

20 Years of Geodetic Monitoring of Dösen Rock Glacier (Ankogel Group, Austria) – A Short Review

V. Kaufmann

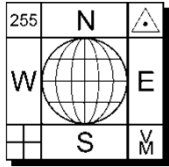
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Working Group Remote Sensing and Photogrammetry

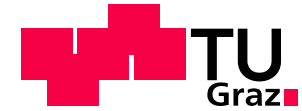
Graz University of Technology, Austria

E-mail: viktor.kaufmann@tugraz.at

<http://www.geoimaging.tugraz.at/viktor.kaufmann/>

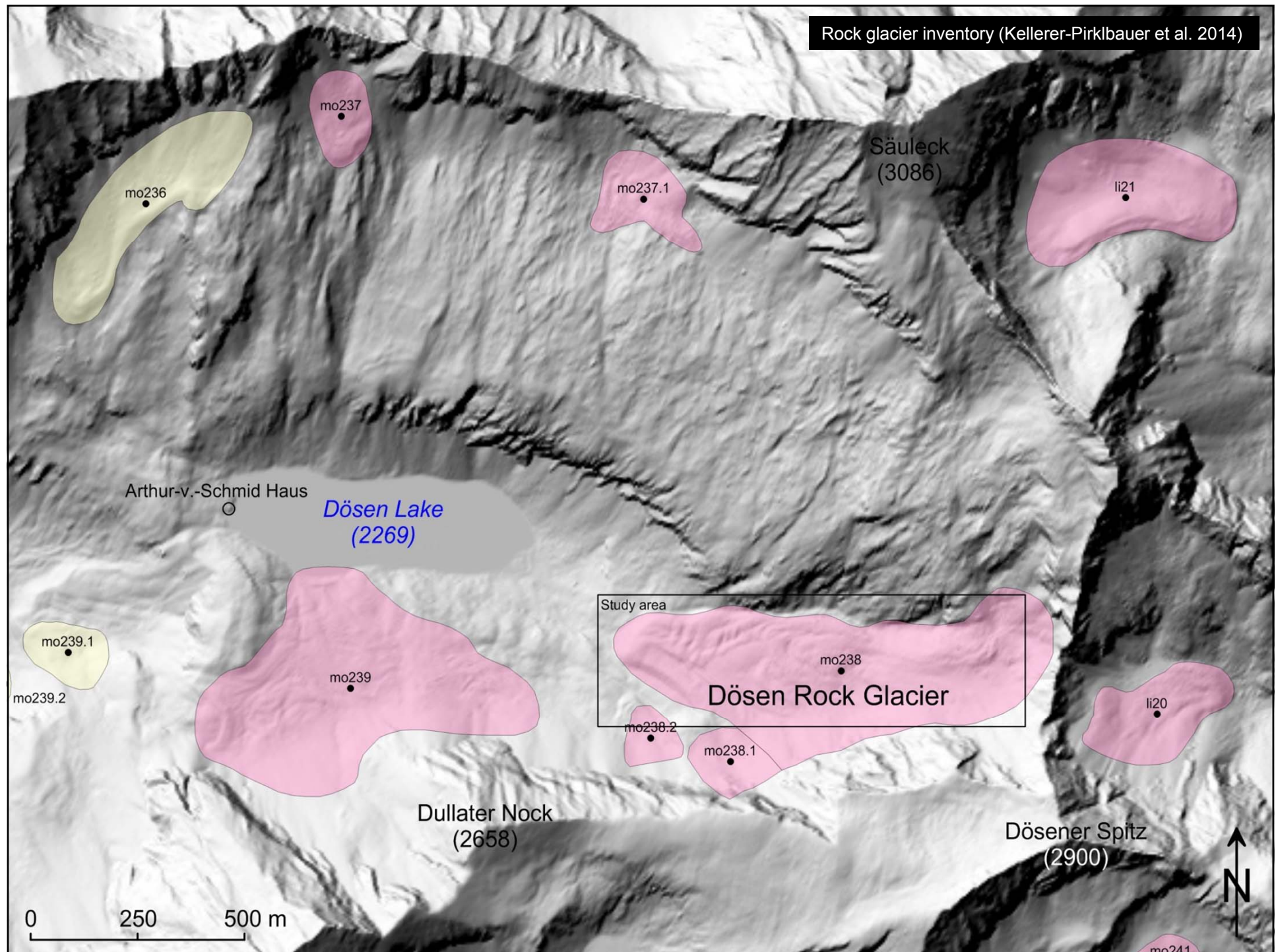


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Contents

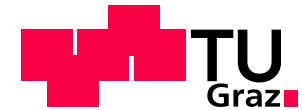
1. Introduction
2. Total Station Measurements 1995-2013
3. GPS/GNSS Measurements 2014-2015
4. Photogrammetric Measurements
5. Results
6. Conclusions and Outlook





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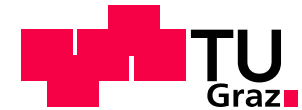


August 17, 2015



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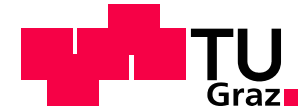


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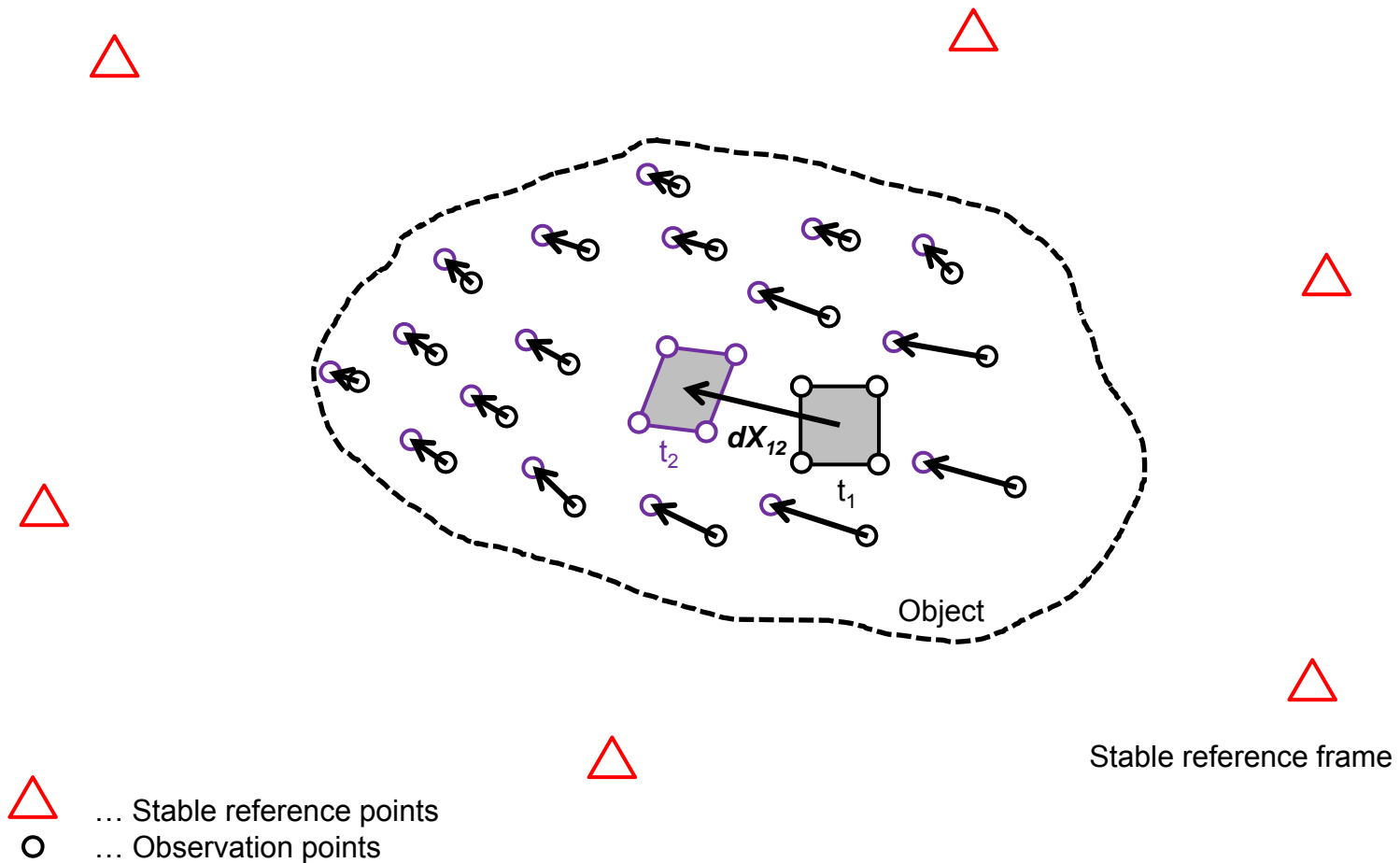
20 Years of Geodetic Monitoring of Dösen Rock Glacier (Ankogel Group, Austria) – A Short Review

1. Introduction



Classical deformation analysis

- (1) Rigid body movement
- (2) Affine deformation





20 Years of Geodetic Monitoring of Dösen Rock Glacier (Ankogel Group, Austria) – A Short Review

1. Introduction



July 26, 1994

A first visit to Dösen rock glacier



20 Years of Geodetic Monitoring of Dösen Rock Glacier (Ankogel Group, Austria) – A Short Review

1. Introduction

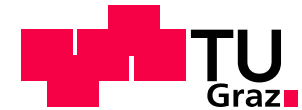


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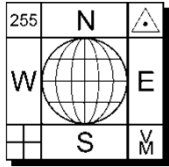


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1. Introduction



July 26, 1994

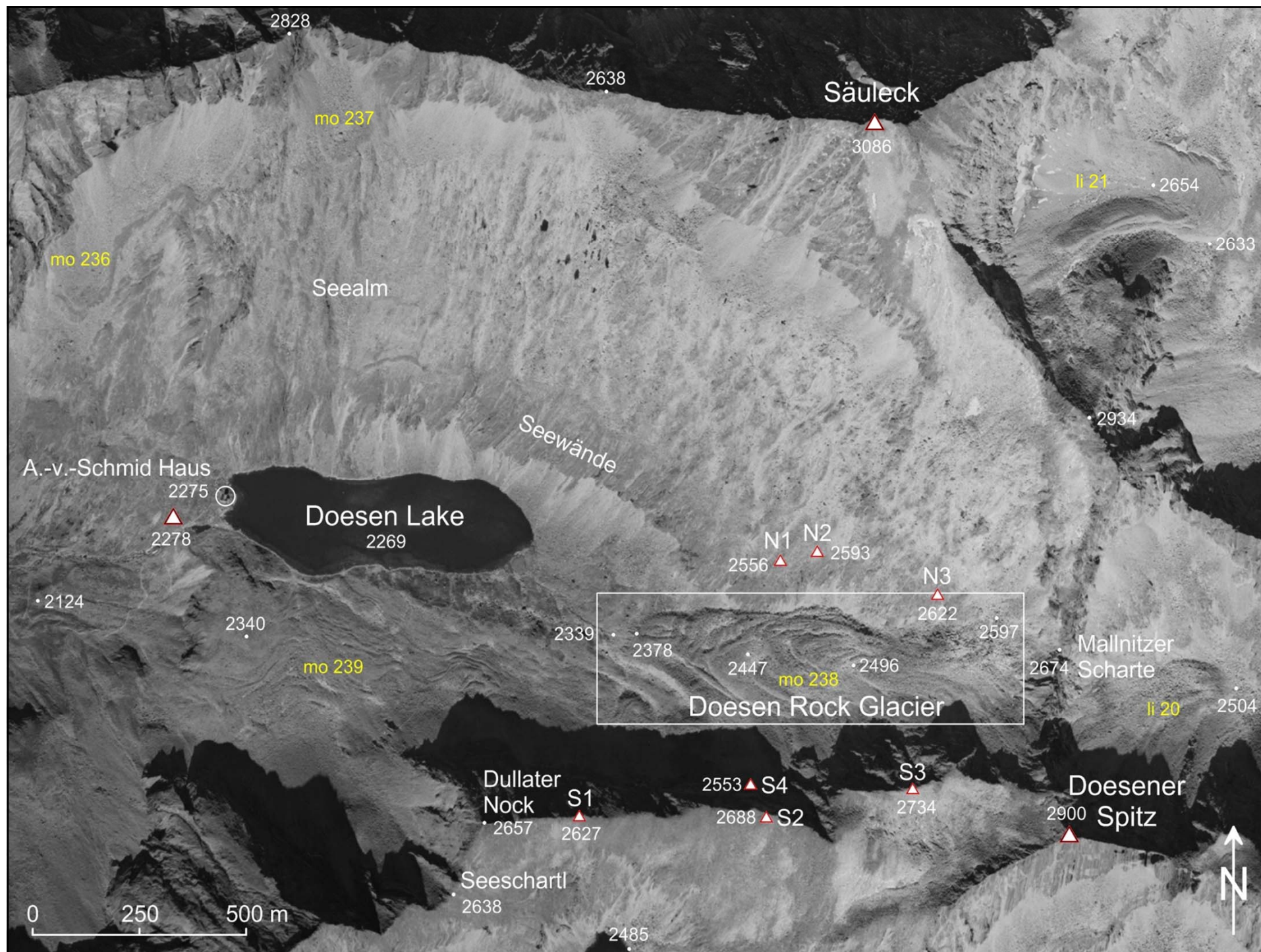


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2. Total Station Measurements 1995-2013

Set-up of a geodetic network and initial (zero) measurement in 1995

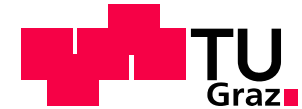
- 7 stable reference points marked with brass bolts & 3 points of BEV
 - 3 additional points (N5, N6 and N7) were added in later stage.
- 107 observation points on the rock glacier
 - 34 points marked with brass bolts
 - 4 profiles (107 points in total, marked with hammer and chisel)
 - 2 longitudinal profiles
 - 2 transversal profiles
- Measurement of the stable reference frame
 - Total station (1995, ...)
 - GPS (1996, ...)
- Initial (zero) measurement of the observation points
 - Total station (1995)
 - Annual measurements in August



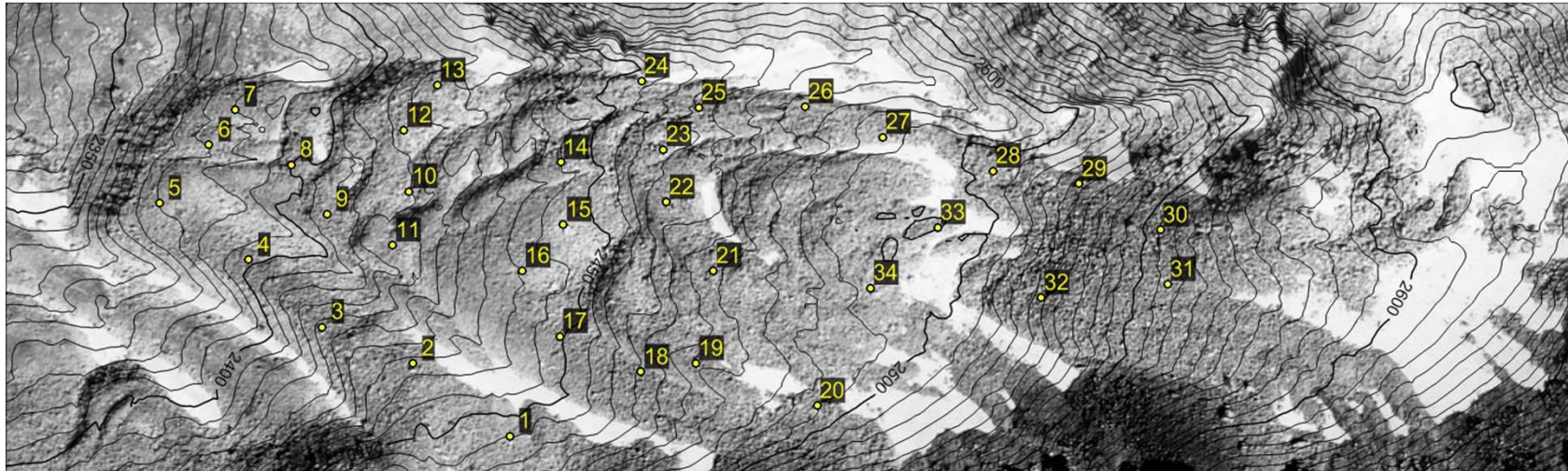


20 Years of Geodetic Monitoring of Dösen Rock Glacier (Ankogel Group, Austria) – A Short Review

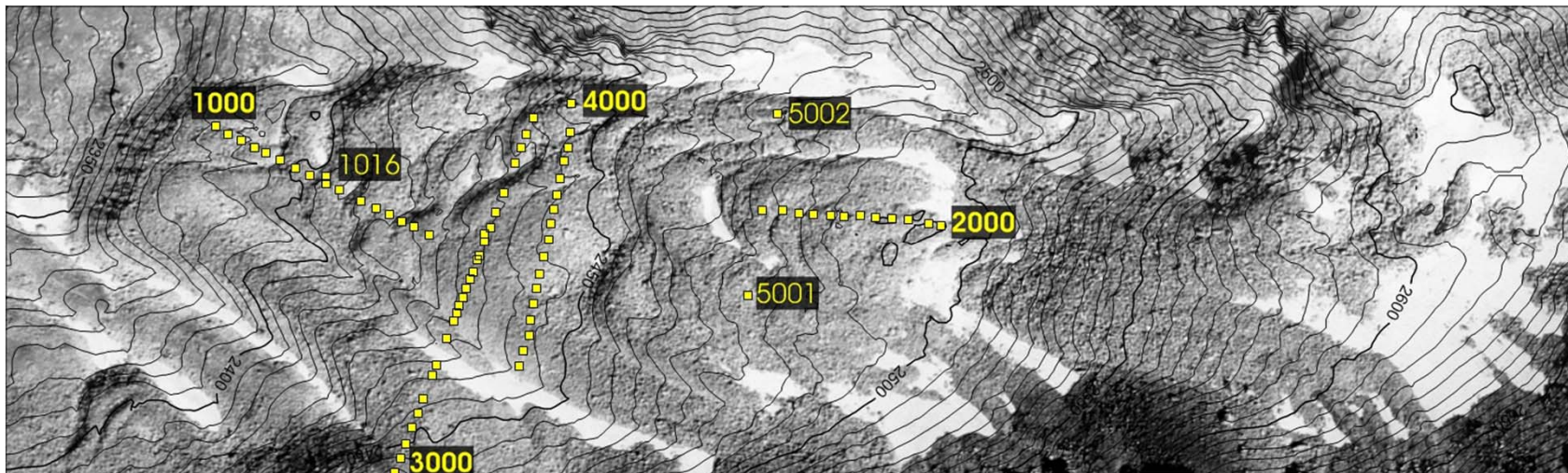
2. Total Station Measurements 1995-2013

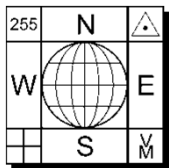


34 observation points marked with brass bolts



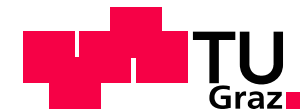
4 profiles: 1000-1015, 2000-2011, 3000-3026, 4000-4016, and additional 3 points 1016, 5001 and 5002





20 Years of Geodetic Monitoring of Dösen Rock Glacier (Ankogel Group, Austria) – A Short Review

2. Total Station Measurements 1995-2013



Gerhard Kienast at point S1

July 26-28, 1995



Kaufmann, Tilg, Kienast, Heiland



Check point at S4



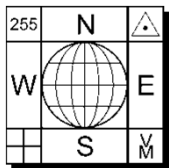
Geodetic survey at the triangulation point AVS

August 12-15, 1997



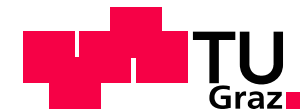
Transport of heavy geodetic equipment

August 13-21, 1995



20 Years of Geodetic Monitoring of Dösen Rock Glacier (Ankogel Group, Austria) – A Short Review

2. Total Station Measurements 1995-2013



Polar method surveying from point S4

August 13-21, 1995



Reflector put on
brass bolt

August 13-21, 1995



August 5-11, 1996



August 13-21, 1995



20 Years of Geodetic Monitoring of Dösen Rock Glacier (Ankogel Group, Austria) – A Short Review

2. Total Station Measurements 1995-2013

Annual repeat measurements between 1996 and 2013

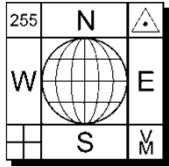
- No measurements were carried out in 2003 because of financial constraints.
- Measurements using a total station terminated in 2013.



Surveying team 2013

August 12-14, 2013





20 Years of Geodetic Monitoring of Dösen Rock Glacier (Ankogel Group, Austria) – A Short Review

2. Total Station Measurements 1995-2013

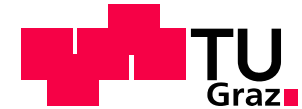
Assessment:

- + High accuracy: $m_x = m_y = m_z = \pm 1 \text{ cm}$
- + Fast (1 day)
- + Independent measurement technique (no third-party service is needed)
- Experienced operator is needed for the total station.
- Strong dependency on the weather (visibility)
- Personnel intensive (5-6 persons)
- Physically strong helpers needed
- High costs because of the personnel
- Difficult and dangerous climb to reach point S4
- S4 is not stable but gradually moving downward.

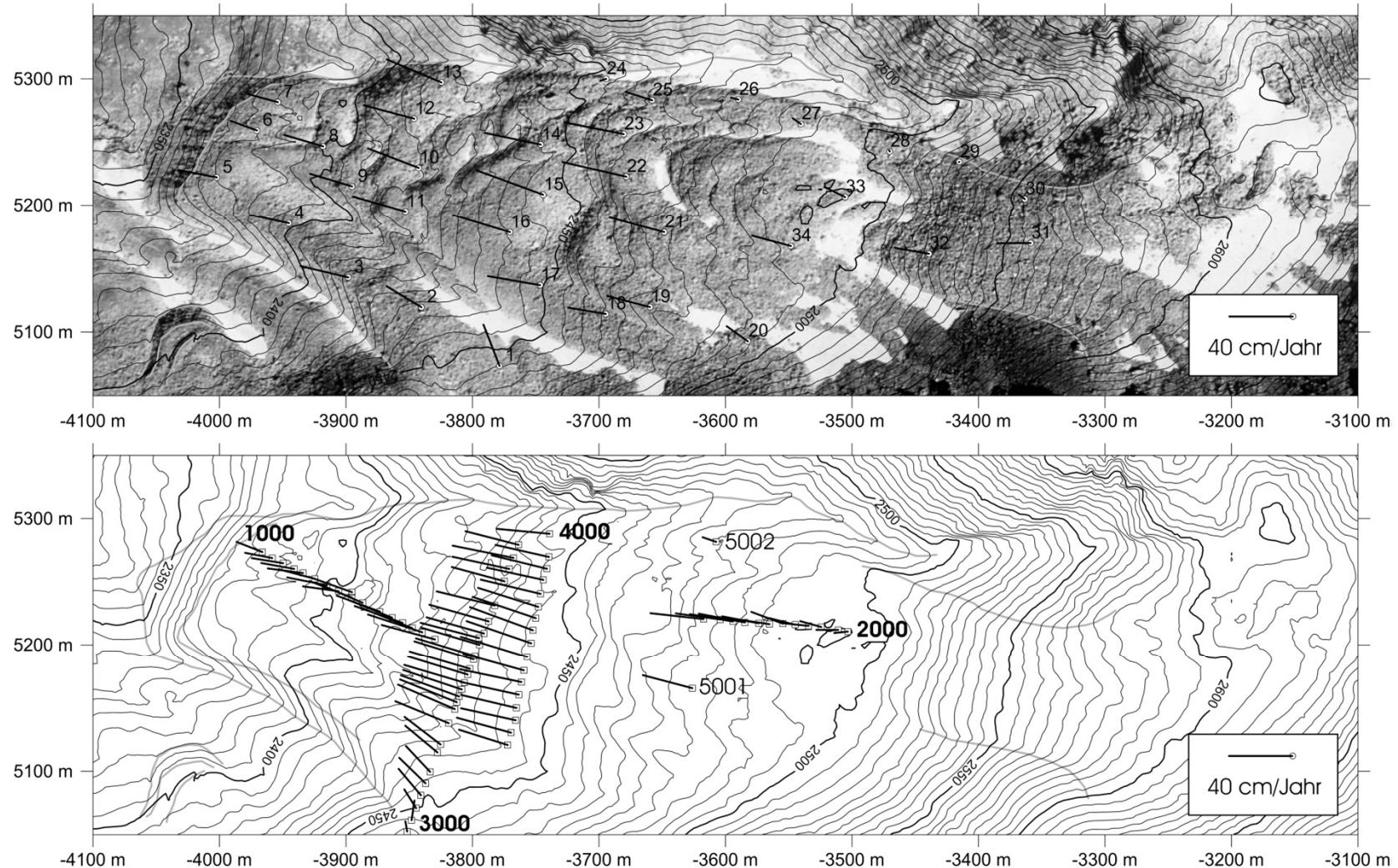


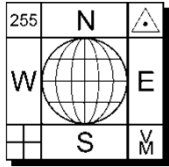
20 Years of Geodetic Monitoring of Dösen Rock Glacier (Ankogel Group, Austria) – A Short Review

2. Total Station Measurements 1995-2013



2D displacement vectors 2012-2013





20 Years of Geodetic Monitoring of Dösen Rock Glacier (Ankogel Group, Austria) – A Short Review

3. GPS/GNSS Measurements 2014-2015



GNSS-based surveying since 2014

- 2014: Validation of the real-time kinematic (RTK) positioning technique at Dösen rock glacier.
 - Reference station (base): Triangulation point (AVS) near Arthur-v.-Schmid Haus
 - Additional stable points M1, M2 and M3 for ease of work
 - Equipment used: Leica Viva GNSS
 - Accuracy: 2-3 times inferior to the classical method used previously
- 2015: RTK-GNSS measurements only



20 Years of Geodetic Monitoring of Dösen Rock Glacier (Ankogel Group, Austria) – A Short Review

3. GPS/GNSS Measurements 2014-2015



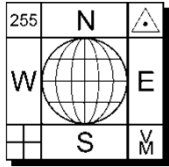
August 18, 2015



August 18, 2015

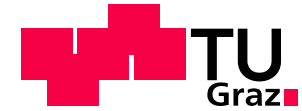


August 12, 2014



20 Years of Geodetic Monitoring of Dösen Rock Glacier (Ankogel Group, Austria) – A Short Review

3. GPS/GNSS Measurements 2014-2015



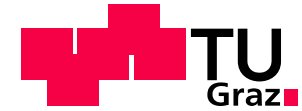
Assessment:

- + Less personnel needed (2-4 persons)
- + More cost-efficient
- + Measurement is independent of weather conditions (visibility).
- + Measurements can be carried out by anybody after a short training.
- ± Adequate accuracy: $m_x = m_y = m_z = \pm 2-3 \text{ cm}$ (= ~10% relative accuracy in respect to the average annual flow velocity)
- Daily output of measured points is limited.
On a fine day all 34 observation points can be measured within 1 day.
- Thus, the measurement of the 4 profiles had to be abandoned.
- Possible problems with bad satellite constellation, signal shadowing, and multipath effects

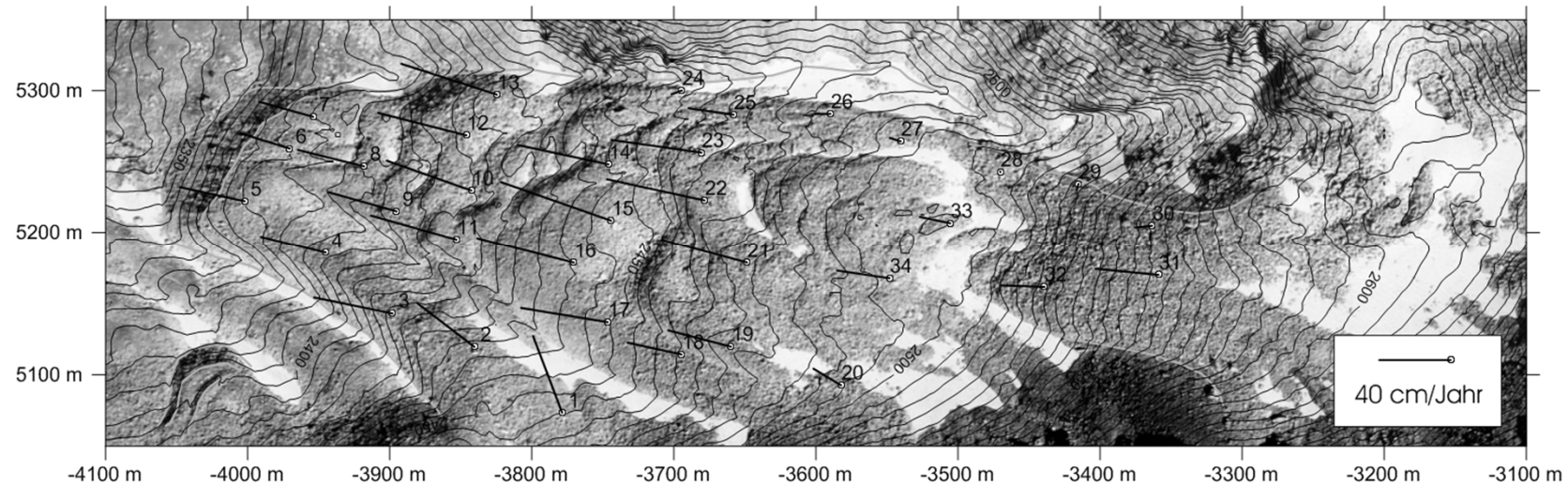


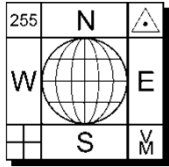
20 Years of Geodetic Monitoring of Dösen Rock Glacier (Ankogel Group, Austria) – A Short Review

3. GPS/GNSS Measurements 2014-2015



2D displacement vectors 2014-2015



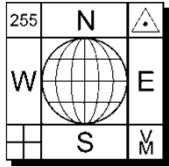


20 Years of Geodetic Monitoring of
Dösen Rock Glacier (Ankogel Group, Austria) – A Short Review
4. Photogrammetric Measurements



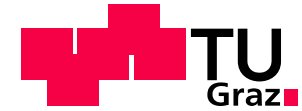
Computer animation: 1969 – 1998 – 2010

Horizontal movement of Dösen rock glacier

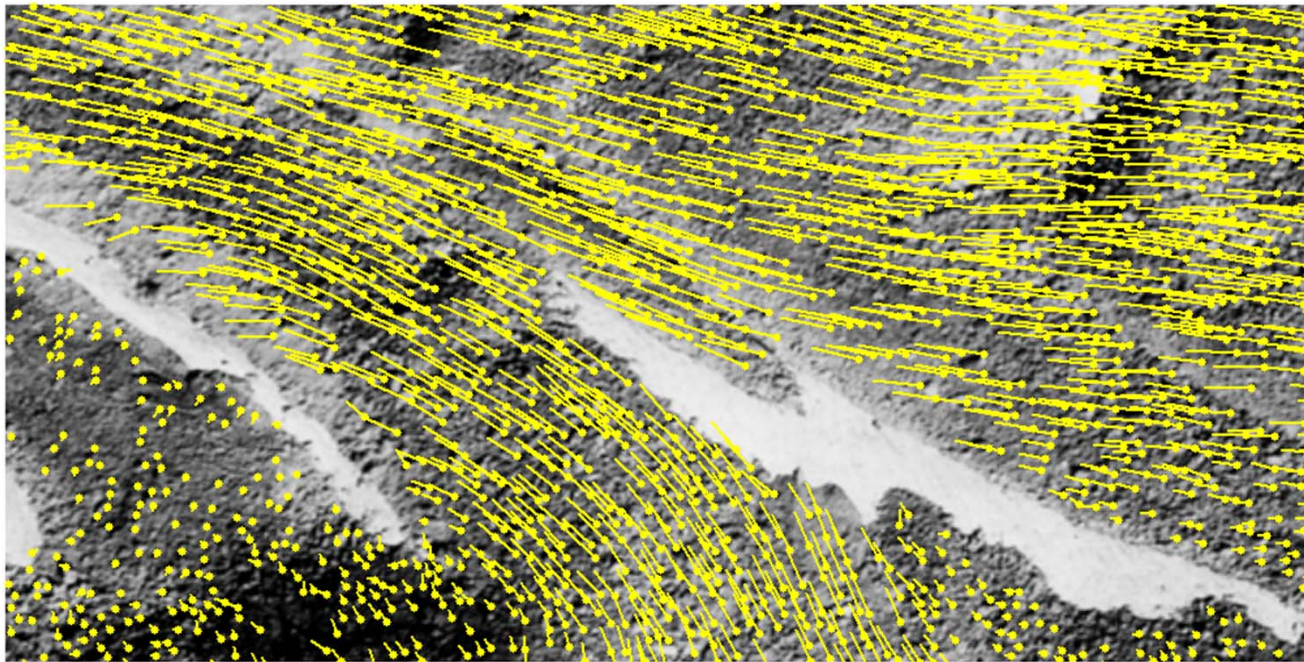


20 Years of Geodetic Monitoring of Dösen Rock Glacier (Ankogel Group, Austria) – A Short Review

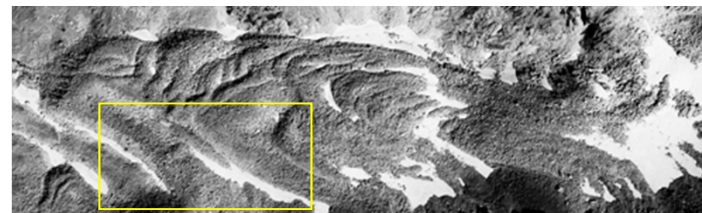
4. Photogrammetric Measurements



Automatic tracking of thousands of points through image matching

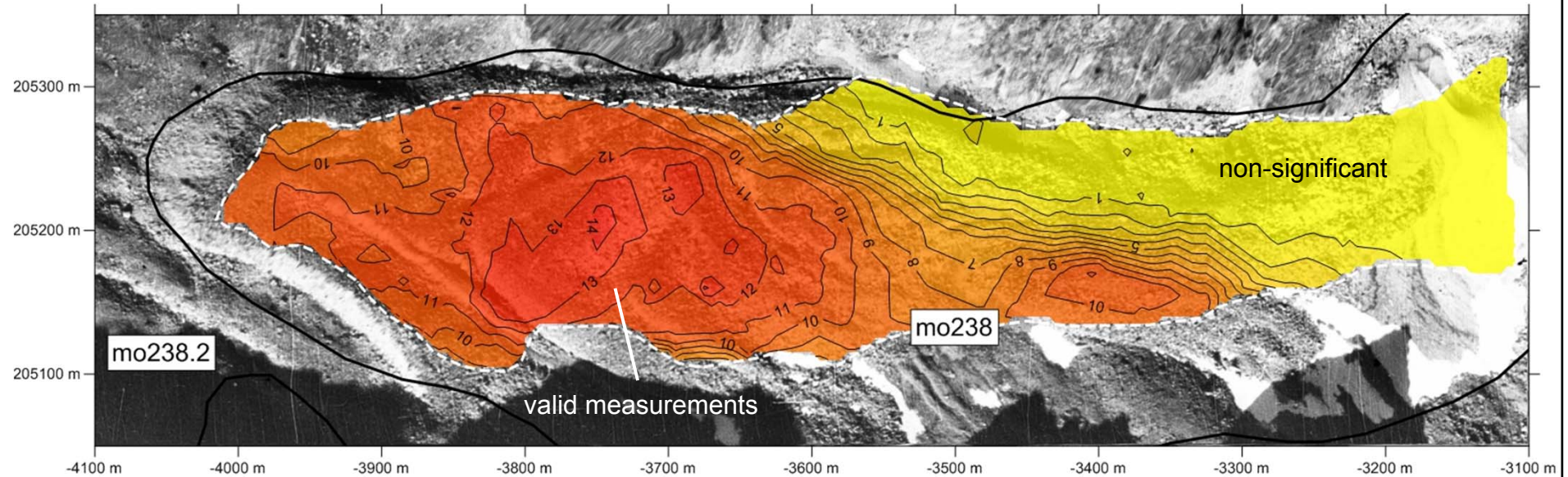


Horizontal displacement vectors derived from large-scale aerial photographs 1993 and 1997.





Total horizontal movement 1954-2010

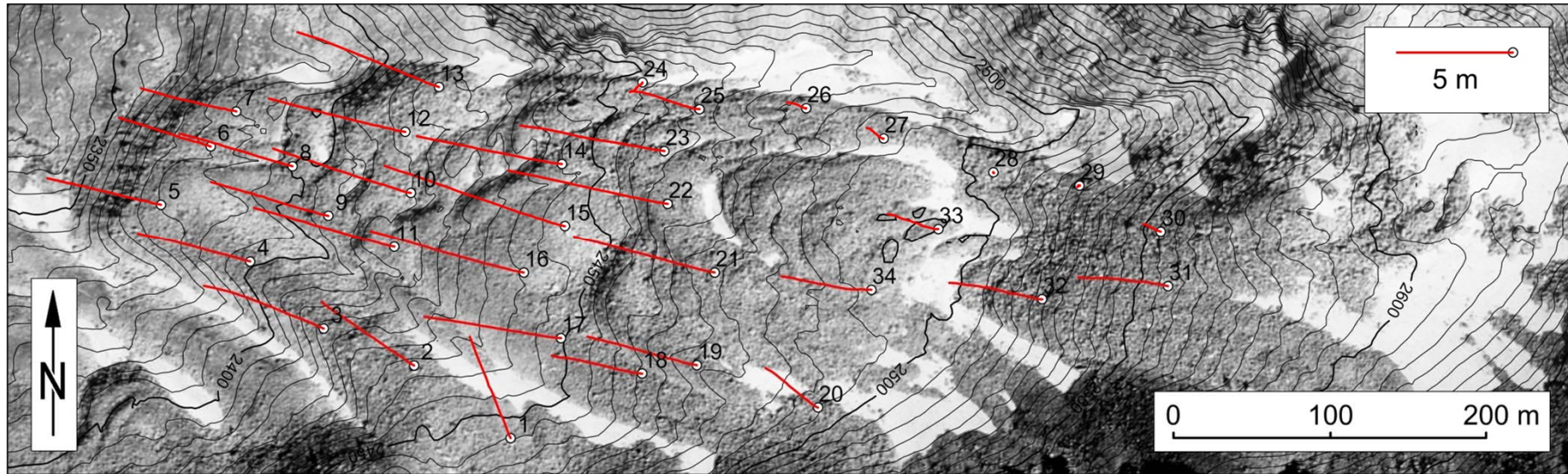
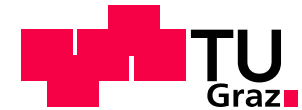


Equidistance of isolines: 1 m
Accuracy: ± 0.9 m (3σ -level)
Maximum movement: 14.67 m (in 56 years)



20 Years of Geodetic Monitoring of Dösen Rock Glacier (Ankogel Group, Austria) – A Short Review

5. Results



Multi-annual horizontal movement (1995-2015) of the 34 observations points at Dösen rock glacier.

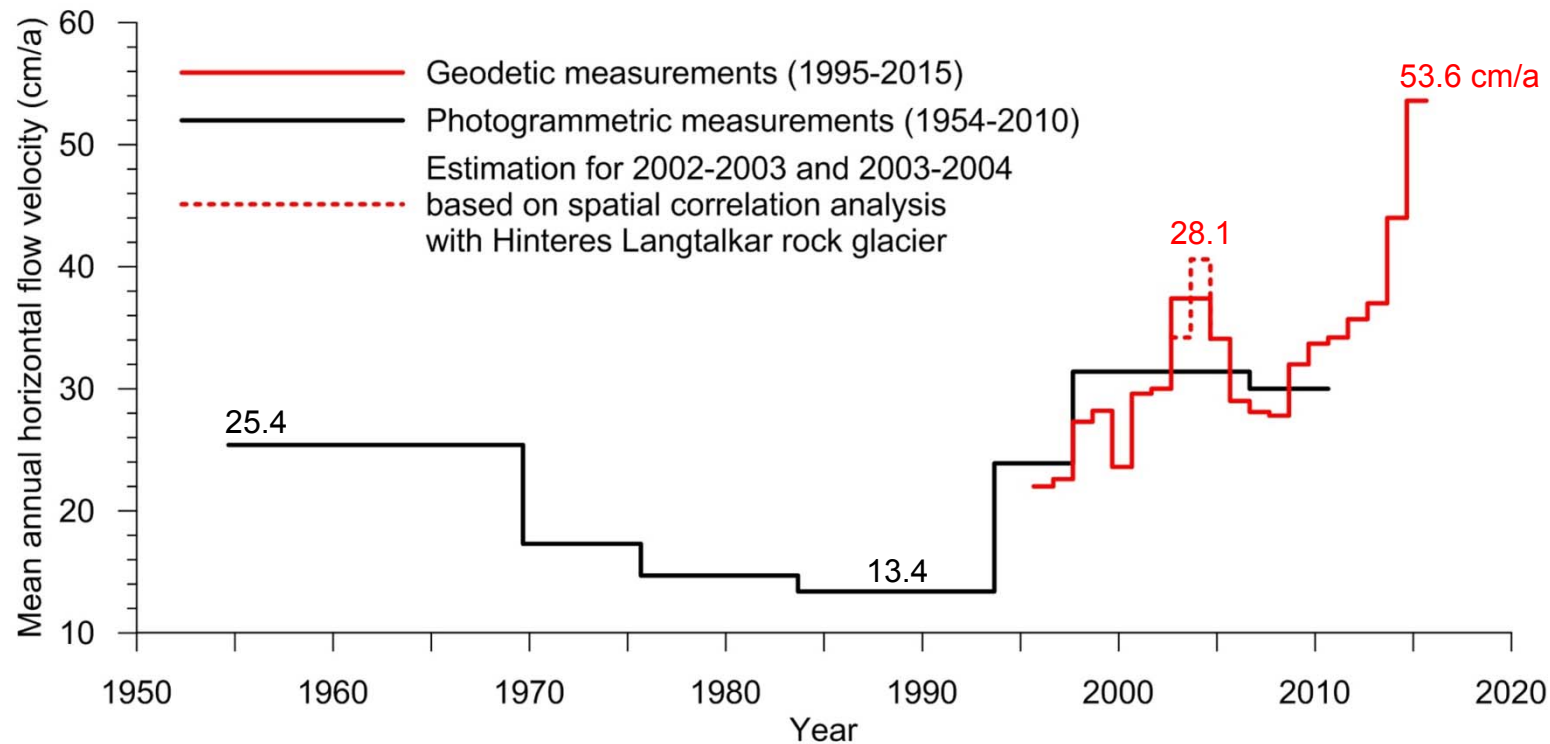
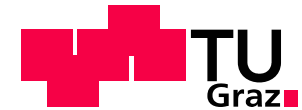
The movement is exaggerated by a factor of 15.

Maximum movement at point 15: 8.10 m (≈ 40.5 cm/a)

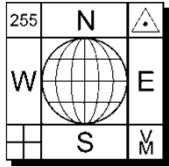


20 Years of Geodetic Monitoring of Dösen Rock Glacier (Ankogel Group, Austria) – A Short Review

5. Results

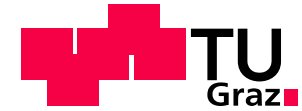


Mean annual horizontal flow velocity of Dösen rock glacier for the time period 1995-2015.
The velocities shown are mean values derived from 11 representative observations points (10-17, 21-23).

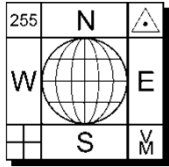


20 Years of Geodetic Monitoring of Dösen Rock Glacier (Ankogel Group, Austria) – A Short Review

6. Conclusions and Outlook



- Mean annual flow velocity is a good indicator to describe rock glacier kinematics.
- RTK-GNSS has proved to be beneficial.
- Accuracy obtained is sufficient.
(Satellite availability will increase in the future: Galileo, Beidou, etc.)
- Deformation analysis is possible.
- Estimation of permafrost degradation (surface lowering due to ice melt) based on sparse point data is difficult. Annual rates computed are in the centimeter-level.
- GPS/GNSS-equipped Wireless Sensor Network (WSN) for monitoring rock glacier kinematics: unattended operation, high spatial and temporal coverage and low cost (cp. Buchli et al. 2012)
 - To resolve intra-annual variations in rock glacier movement
 - To better support process understanding (influence of atmospheric warming, hydrology, etc.)



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For further information, please contact:

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Institute of Geodesy
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Graz University of Technology

Steyrergasse 30
A-8010 Graz, Austria

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