Experimental detection of snowfalls vs. avalanches synchronization and link to prediction uncertainty

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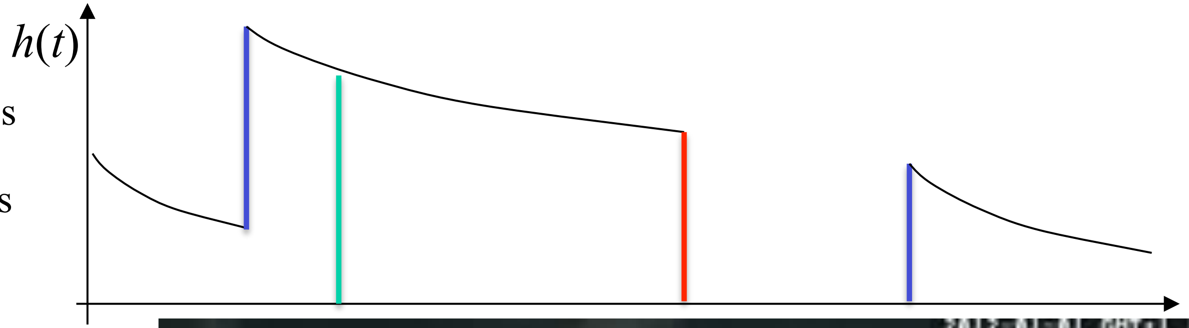
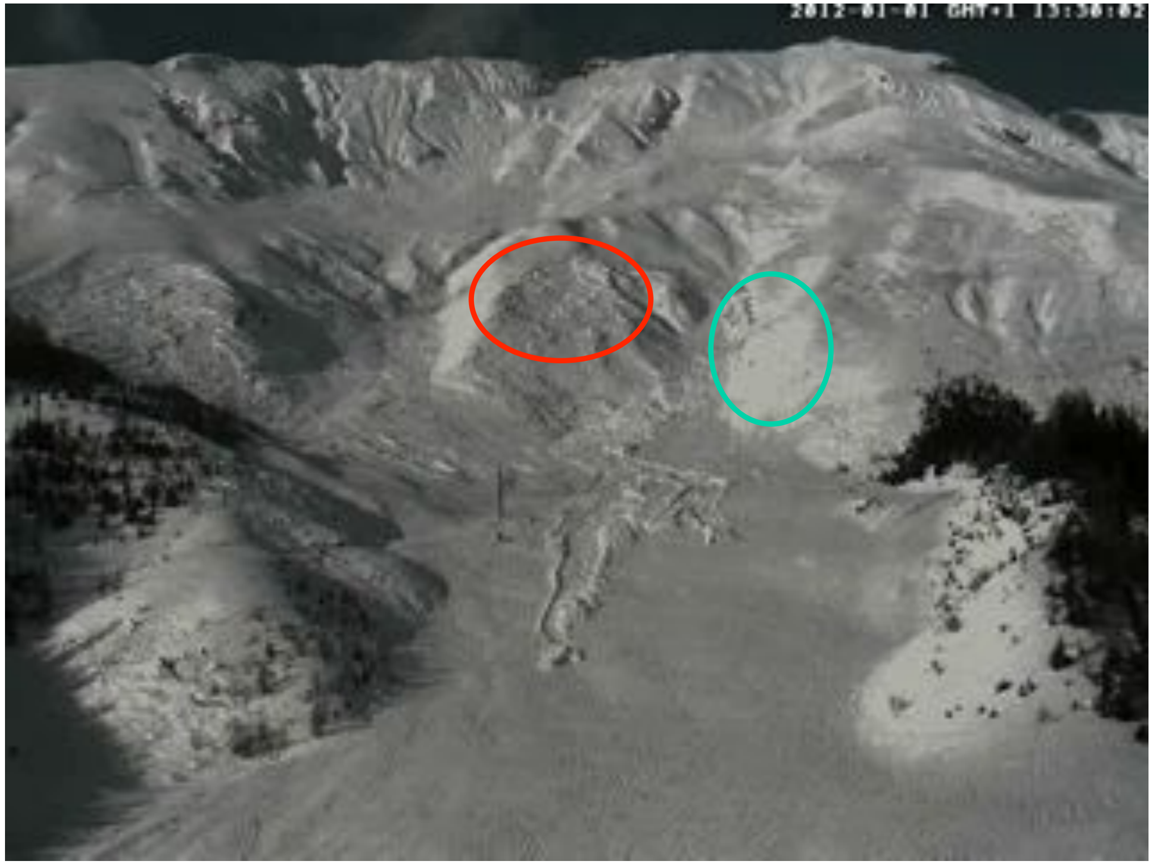
Avalanche occurrence



Complicated problem, multiple dynamics

Snowfall + Compaction + Avalanches

↓ stochastic ↓ deterministic ↓ stochastic



Model

Dephasing between snowfall and avalanche occurence

Restricted set of physical parameters

(Perona et al. 2012)

↓

Aim

Validation

With statistics from field

↓

Focus on

Role of compaction

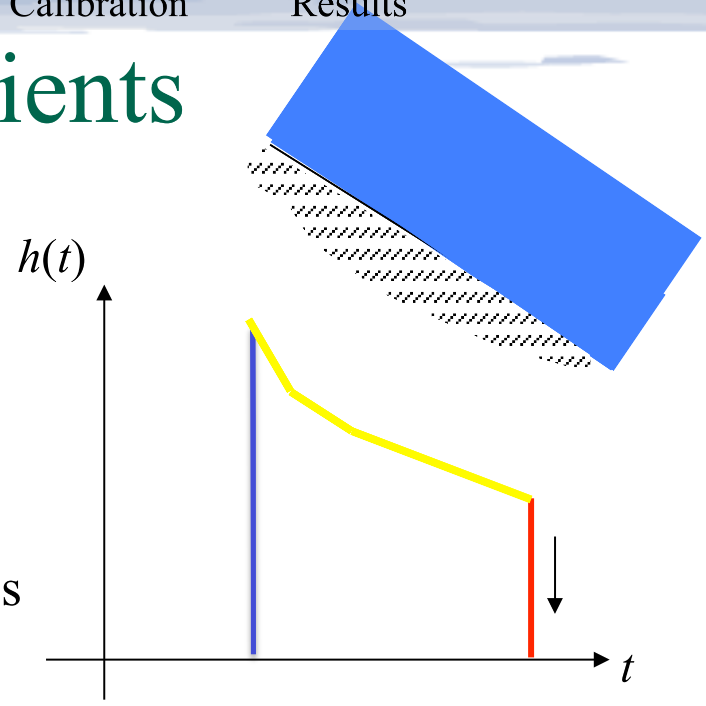
Role of slope

Modelling ingredients

Stochastic snow events

Poisson stochastic process

Rate λ=1/τ



Deterministic compaction

State-dependent compaction rate

Accounts for metamorphism and mechanical properties

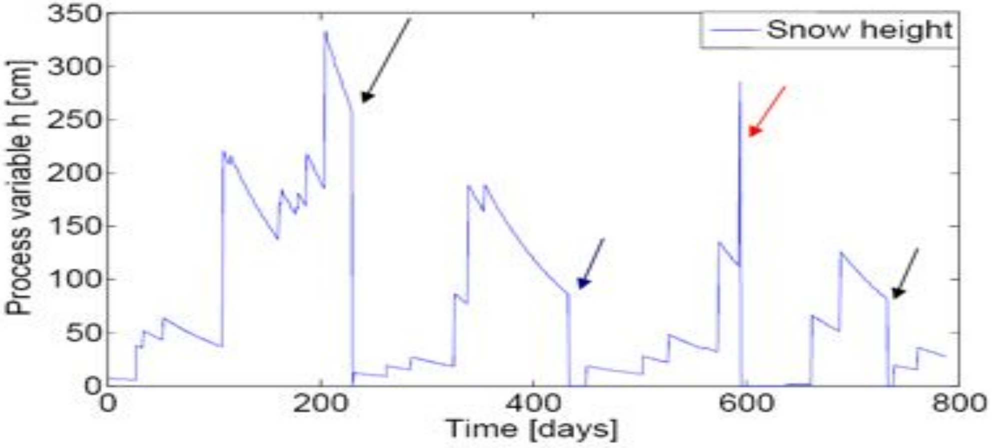
Modelled by an exponential snow depth decrease

Avalanche occurrence

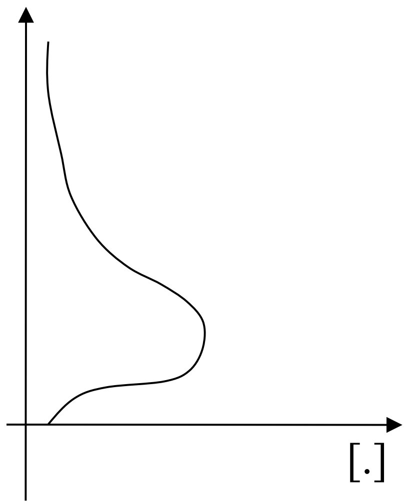
State-dependent rate Poisson process (Daly & Porporato, 2006)

$$\frac{dh}{dt} = \sum y_i \cdot \delta(t - t_i) - \rho_1 h - \sum h(t_j)\,\delta(t - t_j(h))$$

Master equation



Perona et al. 2012



Master equation approach

$p^c(h,t)$: snowdepth

$p_r(h)$: avalanchesize

$p_\tau(\tau)$: avalancheintertim

Synchronization and entropy

Synchronisation

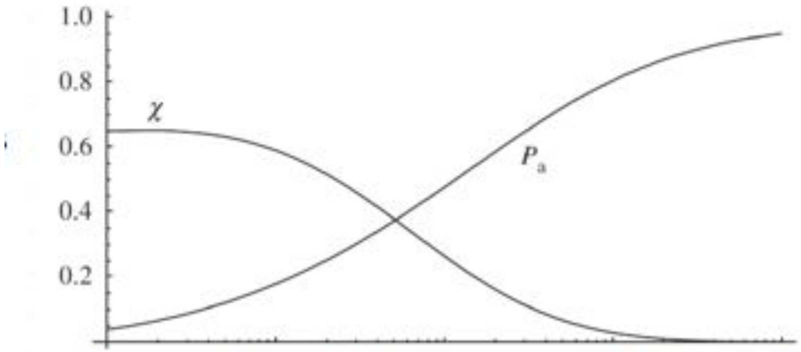
$$P_a = \frac{\bar{\nu}}{\lambda}$$

$$\bar{\nu} = \frac{1}{\tau}$$

$$\lambda = \frac{1}{\tau_p}$$

τ: intertime between avalanches events

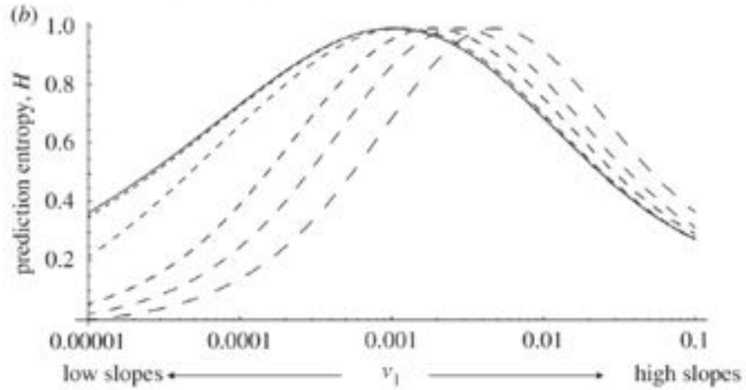
τ_p: mean snowfall events intertime



Measure of decorrelation X and synchronization Pa in function of slope. from P. Perona, et al. 2012

Prediction entropy (uncertainty)

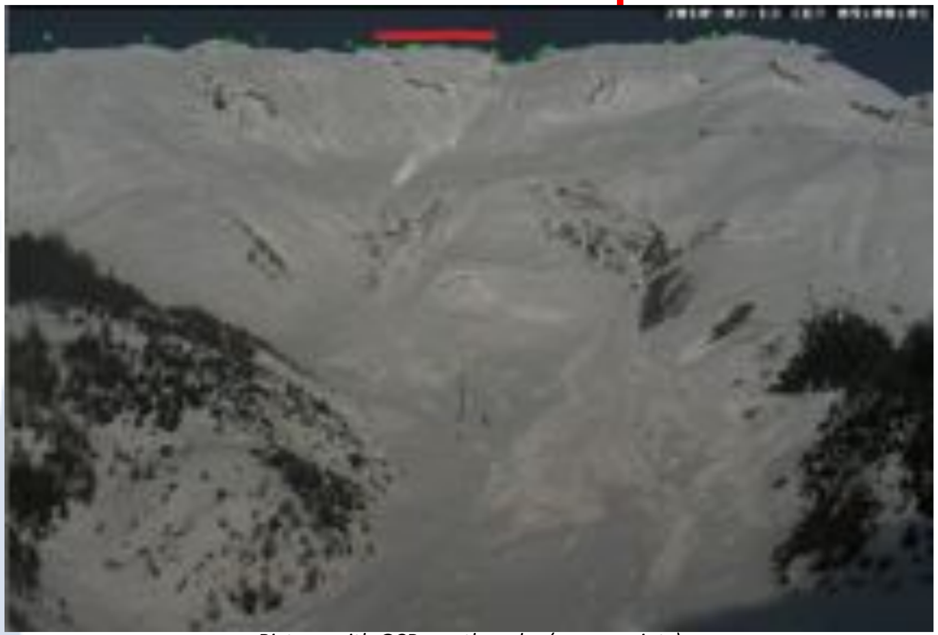
$$H = -P_a \log_2[P_a] - (1-P_a)\log_2[(1-P_a)]$$



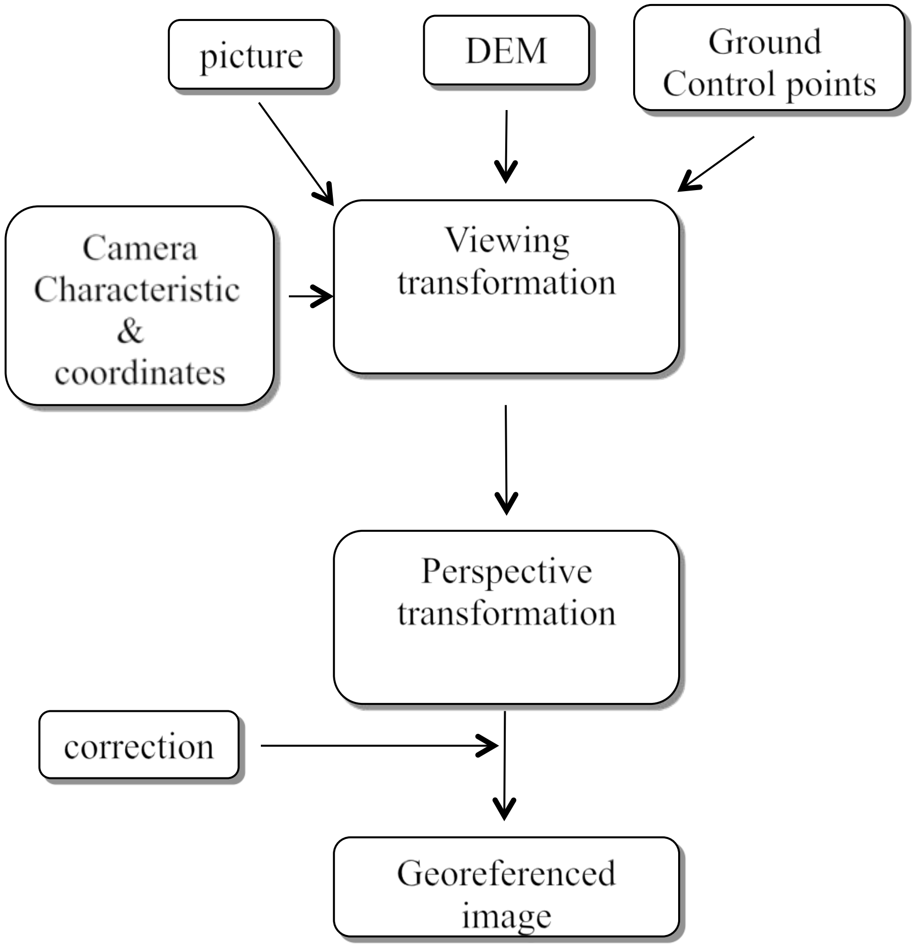
Prediction entropy as a function of slope. The dashed lines show different increasing (from small to larger dashes) compaction

Georeferenciation

Picture calibration process



Picture with GCPs on the edge(green points)

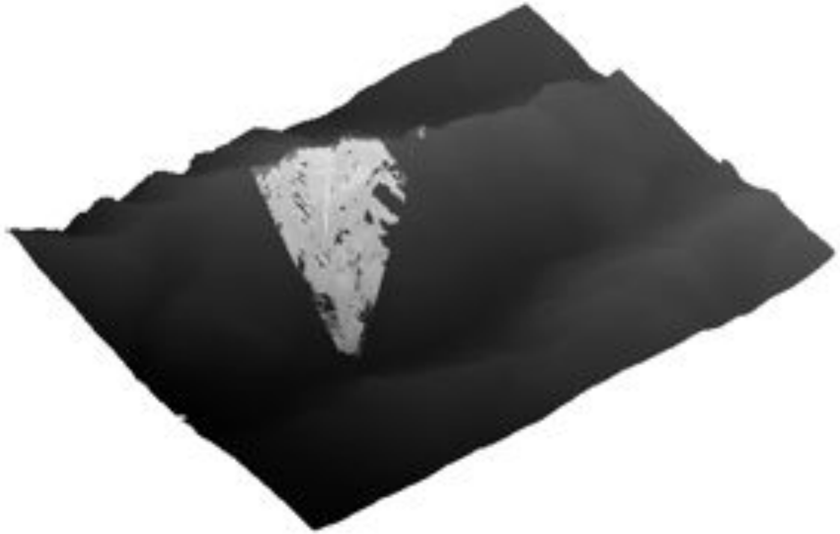


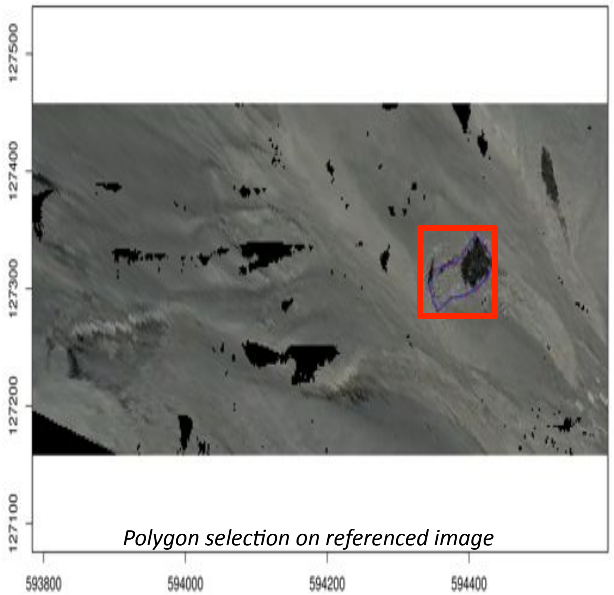
Corripio, J. G. (2003;2004)

Valley of la Sionne hillside

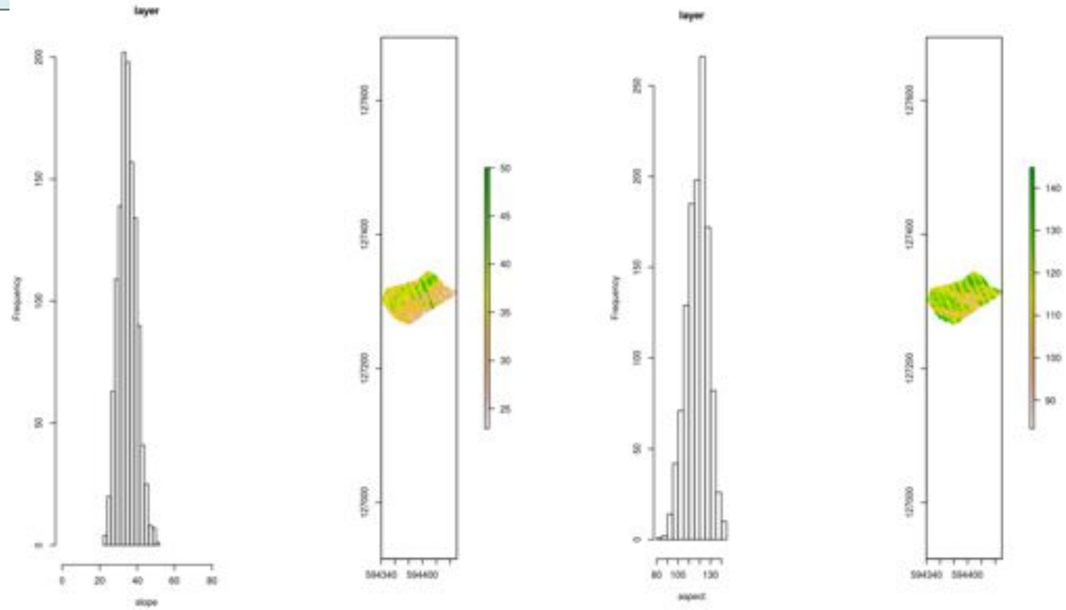
Six years record ,every thirty minutes

626 avalanches events



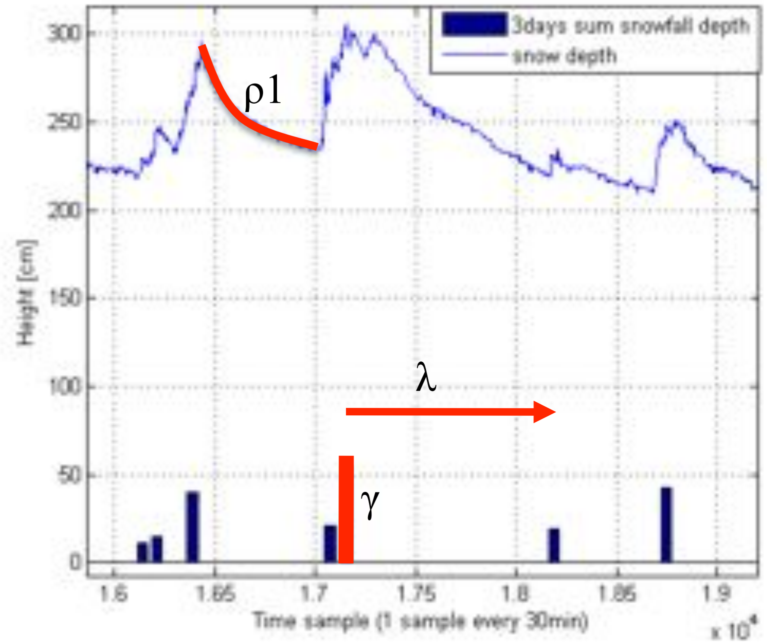


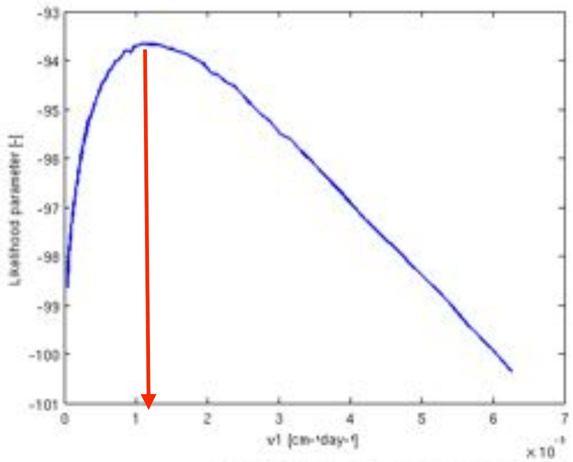
Polygon selection on referenced image

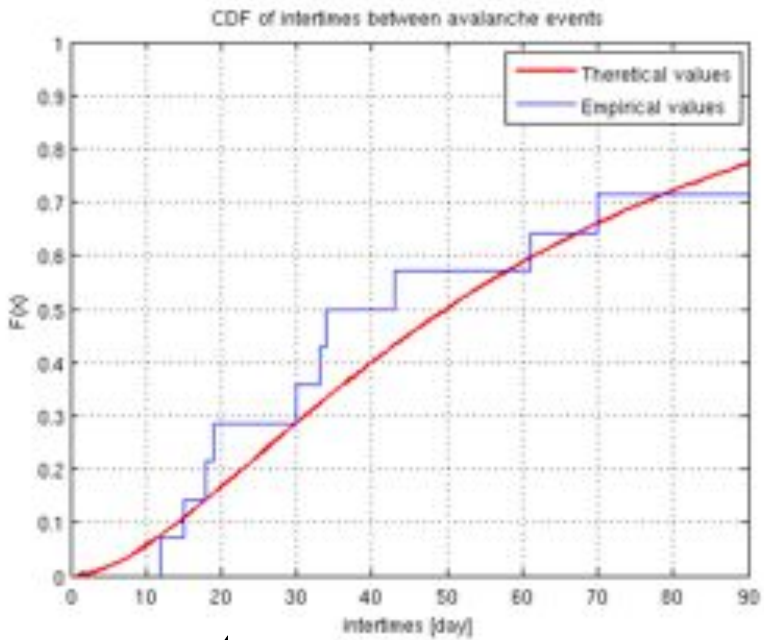


Generated slope and aspect frequencies for points within the polygon based on Corripio, J. G. (2003;2004)

Model calibration







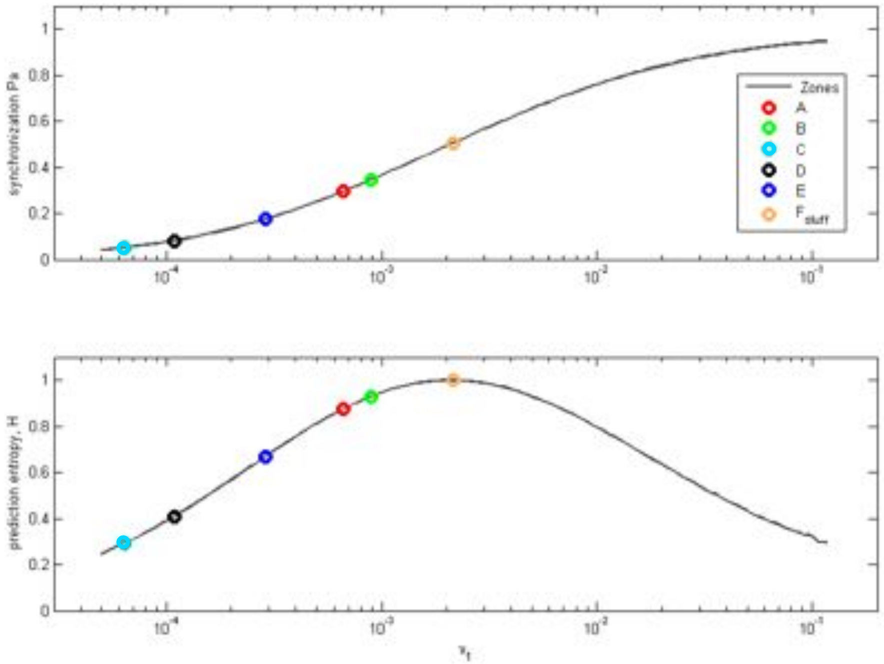
Measured parameters :

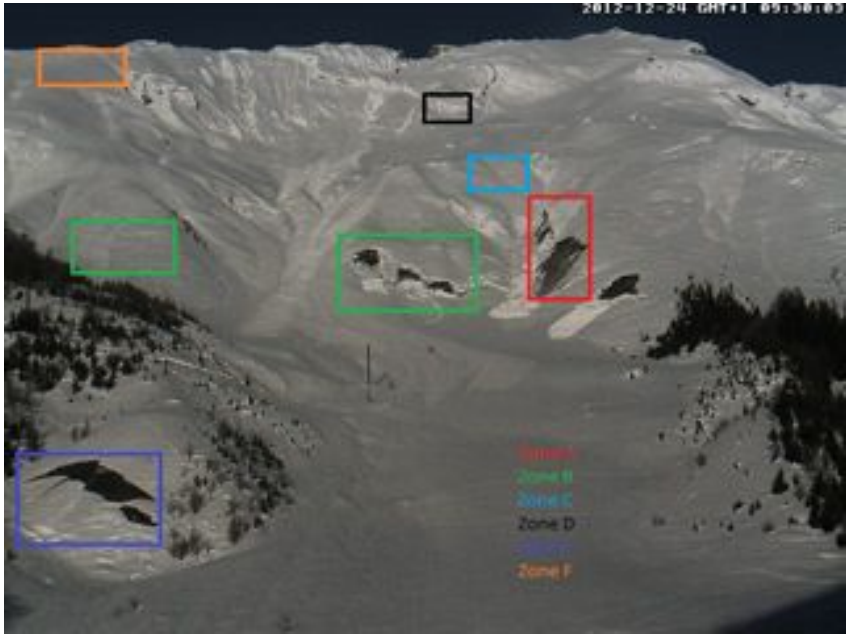
γ : snowfalls magnitude (meteo data)
λ: snowfalls intertime (meteo data + pictures)
ρ_1 : compaction (meteo data)
τ : avalanches intertime (pictures)

Fitting parameter :

ν_1 : topographic influence (slope, roughness)

Results & sensitivity analysis





Studied zones

ν_1 varies while slope constant

⇓

ν_1 = fct(slope, **roughness?**)

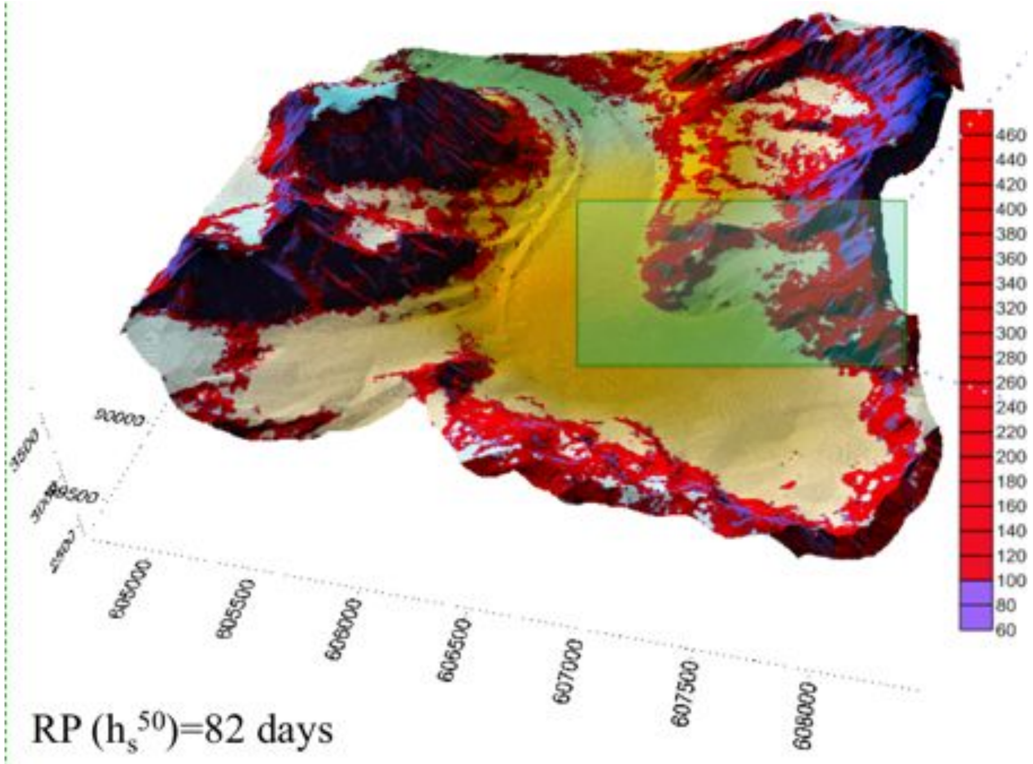
Conclusion

"Partial" validation of the model:

- little field data
- theory (punctual) vs. field (spatial)
- meteo station location (precision)
- seasonal processes

Final goal:

risk assessment from the probability of detachment.



RP (h_s^{50})=82 days

Further analysis:

- better data on compaction
- single out the role of the slope and of the terrain

Thank you for your attention !

Bibliography

- *Corripio, J. G. (2003). Vectorial algebra algorithms for calculating terrain parameters from DEMs and the position of the sun for solar radiation modelling in mountainous terrain, International Journal of Geographical Information Science* ***17****(1), 1–23*

- *Perona, P., E. Daly, B. Crouzy and A. Porporato (2012). Stochastic dynamics of snow avalanche occurrence by superposition of Poisson processes. Proc. Royal Soc. London A,* ***468****, 4193–4208*

- *Forclaz (2013). Detecting natural snow avalanche occurrence from terrestrial photography for validation of a stochastic model*

Acknowledgments

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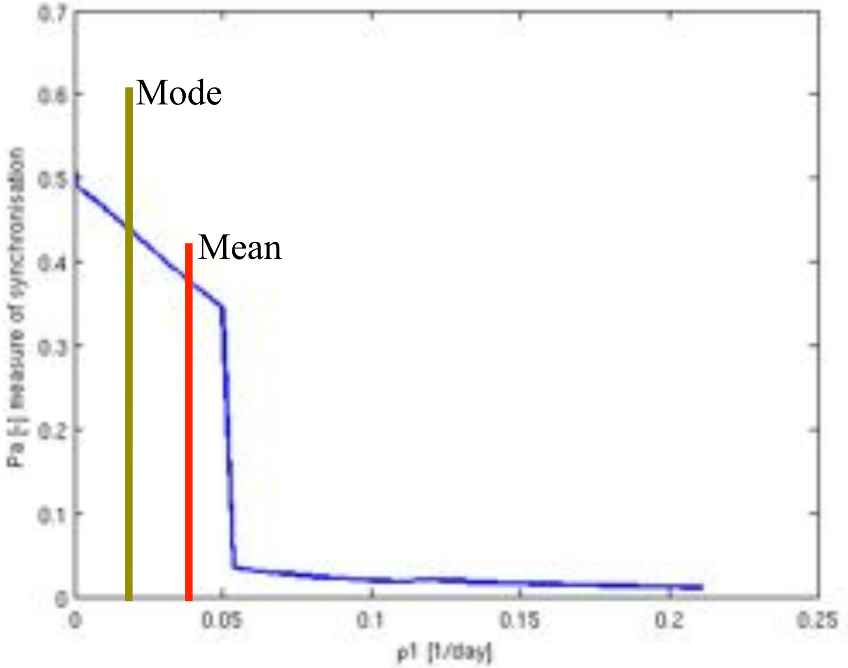

Master equation approach

PDF

$p^c(h,t)$: snowdepth

$p_r(h)$: avalanche size

$p_\tau(\tau)$: avalanche intertime

CDF

$$P(\tau) = -e^{-\frac{\lambda \nu_1 \tau}{\nu_1 + \gamma \rho_1}} \left(\frac{\gamma \rho_1}{\nu_1 - e^{-\rho_1 \tau} \nu_1 + \gamma \rho_1} \right)^{-\frac{\gamma \lambda}{\nu_1 + \gamma \rho_1}}$$