Oral presentation

30 years (1995-2025) of measuring the velocity of the Dösen rock glacier in Austria: Overview and climatic significance

Viktor Kaufmann

Institute of Geodesy
Working Group Remote Sensing and Photogrammetry
Graz University of Technology
Steyrergasse 30, 8010 Graz
e-mail: viktor.kaufmann@tugraz.at
https://www.staff.tugraz.at/viktor.kaufmann/

Andreas Kellerer-Pirklbauer

Department of Geography and Regional Science
Research Group Cascade
University Graz
Heinrichstraße 36, 8010 Graz
e-mail: andreas.kellerer@uni-graz.at
https://geographie.uni-graz.at/

Table of contents

1 Introduction and motivation

1.1 Definitions: rock glacier & permafrost

- **Rock glacier:** Rock glaciers are composed of frozen debris and interstitial ice or ice lenses of variable sizes. They move downhill by creep and sliding (along distinct horizons), driven by gravity. Rock glaciers are striking visual representations of mountain permafrost and can be found in all alpine regions of the world. https://www.rgik.org/what-are-rock-glaciers/

- **Permafrost:** Permafrost is defined as any ground (soil, rock, or organic material) that remains at or below 0°C for at least two consecutive years. https://www.permafrost.org/what-is-permafrost/

  Thus, rock glaciers must not be confused with glaciers.

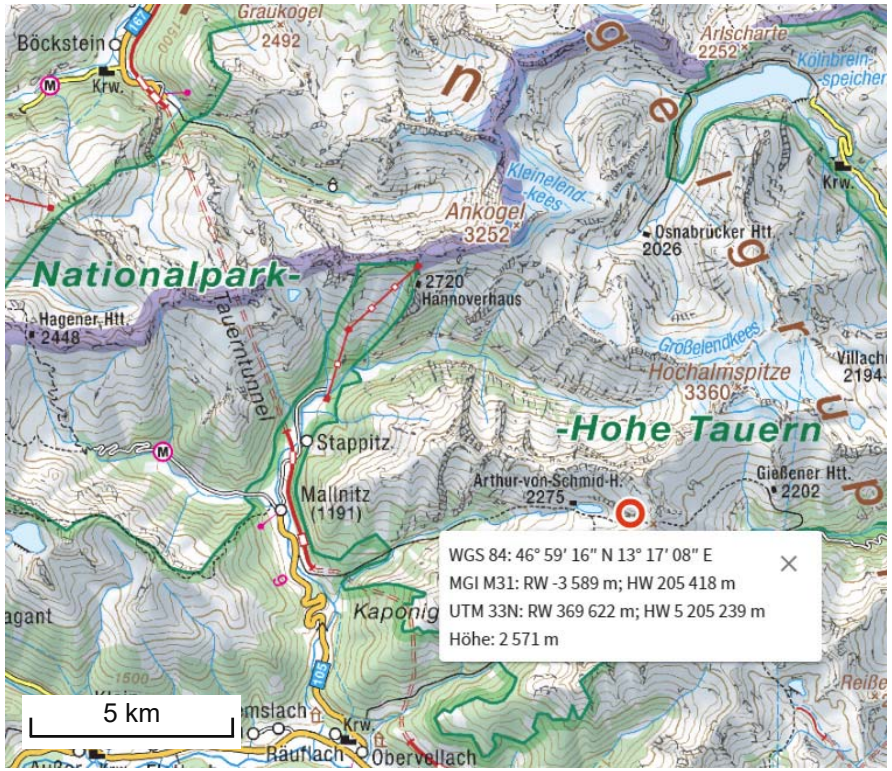
1 Introduction and motivation | 1.2 Rock glacier velocity (RGV)

- **Rock Glacier Inventories and Kinematics (RGIK):** RGIK is a Standing Committee of the International Permafrost Association (IPA). The mission of RGIK is to coordinate the global compilation and distribution of standardized rock glacier products, as well as foster international collaboration and advance the understanding of rock glaciers. https://www.permafrost.org/ and https://www.rgik.org/

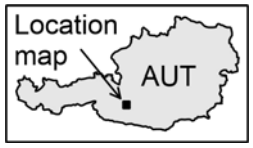
- **RGV:** In 2022, rock glacier velocity (RGV) was officially accepted by the Global Climate Observing System (GCOS) as an essential climate variable **(ECV)** quantity because the variability of RGV is generally influenced by topoclimatic conditions. RGV is categorized under the ECV permafrost, complementing established parameters like permafrost temperature and active layer thickness.

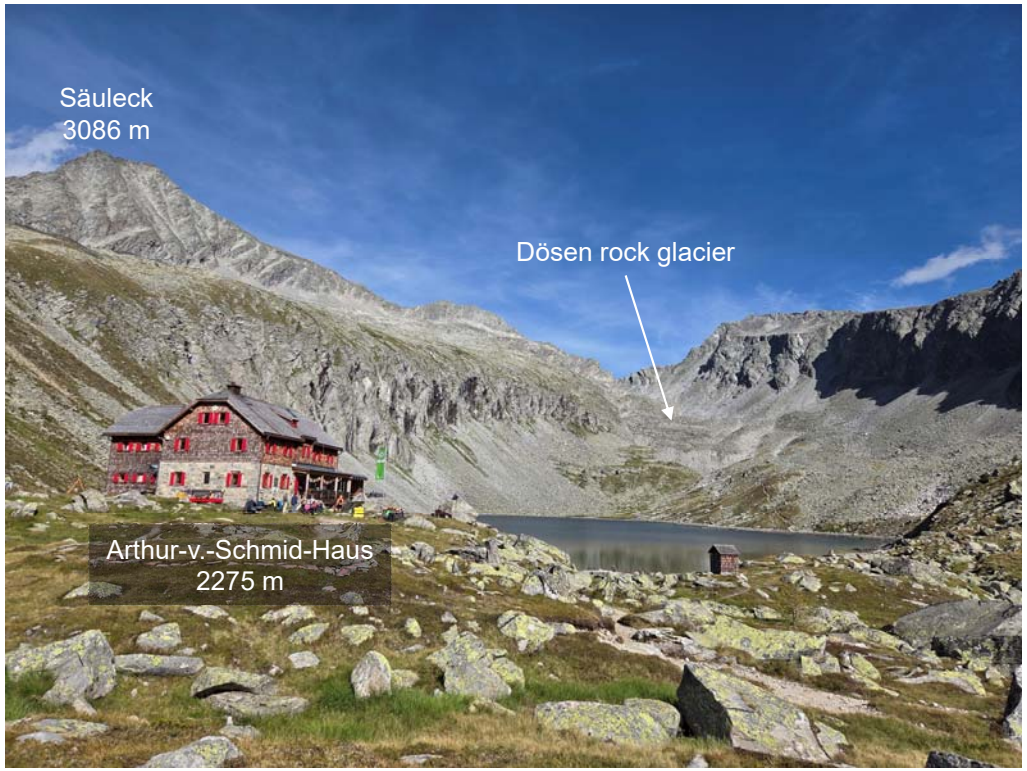
  RGV is a working group of RGIK and focuses on the defining requirements, best practice documents, and processing tools for the production of the new ECV associate parameter RGV.
  The group aims to enhance the systematic production and data compilation of long-term velocity time series on rock glaciers, to be used as climate change indicator.

1 Introduction and motivation | 1.3 Dösen rock glacier



Location map, source: https://maps.bev.gv.at/



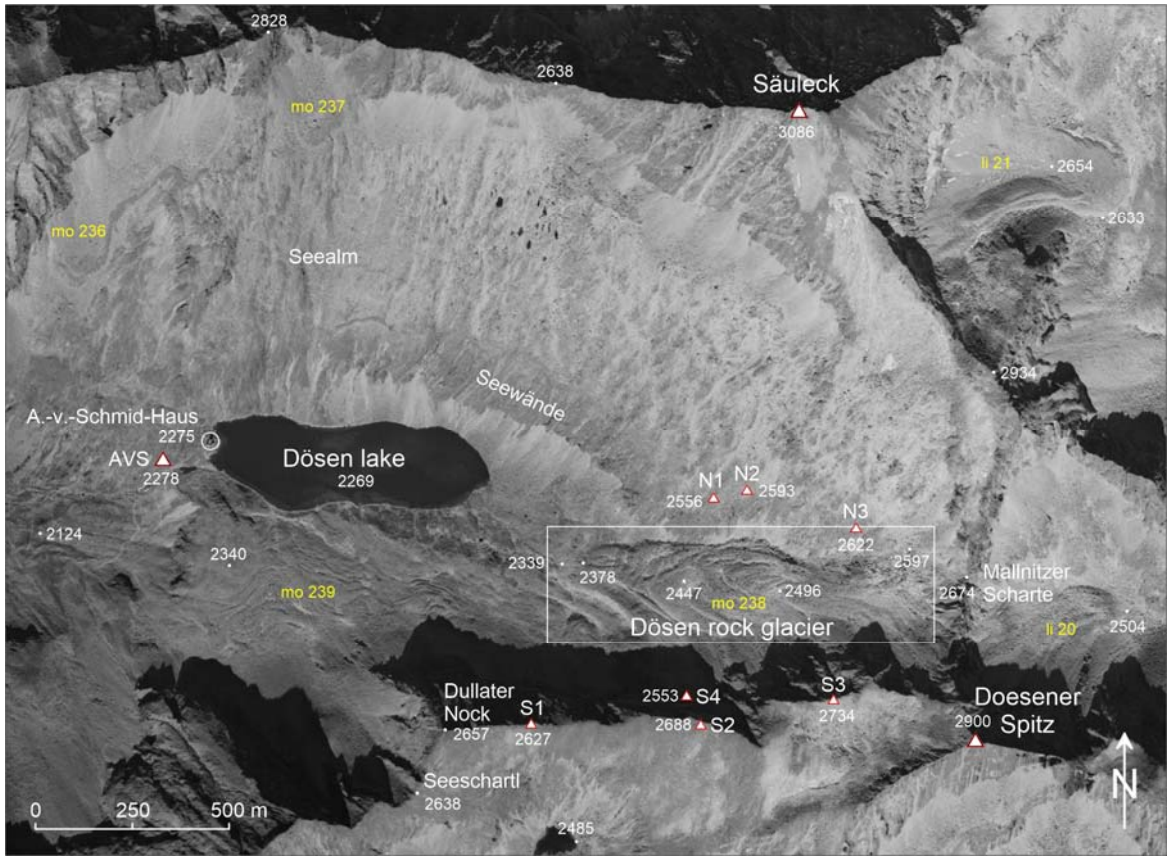


Head of Dösen valley with the Dösen rock glacier, August 25, 2025

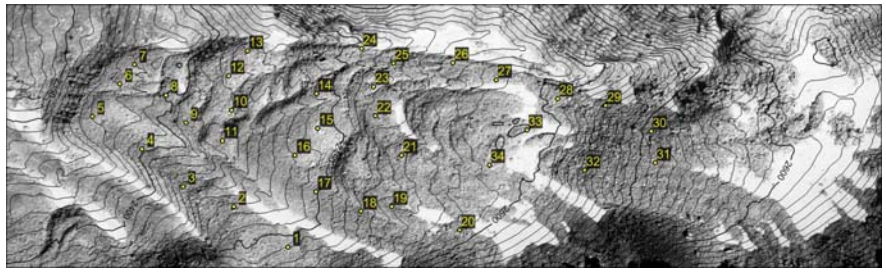
Anniversary celebration of the Graz Permafrost Research Group
at Arthur-von-Schmid-Haus, August 27, 2025

2 Data acquisition 2.1 Geodetic network

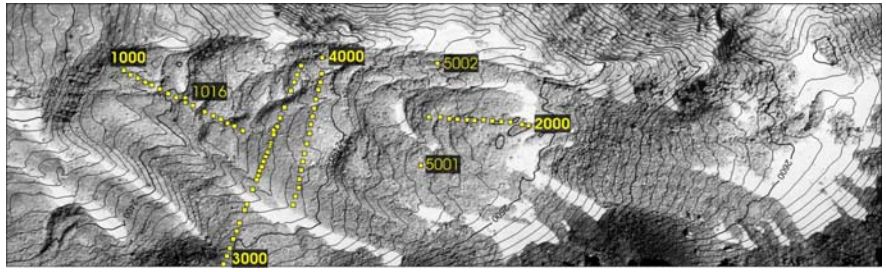
The geodetic monitoring started in 1995 with the establishment of an observation network consisting of stable reference points and 34 presumably moving observation points, stabilized with brass bolts, on the rock glacier.



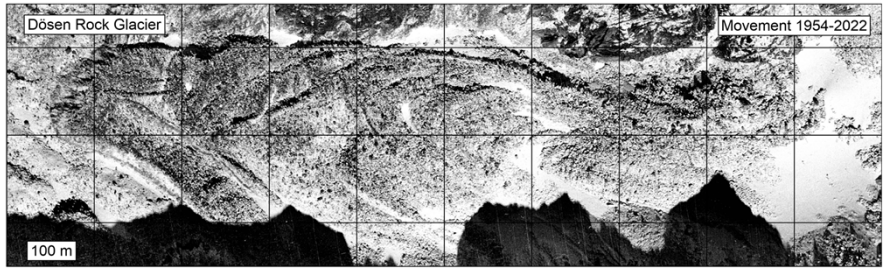
Location of the geodetic reference points



34 observation points



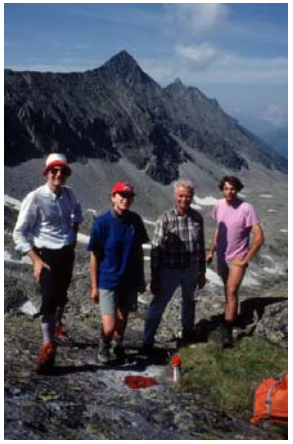
2 longitudinal and 2 transversal profiles



Time-lapse animation

2 Data acquisition 2.1 Geodetic network

Gerhard Kienast at point S1, July 26-28, 1995



Kaufmann, Tilg, Kienast, Heiland

Check point at S4

Geodetic survey at the triangulation point AVS, August 12-15, 1997

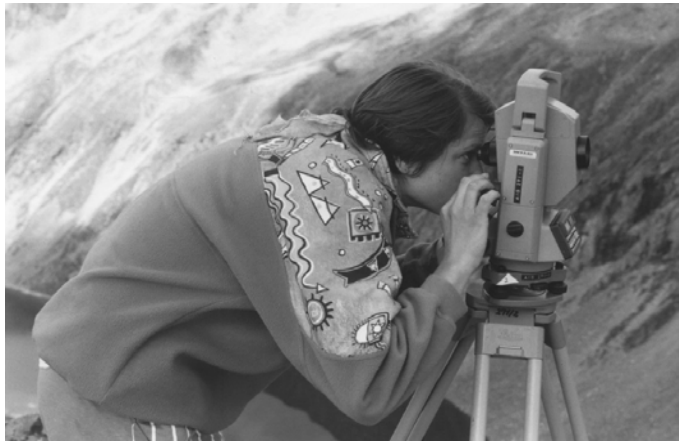
Transport of heavy geodetic equipment, August 13-21, 1995

Since 1995, the geodetic measurements have taken place every year at the end of August.

2 Data acquisition | 2.2 Using a total station: 1995-2013

Polar method surveying from point S4 August 13-21, 1995

Richard Ladstädter August 13-21, 1995



Regina Heiland August 5-11, 1996

Kaufmann, Ranner, Wipfler, Ladstädter August 13-21, 1995

2 Data acquisition | 2.3 Using RTK-GNSS: 2014 onwards

In 2014, the long-term geodetic measurements using a total station
were switched to the RTK-GNSS (Real-Time Kinematic - Global Navigation Satellite System) method.

RTK-GNSS base station, August 26, 2025

RTK-GNSS rover, August 15, 2017

2 Data acquisition | 2.4 Meteorological data

We used continuous ground surface temperature data from one site at the rock glacier surface (DOE-UP-N; 2006-2025; 2626 m asl; snow-influenced) and air temperature data from an automatic weather station located in the rooting zone of the rock glacier (DOE-AWS; 2006-2025; 2603 m asl). The air temperature data series for the period 1995-2006 was extended using correlation analyses by using data of a neighbouring high-altitude station, Sonnblick.

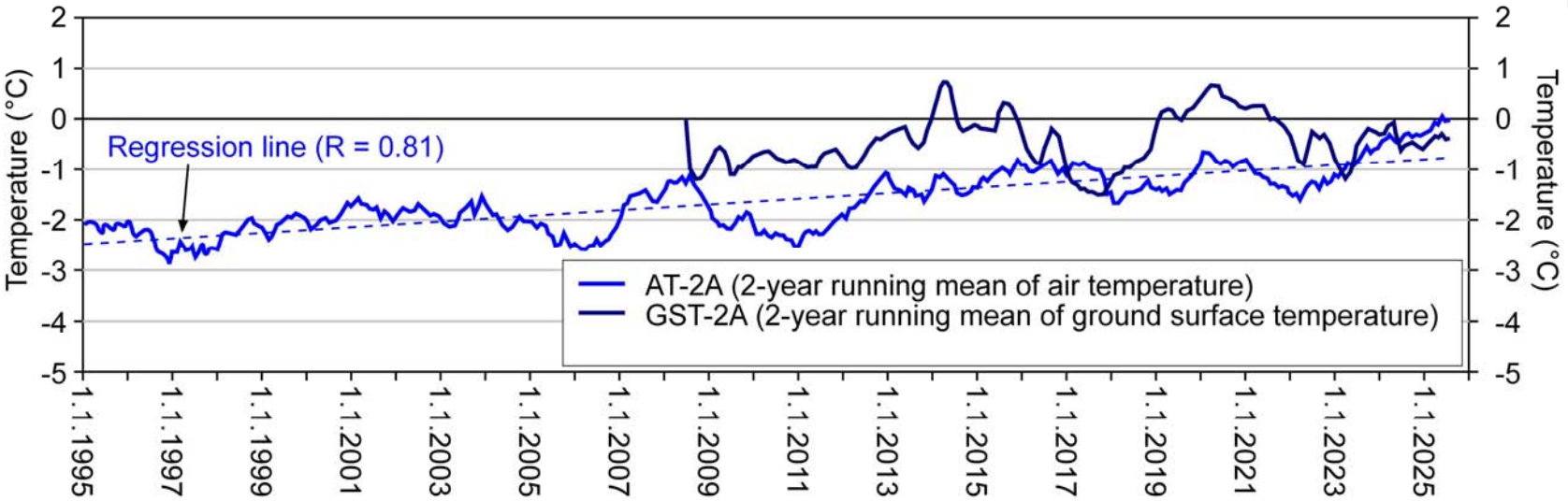


Figure: Running mean of the 24 previous months – of both, the air temperature at site DOE-AWS (AT-2A) and the ground surface temperature at site DOE-UP-N (GST-2A) for the period January 1995 to August 2025 from two monitoring locations at the rock glacier site.

3 Data processing

The working group Rock Glacier Velocity (RGV) of RGIK provides guidelines for the computation of Rock Glacier Velocity (RGV):

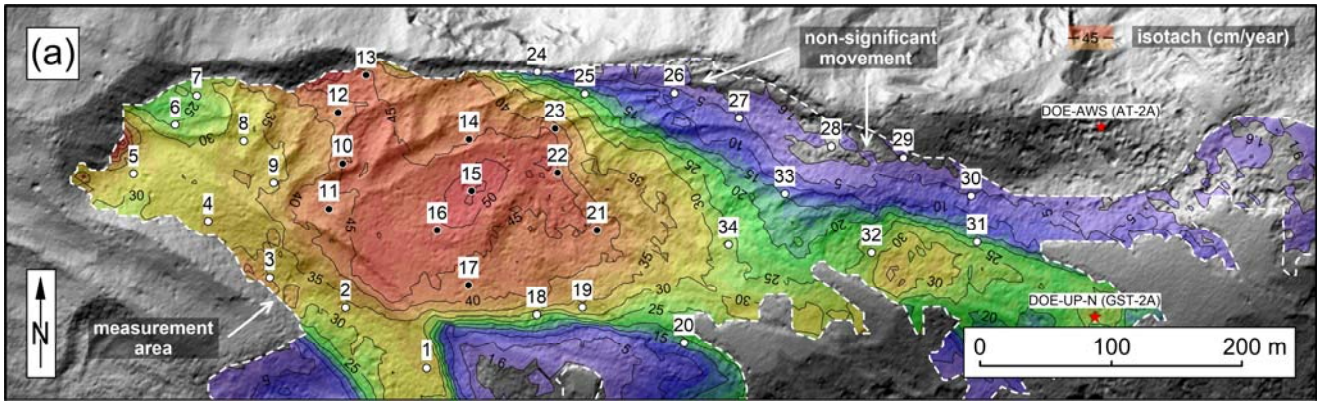
- Baseline Concepts Version 3.2
- Practical Concepts Version 1.2
  (see https://www.rgik.org/resources/)

- Self-developed Matlab routines

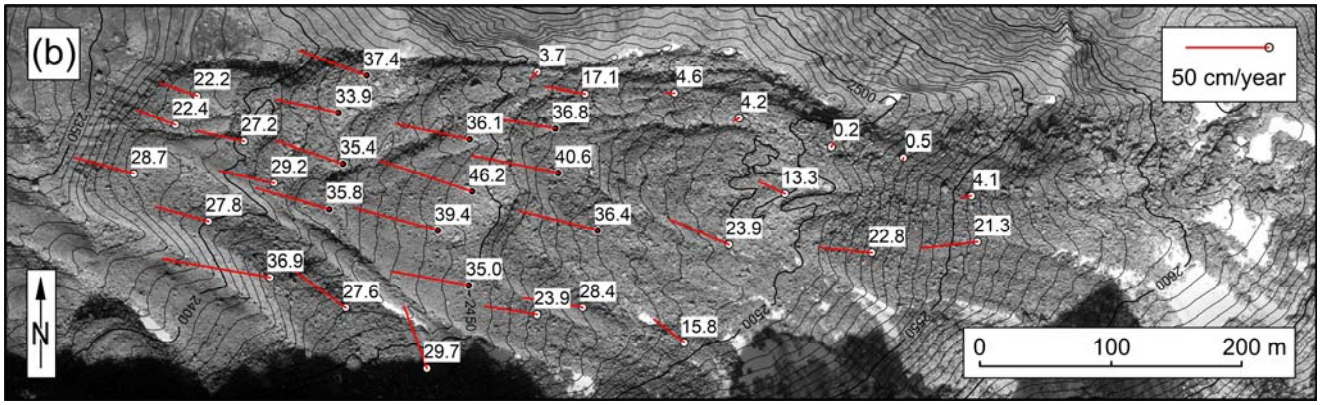
- Cécile Pellet (Department of Geosciences, University of Fribourg, Switzerland) developed a web-based processing tool: https://renkulab.io/p/cecile.pellet/rock-glacier-velocity

    1. Data exploration
    2. Data cleaning
        - Data completeness check
        - Velocity threshold
        - Outlier removal
    3. Gap filling
    4. Clustering

3 Data processing



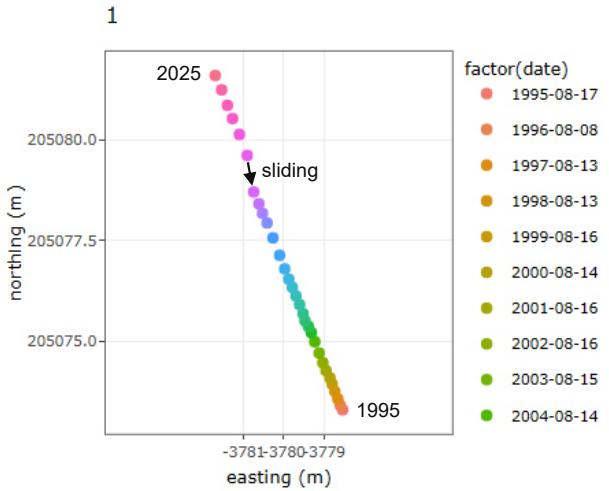
Thematic map showing photogrammetrically derived isotachs (cm/year) for the period 2013-2019

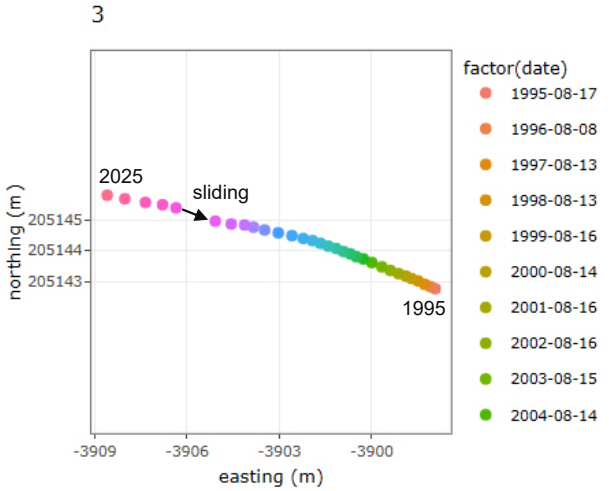


Displacement vectors (red) of the 34 geodetic observation points the period 1995-2025

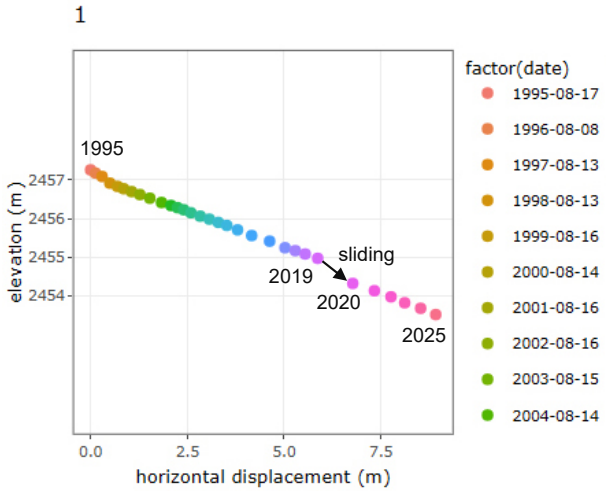
3 Data processing

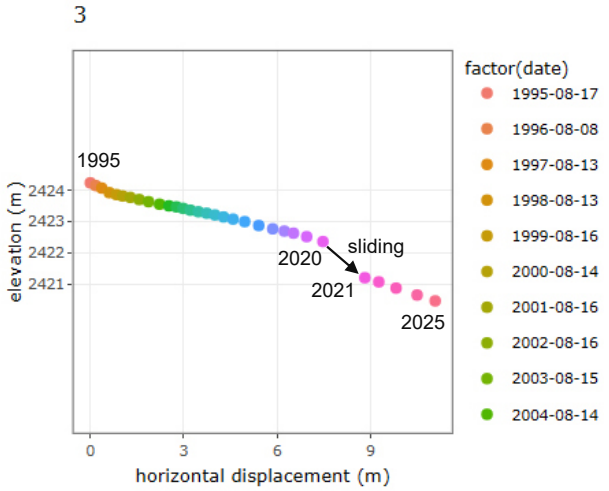
Horizontal displacement:





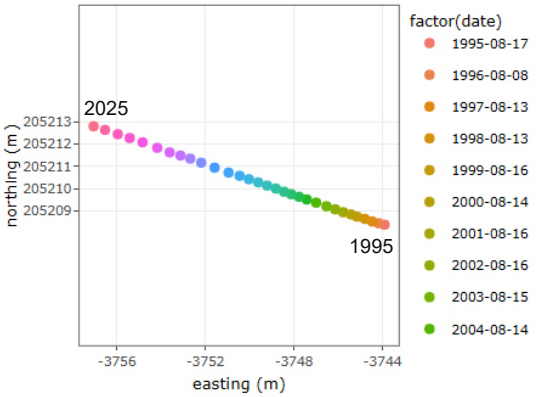
Elevation change:





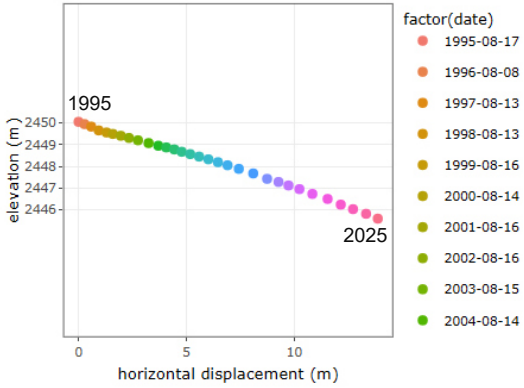
3 Data processing

15 (fastest moving observation point)

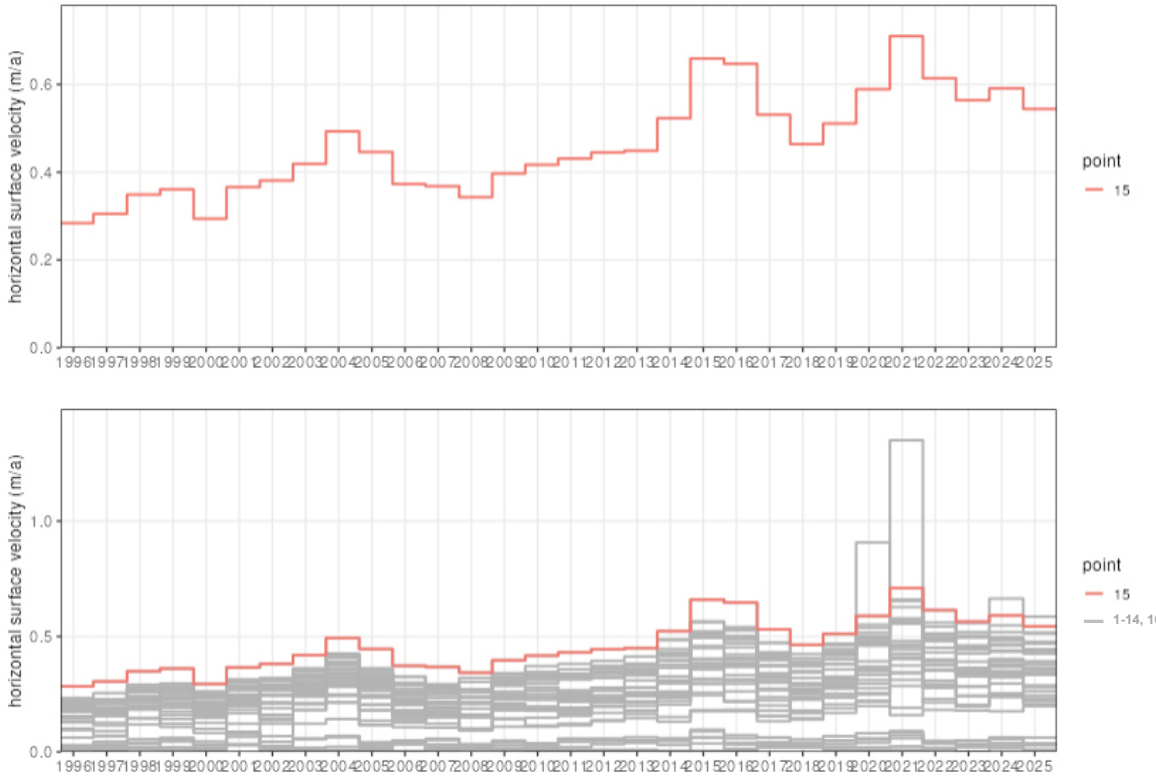


Horizontal displacement

15

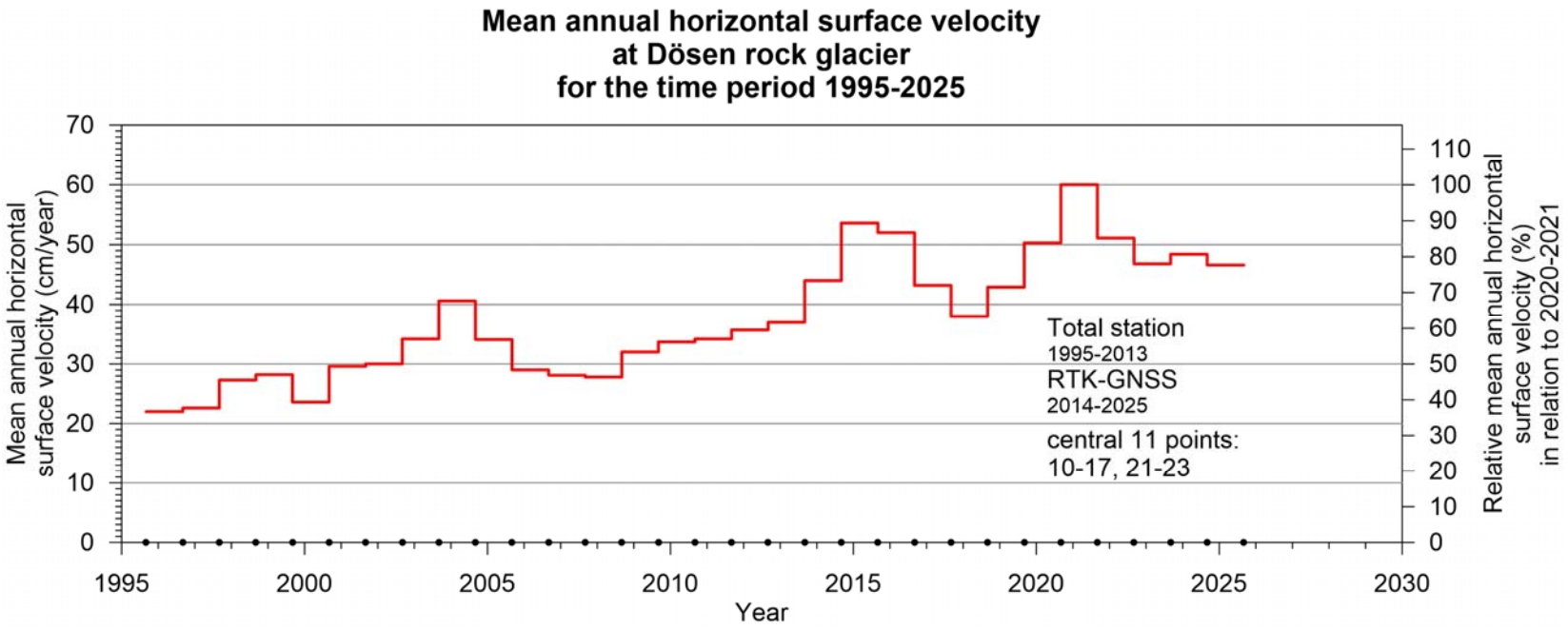


Elevation change



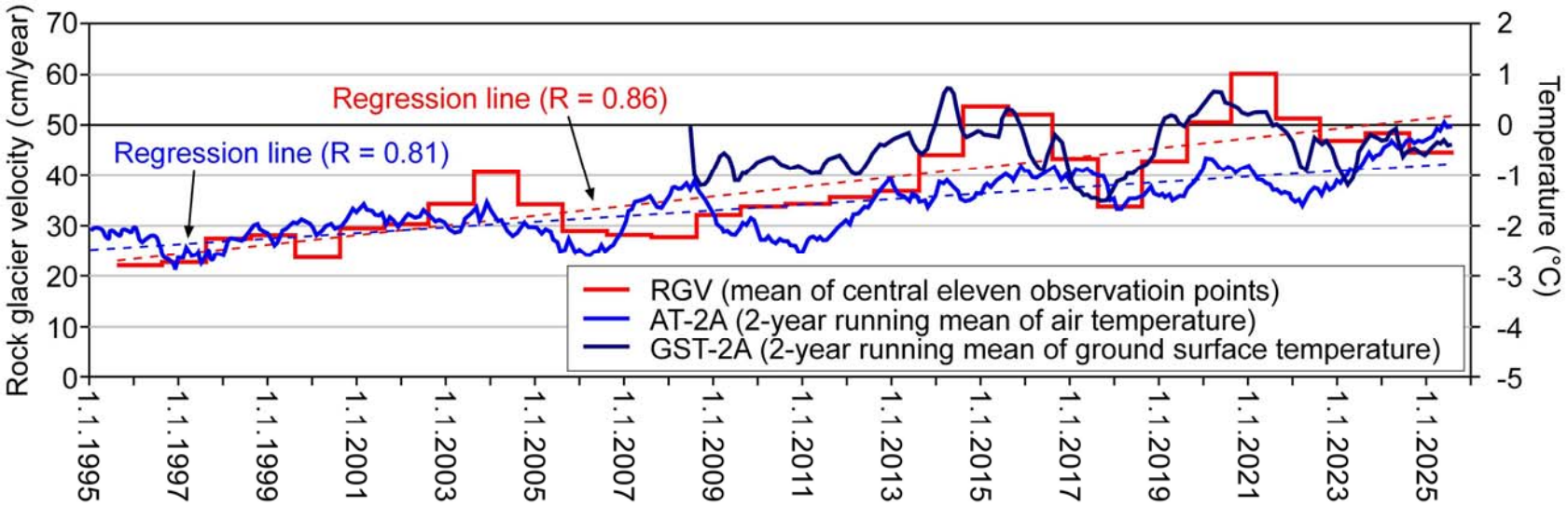
Horizontal velocity

3 Data processing



RGV for the period 1995-2025 shown for the 11 central points

4 Analysis



Long-term monitoring results

The comparison of the 3 graphs (red, blue, black) shows, on the one hand, a significant increase in RGV and air temperatures over time, and on the other hand, a clear pattern in terms of increasing velocities at higher temperatures and decreasing velocities during cooler weather periods.

5 Conclusions

Our results confirm previous findings and also demonstrate the particular value of long-term data series for climate change impact research. Considering that climate research defines a climate normal period (or “climate normal”) only after 30 years, this 30-year threshold value has only been reached at the Dösen rock glacier since last year's measurement. At many other locations in the Alps and elsewhere, this time horizon is still many years away (Kellerer-Pirklbauer et al. 2024). However, this study also shows how important it is to combine kinematic monitoring with meteorological and possibly other monitoring parameters in order to better understand the effect of anthropogenic climate change.

Further reading:

Kellerer-Pirklbauer, A., Bodin, X., Delaloye, R., Lambiel, C., Gärtner-Roer, I., Bonnefoy-Demongeot, M., Carturan, L., Damm, B., Eulenstein, J., Fischer, A., Hartl., L., Ikeda, A., Kaufmann, V., Krainer, K., Matsuoka, N. et al., 2024. **Acceleration and interannual variability of creep rates in mountain permafrost landforms (rock glacier velocities) in the European Alps in 1995-2022.** *Environ. Res. Lett.*, 19 034022. https://doi.org/10.1088/1748-9326/ad25a4

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. https://doi.org/10.1016/j.geomorph.2025.110117

Kaufmann, V., 2026. https://www.staff.tugraz.at/viktor.kaufmann/Doesen_Rock_Glacier.html

Thank you very much for your attention.