8èmes Journées Fiabilité des Matériaux & des Structures
Aix-en-Provence, 9 et 10 avril 2014

Influence de la variabilité spatiale des propriétés mécaniques du manteau neigeux sur la stabilité d'une pente

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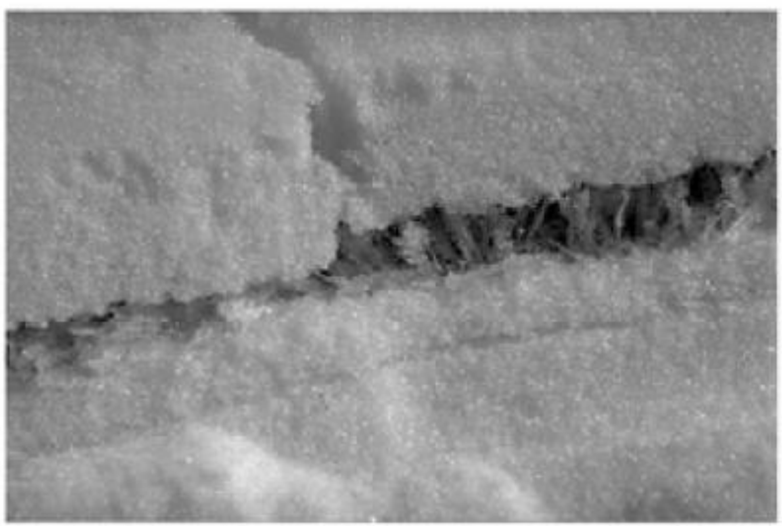
Context

Slab avalanches result from the failure of a weak snow layer underlying a cohesive snow slab



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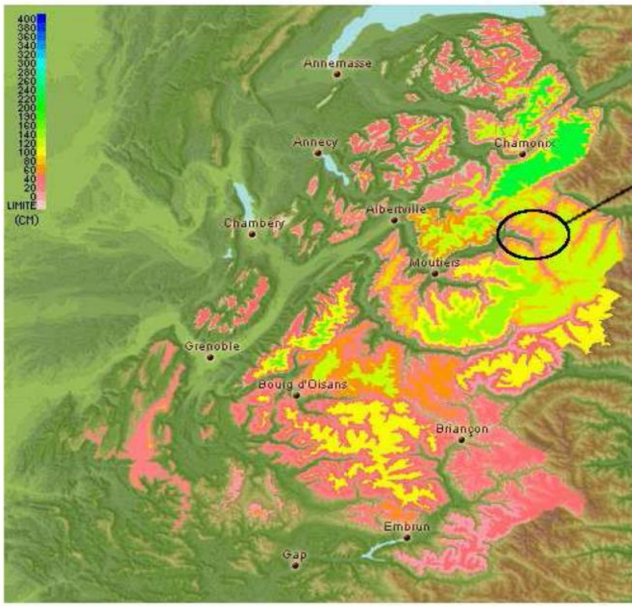
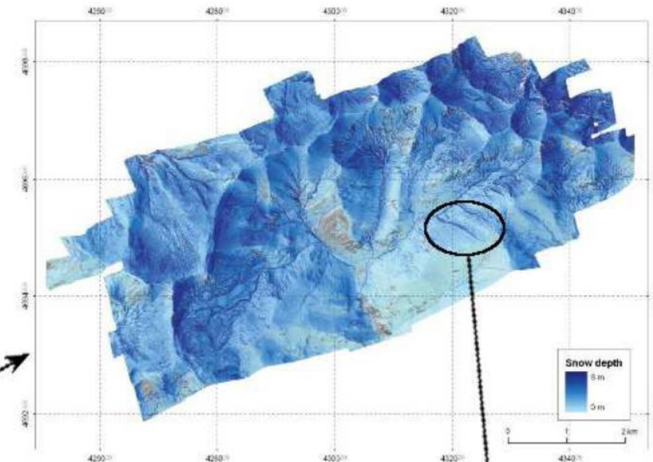
Context

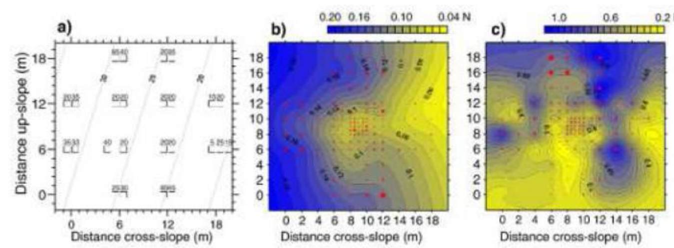
Complexity of avalanche forecasting due to a multi-scale spatial variability



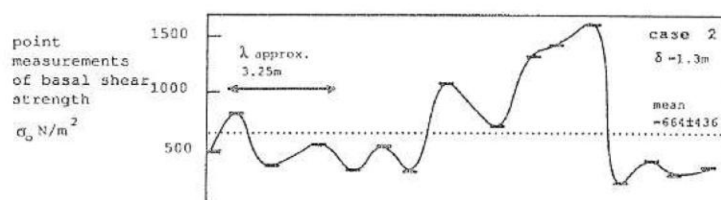
(c) Avalanches-net



From Banos et al 2011



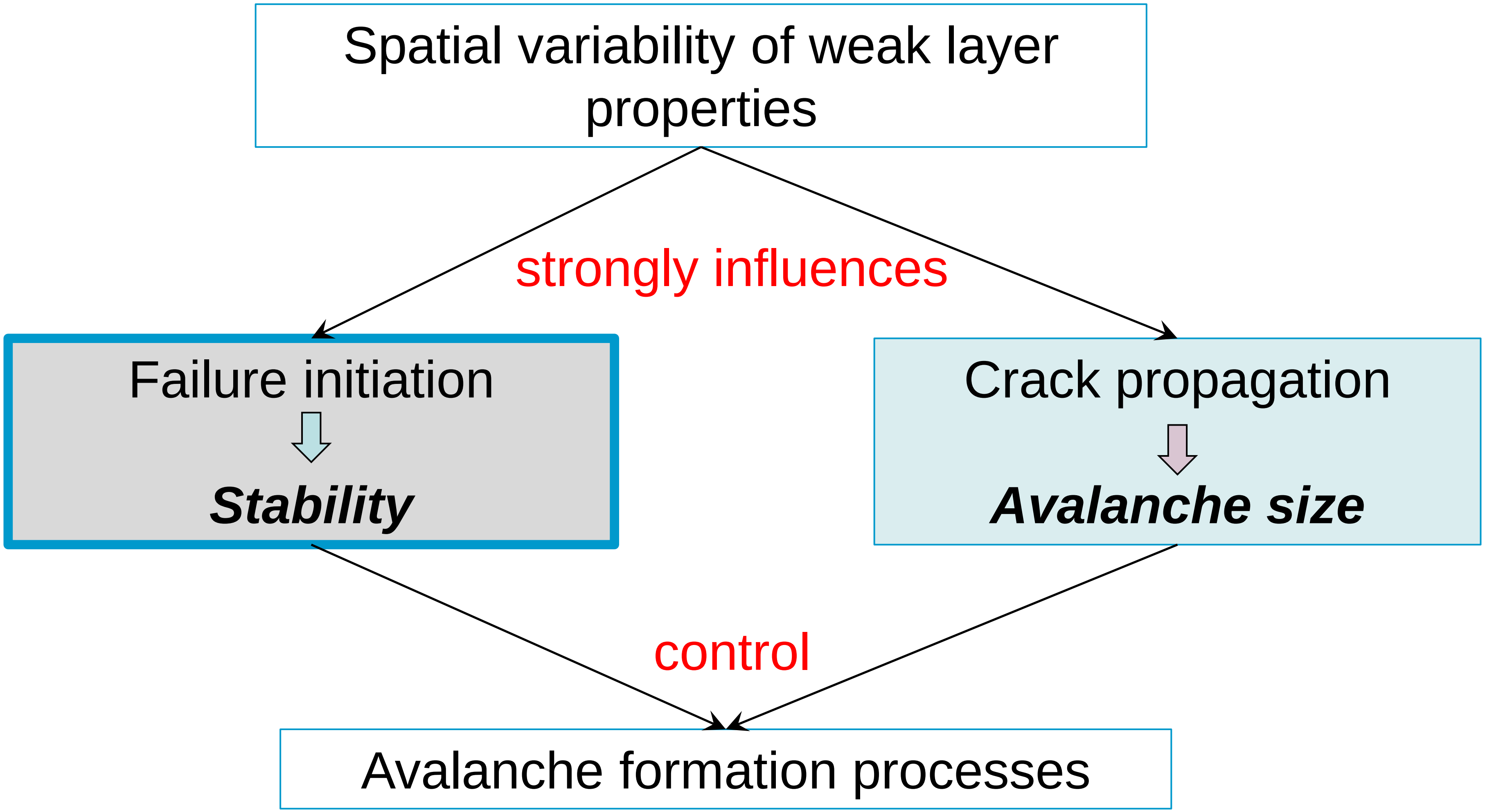
From Schweizer 2008



From Conway and Abrahamson 1988

Context

Importance of spatial variability for avalanche formation (Schweizer et al., 2008)



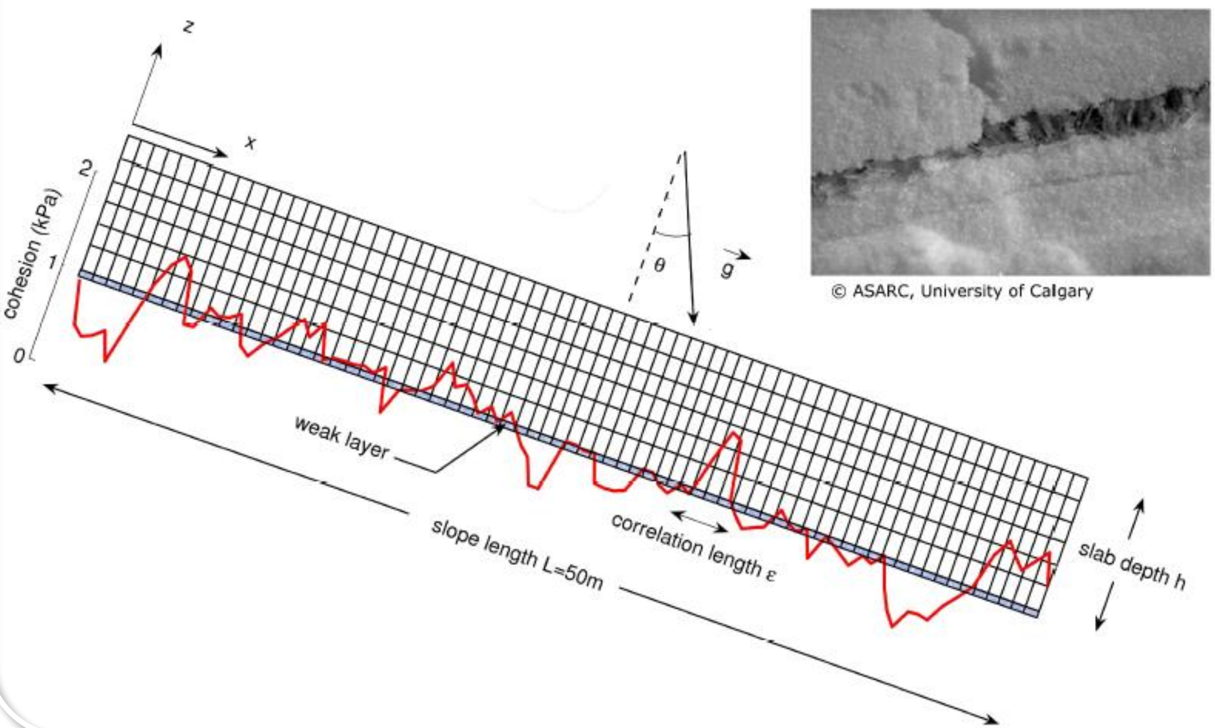
Objective and method

Objective

Spatial variability → ? → slope stability

Method

Mechanically-based statistical model of slab avalanche release
Gaume et al. (2012, 2013a)



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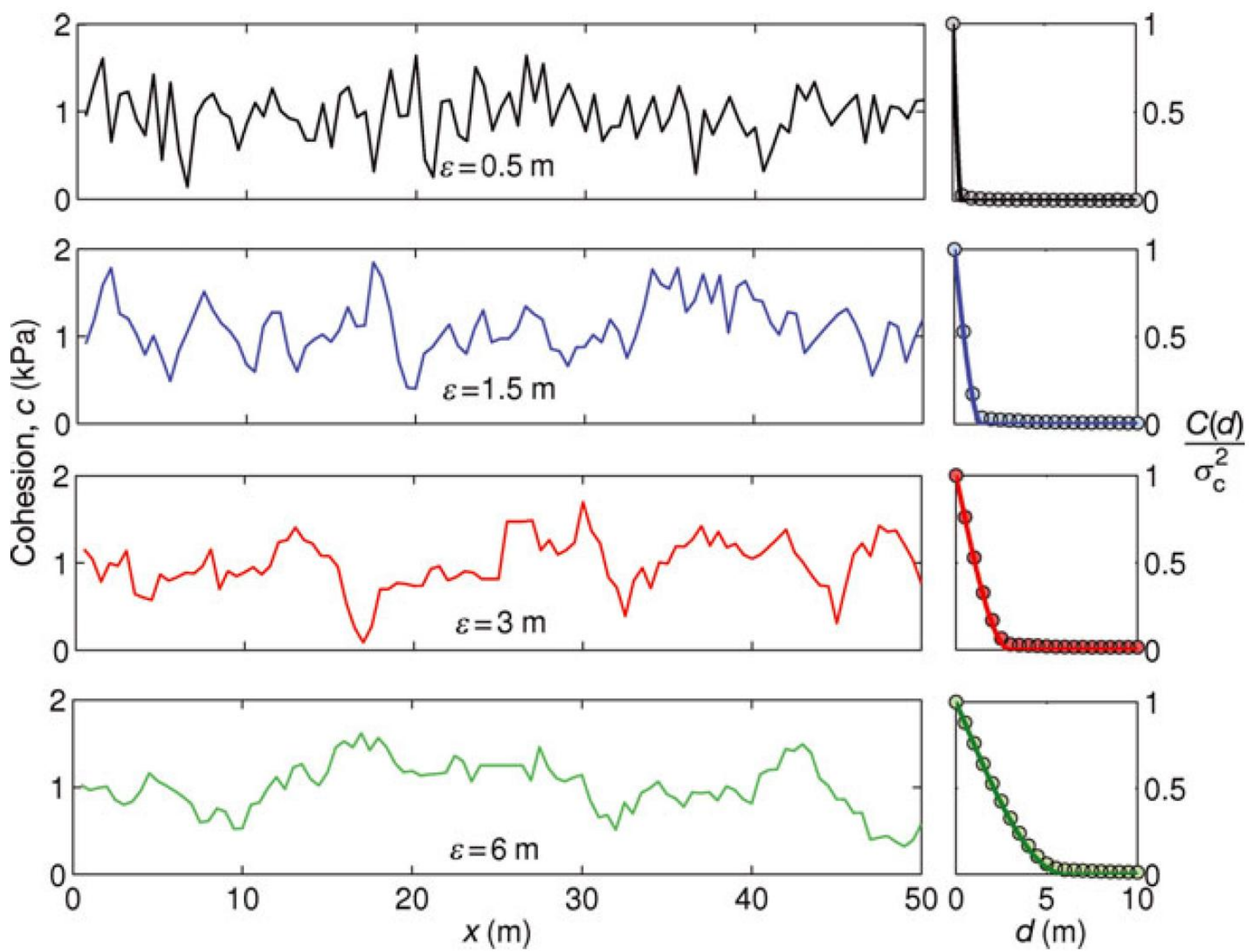
This model takes into account, in particular:

(1) the spatial variations of WL mechanical properties (shear strength);
(2) a shear quasi-brittle constitutive law for the WL;
(3) stress redistribution effects by elasticity of the slab.

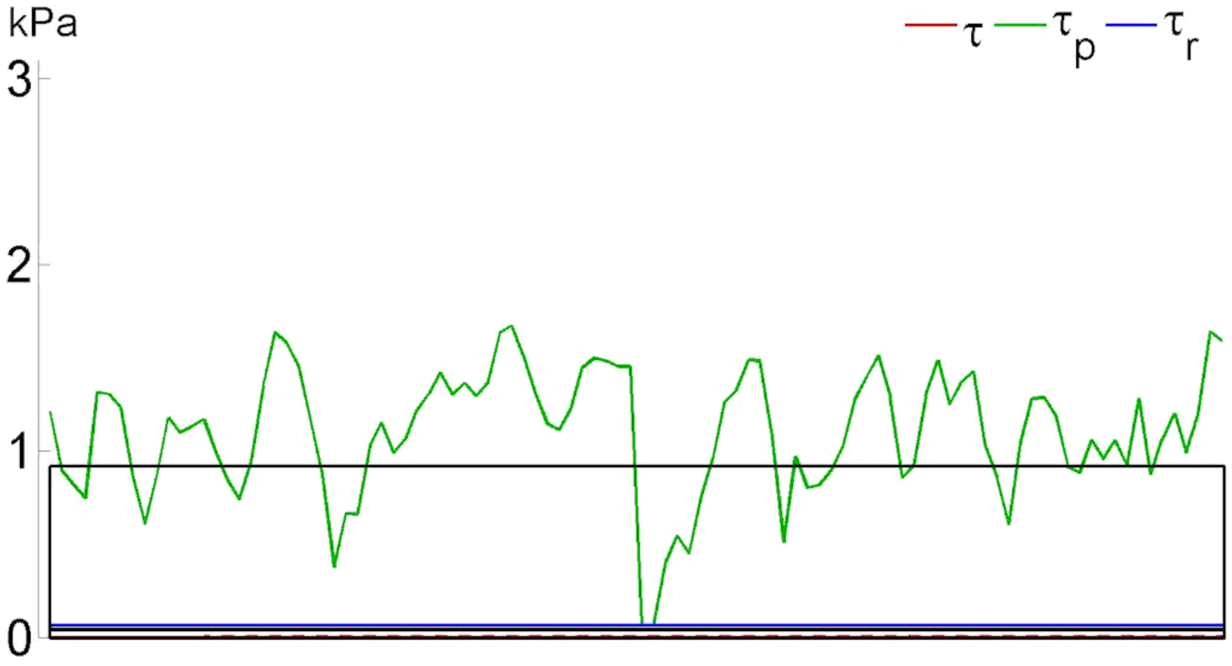
Objective and method

Spatial variability of the weak-layer cohesion: Gaussian distribution with a spherical covariance function



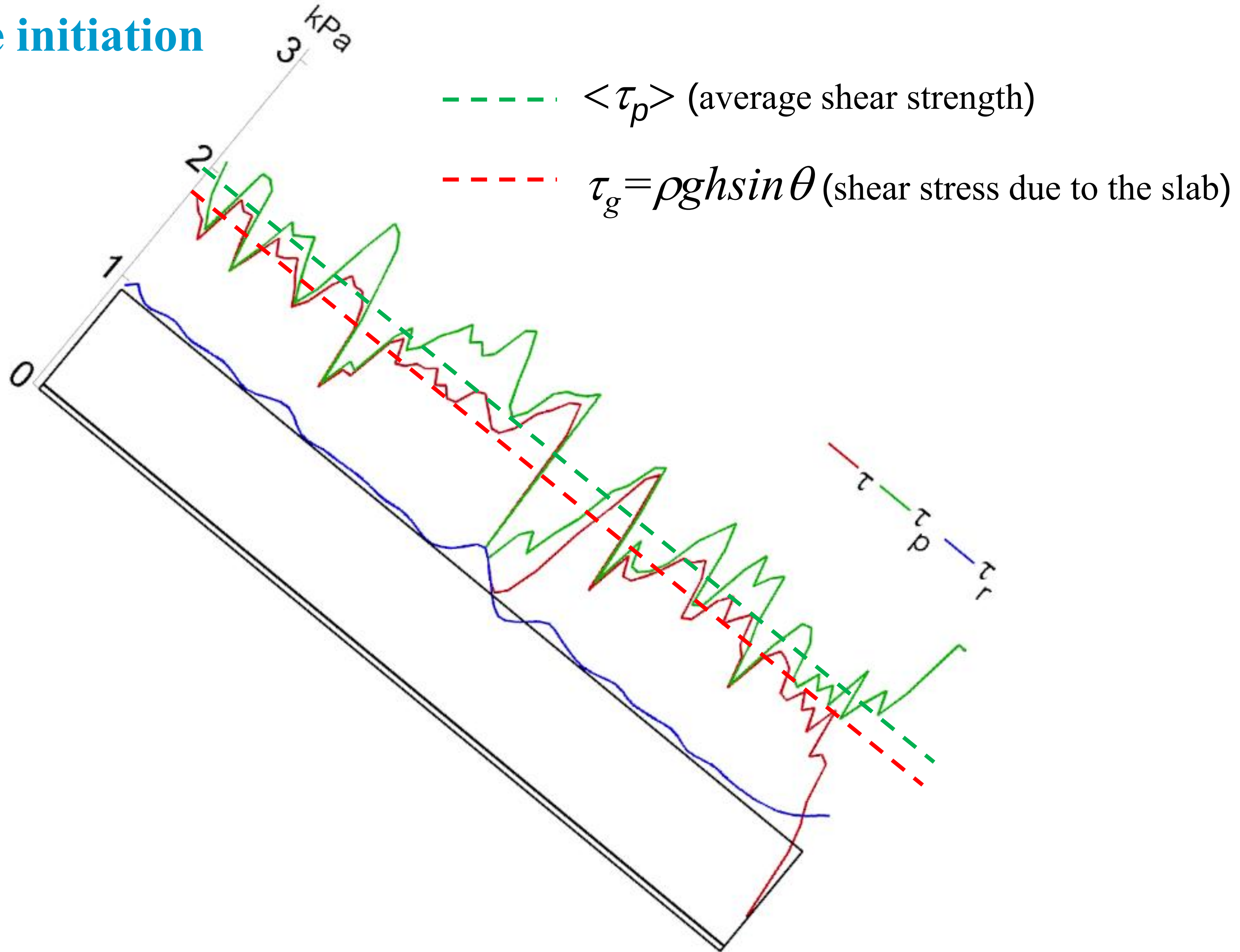
Illustration

Illustration: slope stability evaluation



Illustration

Failure initiation



Results

Avalanche probability evaluation

FE simulations ⟶ Release depth distributions

$$P(h|\theta) = \frac{1}{\sigma_h \sqrt{2\pi}} e^{-\frac{1}{2}\left[\frac{h-<h>}{\sigma_h}\right]^2}$$

$$<h> = f_1\left(\frac{\varepsilon}{h}, \mathrm{CV}, E\right)\frac{<c>}{\rho g F}, \quad \sigma_h = \frac{\sigma_c}{\rho g F}\sqrt{f_2\left(\frac{\varepsilon}{\Lambda}, E\right)}$$

$$F = \sin\theta - \mu\cos\theta, \quad \Lambda = \sqrt{\frac{Eh/(1-\nu^2)}{k_{WL}}}$$

Avalanche release occurs if the slab depth h is higher than the critical depth h_c coming from the mechanical stability criterion:

$$P_{aval} = P = P(h_{real} = h \geq h_c) = \int_0^h P(h_c|\theta)\,dh_c$$

$$\longrightarrow \quad P_{\mathrm{aval}} = \frac{1}{2}\left[1 + \mathrm{erf}\left(\frac{\rho g h F - f_1 <c>}{\sigma_c \sqrt{2 f_2}}\right)\right]$$

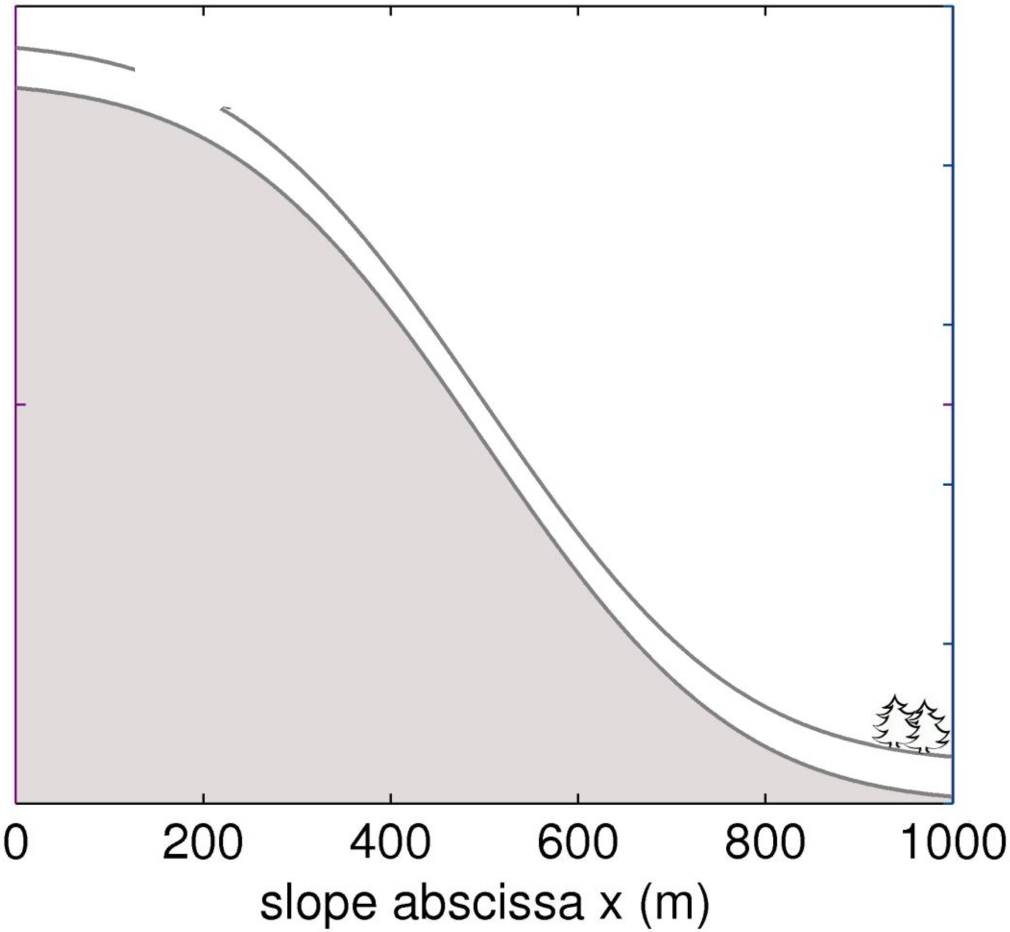
$$f_1 < 1$$

$$f_2 < 1$$

Results

Slope stability evaluation

h_z=50cm
ρ=250kg/m^3
E=1MPa
τ_p=800Pa



Stability index SI

$$= \frac{\text{shear strength}}{\text{shear stress}} = \frac{\tau_p}{\tau_{xz}}$$

Results

Slope stability evaluation

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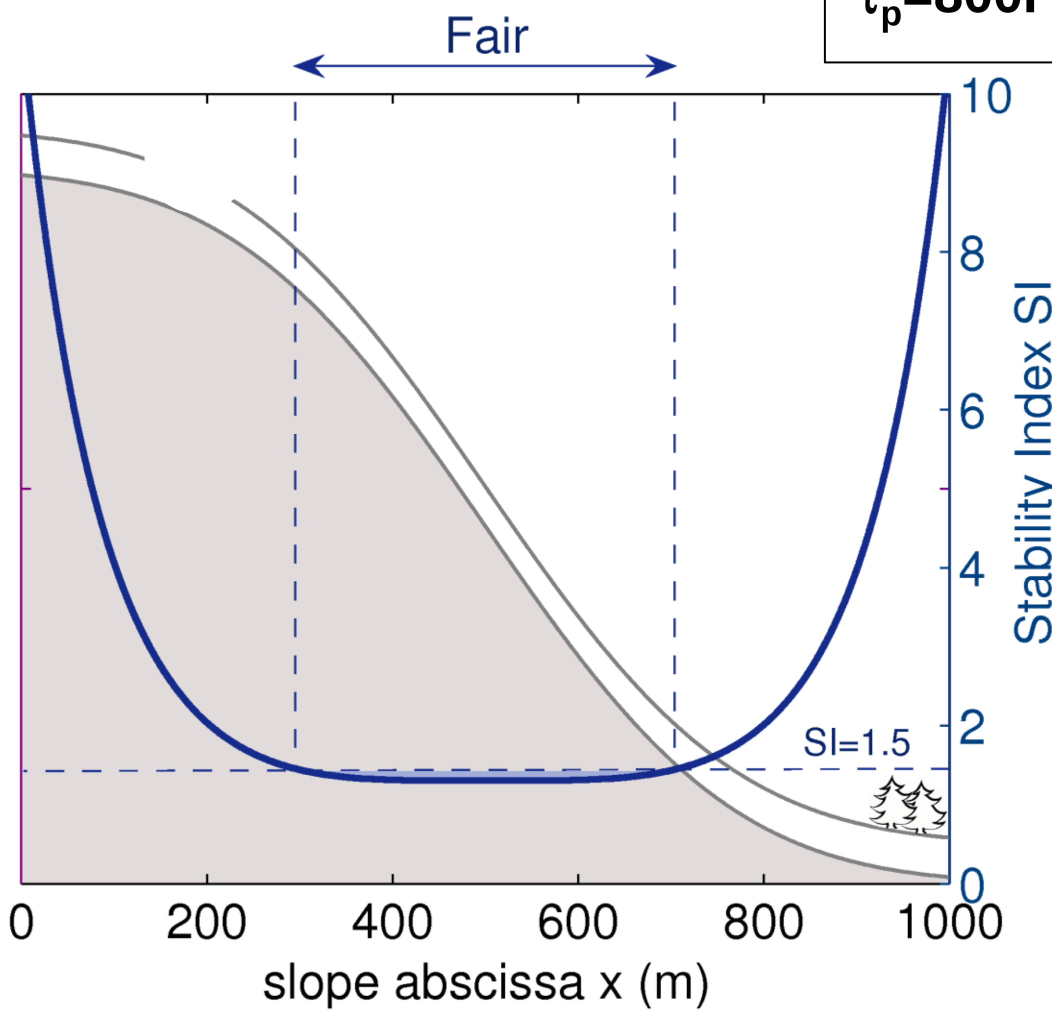

Stability index SI = $\frac{\text{shear strength}}{\text{shear stress}}$ = $\frac{\tau_p}{\tau_{xz}}$

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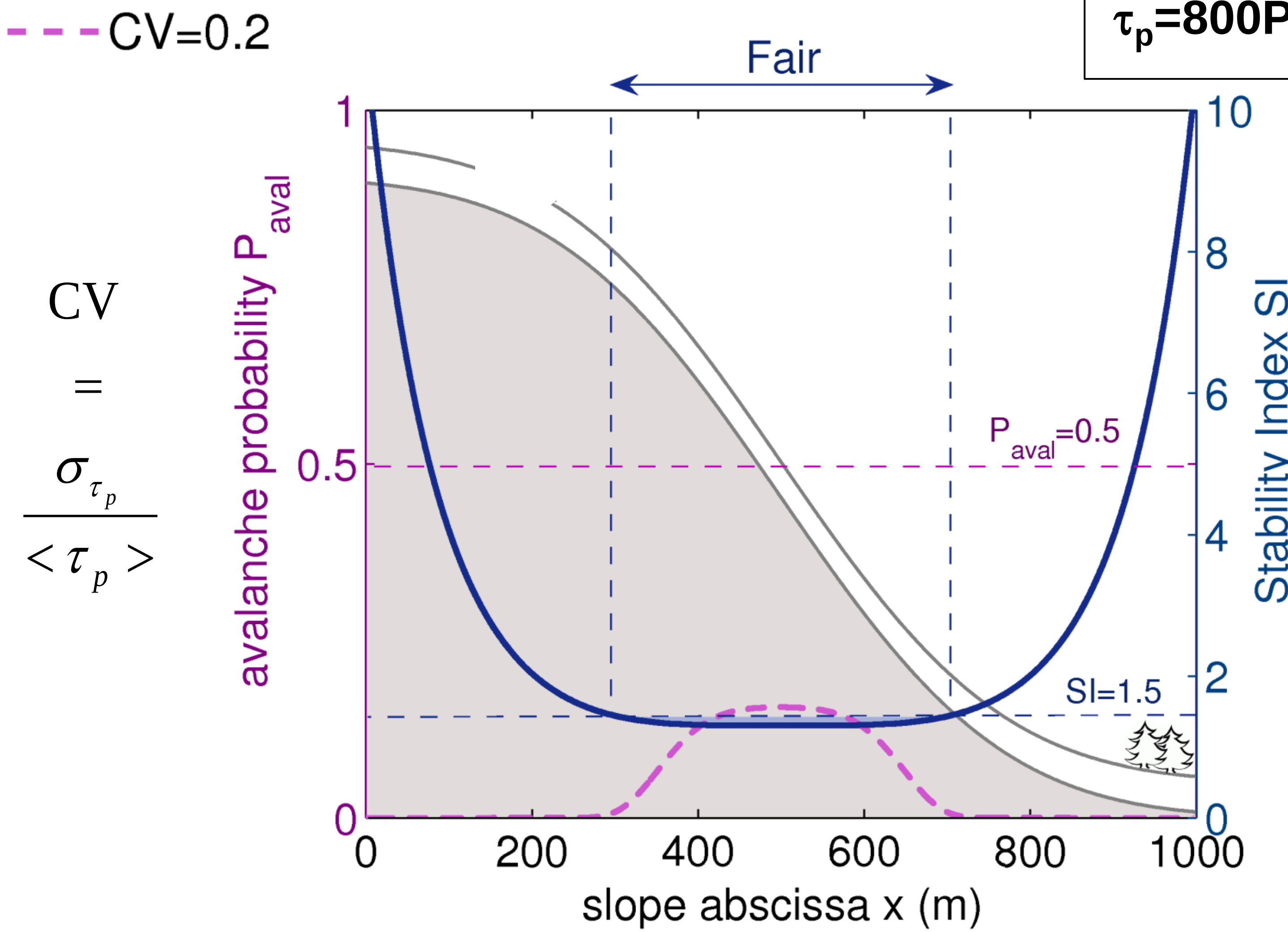

$$CV = \frac{\sigma_{\tau_p}}{<\tau_p>}$$

$$\text{Stability index SI} = \frac{\text{shear strength}}{\text{shear stress}} = \frac{\tau_p}{\tau_{xz}}$$

Results

Slope stability evaluation

h_z=50cm
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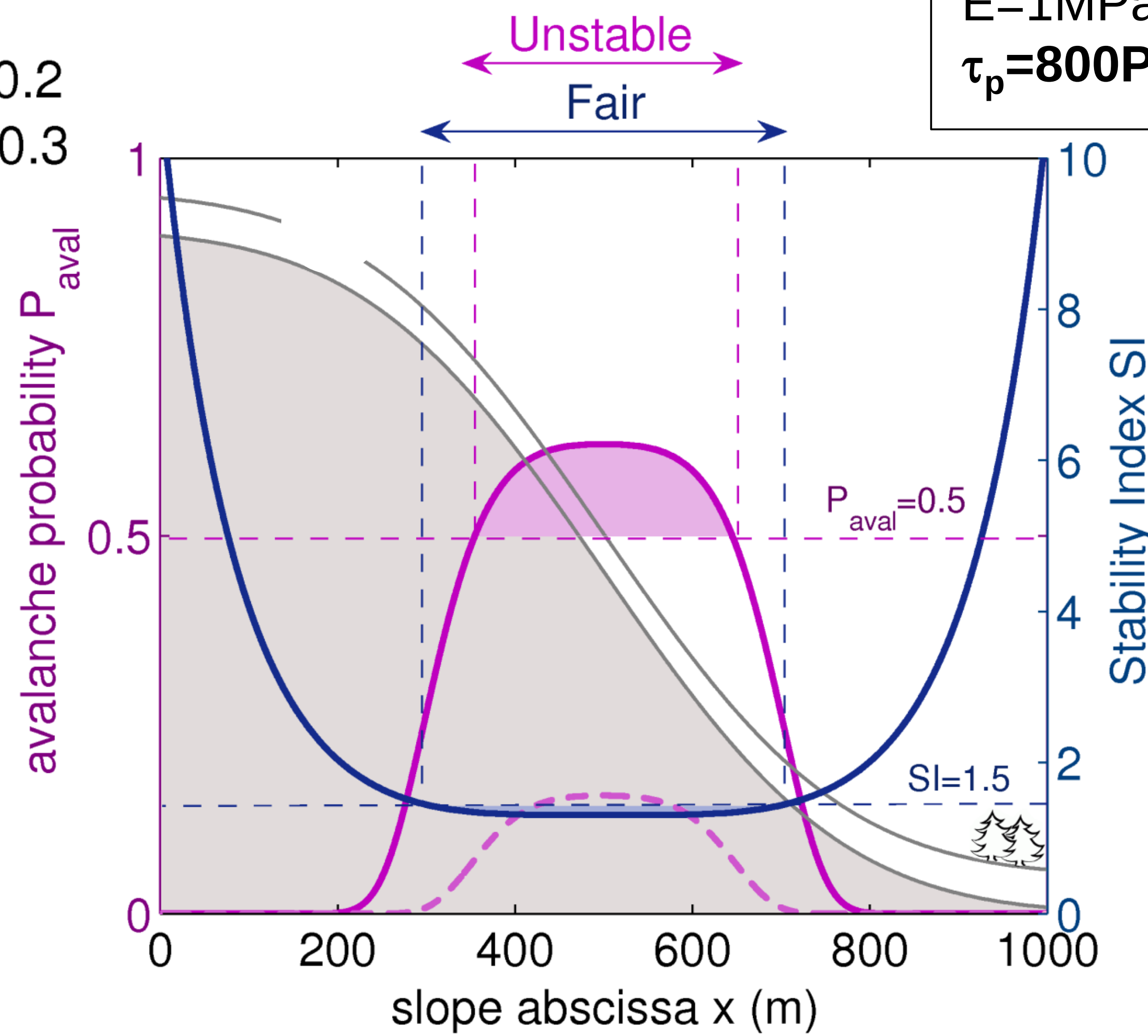
τ_p=800Pa

CV=0.2 (dashed line)
CV=0.3 (solid line)



$$CV = \frac{\sigma_{\tau_p}}{\langle \tau_p \rangle}$$

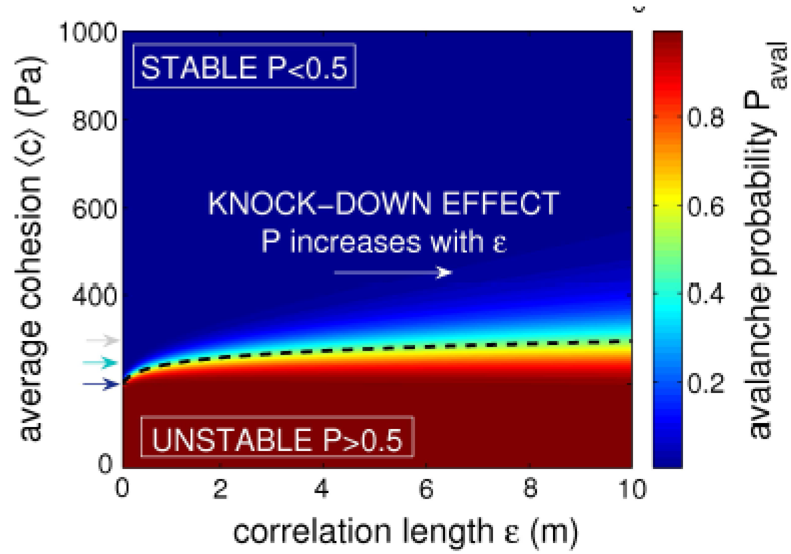
Stability index SI

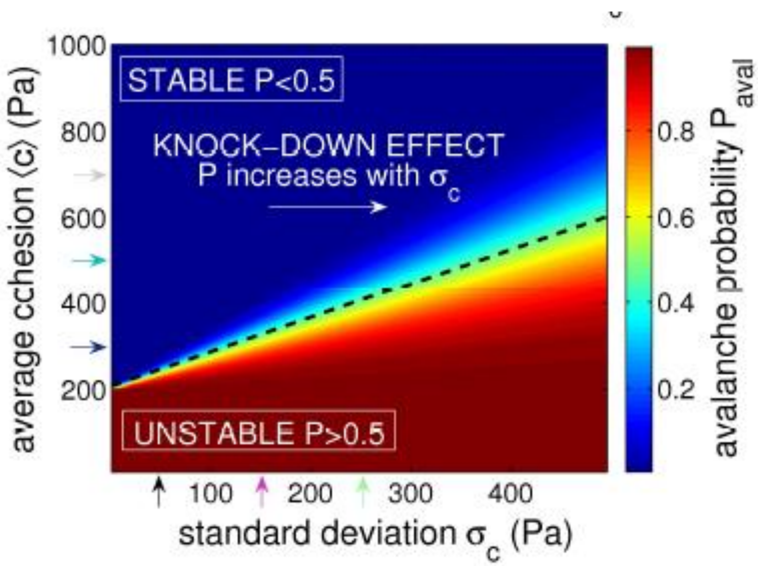
$$= \frac{\text{shear strength}}{\text{shear stress}} = \frac{\tau_p}{\tau_{xz}}$$

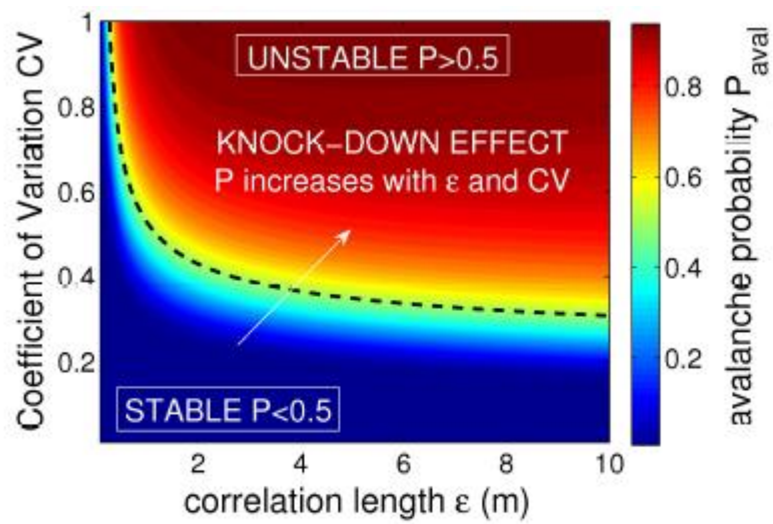
Results

Slope stability evaluation

$$P_{\text{aval}} = \frac{1}{2}\left[1+\text{erf}\left(\frac{\rho g h F - f_1 < c >}{\sigma_c\sqrt{2 f_2}}\right)\right]$$







Conclusions

- **Mechanical-statistical model of the slab-weak layer system**

→ the spatial variations of WL mechanical properties (shear strength);
→ a shear quasi-brittle constitutive law for the WL;
→ stress redistribution effects by elasticity of the slab;

… to study the influence of weak layer shear strength spatial variability

on

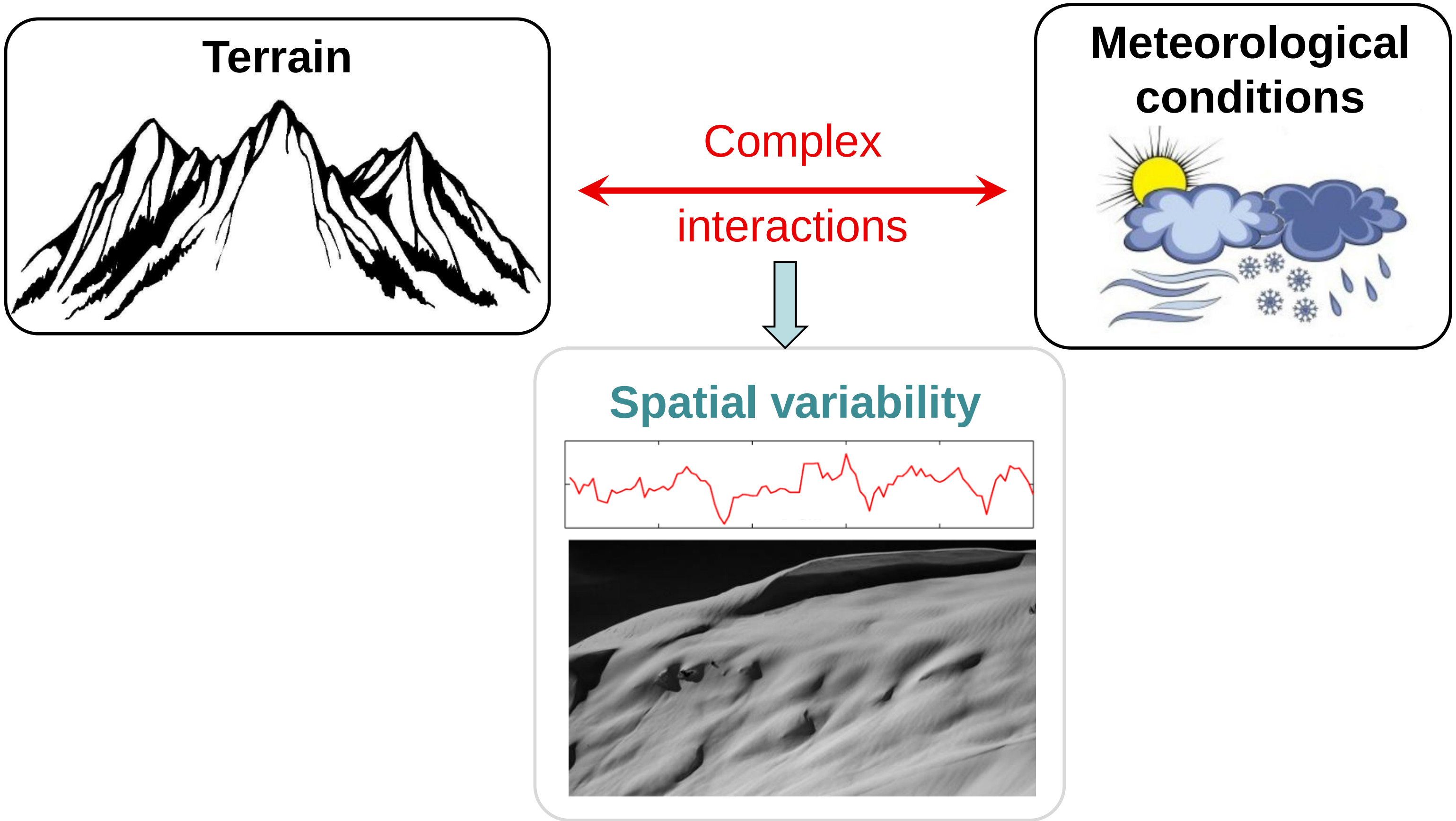
Failure initiation / **snow stability**

Very important "**knock-down**" **effect** on slope stability highlighted

- **An original hazard/geophysically oriented application of the reliability framework**

Outlooks

- Evaluation of the complex link between spatial variability, terrain and meteorological conditions



- Coupling with extreme snowfall for the regional assessment of avalanche release depths (Gaume et al., 2013b)

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Thanks for your attention!