CONTRIBUTION OF TERRESTRIAL LASER SCANNING TO THE LONG-TERM MONITORING OF HIGH-MOUNTAIN SLOPE DYNAMICS IN THE VALAIS ALPS, SWITZERLAND

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Climate change is increasingly impacting the **stability** of **high-altitude mountain slopes** under **permafrost conditions**, triggering **rockwall destabilization**, **landslides**, and **rock glacier acceleration**. At the catchment scale, such dynamics modify the **sediment transfer**, with **cascading consequences** when the mountain top is **connected** to the valley floor. Since the **1990s**, the Geomorphology research group at the University of Fribourg has been investigating some of these processes in the **Valais Alps** and surrounding regions.**Terrestrial Laser Scanning** (TLS) contributes to the multi-decadal observational framework and complement the existing methods, providing **high-resolution morphometric data** on, for instance, **rockwall (in)stability**, **rockfall volumes**, and **sediment budget** of **torrential gullies**.

STUDY SITES

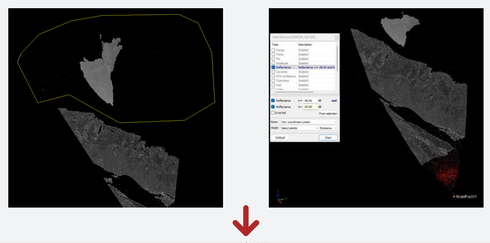




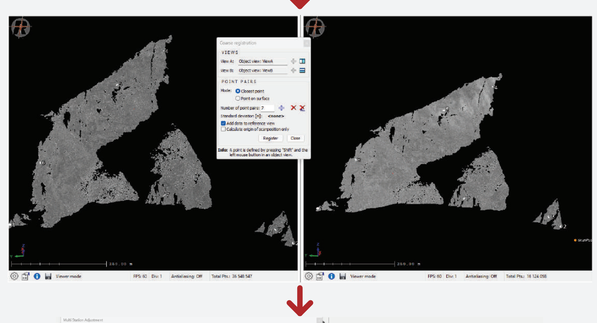
RiSCAN PROCESSING

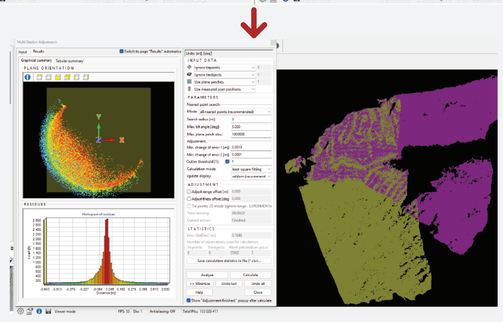
RiSCAN PRO
for *RIEGL* 3D Laser Scanners

Cleaning up
manual + automatic



Coarse registration

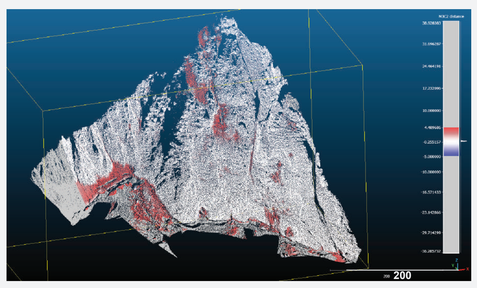


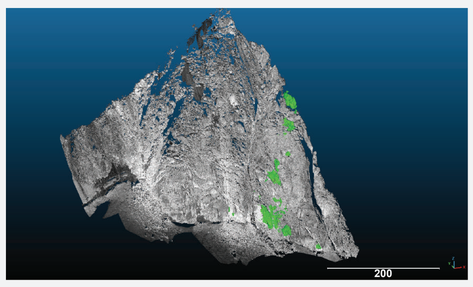


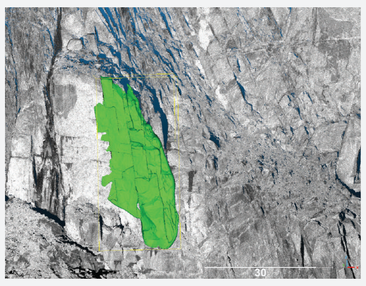
Multi station alignment

CLOUDCOMPARE PROCESSING

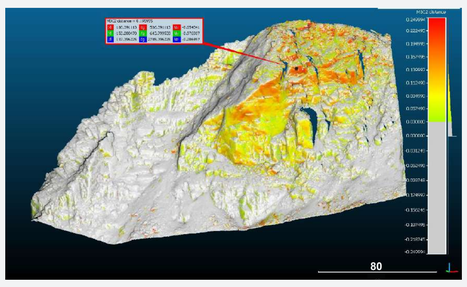
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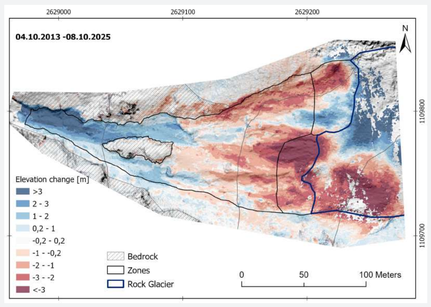




TILTING MONITORING

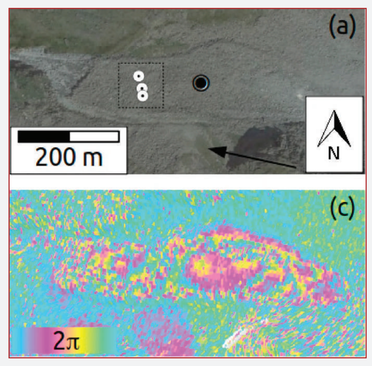


SURFACE CHANGES



OTHER MONITORING TECHNIQUES

InSAR MONITORING
Started in 1995



TEMPERATURE DATALOGGER
Started in 1997



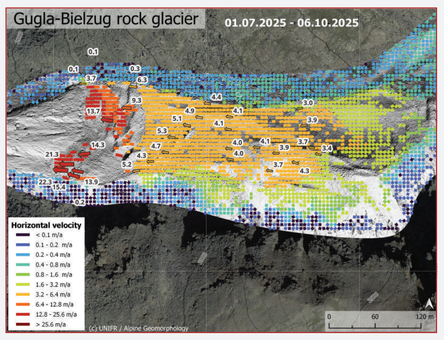
GNSS MEASUREMENTS
Started in 2001



WEBCAM MONITORING
Started in 2009



UAV SURVEYS
Started in 2021



The **long-term**, **multi-method monitoring** approach developed at the University of Fribourg addresses a critical gap in the current literature, as few studies to date combine multi-decadal datasets with such a broad instrumental framework to **characterize slope dynamics in periglacial environments**. From a LiDAR perspective, although the data processing workflow would benefit further refinement, the results obtained are encouraging and demonstrate the **potential of TLS for quantifying morphological changes over time**. Beyond their scientific contribution, these observations carry **significant applied value**: their **integration with local authorities** and **cantonal risk management services** offers a concrete pathway toward **improved hazard anticipation** and **evidence-based mitigation strategies** in a rapidly evolving alpine landscape.

Courtial-Manent, L., Ravanel, L., Mugnier J.-L., Deline, P., Lhosmot, A., Rabatel, A., Duvillard, P.-A., Batoux, P. (2024). 18-years of high-Alpine rock wall monitoring using terrestrial laser scanning at the Tour Ronde east face, Mont-Blanc massif. Environment Research Letters, 19 034037, DOI 10.1088/1748-9326/ad281d

Kellerer-Pirklbauer, A., Bodin, X., Delaloye, R., Lambiel, C., Gärtner-Roer, I., Damm, B., Ikeda, A., Kaufmann, V., Krainer, K., Seppi, R., Scapozza, C., Stocker-Waldhuber, M., Thibert, E. (2026). Rock glacier velocity monitored by annual in-situ geodetic surveys: Long-term challenges, solutions and suggestions. Geomorphology, 495 (2026) 110117, DOI 10.1016/j.geomorph.2025.110117

Hendrickx, H., Le Roy, G., Helmstetter, A., Pointner, E., Larose, E., Braillard L., Nyssen, J., Delaloye, R., Frankl A. (2022). Timing, volume and precursory indicators of rock- and cliff fall on a permafrost mountain ridge (Mattertal, Switzerland). Earth Surface Processes and Landforms, 1–18. DOI 10.1002/esp.5333

Hendrickx, H., Le Roy, G., Helmstetter, A., Pointner, E., Larose, E., Braillard L., Nyssen, J., Delaloye, R., Frankl A. (2023). Multi-method monitoring of a failing rock face, Swiss Alps. 5th Virtual Geoscience Conference, Dresden, Germany

Kummert, M. & Delaloye, R. (2018). Mapping and quantifying sediment transfer between the front of rapidly moving rock glaciers and torrential gullies. Geomorphology 309, 60-76. DOI: 10.1016/j.geomorph.2018.02.021

Strozzi, T., Caduff, R., Jones, N., Barboux, C., Delaloye, R., Bodin, X., Kääb, A., Mätzler, E., Schrott, L. (2020). Monitoring rock glacier kinematics with satellite synthetic aperture radar. Remote Sensing, 12(3) 559, DOI: 10.3390/rs12030559