Spatial rockfall susceptibility prediction from rockwall surface classification

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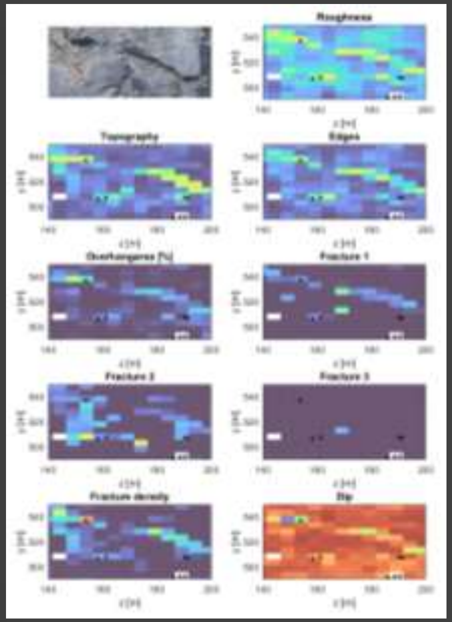

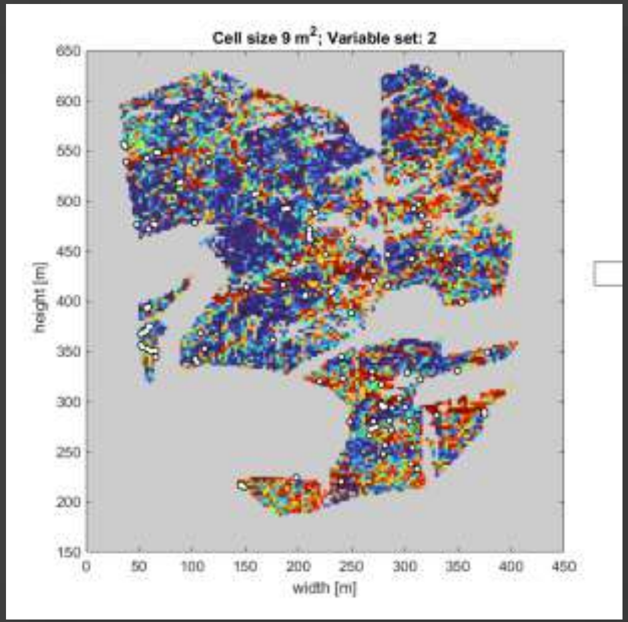

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Background

- rockfall both is a major **shaping** and **hazardous** process in steep topography
- also abundant **permafrost-free** over-steepened rockwalls releasing rockfall
- spatial **surveys** used for fracture pattern, kinematic and rockfall event analyses

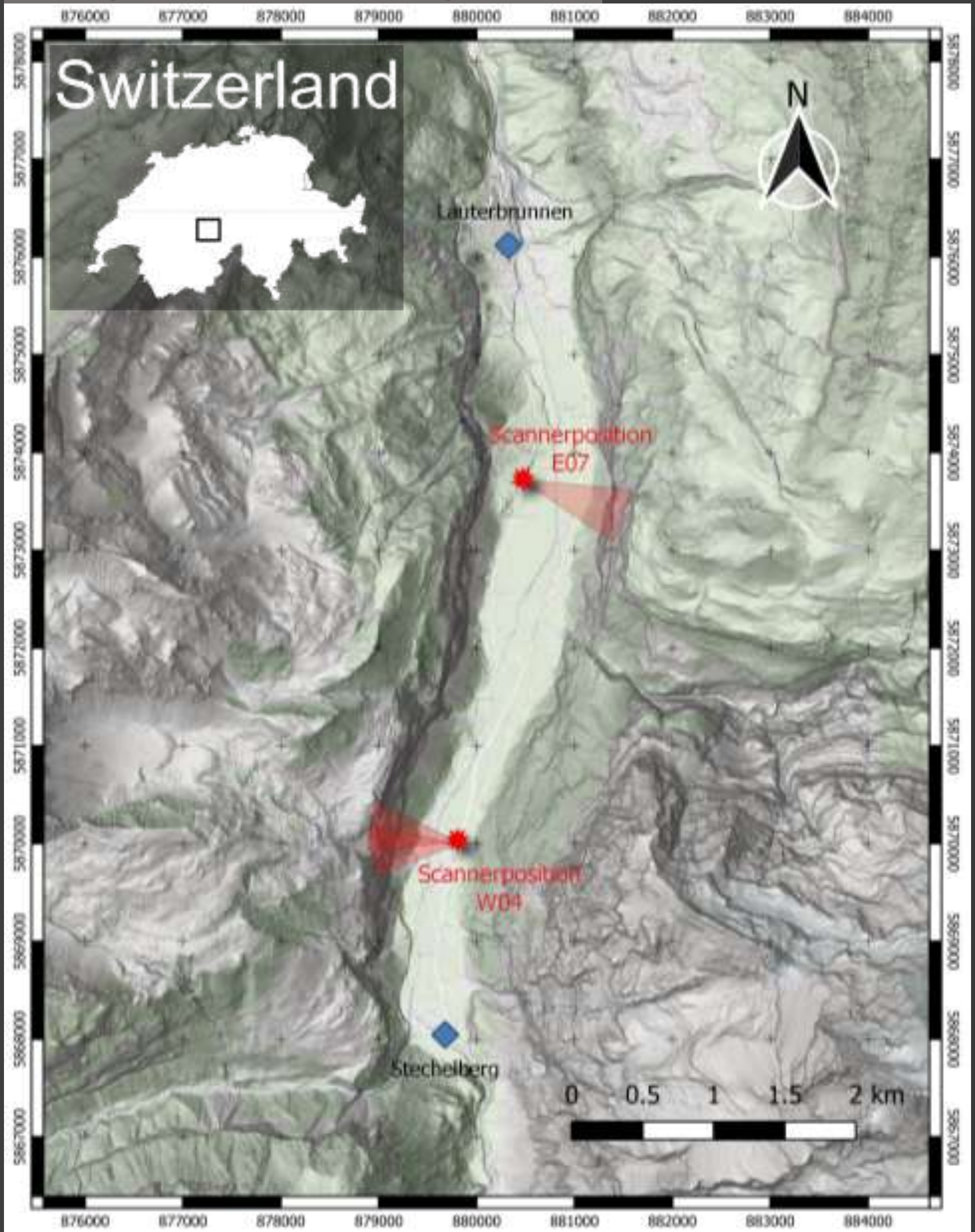
➢ though, rarely used to **predict** local rockfall **susceptibility** vs. observed events

-> How does **classification** of high-res rockwall surface

perform in **predicting** rockfall events?

TLS surveying

Examples of the scanner positions



Field site

- Lauterbrunnen valley, Canton Bern, Switzerland
- 5km^2 of 800m distant, ~vertical **limestone** walls
- up to **1'000m high**, variable fracture patterns

Field work

- TLS from **40 sites** using ILRIS-LR
- 900 scans of **~5cm** spatial resolution 2014-2020

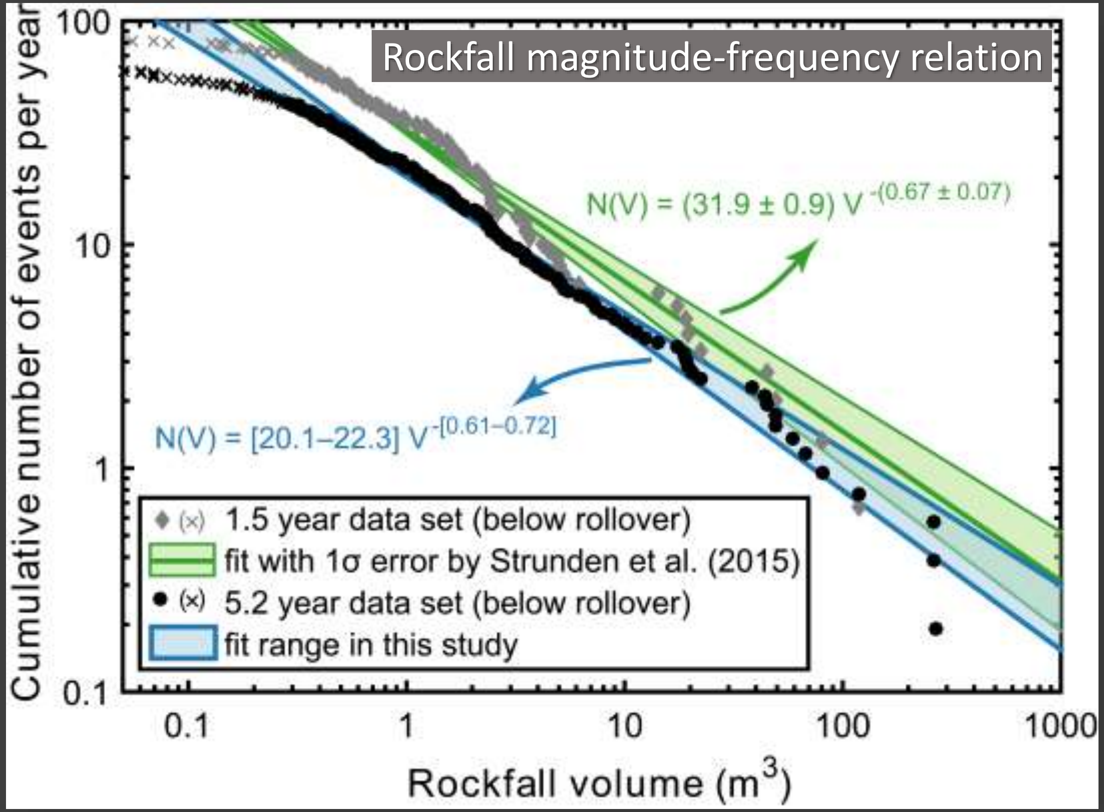
Upstream view along the valley

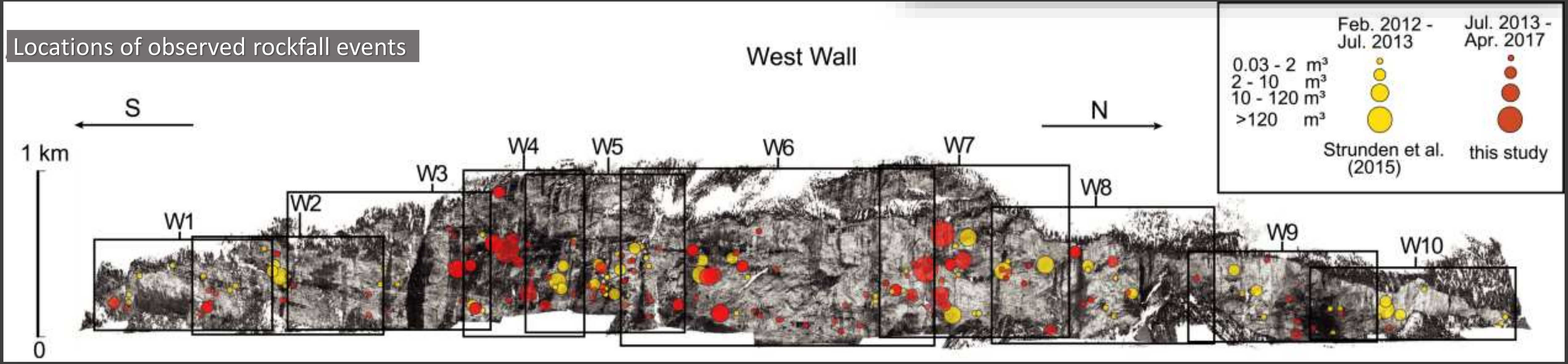
Previous work

TLS epochs change detection

- hand-cut to remove vegetation and fringes
- referenced by fixed points and ICP algorithm
- epoch change in the direction against the wall
- rockfall frequency and shape analyses

Mohadjer et al., 2020, Geology, https://doi.org/10.1130/G47092.1





Methods 1: Rockwall surface analysis

Surface parameters definition

- rasterized 3D data points (3^2, 5^2, 10^2, 15^2, 25^2, $40^2 m^2$)
- calculated several **surface parameters** per cell
- grouped them in 6 sets

Surface parameters, grouped in sets

name	entity	definition	variable set affiliation
Roughness	m	average mean distance to a 0.5 m circle around every point (Attachment 1) of a cell	A, B, C, D, E
Edge	/	average normal vector change rate (Attachment 2) of a cell	A, B, C, D, E
Topography	m	mean distance of all points within a cell to the best fitting plane	A, B, C, D, E
Overhangarea	%	area with less than 60 ° of the total surface	B, D, E
Fracture 1; Fracture 2; Fracture 3	m	mean distance between fractures	D, E, F
Fracture density	1/m²	number of fractures within a cell normalized to the cell size	D, E, F
Dip	degrees	average dip direction of a cell	C, E

Methods 2: Rockwall surface classification

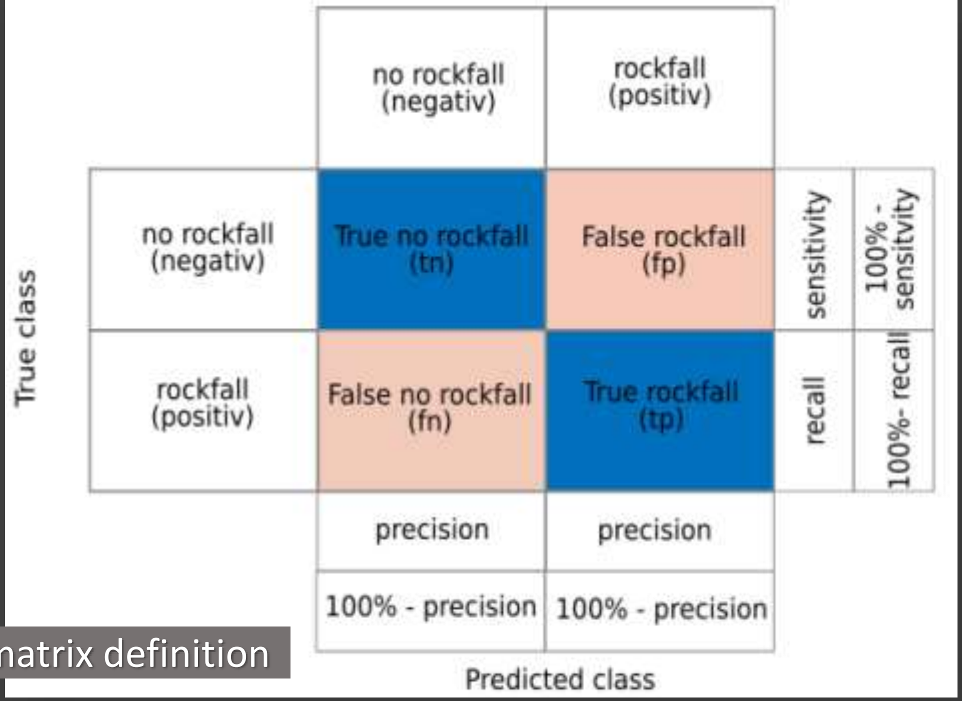
Bayesian classification procedure

- cells classified as **rockfall vs. non-rockfall cells** (based on 6a of TLS change-detection)
- implemented **Naïve-Bayes-Classifier** with 6 parameter sets and 9 variable combinations (distributions and probabilities, including misclassification cost)
- trained on the 6 cell sizes = **324 models** on one wall (T1) predicting rockfall susceptibility
- **performance** visualized by confusion matrix,

  quantified by Mathews correlation coefficient (**MCC**)

Mathews correlation coefficient

$$MCC = \frac{tp * tn - fp * fn}{\sqrt{(tp + fp) * (tp * fn) * (tn * fp) * (tn * fn)}}$$

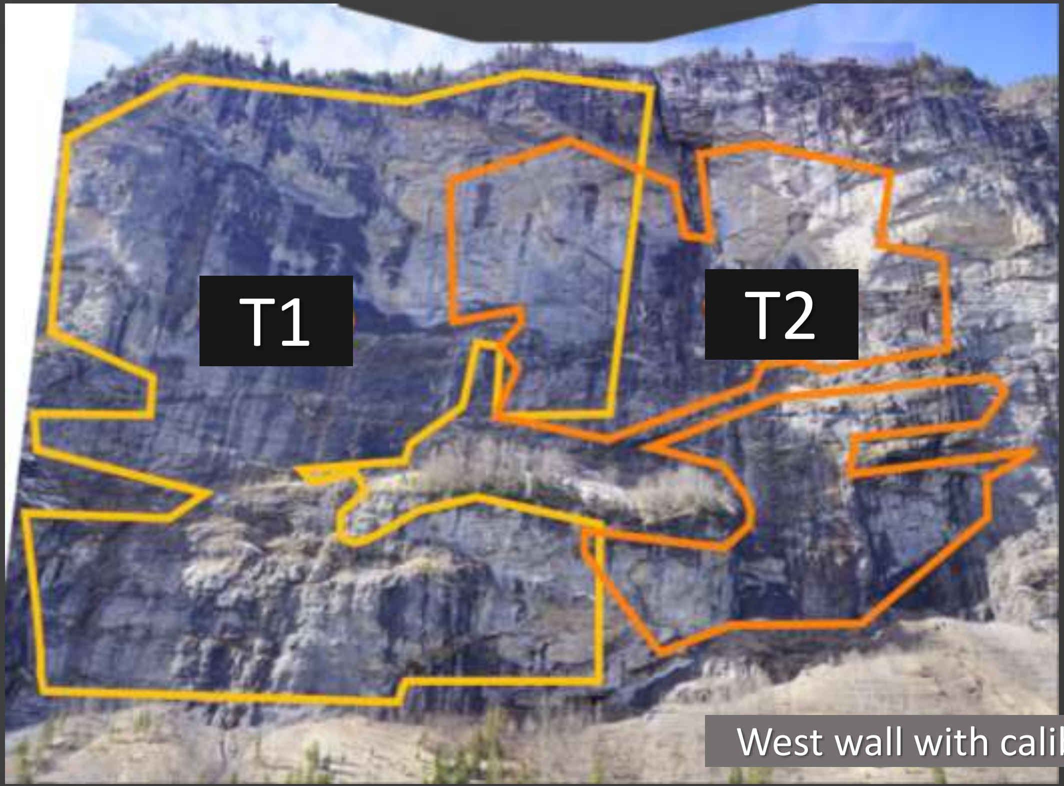


Confusion matrix definition

Results 1: Rockwall classification

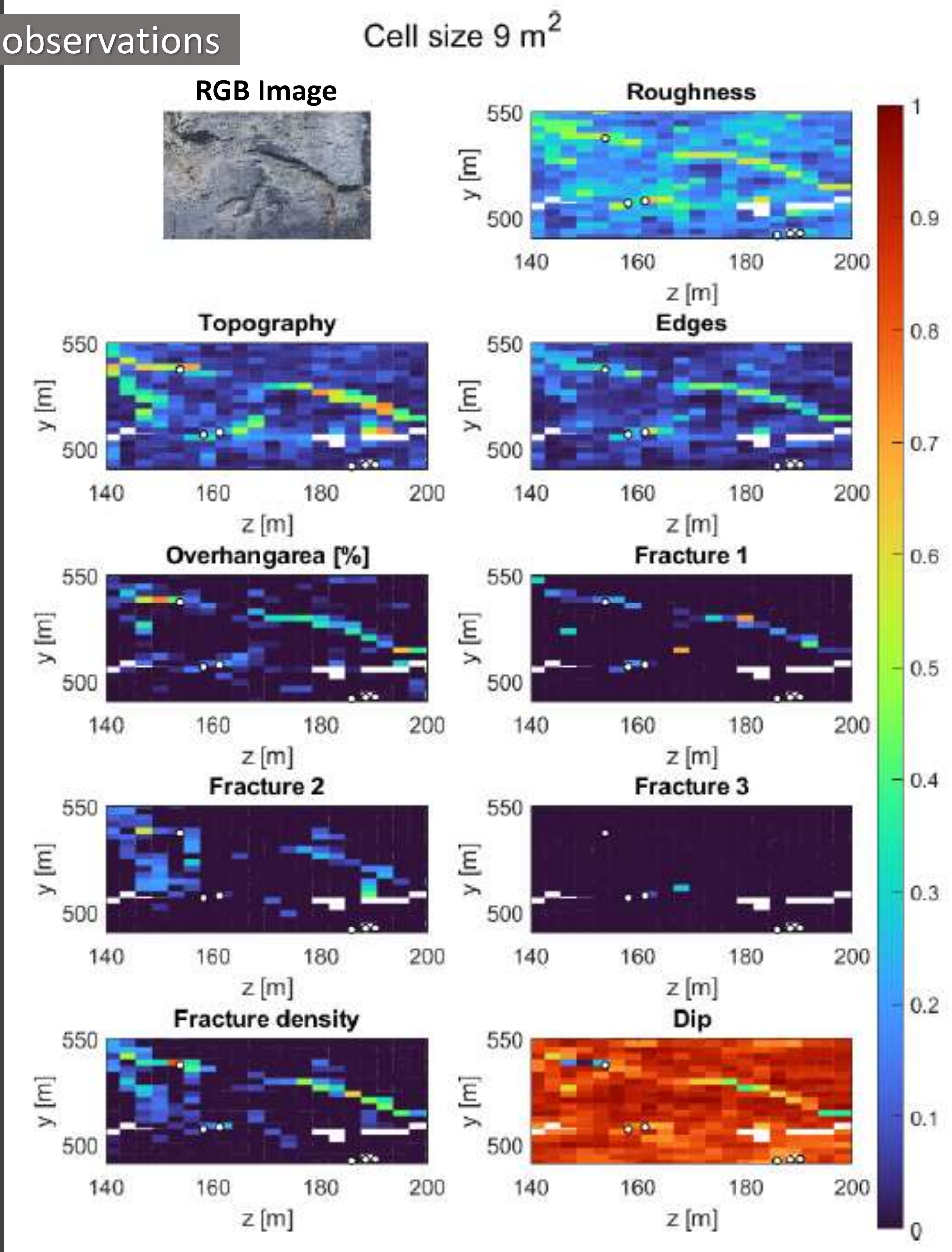
Naïve-Bayes-Classifier application:

- trained on 6 cell sizes = **324 models** on wall site T1
- tested for **performance** on adjacent wall site T2
- structures best and well presented in 3^2m^2 cell sizes



West wall with calibration sites

Prediction vs. observations

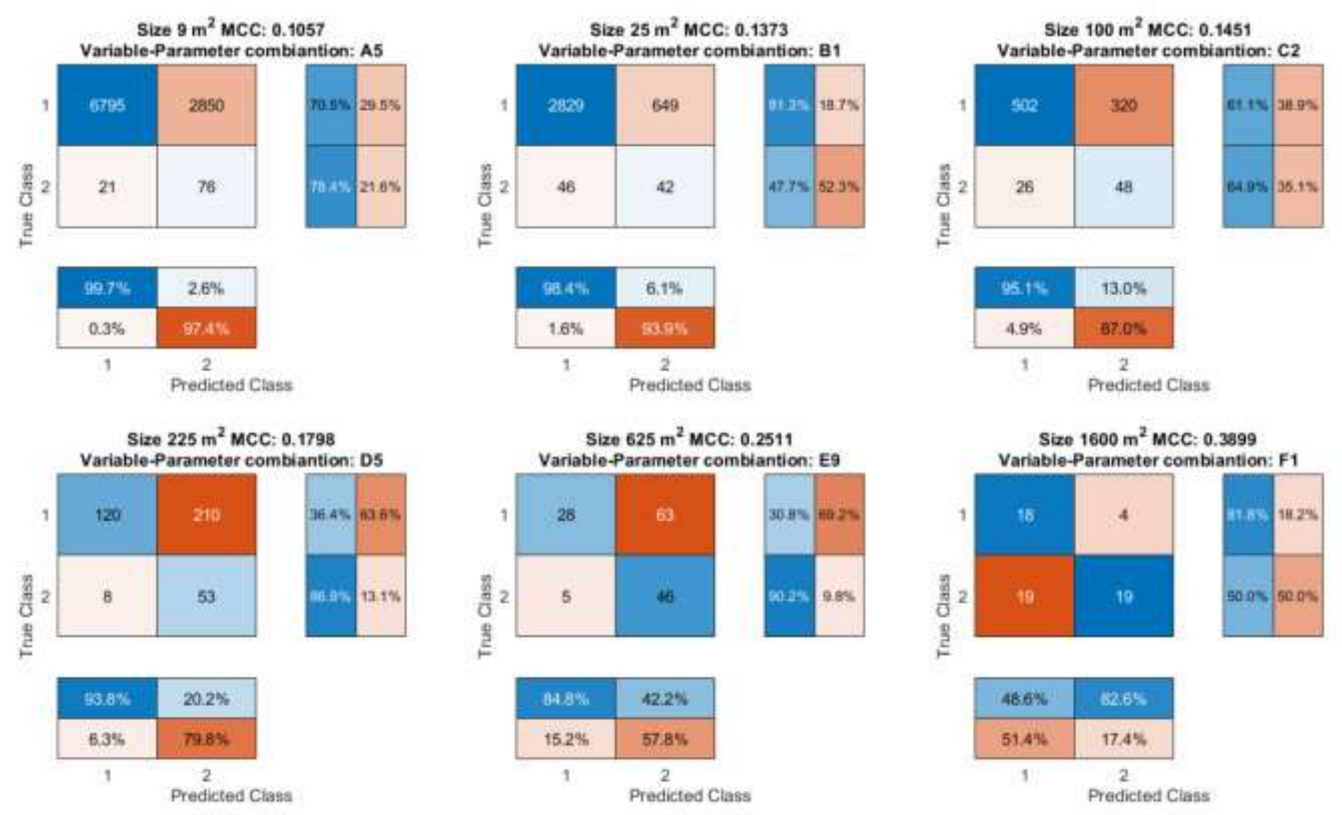


Results 2: Rockfall Classifier evaluation

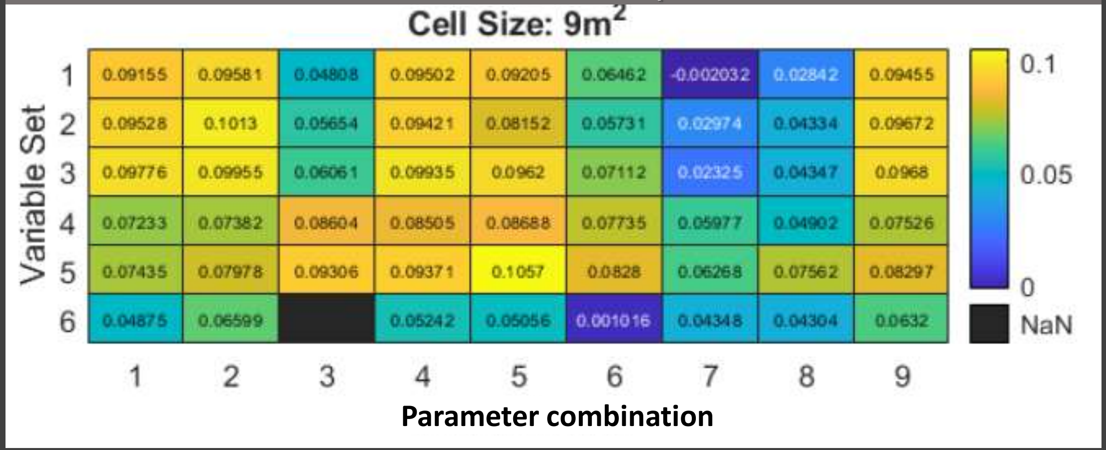
Classifiers per cell size:

- generally more rockfall predicted than observed (but only 6a observations)
- hence **small MCC-values**

Confusion matrices of the best classifiers per cellsize



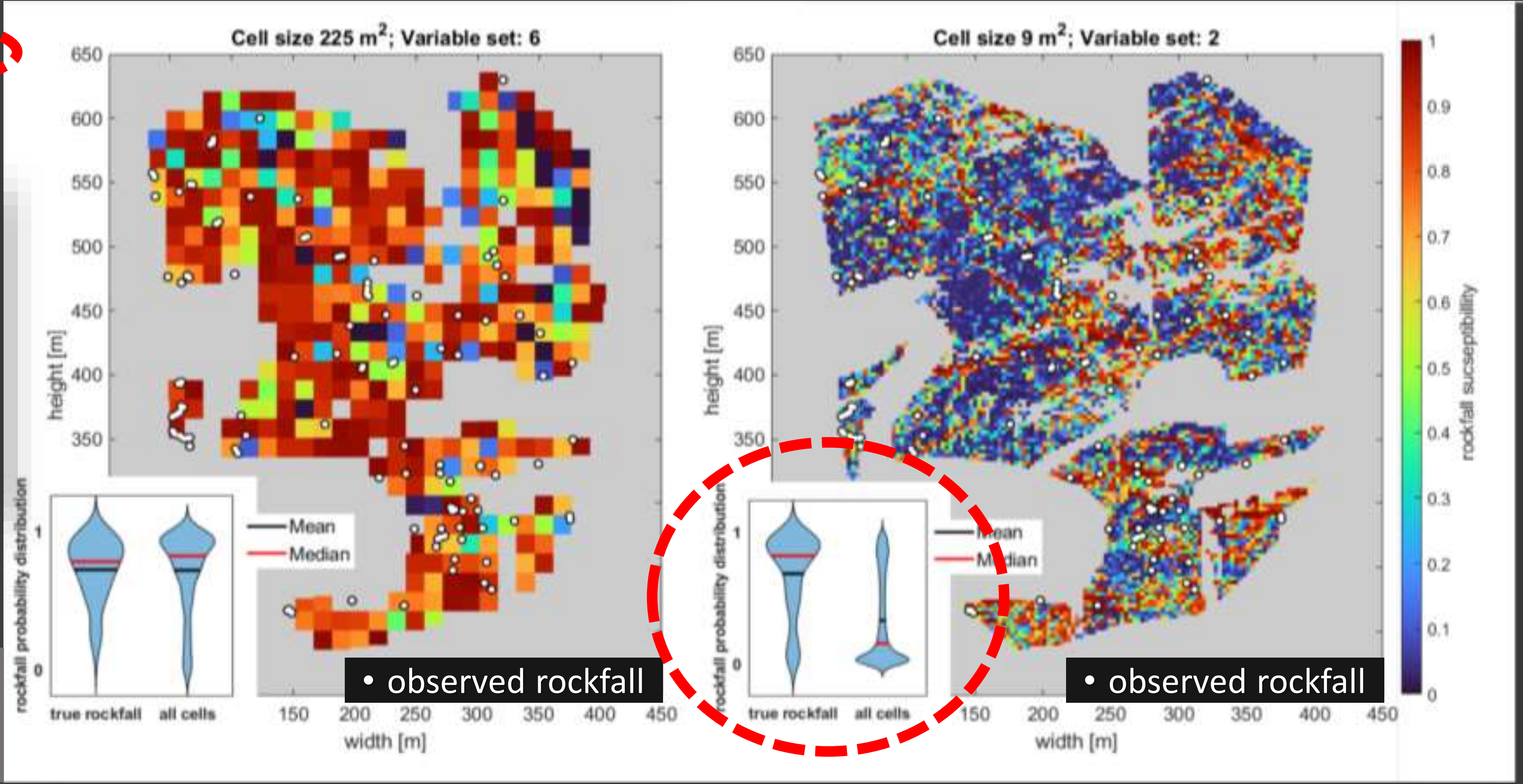
MCC-scores for all variable sets and parameter combinations



Rockfall susceptibility evaluation 1

Check:

- best variable set: Roughness, Edges, Topography, and Overhang-Area (not fractures)
- best parameter combination: kernel density estimation, uniform probability
- probability 0.73 vs 0.3

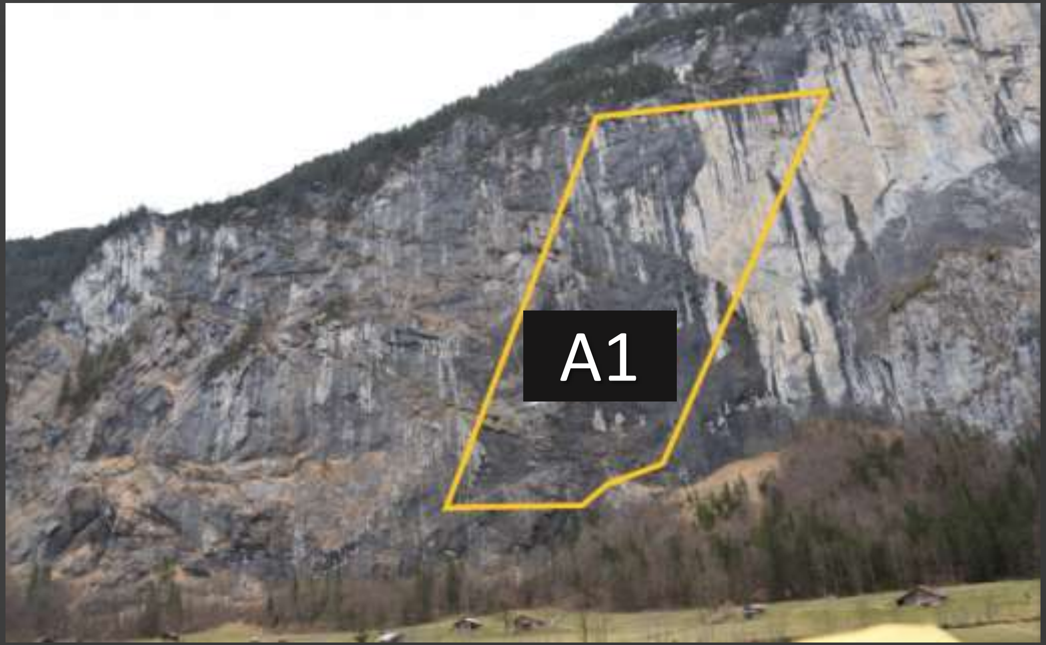


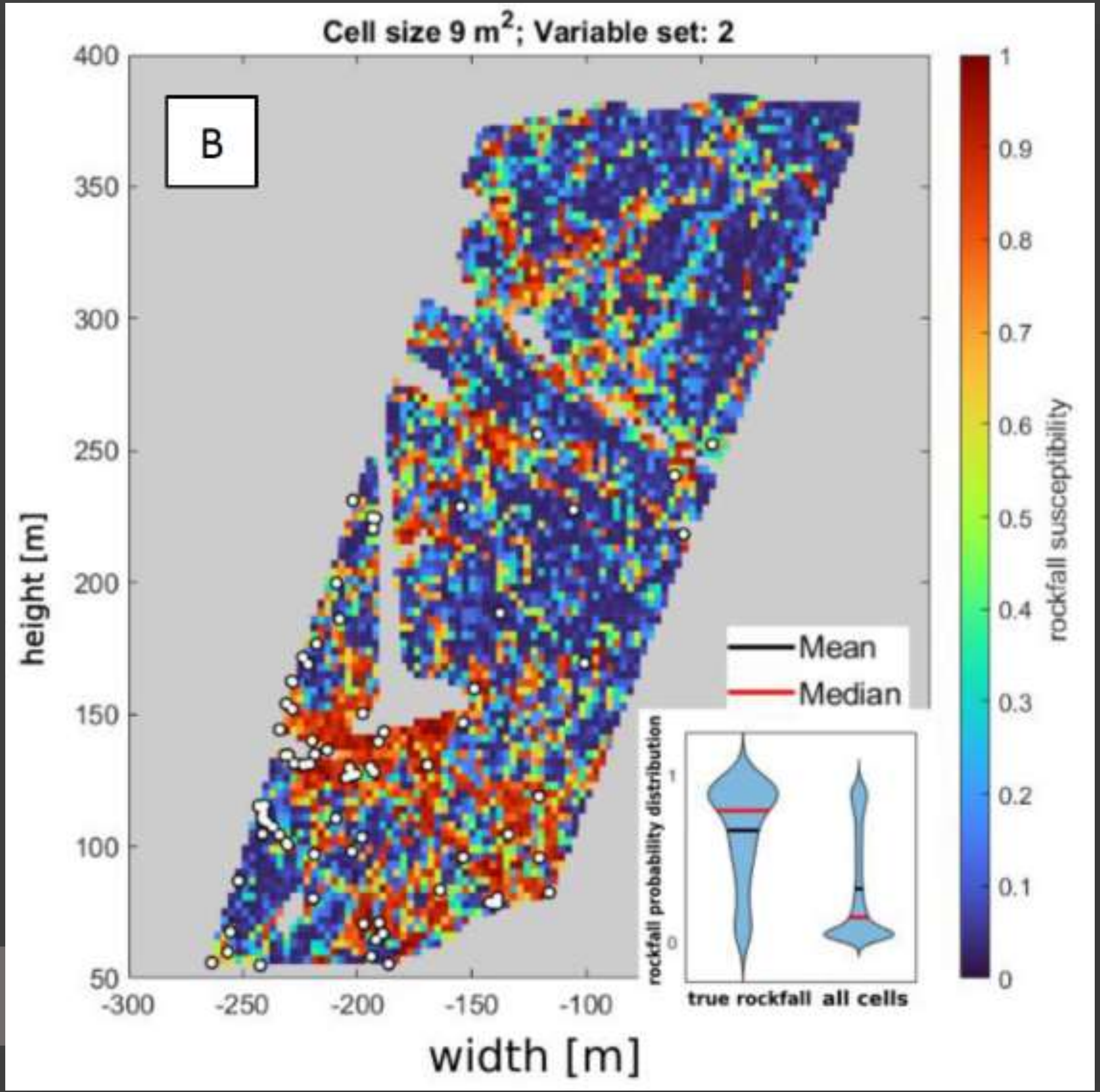
Application of the best classifier at wall T2 for different cell sizes

Rockfall susceptibility evaluation 2

Transfer:

- apply method to different rockwall A1
  (other valley side, less fractured, smooth face)





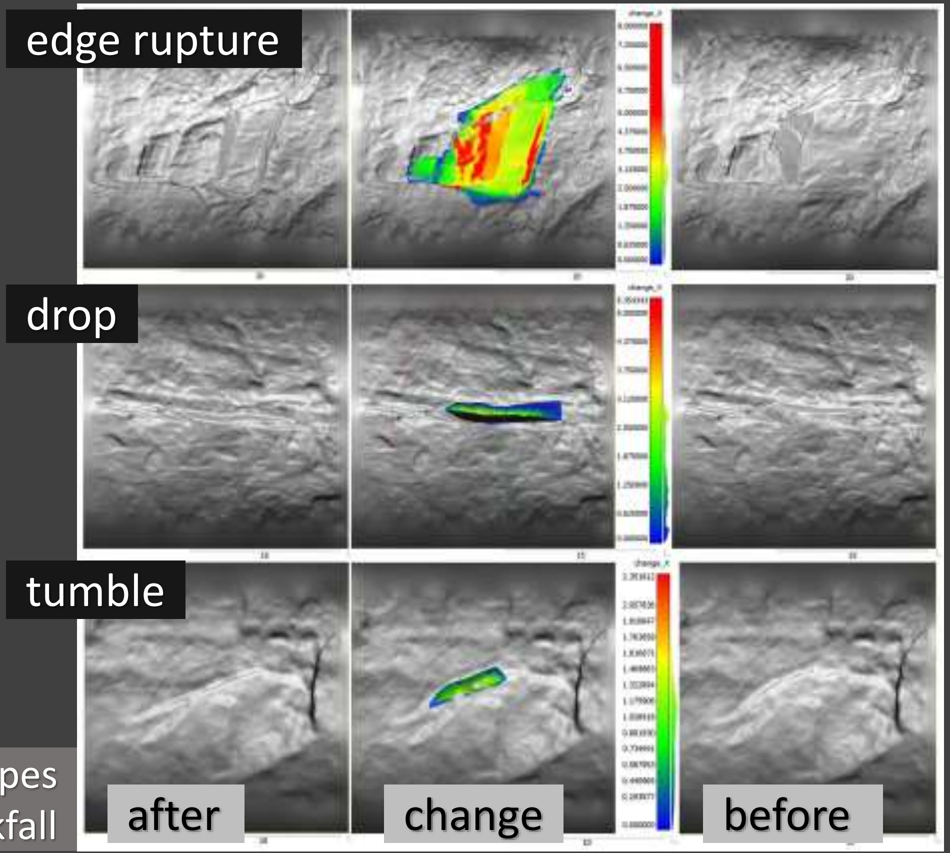
Application of the best classifier at wall A1

Wrap-up

- NB classifier **simple and fast** for non-contact rockfall susceptibility mapping
- generally **transferable** (for ≤ ~10^2 m^3), since only orientation-dependent
- small **cellsize** better; fracture sets not useful in cell-based approach

➢ fractures and overhangs well detected

➢ next: also predict **rockfall types**



Observed types of rockfall