

Regional snowline elevation retrieval using public webcam images

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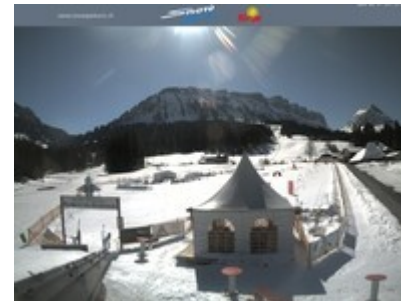
Regional snowline elevation (RSLE)

- Important indicator of snow cover in mountainous regions
- Input for hydrological modeling or cloud removal in satellite-based snow cover retrieval



Public webcams

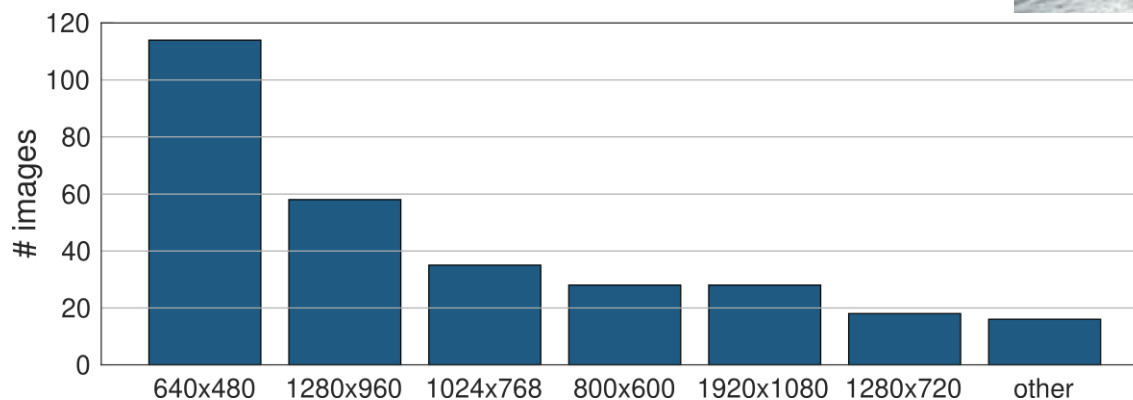
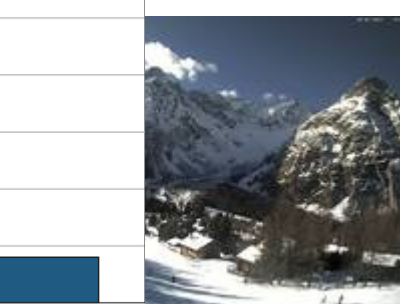
- high spatio-temporal resolution
- high areal coverage
- view below cloud cover
- oblique view on mountains



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Public webcams

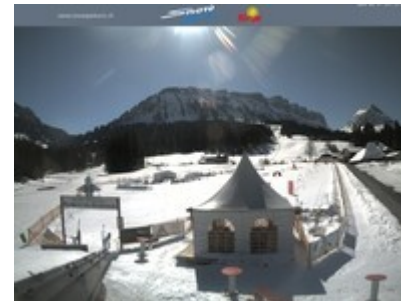
- high spatio-temporal resolution
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- view below cloud cover
- oblique view on mountains
- low quality images



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Public webcams

- high spatio-temporal resolution
- high areal coverage
- view below cloud cover
- oblique view on mountains
- low quality images
- missing camera information!

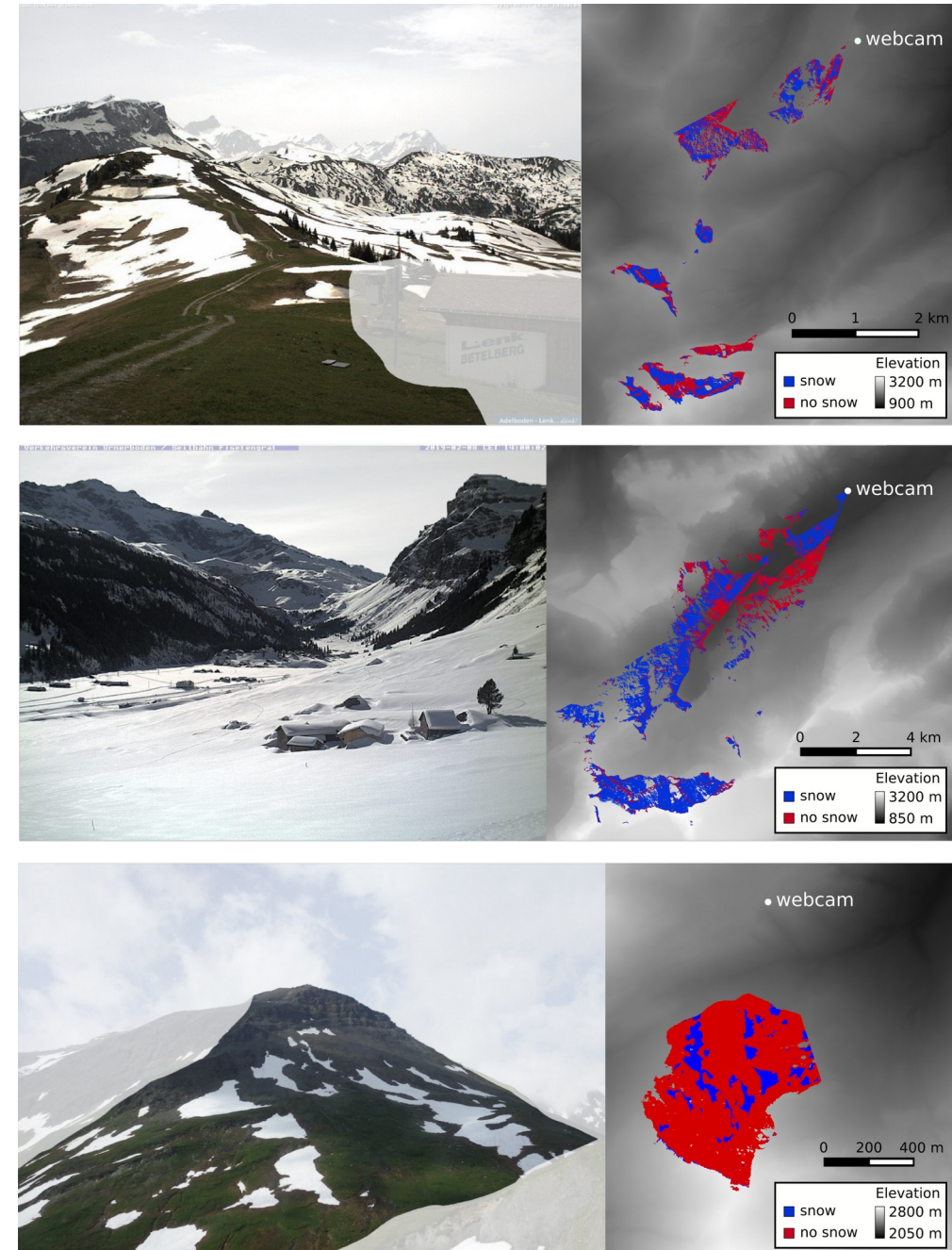


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Webcam-based snow cover monitoring

Semi-automatic procedure to derive snow cover maps from publicly available webcam images

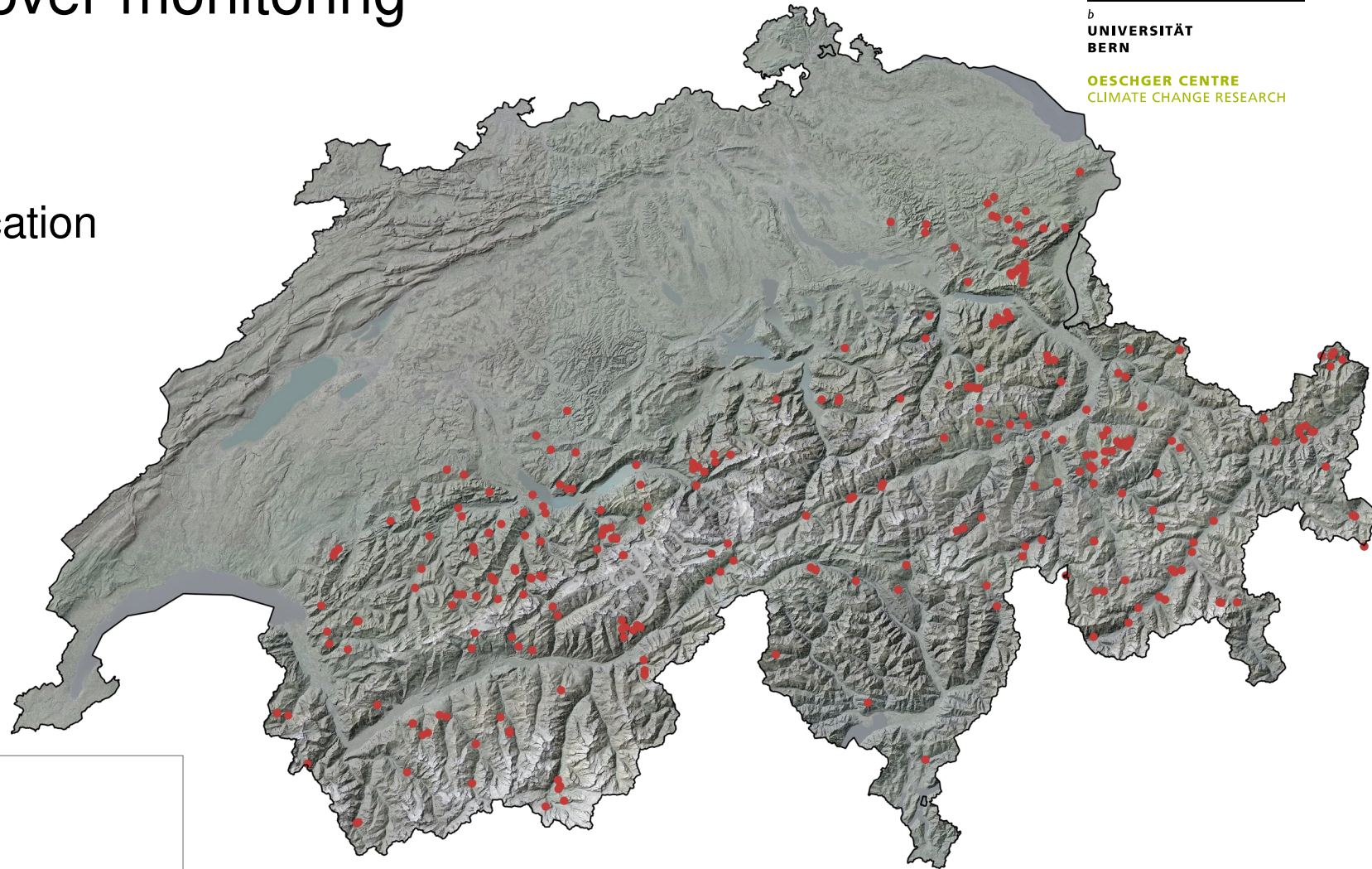
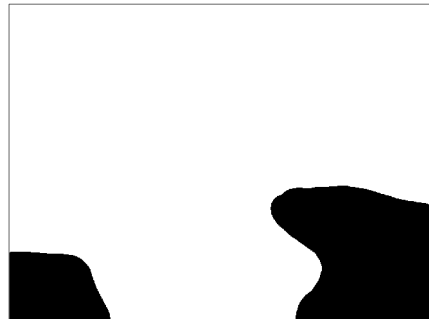
1. Preprocessing
2. Image-to-DEM registration
3. Image-to-image alignment
4. Snow classification



Webcam-based snow cover monitoring

1. Preprocessing

- Manually estimate camera location
- Selecting Master Image
- Defining input mask



Webcam-based snow cover monitoring

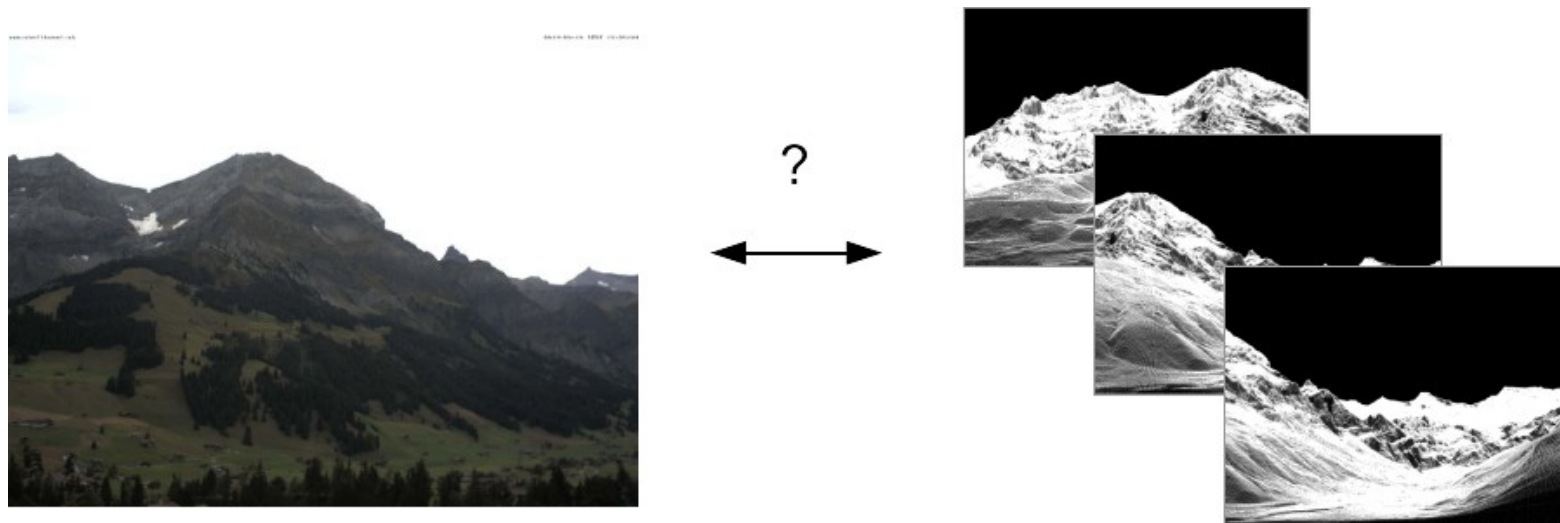
2. Image-to-DEM registration

Input

- Webcam location
- Master Image
- High-resolution DEM

Output

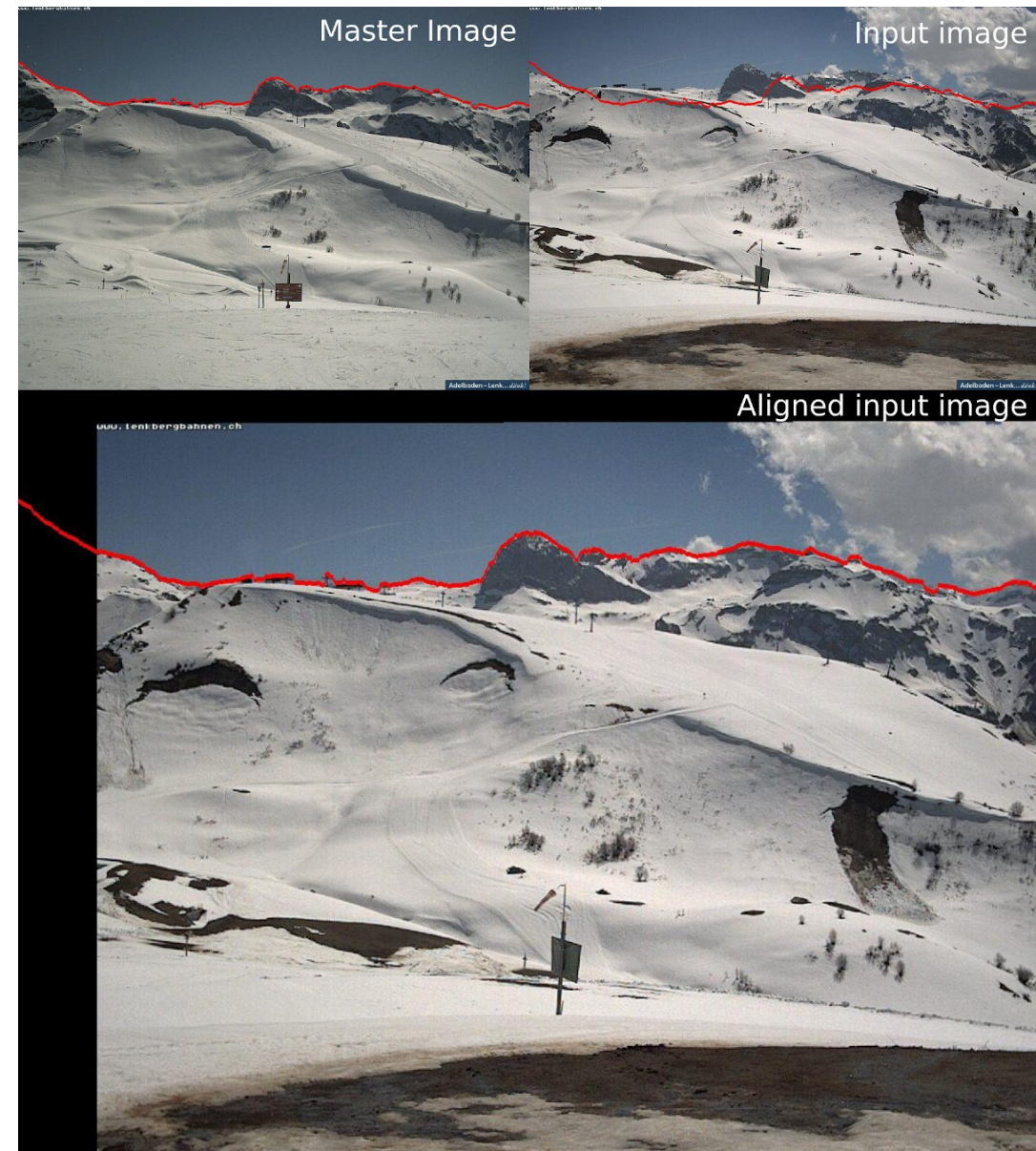
- Transformation matrix



Webcam-based snow cover monitoring

3. Image-to-image alignment

- Solving for homography
- Scale Invariant Feature Transform (SIFT; Lowe, 2004)
- fitting model RANdom SAmple Consensus (RANSAC; Fischler and Bolles, 1981)



Webcam-based snow cover monitoring

4. Snow classification

- Blue band classification (Salvatori et al. 2011)
→ blue band frequency histogram, threshold at first local minimum above intensity value 127
- Blue band + PCA (Härer et al. 2016)
→ PCA to detect shaded snow cover

Blue-band classification (Salvatori et al. , 2011)



Blue-band + PCA (Härer et al. , 2016)

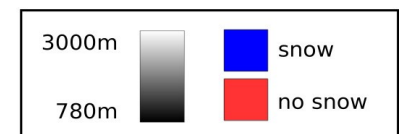
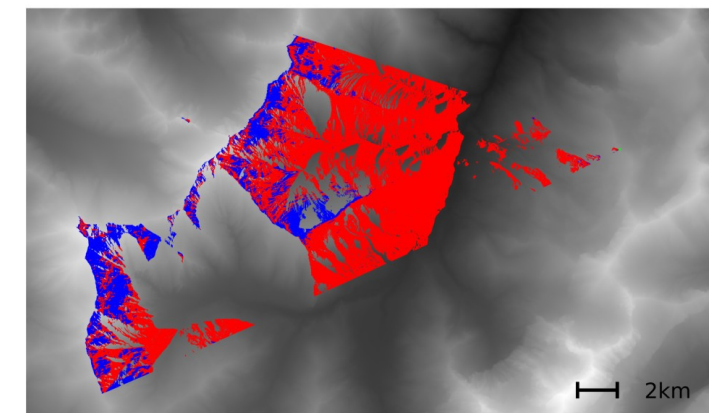
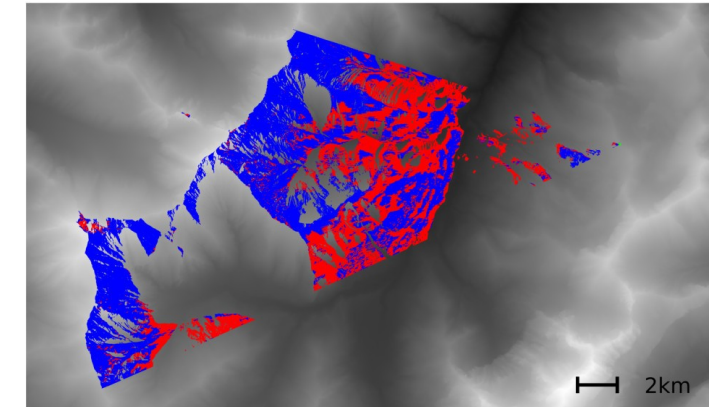
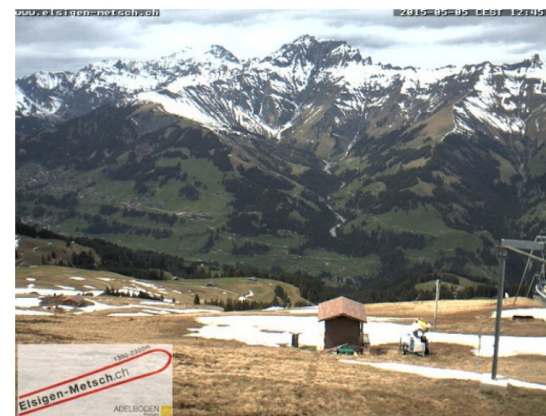


Webcam-based snow cover monitoring

Snow cover maps

- transformation matrix is used to find for each DEM grid the associated image pixel
- for each DEM grid, the associated classification result ('snow', 'no snow') is set

→ 2m resolution snow cover maps



Mapping accuracy

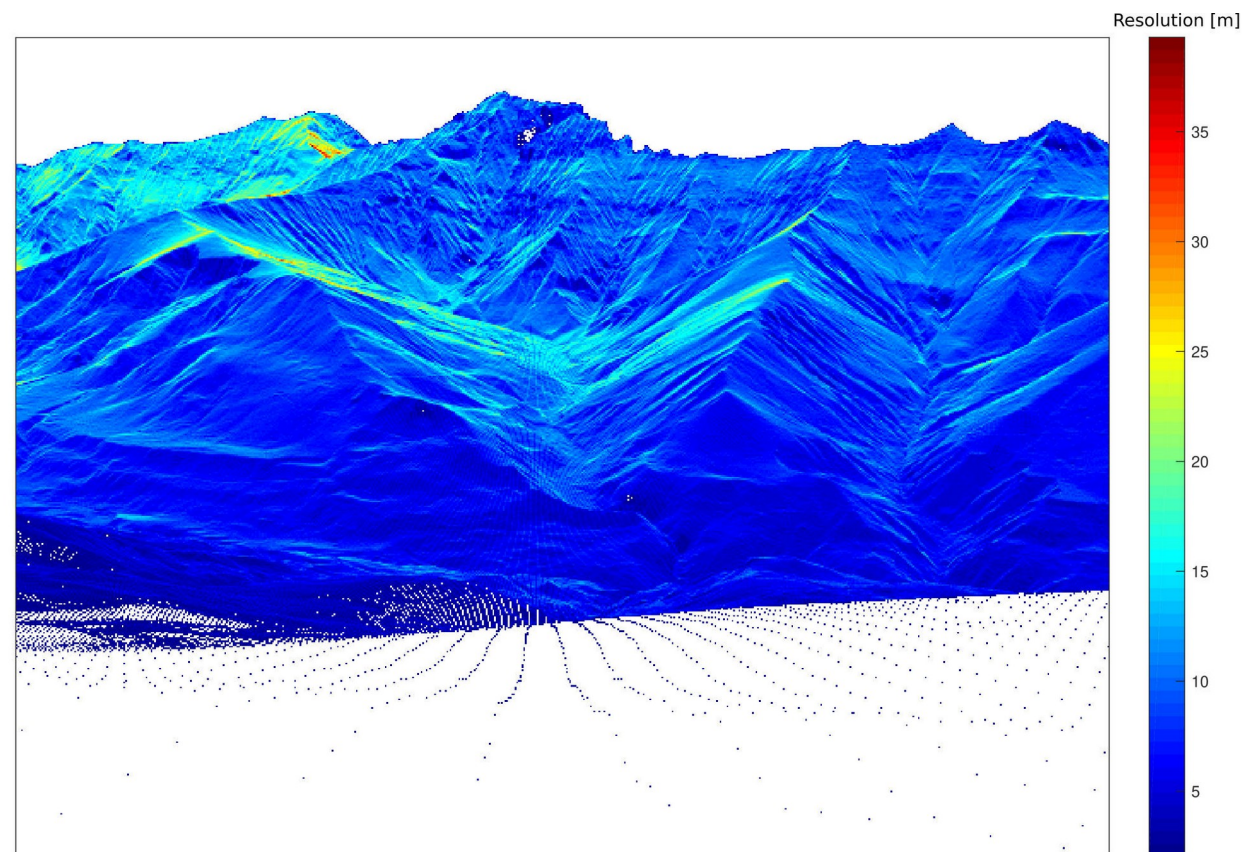
Projection uncertainty

- image pixel can be mapped onto several DEM grid cells, depending on:
 - image resolution
 - FOV
 - distance of the terrain to the webcam
 - slope and orientation of the terrain

Mapping accuracy

Projection uncertainty

- Projected image pixel resolution



Mapping accuracy

Projection uncertainty

- Projected image pixel resolution
 - 45 webcams: mean projected pixel resolution: 4.5 ± 4.4 m.
 - DEM grids within distance < 20 km to webcams: 2.9 ± 1.5 m.

Mapping accuracy

Registration accuracy

- 142 GCPs, 20 webcams
- RMSE of 23.7m (14.1m if excluding wide-angle lens webcams)

Mapping accuracy

Registration accuracy

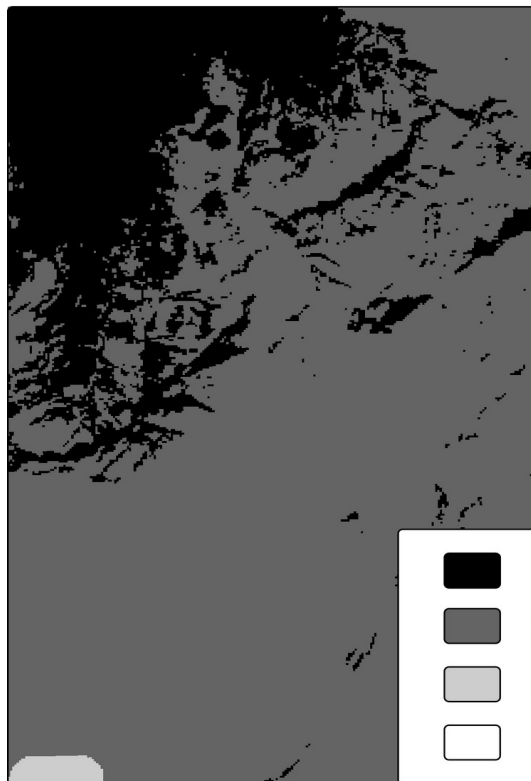
- 142 GCPs, 20 webcams
- RMSE of 23.7m (14.1m if excluding wide-angle lens webcams)

→ precise enough to validate satellite-derived snow cover maps..?

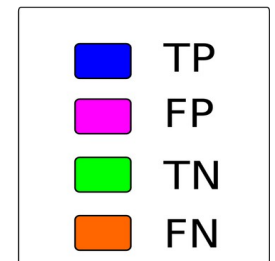
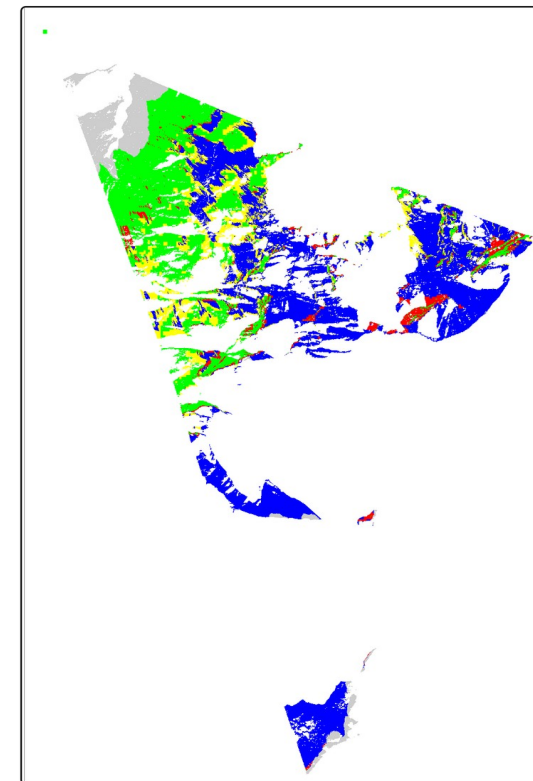
Applications

- Validation of satellite-based snow cover maps

Sentinel-2 snow cover map

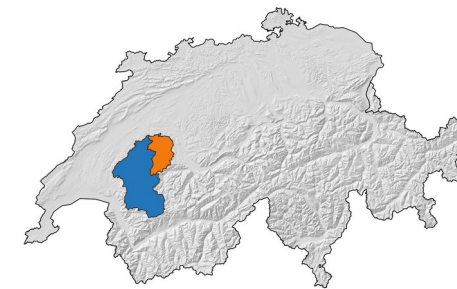
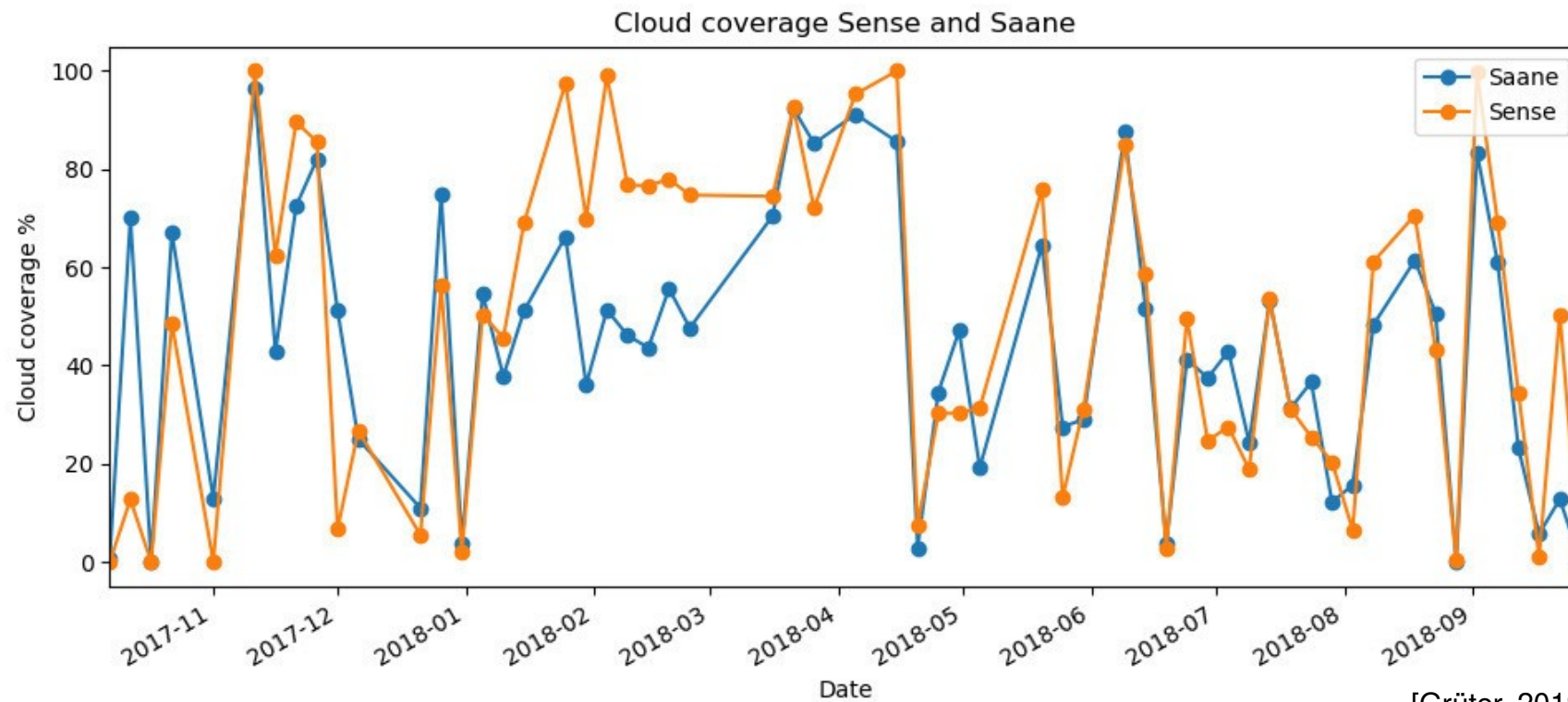


Webcam snow cover map



Applications

- Validation of satellite-based snow cover maps
- Complement satellite-based snow cover information

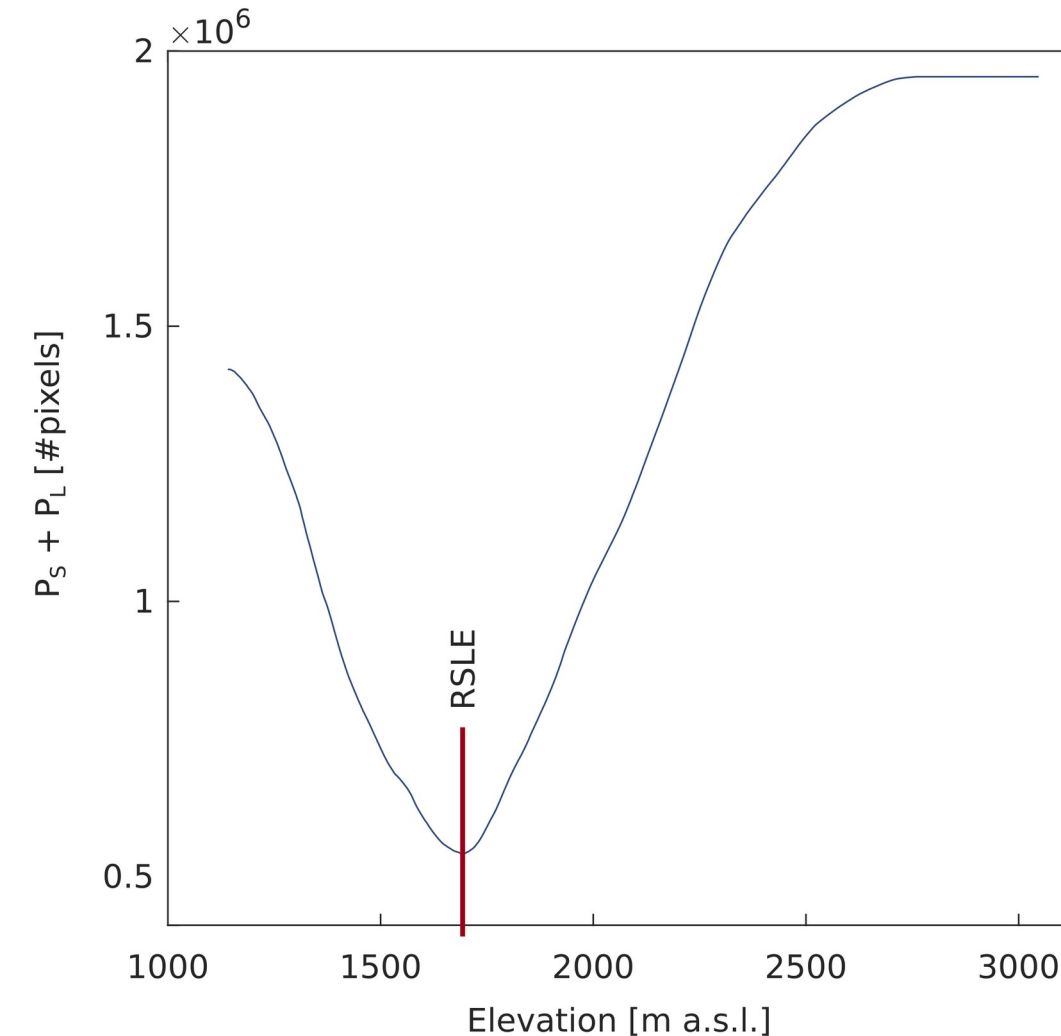
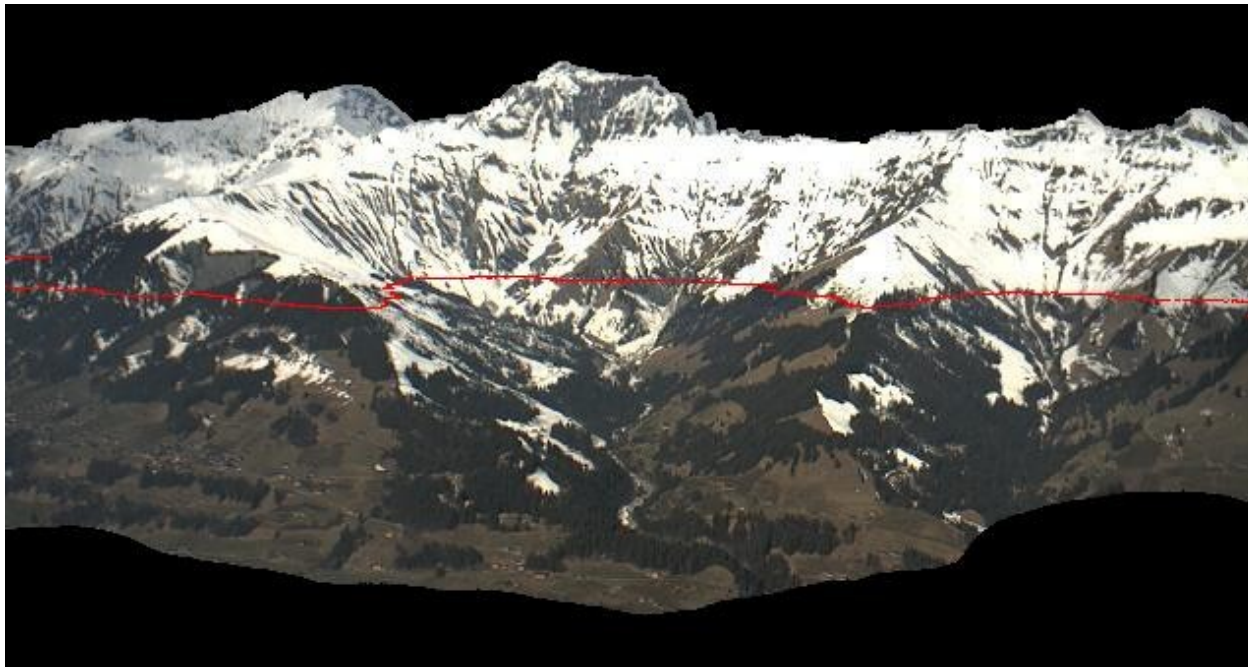


Regional snowline elevation (RSLE)

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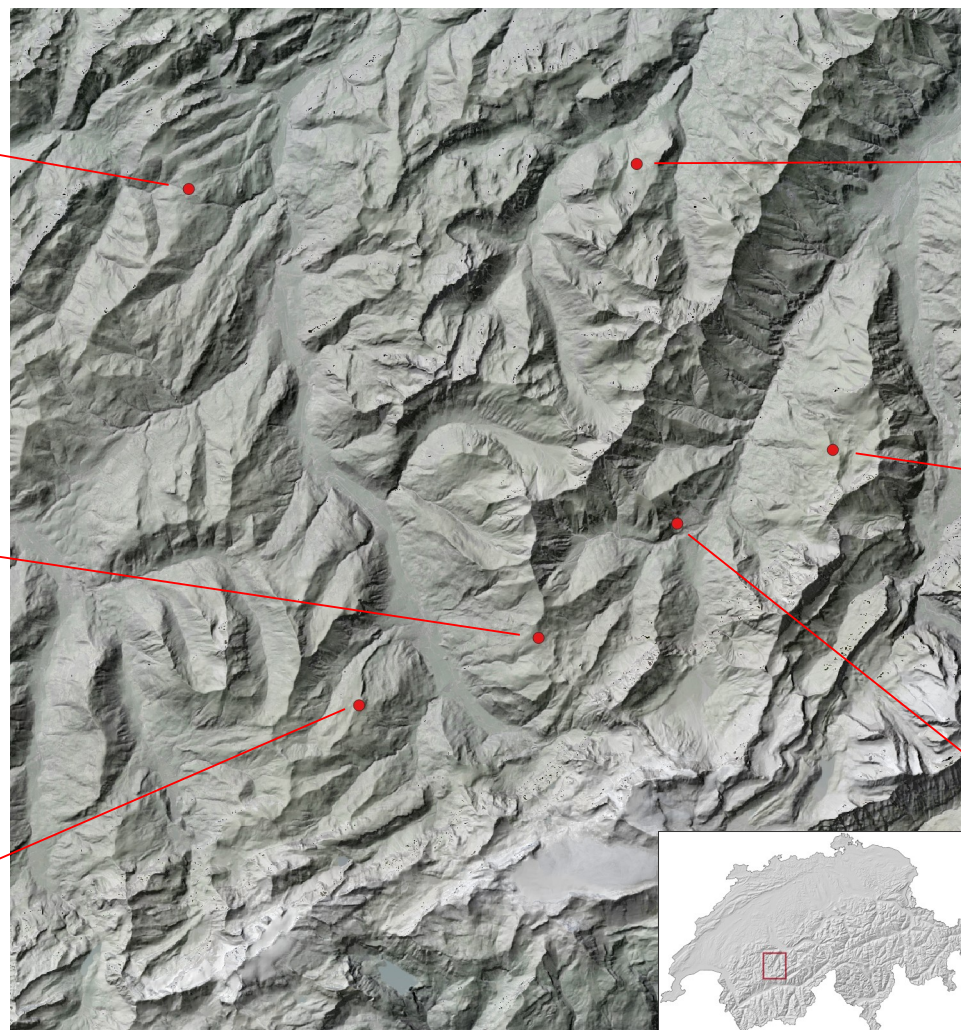
RSLE estimation method proposed by Krajčů et al. (2014)

→ find elevation (RSLE) for which the sum of snow covered pixels below (P_s) and land pixels above (P_L) the RSLE is minimized



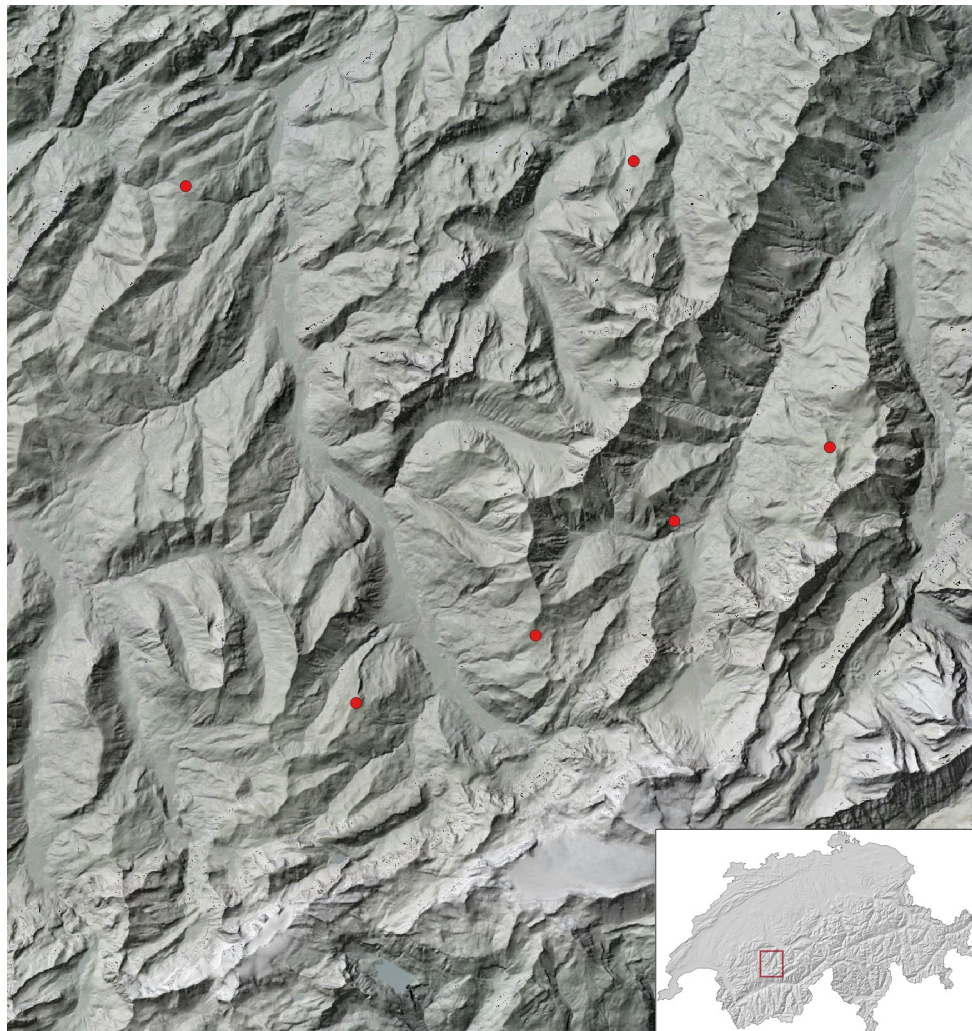
Regional snowline elevation (RSLE) - Data

Webcams

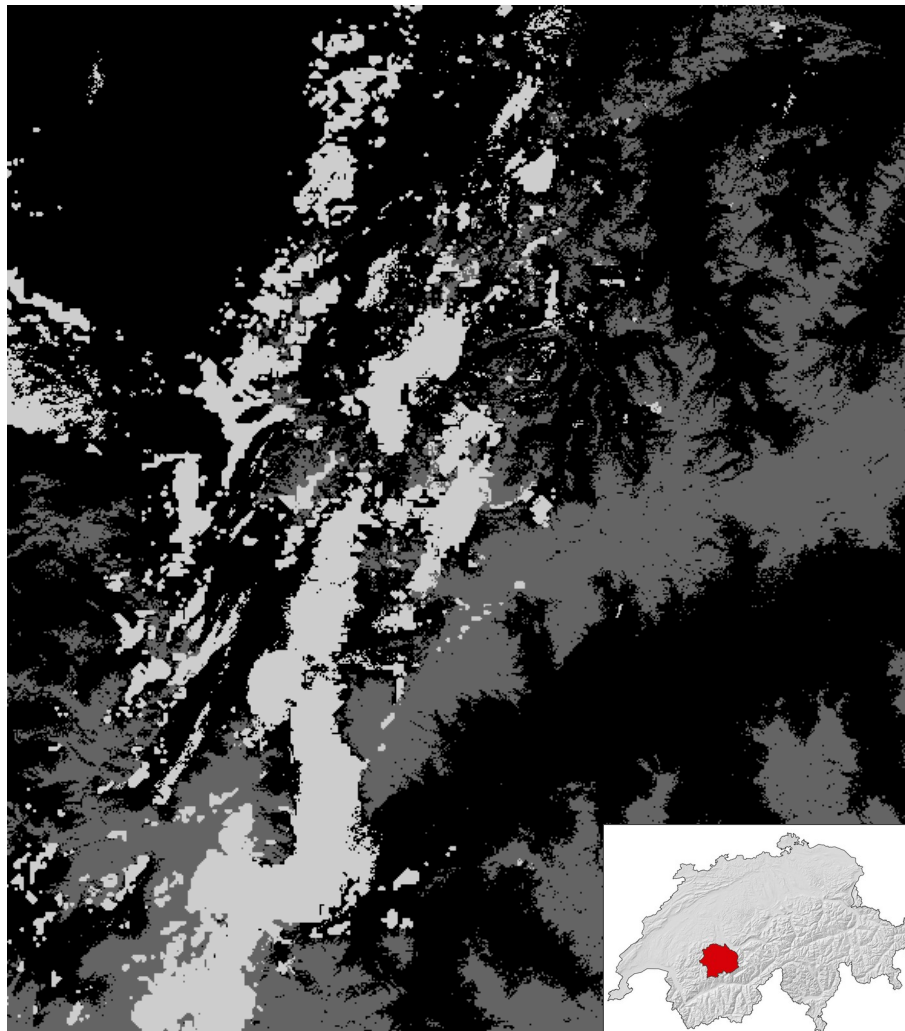


Regional snowline elevation (RSLE) - Data

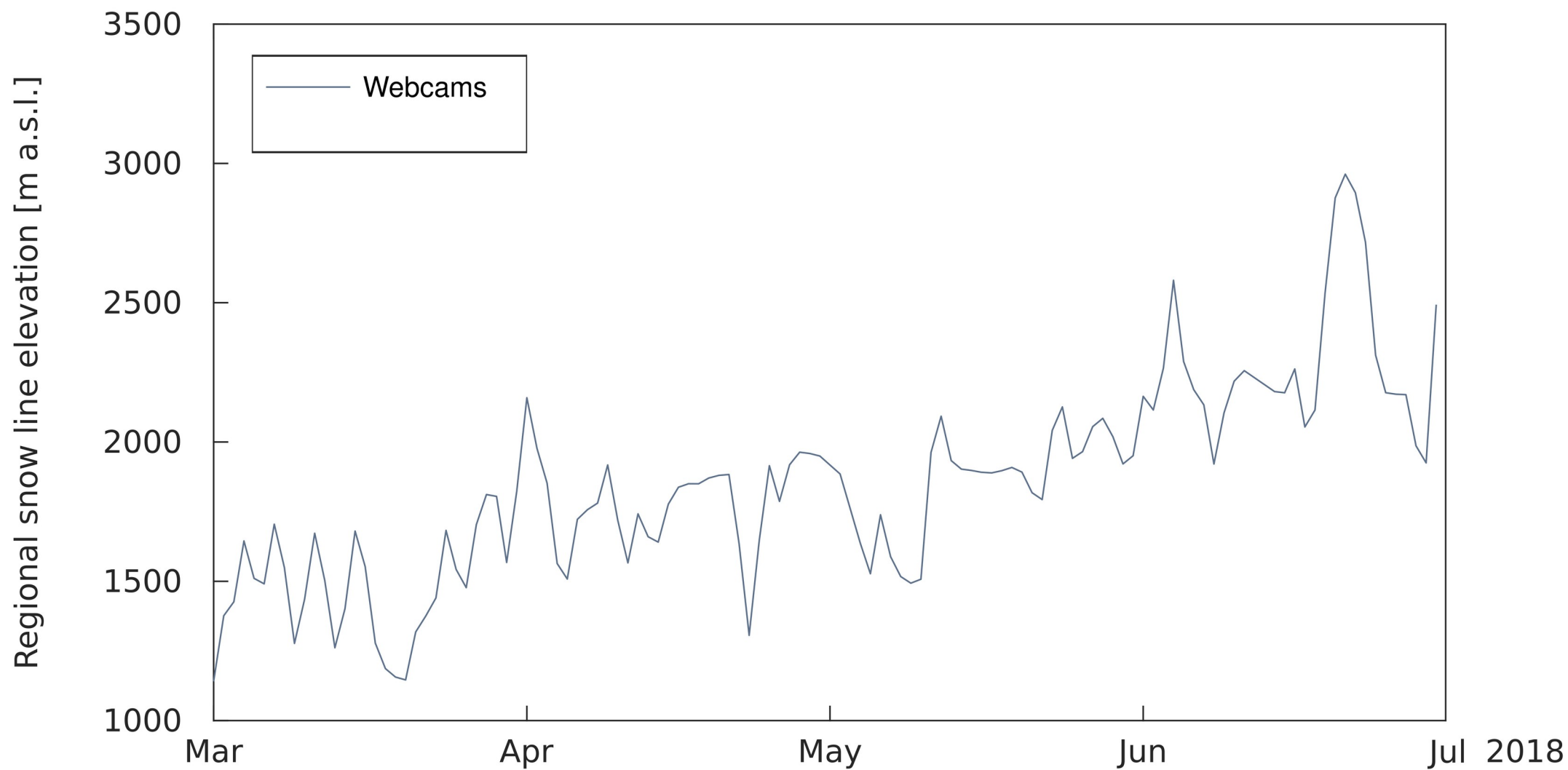
Webcams



Sentinel-2 snow cover maps



Regional snowline elevation (RSLE)

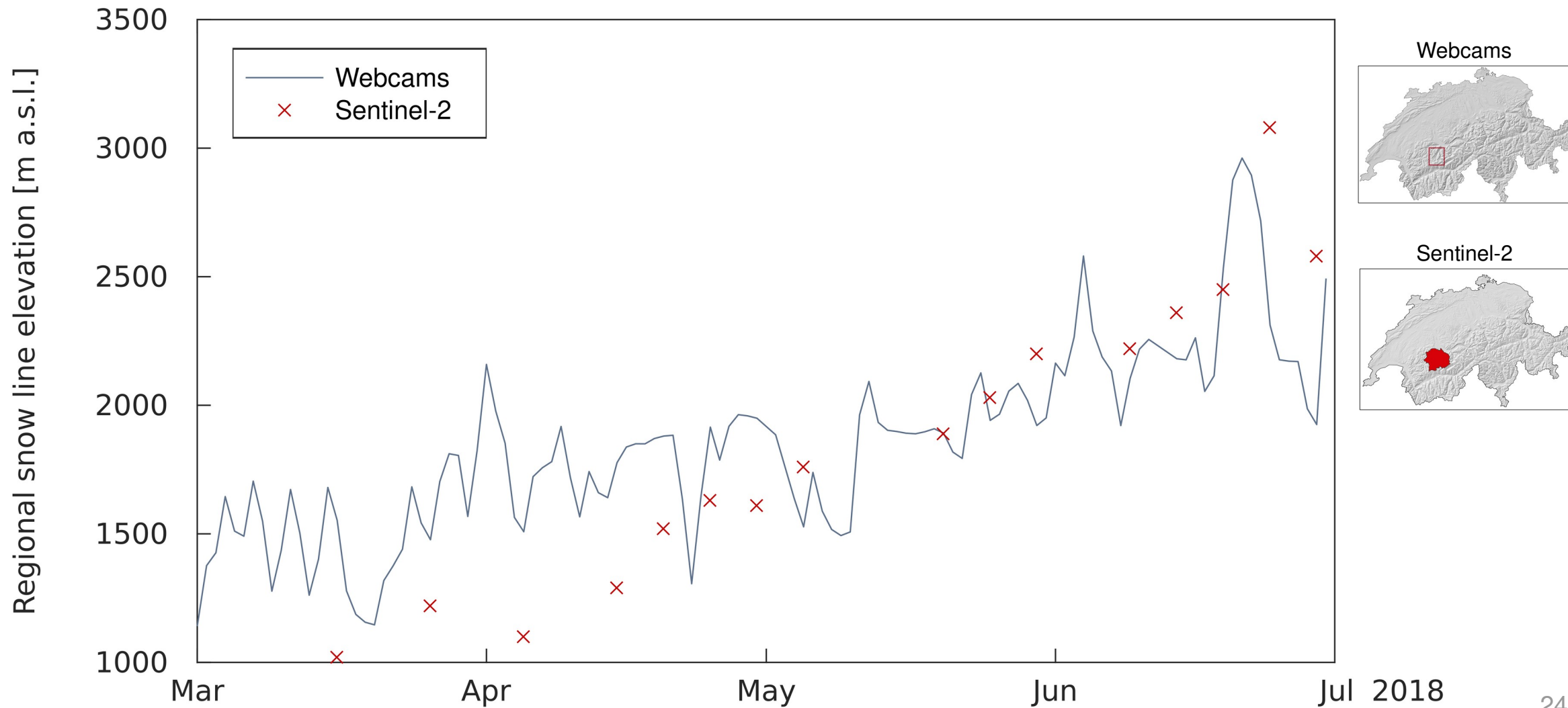


Regional snowline elevation (RSLE)

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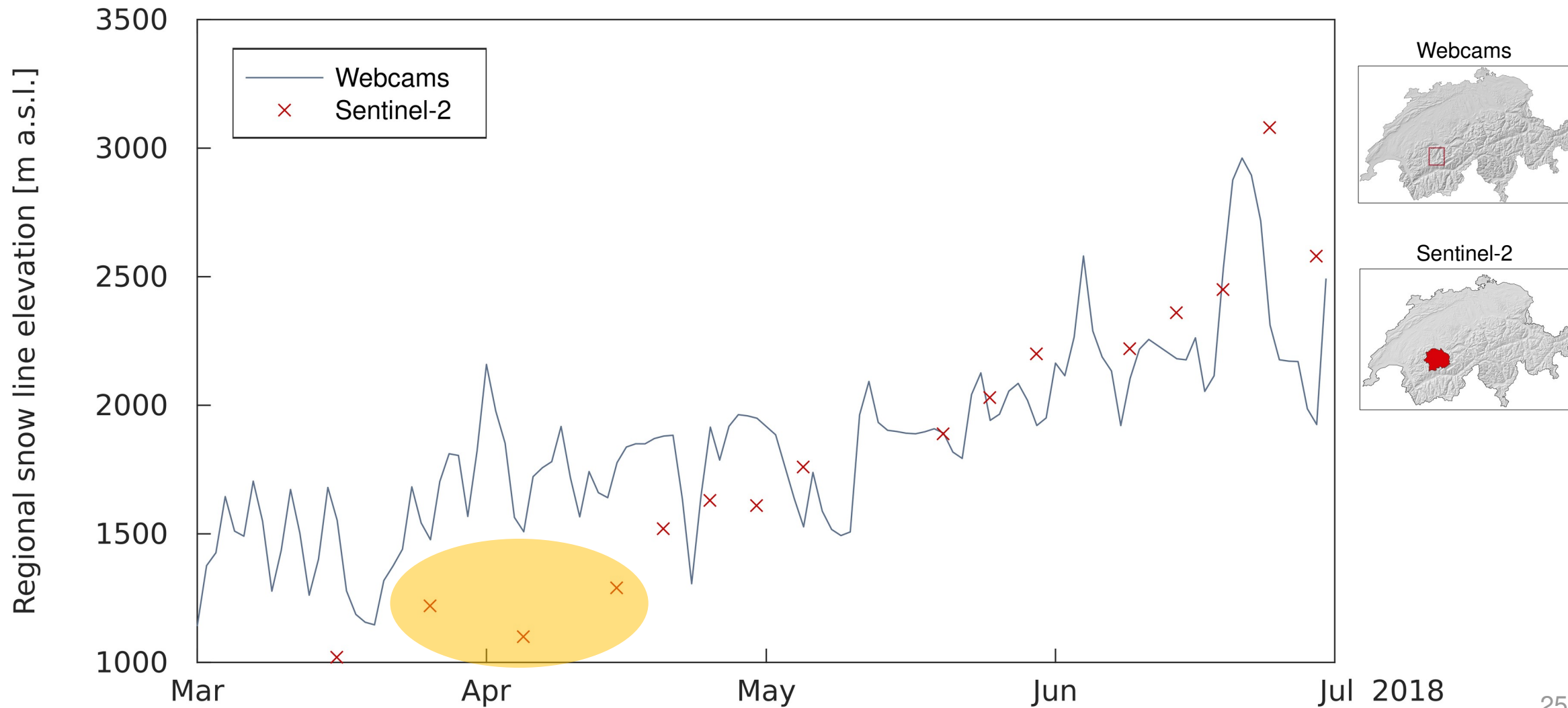


Regional snowline elevation (RSLE)

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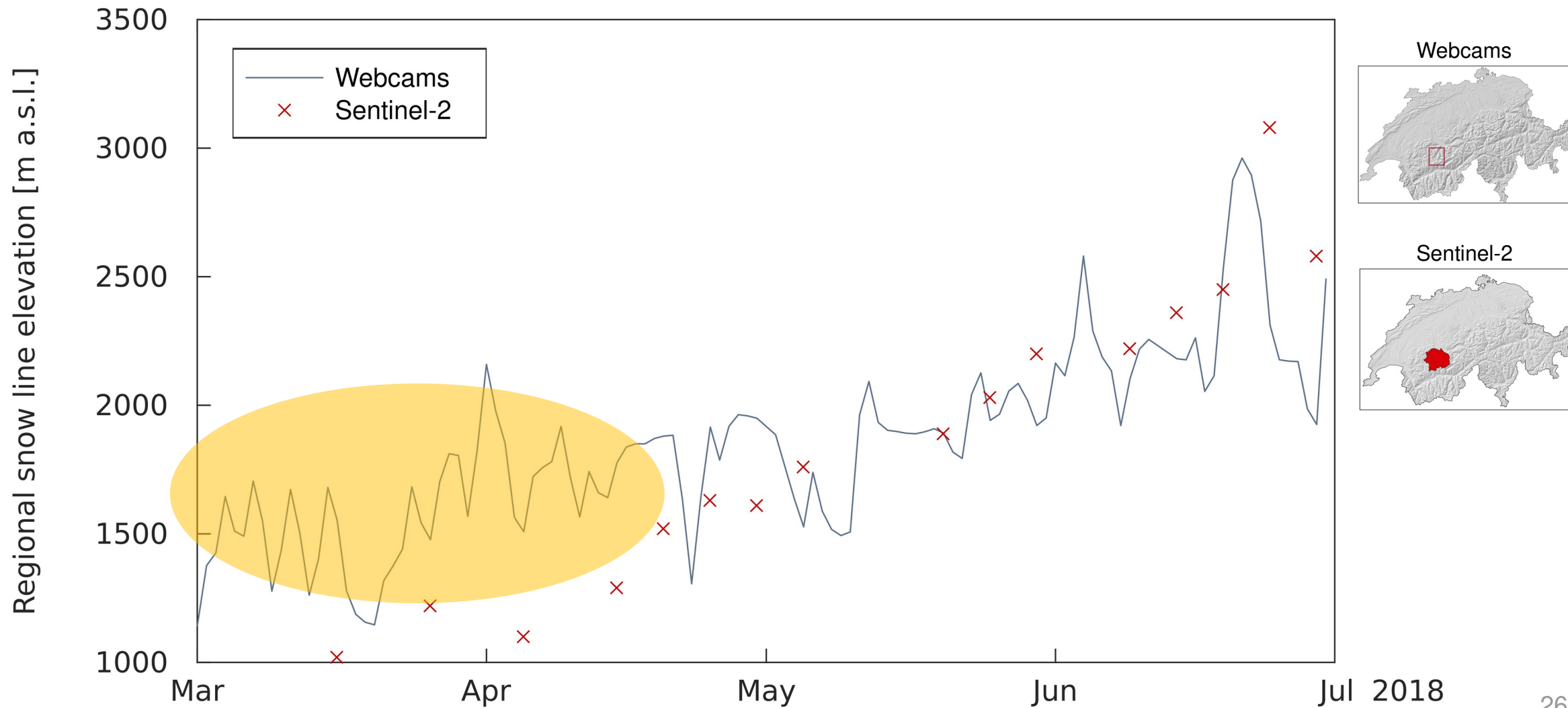


Regional snowline elevation (RSLE)

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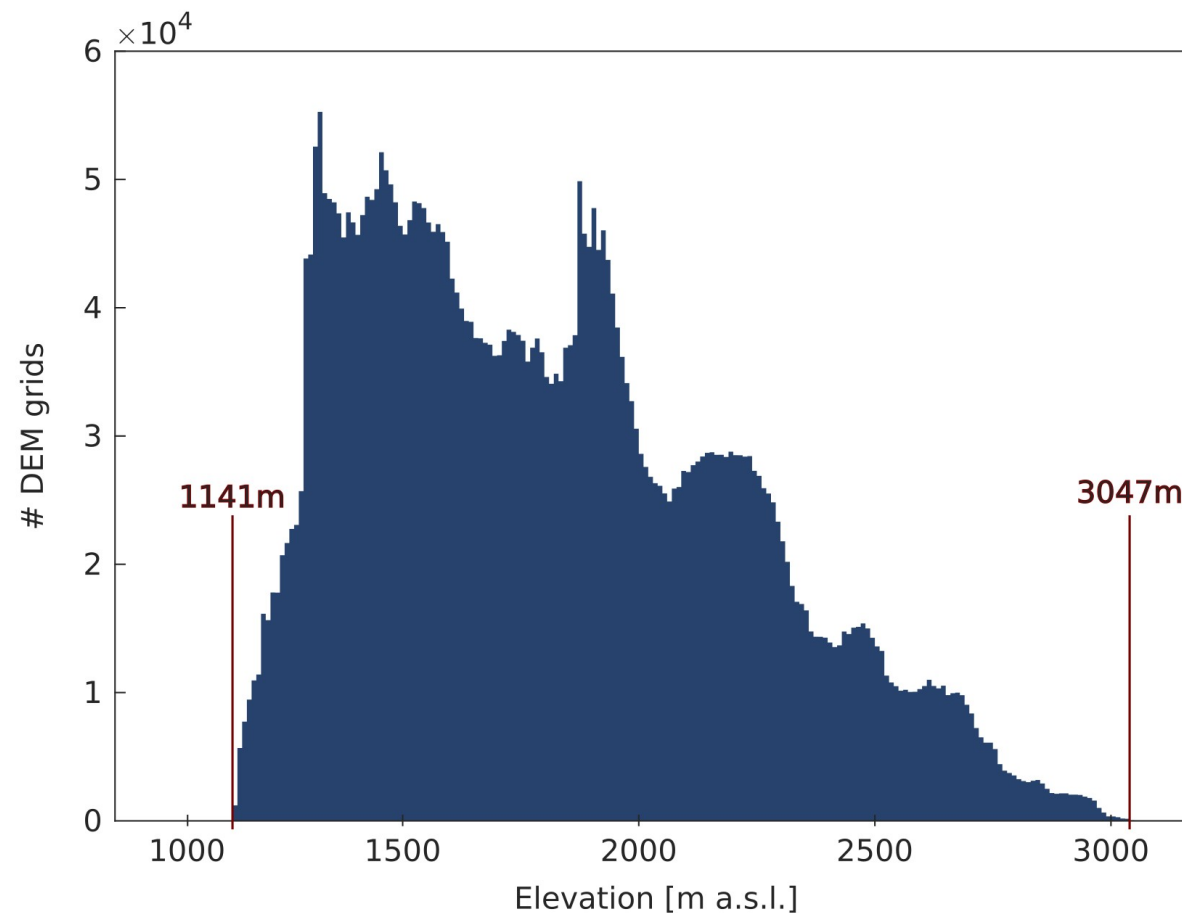
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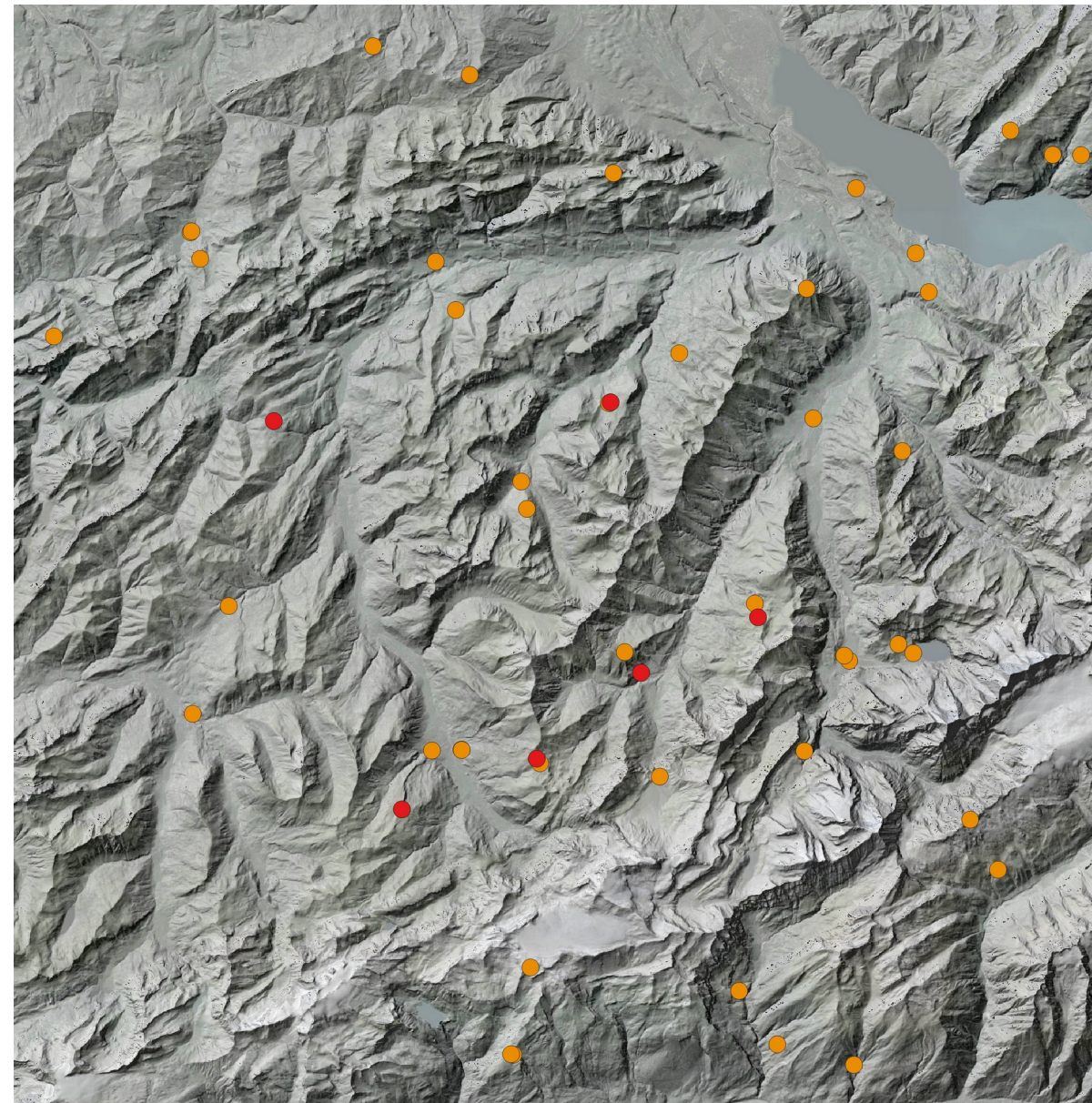
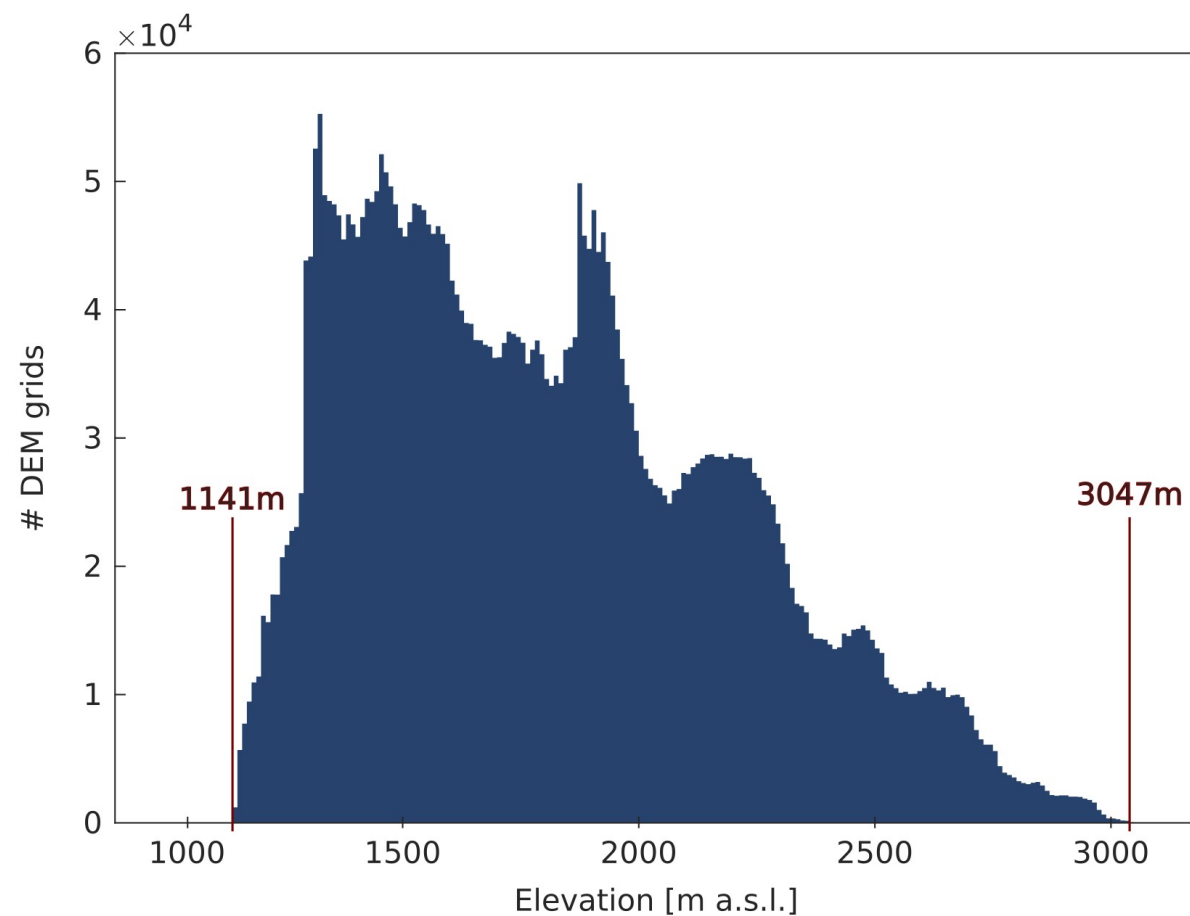
Regional snowline elevation (RSLE)

Smaller elevation range, low number of webcams



Regional snowline elevation (RSLE)

Smaller elevation range, low number of webcams

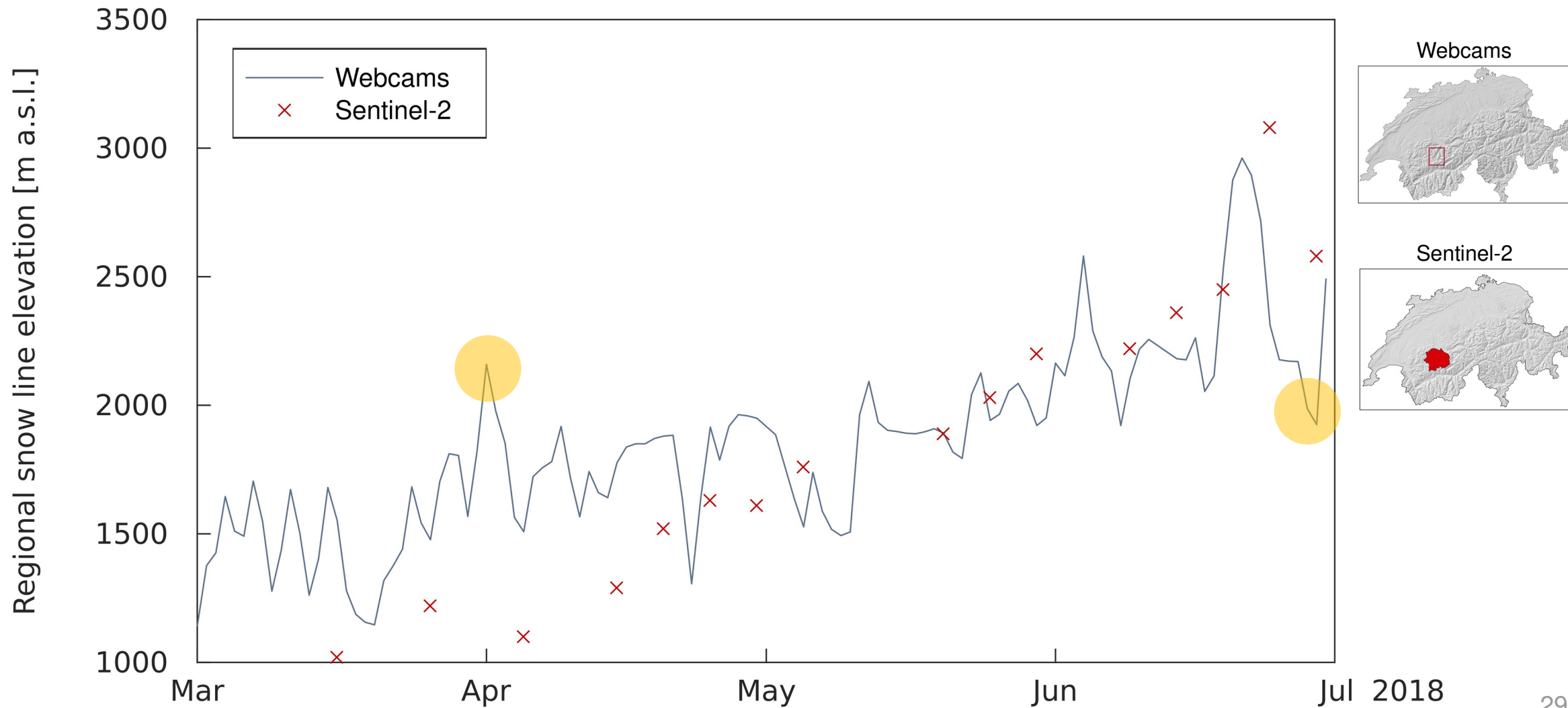


Regional snowline elevation (RSLE)

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Regional snowline elevation (RSLE)

Snow misclassification

- shadows, low light situations, bright rock surfaces

31 March: underestimation → both methods fail

Webcam image



Blue-band (Salvatori et al. , 2011)



Blue-band + PCA (Härer et al., 2016)



Regional snowline elevation (RSLE)

Snow misclassification

- shadows, low light situations, bright rock surfaces

26 June: overestimation

Blue-band + PCA (Härer et al. 2016)



Regional snowline elevation (RSLE)

Clouds vs. snow



SnowNet - a deep learning approach for automatic snow and cloud classification in public webcam images (in preparation)

→ train a deep convolutional neural network that considers an entire image patch instead of only a small local neighborhood to predict a single pixel

Conclusion & outlook

- Webcams offer huge potential to analyze small-scale variability of snowline on a high spatio-temporal resolution
 - detailed analyses, especially during spring snowmelt period or long-lasting cloud cover
- Need for improved snow classification and cloud detection
- Combining webcam-based snow cover information with satellite-based snow cover information

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Härer, S., Bernhardt, M., and Schulz, K.: PRACTISE – Photo Rectification And Classification Software (V.2.1), Geosci. Model Dev., 9, 307–321, <https://doi.org/10.5194/gmd-9-307-2016>, 2016

Lowe, D.G.: Distinctive image features from scale-invariant key points. Int. J. Comput. Vis., 60, 91–110. doi: 10.1023/B:VISI.0000029664.99615.94, 2004.

Portenier, C., Hüsler, F., Härer, S., and Wunderle, S.: Towards a webcam-based snow cover monitoring network: methodology and evaluation, The Cryosphere Discuss., <https://doi.org/10.5194/tc-2019-142>, in review, 2019.

Salvatori, R., Plini, P., Giusto, M., Valt, M., Salzano, R., Montagnoli, M., Cagnati, A., Crepaz, G., and Sigismondi, D.: Snow cover monitoring with images from digital camera systems, Ital. J. Remote Sens., 43, 137–145, <https://doi.org/10.5721/ItJRS201143211>, 2011.