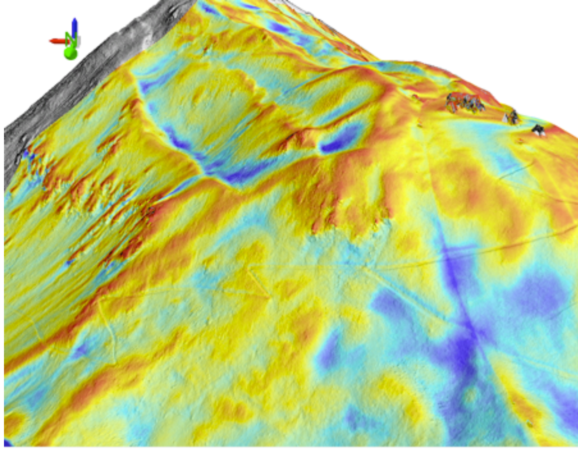


Efficient geo-data acquisition in high alpine terrain using UAS

Yves Bühler & Andreas Stoffel, SLF Davos
Ruedi Bösch & Christian Ginzler, WSL Birmensdorf

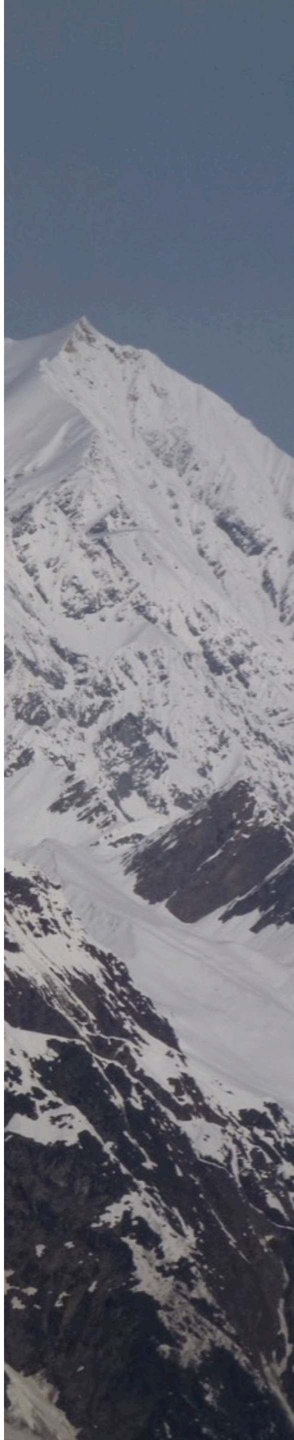
AHORN 2015 – Wildhaus SG, Schweiz

Motivation

- Poorly accessible, steep and dangerous **terrain**
- High **geomorphological activity** (rockfall, debris flows, snow avalanches) ➔ frequent and substantial terrain **changes**
- Rising demand for accurate and timely geo-information (orthophotos, digital surface models, 3D Animations …)

Main applications:

- **Numerical simulations** of natural hazards
- **Documentation** of specific hazard events
- Planning and monitoring of **mitigation measures**
- **Water** resource management: Hydropower and tourism
- Ideal location for weather stations ……………



Main challenges

UAS are mainly developed for quite **flat** regions and **good weather** conditions, but we regularly face:

- High **wind** speeds and gusts
- High **elevation**, 1500 – 3500 m a.s.l. and big elevation differences up to 2000 m
- Cold **temperatures** (down to – 30°) in particular in winter
- Areas of interest cannot be trespassed and is often **poorly accessible,** no flat terrain for **landing**
- Fast **changing** conditions (weather, sight, snowpack, …)

Unmanned Aerial Systems UAS

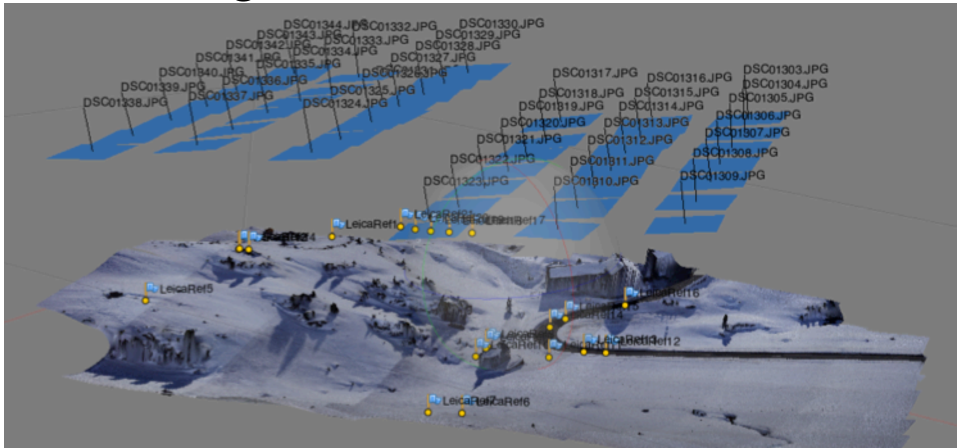
- Also called **drones**, remotely piloted aircraft systems **RPAS** or Unmanned Aircraft Vehicles **UAV**
- Boom! big variety of economic devices available today
- Legal situation is varying from country to country, often unclear

Our UAS: Ascending Technologies **Falcon 8**

- Octocopter, fully stabilized Sony NEX-7 camera (24 Mpixel)
- 2.3 kg total weight, no special permit necessary in Switzerland
- Portable in a backpack, applicable in complex terrain, very wind resistant, starting and landing from hand possible
- Flight time with one battery: ca. 8 min at 8-10 m/s = 100 pictures

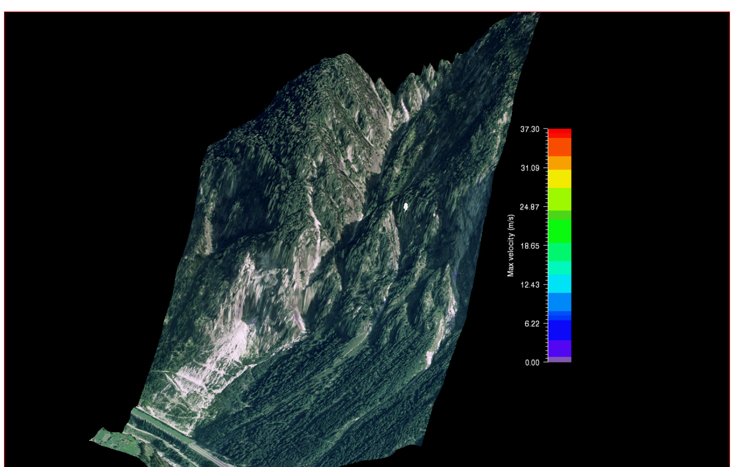
Software

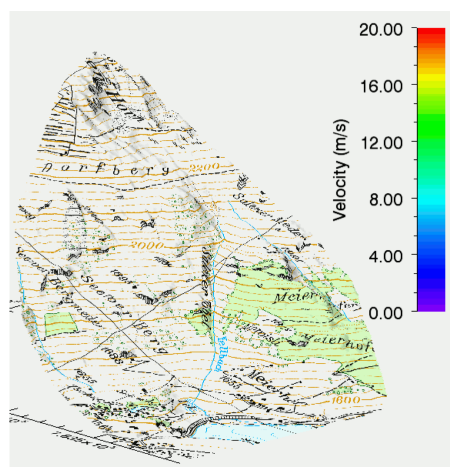
- Flight planning: AscTecNavigator v 3.2
  - Import of swisstopo maps 1:25’000 (contour lines!)
  - Definition of ground sampling distance GSD & overlap
  - Demanding task in alpine terrain
- Data Processing: Agisoft PhotoScan Pro v. 1.1.6
  - Fast image alignment and point matching
  - Easy registration with reference points
  - Point cloud building needs several hours

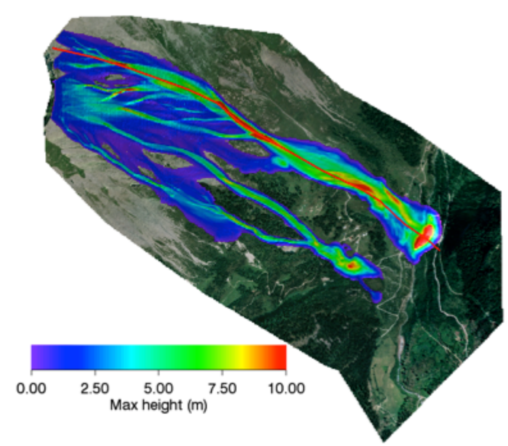


Application I: event documentation

- Natural hazards such as snow **avalanches**, **debris flows** or **rockfalls**
- **Fast** and **flexible** data acquisition
- High precision measurements of **release disposition** in poorly accessible terrain.
- Efficient documentation of the **translation** and **deposition zone** including runout distances, deposition and erosion volumes as well as damage
- This is essential information for numerical process simulations





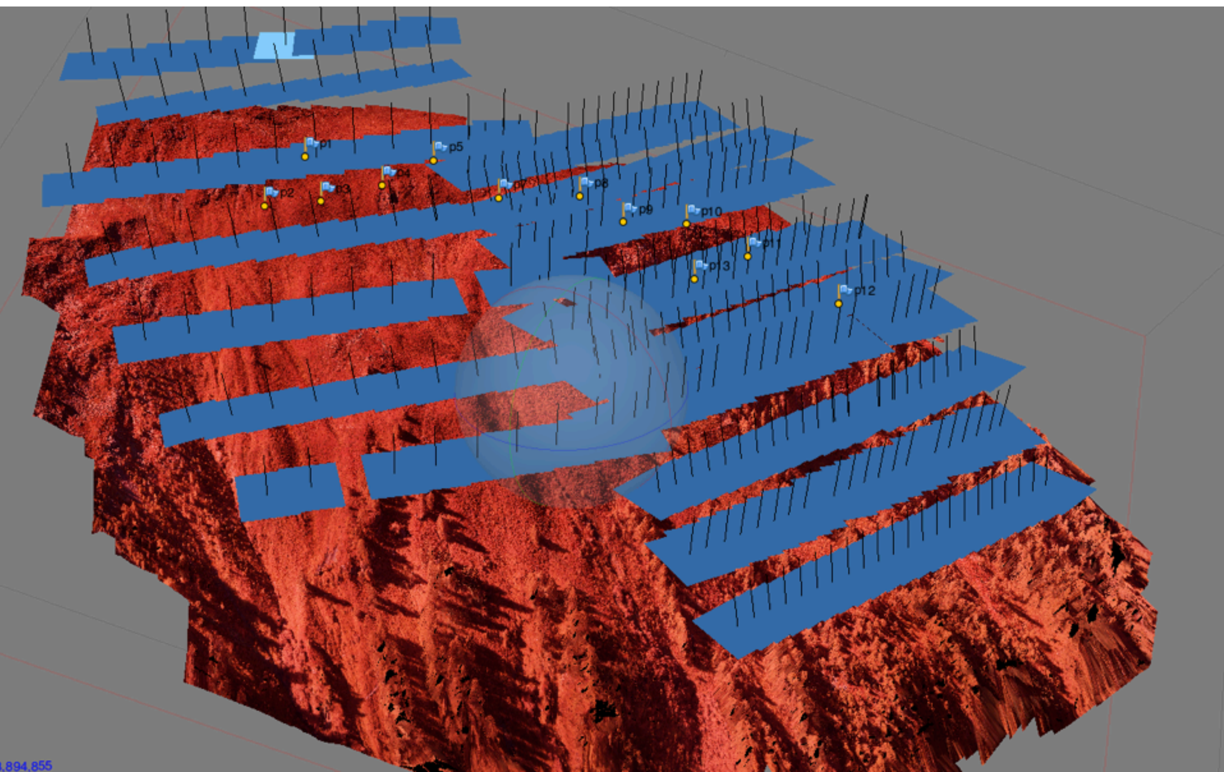


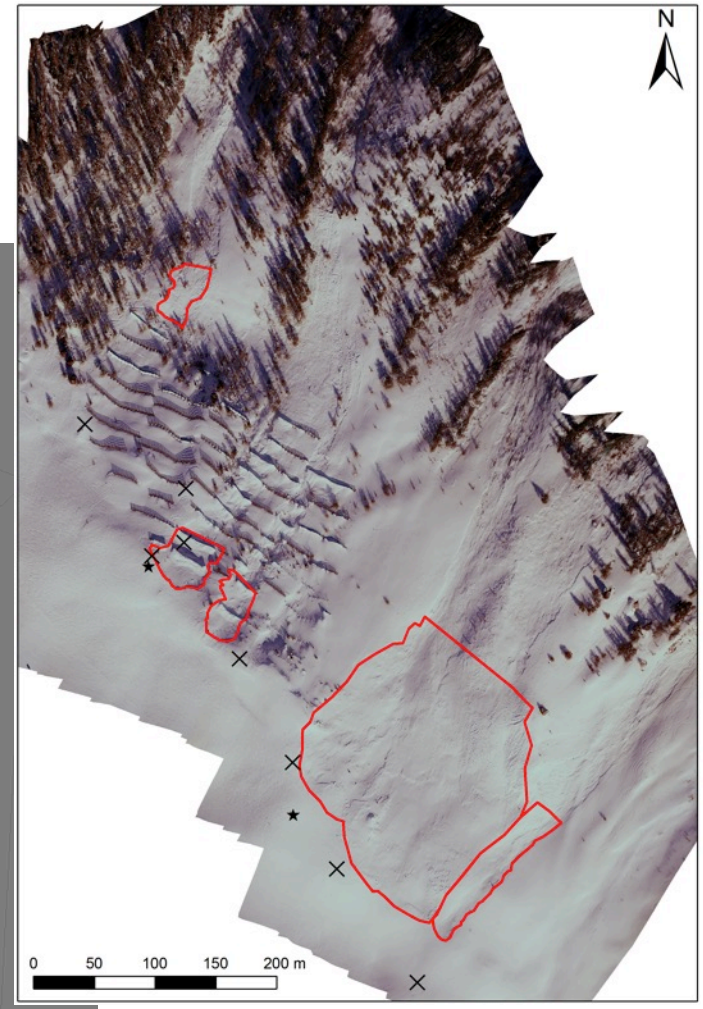
Wildi Avalanche, Davos Switzerland

- Easter, 04. April 2015
- Bad weather conditions, poor visibility
- One snowboarder buried, found dead 10 days later
- Cold, dry snow starting zone; erosion of warm, moist snow
- Release: approximately 20’000 m^3 @ 2300 m a.s.l., d0 ≈ 0.8 m
- Deposition volume approximately 40’000 m^3 @ 1600 m a.s.l.
- Runout distance approximately 1 km, 700 m elevation difference

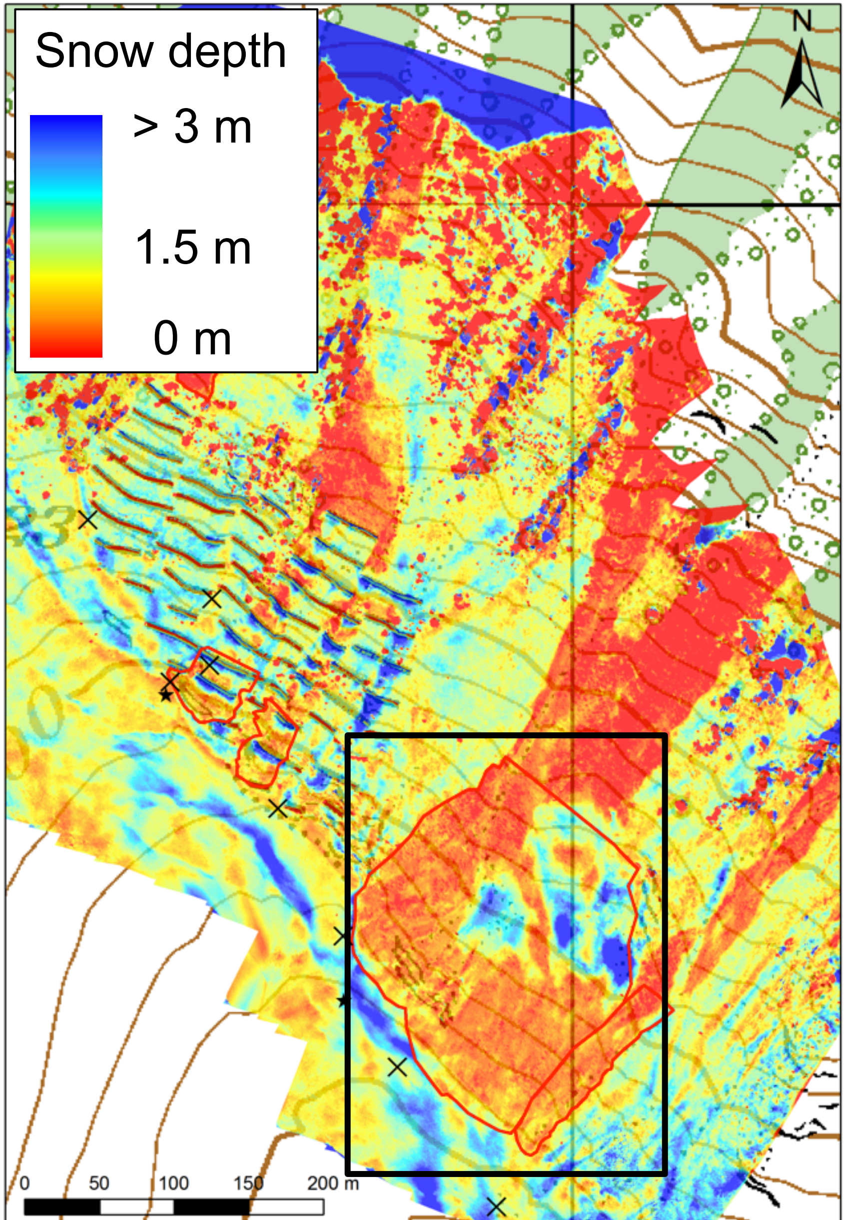
Wildi Avalanche, Release zone

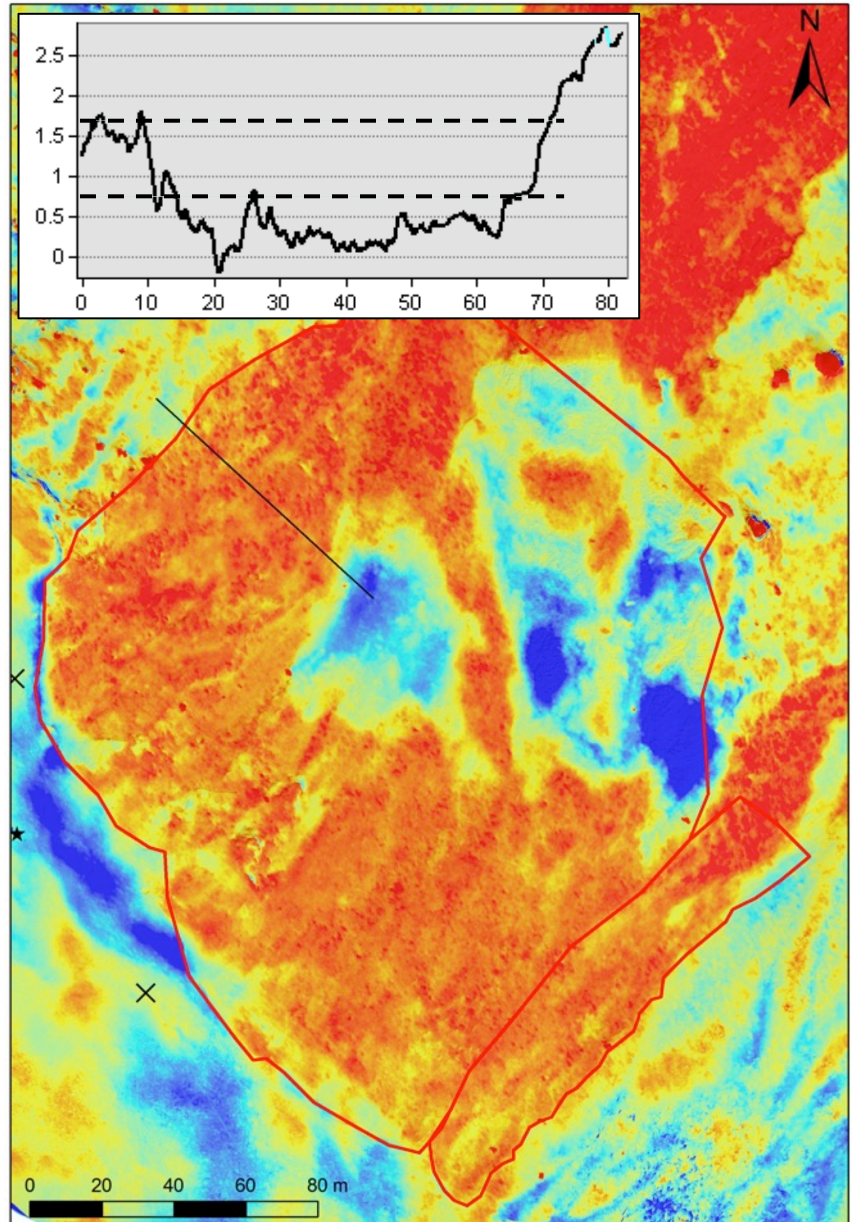
- Winter data: 07. April 2015, Summer data: 21. September 2015
- Flight elevation ≈ 100 m above ground, 70% overlap, GSD ≈ 2 cm, 260 single images, positioning accuracy < 7 cm (dGNSS)
- 5 batteries, flight elevation 150 m **below** starting point ➔energy management !!!





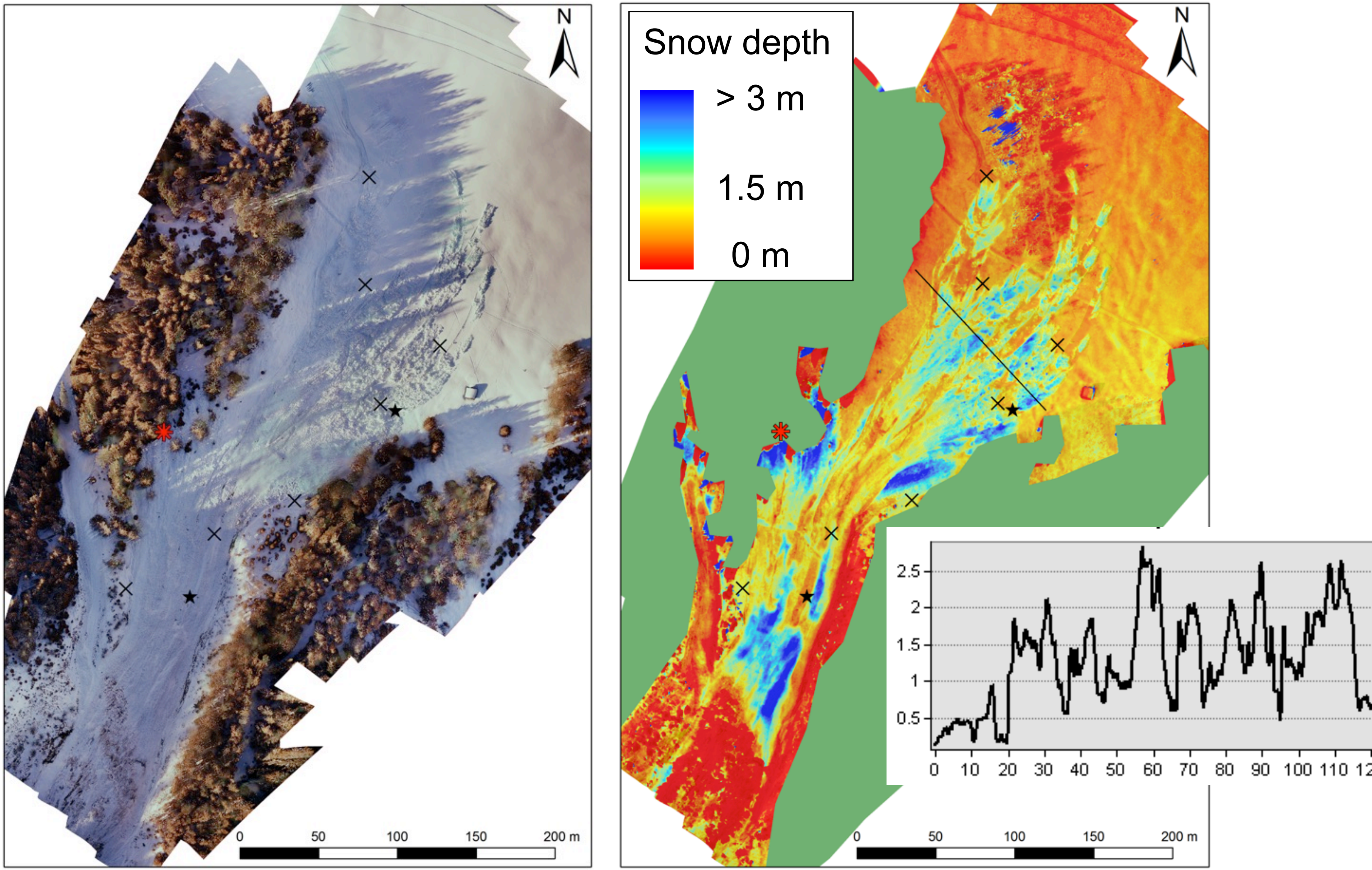
Wildi Avalanche, Release zone





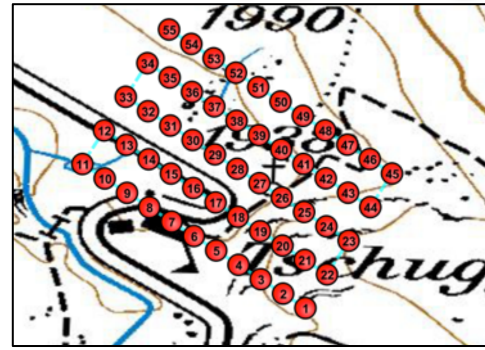
Wildi Avalanche, Deposition zone

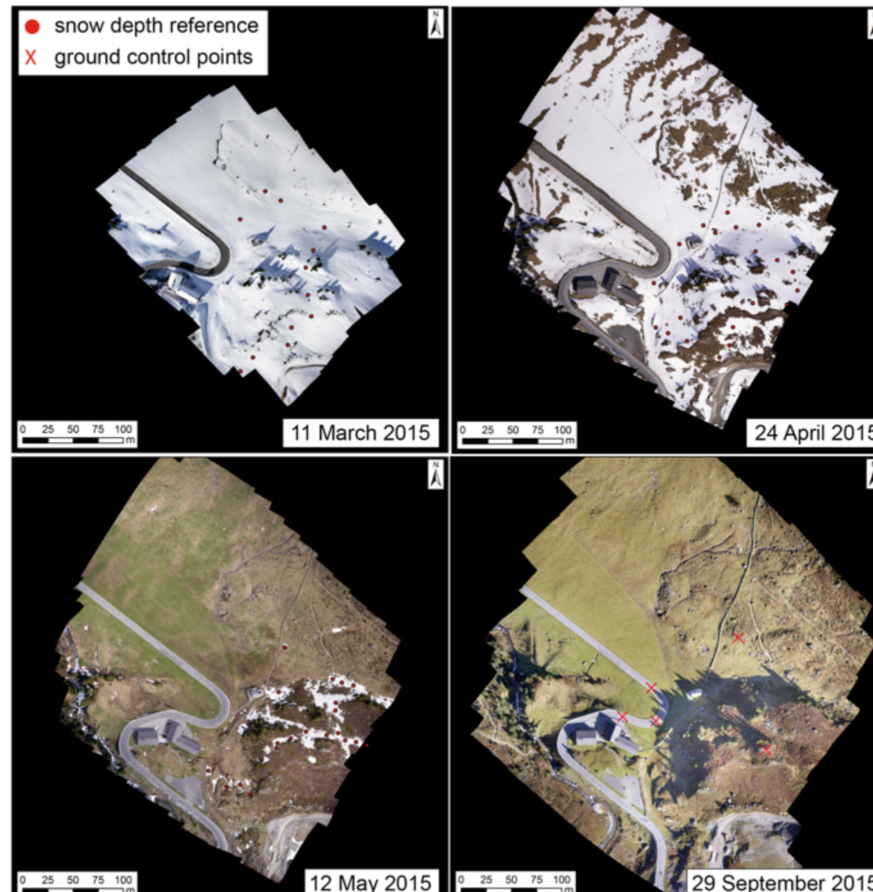
- Winter: 07. April 2015, summer: 07. August 2015

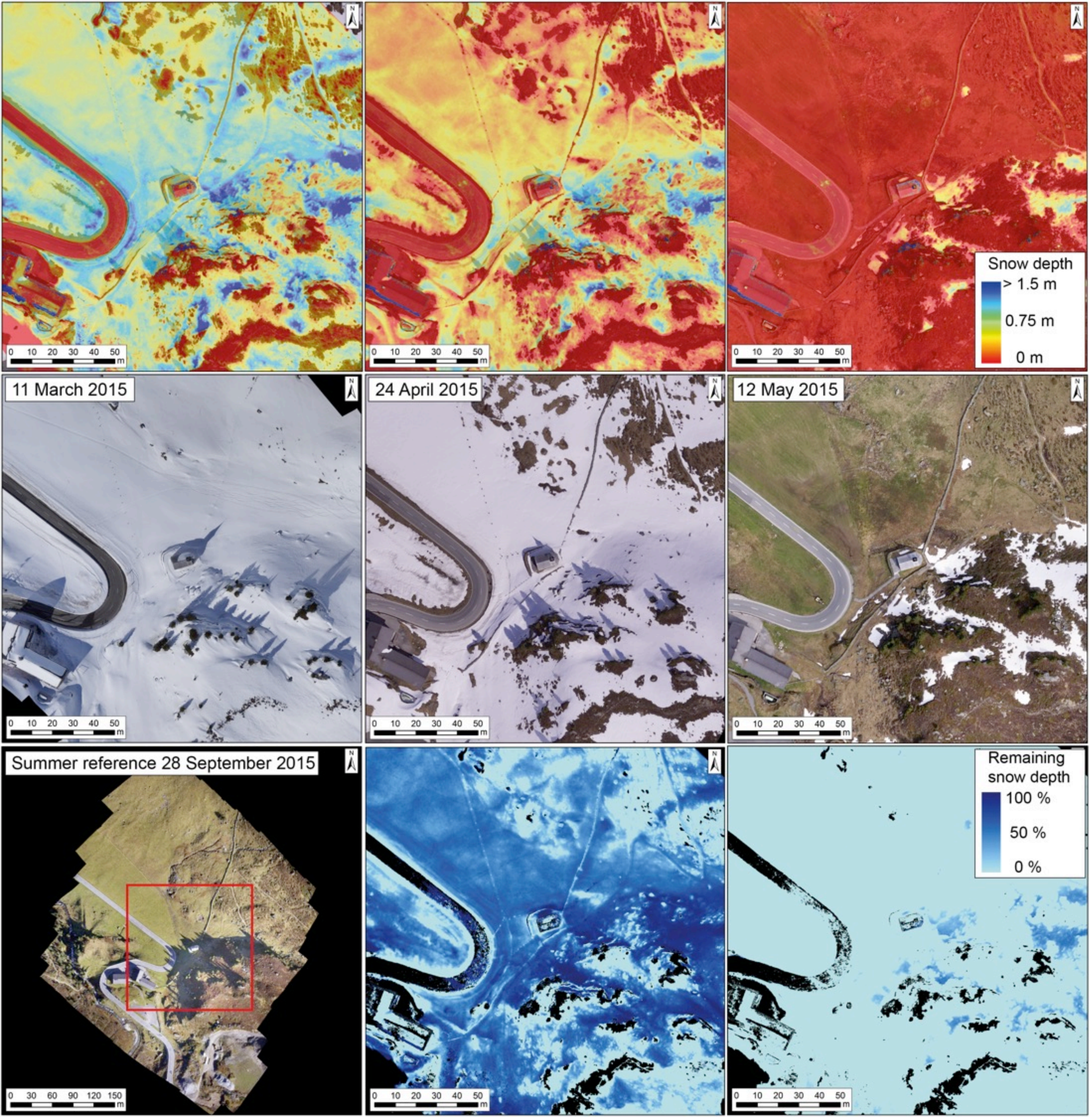


Application II: Snow depth mapping

- Test site Tschuggen, 300 x 200 m; 1930 – 2000 m a.s.l
- Flight dates:
  - 11 March 2015 (close to peak of winter)
  - 24 April 2015
  - 12 May 2015
  - 28 September 2015 (snwo free)
- 5 absolute reference points, 10 check points, Positioning accuracy < 5 cm
- 55 images, flyable with one battery







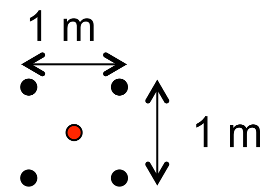
Snow depth HS

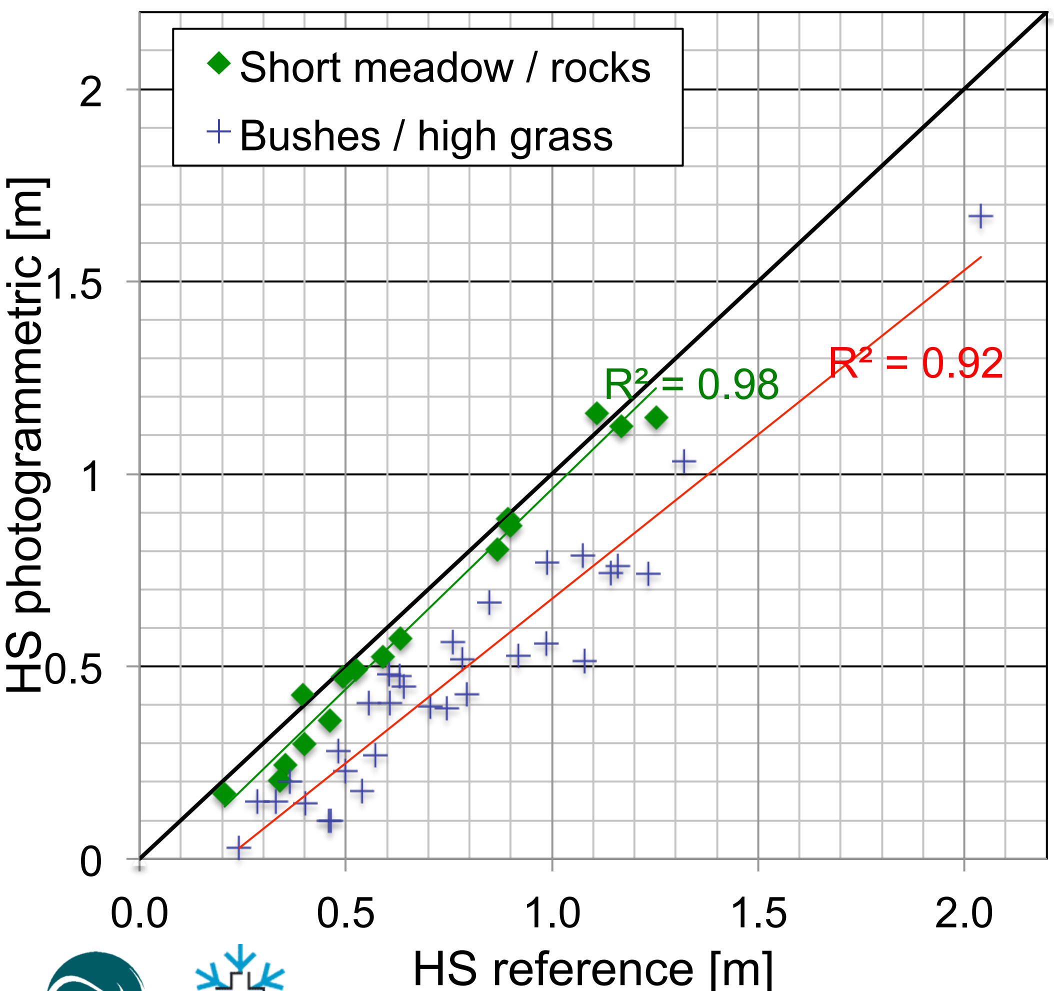
Ortho imagery

Relative snow depth compared to max HS

Validation

- 50 reference plots à 5 probe measurements



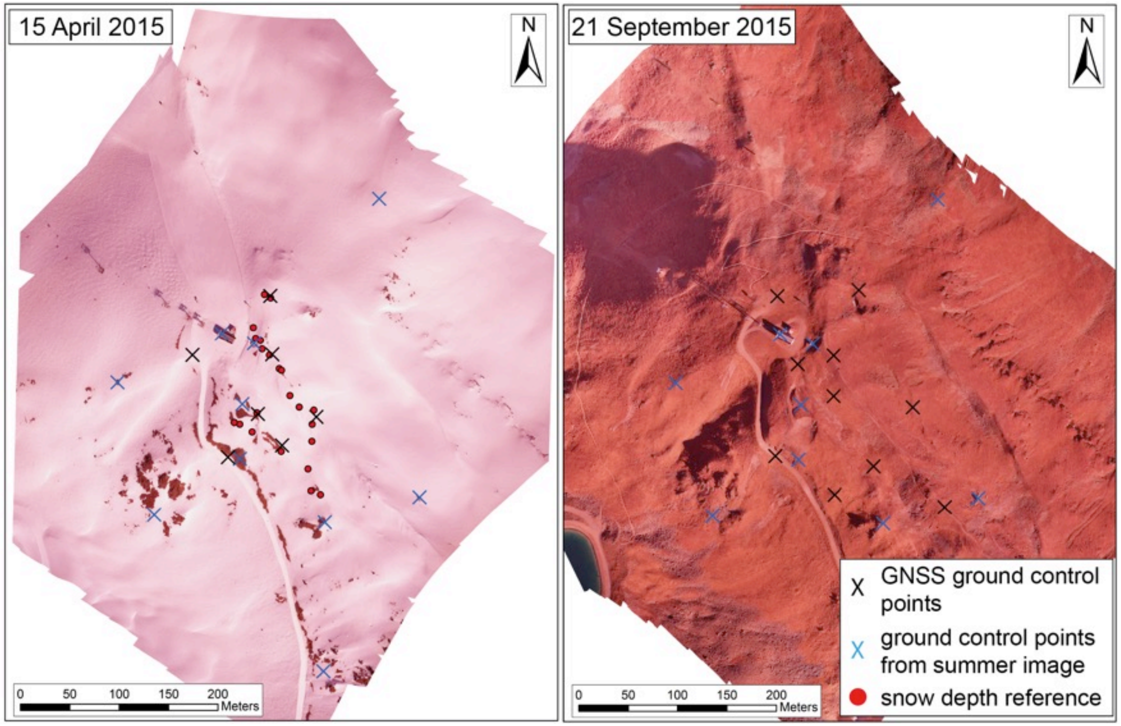


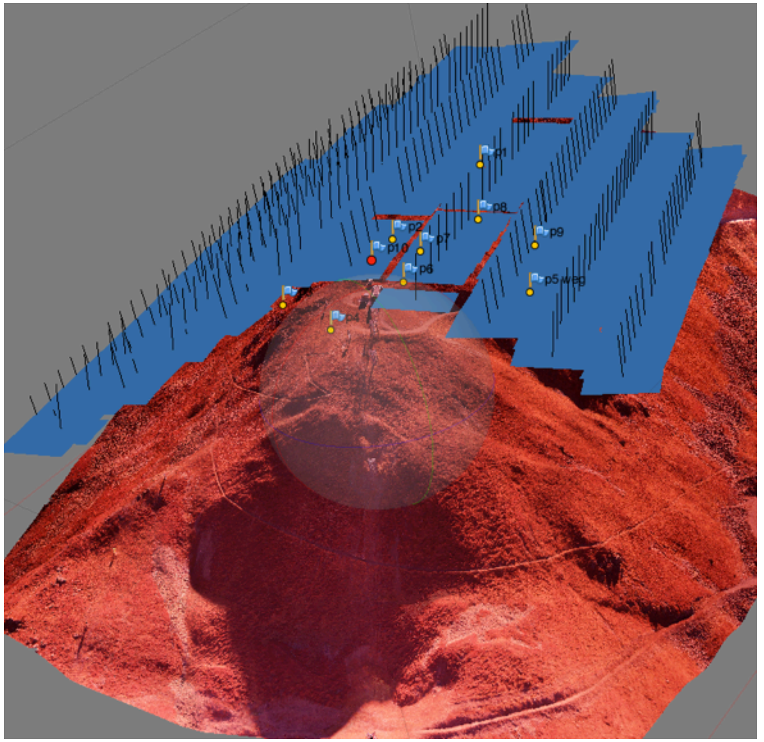
- RMSE over short grass / rocks = 7 cm
- RMSE Bushes = 30 cm
- RMSE tot = 25 cm

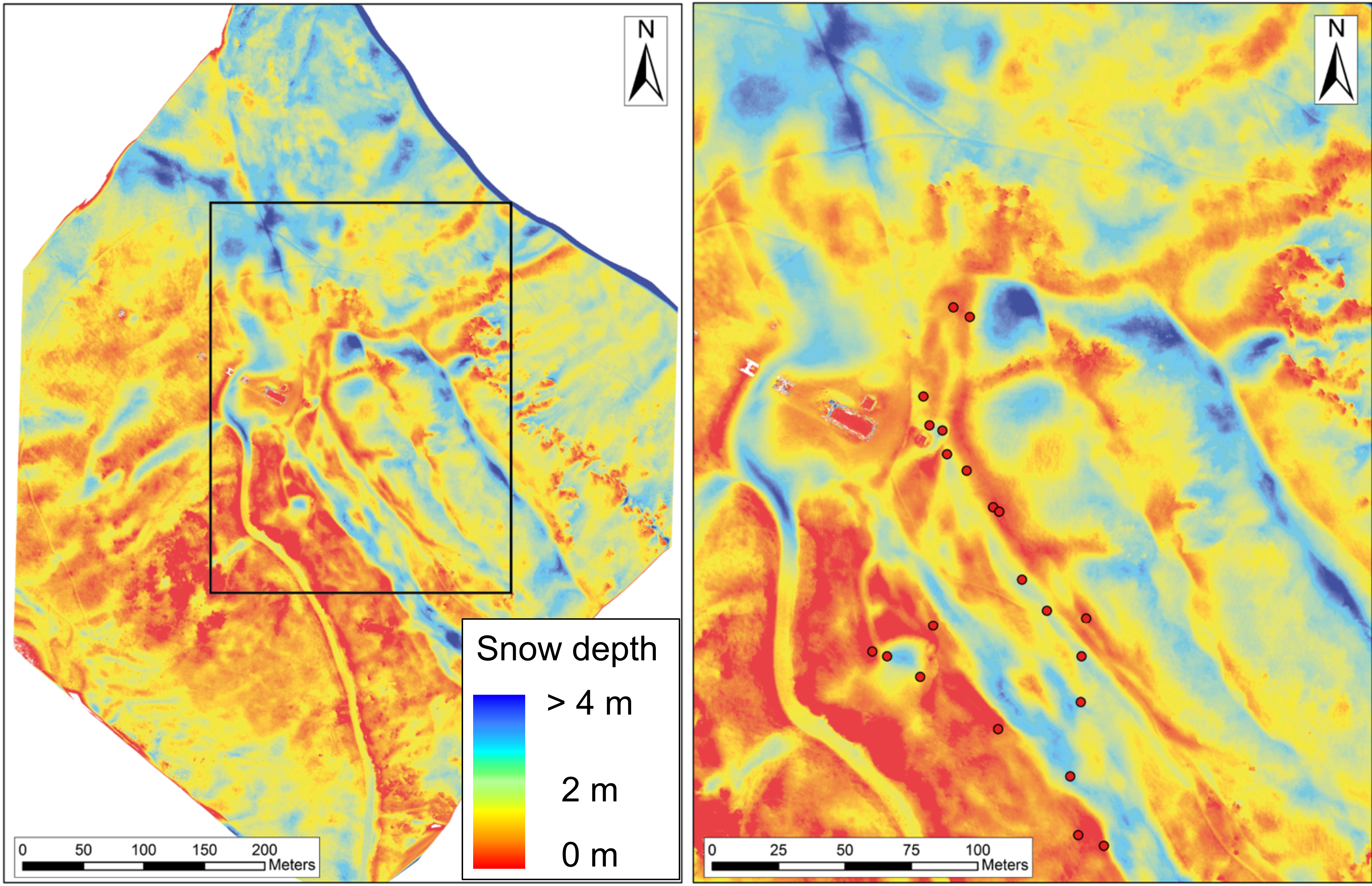
- Underlying Vegetation in summer DSM
- “True HS” in between photogrammetric HS and probe HS

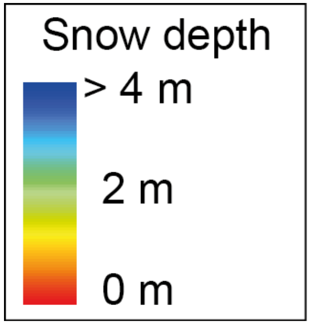
High alpine test site Brämabühl

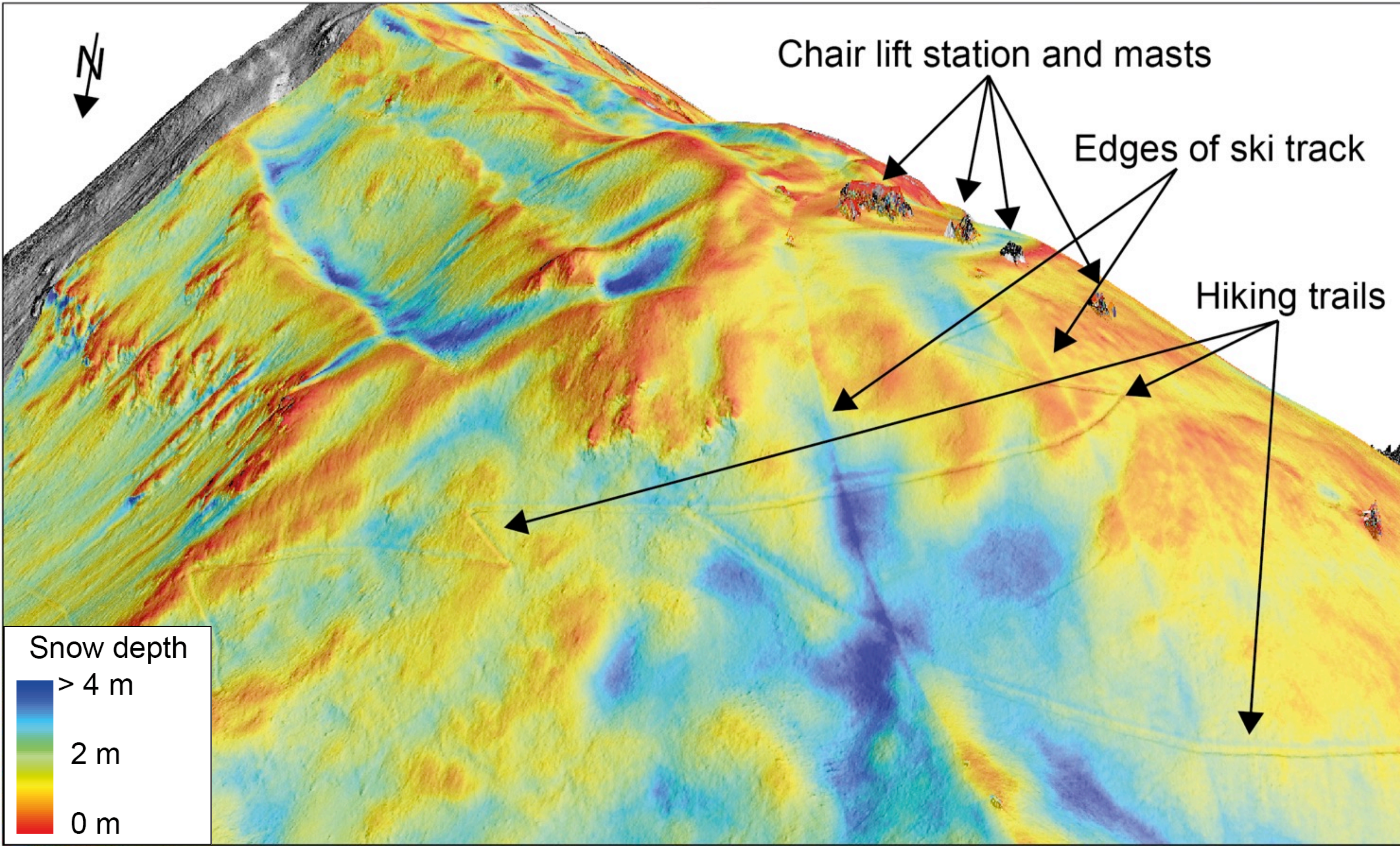
- 2400 – 2500 m a.s.l. mountain top: high wind speeds & artificial snow production / grooming, area: ~ 400 x 400 m
- 274 images @ 100 m above ground
- 4 batteries
- Positioning accuracy < 15 cm with 10 reference points






N
Snow depth
> 4 m
2 m
0 m
0 50 100 150 200
Meters
N
0 25 50 75 100
Meters

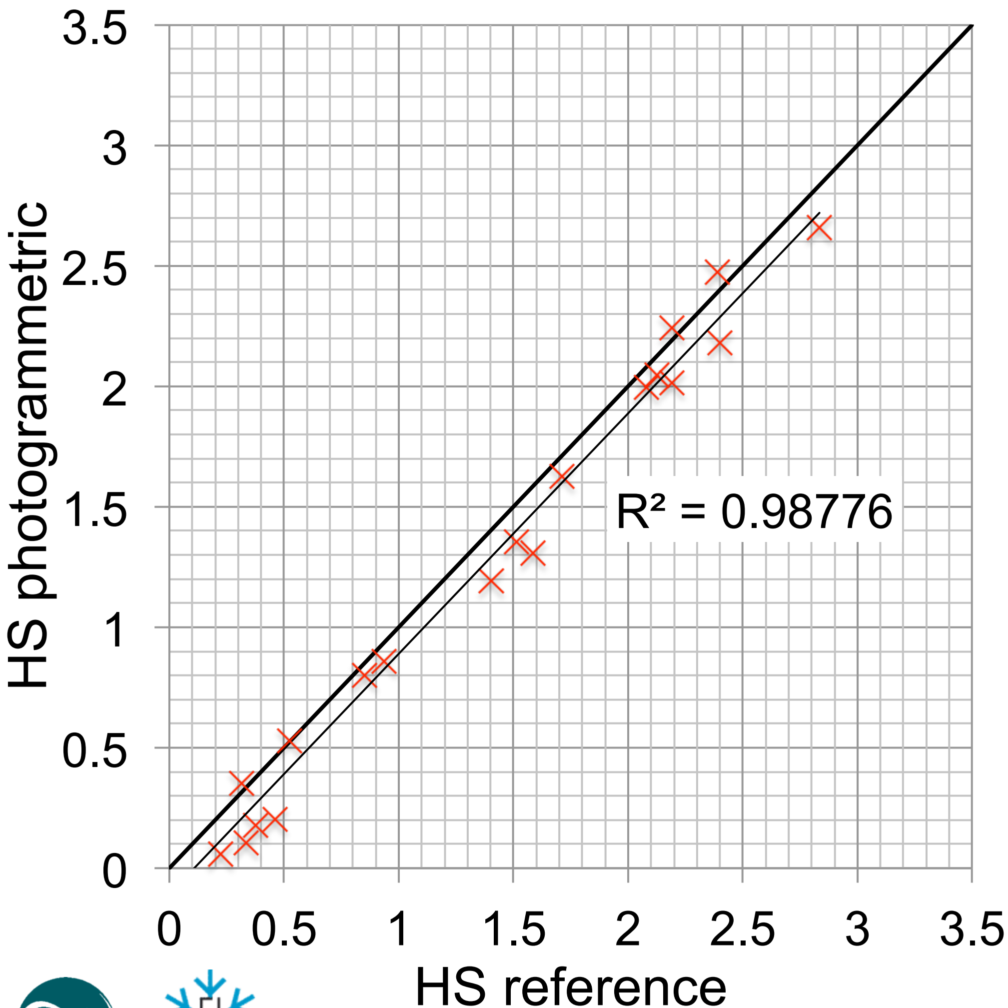

Snow depth
> 4 m
2 m
0 m



N
Chair lift station and masts
Edges of ski track
Hiking trails
Snow depth
> 4 m
2 m
0 m

Validation Brämabühl

- 22 reference plots à 5 probe measurements

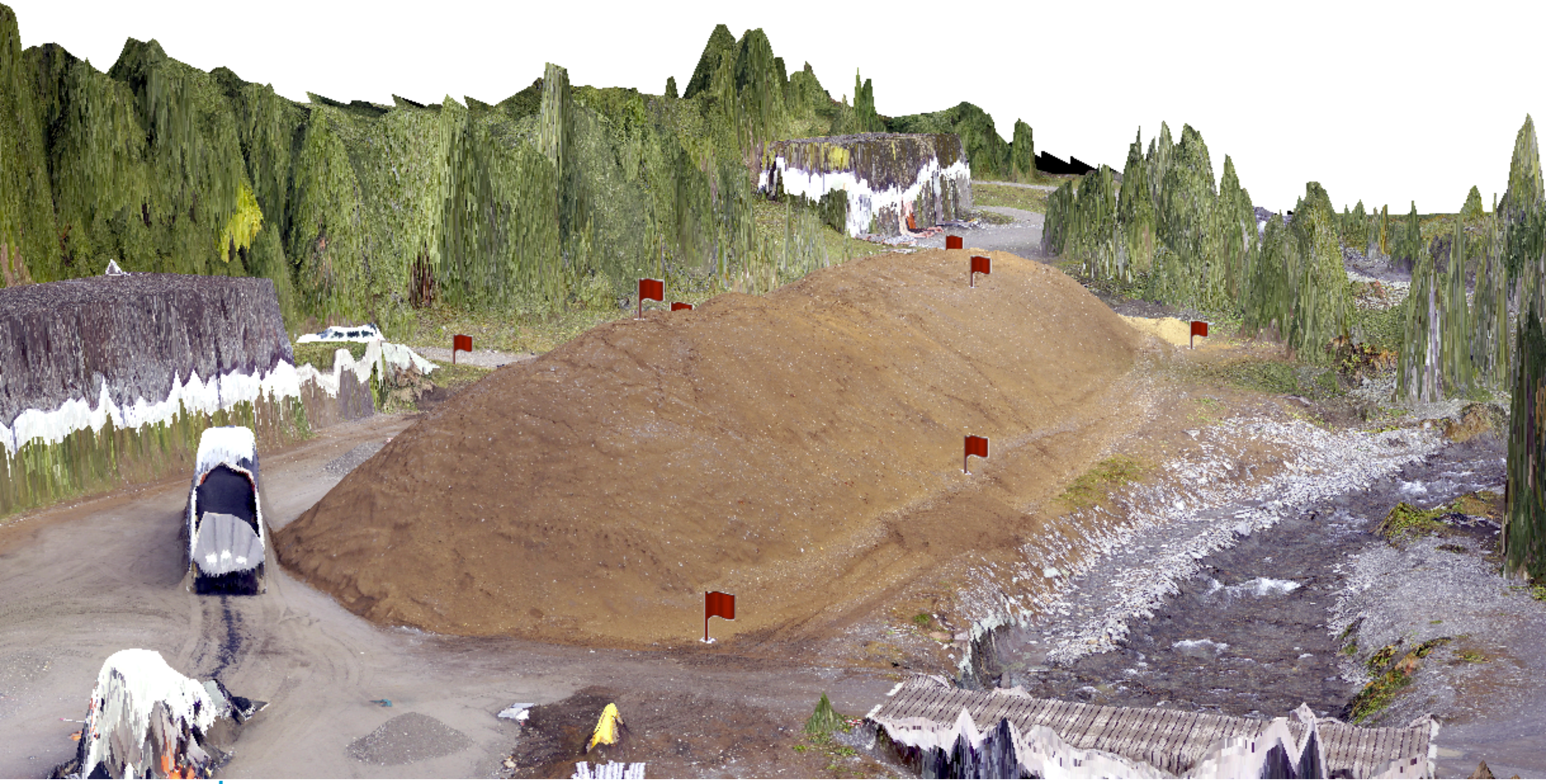


- RMSE = 15 cm

- Small shift of 10 cm
- This can be explained by low grass and small bushes in the summer DSM

- Very accurate mapping of HS variability

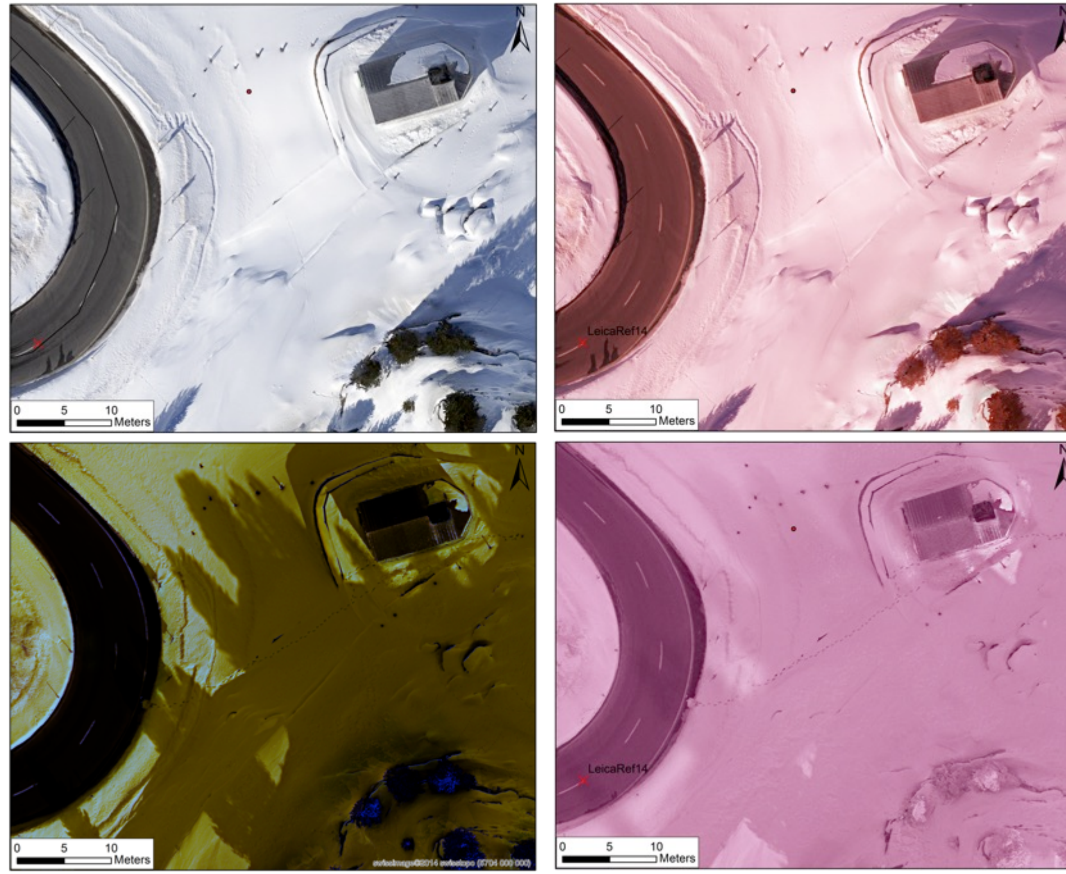
- Ski track management
- Snow farming



Near Infrared NIR

Modified Sony NEX-7 camera

- RGB
- NIR undefined
- Filter λ > 550 nm
- Filter λ > 830 nm
- Ongoing investigation on advantage of NIR on snow covered areas

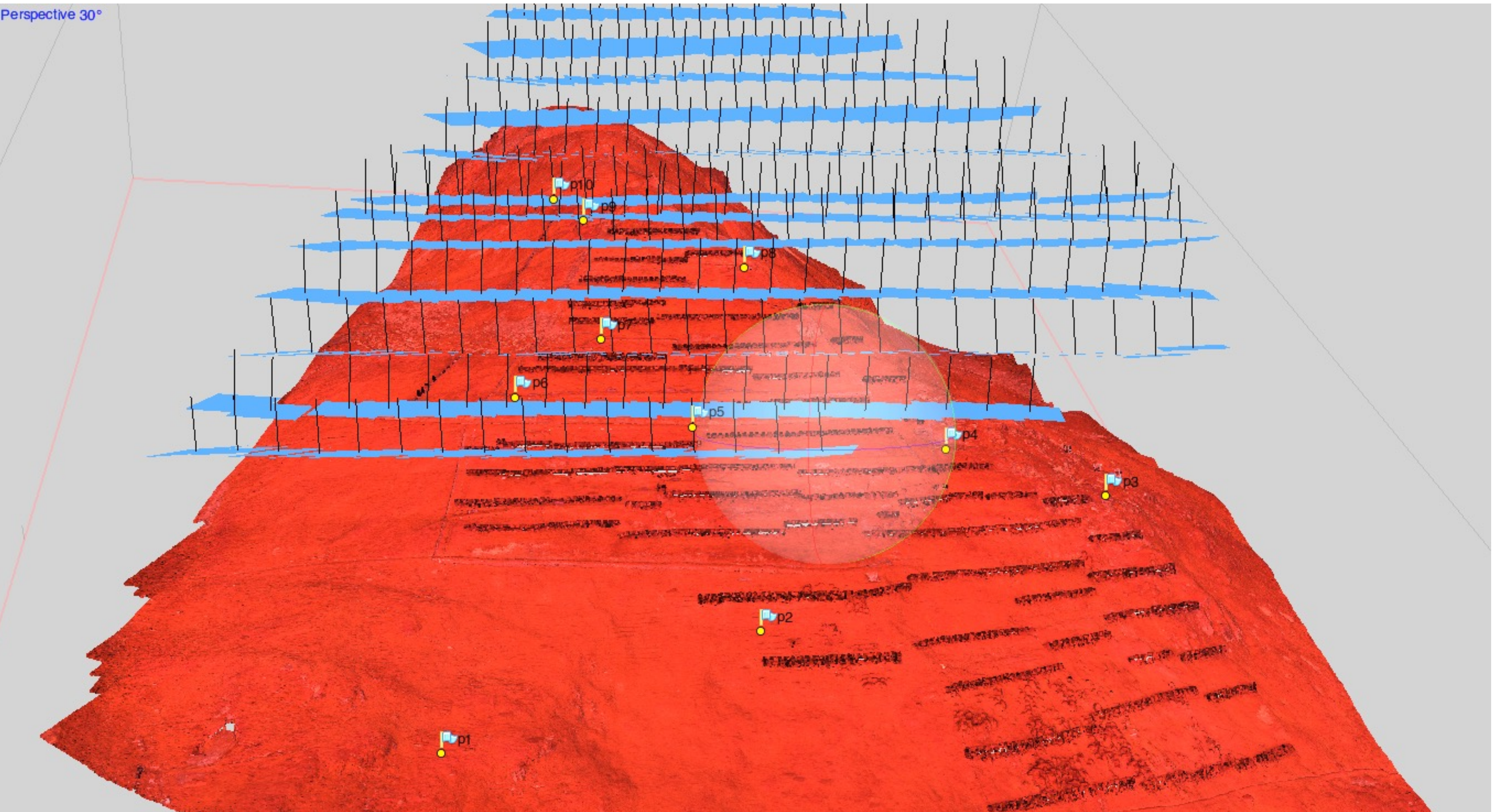


Bühler, Y., L. Meier, and C. Ginzler (2015), Potential of operational, high spatial resolution near infrared remote sensing instruments for snow surface type mapping, *Geoscience and Remote Sensing Letters, IEEE*, *12*(4), 821 - 825.

WSL SLF

Application III: Mitigation measure monitoring

- Salezer Horn avalanche supporting structures



Application IV: Protection forests

- Stillberg afforestation, 1960 – 2260 m a.s.l.
- Tree position, tree height, tree conditions (NDVI)

Conclusions

- ✧ Fast, flexible, accurate geo-data acquisition
- ✧ Ortho imagery GSD ~2cm DSM GSD ~10 cm
- ✧ Reliable in complex terrain (elevation differences of several 100 m) and under windy conditions (> 10 m/s)
- ✧ Big potential for survey of hazard events and snow depth mapping (RMSE < 10 cm) as well as for further applications

- ◆ Flight time insufficient! Max. ~8 min @ 2000 m a.s.l.
- ◆ Positioning of reference points at ground often time consuming and/or dangerous. How well works RTK ?
- ◆ Errors due to high summer vegetation

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Future challenges / questions:

- How perform winged UAV in alpine terrain? Safety?
- Where are the limits in elevation differences & range?
- Comparison to Terrestrial / Airborne Laser Scanning
- Comparison of different processing software packages

Snow:

- New snow cover? Too homogenous to find matching points?
- Advantage of near infrared bands?
- Can we develop improved processing algorithms for snow?