

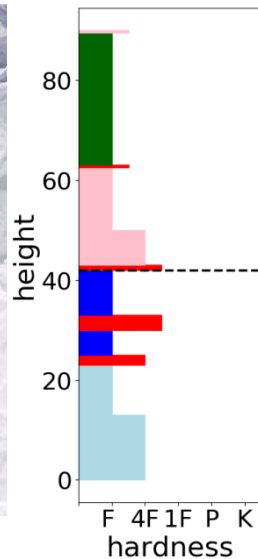


# A random forest model to assess snow instability from simulated snow stratigraphy

Stephanie Mayer, Alec van Herwijnen, Jürg Schweizer  
EGU, 27 April 2021

# How to decide whether the snowpack is unstable?

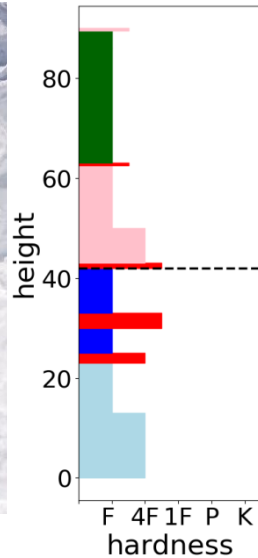
... in the field



- Dig a snow profile
- Do a stability test (e.g. Rutschblock)

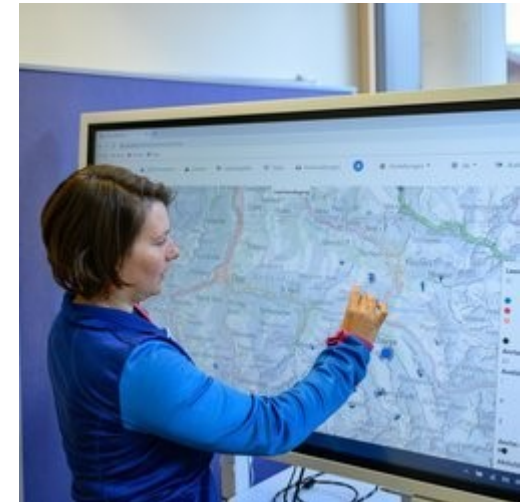
# How to decide whether the snowpack is unstable?

... in the field



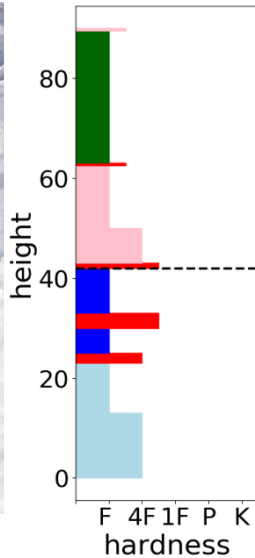
- Dig a snow profile
- Do a stability test (e.g. Rutschblock)

... in (home) office?!



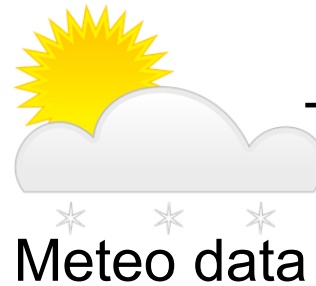
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... in the field

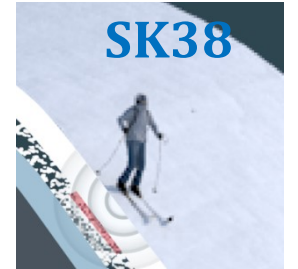
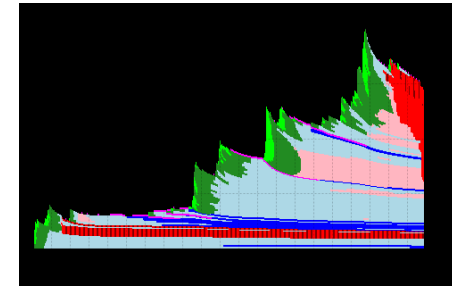


- Dig a snow profile
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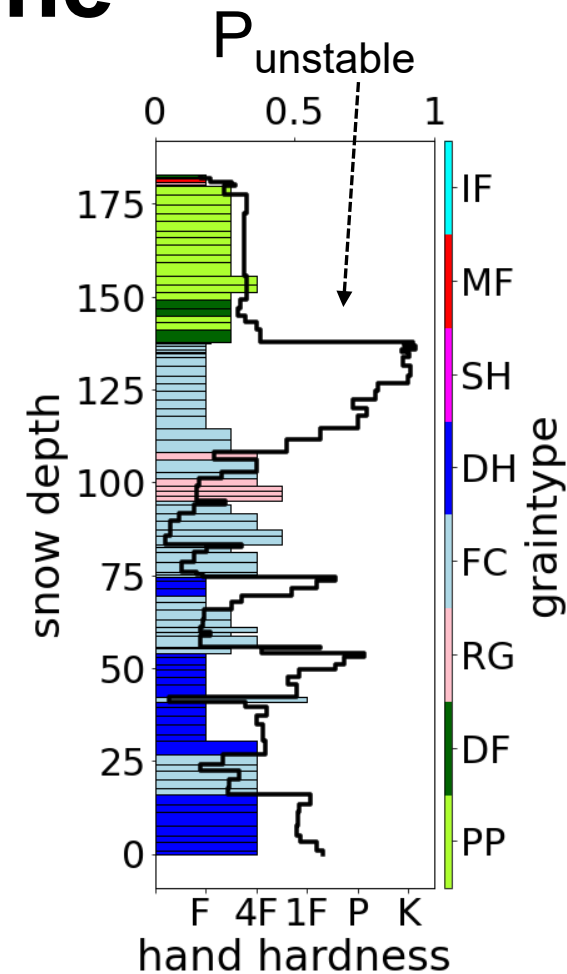
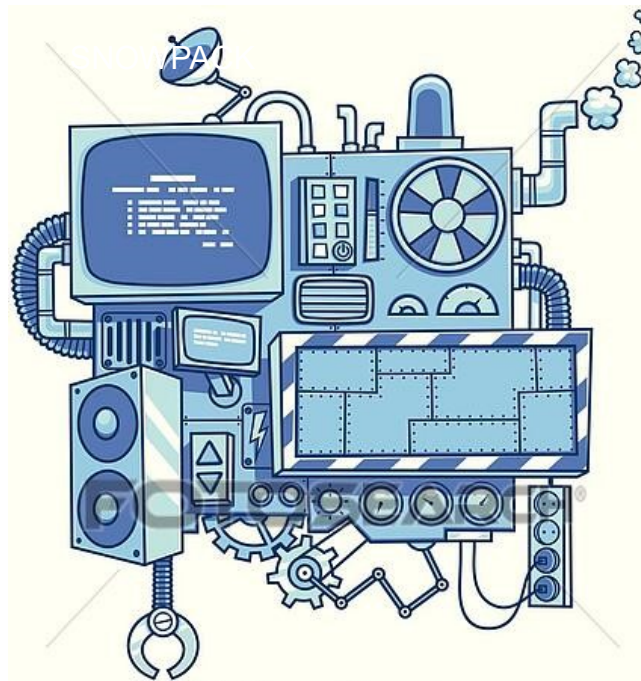
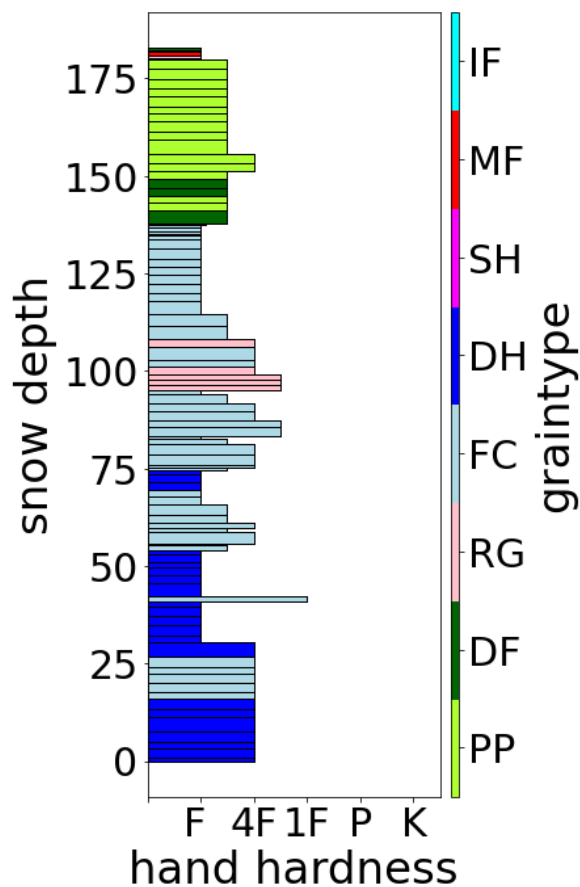


SNOWPACK



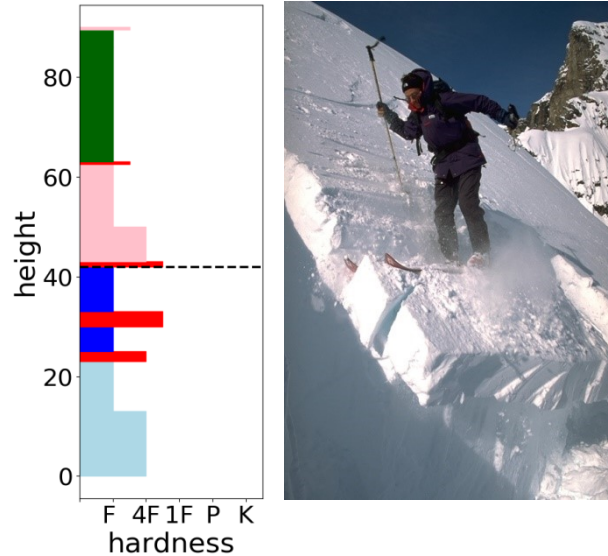
- Simulate a snowpack profile
- Compute properties of weak layer and slab

# Research objective: Instability machine



Given a simulated snow profile, compute the probability that the combination of a given layer and the overlying slab is unstable.

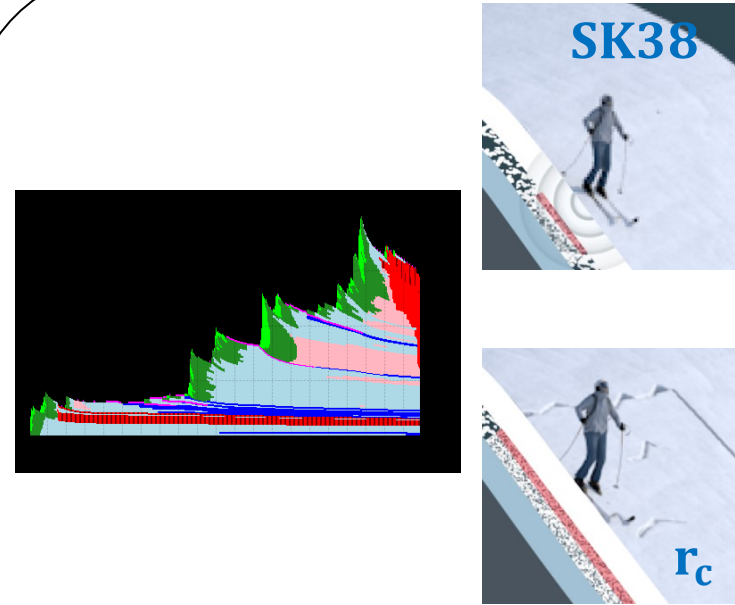
# Generate training data: Observations vs. simulations



## 796 manual snow profiles

- incl. Rutschblock-test (RB)
- from 17 different winters
- Locations: Swiss Alps, mostly region of Davos (N=566)

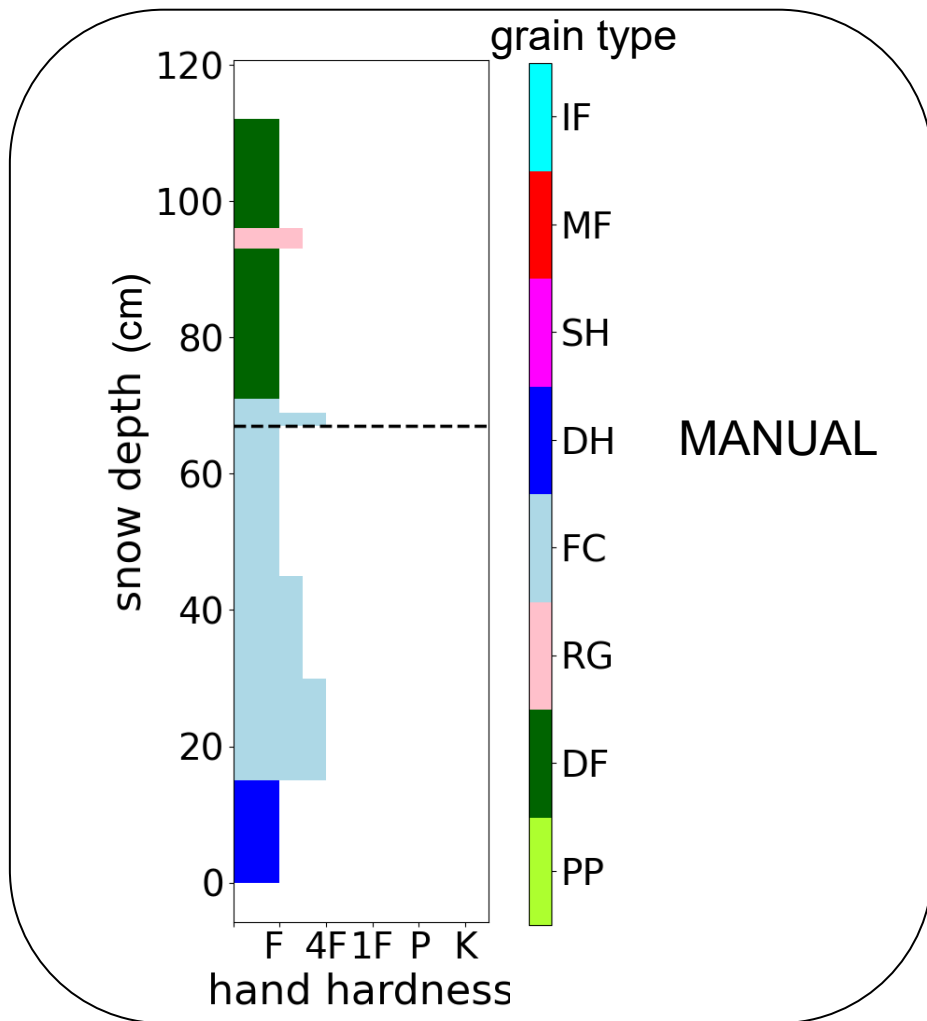
VS.



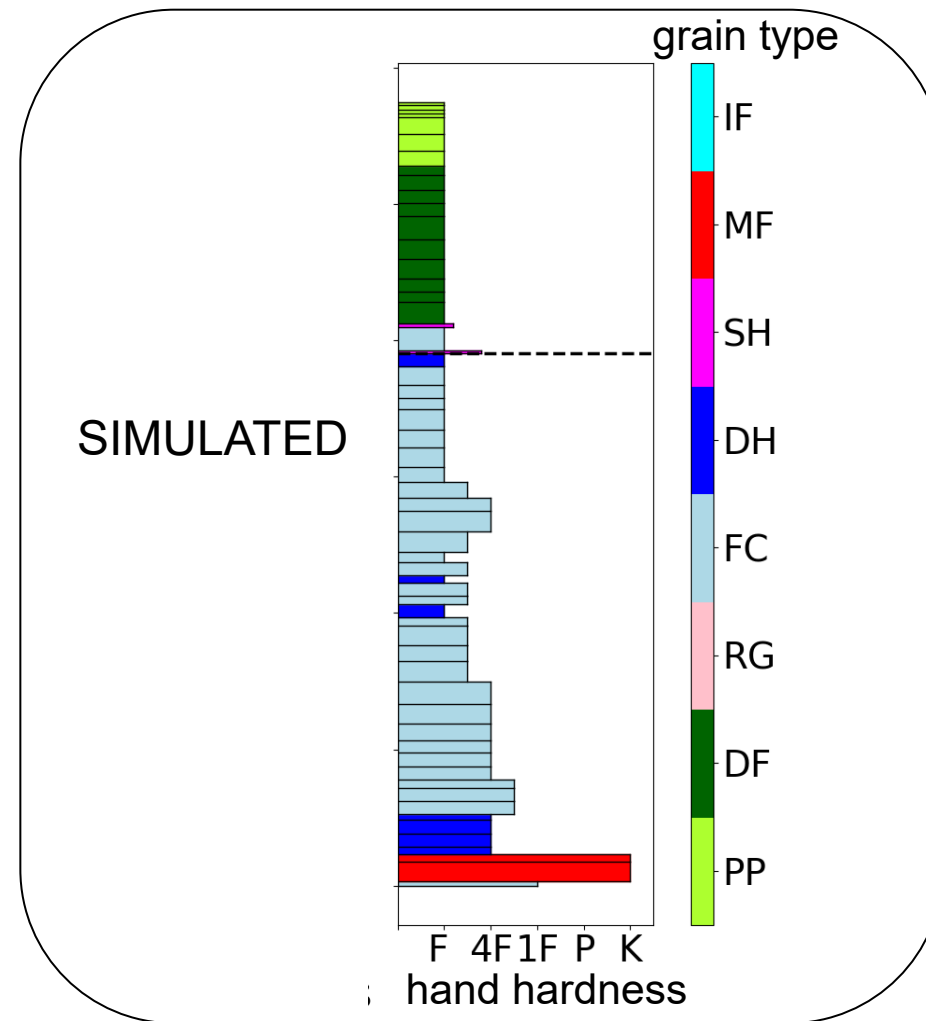
## 796 SNOWPACK simulations

- Interpolation of measurements from automatic weather stations

# Generate training data: Observations vs. simulations



vs.



# Training of the Random Forest model

Idea: Learn from «**extreme**» profiles

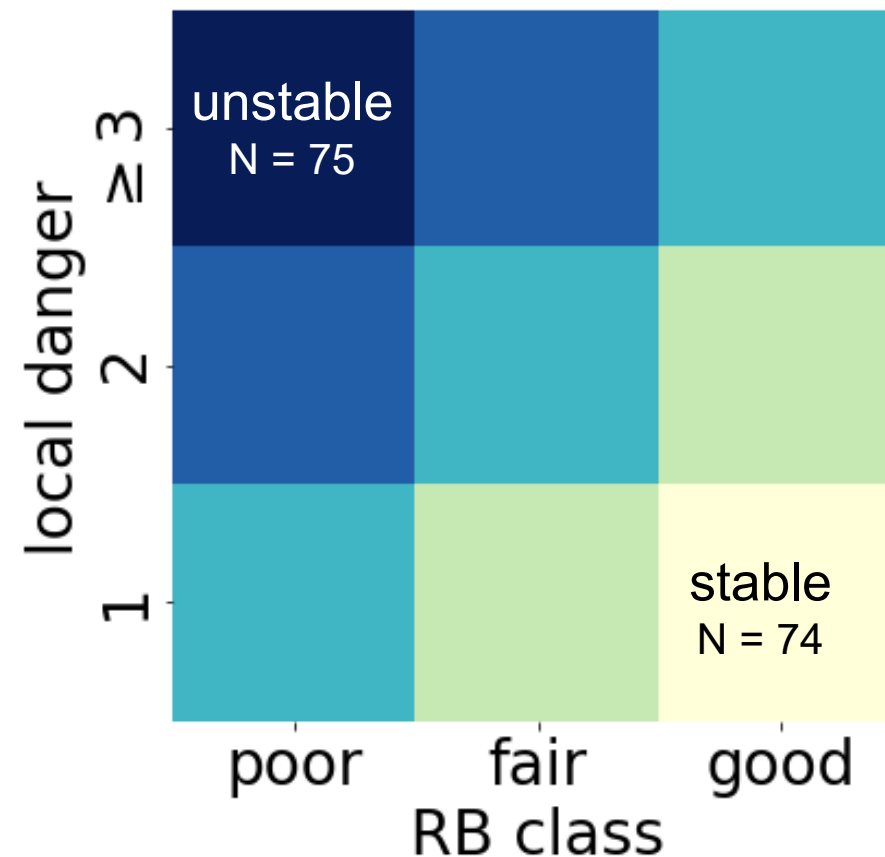
**Binary target variable:**

**1** unstable:  
observed RB = unstable  
local danger  $\geq$  considerable (3)

**0** stable:  
observed RB = good  
local danger = low (1)

**Explanatory variables:**

Simulated properties of weak layer & slab



Classification according to RB score & release type

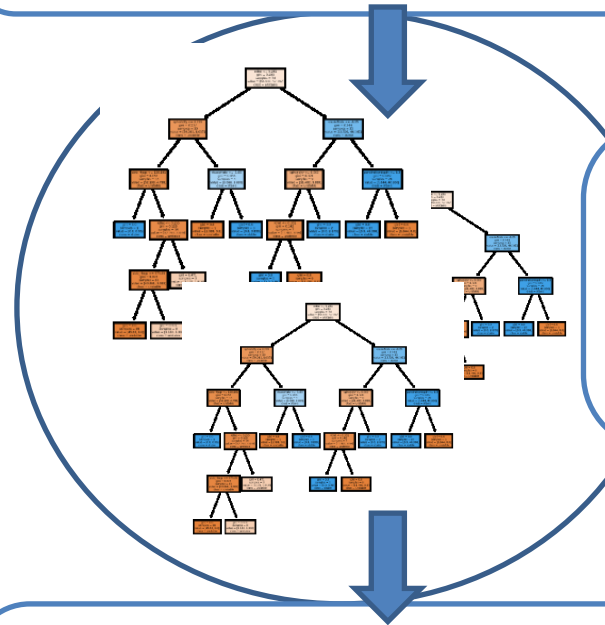
# Training of the Random Forest model

Binary target variable:

**1** unstable class

**0** stable class

**INPUT: Explanatory variables**  
Properties of weak layer and slab



**Random forest:**  
Every tree votes for **0** or **1**

**OUTPUT:** mean vote =  $P_{\text{unstable}}$

$> 0.5$ : class **1**

$\leq 0.5$ : class **0**

# Training of the Random Forest model

Binary target variable:

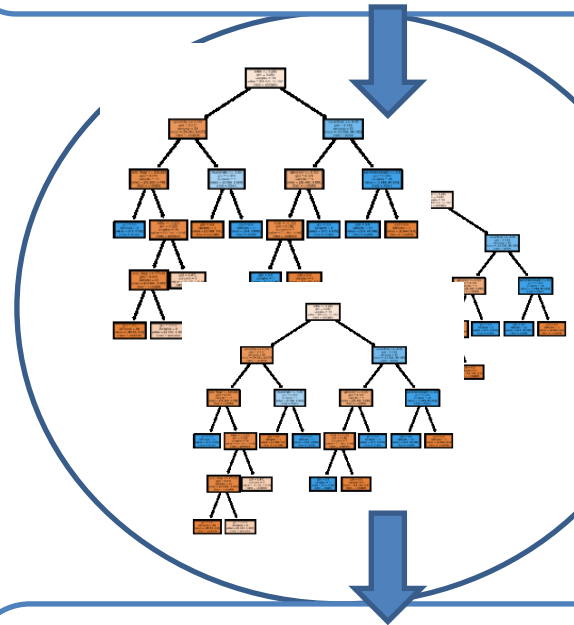
**1** unstable class

**0** stable class

Final features:

- viscous deformation rate
- critical cut length
- grainsize & sphericity (weak layer)
- skier penetration depth
- density/grainsize (slab)

**INPUT: Explanatory variables**  
Properties of weak layer and slab



**Random forest:**  
Every tree votes for **0** or **1**

**OUTPUT:** mean vote =  $P_{\text{unstable}}$

$\geq 0.5$ : class **1**

$\leq 0.5$ : class **0**

# Validation of the Random Forest model

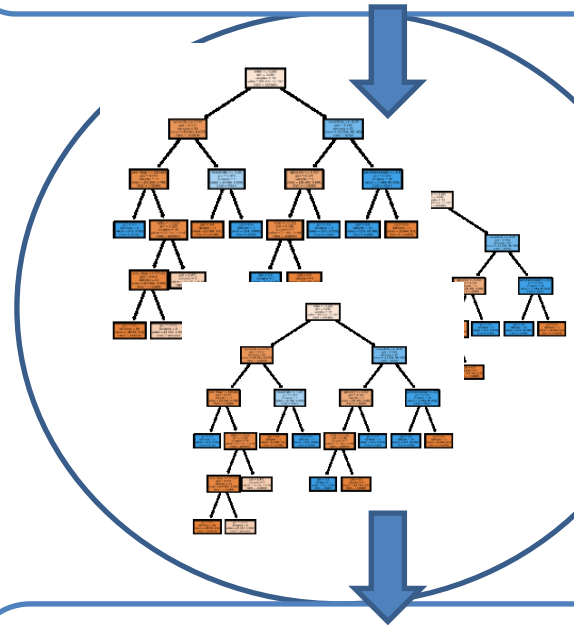
Binary target variable:

**1** unstable class

**0** stable class

**classification PERFORMANCE:**  
Accuracy: 89 % (independent data)

**INPUT: Explanatory variables**  
Properties of weak layer and slab



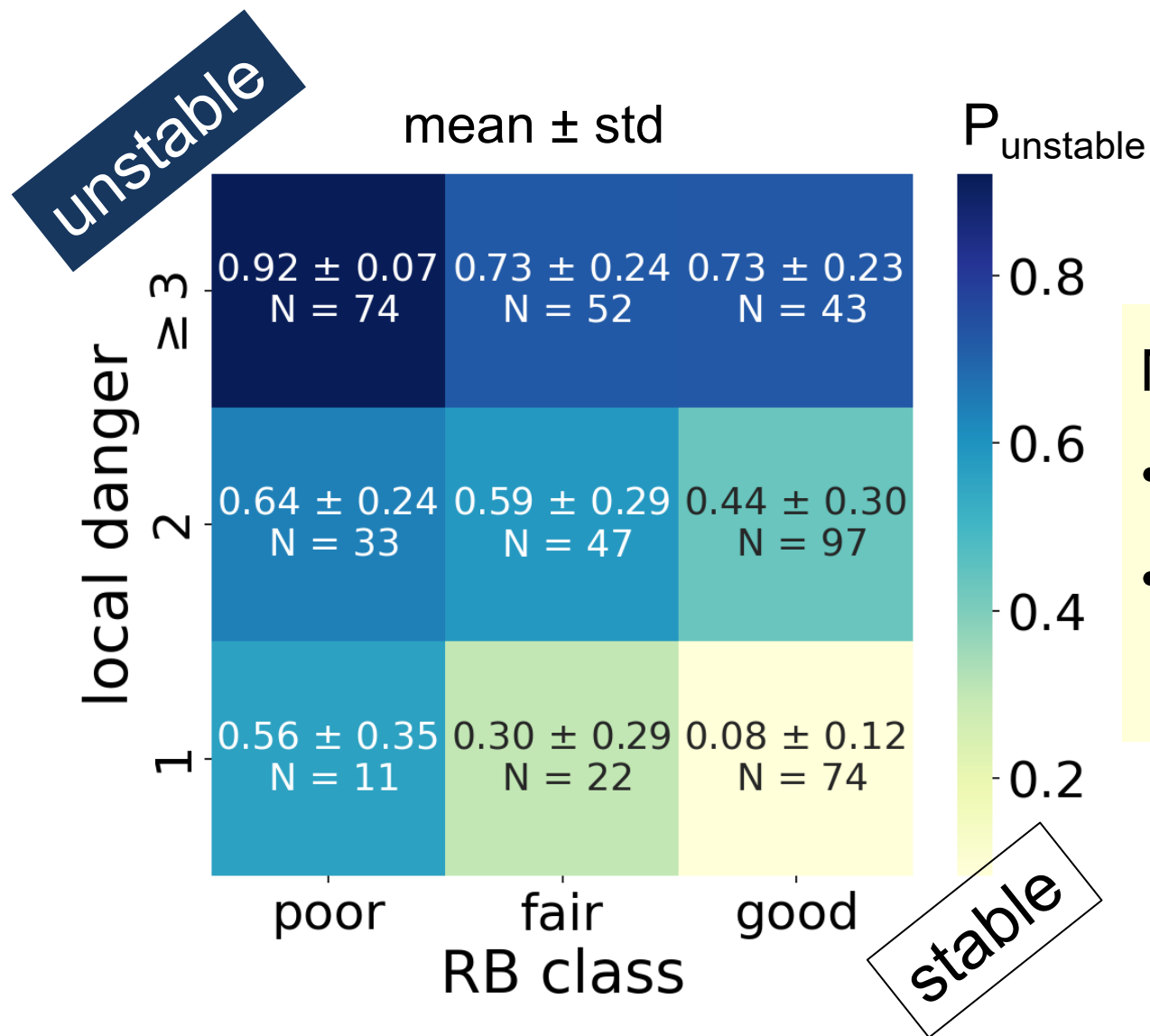
**Random forest:**  
Every tree votes for **0** or **1**

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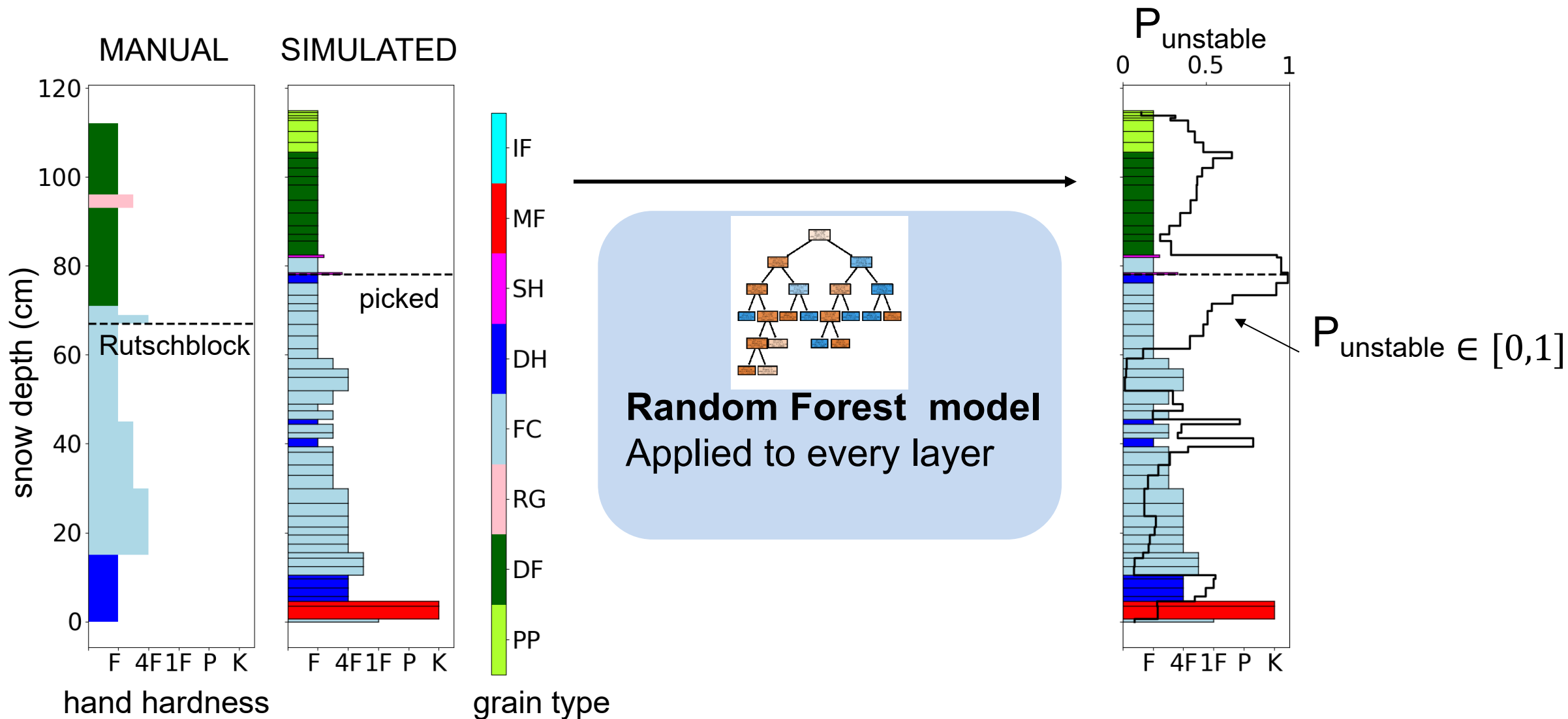
# Results: Probability of instability $P_{\text{unstable}}$



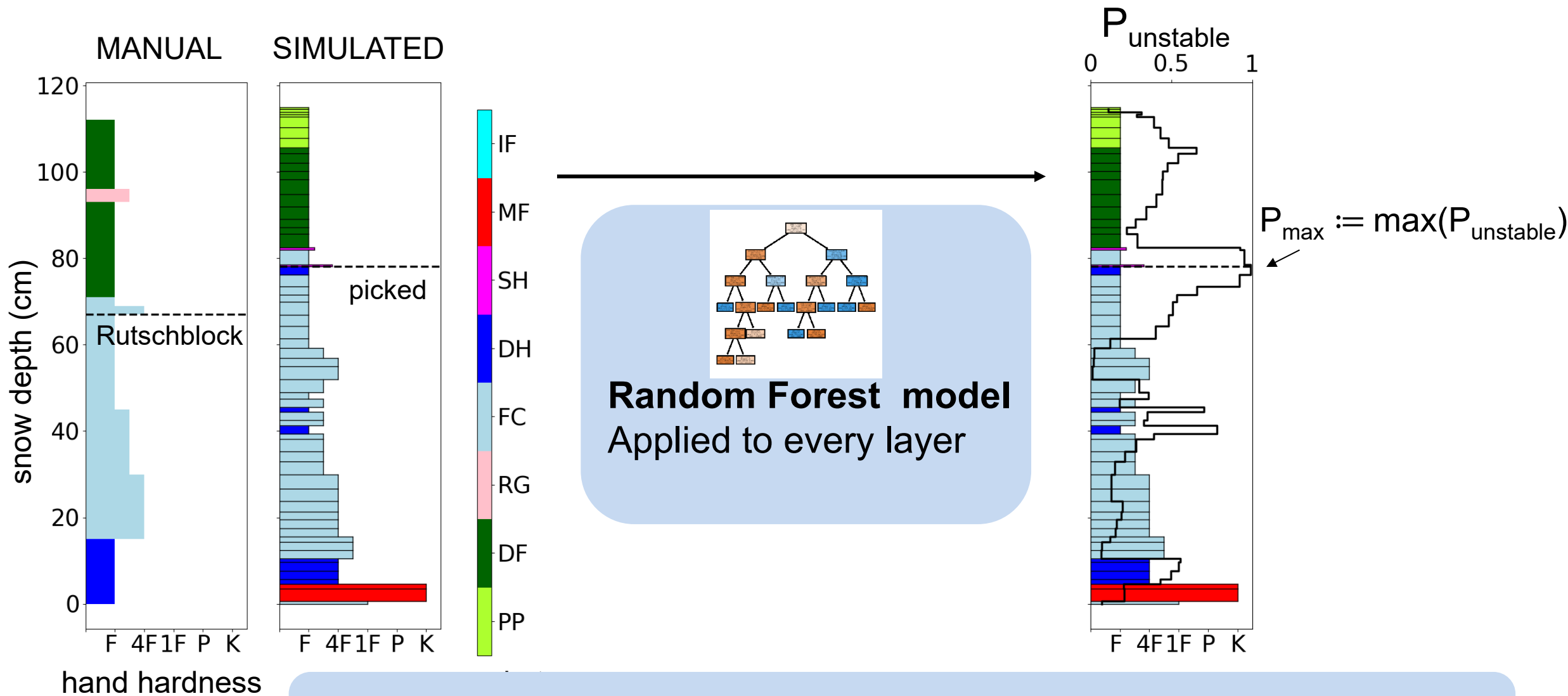
Mean probability  $\langle P_{\text{unstable}} \rangle$

- increases with increasing danger
- increases with increasing Rutschblock instability

# Random Forest is applicable to complete profiles



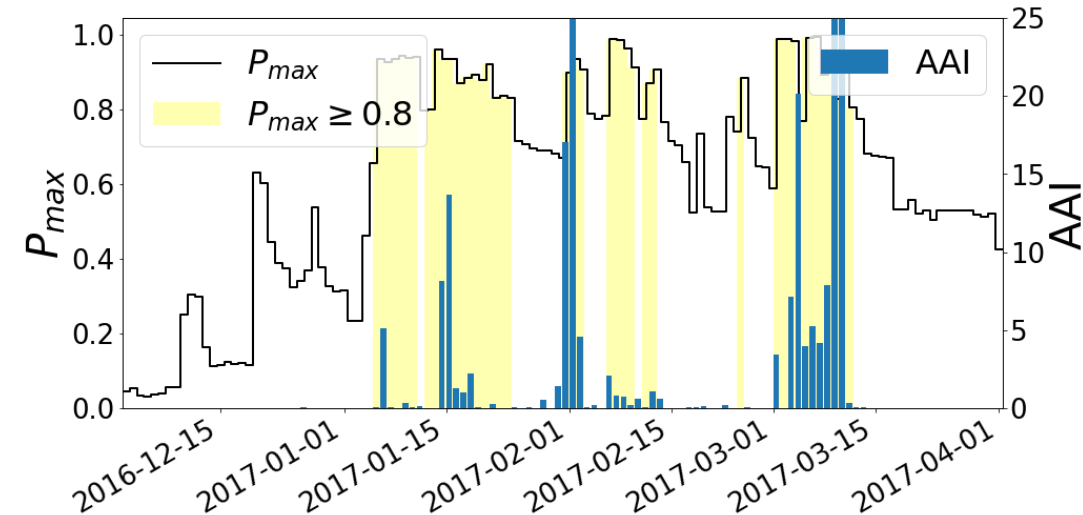
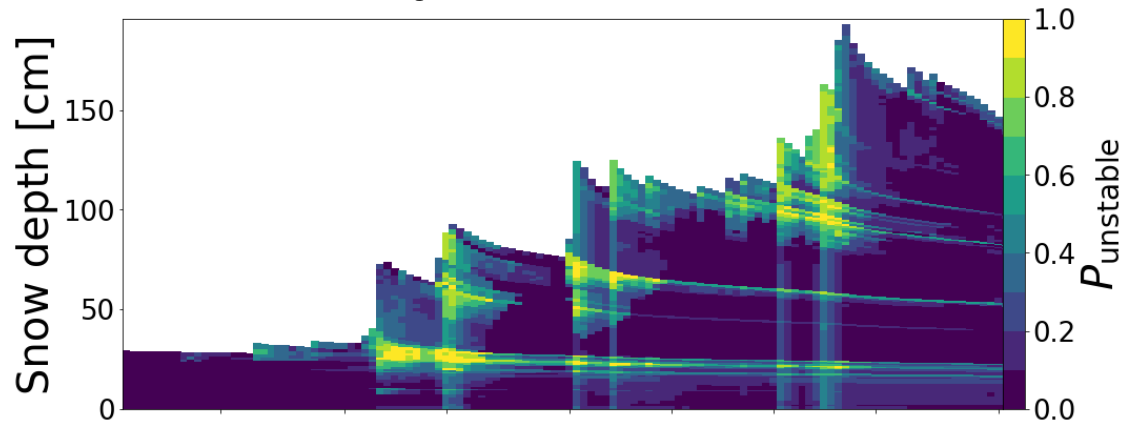
# Random Forest is applicable to complete profiles



Weak layer unknown?  $\rightarrow$  compute maxima of  $P_{\text{unstable}}$

# Random Forest applied to complete winter seasons

Weissfluhjoch, winter 2016/17



Time evolution of  $P_{\text{unstable}}$  for all layers



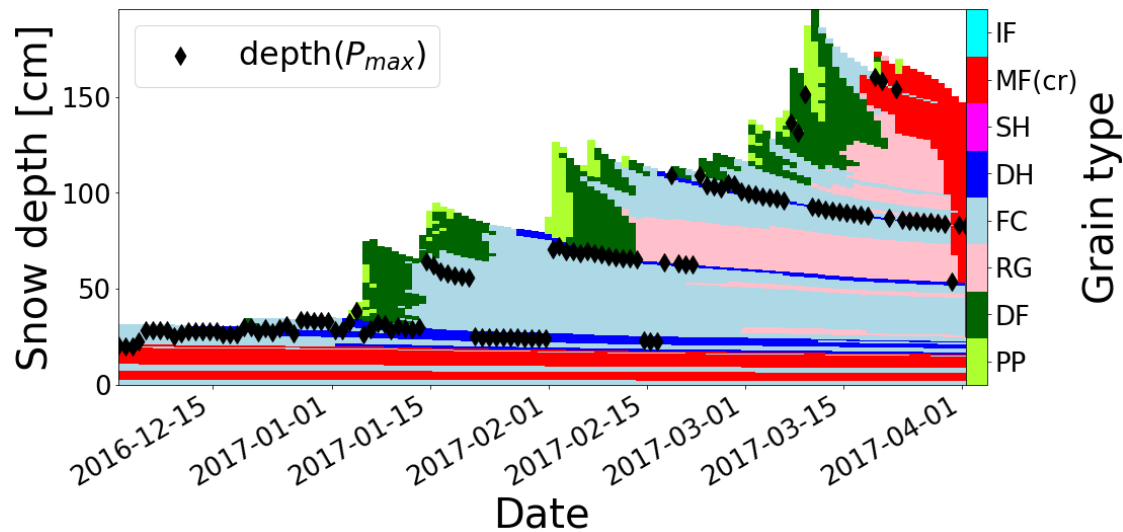
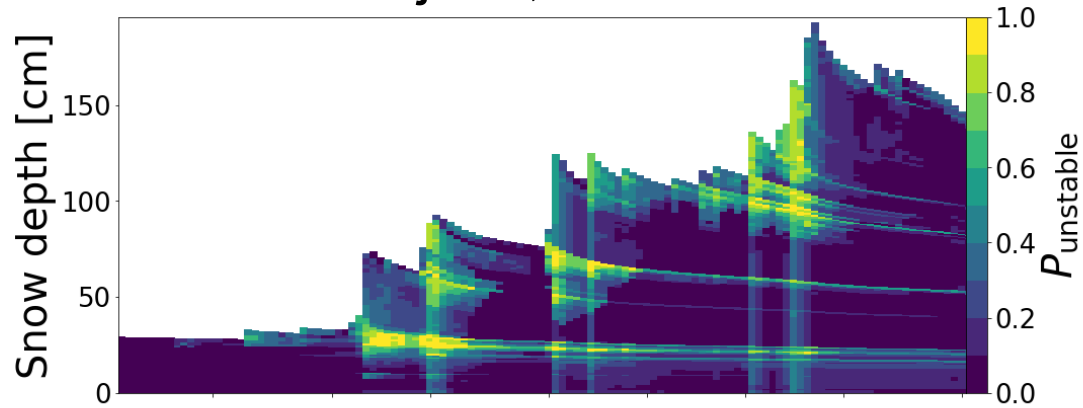
Take daily  $P_{\text{max}} := \max(P_{\text{unstable}})$



Compare with avalanche activity index (AAI):  
Avalanche cycles  $\rightarrow$  high values of  $P_{\text{max}}$

# Random Forest applied to complete winter seasons

Weissfluhjoch, winter 2016/17



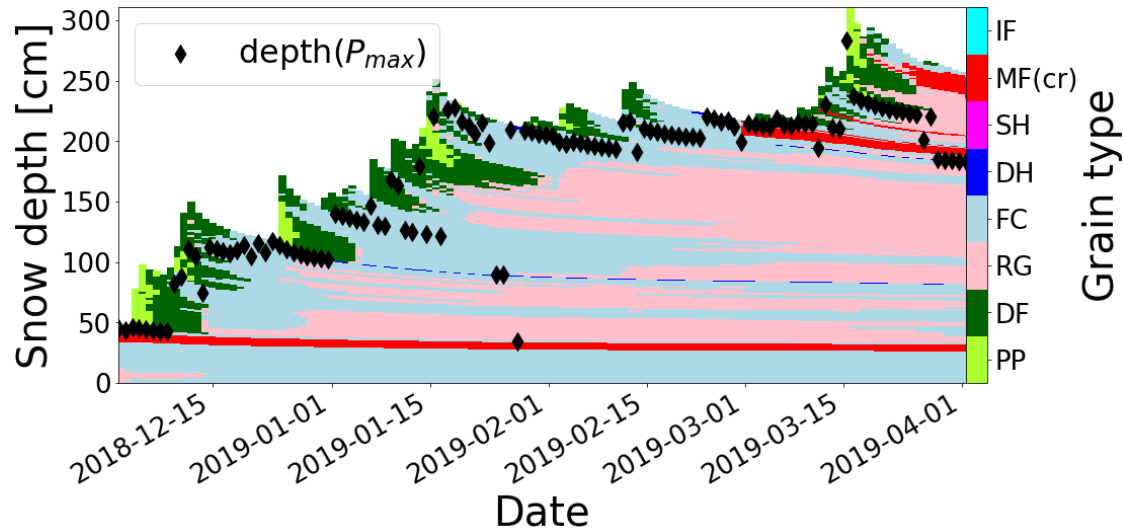
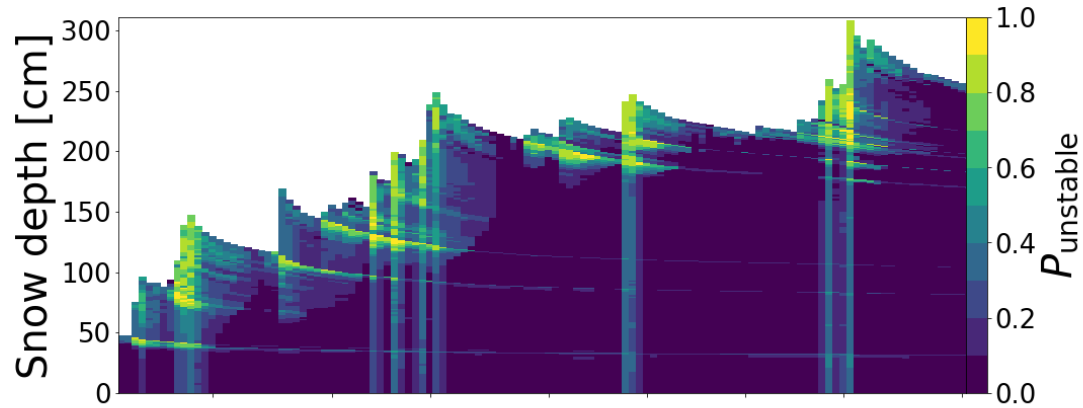
Depth of  $P_{\text{max}}$  and corresponding grain type

↓  
avalanche problem



# Random Forest applied to complete winter seasons

Weissfluhjoch, winter 2018/19



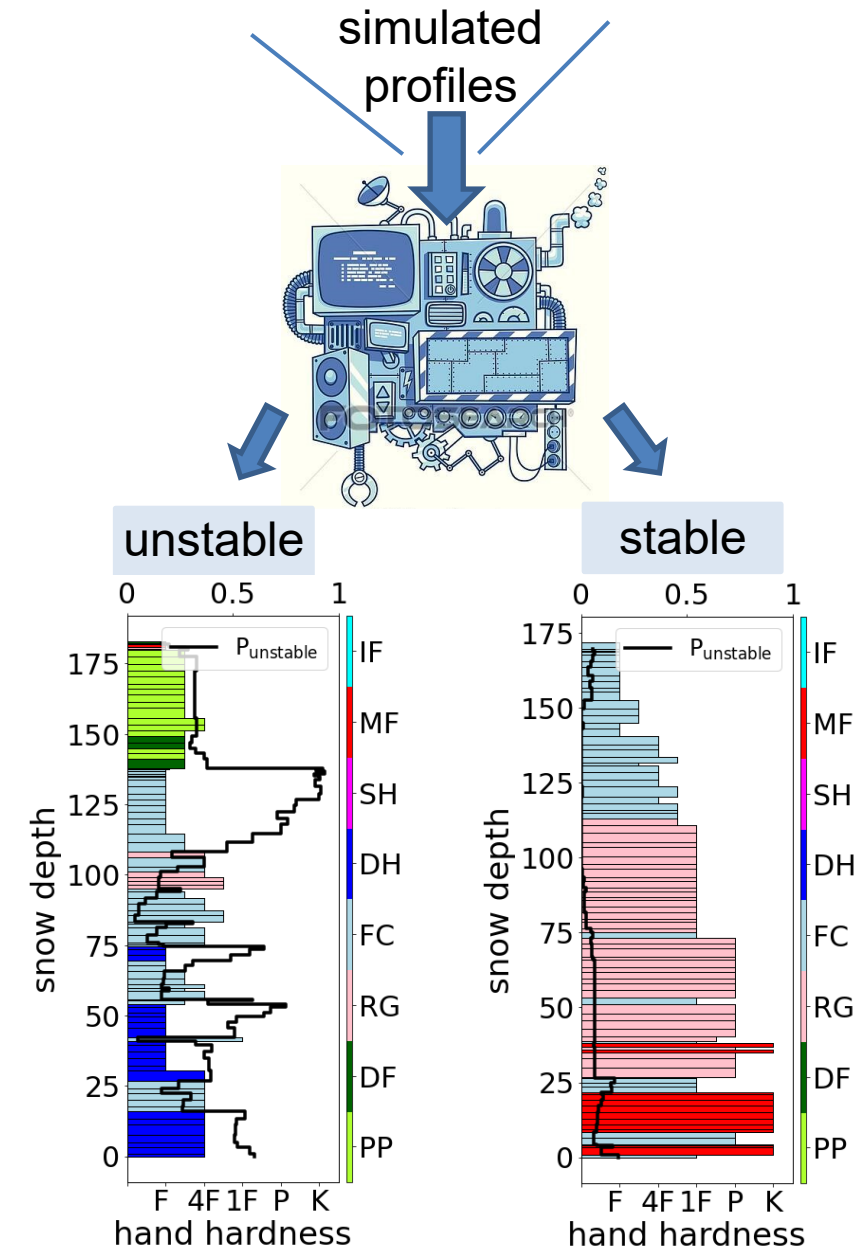
Depth of  $P_{\text{max}}$  and corresponding grain type

↓  
avalanche problem



# Conclusion: The Random Forest model...

- ...was trained based on a comparison between observed stability and properties of simulated snow layers
- ... calculates a probability of instability  $\in [0,1]$  for each layer of a profile
- ... performs well in the differentiation between unstable and stable profiles and the detection of weak layers
- ... is applicable to complete winter seasons and can assist in determining avalanche problems (work in progress)





**Thank you for your attention.**