EGU 2020 Session CR3.3 Snow avalanche dynamics: from basic physical knowledge to mitigation strategies

Impact of land cover on avalanche hazard: how forest cover changes affect return periods and dynamical characteristics simulated by a statistical-numerical avalanche model.

Taline Zgheib[1], Florie Giacona[1], Anne-Marie Granet-Abisset[2], Samuel Morin[3], Nicolas Eckert[1]

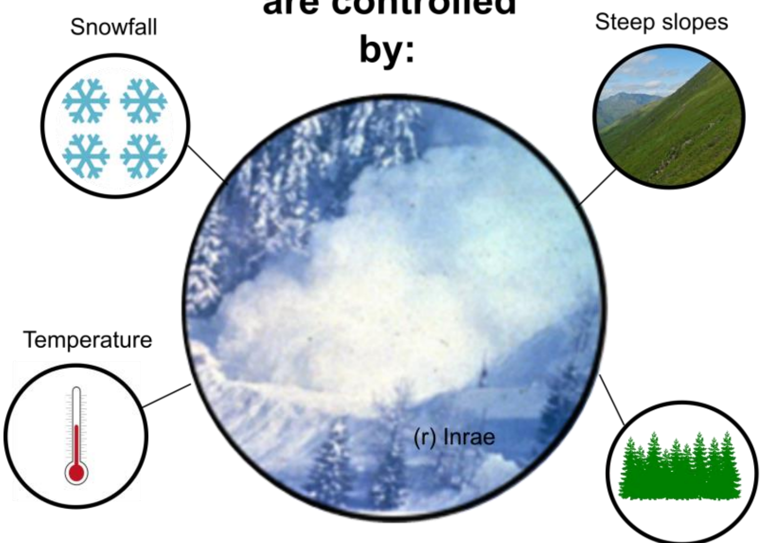
[1] Univ. Grenoble Alpes, INRAE, ETNA, 38000 Grenoble, France
[2] Univ. Grenoble Alpes, UMR CNRS 5190 Laboratoire de Recherche Historique Rhône-Alpes (LARHRA)
[3] Univ. Grenoble Alpes, Université de Toulouse, Météo-France, Grenoble, France, CNRS, CNRM, Centre d'Etudes de la Neige, Grenoble, France

Trajectories
Univ. Grenoble Alpes

METEO FRANCE

Context

Snow avalanches are controlled by:



(Gubler and Rychetnik, 1991)

Land cover : Forests

Protection against snow avalanches.

Prevent avalanche release.

Decelerate flowing avalanches.

Forest/avalanche interaction

Detrainment approach (Feistl et al.,2014)

This approach explicitly extracts the snow mass from the avalanche flow that had been stopped by trees.

Friction approach

➡ by adjusting the friction parameters

➡ Example : Voellmy fluid flow law:

Total basal friction

$$Fric = \mu g \cos\phi + \frac{g}{\xi h} v^2$$

Dry Coulumb friction +Δ 0.02 in forests

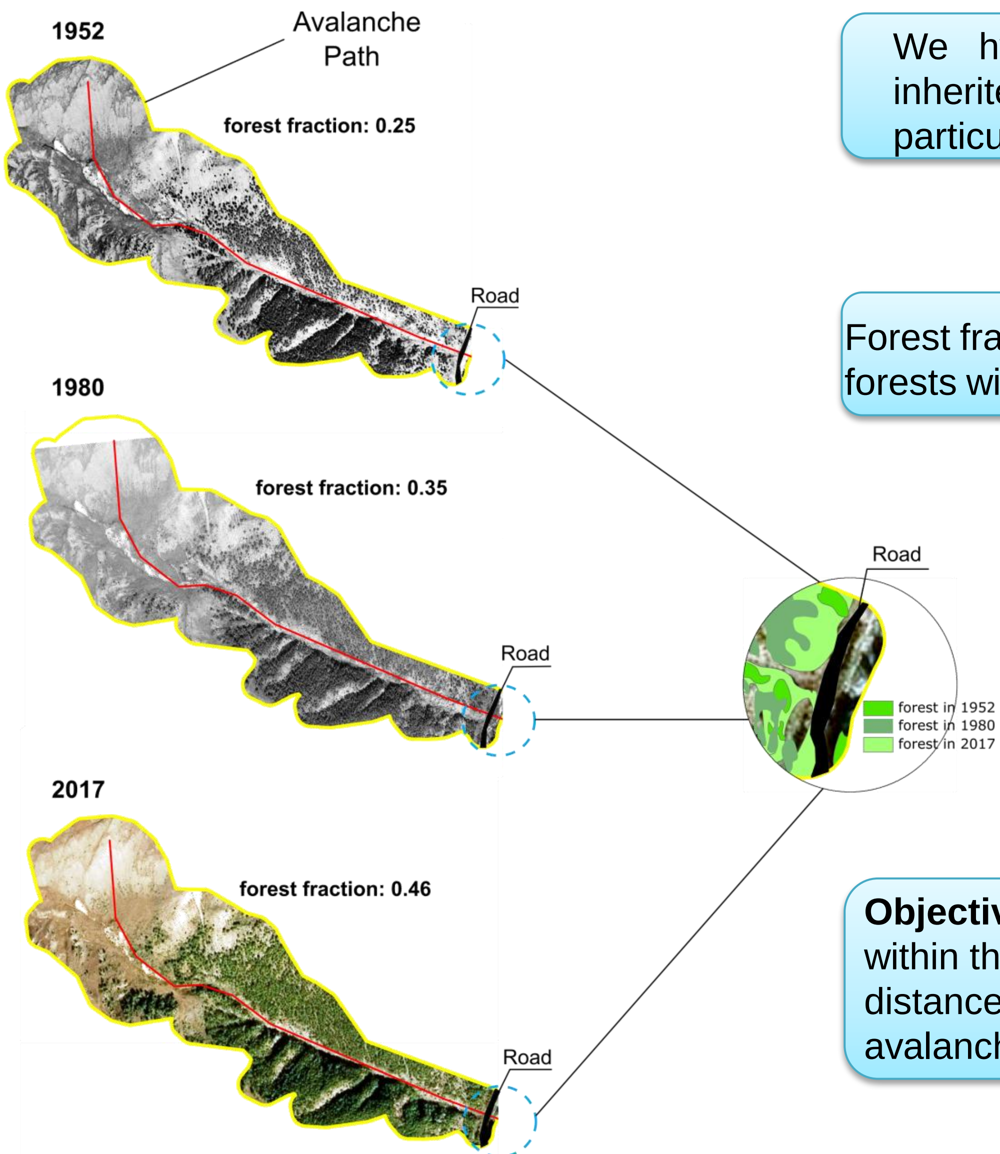
Turbulent friction in forests set to : 400 m/s²

Assumption: summarize snow properties

Assumption: represent roughness of path (related to land cover)

(Gruber et al.,2007)

Objective



We hypothesize on the temporal variability of μ, inherited from its dependability on land cover, particularly the forest fraction.

Forest fraction = the aerial percentage of the terrain covered by forests within the extension of the avalanche path.

Objective: show how the evolution of the forest fraction within the avalanche path affects the return period of runout distances and further dynamical characteristics of simulated avalanches.

INRAE — LARHRA UMR 5190 Laboratoire de recherche historique Rhône-Alpes — Trajectories Univ. Grenoble Alpes — Météo France

Study area and collected data

Selected Path

Abriès 5 : RAVIN DE COTE-BELLE

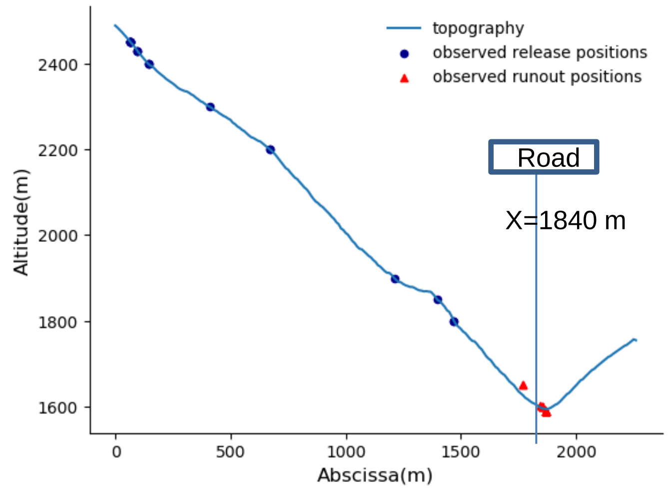
-The selected avalanche path is located in Abriès, a municipality of the Queyras massif in the Southern French Alps.

Path Characteristics

- 21 recorded events in total
- 3 events before 1952
- 17 events after 1952 (used for calibration.)

Snow avalanche data

	Descriprion
X_{start} (m)	release abscissa
V_{stop} (m^3)	deposit volume
h_{start} (m)	mean snow depth in the release zone
L_{start} (m)	length of release zone
l_{start} (m)	width of release zone
$V_{starteq}$ (m^3)	equivalent release volume
$X_{stopdata}$ (m)	runout distance



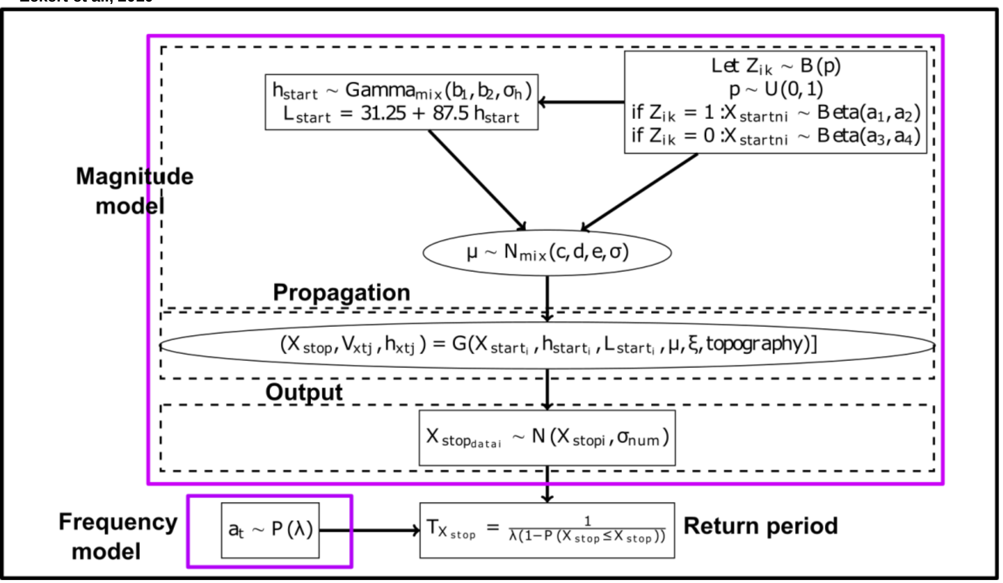
Topography and available historical data for the case study. Abriès township, path EPA No. 5.

Methodology

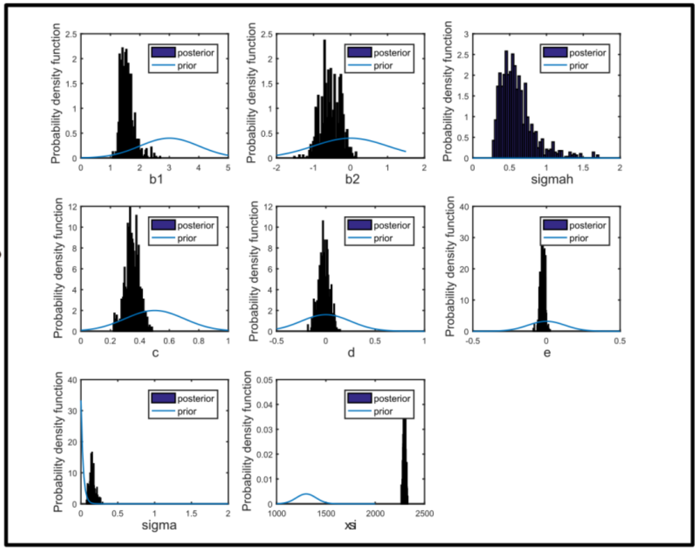
1 Model parameter calibration

Eckert et al., 2010

Direct acyclic graph of the stochastic avalanche model



Output: Posterior distribution of model parameter



- Bayesian statistical-dynamical model used to calibrate of the depth- averaged Saint –Venant propagation model (denoted as G in the acyclic graph) using local data.
- The friction law used is the Voellmy fluid flow law.

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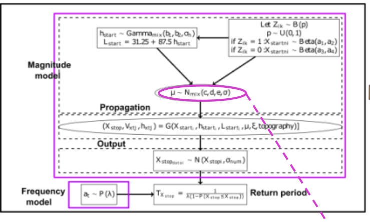
- From the calibration process, we obtain the posterior distribution of the model parameters .

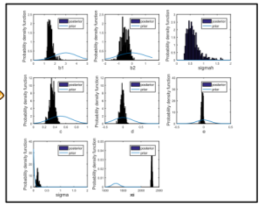
Methodology

① **Model parameter calibration**

Direct acyclic graph of the stochastic avalanche model



Output: Posterior distribution of model parameter



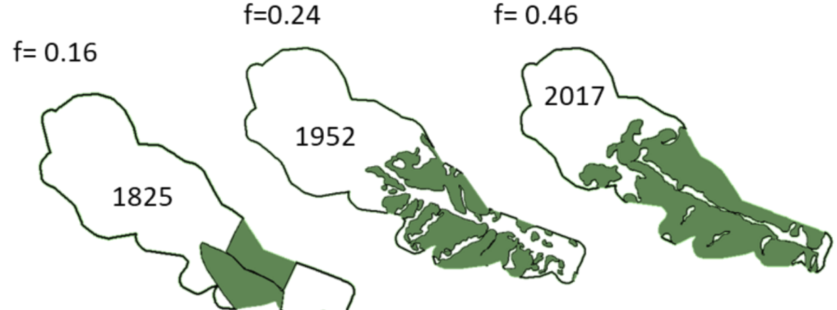
$$\mu \sim N(c + d\,Xstartni + e\,hi,\ \sigma)$$

② **Avalanche simulation** **(10,000 simulations per forest fraction)**

For the simulation, we introduce another parameter fk , the forest fraction in the path for t1, t2,t3 ..,tn

$$\mu \sim N(c + d\,Xstartni + ehi + g\,(fk - fmean),\ \sigma)$$

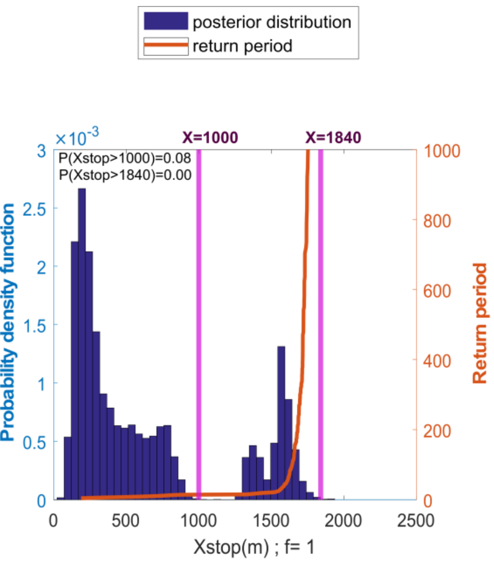
where $g = cov(\mu mean) = stdv(\mu i) / mean(\mu i) = 0.6$

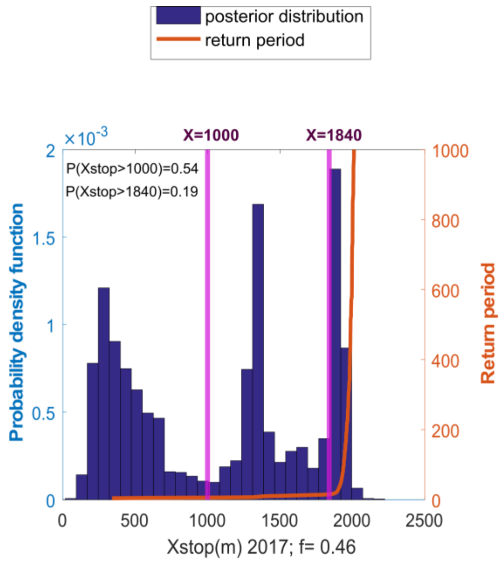


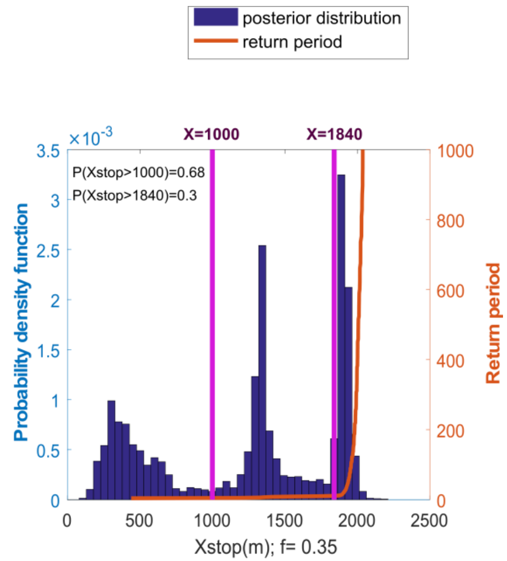
Where f=forest fraction

- The model is implicitly calibrated for the mean forest fraction of the calibrated period (1960-2018). This fraction **f=0.35** corresponds also to the forest fraction in 1980 .
- We introduce a fifth parameter **'g'** that characterizes the **dependency of μ on the forest fraction.**

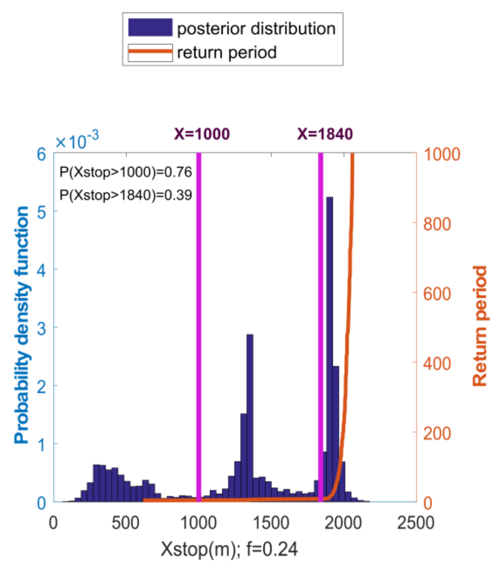
Results: Runout distance

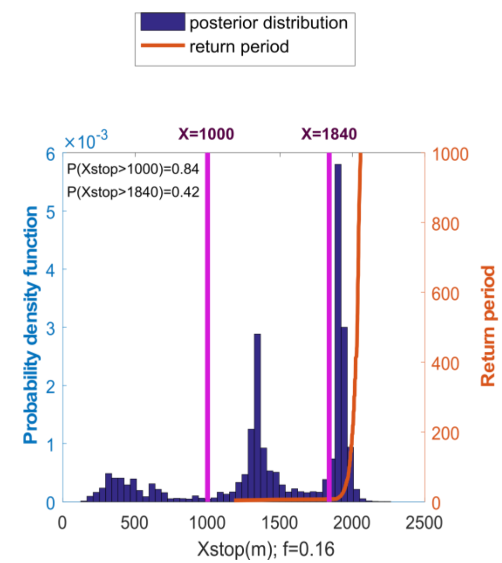


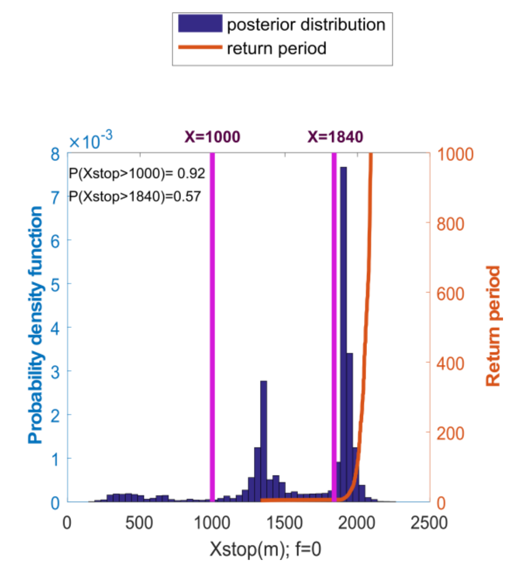




P(Xstop>1000 m) and P(Xstop >1840) decrease when the forest fraction increase

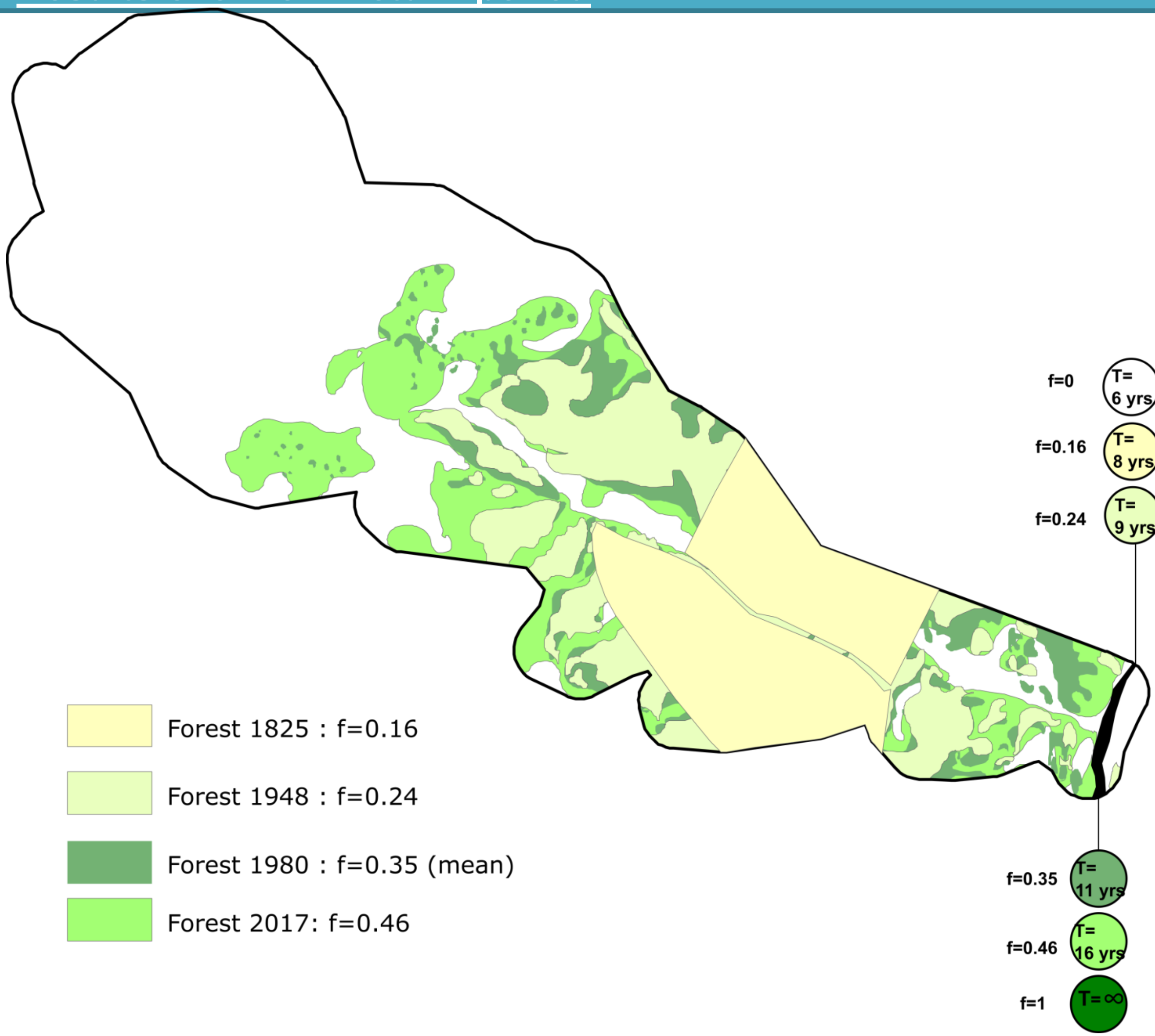






For a completely reforested path, there is no chance that snow avalanches will reach the road.

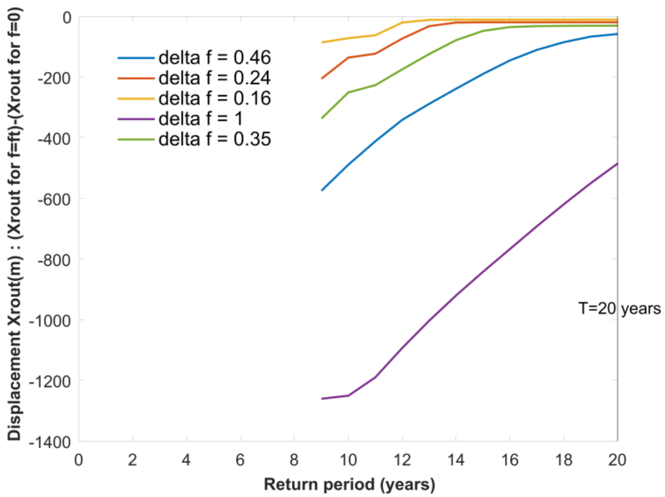
Results overview: return period

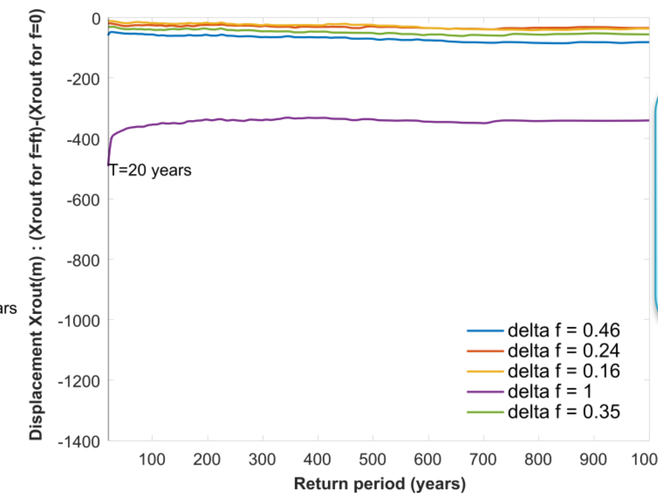


Return period of avalanches that reach the road at X=1840 m increase with an increasing forest fraction.

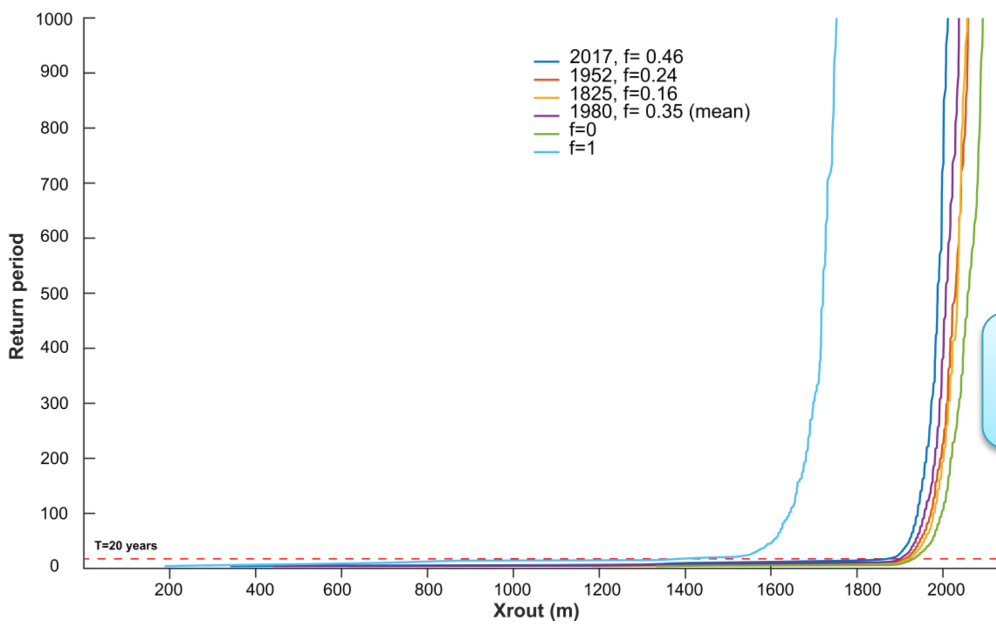
Results overview : return period

Displacement of Xrout is more significant for smaller return periods (less than 20 years).





For return periods larger than 20 years, the displacement is less intense and roughly constant.

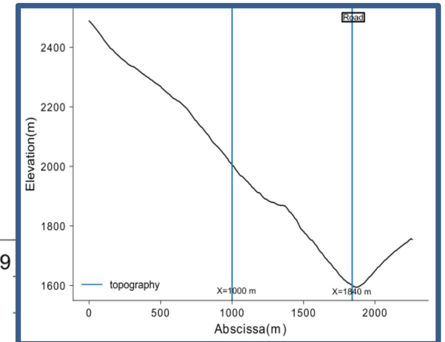


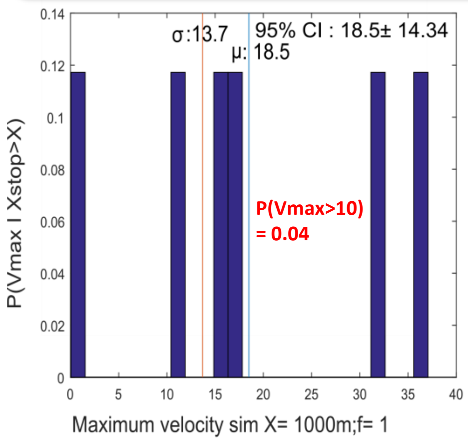
The larger the forest fraction the higher the return period of runout distances.

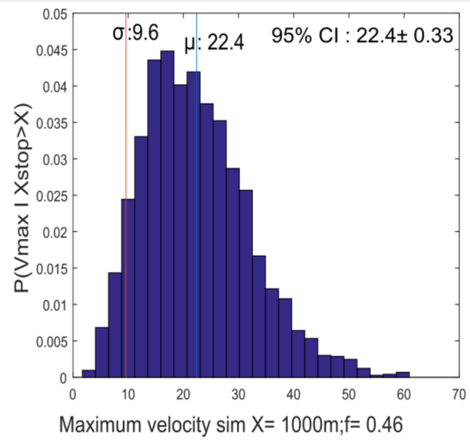
Results overview: evolution of the maximum velocity:

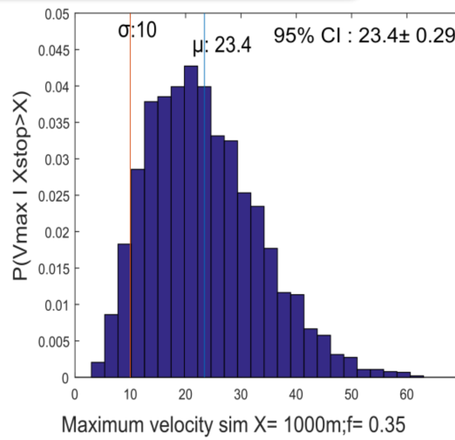
The graphs below show the evolution of the P(Vmax|Xstop>X) of the maximum velocity at X=1000 m for f = 1, 0.46, 0.35, 0.24, 0.16 and 0.

P(Vmax>10)= P(Vmax>10 I Xstop>1000) P(Xstop>1000)

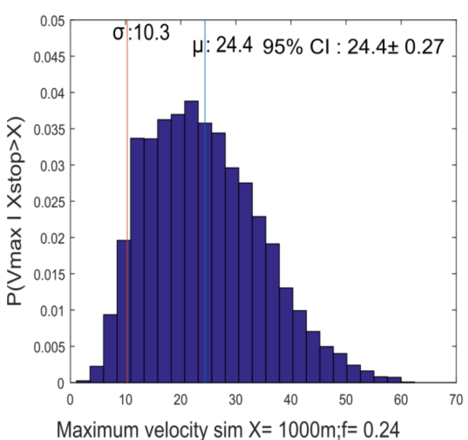


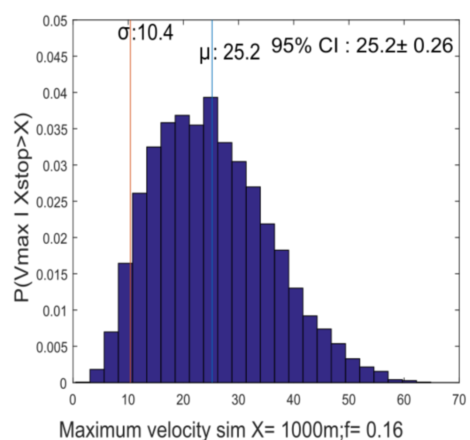


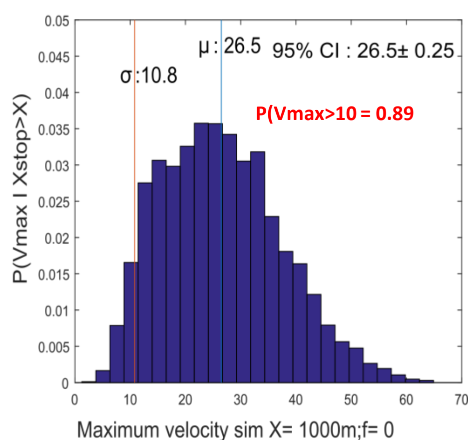




When the forest fraction decrease, avalanches with higher velocities occur.



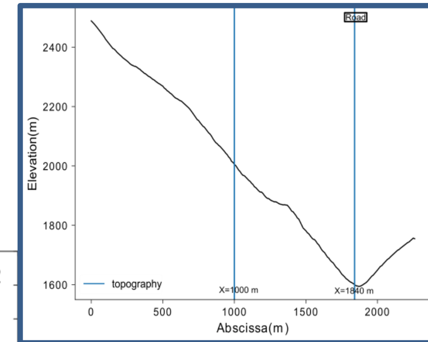




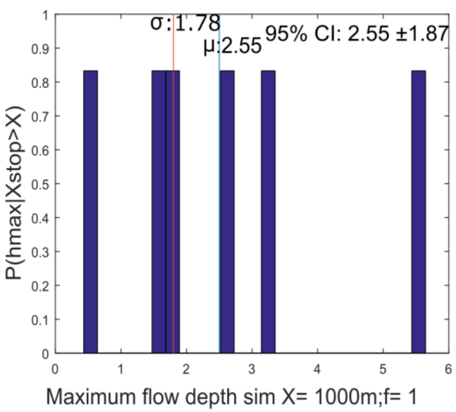
No extream variation in the mean maximum velocity between forest fractions

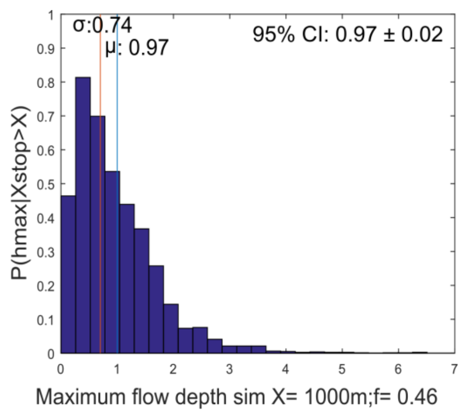
Results: evolution of the maximum flow depth:

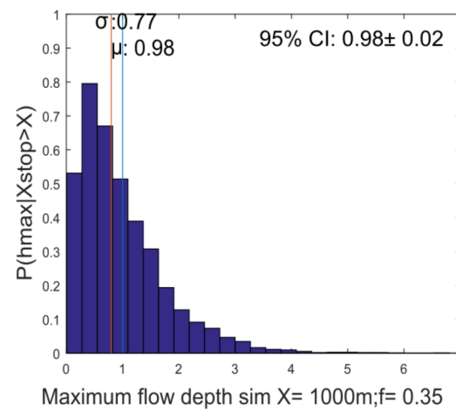
The graphs below show the evolution of the P(hmax|Xstop>X) at X=1000 m for f = 1 , 0.46,0.35, 0.24 ,0.16 and 0.

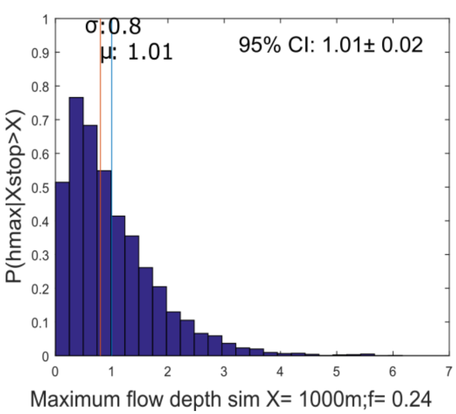


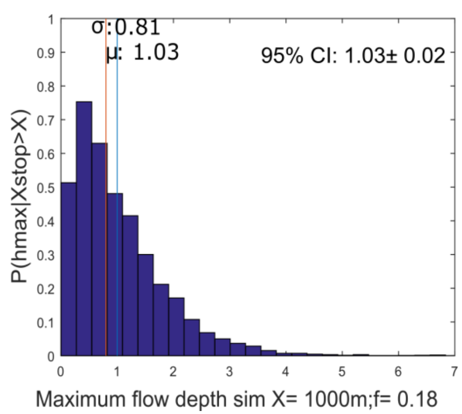
The smaller the forest fraction, larger avalanches with slightly higher flow depth appear

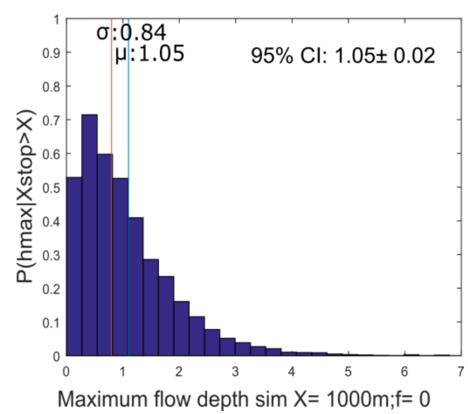












No extream variation in the mean maximum snow depth between forest fractions

Future work

1. Asses how evolution of the forest fraction impacts, the return period and dynamical characteristics of snow avalanches when included:

   a) As a part of the turbulent friction ξ. To increase TBF ξ must be decreased.

   b) As a part of both the turbulent friction ξ and the dry –Coulomb friction μ.

2. Future work will include the explicit calibration of the forest cover dependency within the statistical-dynamical approach.

List of references

Eckert et al., 2010

Feistl et al.,2014

Gruber et al.,2007

Gubler and Rychetnik, 1991

Contact details of corresponding author:

Taline zgheib

Email: taline.zgheib@inrae.fr
Linkedin: https://www.linkedin.com/in/talinezgheib