

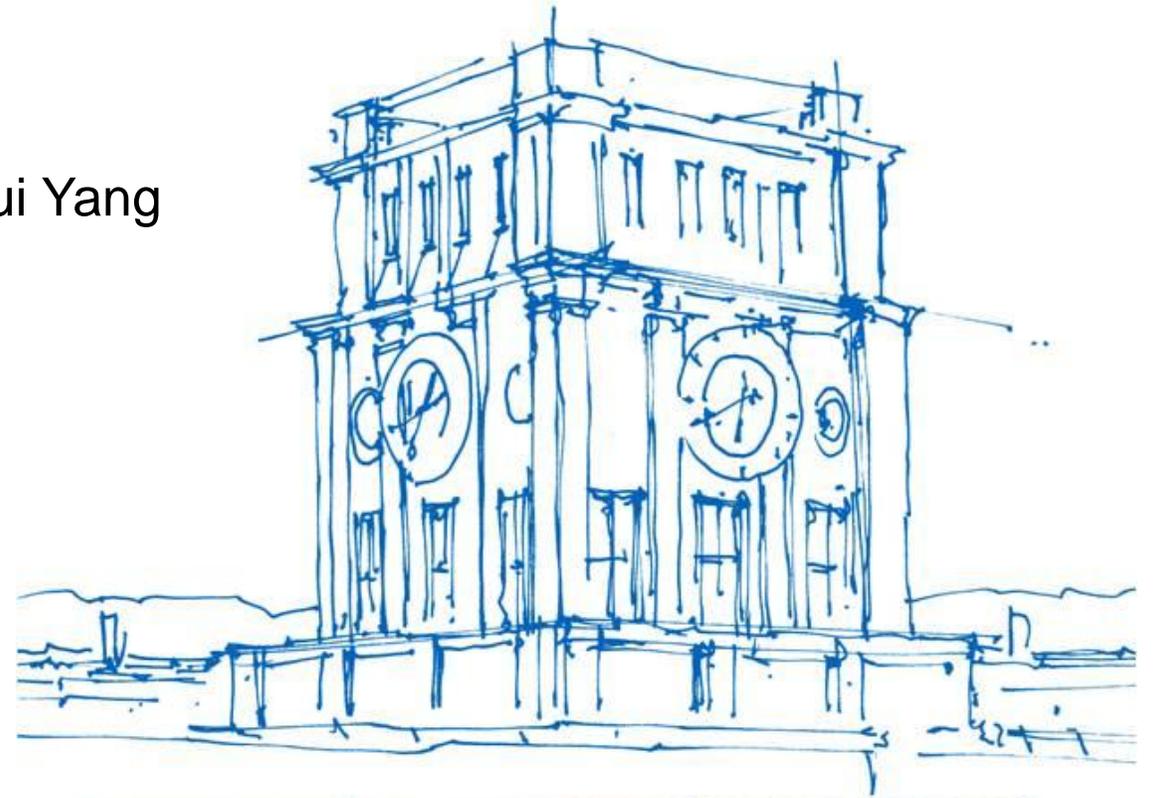
Geodätisches Monitoring von alpinen Bergstürzen und Hangrutschungen

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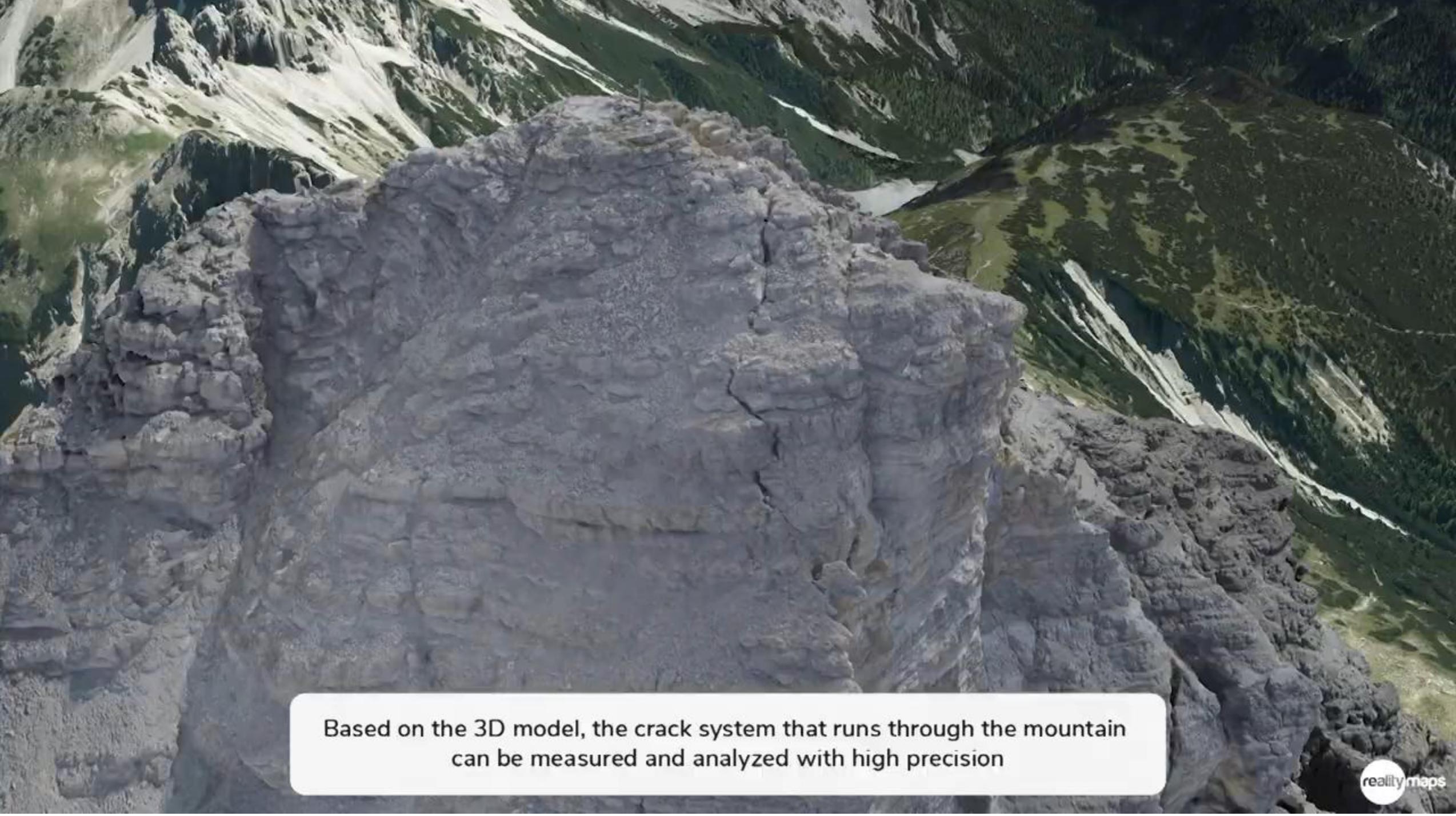
InfoVerm der Bayerischen Vermessungsverwaltung
03.04.2025, Technische Universität München



Uhrenturm der TUM

Mountain Hochvogel (2592 m NHN)



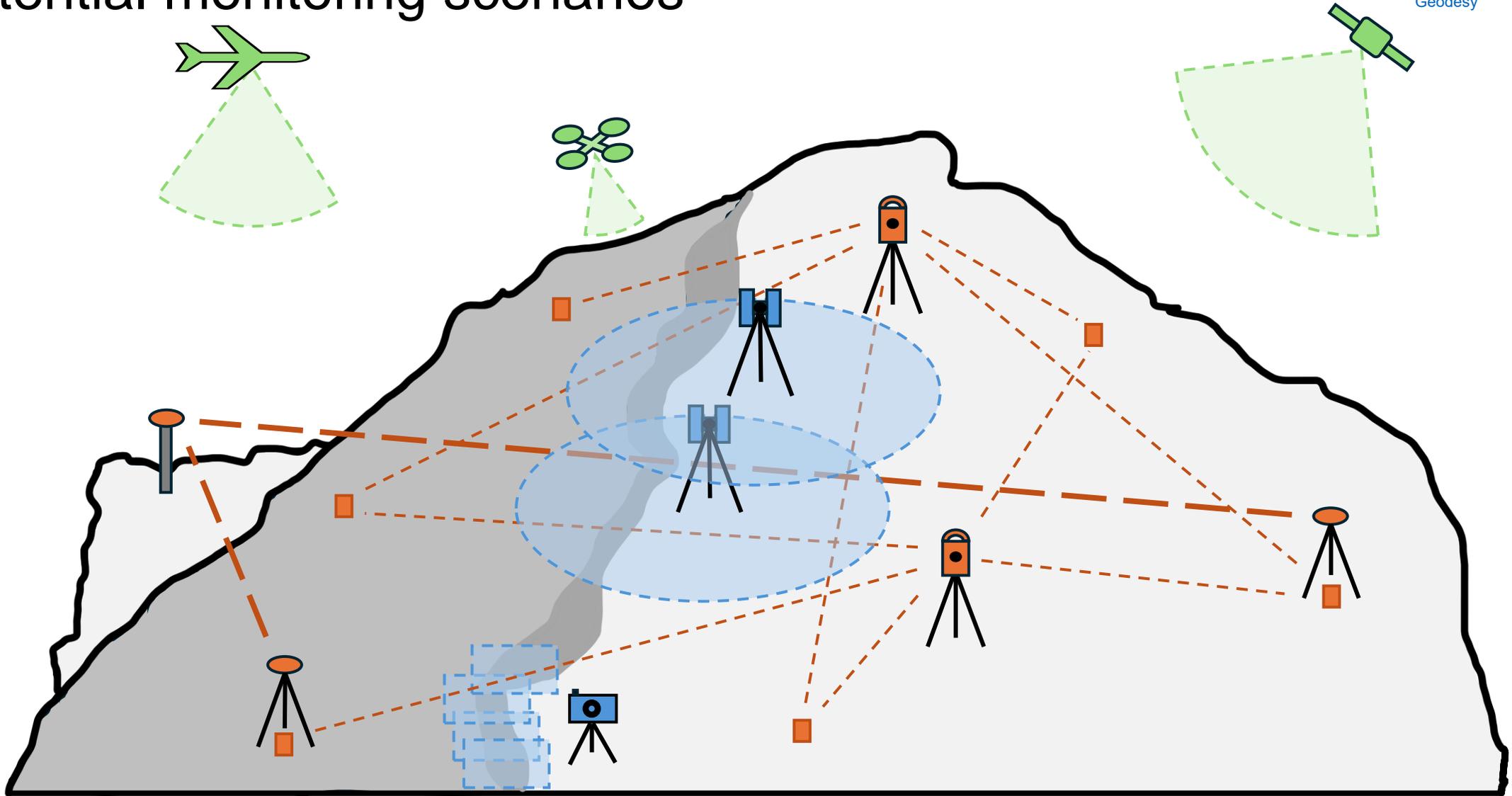


Based on the 3D model, the crack system that runs through the mountain can be measured and analyzed with high precision

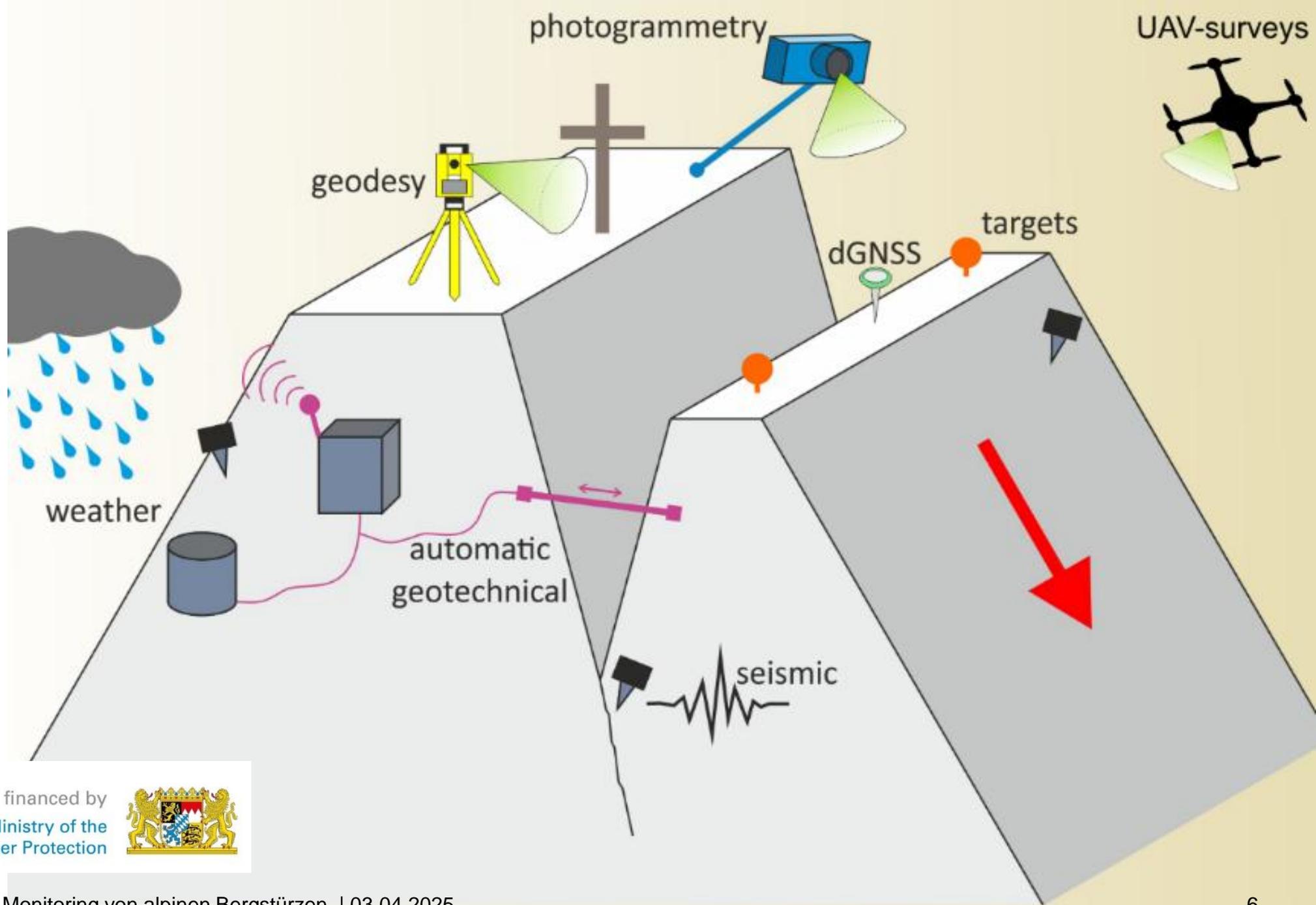
The mountain breaks



Potential monitoring scenarios



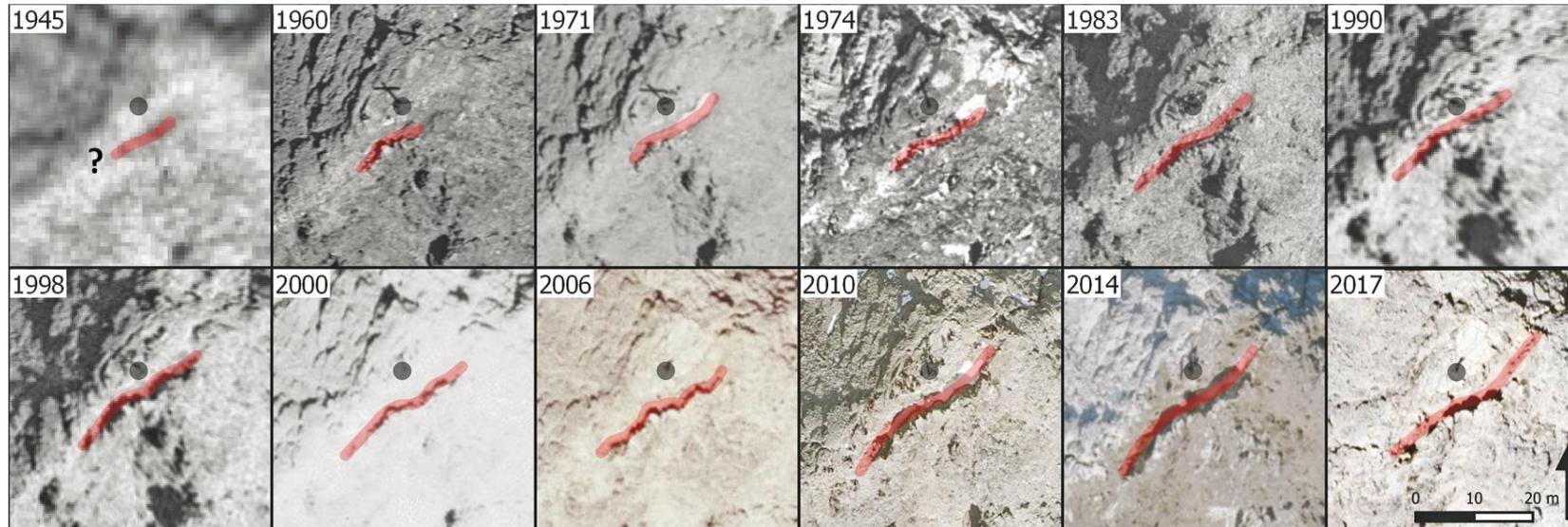
AlpSense Project



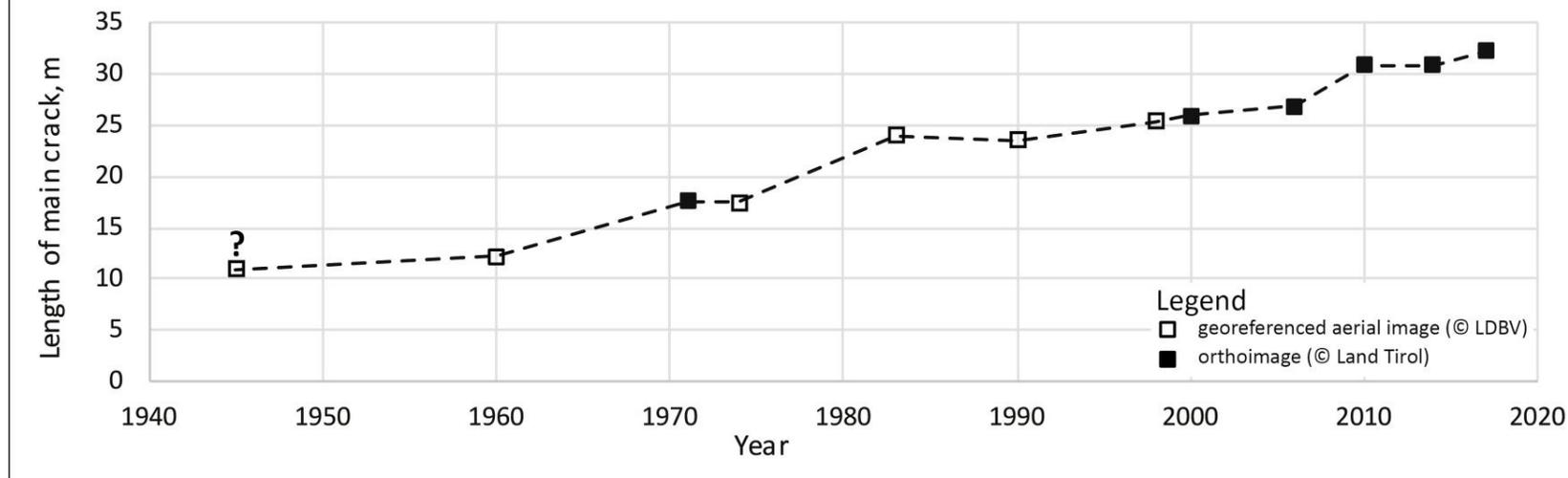
financed by
Bavarian State Ministry of the
Environment and Consumer Protection



Pre-study: Aerial images / orthophotos by LDBV & Tirol

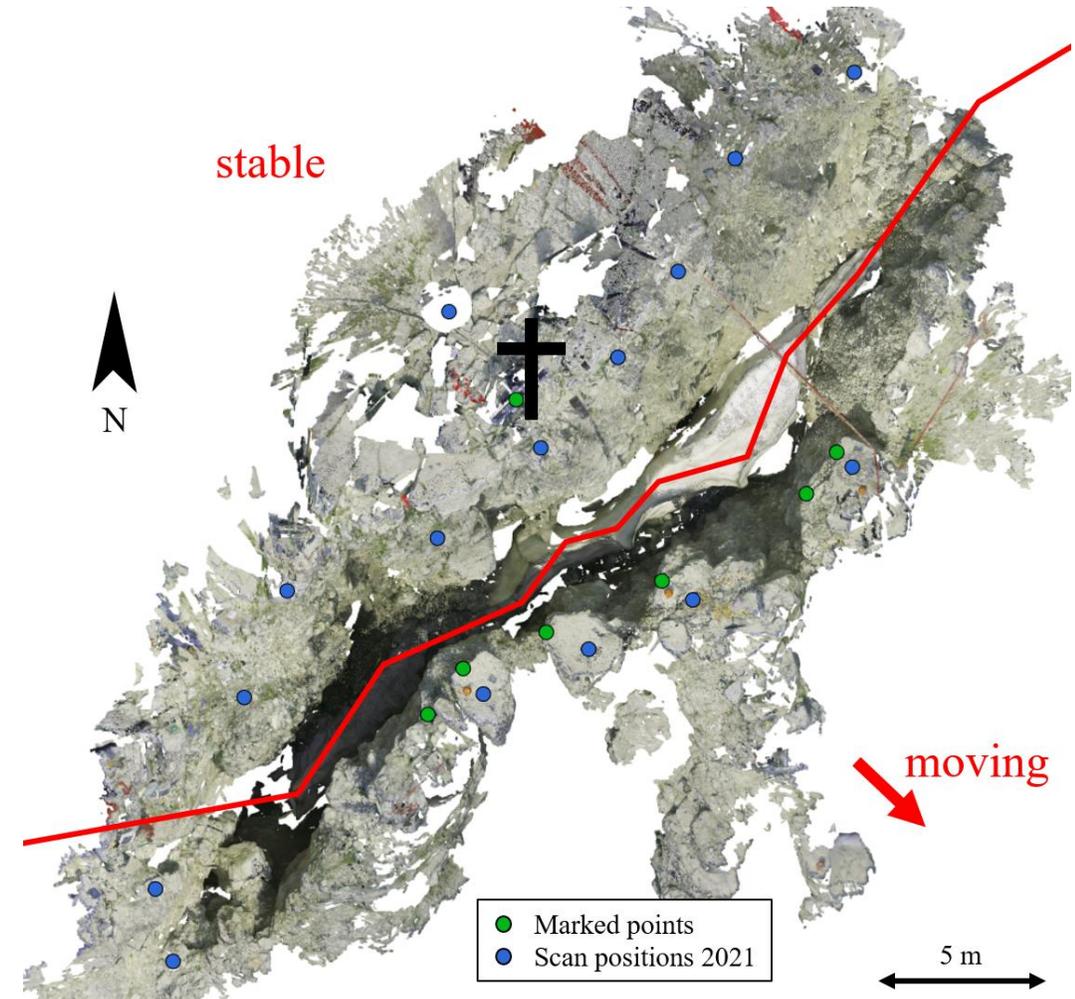
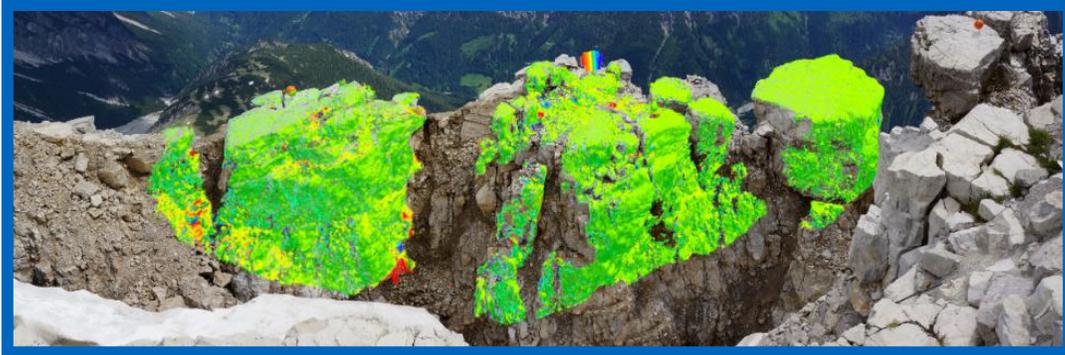


dot in panels marks the location of the summit cross

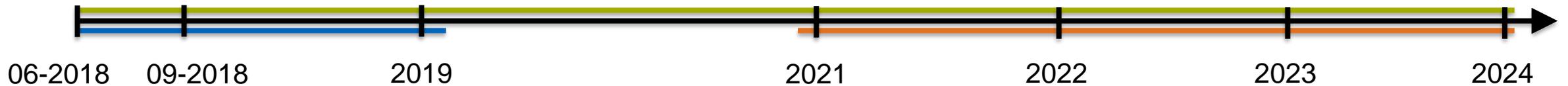


[Leinauer et al.,2020]

Geodetic monitoring at Mt. Hochvogel



Zero epoch



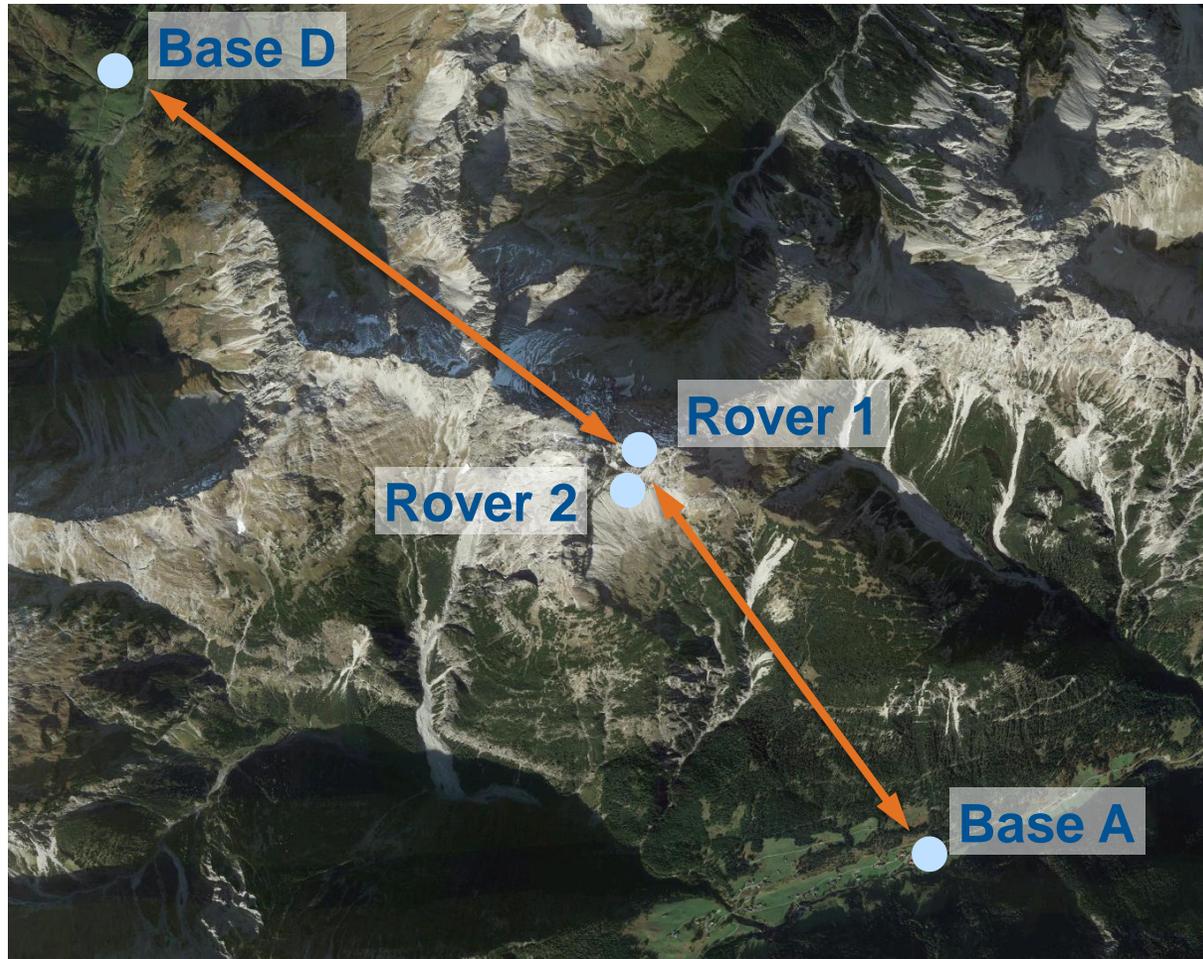


At Hochvogel (2592 m) in the Allgäu a huge rock fall threatens

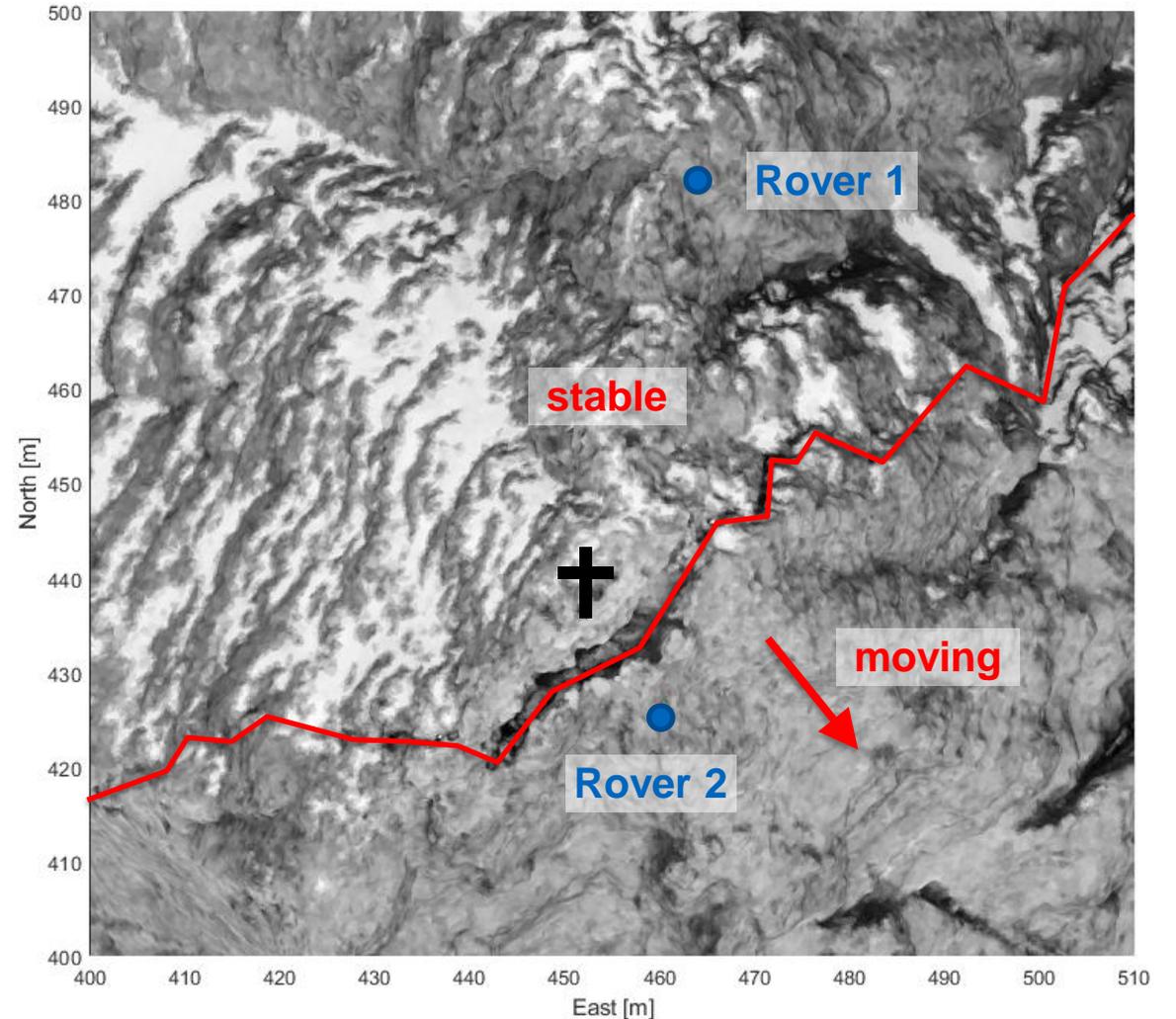
GNSS, total station and laser scanner



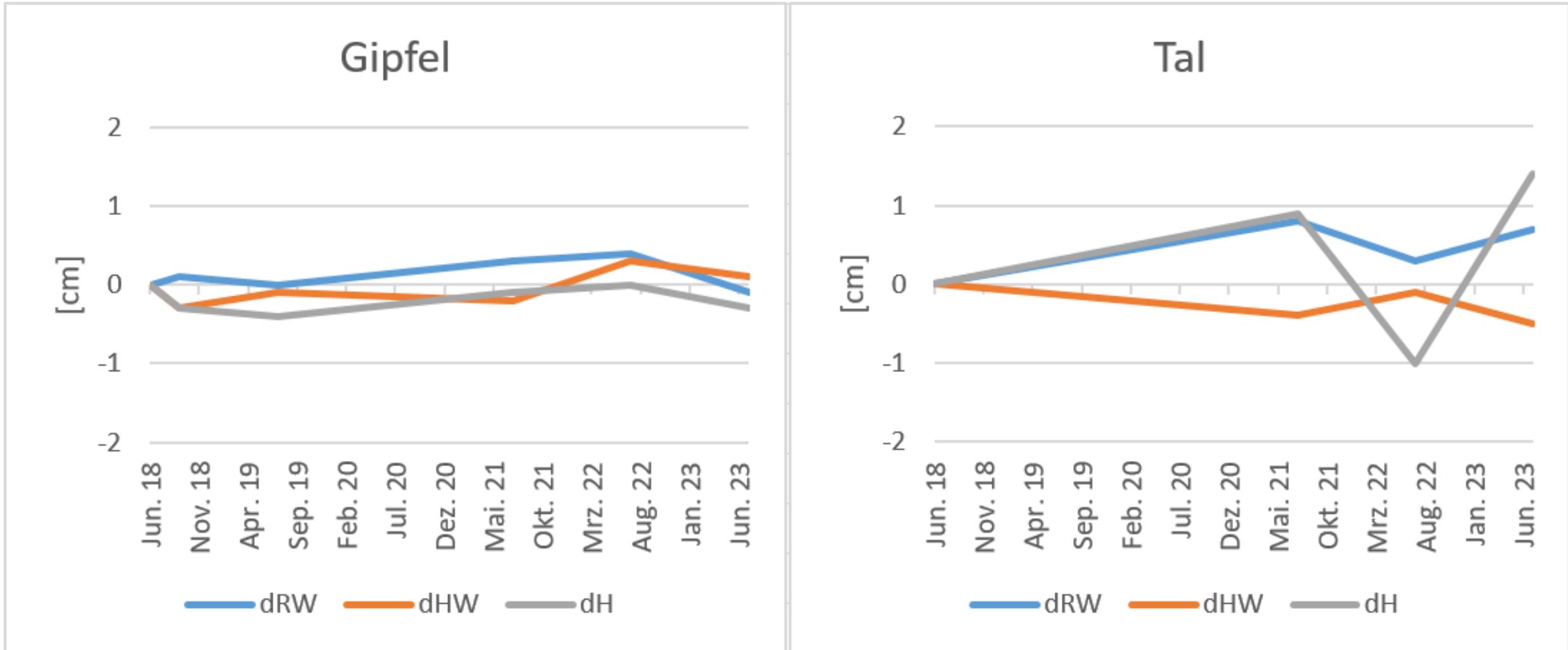
SAPOS-GNSS for geo-referencing



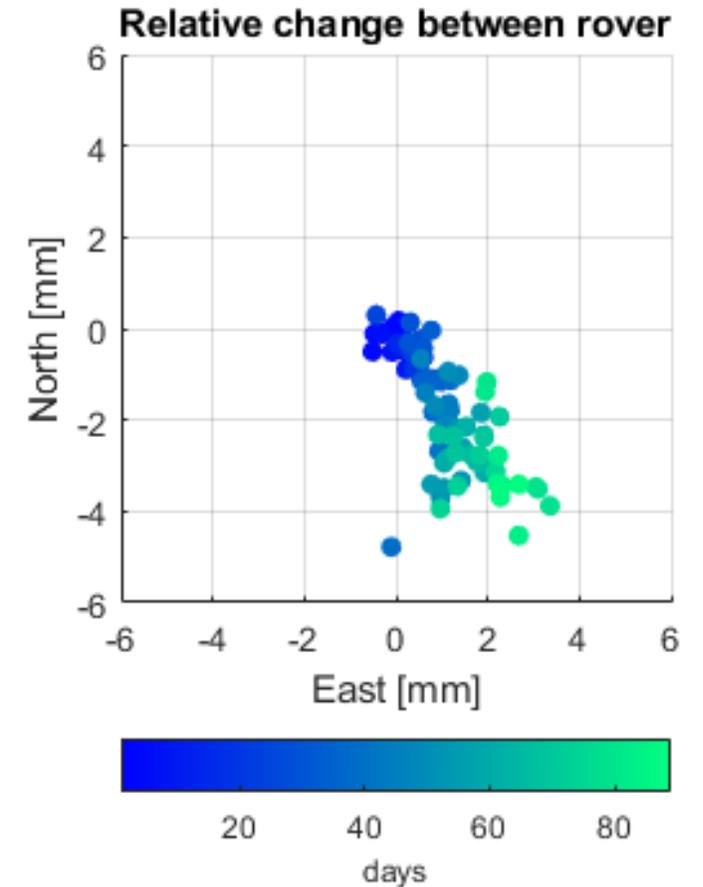
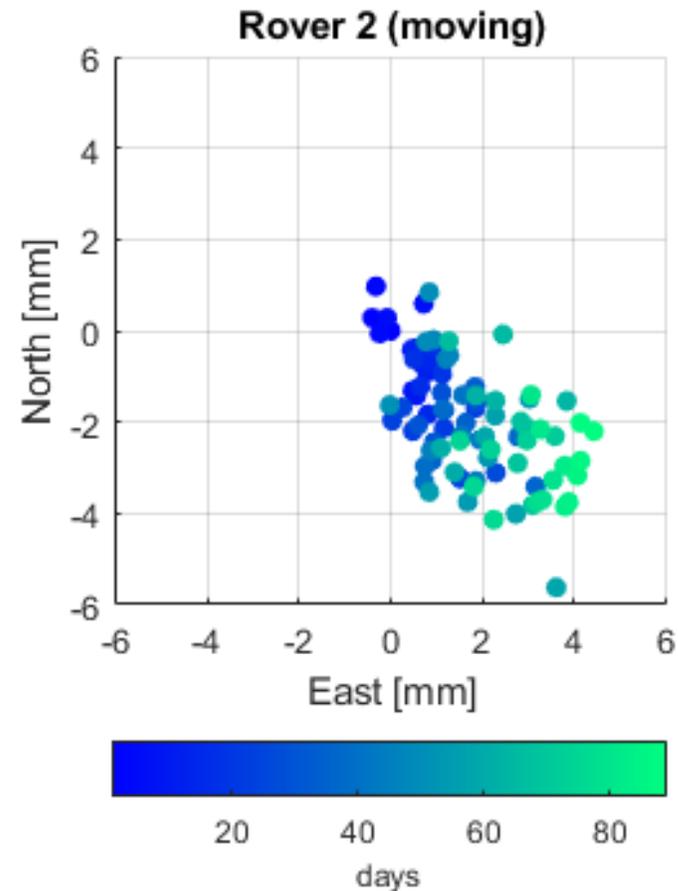
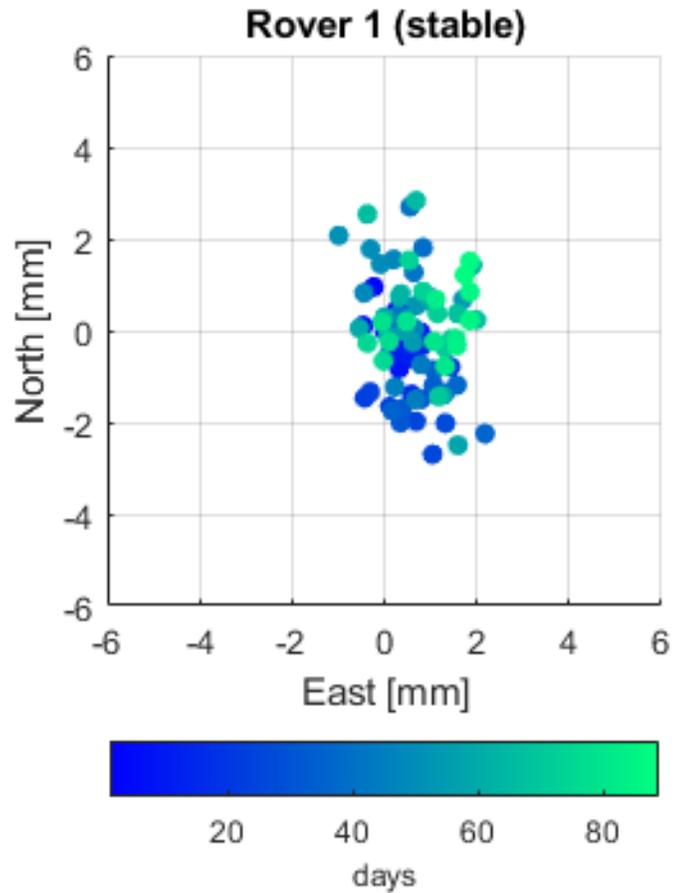
$D > 5 \text{ km}; \Delta h \approx 1,5 \text{ km}$



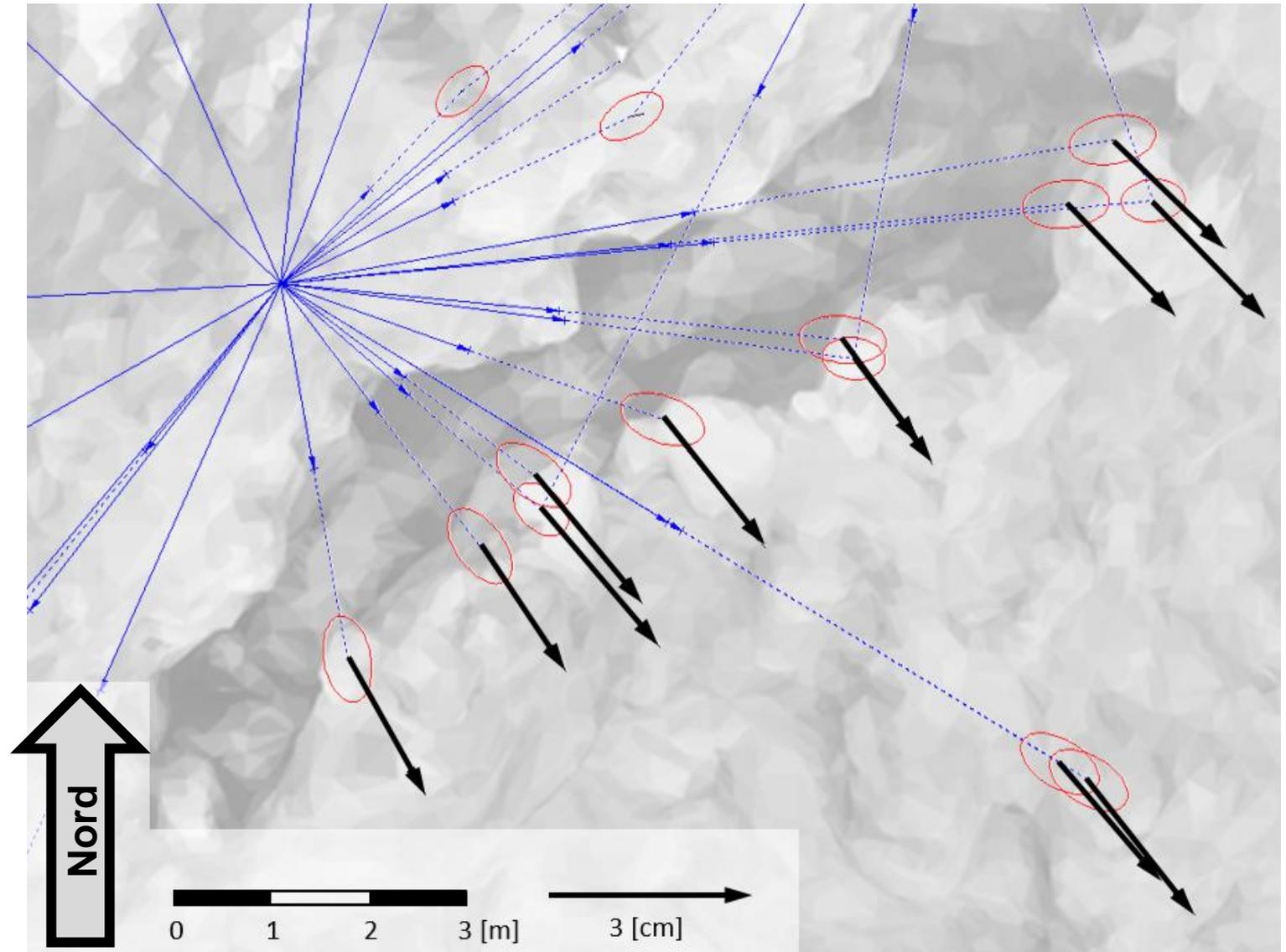
Temporal change of absolute SAPOS coordinate



Movements in 48-hours-average (Jul. 2021 – Oct. 2021, 89 days)



Deformation vectors total station (Sep. 2018 – Jul. 2019)

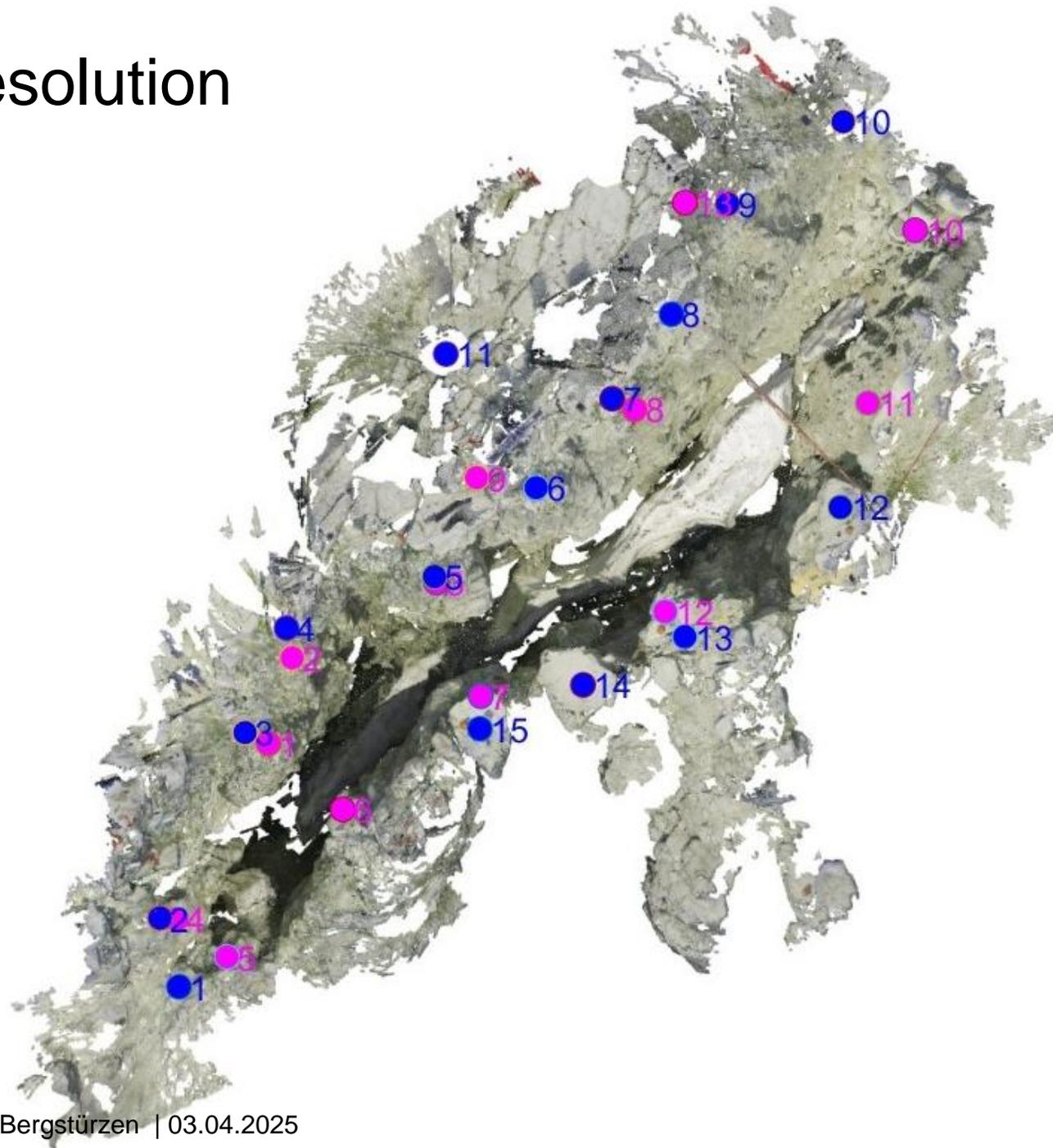


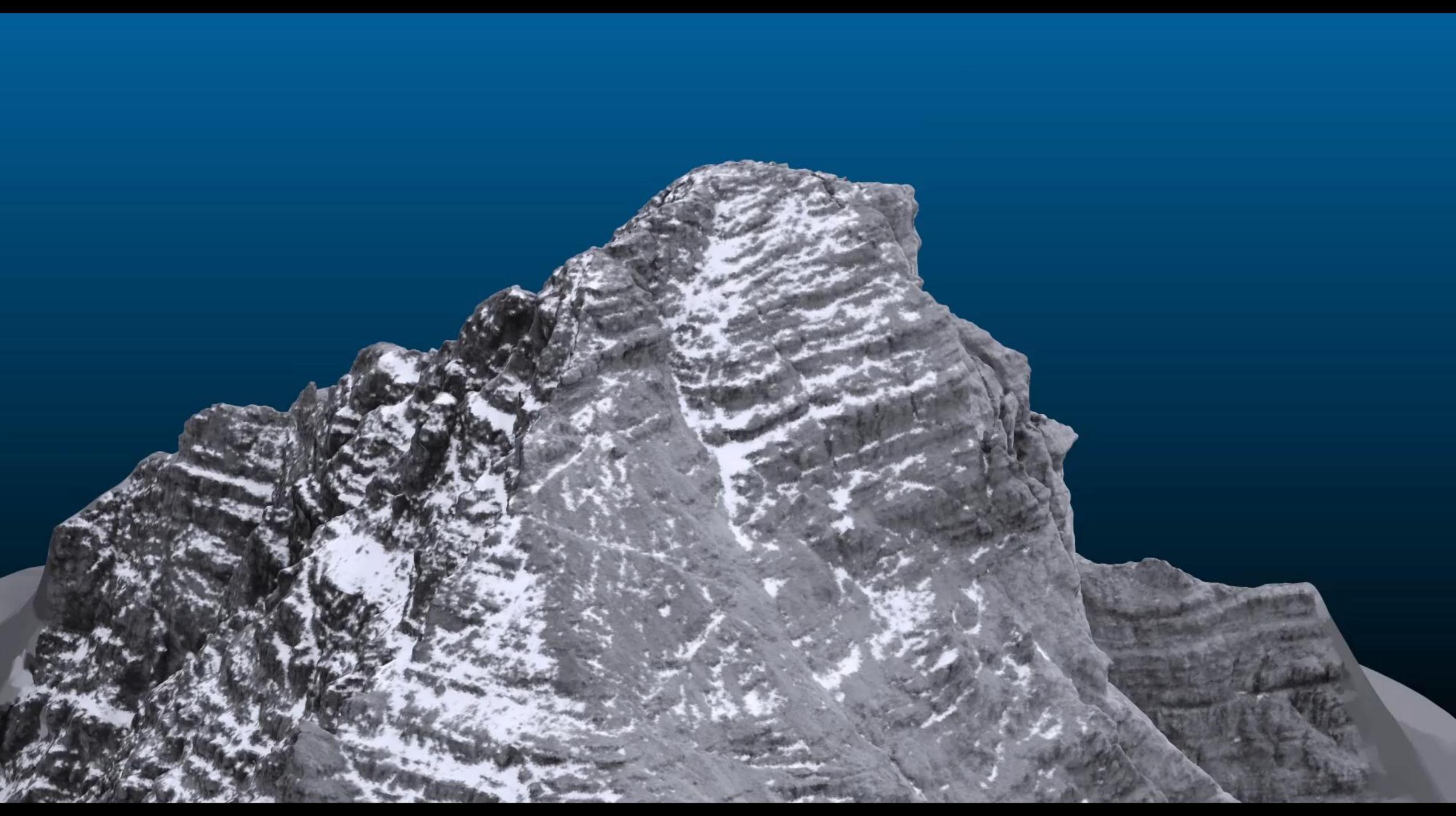
Terrestrial laser scanning



TLS for high spatial resolution

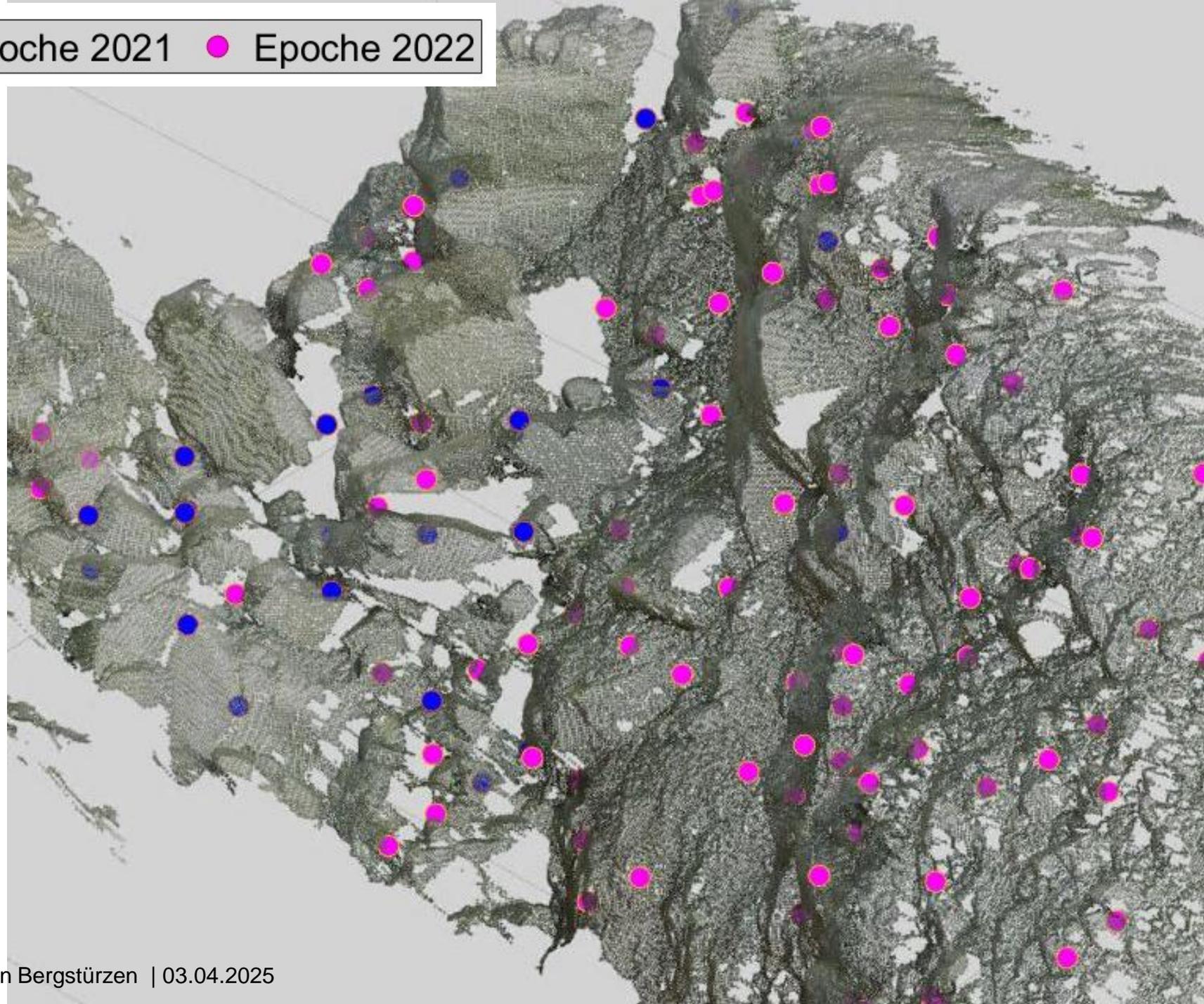
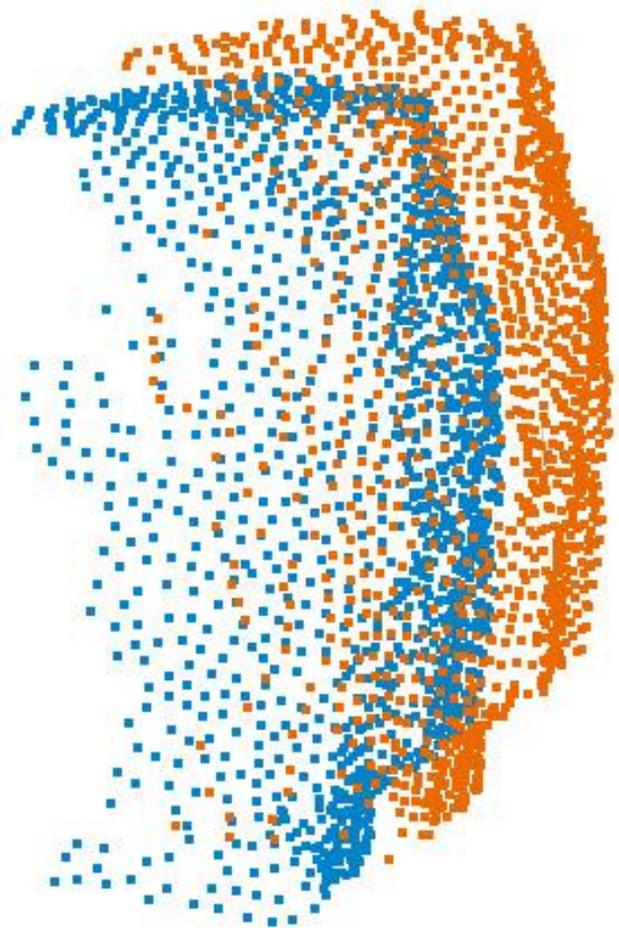
- Epoche 2021
- Epoche 2022



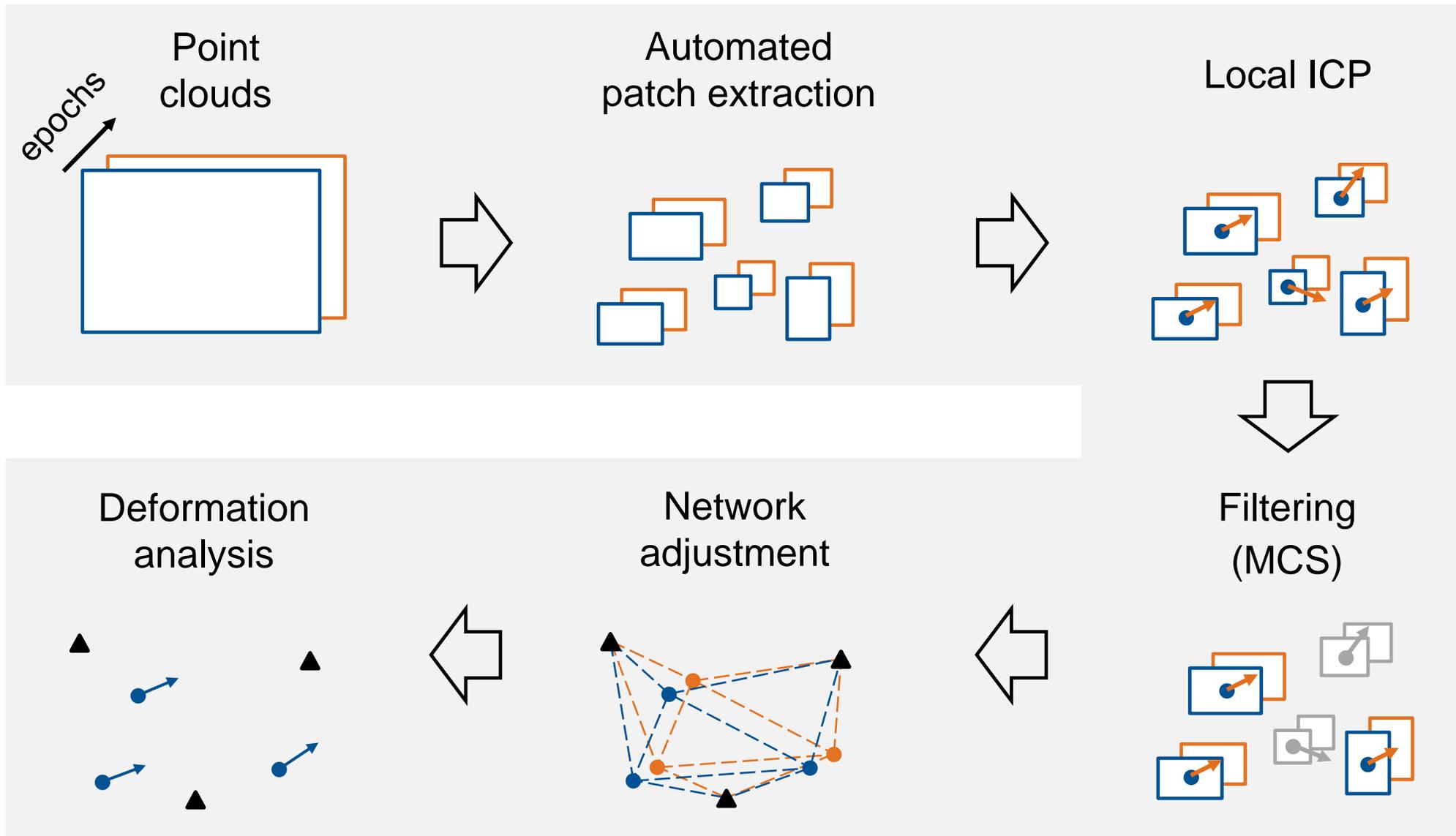


Prominent areas = Patches

● Epoche 2021 ● Epoche 2022

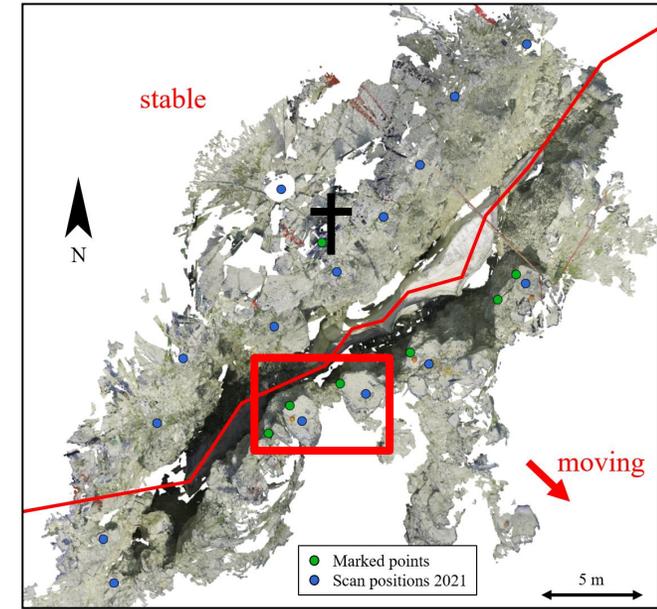
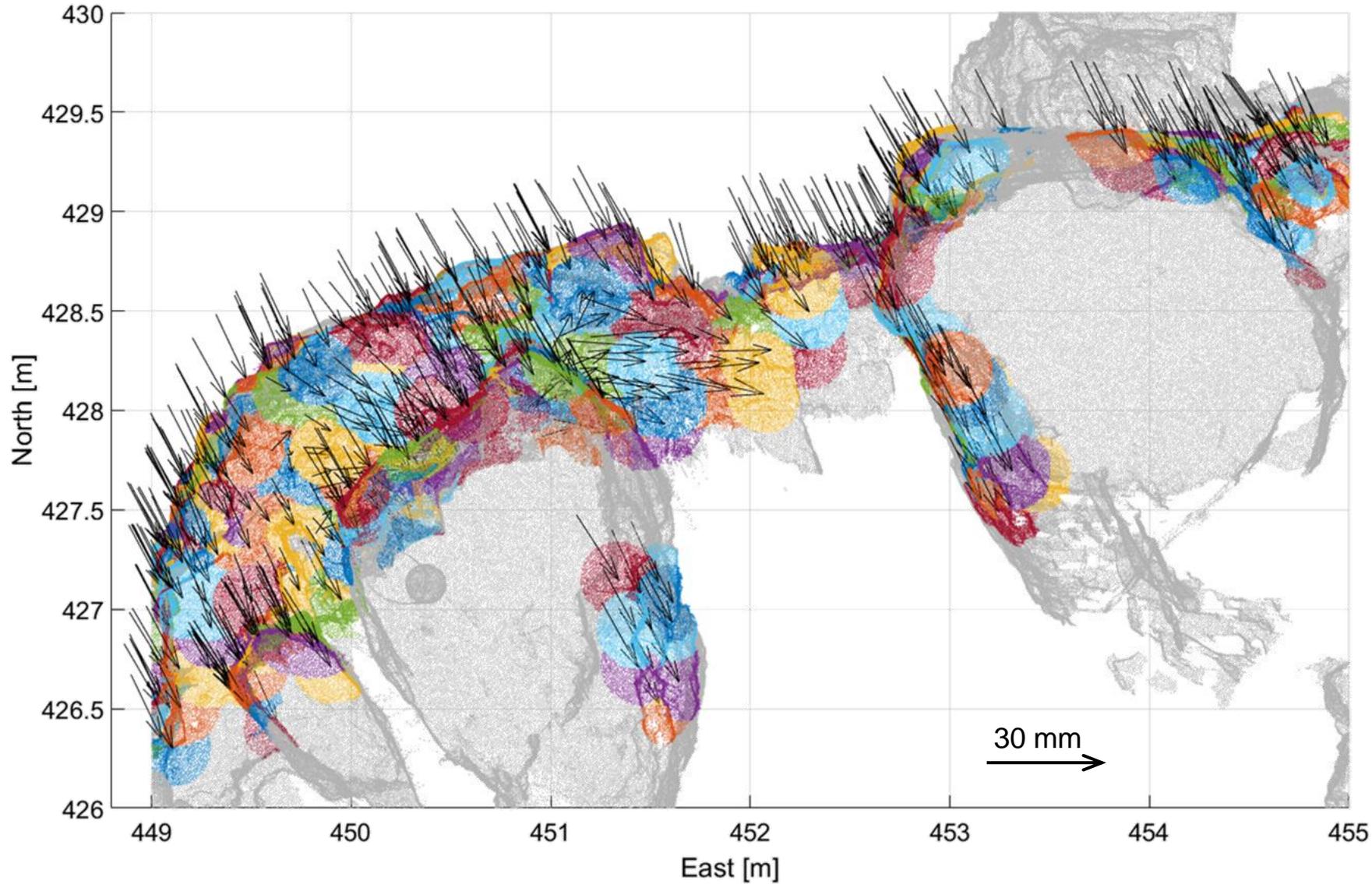


Workflow



▲ total station

Deformation vectors 2021-2022



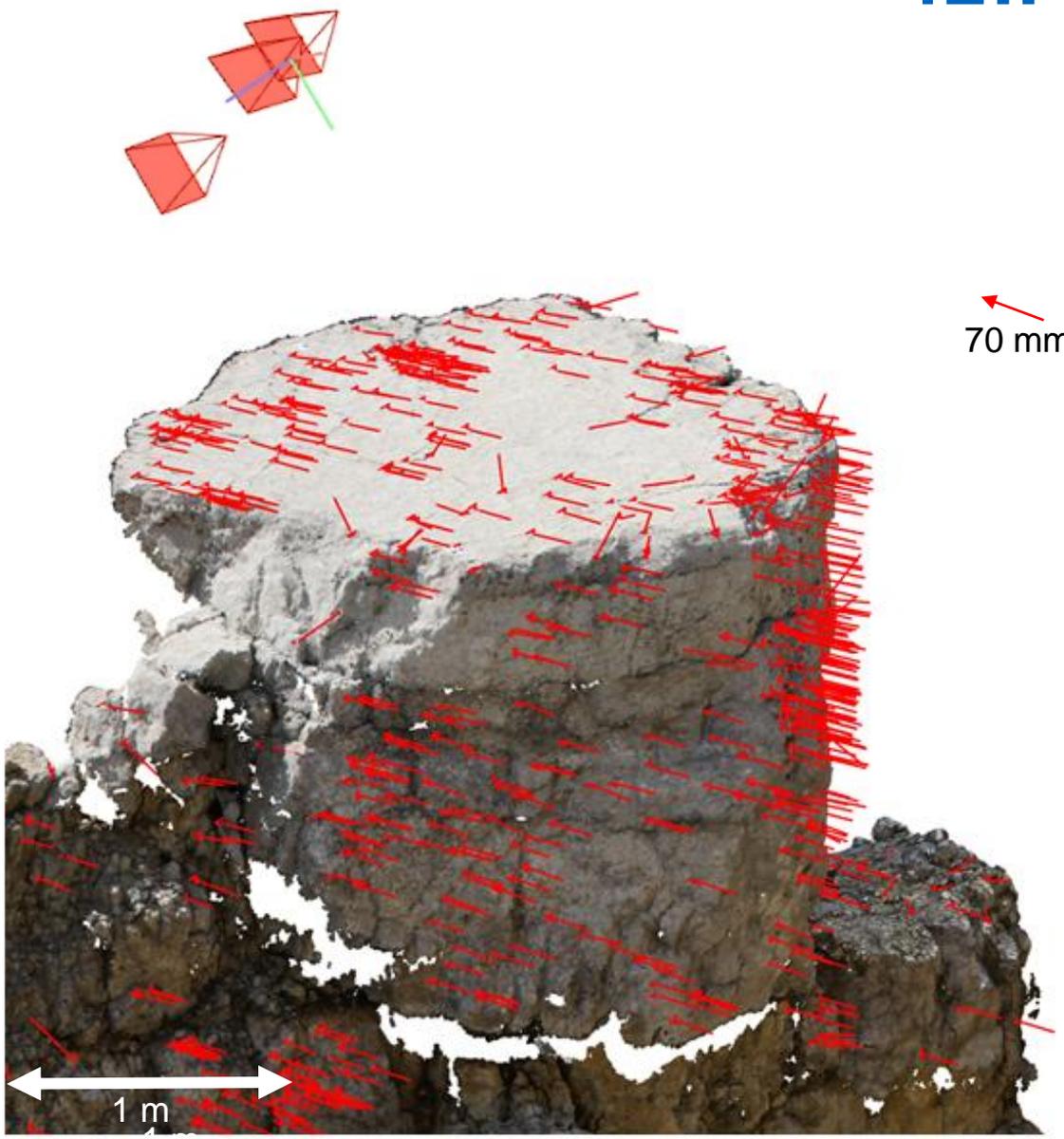
vectors: 451

$\sigma_{3D} = 1 - 4 \text{ mm}$ (mean: 2.4)

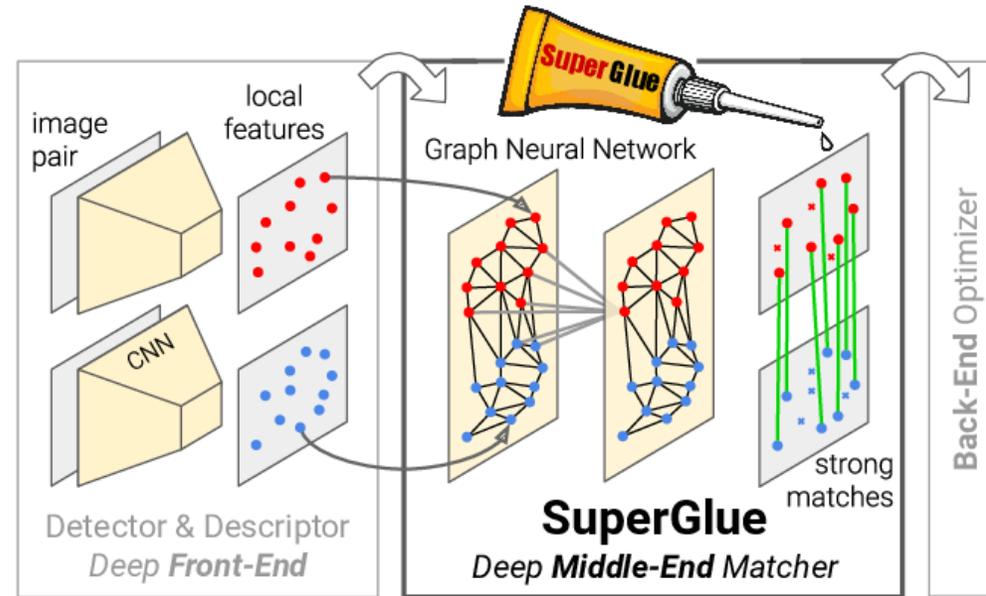
Photogrammetric 3D reconstruction



Bundle adjustment

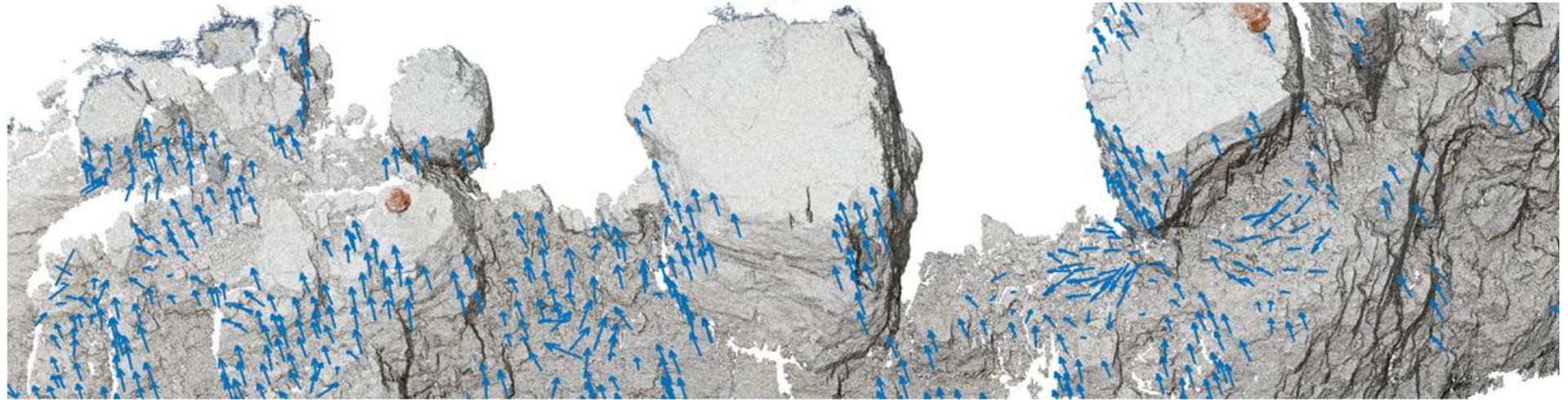


Deep learning-based matching



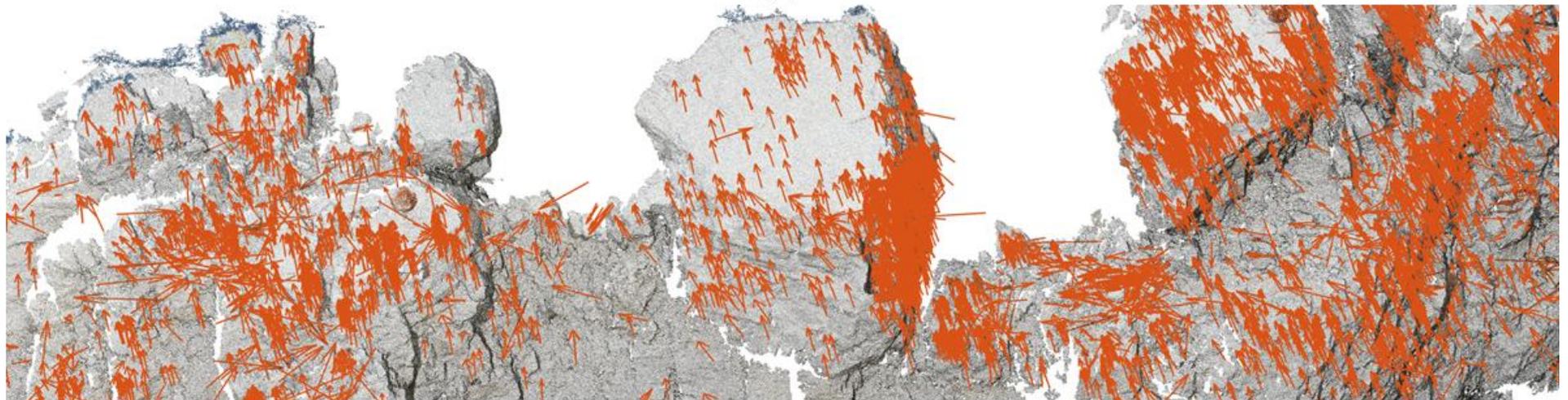
Comparison TLS and photogrammetry

**TLS / Patch-based
Tracking**



(b)

**Photogrammetry /
Feature-based
Tracking**



Absolute movements

- The northern side is stable, the southern side is breaking away towards Austria
- Movement about 2.5 mm / month
- So far no signs of acceleration!

Relative movements

- The behavior is becoming more complex, secondary cracks are forming
- Frequent small rockfalls (size: decimeters) into cracks
- Rock otherwise solid

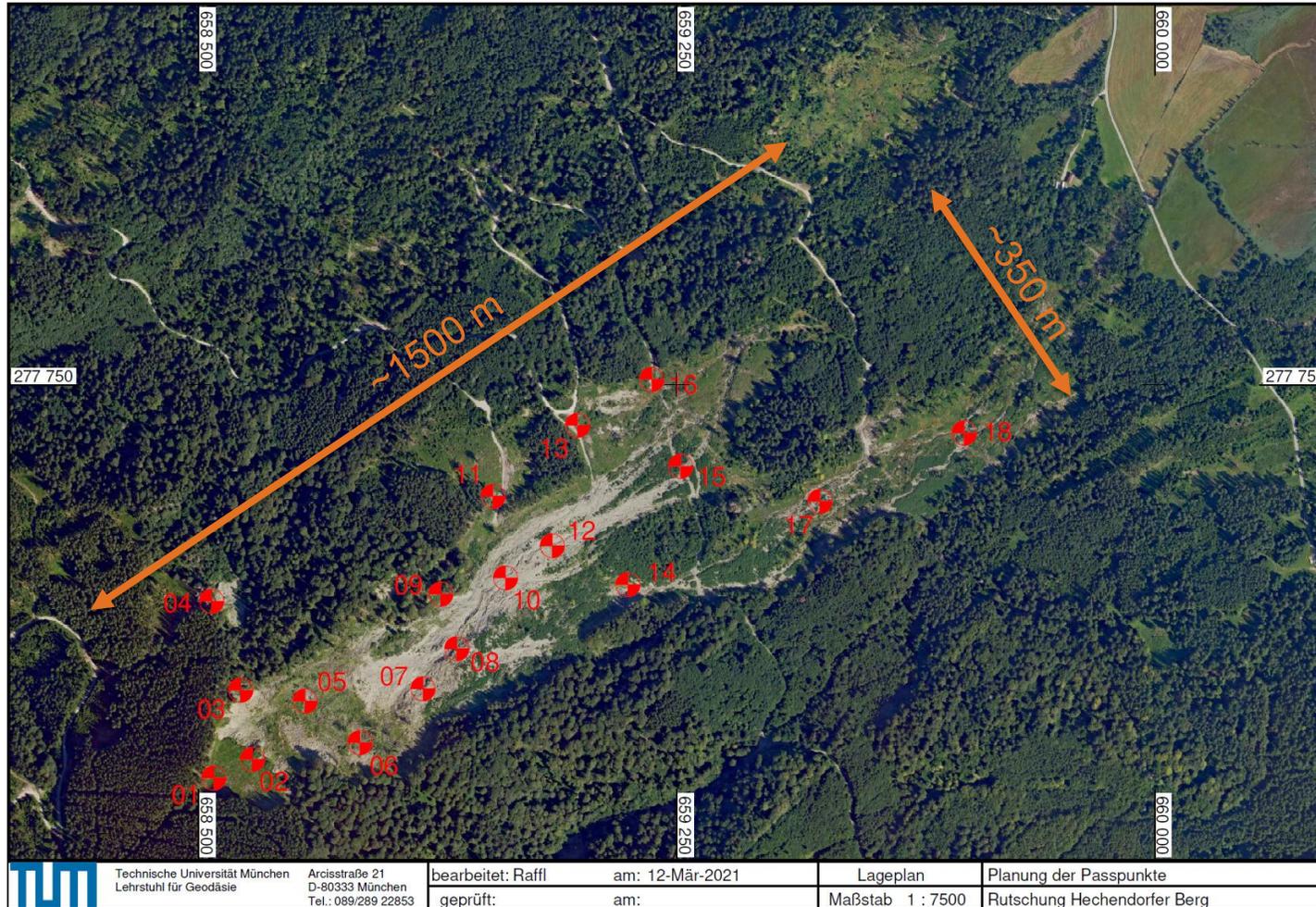
Monitoring solution: GNSS & TPS, TLS & camera

=> Future: permanent monitoring planned

Great public interest



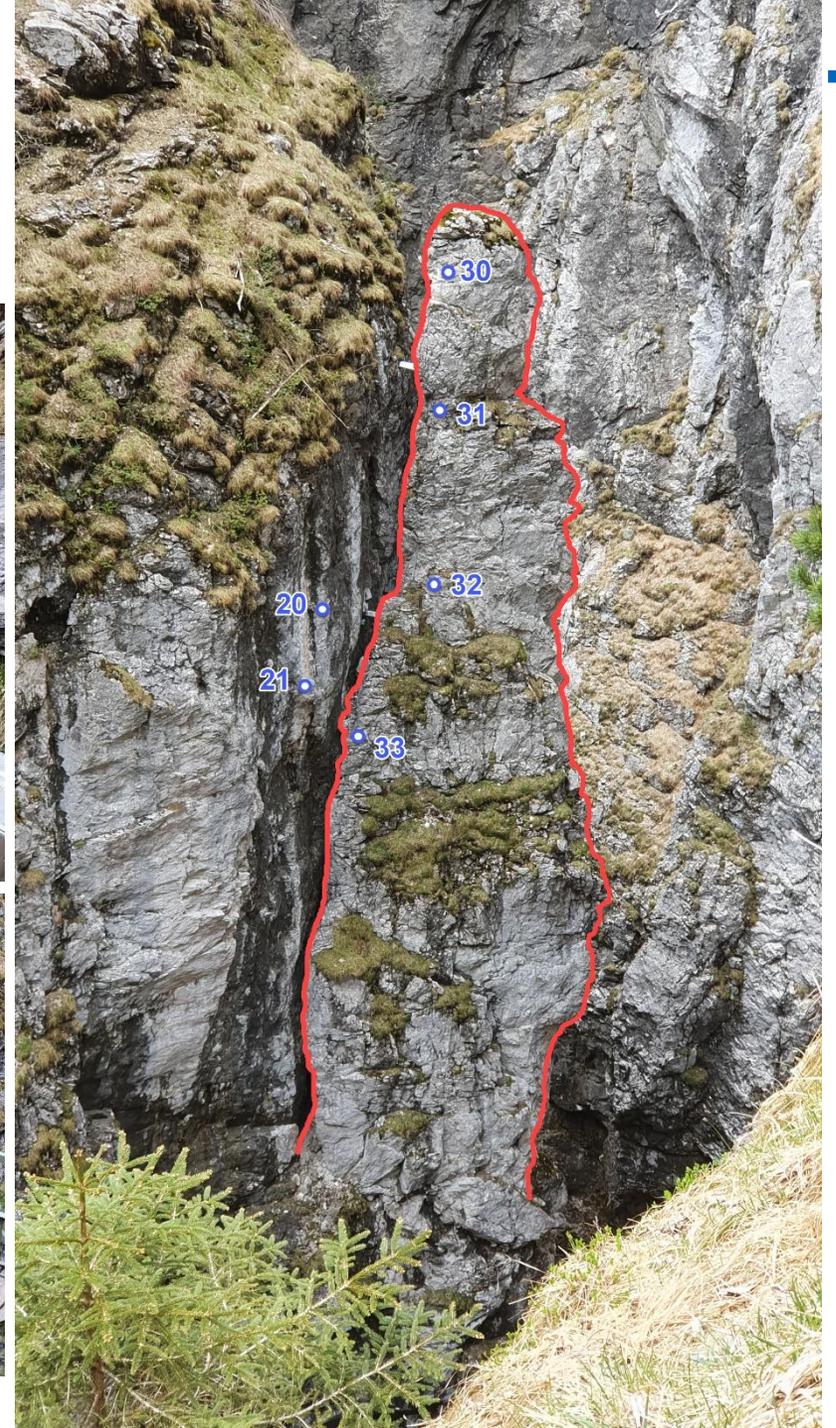
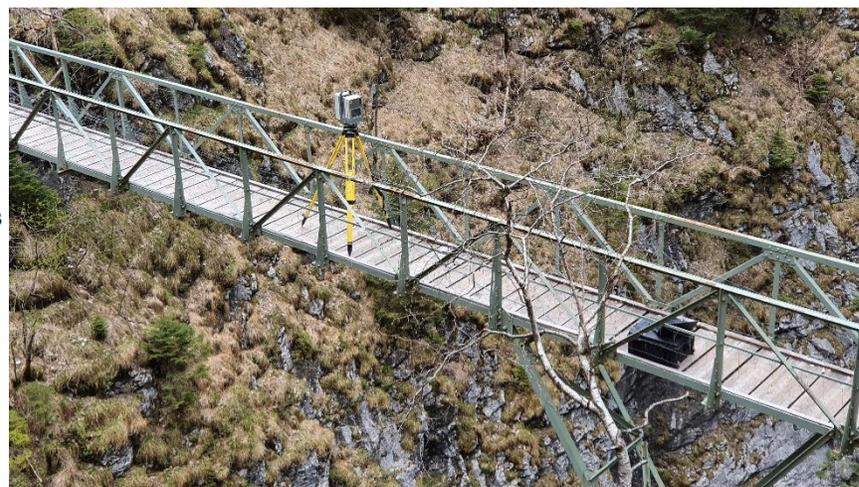
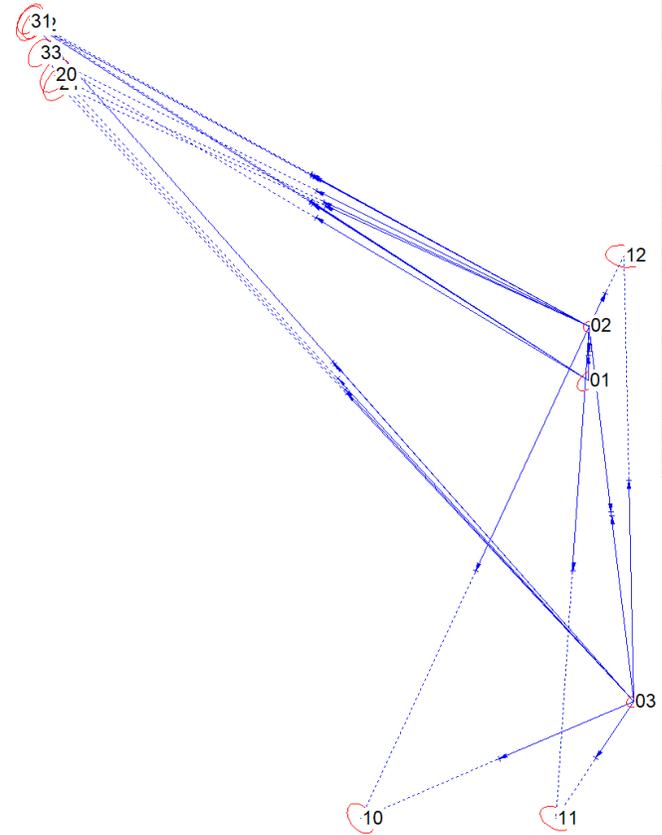
Hechendorfer Berg



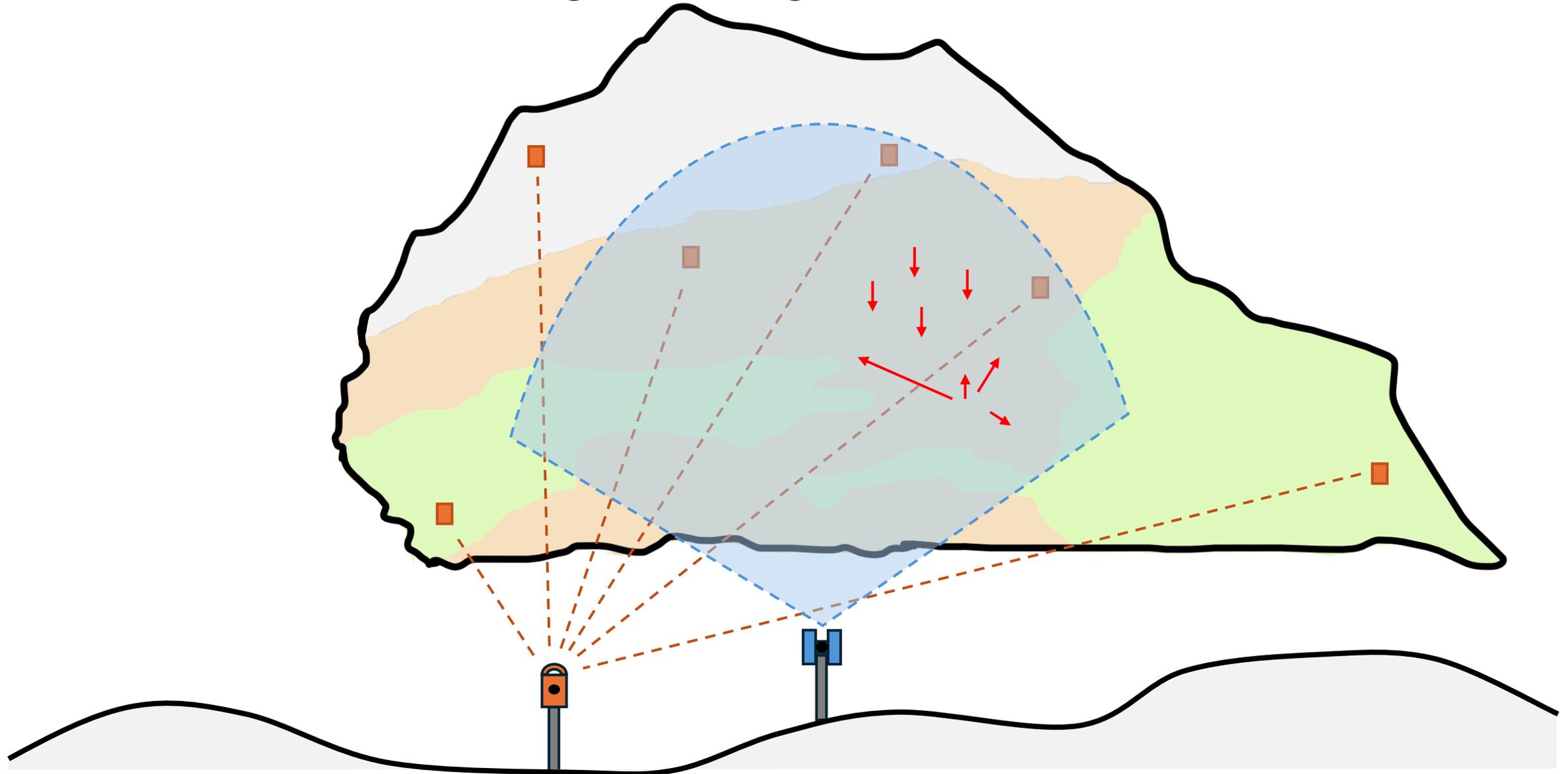
- Largest landslide in Bavaria
- Movements of ~ 1 m / year
- Highest activity after heavy rain
- 18 object points
- 4 fixed points
- SAPOS GNSS measurements



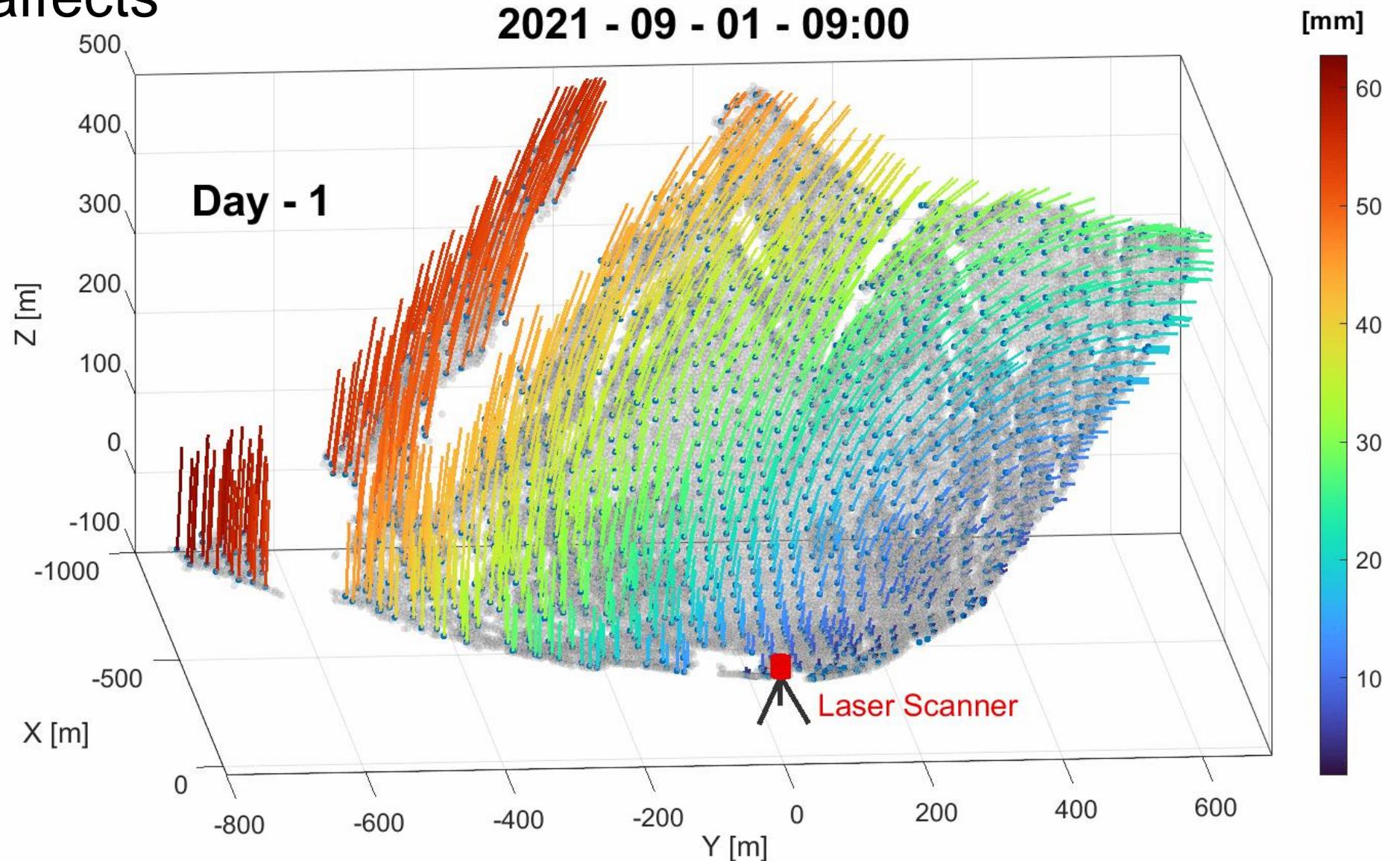
Höllentalklamm



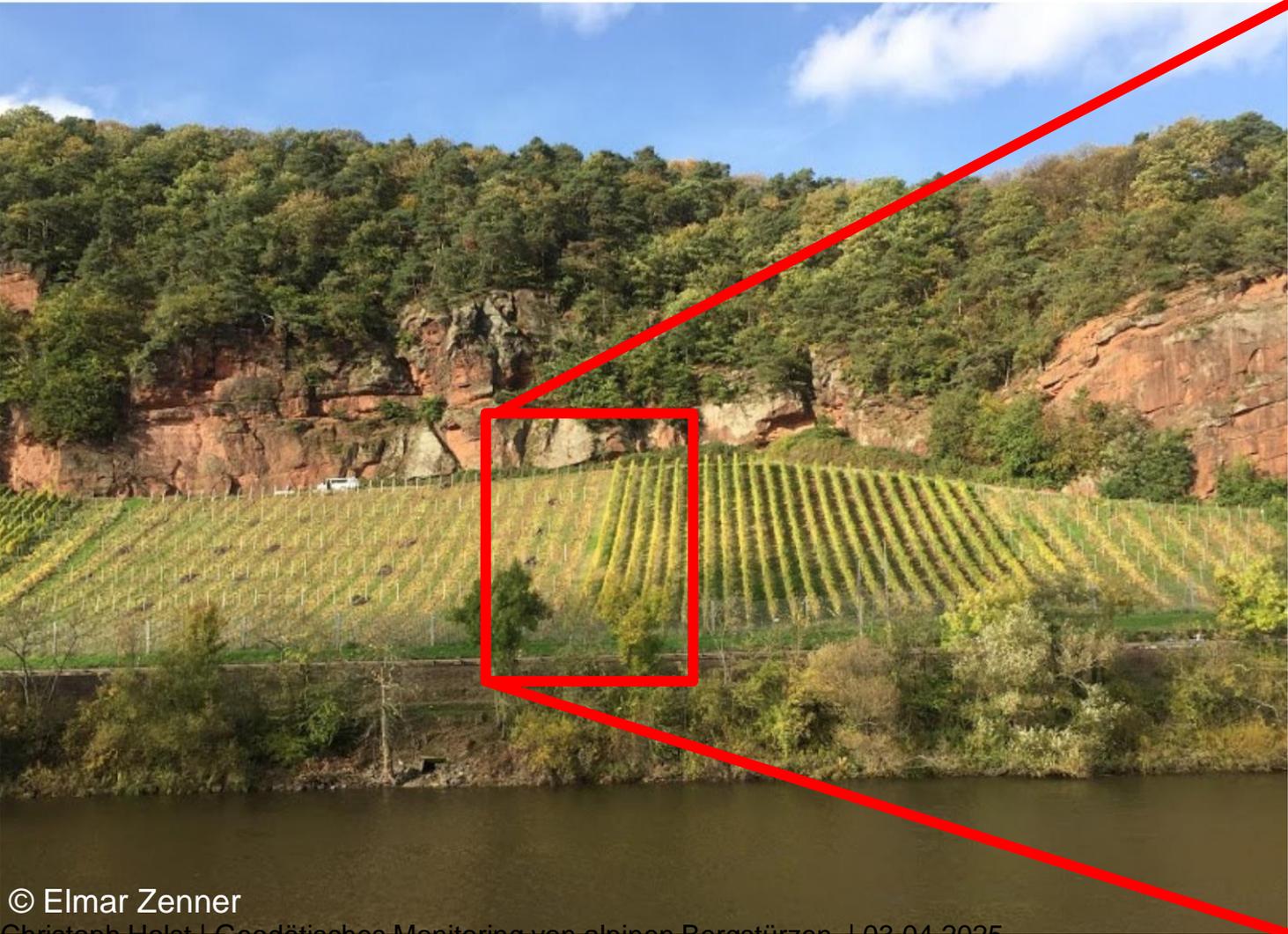
Permanent laser scanning over large distances



Potential impact of instable geo-referencing and atmospheric affects



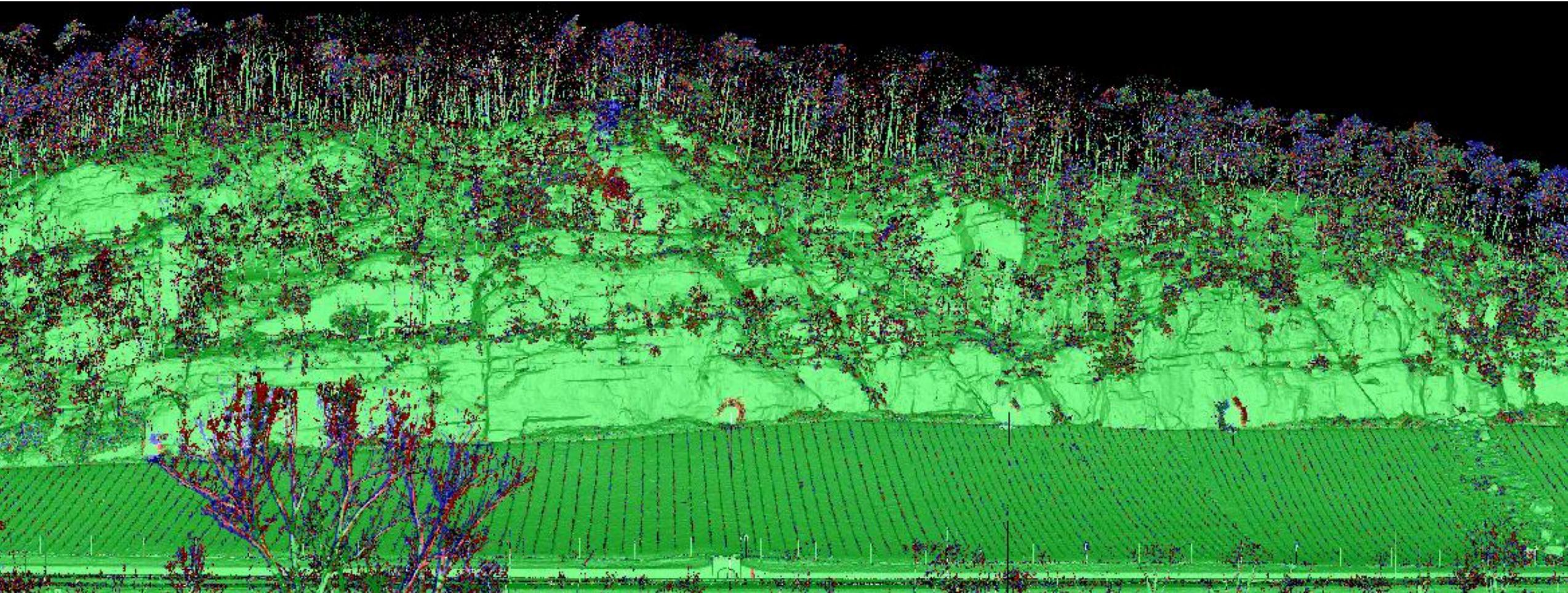
Trierer Augenscheiner, Vineyard, Trier



Permanent monitoring with laser scanner & total station



One point cloud each 30 minutes



Event on 26.08.2024

Provided by
Uni Heidelberg,
Ronald Tabernig &
Prof. Bernhard Höfle



- Release area
- New boulder fragments

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Thank you for your attention!

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