  

Comparing simulated and manual snow profiles to derive thresholds for modeled snow instability metrics

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Avalanche formation – what is required?

Necessary:

- Slab
- Weak layer

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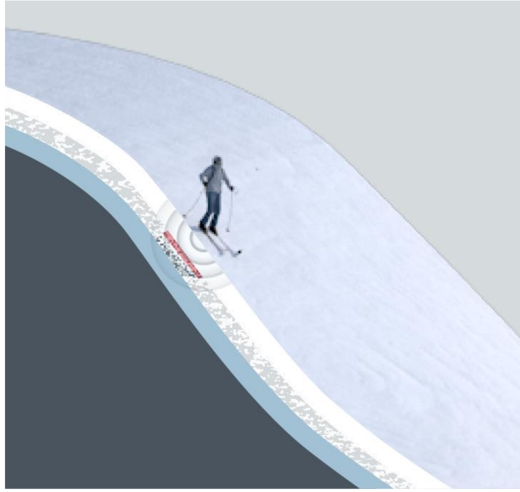
But how weak is weak?!

Dry-snow instability can be modeled.



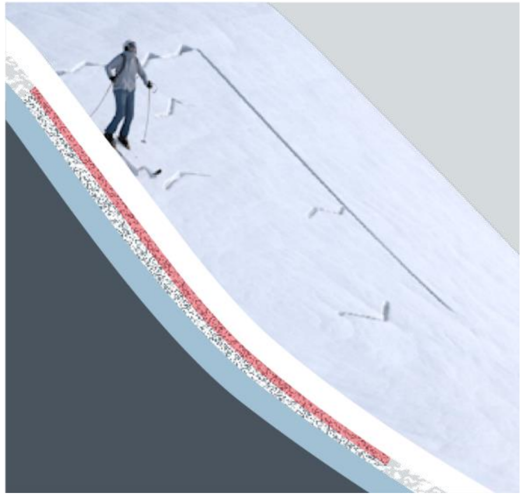
Failure initiation:

Skier stability index

(Föhn 1987, Monti 2016)

$$\mathbf{SK38} = \frac{\text{strength}_{\text{weak layer}}}{\text{stress}_{\text{slab}} + \text{stress}_{\text{skier}}}$$

Picture: M. Boss



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Crack propagation:

Critical crack length

(Gaume 2017, Richter 2019)

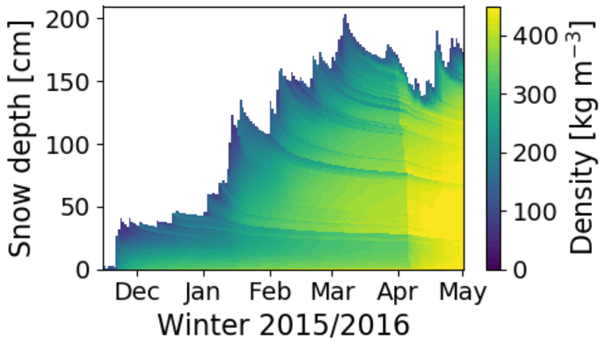
$$r_c = f(\text{stress}, \text{strength}, \text{elastic modulus})$$

Dry-snow instability can be modeled.

INPUT:
- Meteorological measurements
- Numerical weather prediction data

→ **SNOWPACK** →

Snow stratigraphy:



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OUTPUT:
Stability indices
- SK38
- r_c

Missing: Threshold values for stability indices

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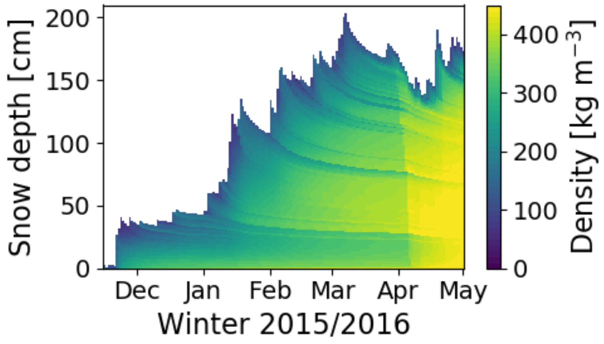
- Meteorological measurements
- Numerical weather prediction data

SNOWPACK

Snow stratigraphy:



OUTPUT:
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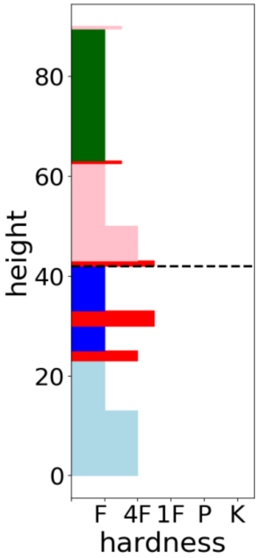
How to discriminate stable from unstable conditions?

GOAL: Derive thresholds for stability indices

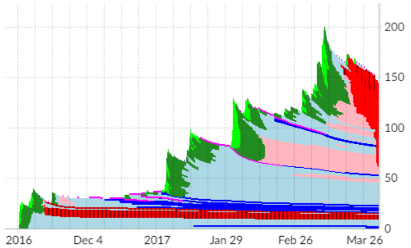
We created a unique dataset to derive thresholds.

Manual profile



vs.

SNOWPACK simulation



- 532 manual snow profiles from 17 winters, region of Davos (CH)
- Including: Rutschblock test, observations of signs of instability (avalanches, whumpfs, shooting cracks)

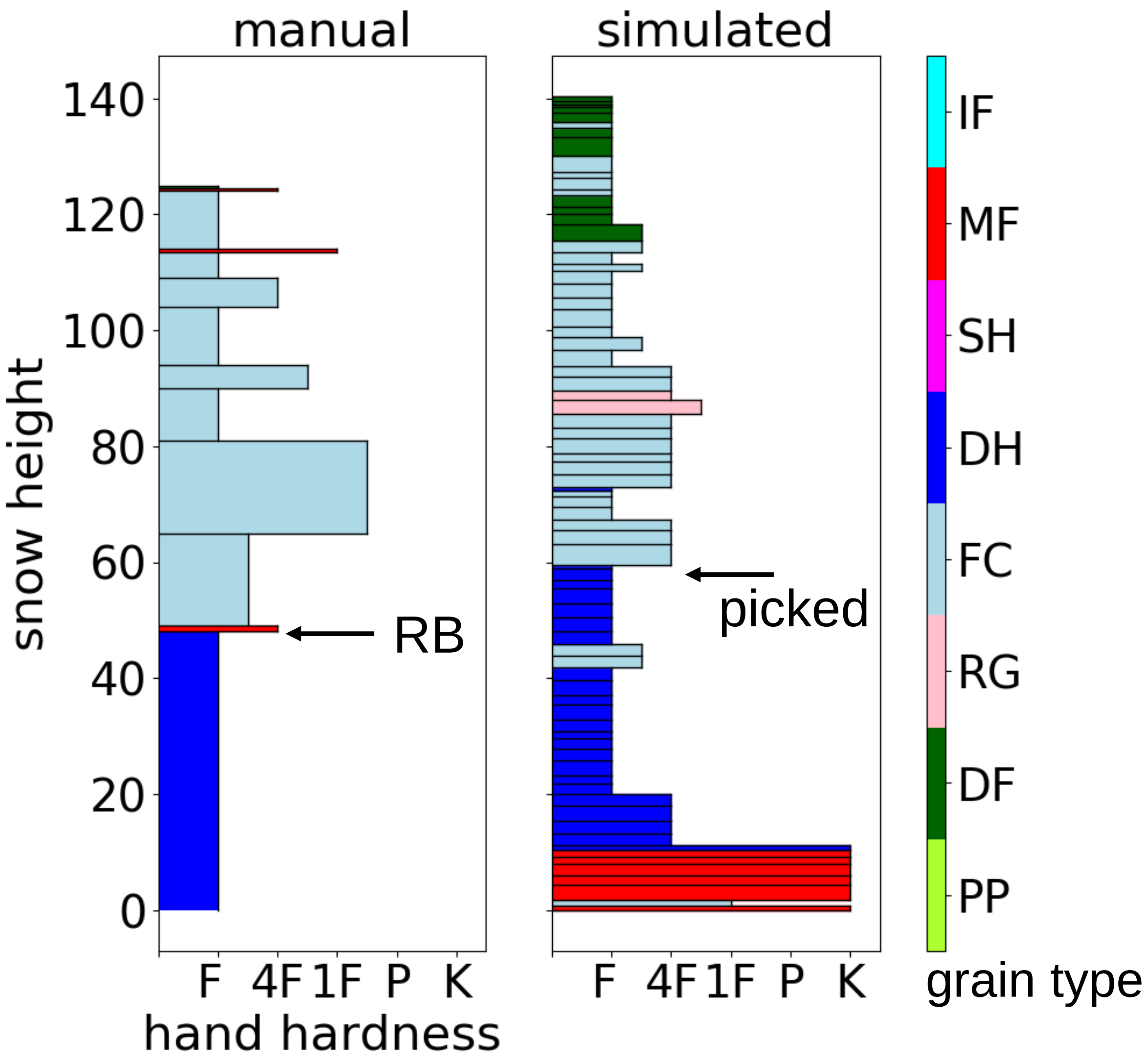
- 532 individual simulations with MeteoIO/ SNOWPACK
- Interpolation of measurements from a network of automatic weather stations to the locations of the manual profiles

Rutschblock (RB) test

- Considered the most reliable test to find critical weaknesses in the snowpack.
- A skier exerts a gradually increasing force onto an isolated block of snow.
- RB scores increase with stability:
  1-3: poor
  4-5: fair
  6-7: good

Picture: B. Jamieson

Profiles were first compared manually in 3 steps.

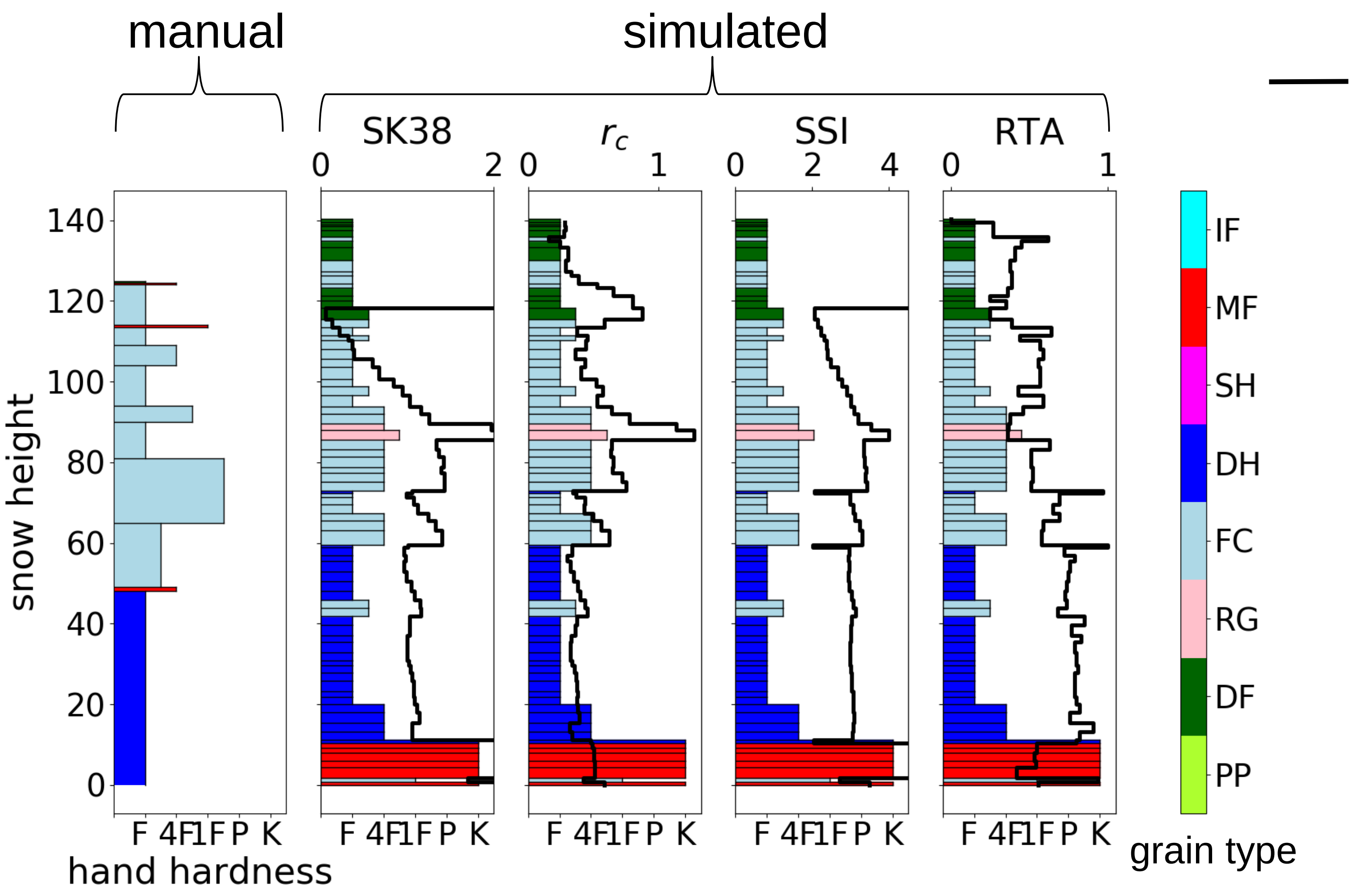


1. Pick weak layer in the simulated profile (i.e. the layer assumed to correspond to the Rutschblock failure layer)

2. Assess the similarity of the two profiles (i.e. weak layer and slab existing in both manual and simulated profile? – here: yes)

3. Assign an avalanche problem (old snow, new snow, wind slabs or combination?) here: old snow

Stability indices calculated for each weak layer

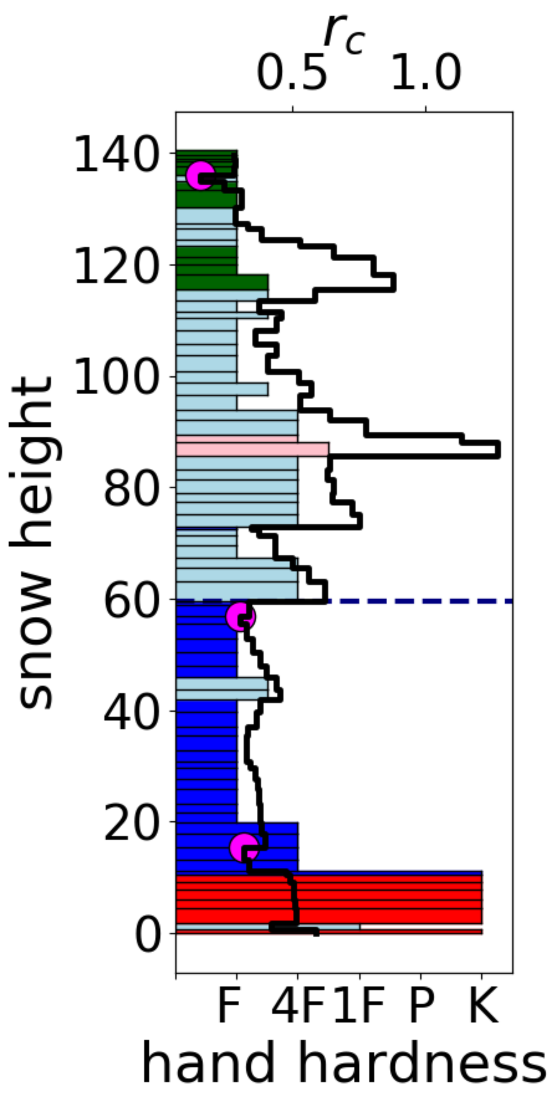


Failure initiation:
SK38: skier stability index (Föhn, 1987; Jamieson & Johnston, 1998)

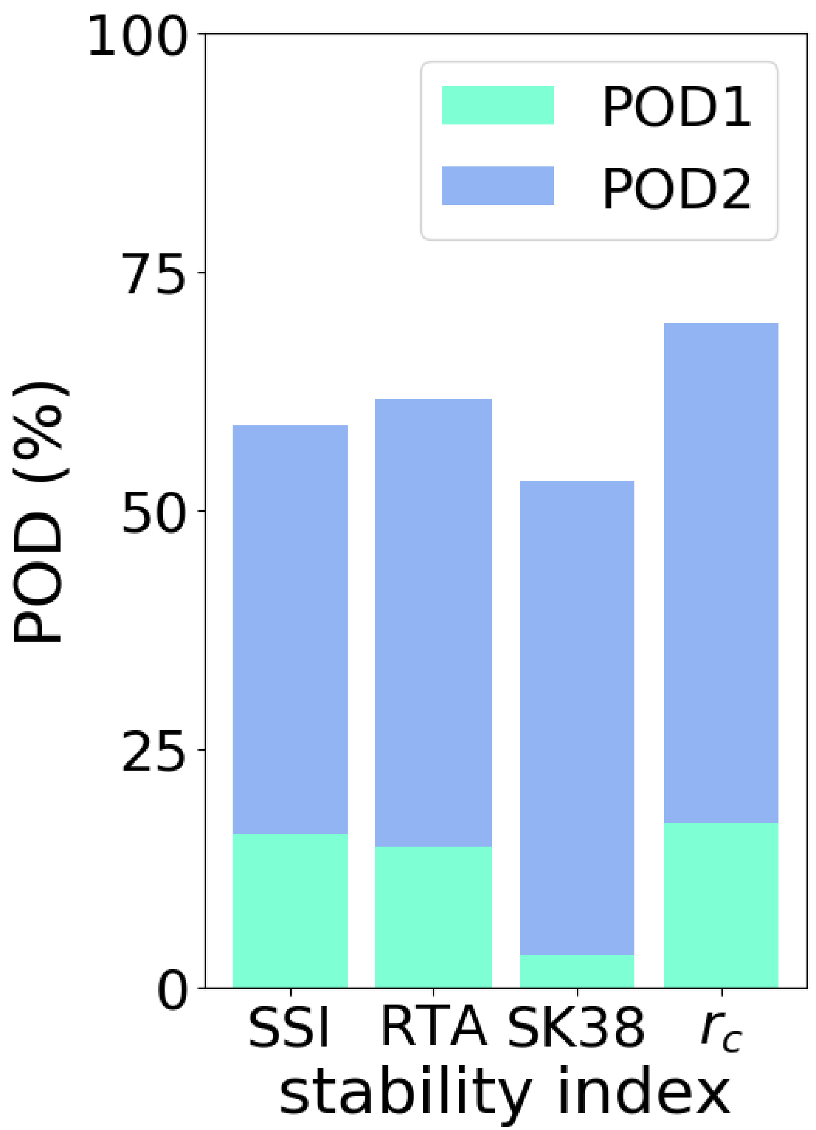
Crack propagation:
r_c : critical crack length (Richter et al., 2019)

Weak layer detection:
SSI: structural stability index (Schweizer et al., 2006)
RTA: relative threshold sum (Monti et al., 2013)

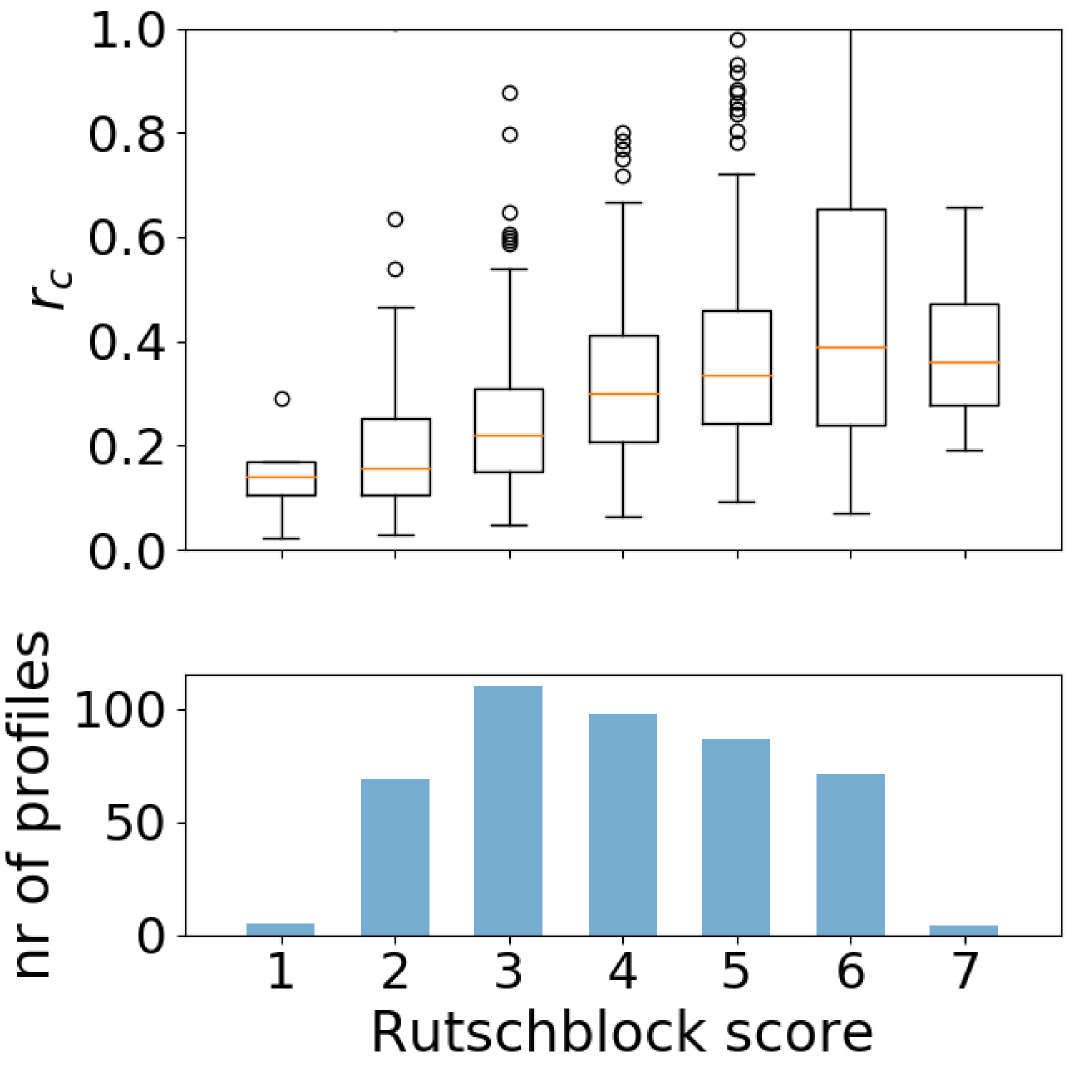
Critical crack length detects weak layer most reliably



- The probability that the global minimum (maximum for RTA) detects the weakest layer is low (<20%) for all stability indices (POD1).
- The probability that one of the 3 smallest local minima detects the weakest layer ± 5 cm is highest for the critical crack length (70%, POD2).
- Here: Only old-snow problem considered (N = 342)

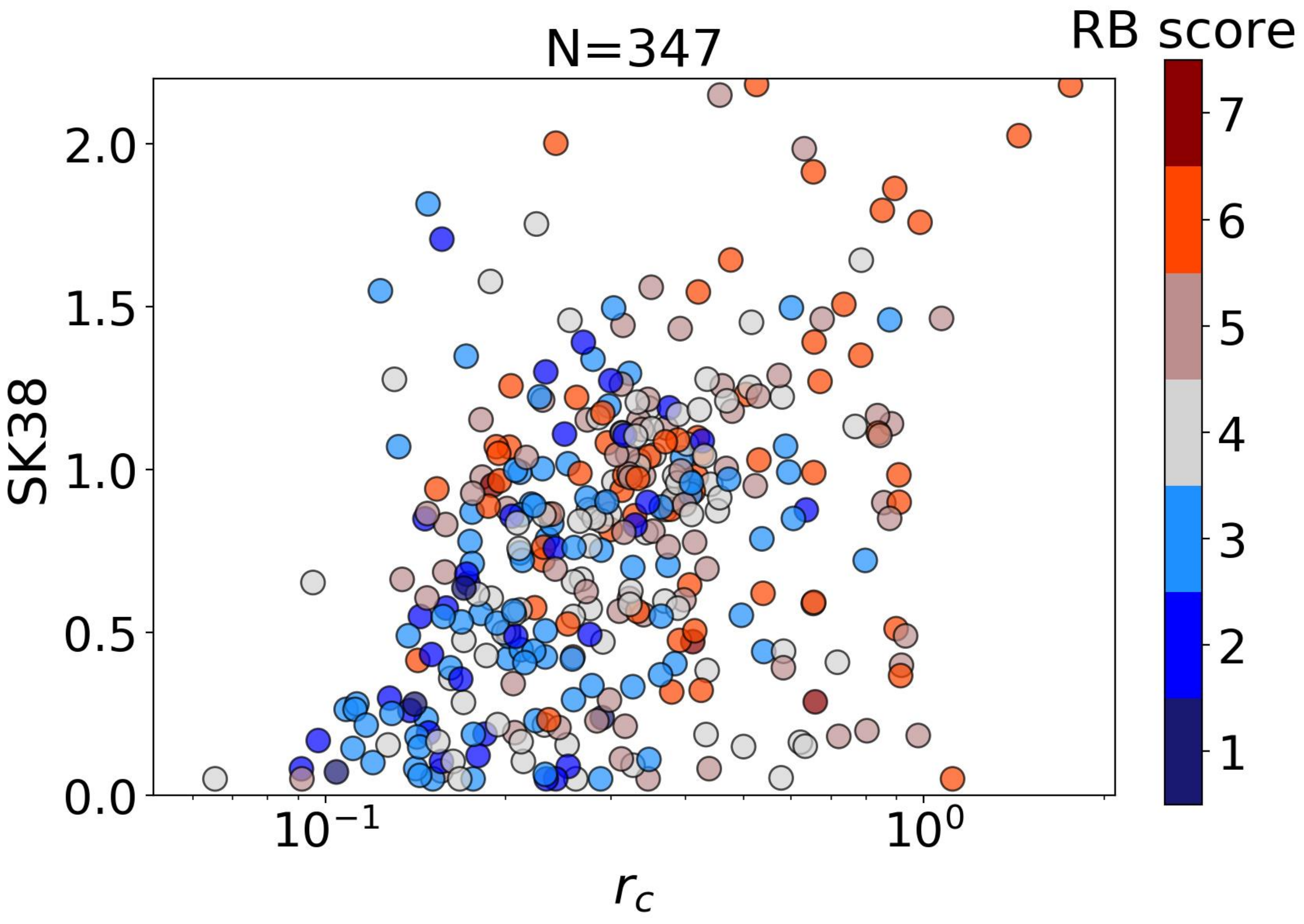


Median critical crack length increases with RB score



- Simulated critical crack length for the picked weak layer increases with increasing observed stability, as expected.
- $N_{tot} = 444$
  (Only profiles with sufficient similarity between simulated and observed stratigraphy were considered.)

Can we combine r_c and SK38 to infer stability?



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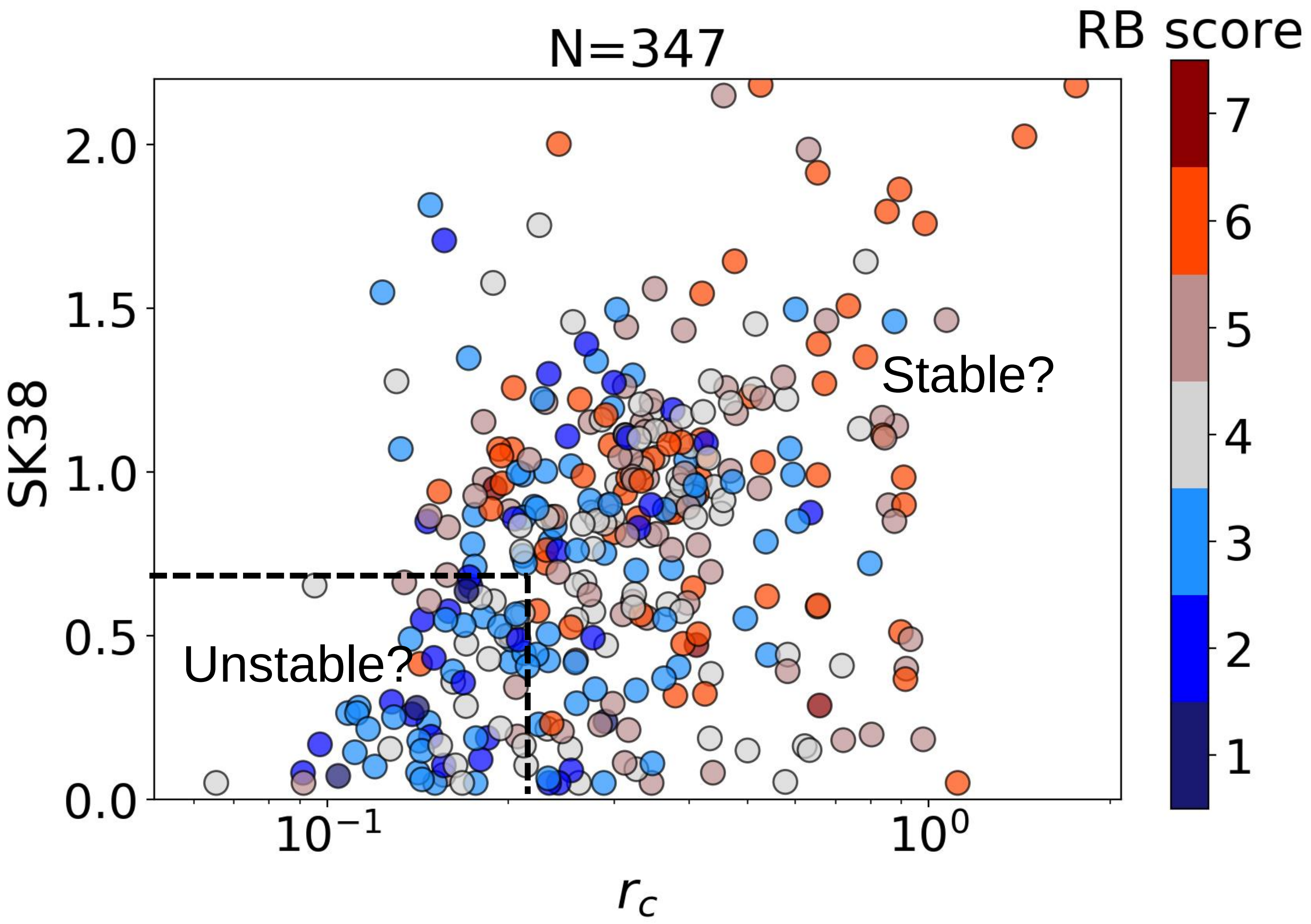

No obvious threshold values that discriminate stable from unstable.

Conclusions and outlook

- We created a comprehensive dataset allowing a comparison between observed and simulated snow profiles.

- Deriving snow instability from simulated snow stratigraphy is a multi-dimensional, nonlinear problem.

- To tackle this challenge, we need to:
  - Improve stability indices
  - Identify the best combination of stability indices.

References

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