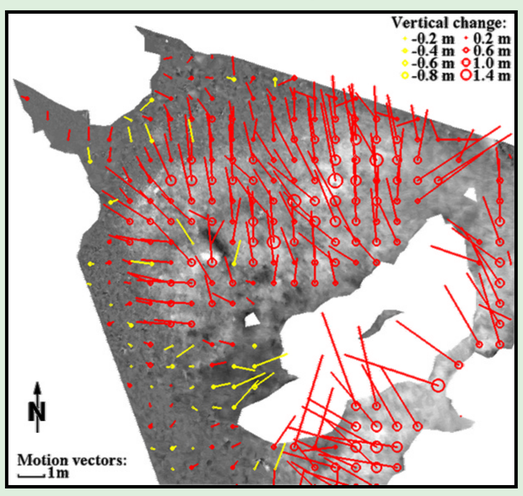


Fig.9:

Analysis by surface structure matching:
Change between 08/2000 and 08/2001.

Circles describe vertical changes;
vectors display the horizontal movement.

Horizontal motion: up to 1.5m a^{-1}.
Vertical deformation: up to 1.2m a^{-1}.

Conclusions

- Monitoring of rock glacier front slope with high temporal and spatial resolution is feasible.
- Operational system is available as mobile or stationary unit.
- 3D high resolution surface deformation data is obtained by DEM difference analysis.
- Both global permafrost (rock glacier velocity field distribution) and local geomorphic (debris flows, rock falls) effects can be identified and evaluated.
- Quantification of local mass movements.
- Results are available immediately after measurement.
- Accuracy depends on viewing geometry and footprint size of the laser beam.
- Dangerous field work on highly active rock glaciers can be avoided.
- Same methods can be applied to debris covered glaciers, snow cover determination, and rock slide monitoring.