

Machine learning as a tool for avalanche forecasting

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Abstract

- Assessing and forecasting avalanche hazard is crucial for the safety of people and infrastructure in mountain areas.

- Over 20 years of data covering snow precipitation, snowpack properties, weather, on-site observations, and avalanche danger has been collected in the context of operational avalanche forecasting for the Swiss Alps. The quality and breadth of this dataset makes it suitable for machine learning techniques.

- Forecasters mainly process a huge and redundant datasets “manually” to produce daily avalanche bulletins during the winter season. The purpose of this work is to provide the forecasters automated tools to support their work.

- By combining clustering and classification algorithms, we are able to reduce the amount of information that needs to be processed and identify relevant weather and snow patterns that characterize a given avalanche situation.

The project – Sarted in autumn 2019

SDSC

Swiss Data Science Center

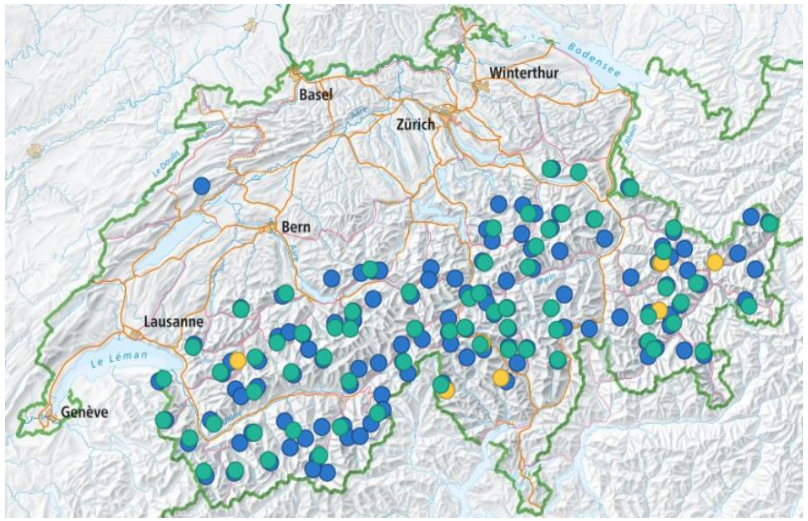
WSL SLF

The WSL Institute for Snow and Avalanche Research

Machine Learning applied to avalanche forecasting

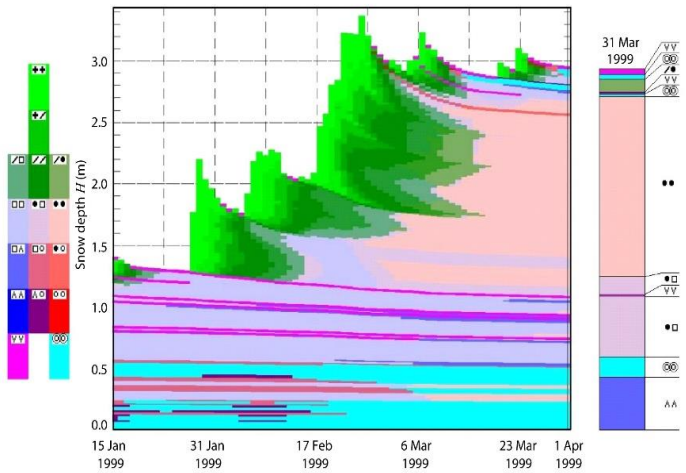
20 years of data

Meteorological and snow data



- 182 automated stations (IMIS network) covering Swiss Alps and Jura measuring snowpack and meteorological features (e.g. snow depth, snow surface temperature, wind speed, relative humidity, ...)

Snow cover simulation (the SNOWPACK model)



- Snow stratigraphy is simulated using IMIS data

→ crucial information about snowpack properties and stability

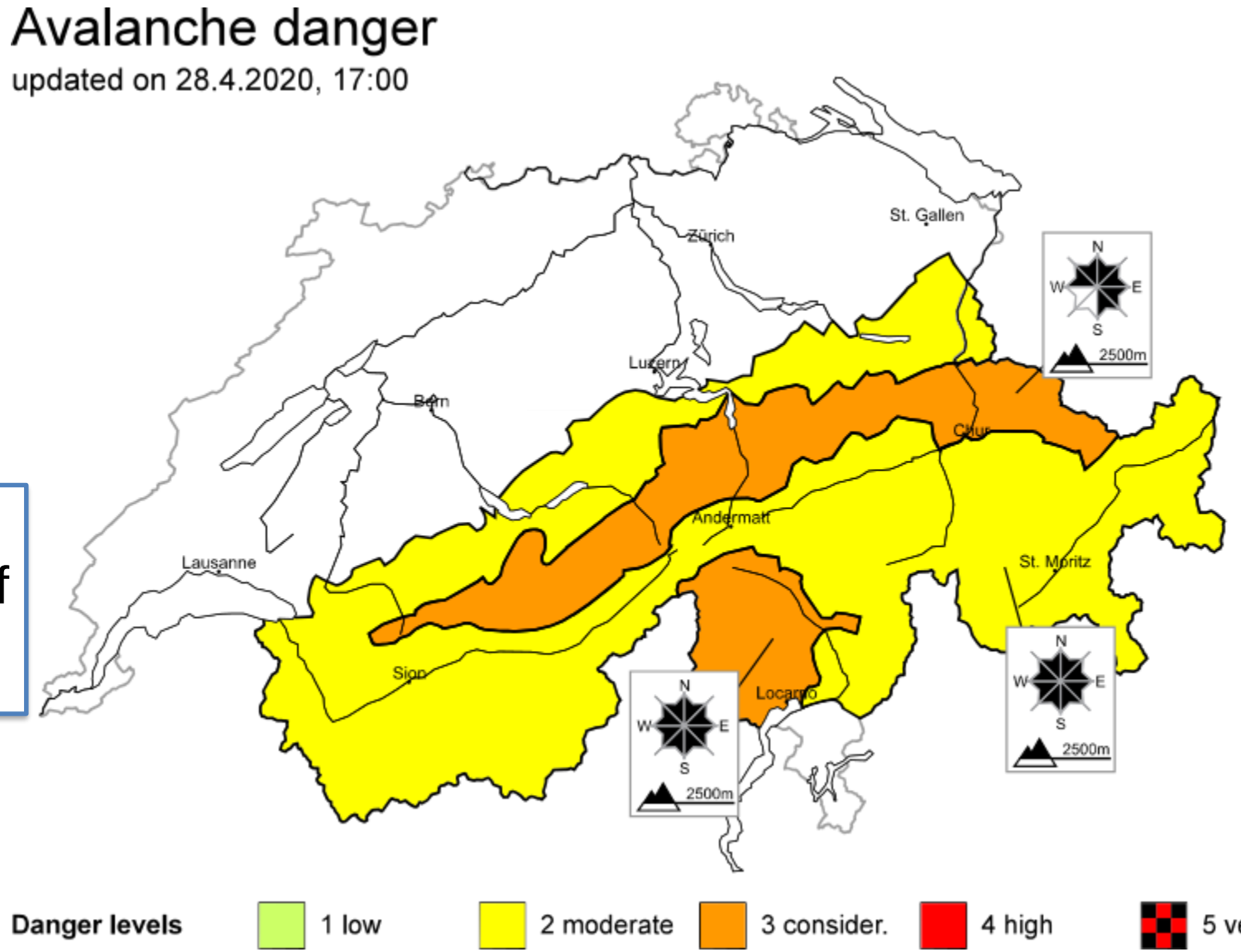
Field observation

- Experts carry out on-site manual measurements and observations (manual snow profile, avalanche danger level evaluation, …)

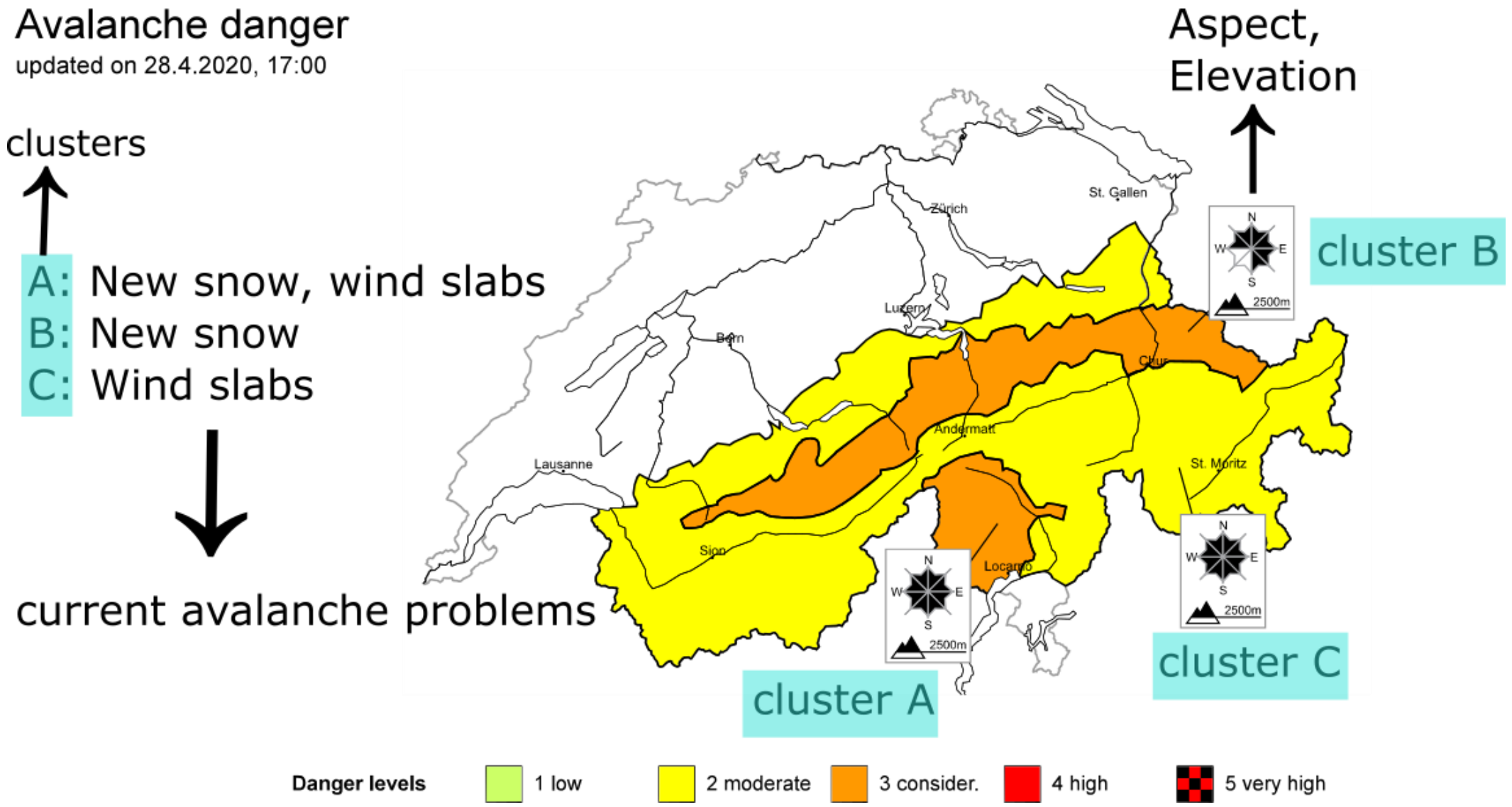
The Swiss avalanche bulletin

- Map containing clusters
  (on the right: 3 clusters)
- Clusters depends on the avalanche situation
- Cluster: area characterized by same set
  (danger level, avalanche problem, aspect & elevation of the problem)

targets for Machine Learning



The Swiss avalanche bulletin



Target: Avalanche danger prediction - method

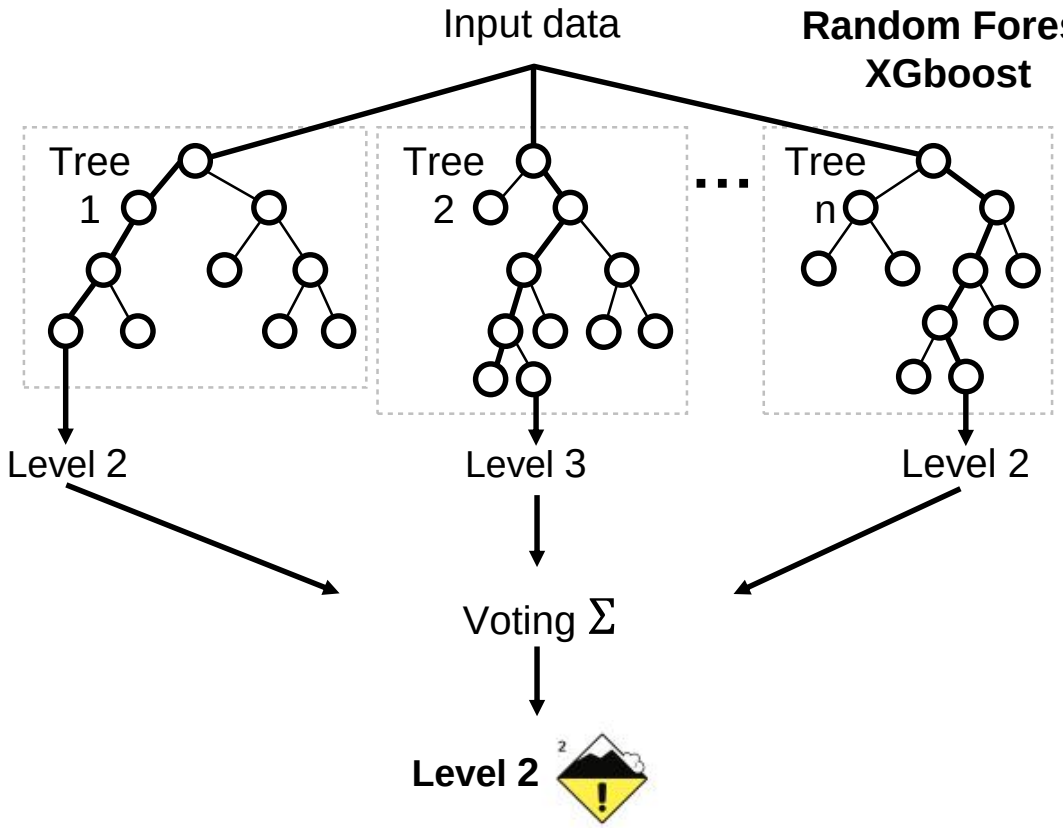
Large database (20 years):

182 weather stations
covering Swiss Alps

Input:
—> **Meteorological** data
—> **Snow cover simulations**
—> **Wet/dry** snow avalanche (flag)

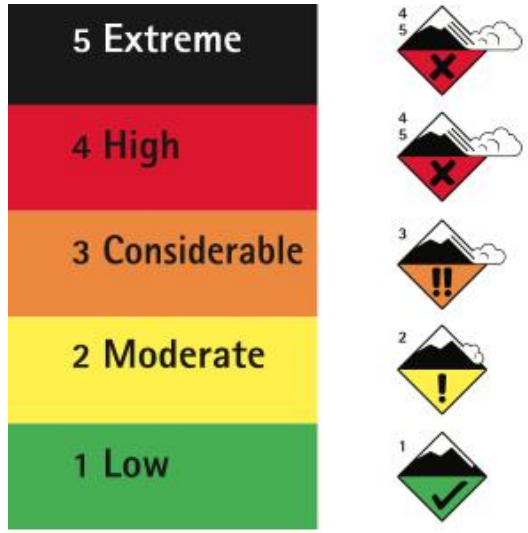
Output/target:
—> Avalanche **danger level**

Supervised learning methods:



Output predictions:

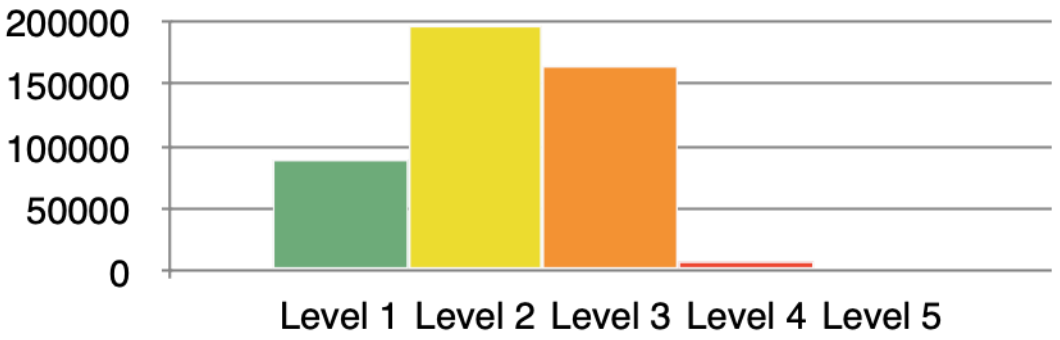
Danger scale



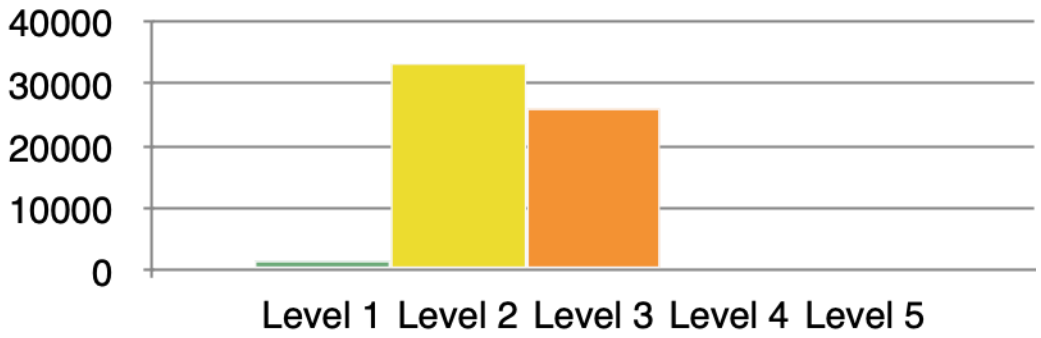
Danger Level

Target: Avalanche danger prediction - results

Danger level distributions:

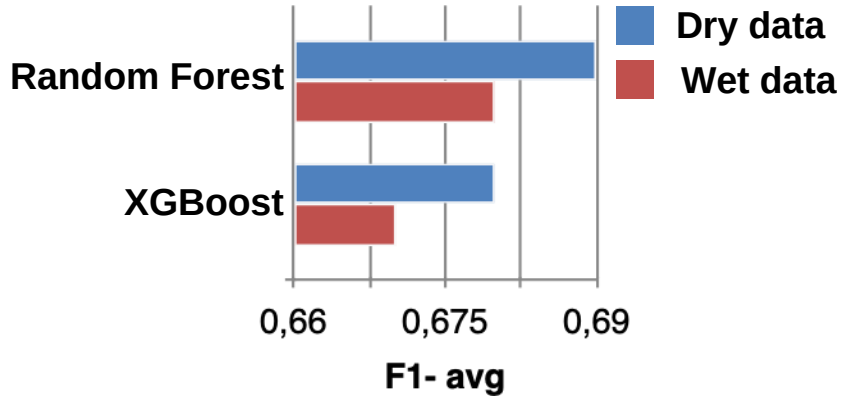


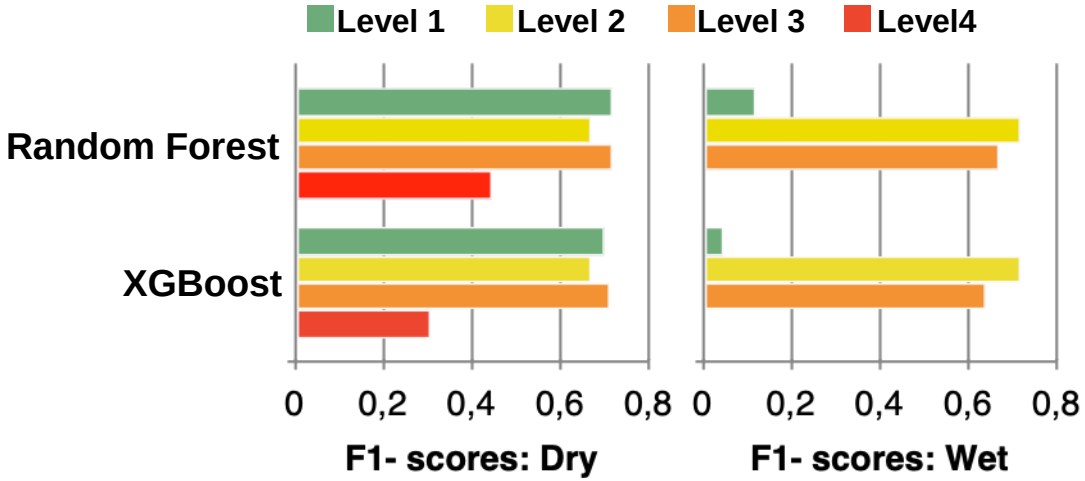
Danger Level: Dry data



Danger Level: Wet data

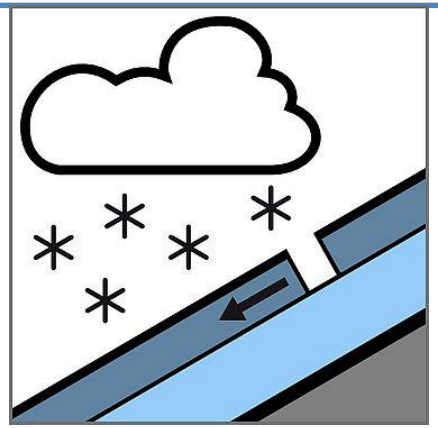
Model performance:





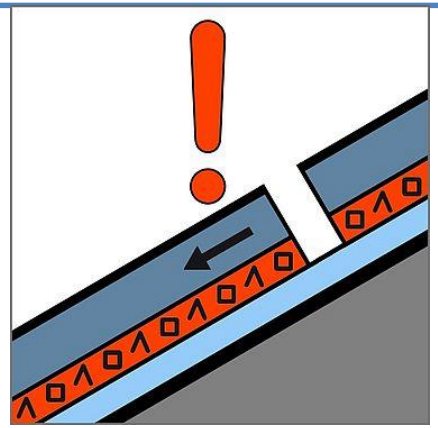
Avalanche problem: the different types (dry-snow conditions)

New snow



Critical additional loading on the snowpack due to recent snow precipitation

Old snow



Presence in the snowpack of persistent weak layer(s) along which a critical crack can propagate

Wind slabs

Wind transported snow adds load on the top of a weak layer and builds a slab

Avalanche prone situations

Target: Avalanche problem (dry-snow conditions)

pwl predicted by Random forest

- Avalanche problem depends on: the amount of new snow, the presence or not of a persistent weak layer and wind transport of the snow
- Avalanche problem type: New snow, Wind slabs, persistent weak layer (old snow) and combination

⇨ New snow is directly assessed from the data (ML not needed)

⇨ Persistent weak layer (pwl) predicted by using a random forest

⇨ Wind transport (future work)

Input features:

- deformation index
- natural stability index
- skier stability index
- structural stability index

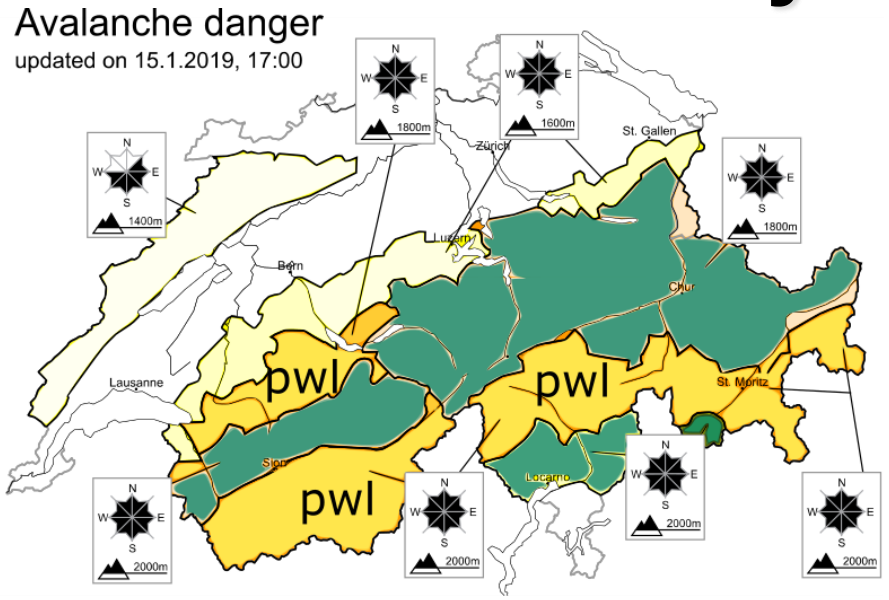
from

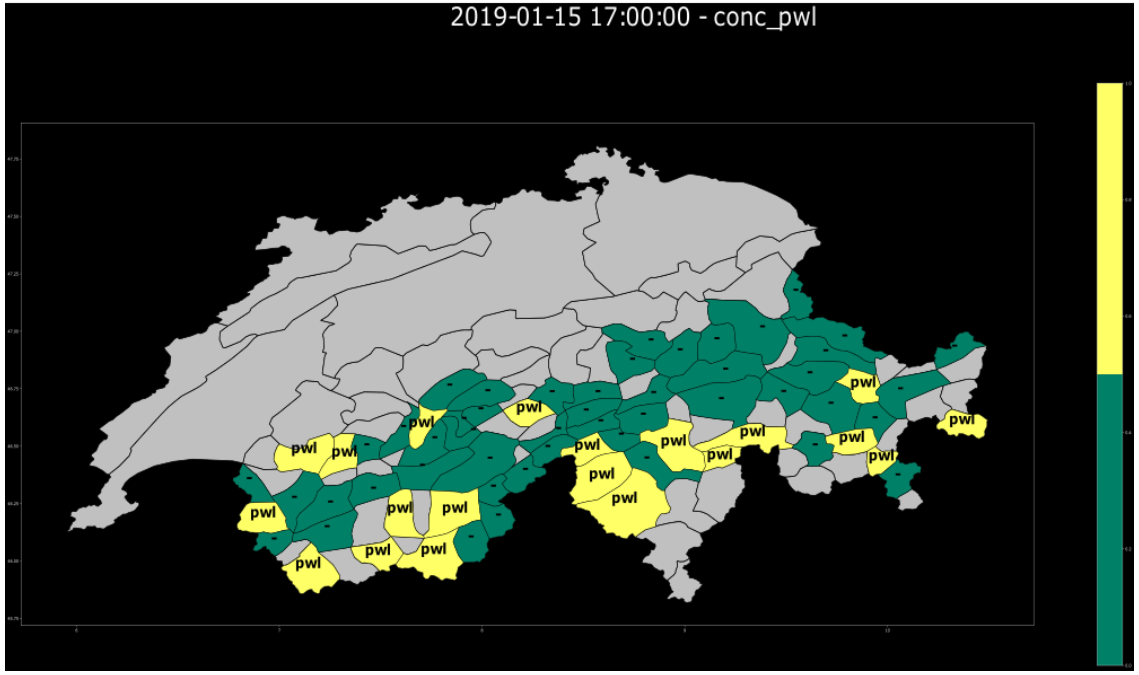
snow cover simulations

Model performance
(0 no pwl, 1 pwl)

```
### trained model run on test values
              precision    recall  f1-score   support

         0.0       0.89      0.89      0.89      2814
         1.0       0.85      0.85      0.85      2030

    accuracy                           0.88      4844
   macro avg       0.87      0.87      0.87      4844
weighted avg       0.88      0.88      0.88      4844

### trained model run on trained values
              precision    recall  f1-score   support

         0.0       0.99      0.99      0.99      8577
         1.0       0.99      0.98      0.99      5952

    accuracy                           0.99      14529
   macro avg       0.99      0.99      0.99      14529
weighted avg       0.99      0.99      0.99      14529
```

Target: Persistent weak layer - results

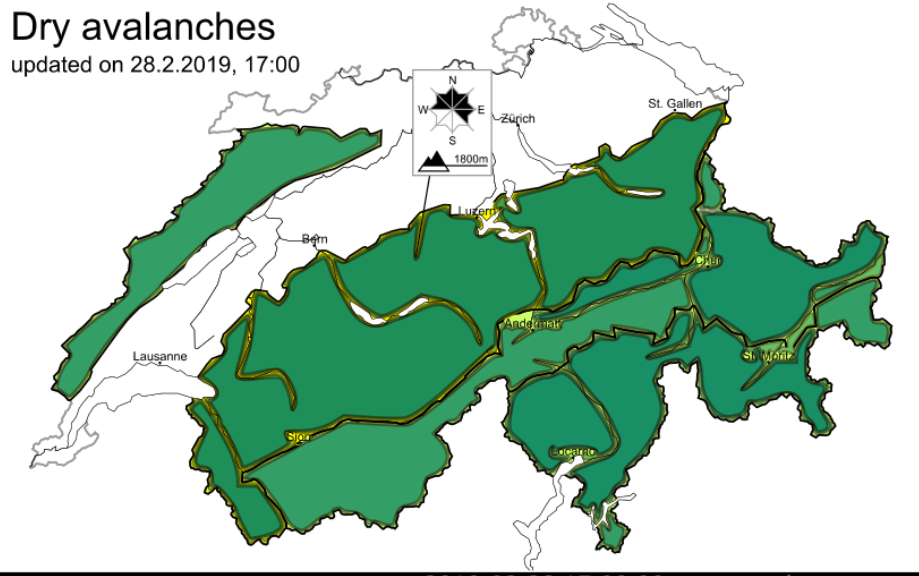


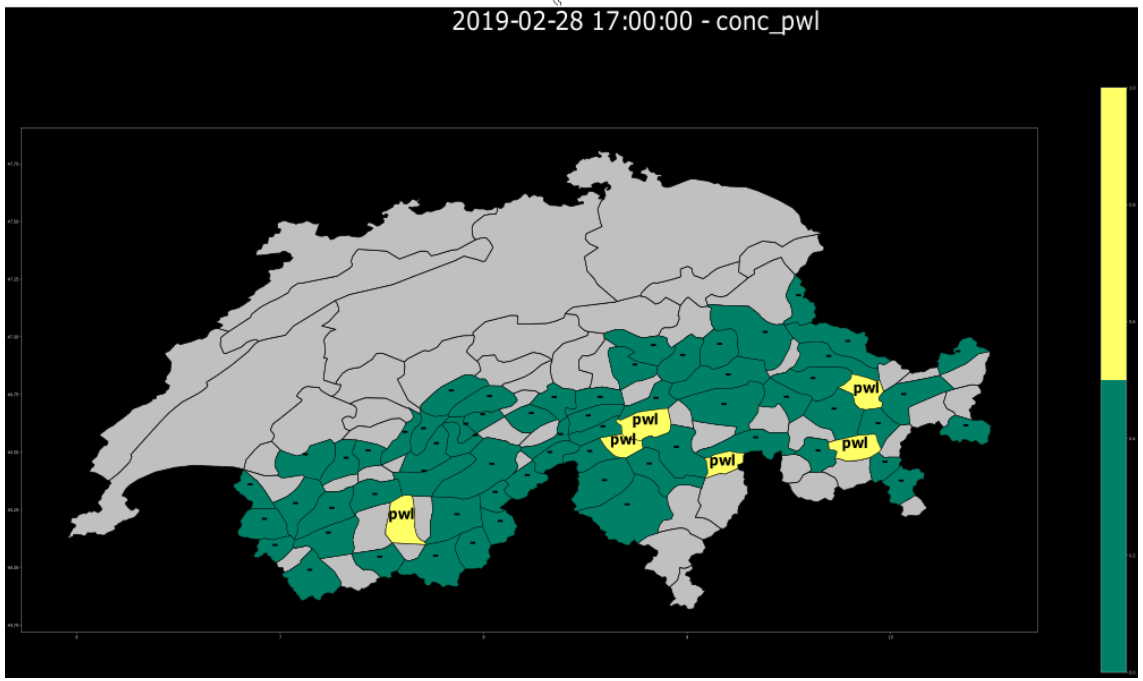


bulletin

ML prediction

Target: Persistent weak layer - results





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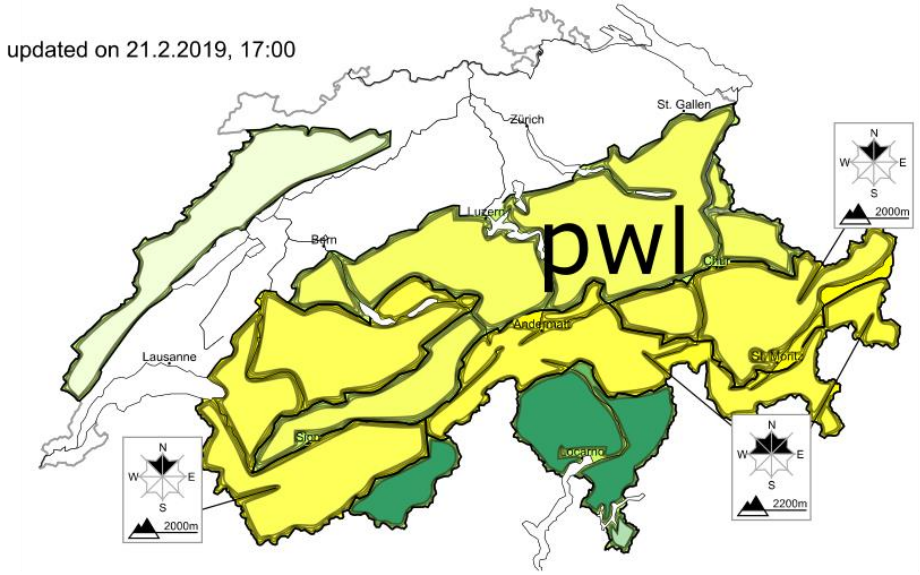
ML prediction

Target: Persistent weak layer - results



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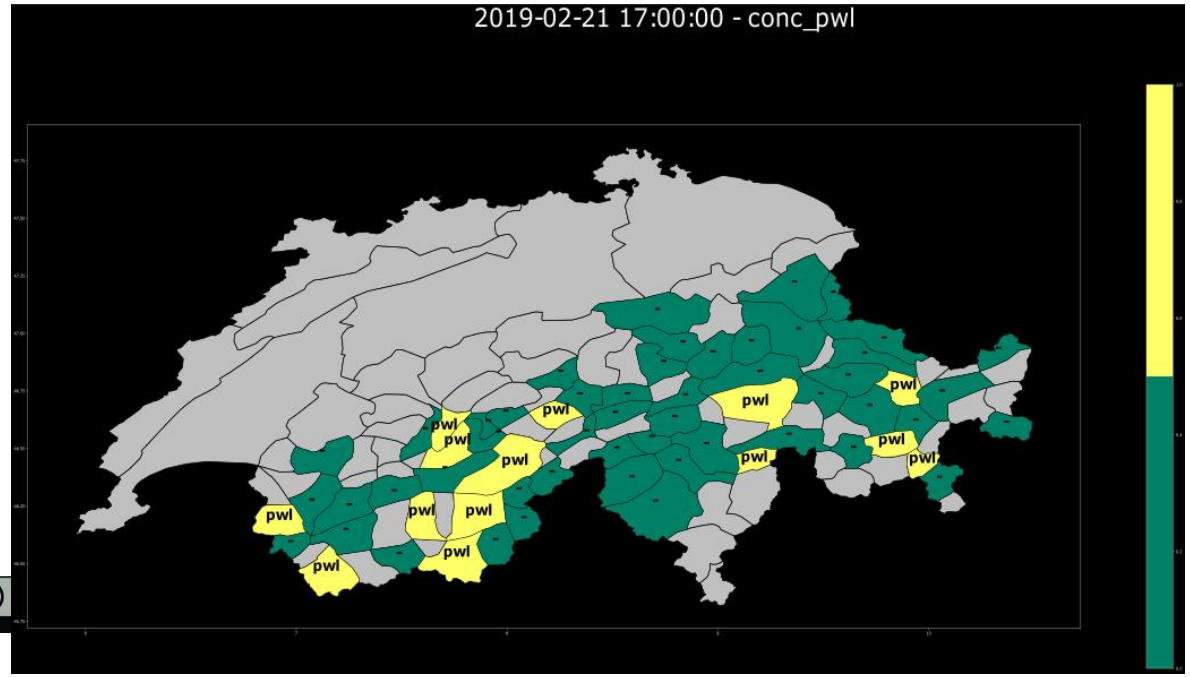

ML prediction

Outlook:

- Time series (under progress LSTM to predict danger level)
- Work on elevation/aspect
- Work on wind transport
- Explore other classifiers
- Explore unsupervised method to study data's natural patterns/clusters (under progress)