



Implementation and Performance Test of Machine Learning Approaches for Snow Cover Mapping in Webcam Imagery

Andreas Kollert (presenting author), Andreas Mayr, Felix Dahle, Stefan Dullinger, Martin Rutzinger



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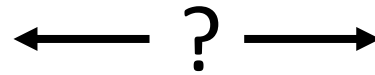
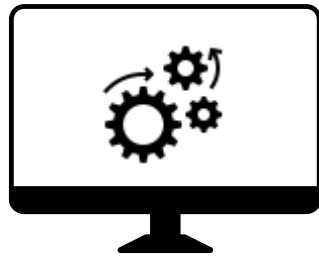


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Institute of Geography
Remote Sensing &
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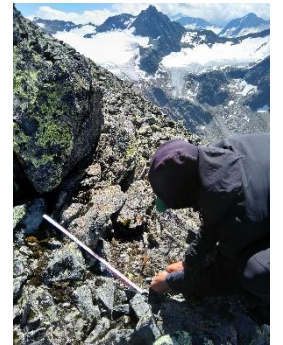
MICROCLIM - Background

Impact of **climate change** on **alpine vegetation** - Special focus on microrefugia (hence *microclim*)

Species distribution modelling



Field observations

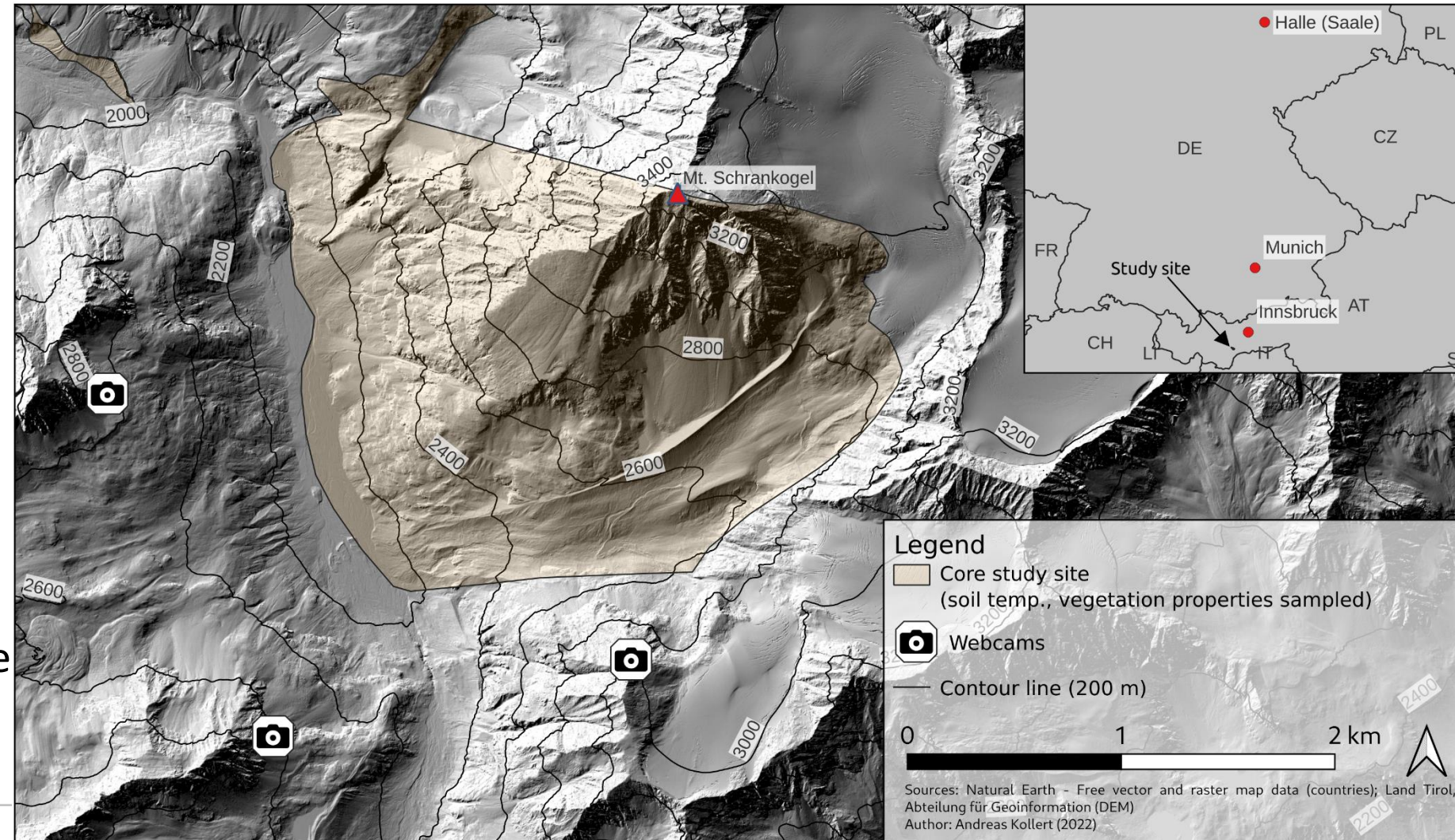


Input

- **High-res. snow cover**
- Soil temperature
- Geomorphologic disturbance

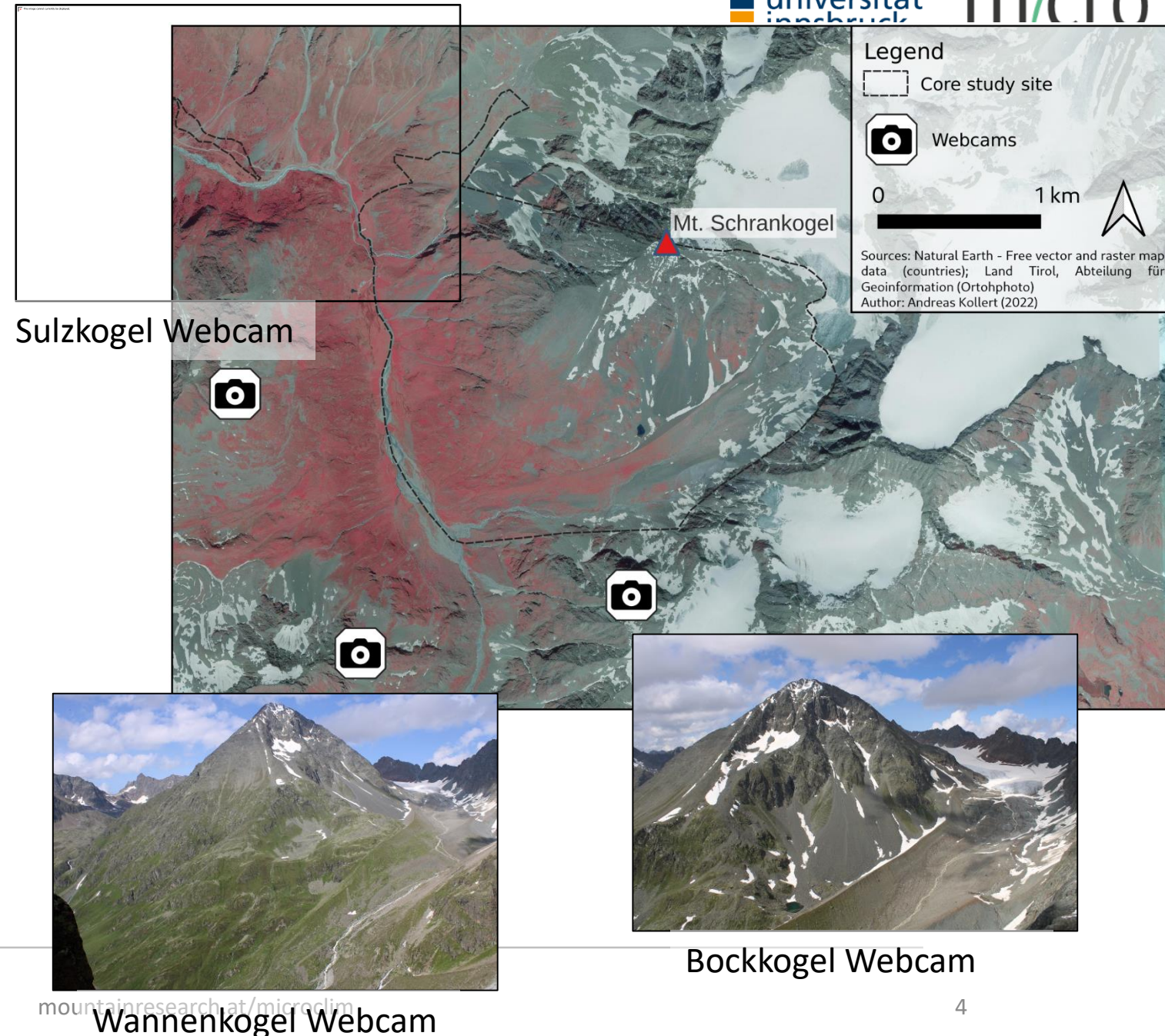
Study site

- Stubai Alps
- Area:
ca. 5.5 km²
(light orange in map)
- ca. 1800 –
3500 m asl
- GLORIA Master site



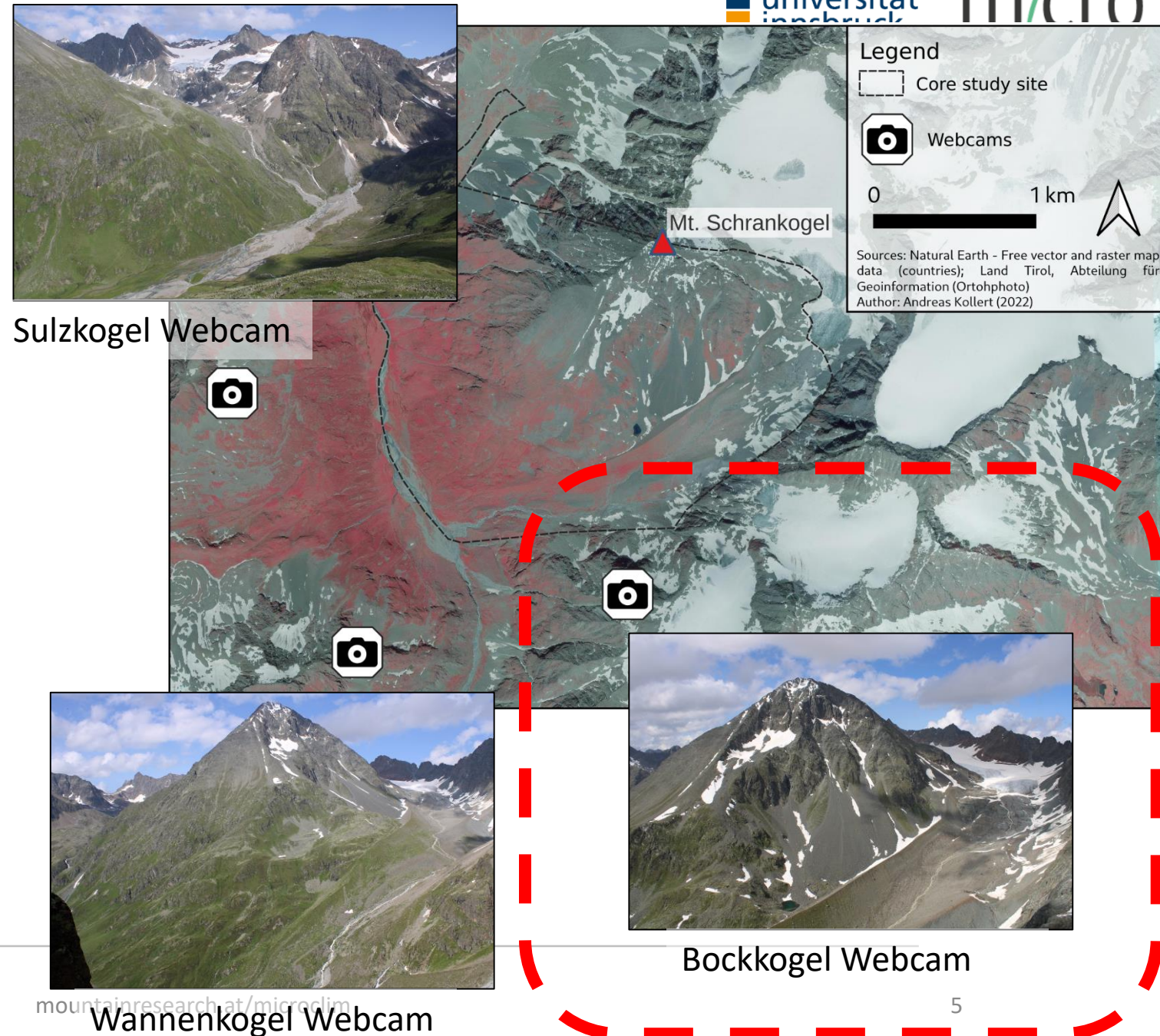
Webcam imagery

- 3 Webcams **autonomously operating** since July 2021
- **Canon EOS 2000D**
 - 24 Megapixel
 - **RGB** imagery (high quality, consumer grade SLR camera)
- **>= 30 min temporal** resolution
- Main application:
Derivation of high resolution **snow cover**



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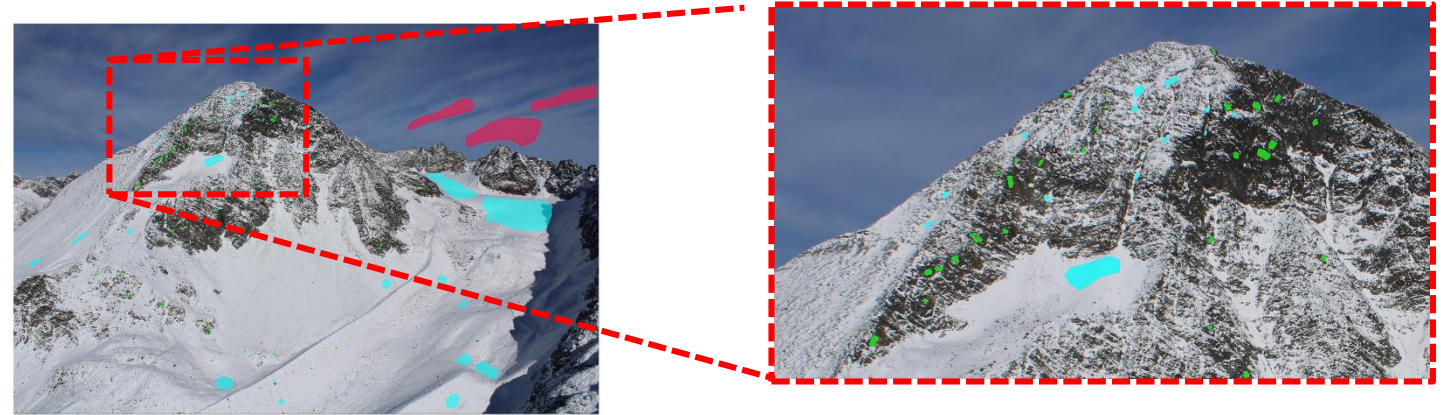
Challenges

- Shadows
 - By clouds
 - By topography
- Clouds
- Precipitation
- Limitation: RGB only

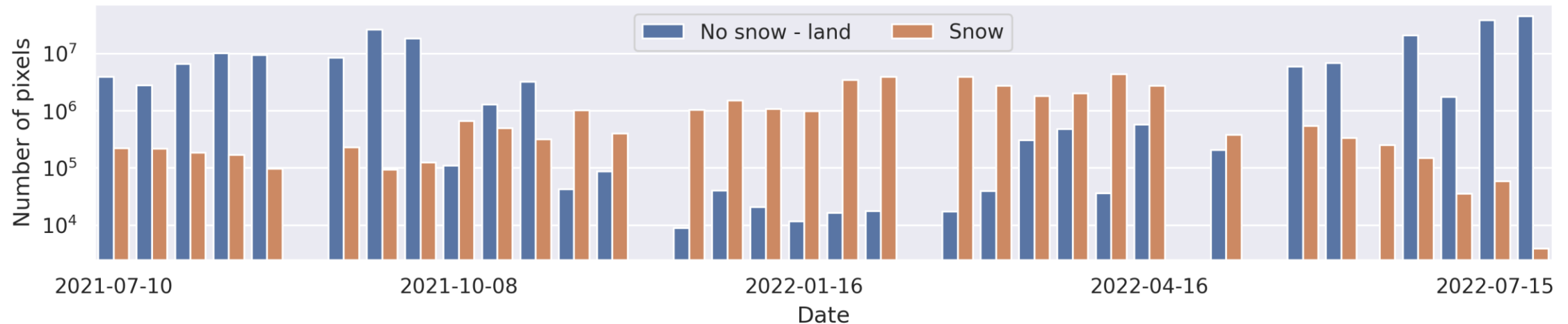


Current reference data set

- **36 images** covering an entire year
- Polygons digitized - **extracted pixel-wise**
- „Complicated“ cases included: **small patches of snow, shadowed areas**

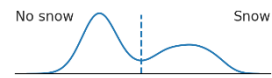


Temporal distribution of reference data

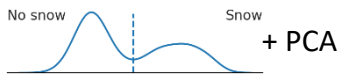


Webcam-based snow retrieval: current state

Threshold-based



Salvatori et al. (2011)



Improved by
Härer et al. (2018)

Used, e.g., by Arslan et al. (2018), Salzano et al. (2019),
Portenier et al. (2020)

Machine Learning-based

- Various Models
(parametric, non-parametric)
- Mostly monotemporal or intra-day (e.g. median) features
- E.g., Fedorov et al. (2016), Salzano et al. (2019)



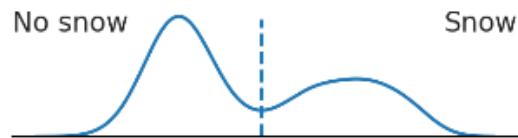
→ Widespread use of **multitemporal features** in satellite remote sensing and **novel algorithms**

Improvements for classification of webcam imagery **possible?**

Tested implementations

Threshold-based

- Single (adaptive) threshold on blue band (Salvatori et al., 2011)



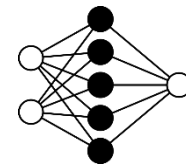
Machine Learning-based

- Random Forest Classification
- Single RGB image
- 3x3 window + local average + global average of each channel (Fedorov et al., 2016)



Deep learning-based

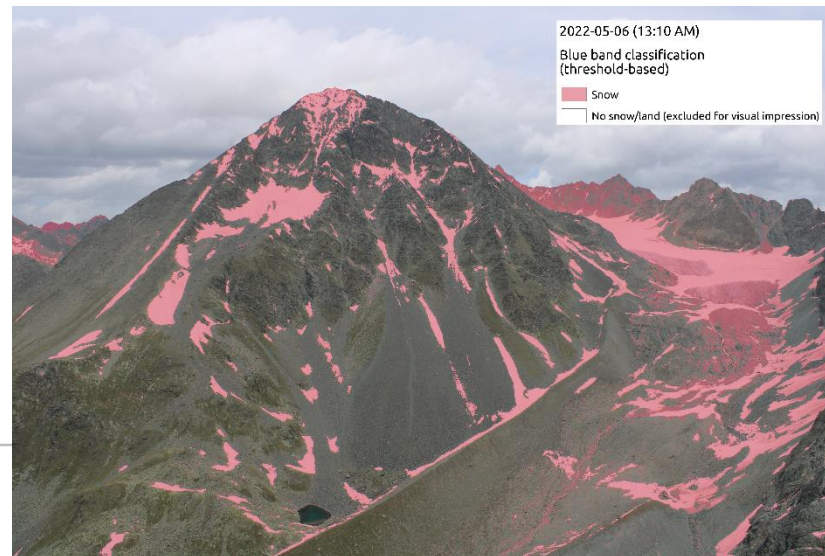
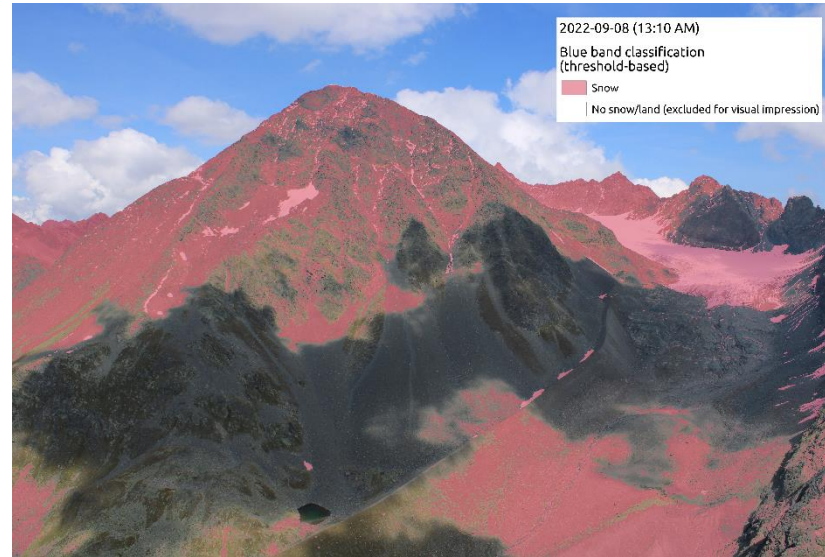
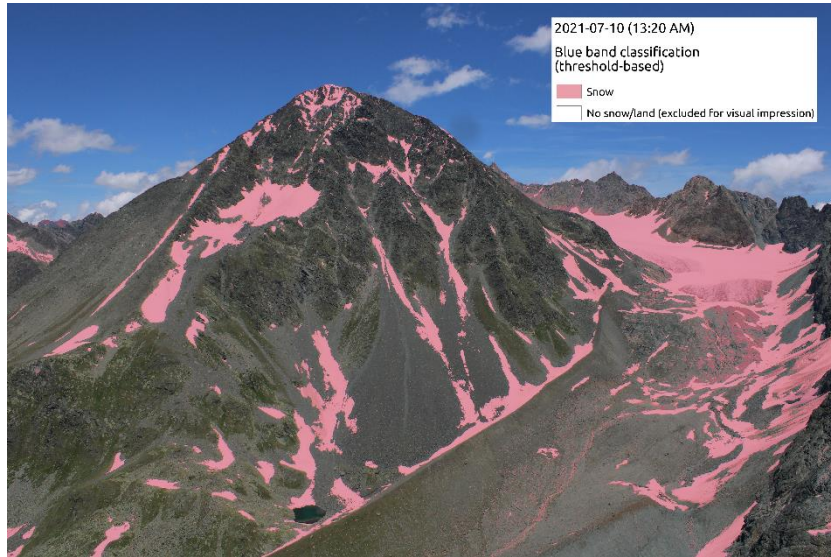
- Convolutional neural network (by Felix Dahle)



+

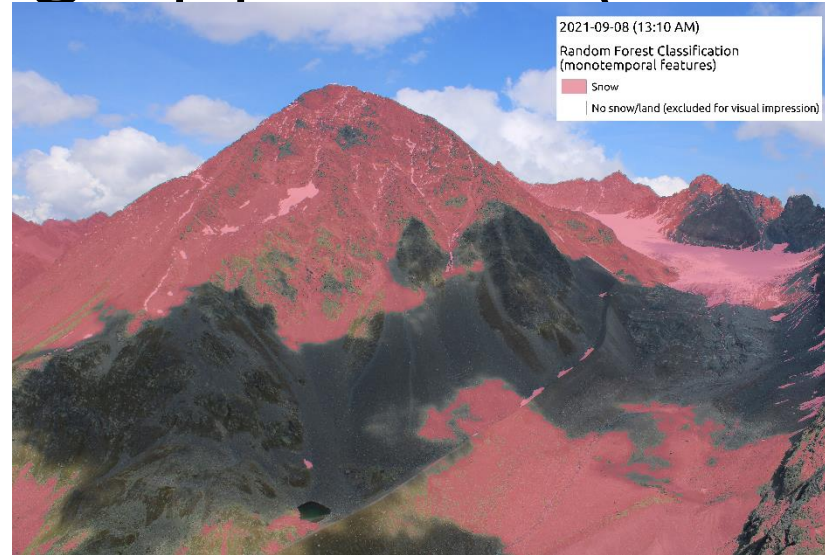
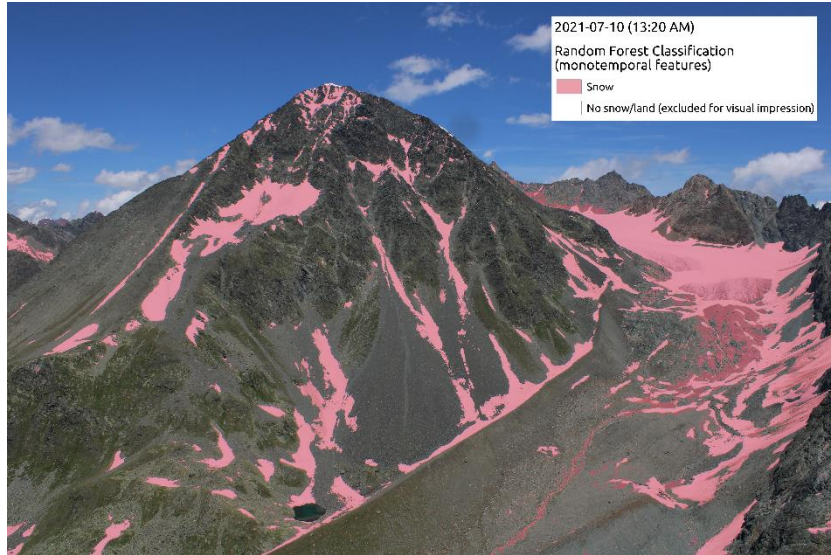
- One image for **current day**
- **Previous 2 days**

Blue-band threshold classification



- Works **well** for **uniformly illuminated** scene
- **Shadows**, both by cloud and topography, pose **problems**
- Overall accuracy: 96.15 %
- **Metrics** are **very good** (!) despite obvious issues seen here → **positive bias** due large validation polygons 10

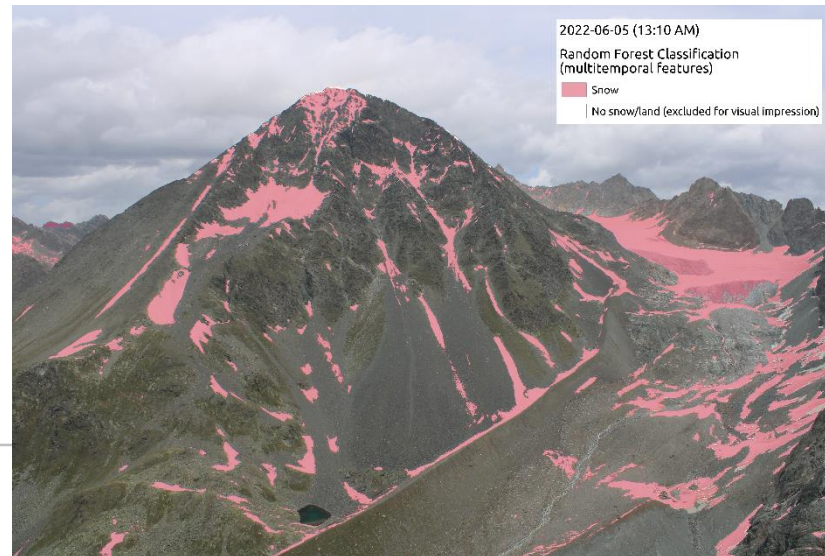
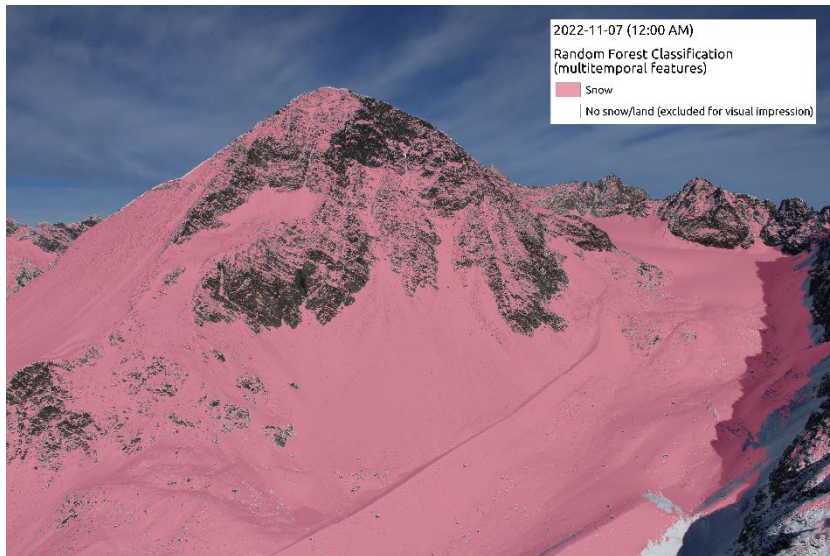
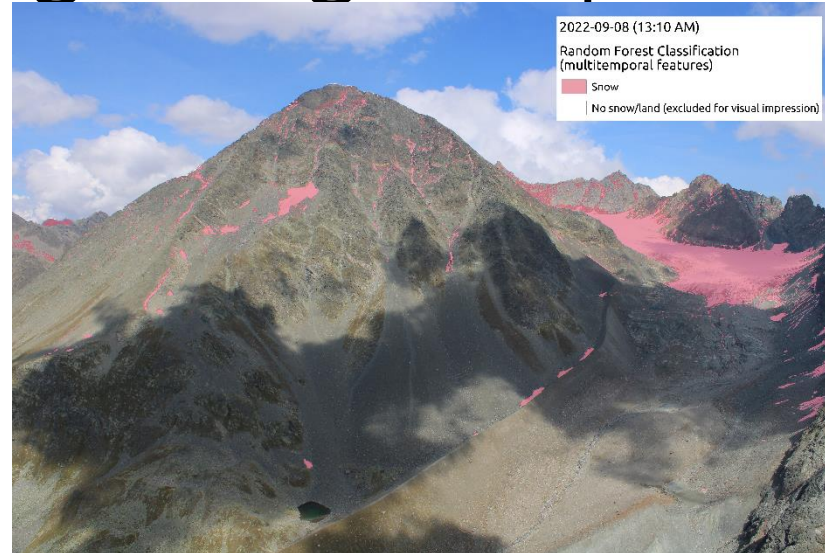
Machine learning approach (monotemporal)



- Works **well** for **uniformly illuminated** scene
- **Shadows**, both by cloud and topography, pose **problems**
- Overall accuracy: **98.03 %**
- **Metrics are very good** (!) despite obvious issues seen here → **positive bias** due large validation polygons

Machine learning using temporal features

Image 2021-07-10: no multitemporal data available

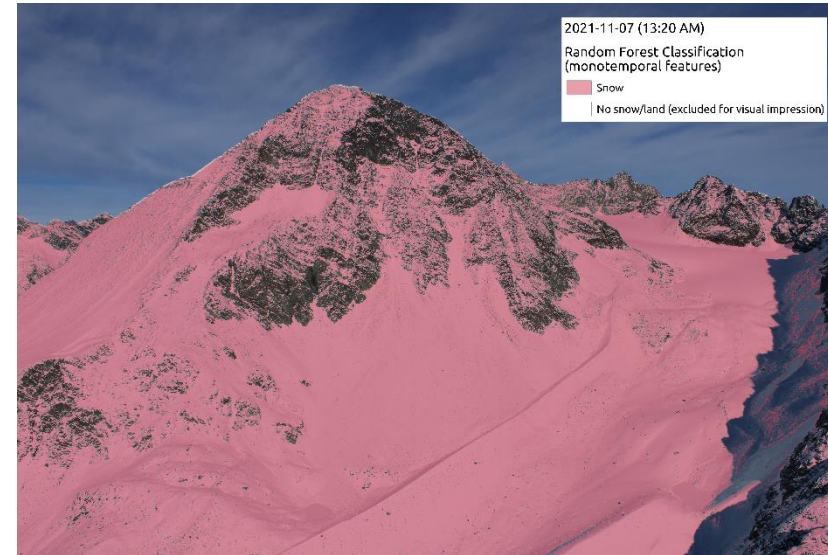


- Works relatively **well** under **most conditions**
- **Shadow issues reduced**
- Overall accuracy: 98.08 %
- **Metrics are very good** probably still **positively biased**
→ visual impression is a lot better than previous methods

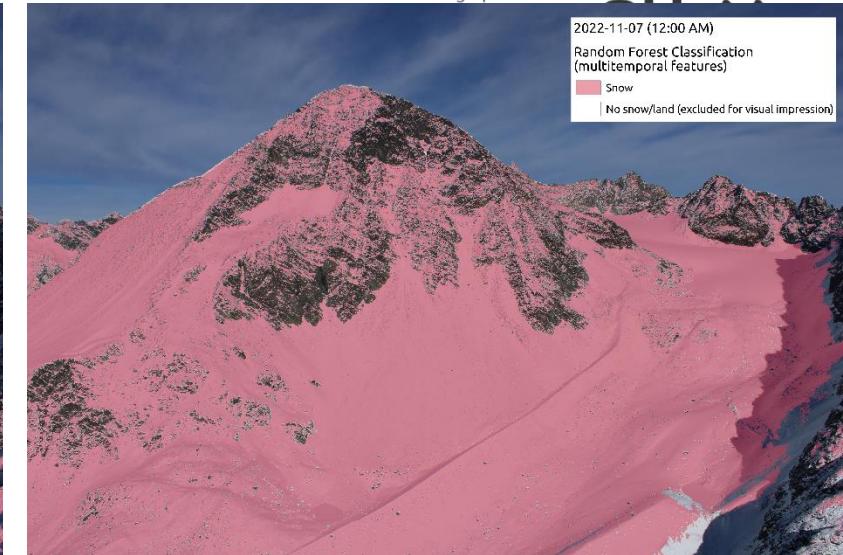
Comparison



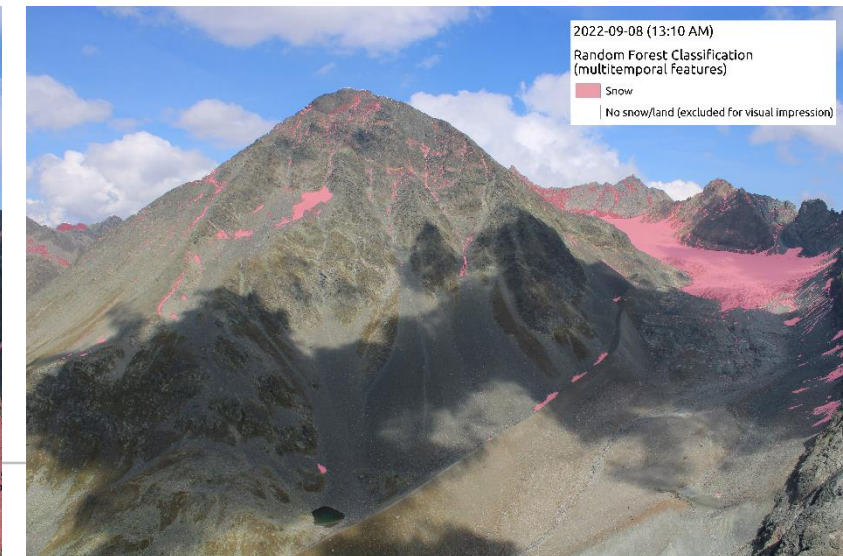
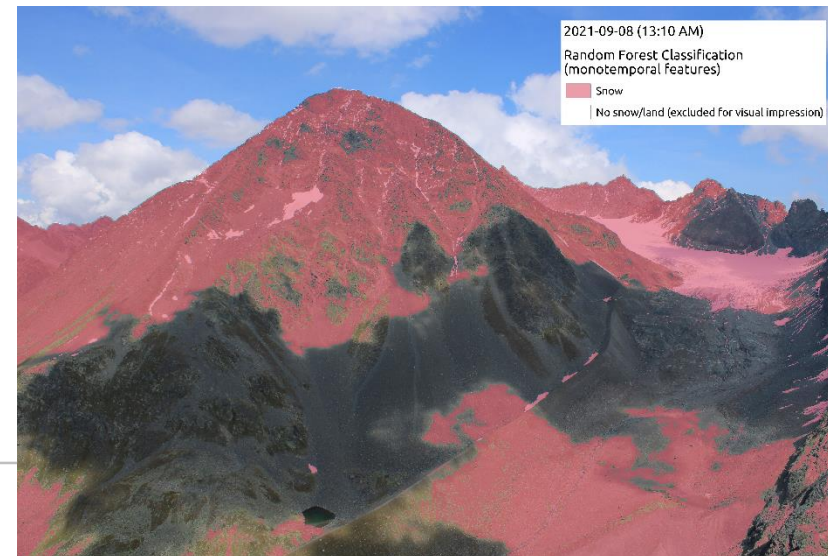
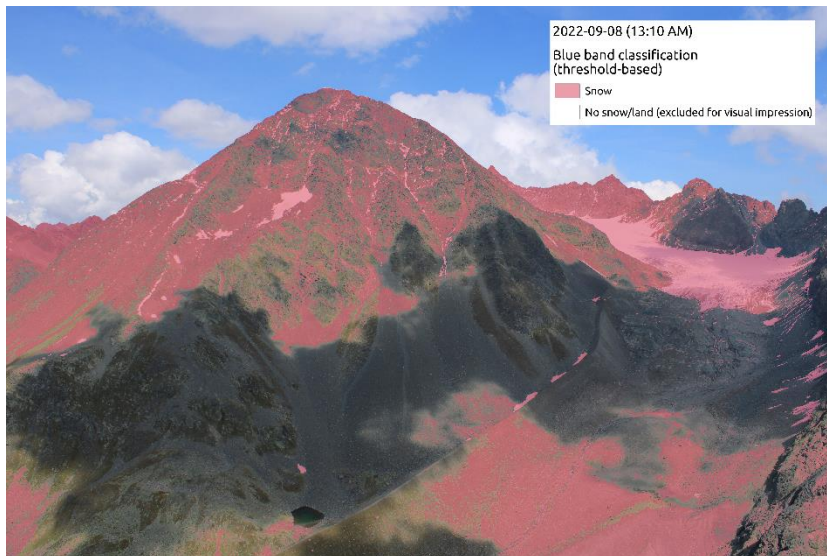
Blue band threshold



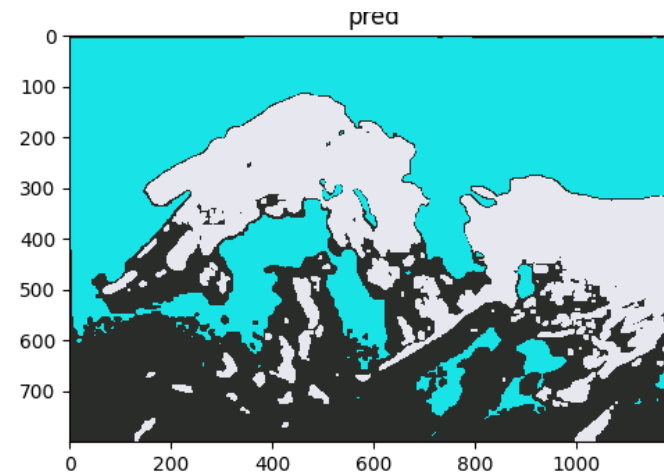
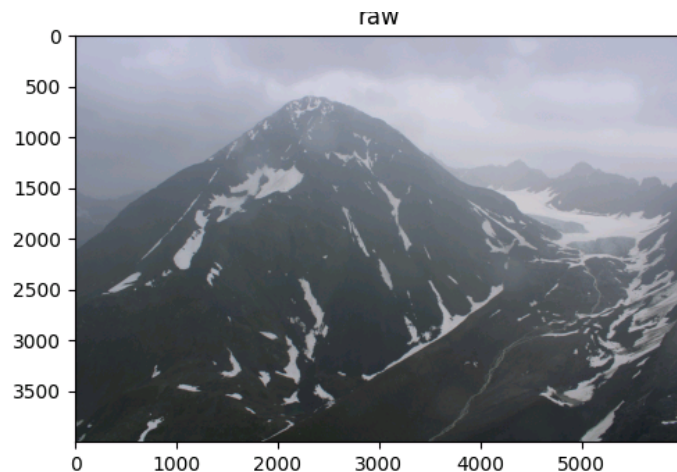
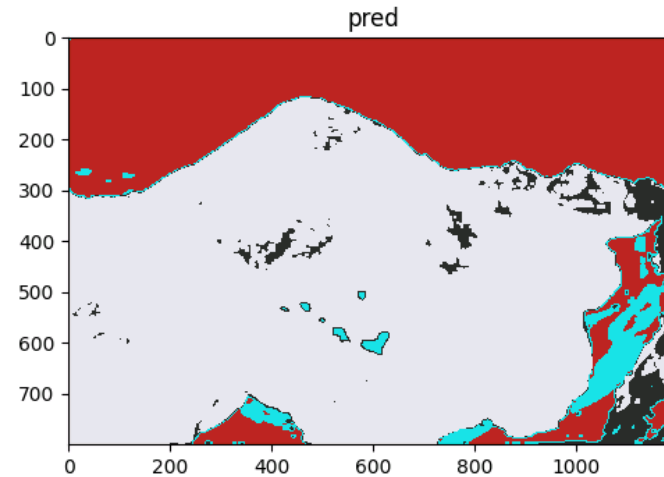
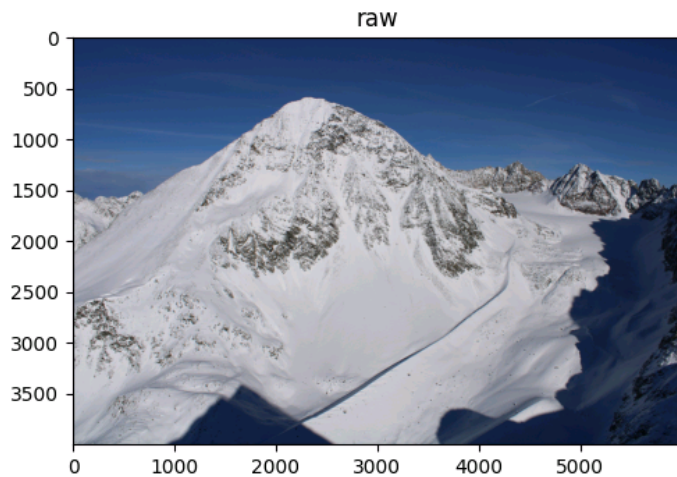
Single timestep



Multitemporal (3 days)



Deep learning approach



- U-net architecture
 - Semantic segmentation (compared to pixel-wise classification)
- Some promising results
- Quantitative validation pending

(Implemented by Felix Dahle)

Conclusion & Outlook

- Previous **issues** by **baseline methods** reproduced
- **Multitemporal** features **improved** result
- Future work:
 - **include quality indicators**
 - implement **algorithmic improvements**
 - Thorough quality assessment of multitemporal approach

Interested in

- Alpine microclimate?
- Modelling of alpine plant distribution?
- High resolution modelling and monitoring of snow cover and soil temperature?

Follow Microclim here:

mountainresearch.at/microclim

<https://twitter.com/microclim2>

Referenzen

- Arslan, A. N., Tanis, C. M., Metsämäki, S., Aurela, M., Böttcher, K., Linkosalmi, M., & Peltoniemi, M. (2017). Automated webcam monitoring of fractional snow cover in northern boreal conditions. *Geosciences*, 7(3), 55.
- Fedorov, R., Camerada, A., Fraternali, P., & Tagliasacchi, M. (2016). Estimating snow cover from publicly available images. *IEEE Transactions on Multimedia*, 18(6), 1187-1200.
- Härer, S., Bernhardt, M., Corripio, J. G., & Schulz, K. (2013). Practise–photo rectification and classification software (v. 1.0). *Geoscientific Model Development*, 6(3), 837-848.
- Härer, S., Bernhardt, M., Siebers, M., & Schulz, K. (2018). On the need for a time-and location-dependent estimation of the NDSI threshold value for reducing existing uncertainties in snow cover maps at different scales. *The Cryosphere*, 12(5), 1629-1642.
- Portenier, C., Hüsler, F., Härer, S., & Wunderle, S. (2020). Towards a webcam-based snow cover monitoring network: methodology and evaluation. *The Cryosphere*, 14(4), 1409-1423.
- Salvatori, R., Plini, P., Giusto, M., Valt, M., Salzano, R., Montagnoli, M., ... & Sigismondi, D. (2011). Snow cover monitoring with images from digital camera systems. *Ital. J. Remote Sens*, 43(6).
- Salzano, R., Salvatori, R., Valt, M., Giuliani, G., Chatenoux, B., & Ioppi, L. (2019). Automated classification of terrestrial images: The contribution to the remote sensing of snow cover. *Geosciences*, 9(2), 97

Study site



Viewing direction north

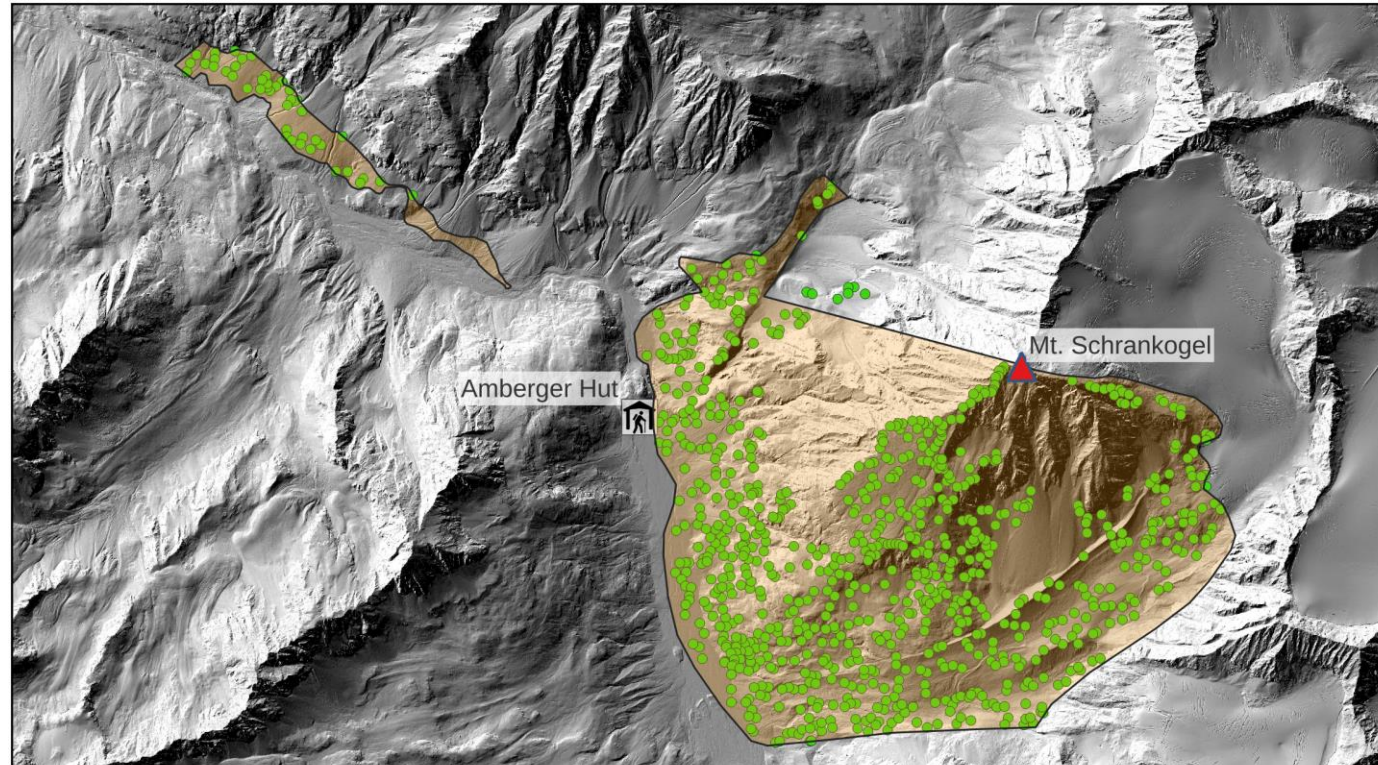


Viewing direction north-east

Monoplotting – work in progress

- Some established methods (e.g. Portenier et al., 2020; Härer et al., 2013) but camera calibration externally realized
- Accuracy however dependent on calibration
- Main issues:
 - Cameras already mounted
 - Accessibility: physically and technically demanding
 - Housing with additional lens (might introduce further distortion)
- Planned:
 1. Calibrate same camera model – better than no calibration at all
 2. Calibrate actual cameras in the field with a checkerboard (potentially realized at some point)

Study site – Sampling density



- Sampled area
(Soil temperature, Vegetation properties)
- Temperature logger positions



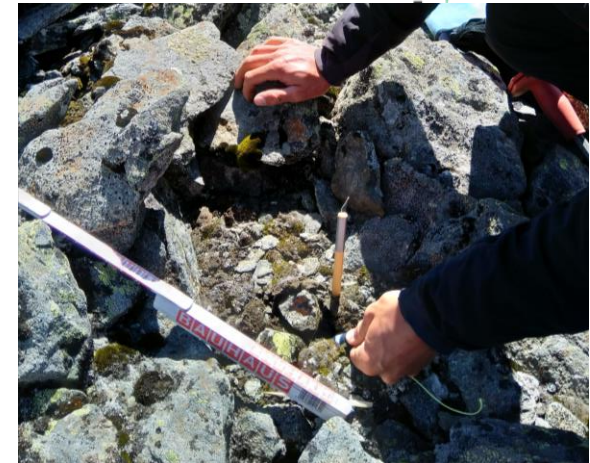
Sources: Land Tirol, Abteilung für Geoinformation (DEM)
Author: Andreas Kollert (2021)

Soil temperature measurement

- 900 temperature loggers (GeoPrecision MLog-5W)
- Placed at 10 cm soil depth
- Hourly meas. interval
- Predefined sampling scheme
- Wireless in-situ readout
- Measuring since summer 2021
- Main application:
 - Development and validation of soil-temp. model
 - Validation of snow cover maps through distinct signature of temperature



Temperature logger and reference



Logger placement (Image: Andreas Mayr)



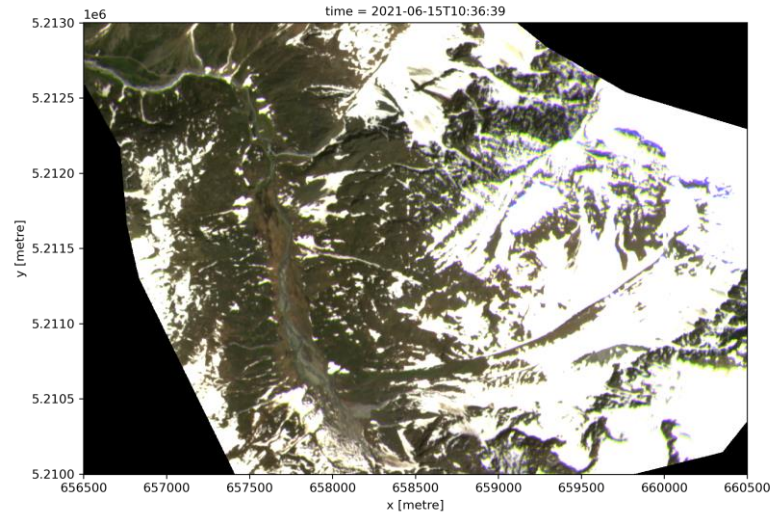
GNSS-Measurement of logger position (Image: Andreas Mayr)



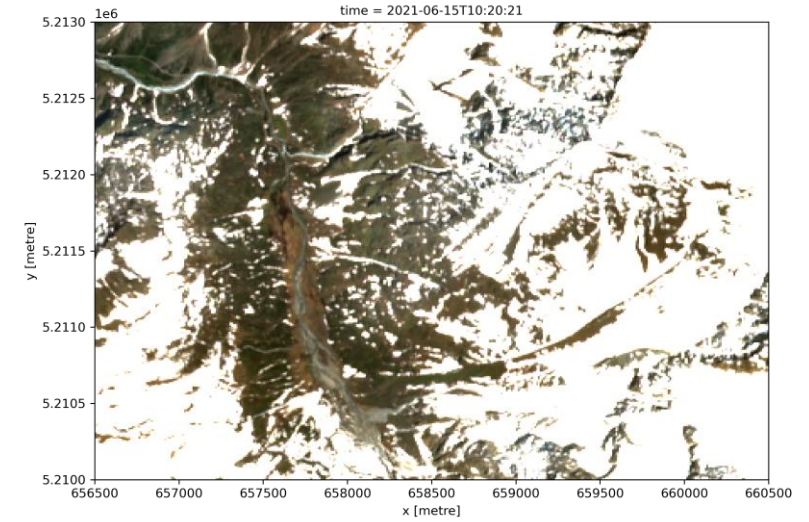
Standardizing logger placement (Image: Martin Rutzinger)

Remotely sensed snow cover - scales

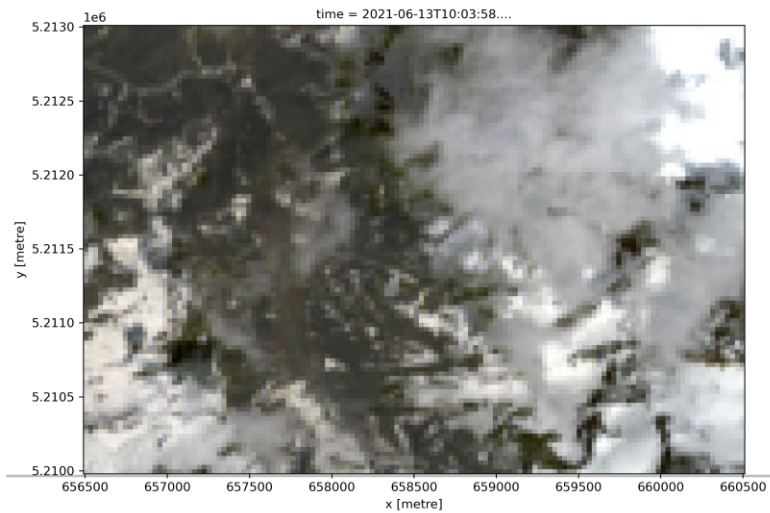
Planet cubesat
3 m resolution



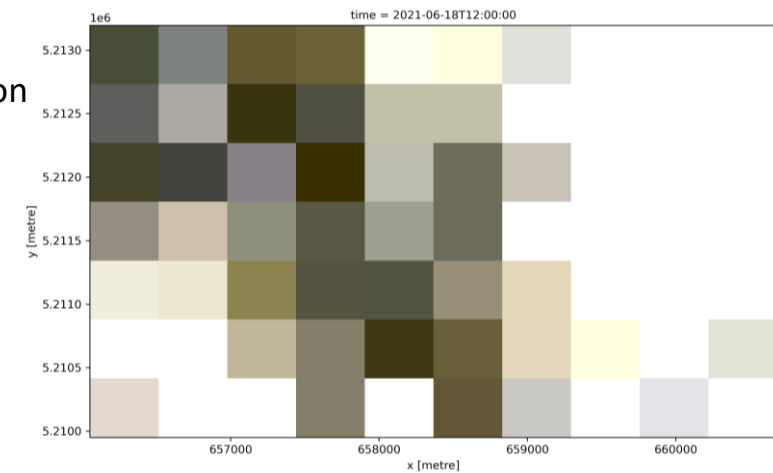
Sentinel-2
10 m resolution



Landsat
30 m resolution

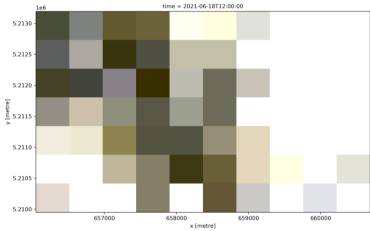


MODIS
ca. 500 m resolution

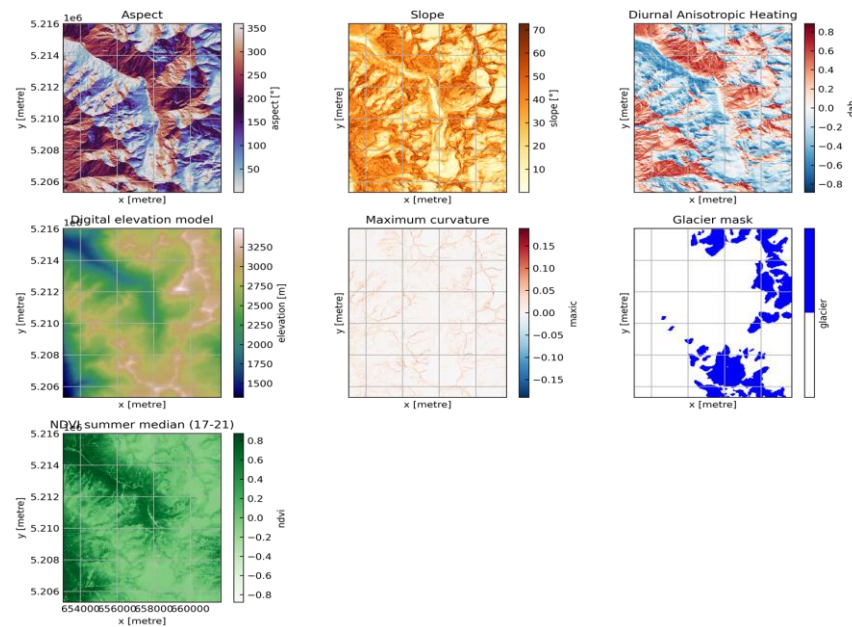


Snow cover downscaling

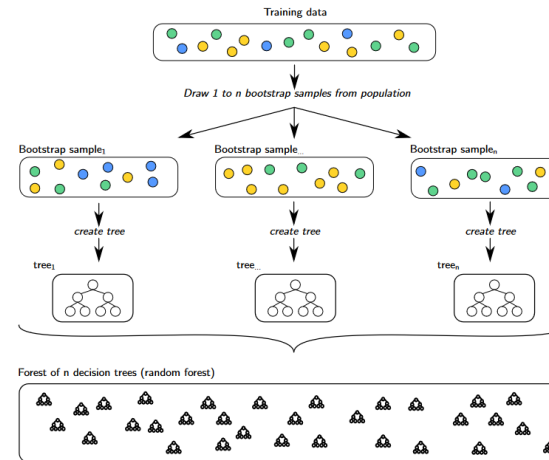
MODIS snow cover product
ca. 500 m resolution



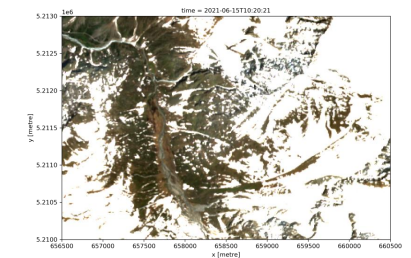
Topographic variables @ Sentinel-2 resolution



Random Forest Model



Sentinel-2 like snow cover



Temporal data coverage

