

Future snow avalanche activity?

Characterizing avalanche climates and winter seasons

Atelier Neige et Climat

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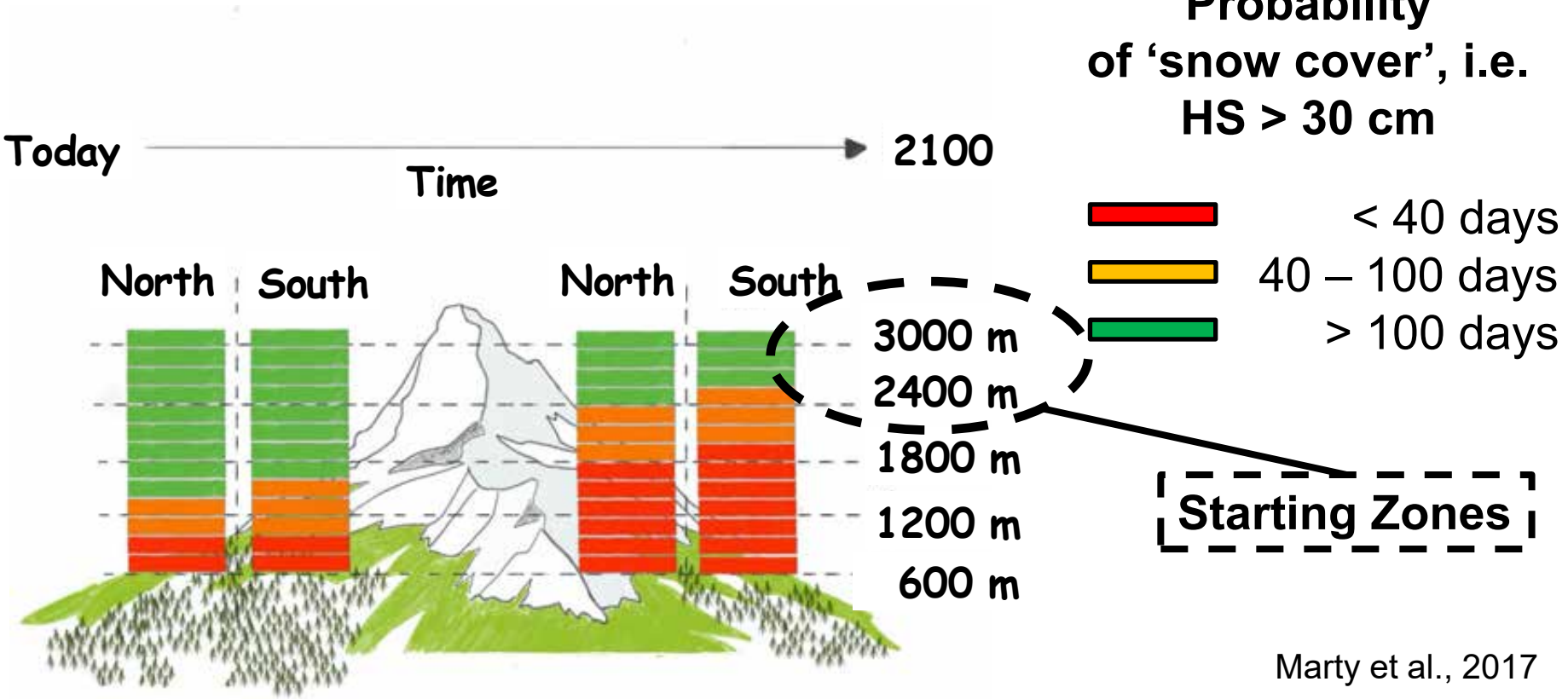
Snow in the Alps?



Marty et al., 2017

Extreme events

Extreme precipitation in the Alps?

→ more frequently

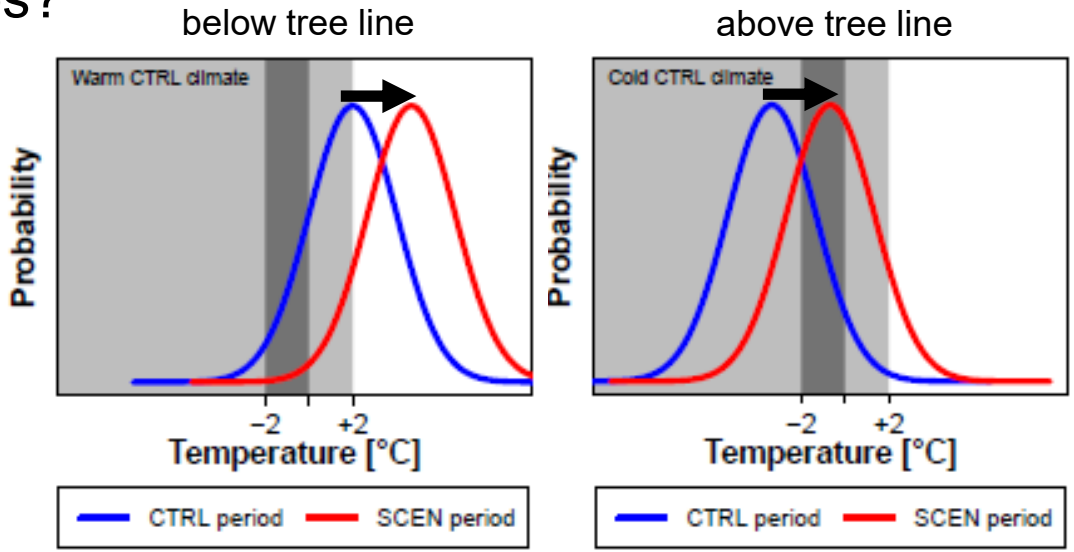
→ more intense

Extreme snowfall?

→ more snow at high elevation

Extreme rain events?

→ at higher elevations even during winter



Rajczak and Schär, 2017
Frei et al., 2018
Serquet et al., 2013

Conditions in the Alps

- The ‘ingredients’ for avalanches, i.e. weather and snow, will still be there in the future, but:
  - Less snow at low elevation.
  - Weather severity may increase.

- At low elevation, avalanches run shorter, are less frequent and deposits are more often wet

- At high elevations, snow cover thickness and new snow amounts persist, trends?

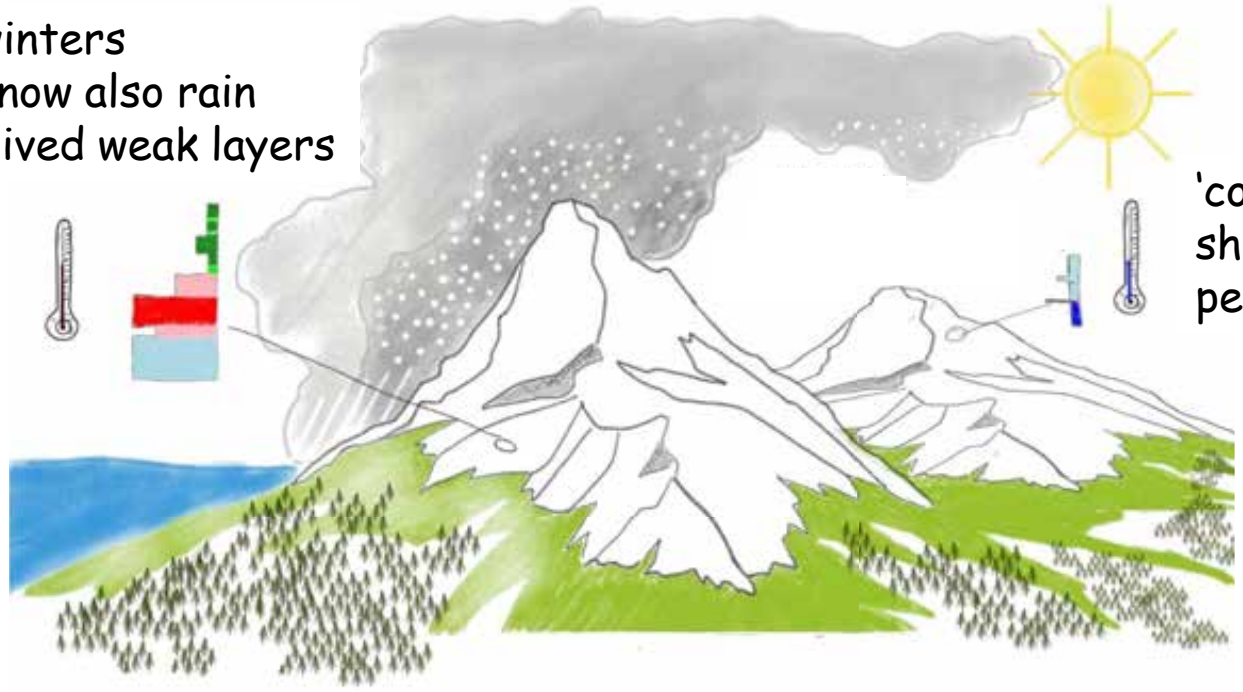
Eckert et al., 2013
Castebrunet et al., 2012

Frei et al., 2018
Lavigne et al., 2015
Castebrunet et al., 2014

Impact on different climates?

Maritime Climate — Continental Climate

'mild' winters
more snow also rain
short-lived weak layers



'cold' winters
shallow snow cover
persistent weak layers

New snow

Old snow
(persistent WL)

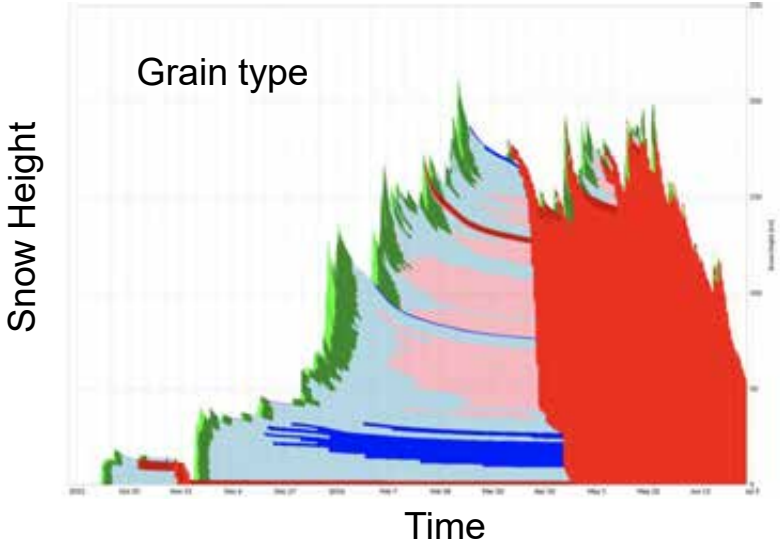
Avalanche problems from snow cover simulations

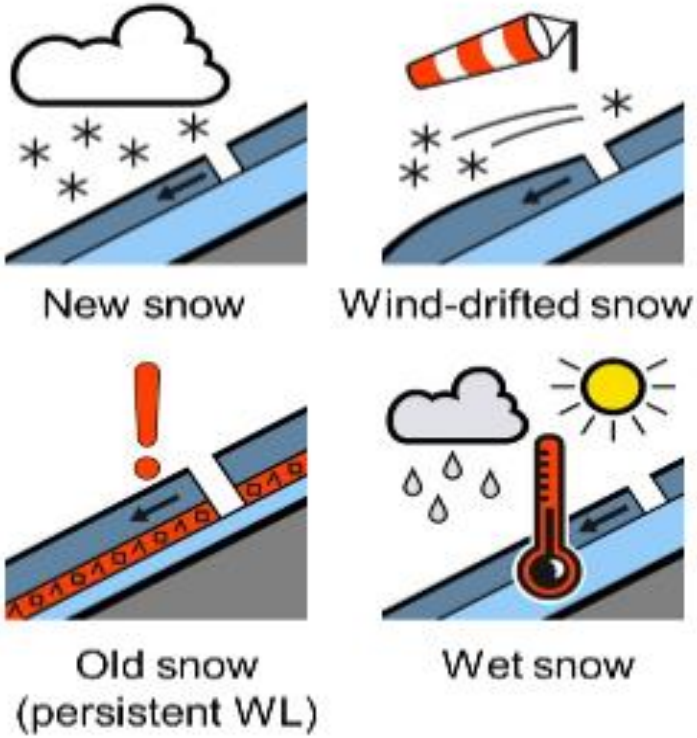
Questions:

Characteristics of avalanche danger?

Impact on regional snow climates?

1-season snow cover simulation





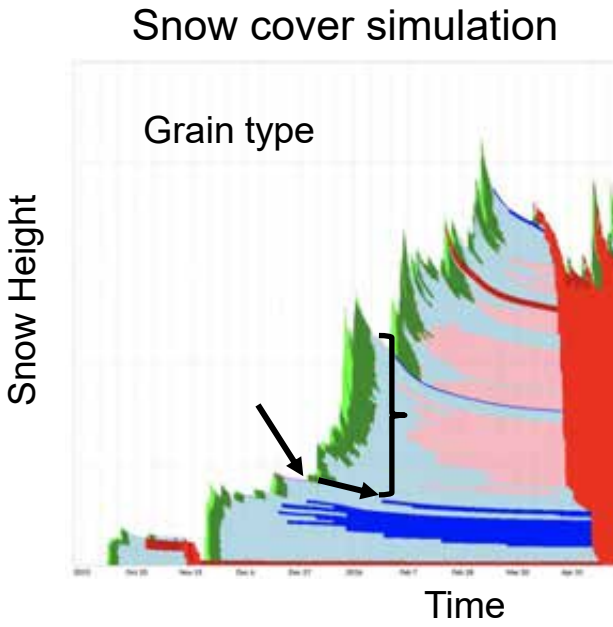
Weak layer detection and tracking

Detect weak layers

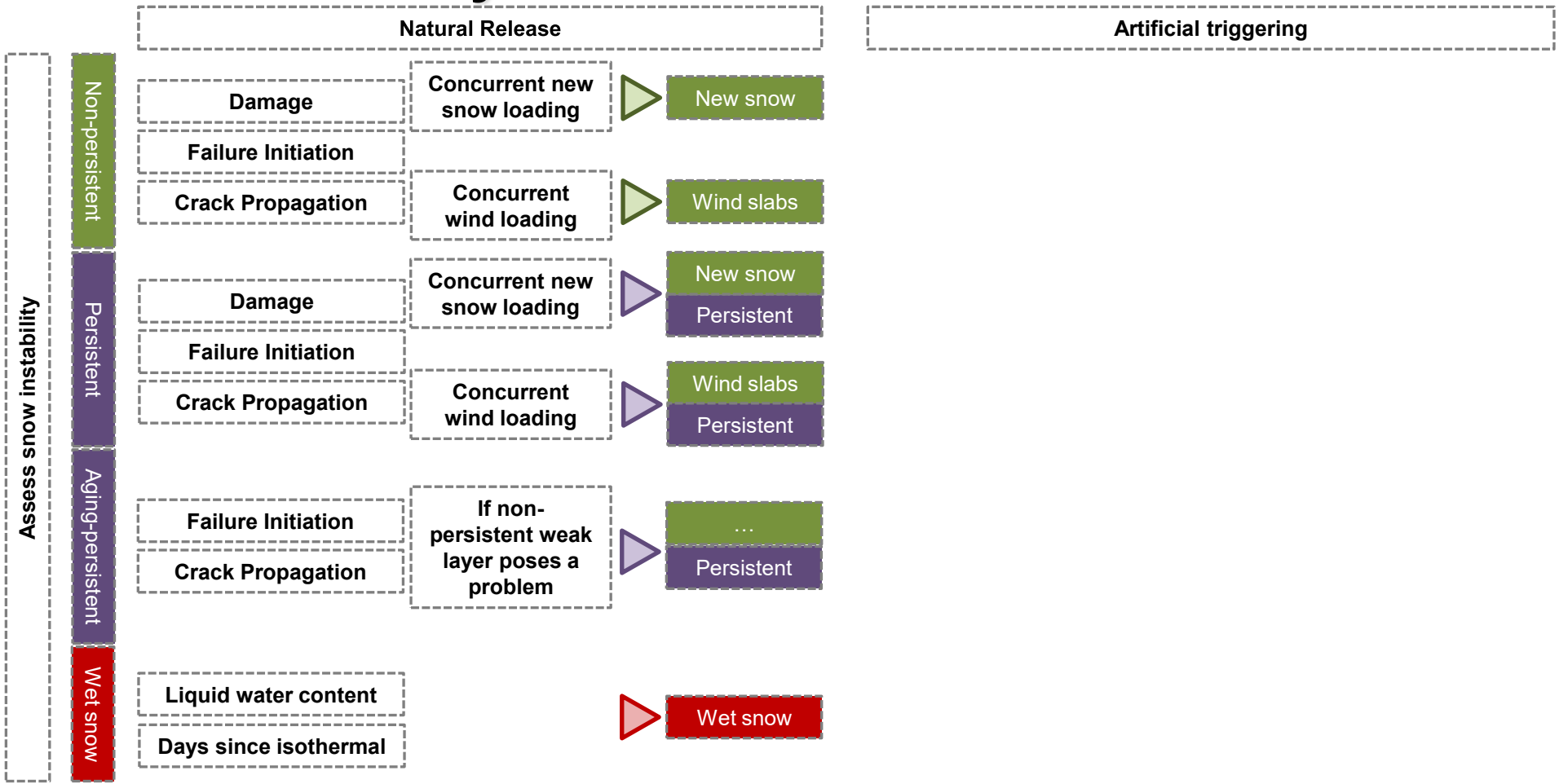
New WL?	Relevance	Instability	Keep +1 day?
Non-persistent	Burial depth? + Slab density?	Assess, if slab has formed	Keep for +1 day
Persistent WL	Burial depth? + Slab density?	Assess, if slab has formed	Keep

Keep track of weak layers

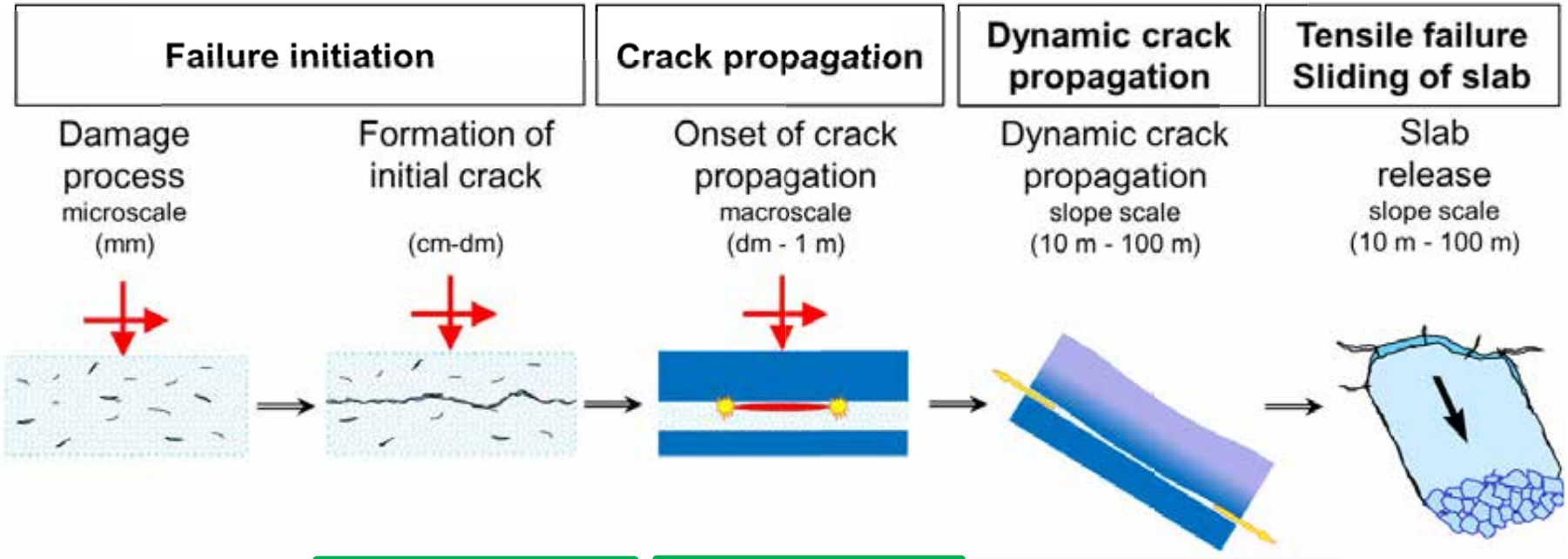
Existing WL?	Relevance	Instability	Keep +1 day?
Non-persistent	Burial depth? + Slab density?	Assess, if slab has formed	Only keep, if recently loaded
Persistent WL	Burial depth? + Slab density?	Asses, if slab has formed	Keep, may become aging persistent
Aging persistent WL	always	always	Keep, until exceeds stability



Snow instability assessment



Snow instability indices for SC modelling



Initiation criterion

Crit crack length

Slab tensile criterion

Natural stability index

Skier stability index

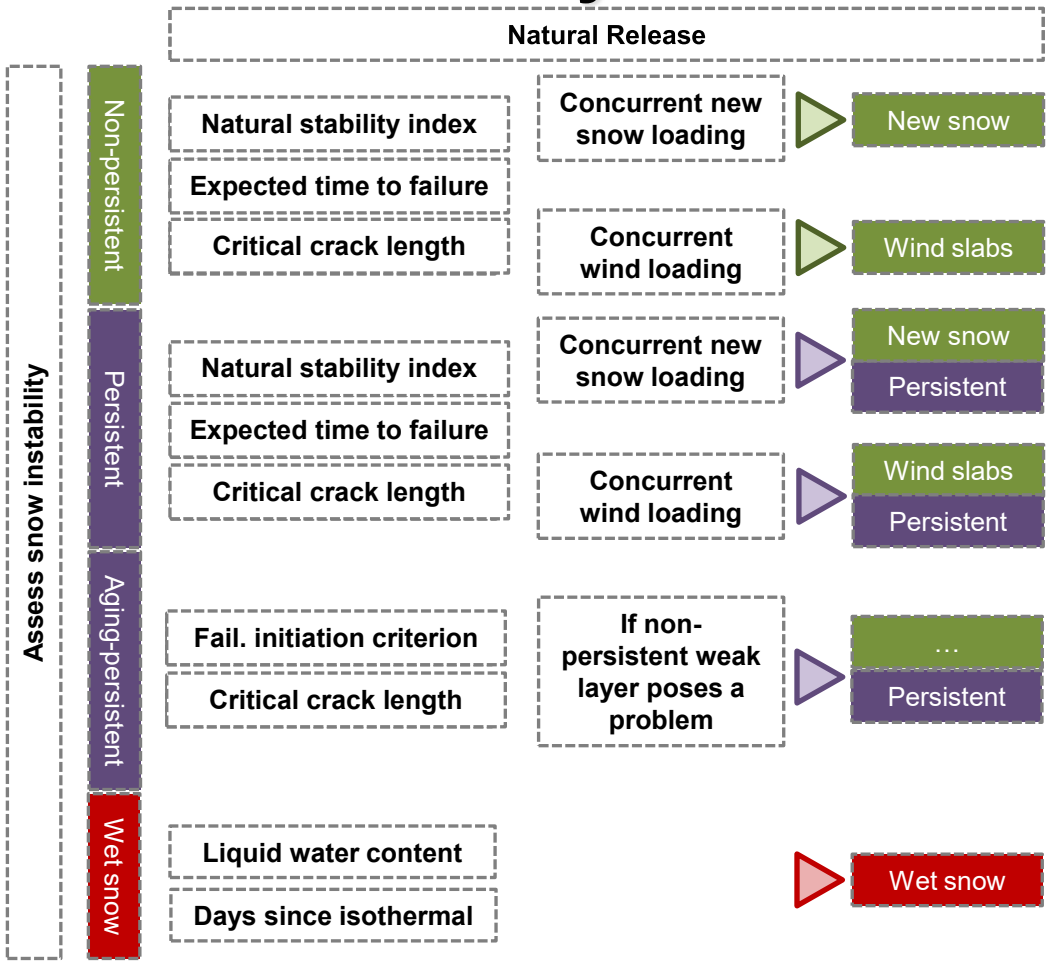
Propagation speed?

Time to failure

Skier crack length

Friction angle

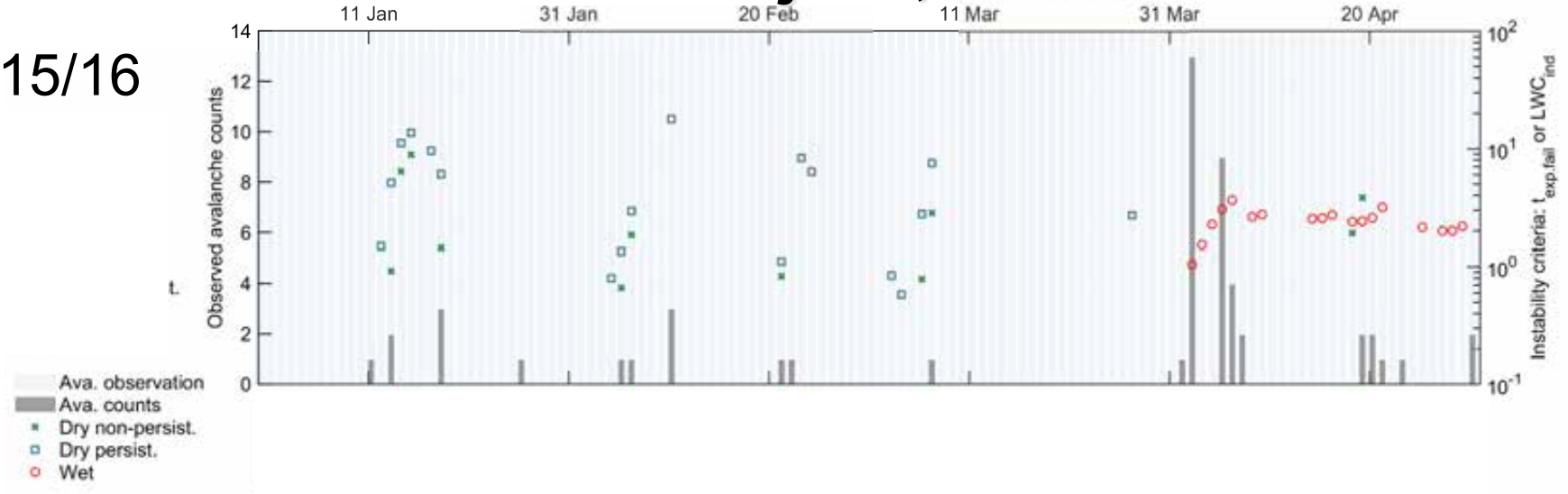
Snow instability assessment



Natural release at Weissfluhjoch, Davos

2015/16

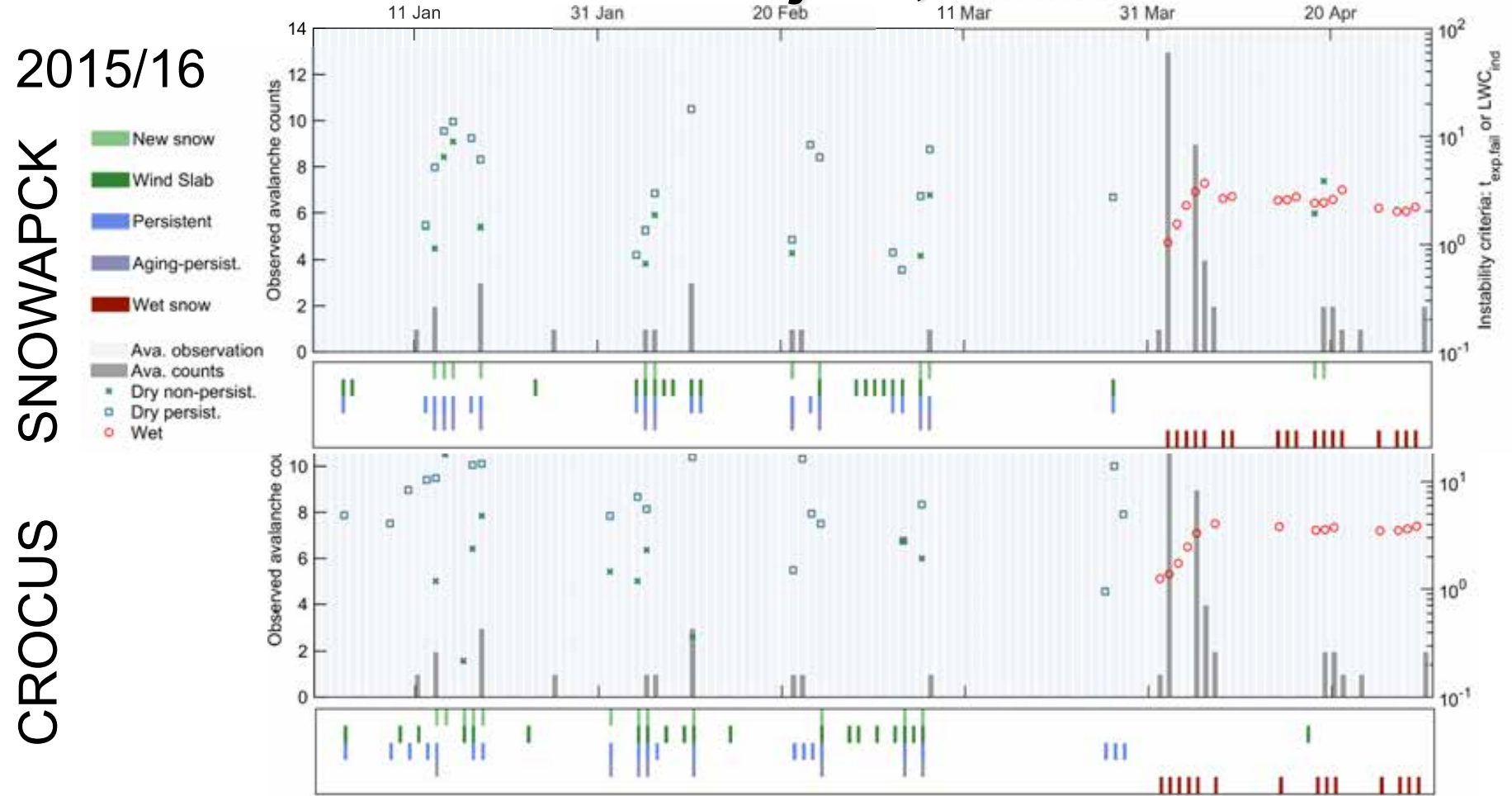
SNOWAPCK



(Non-)persistent weak layer *and* loading

Snow wetness

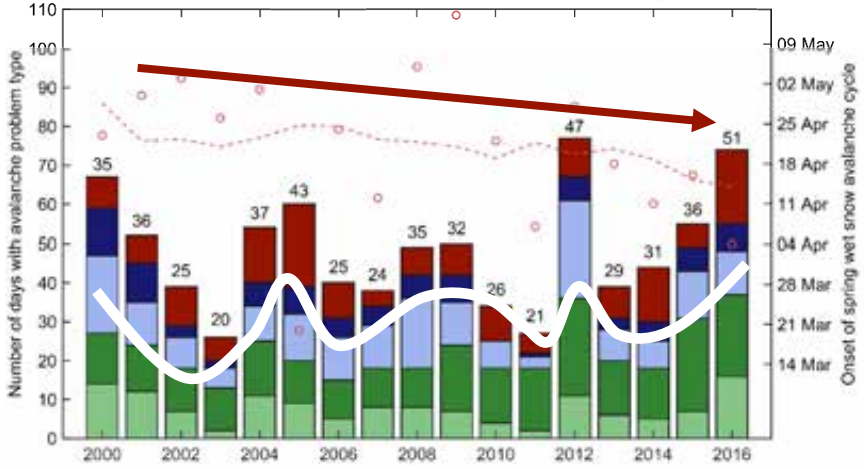
Natural release at Weissfluhjoch, Davos

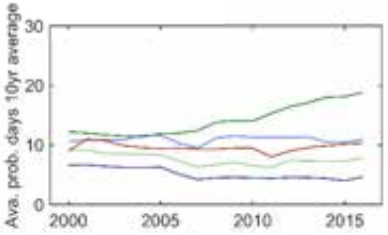


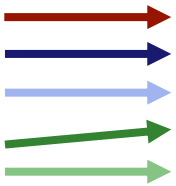
Natural release at Weissfluhjoch, Davos

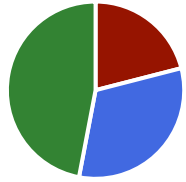
16 years

SNOWAPCK

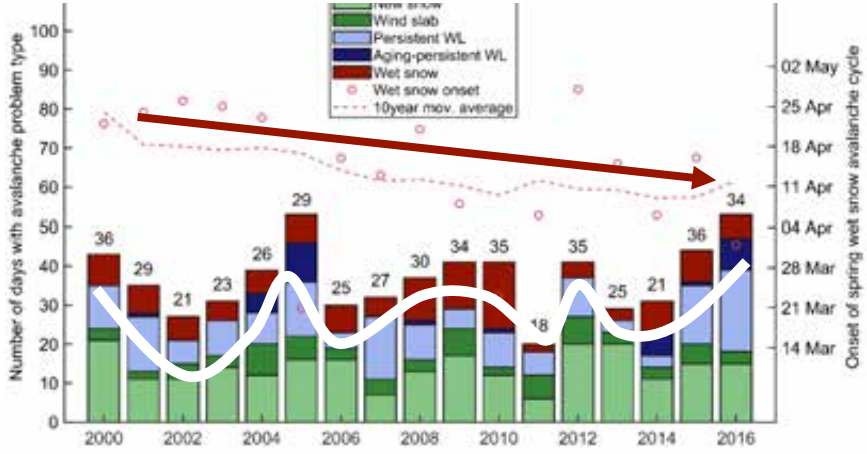


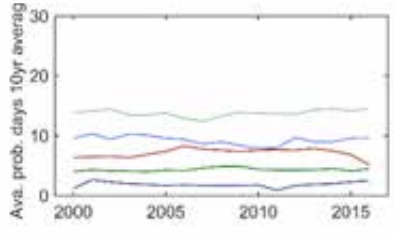


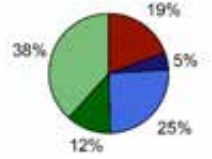


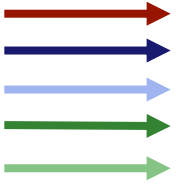


CROCUS

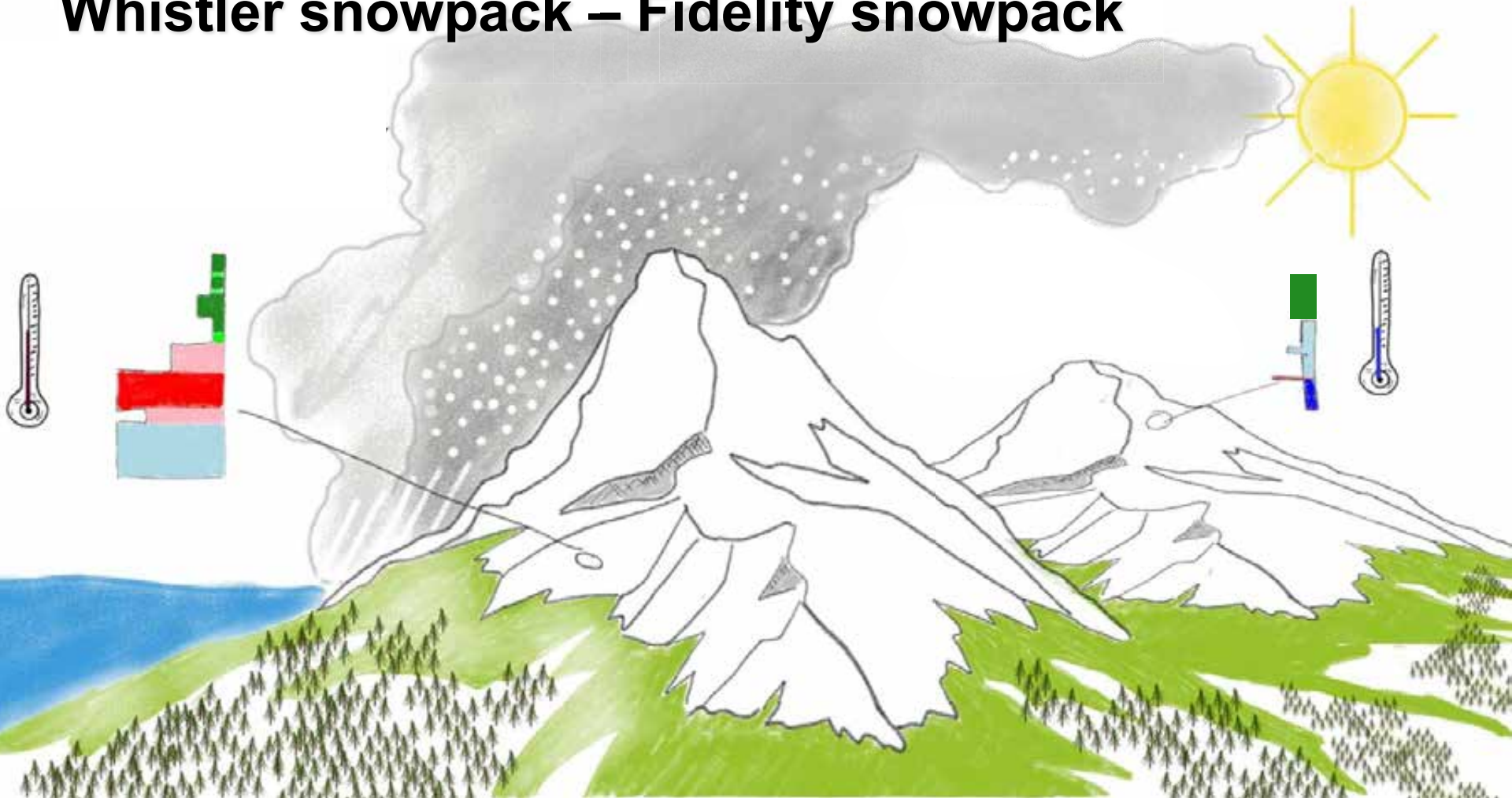




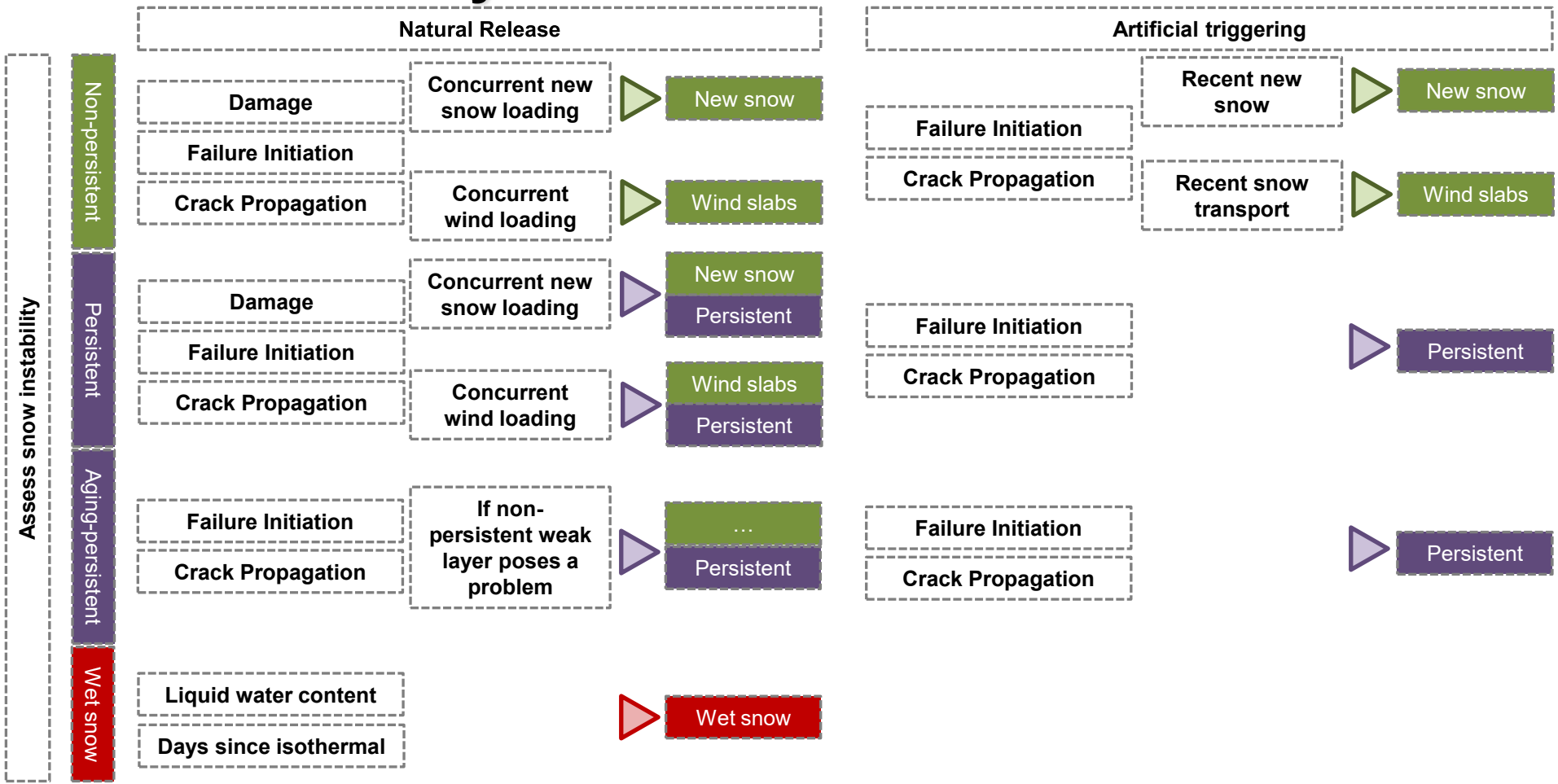




Whistler snowpack – Fidelity snowpack



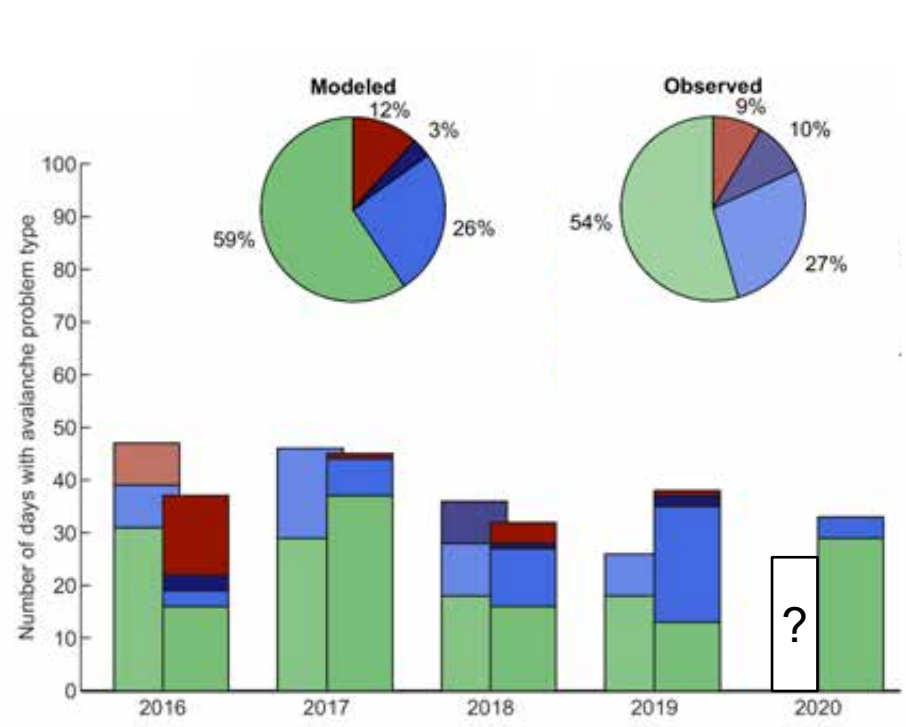
Snow instability assessment

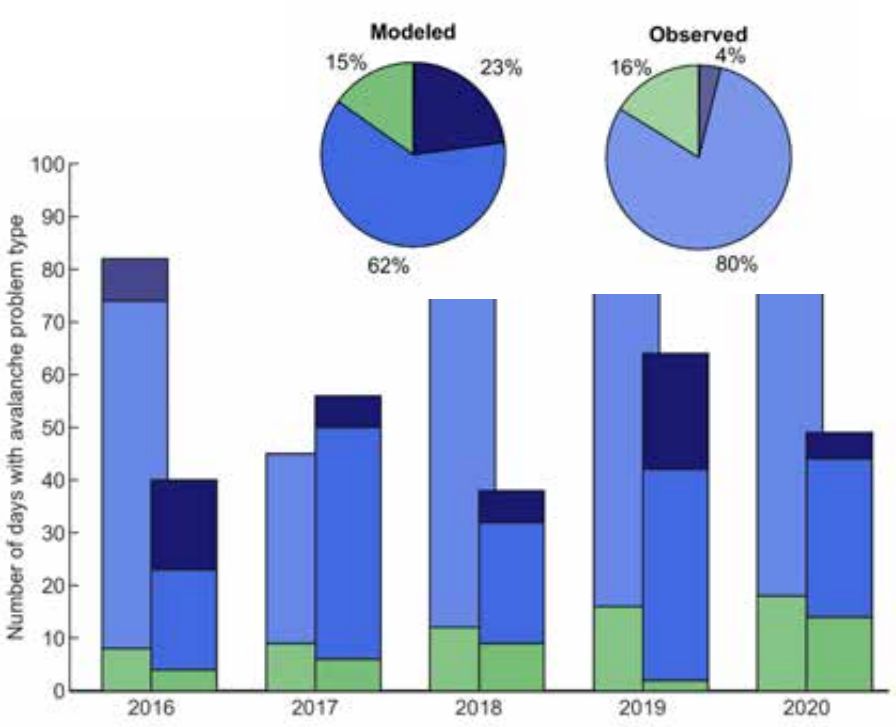


Whistler snowpack – Fidelity snowpack

Modeled (bright) and observed (pale) avalanche problems

Time period: 1 Dec – 1 April, from 2015/16 to 2019/20

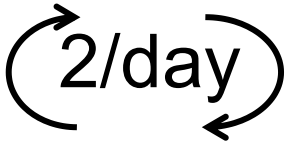


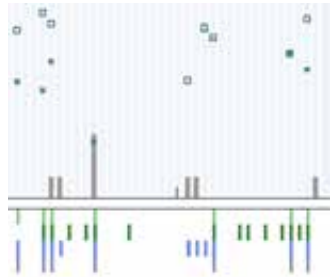


Summary: Model and validation

- Stepwise approach for natural release *or* artificial triggering
  - Weak layer detection
  - Weak layer tracking
  - Snow instability

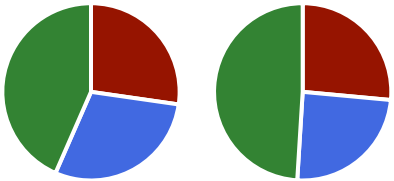
  → *Relevant* avalanche problem type(s)





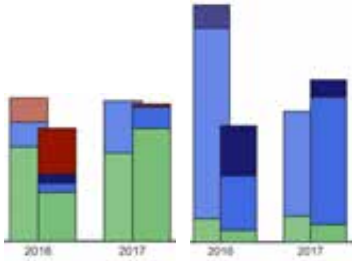
- Modeled avalanche days and natural release coincided

- SNOWPACK and Crocus simulations produced similar frequencies of avalanche problems



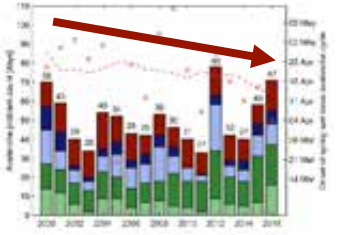
Conclusions: Model application

- Applicable to snow cover model data
- Can describe any climate

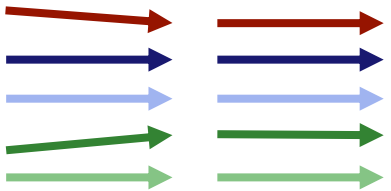


16-years at Weissfluhjoch (2500 m):

- Earlier onset of wet snow avalanche cycle at 2500 m

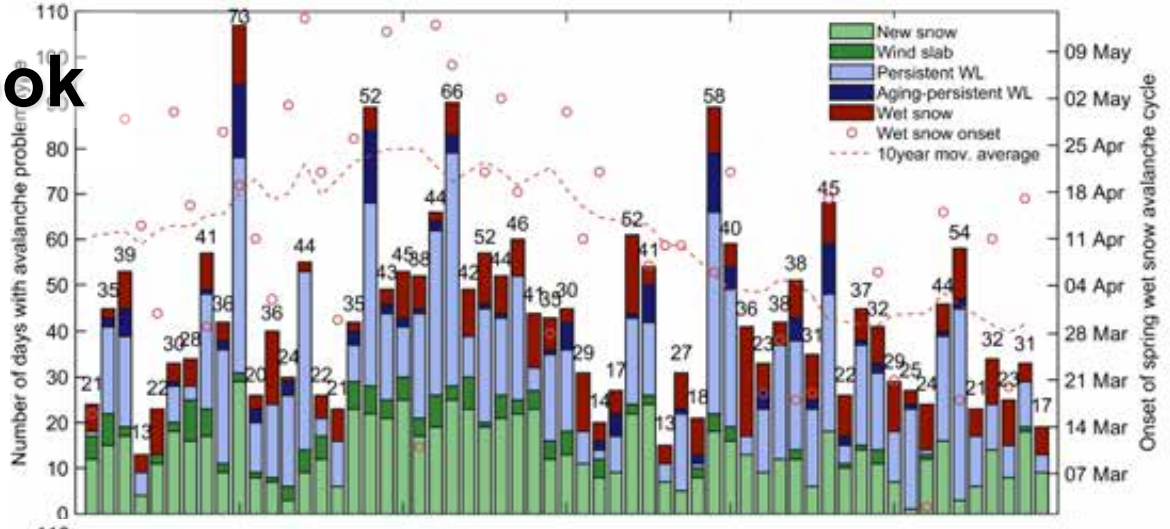


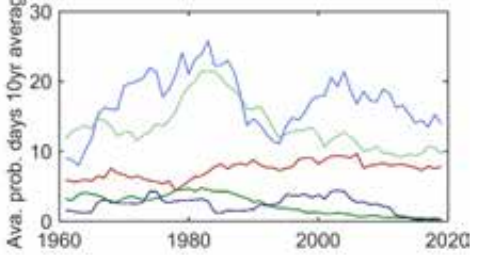
- Avalanche problem frequency «rather constant»

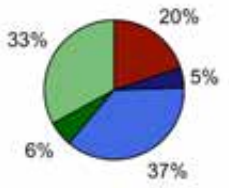


Outlook

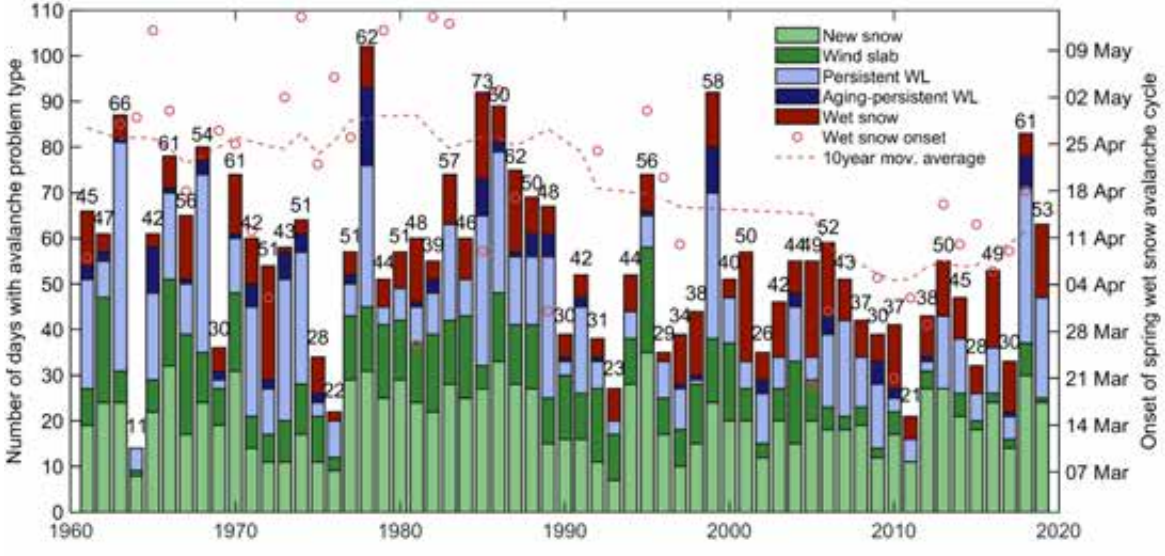
Inner-Alpine (E)

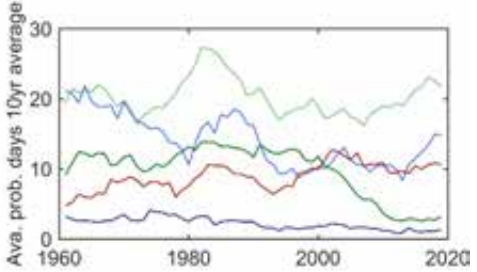


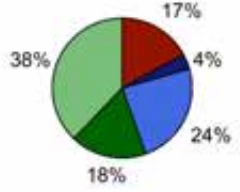




Front-Range (W)

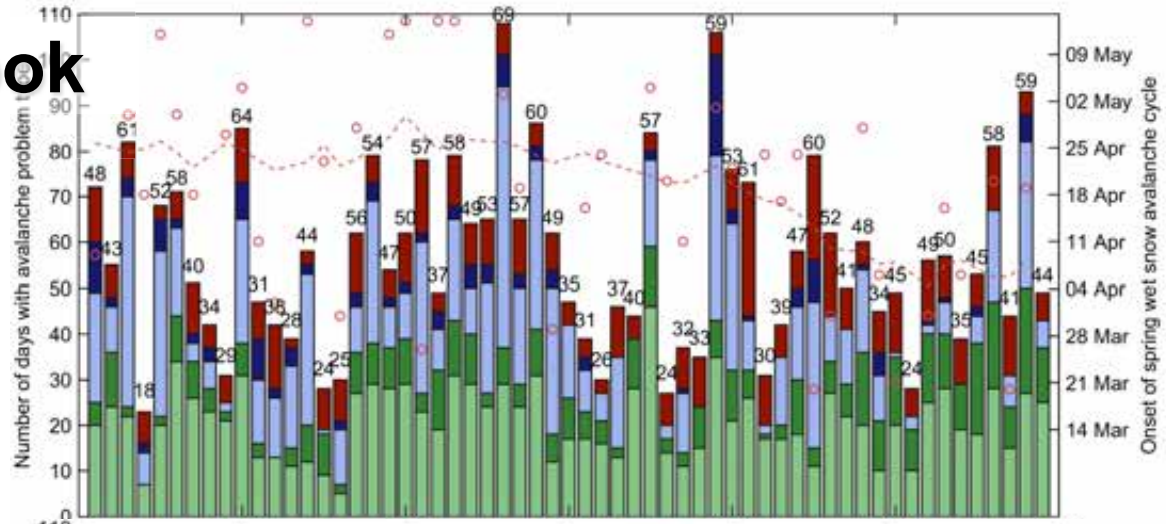


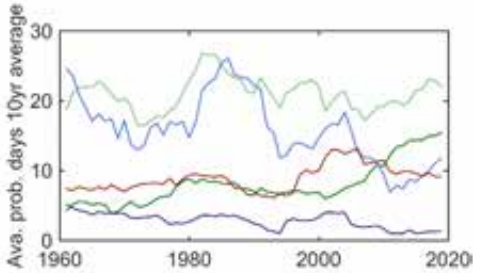


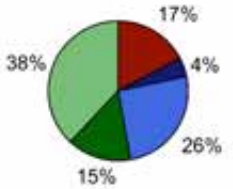


Outlook

Front-Range (N)







Warm (S)