Atelier neige : wet snow

Wet snow avalanches : what's up ?

Mohamed Naaim and Nicolas Eckert

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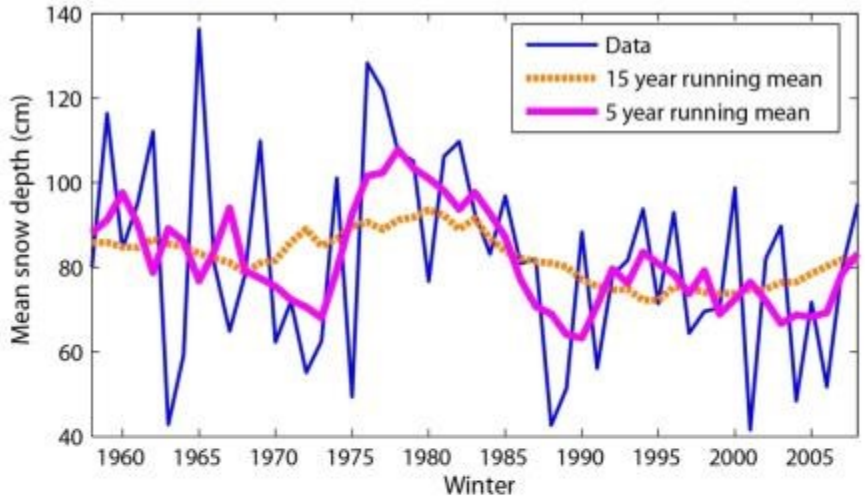
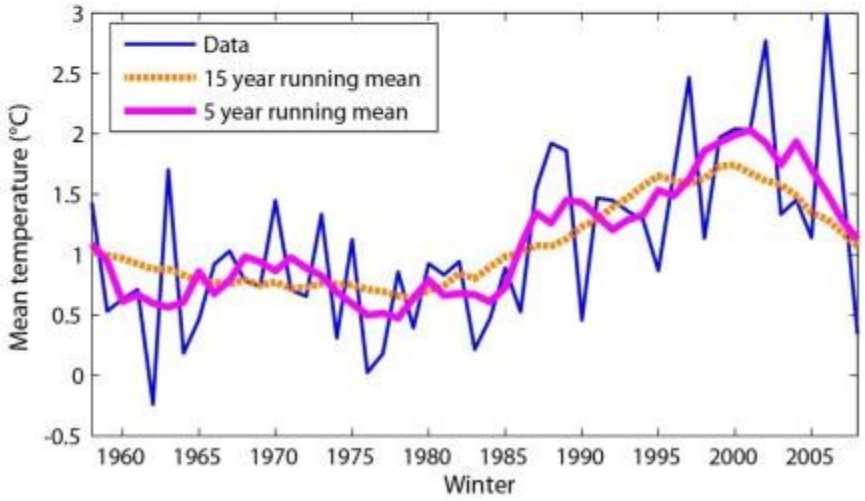
French Alps: recent winter snow/climate change





Synthetic snow and weather covariates at 2400 m in the French Alps : annual signal and underlying trends. (top) Modelled Crocus mean winter snow depth. (bottom) Modelled SAFRAN mean winter temperature.

Durand et al., JAMCS 2009ab

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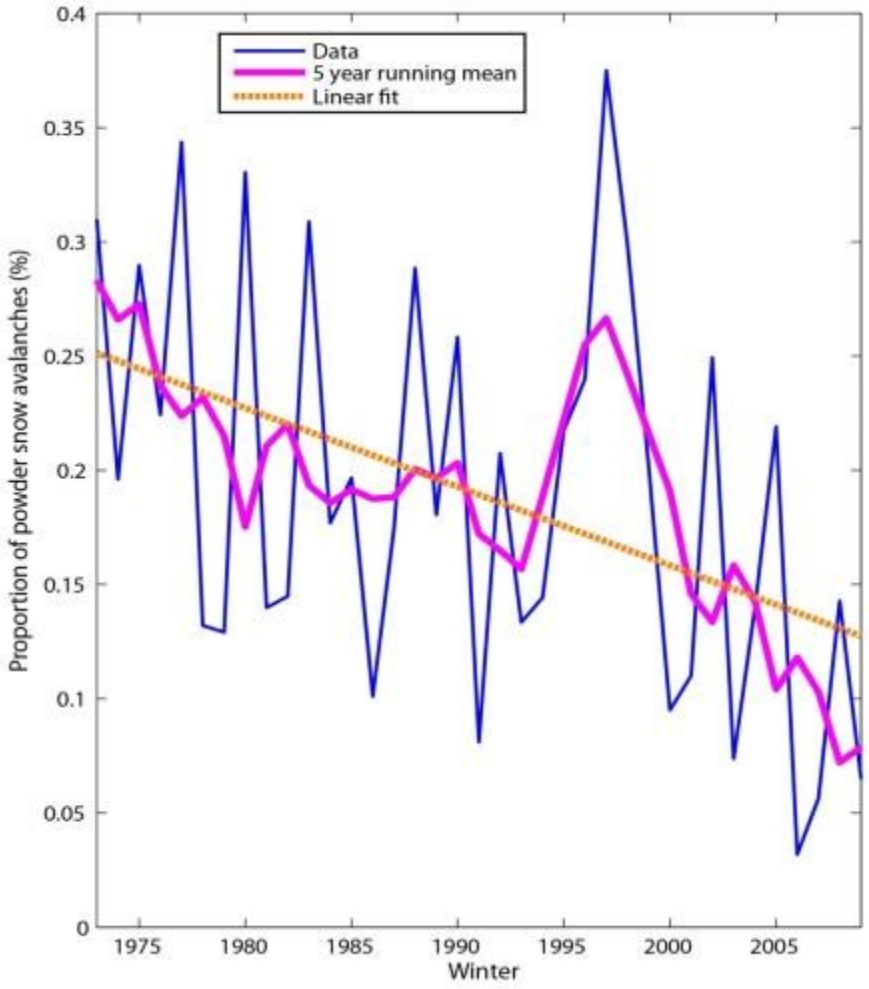
French Alps: proportion of powder snow avalanches



The proportion of powder avalanches decreases (Eckert et al., JOG 2009)

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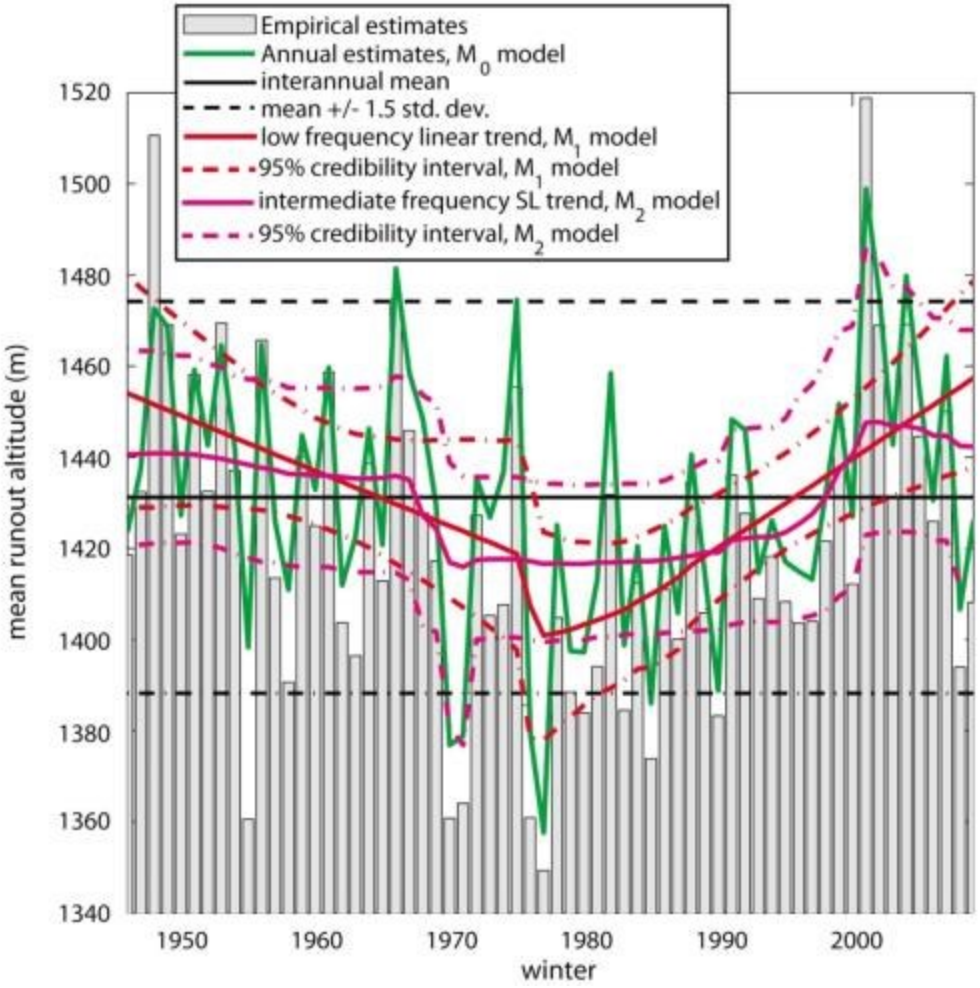
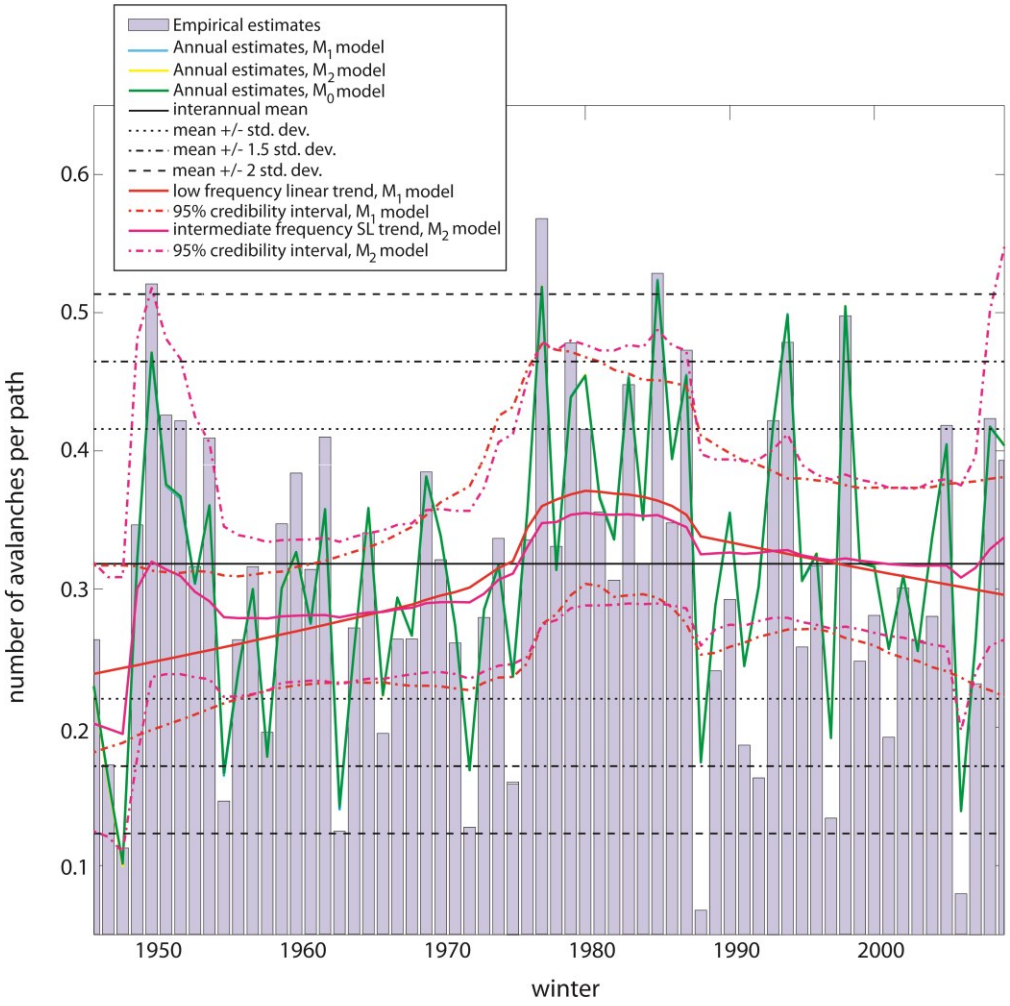
French Alps: avalanche runout altitude



Increase since 1980 (Eckert et al., Jclim 2010)

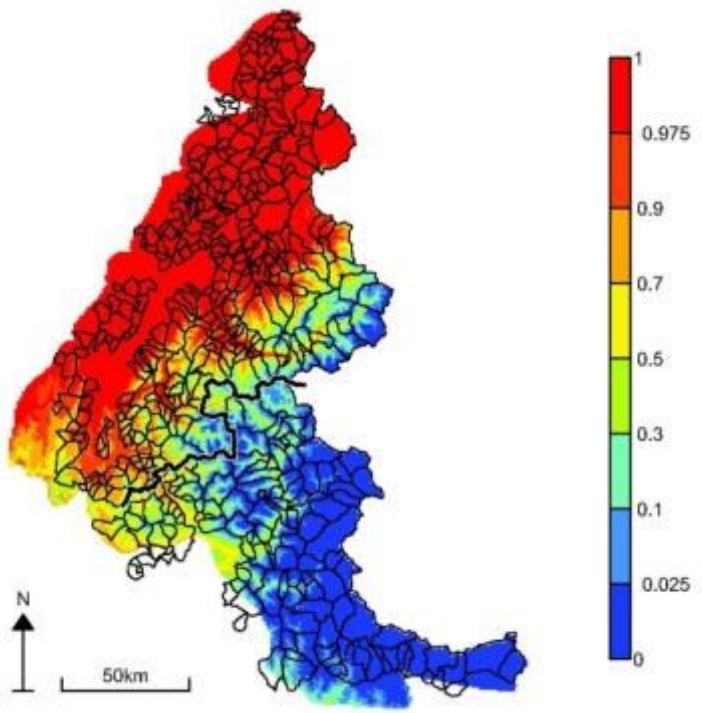
French Alps: total avalanche number

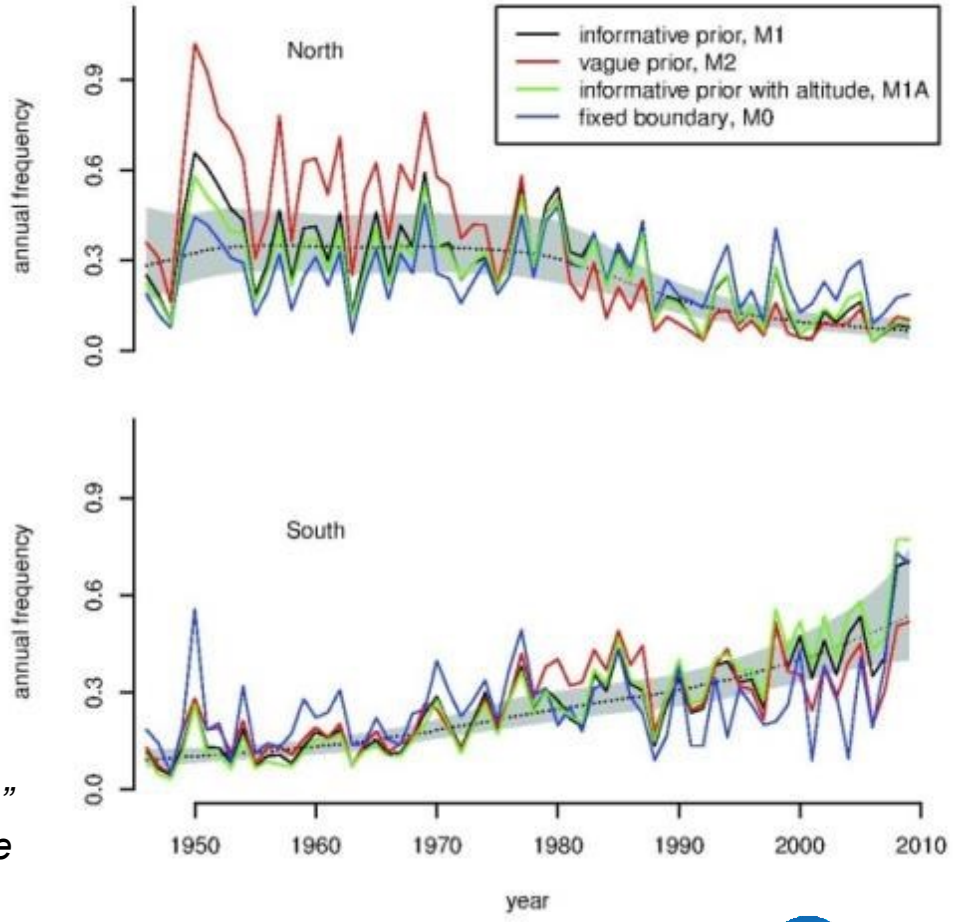


Slight decrease since 1980, but strong interannual variability (Eckert et al. ClimChange 2010)

Changes in types/regimes/season?

French Alps: spatial and altitudinal effect

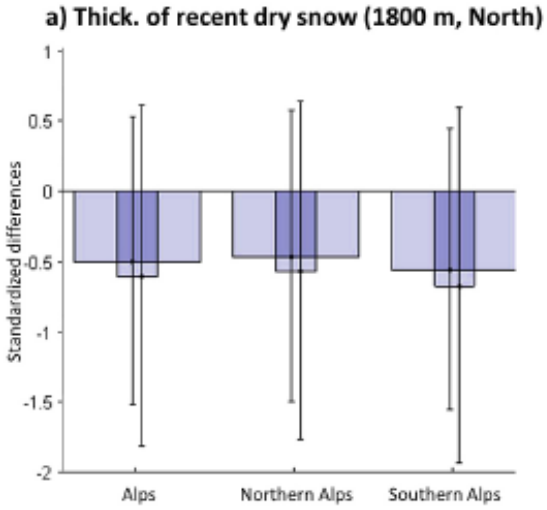


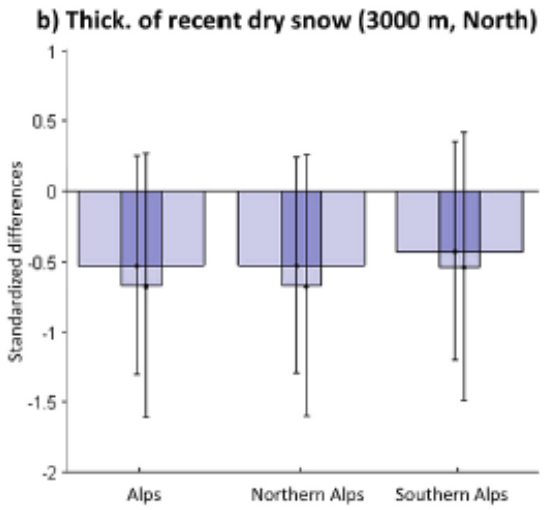


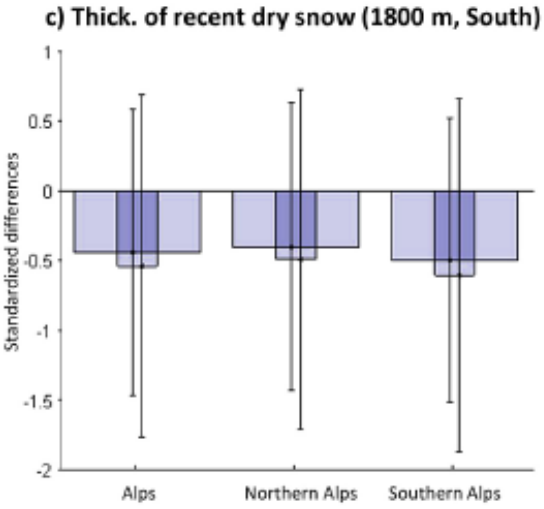
Probability for each township to belong to the "north" (low altitude) zone, with altitude included in the classification. Lavigne et al. (Environmetrics ,2012).

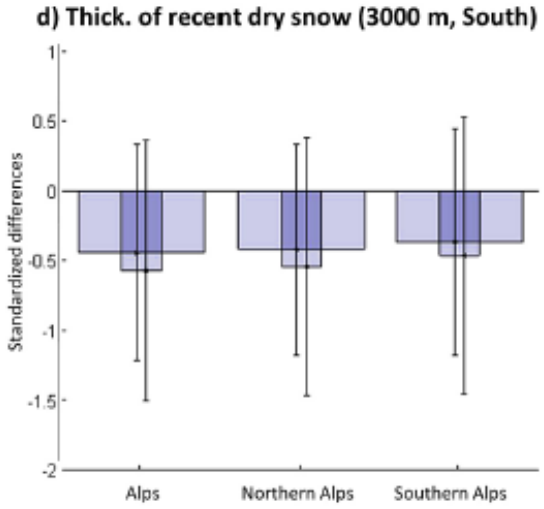
Corresponding time trends, from Lavigne et al., (J. Roy. Stat. Soc. 2015).

Prognose : total snow depth decrease



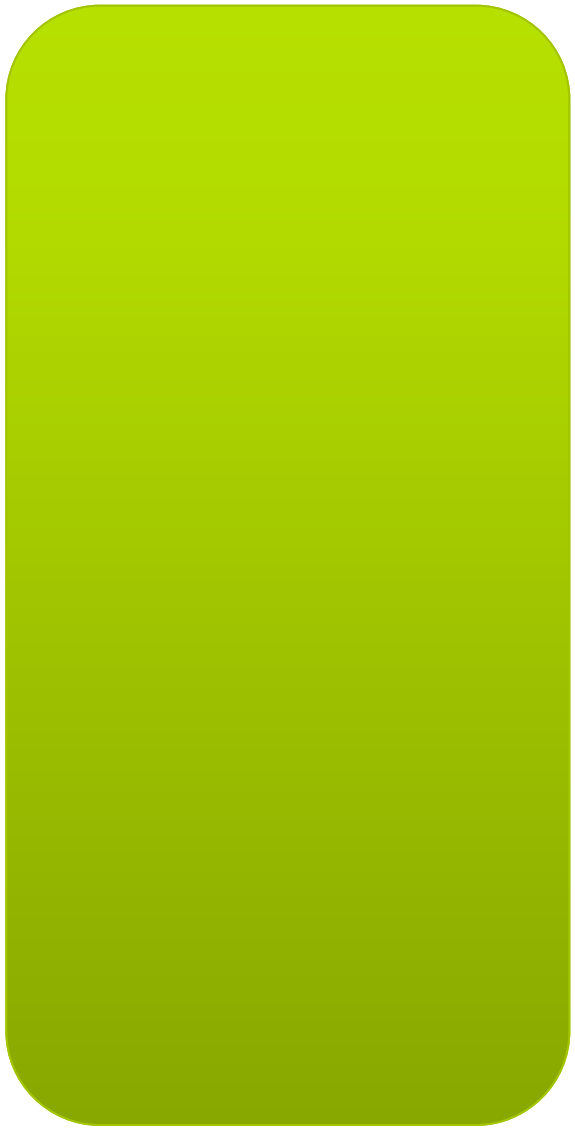


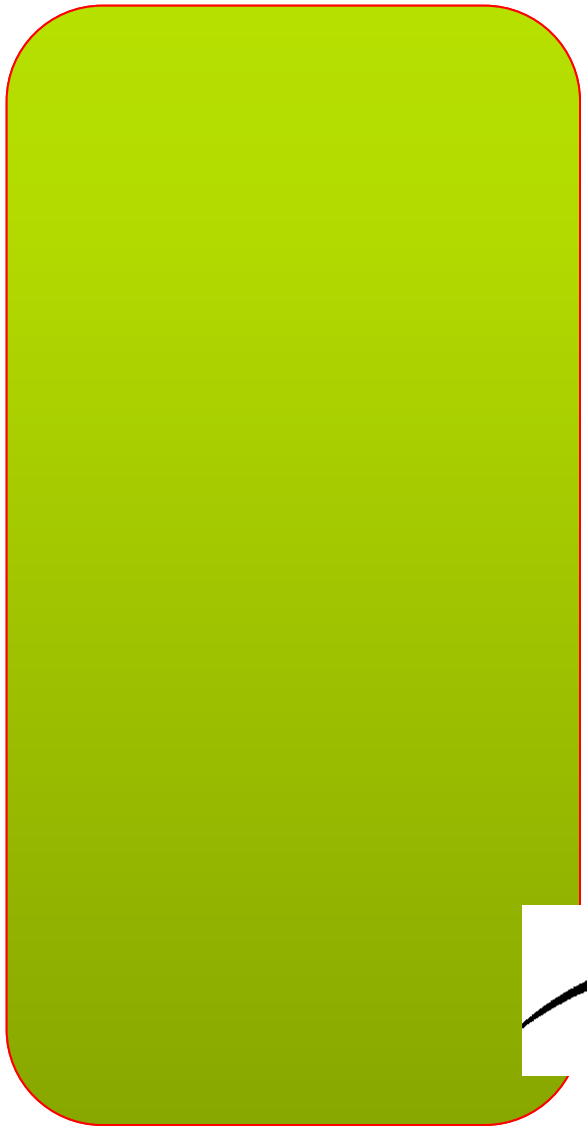




Castebrunet et al. TC 2014

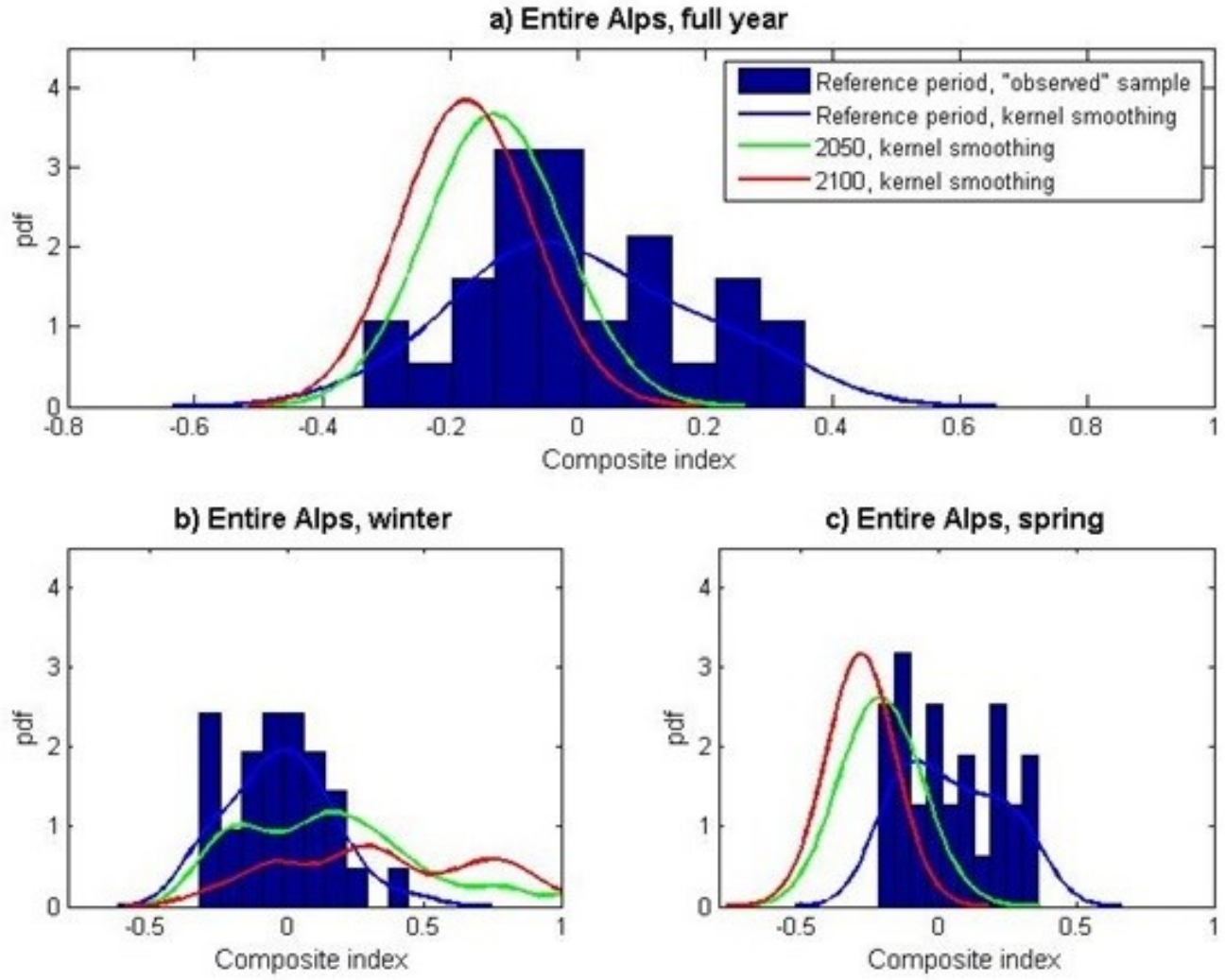
Prognose : wetsnow





Castbrunet et al.
TC 2014

Prognose: shift of avalanche activity



Avalanche activity index over the reference period (1960-90, Castebrunet et al., Clim. Past 2012) and in 2020-50 and 2070-2100,

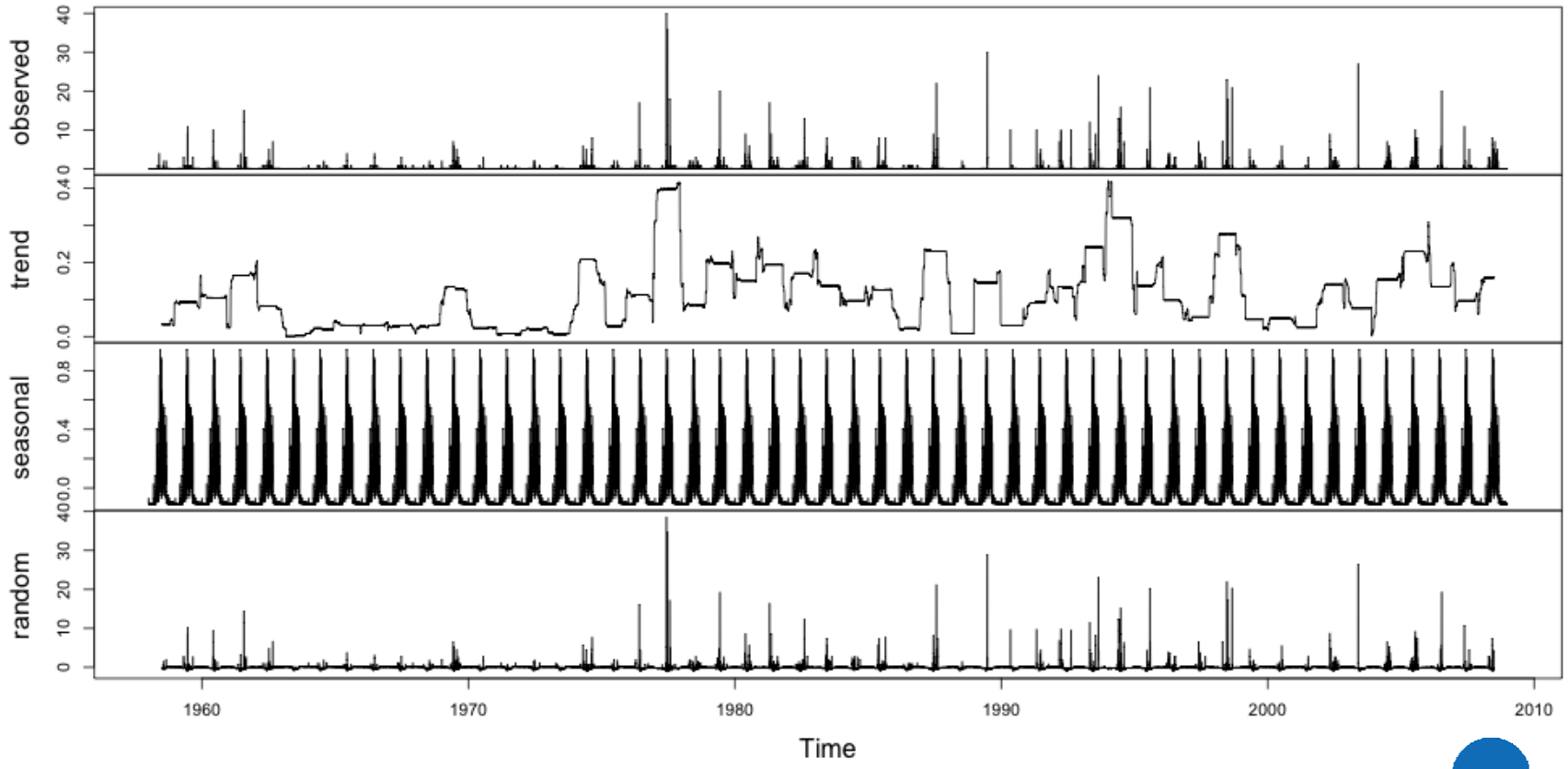
Castebrunet et al. (TC 2014).

More full winter wet snow avalanches!

In data also?

Mont Blanc massif : number of snow avalanches

EPA chronicle



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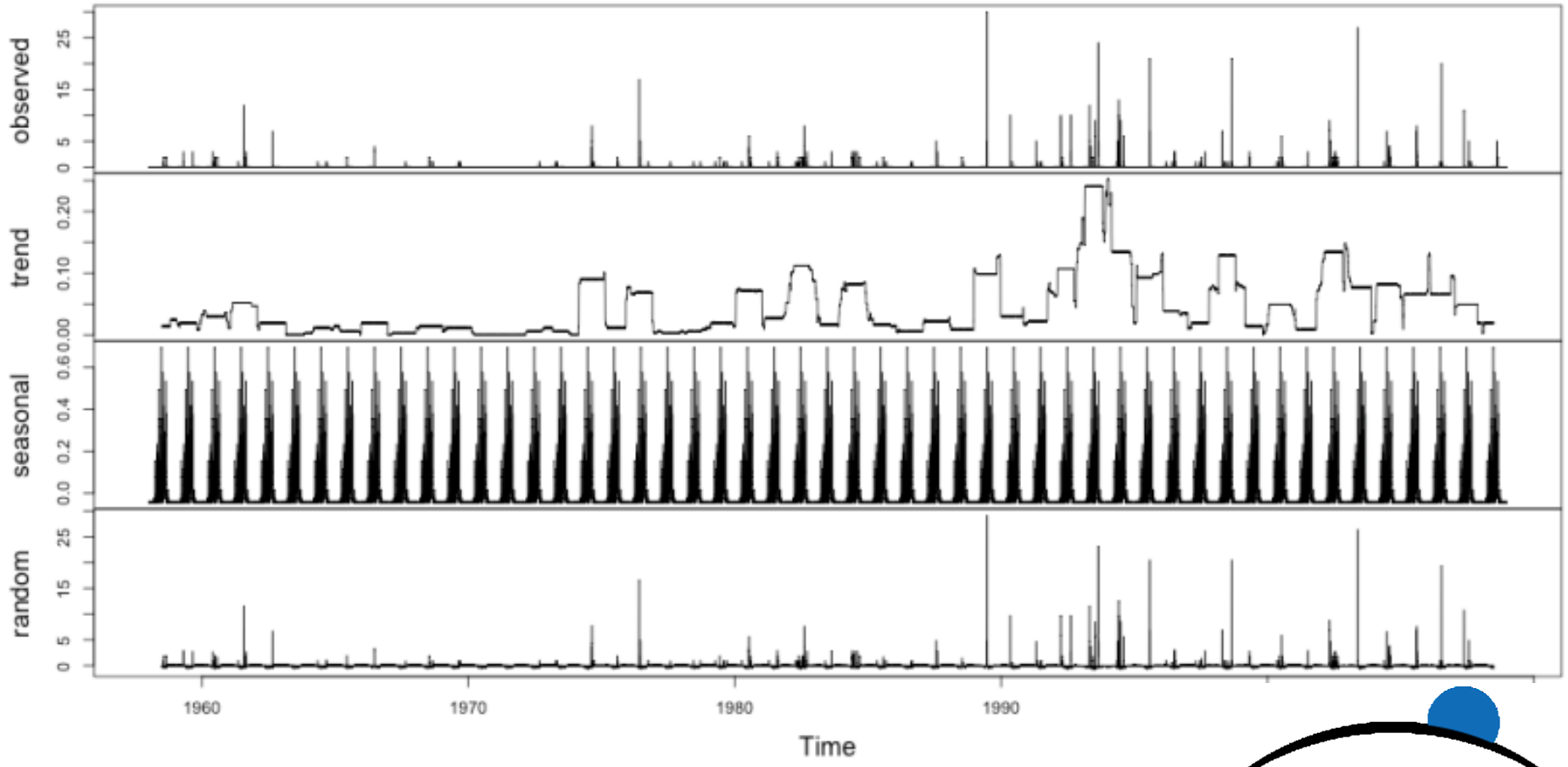
Mont Blanc massif : number of wet snow avalanches

Crossing EPA and Safran-Crocus reanalysis (Durand et al. 2009)



Avalanche with snow mantle made of at least 30 % of wet

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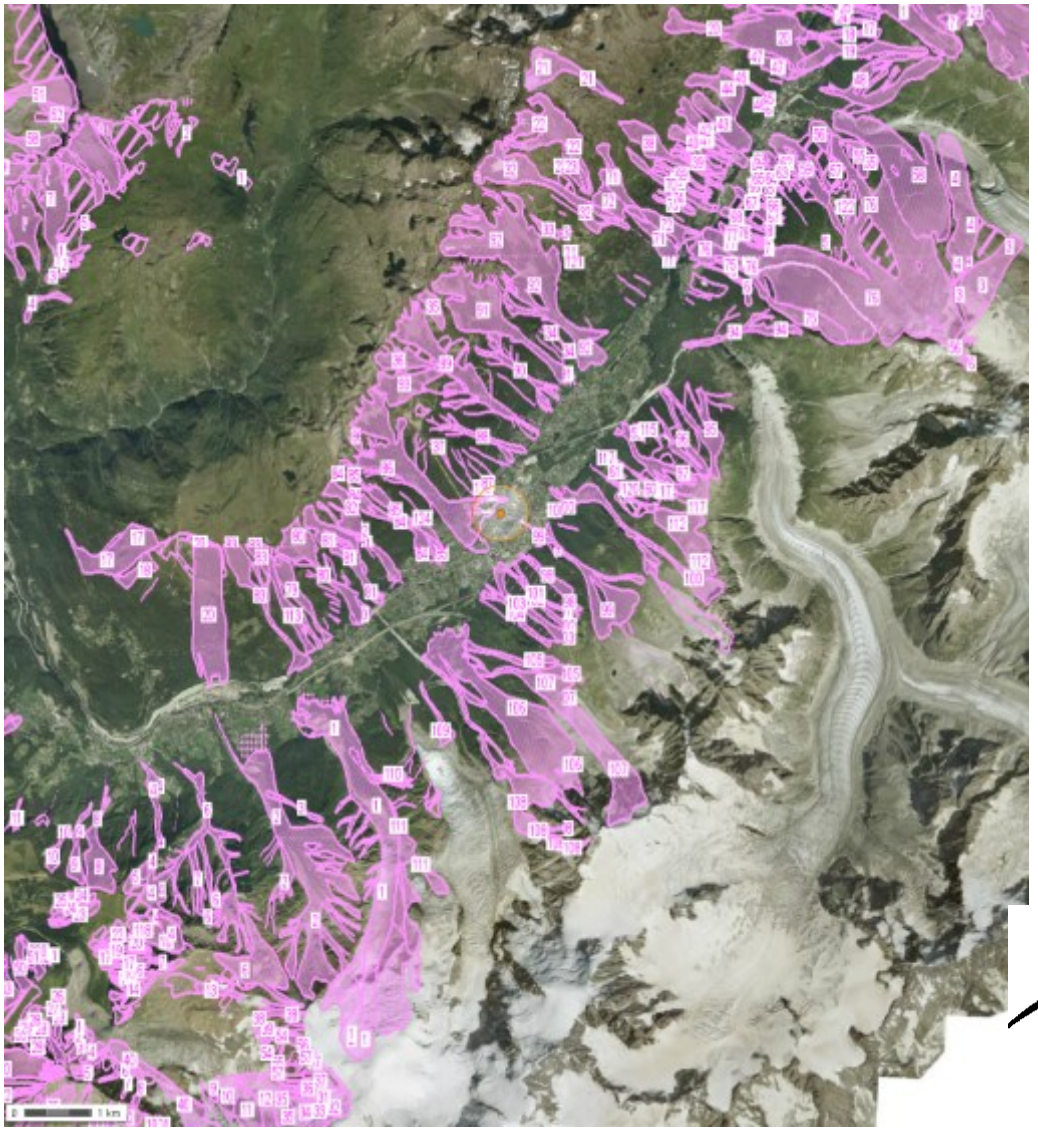
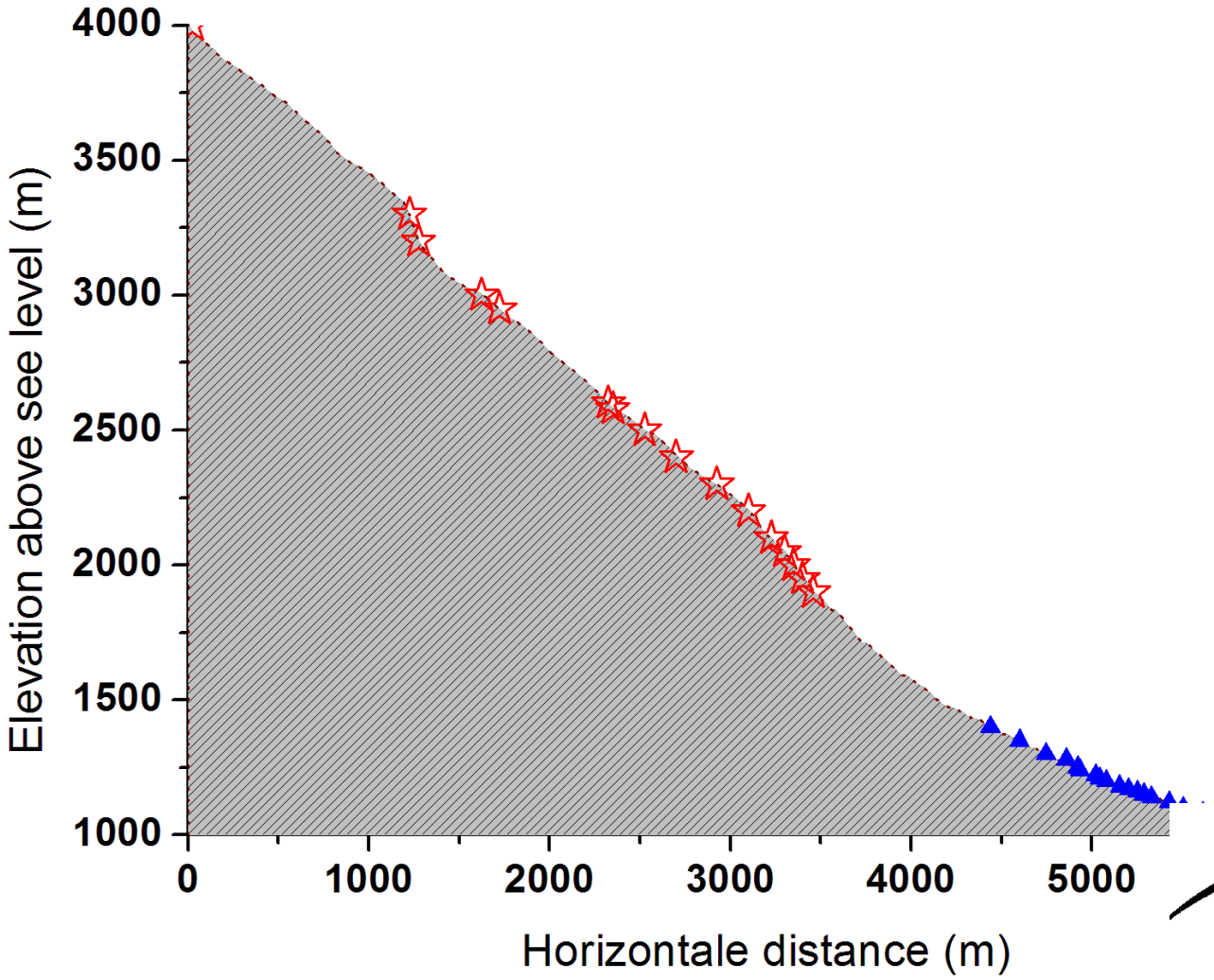
Chamonix valley : 730 avalanches reanalyzed

EPA chronicle



Chamonix valley : 730 avalanches reanalyzed

EPA Chronicle



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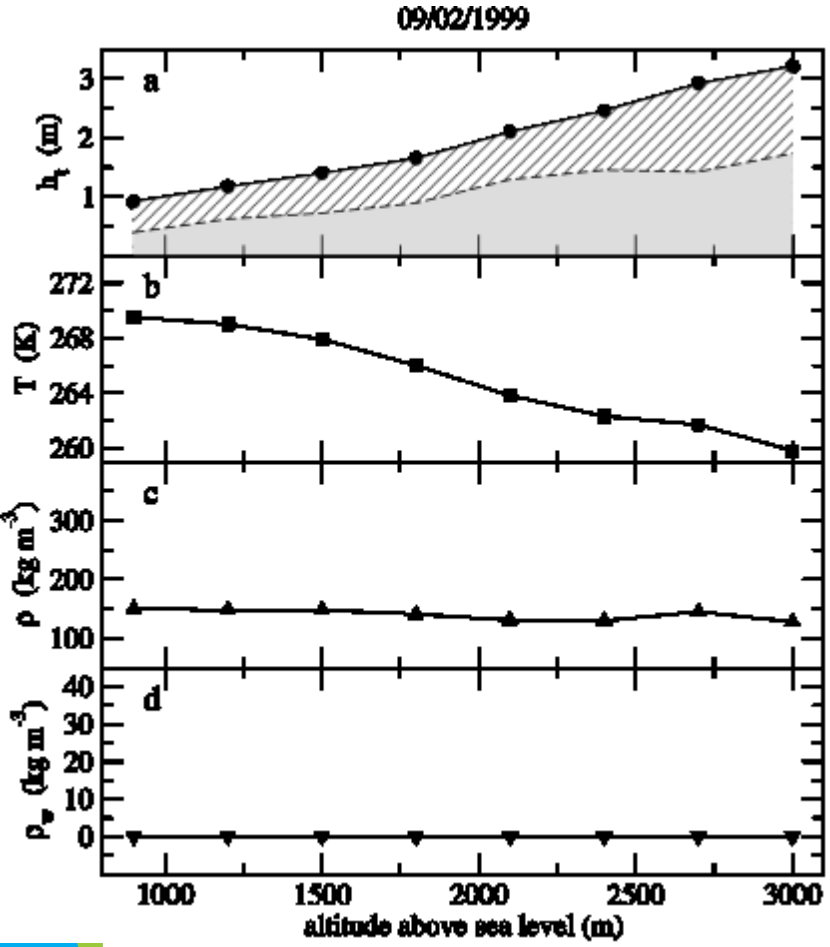
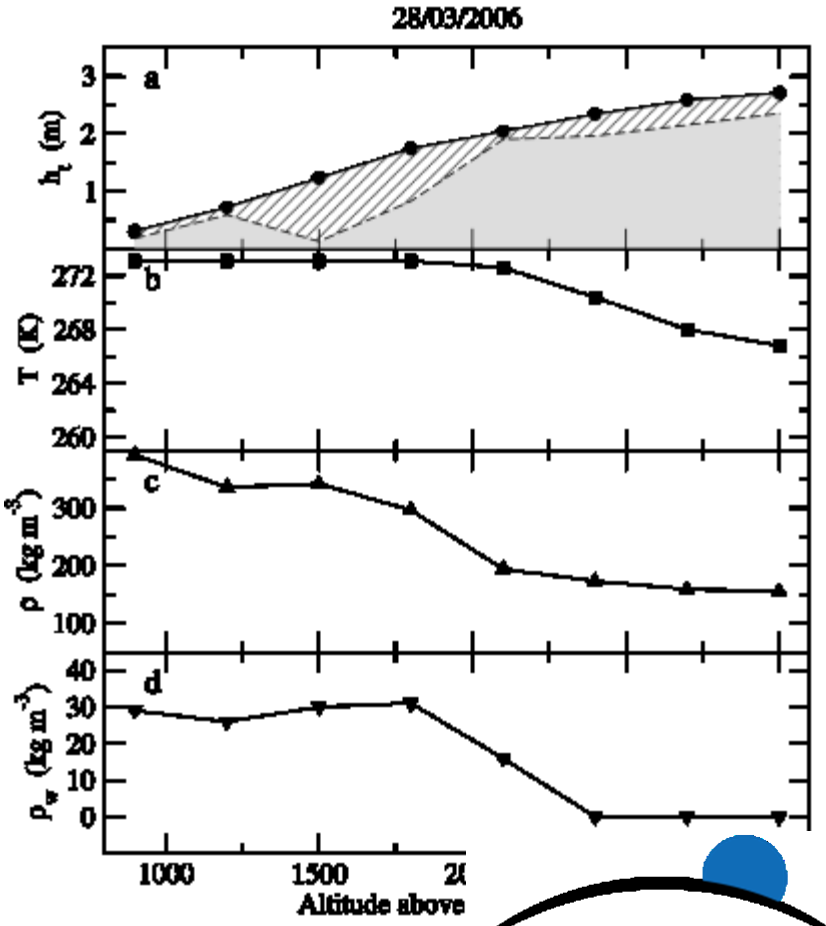
Chamonix valley : 730 avalanches reanalyzed

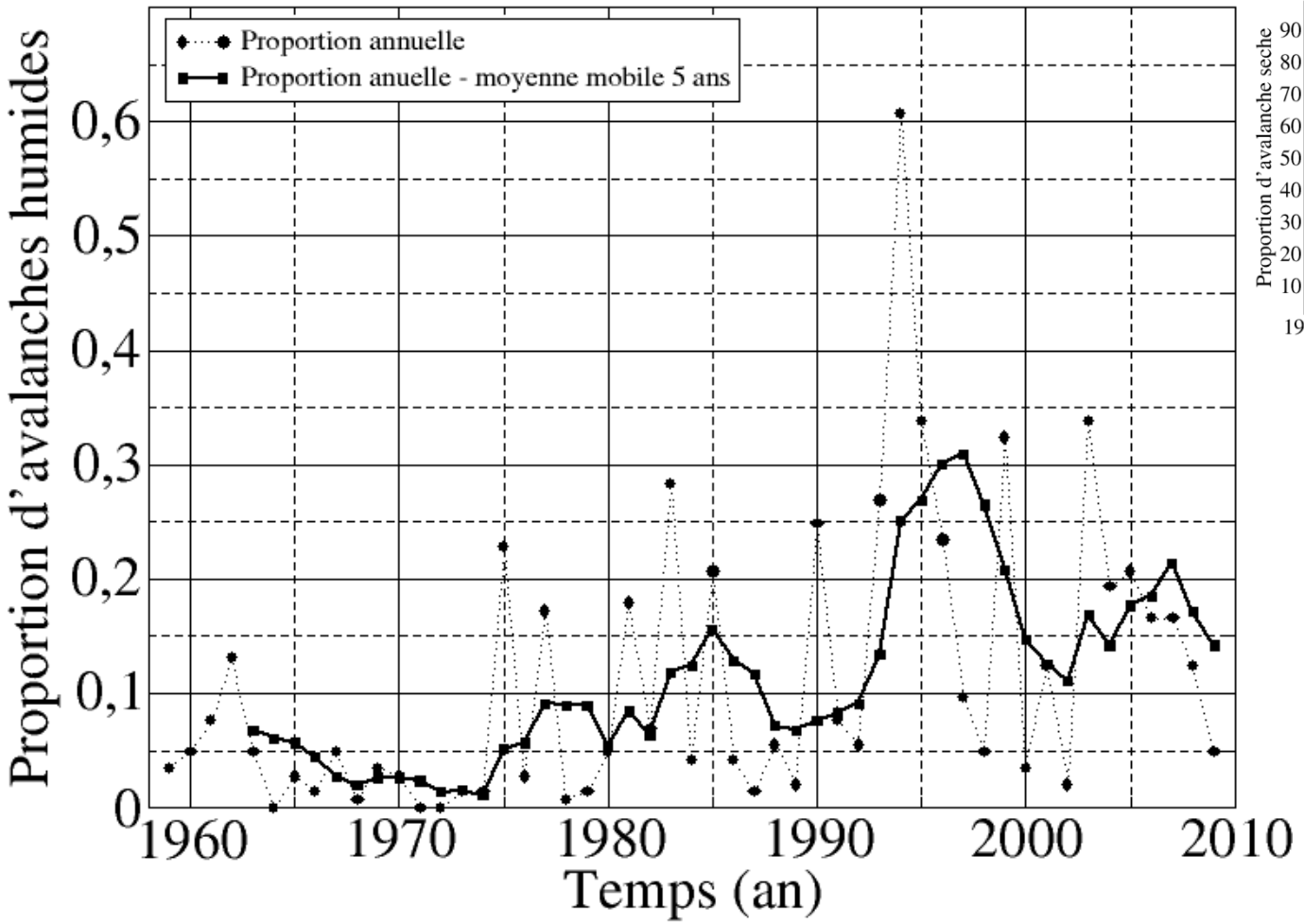
Safran-Crocus reanalysis (Durand et al. 2009)

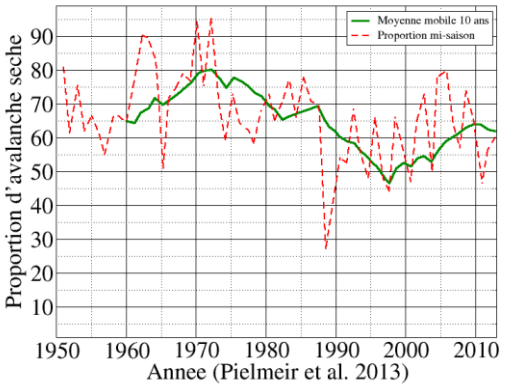




Chamonix: Increase of wet snow avalanches

Chamonix : crossing EPA and and Safran-Crocus reanalysis (Durand et al. 2009)





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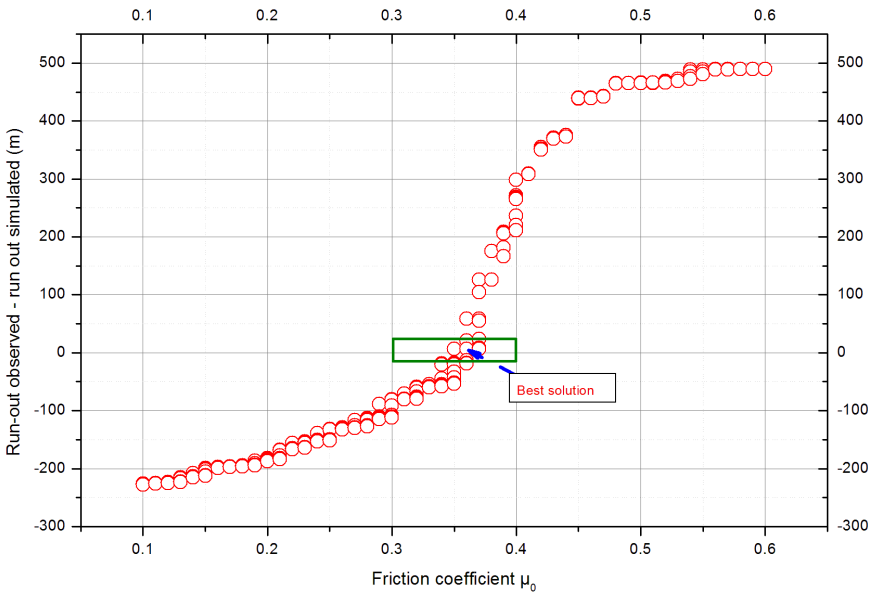
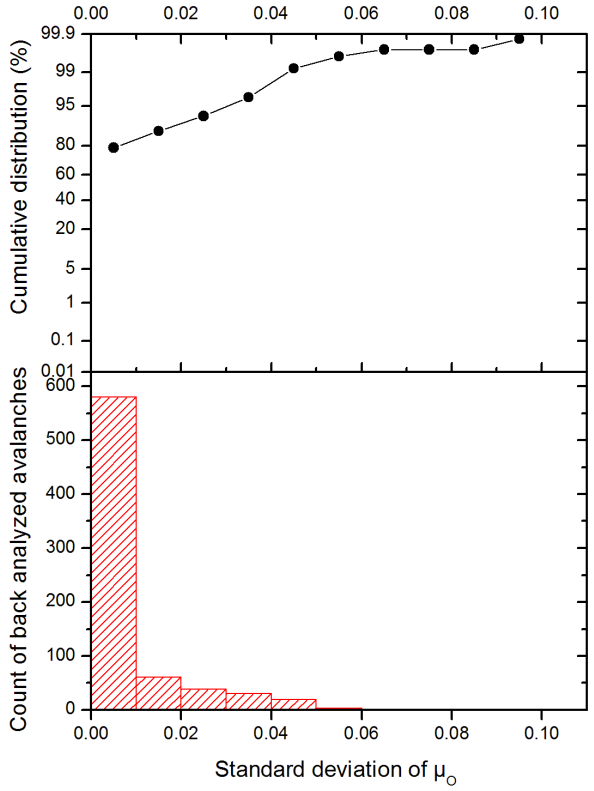
Model calibration

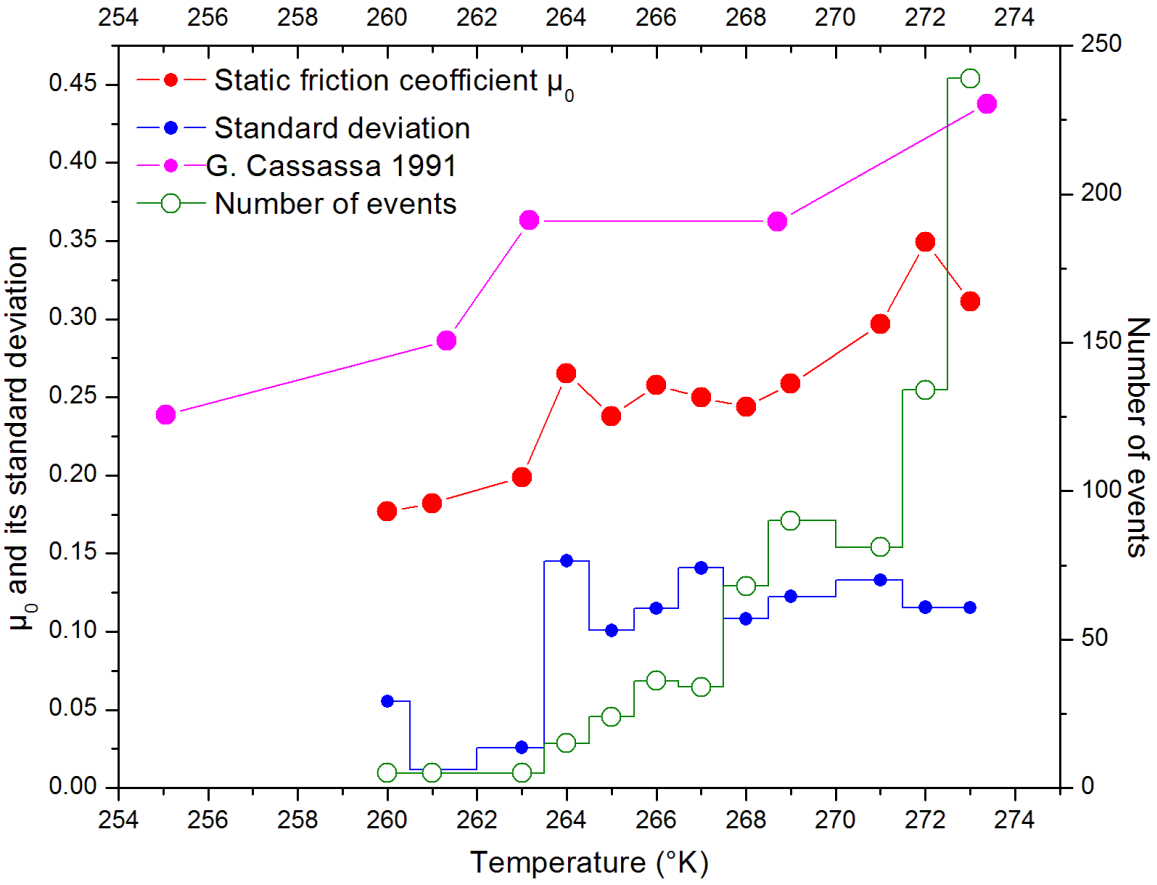
$$\tau = \sigma(\mu + \frac{g}{\xi} F^2$$

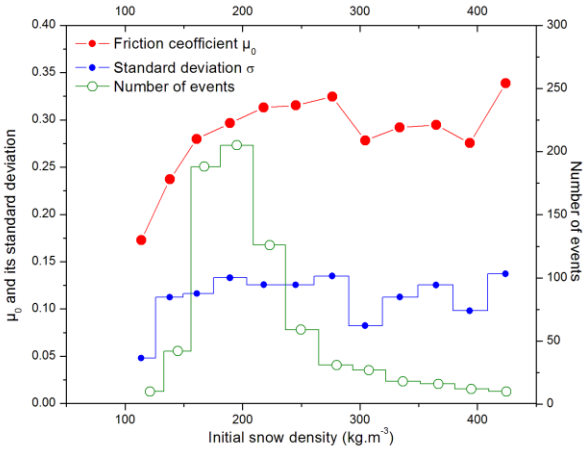
Equations :
Mass conservation
Momentum conservation





Snow avalanche friction: increase with temperature





Naaim et al., IOG 2013

Run–out distance reduction with temperature !

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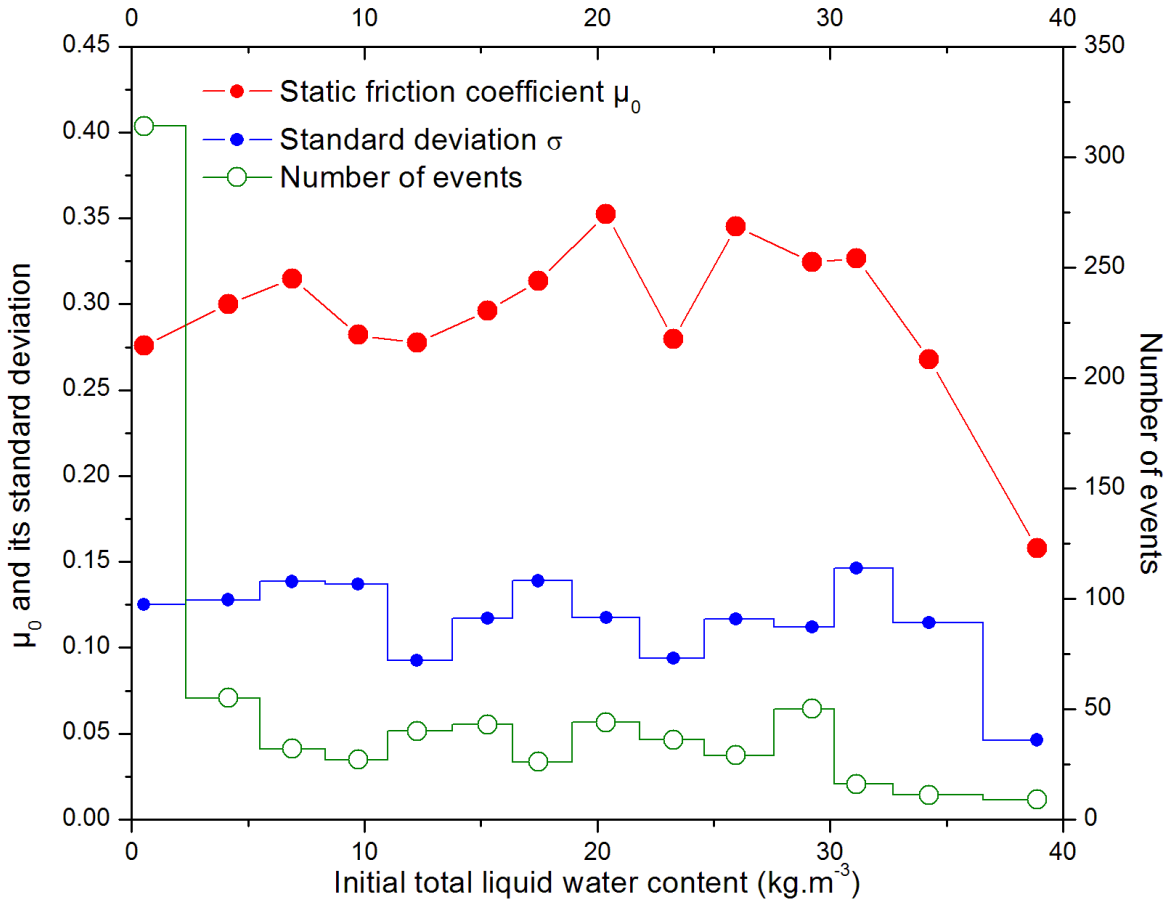
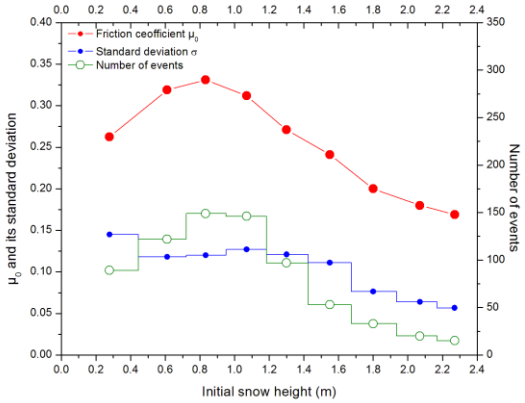
Wet snow avalanche dynamics: tlwc threshold

!Chamonix : croissing EPA et ERA40



Naaim et al. JOG 2013



Runout : beyond 30 kg.m^{-3} strong increase … Montroc

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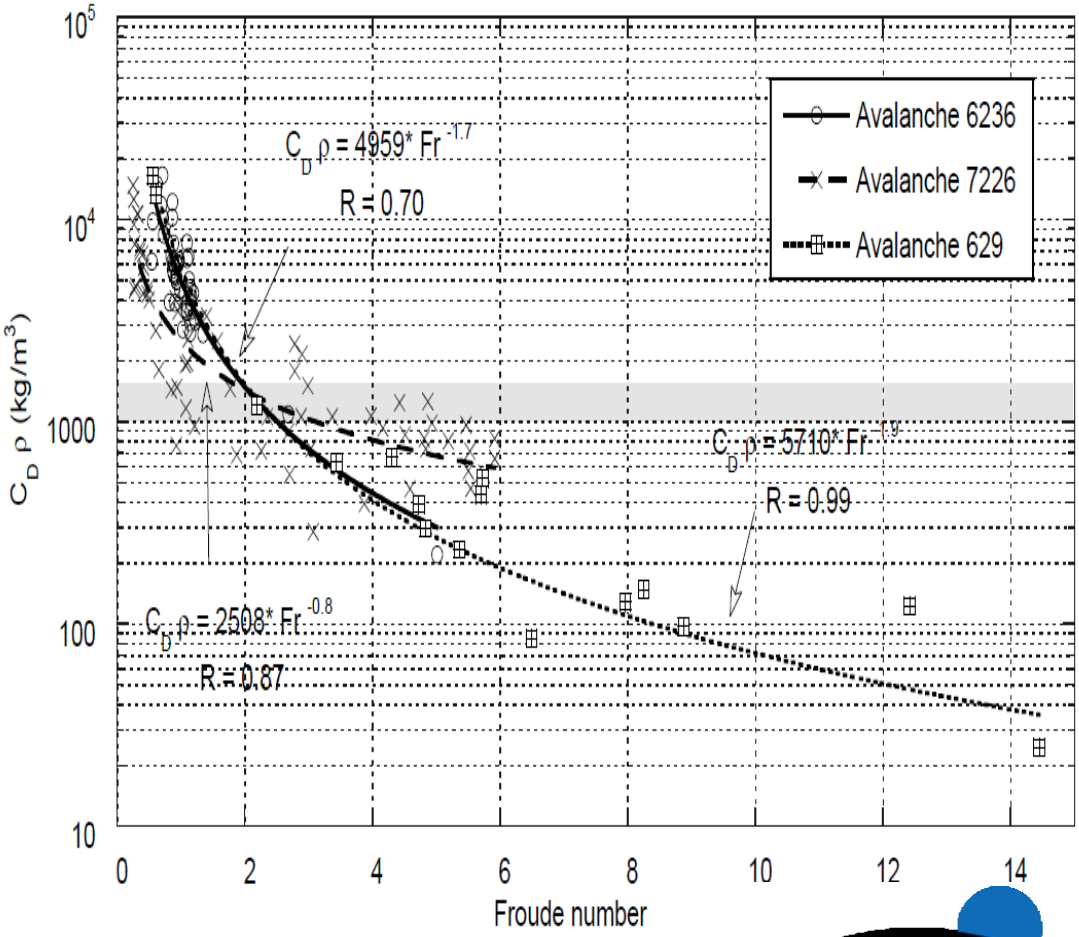
Wet snow avalanches: slow and deep

Pression d'impact

U : avalanche velocity
H : avalanche height

$$F = \frac{U}{\sqrt{gH}}$$

$$C_d\rho = \frac{P}{U^2}$$



Sovilla et al. 2010

Wet snow avalanches: slow and deep

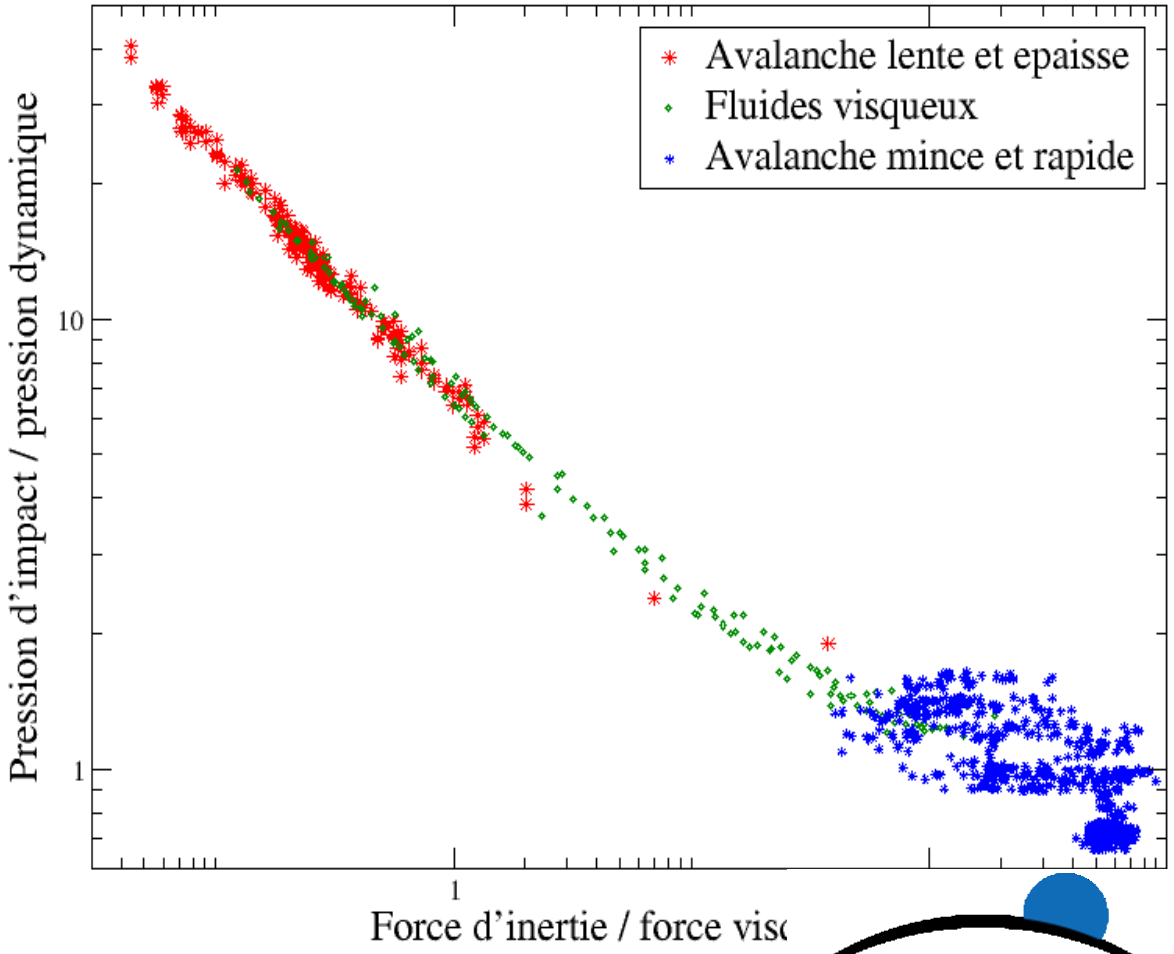
Pression d'impact

U : avalanche velocity
H : avalanche height

$$F = \frac{U}{\sqrt{gH}}$$

$$R_e = \frac{3F^2}{\tan(\theta)}\frac{d}{H}$$

$$C_d = \frac{P}{\rho U^2}$$



Naaim et al. 2008

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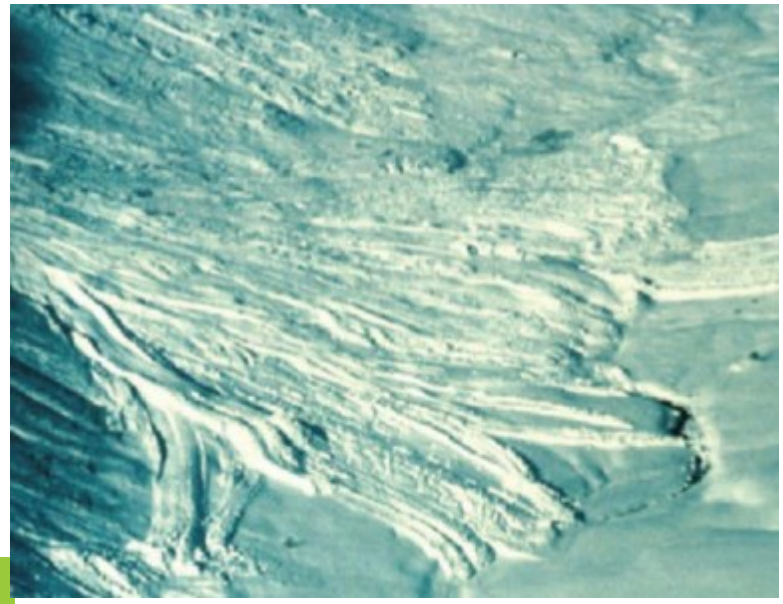
Wet snow avalanches: open questions

- Specific behaviors of wet avalanches
- Any topography change, even minor, may modify significantly the trajectory : unexpected path
- Fingering deposits
- Wet avalanche may overflow a physical work even at low velocity
- Needs to investigate the rheology of wet snow



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