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

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Snow avalanches are controlled by:

- Snowfall
- Steep slopes
- Temperature

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:

\[ F_{\text{fric}} = \rho g \cos \phi + \frac{g}{\mu} v^2 \]

- Dry Coulomb friction: +\( \Delta 0.02 \) in forests
- Turbulent friction in forests set to: 400 m/s²

Protection against snow avalanches.

Prevent avalanche release.

Decelerate flowing avalanches.

Land cover: Forests

(Gubler and Rychetnik, 1991)

(Gruber et al., 2007)

(Gruber et al., 2007)
Objective

We hypothesize on the temporal variability of $\mu$, 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.
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

<table>
<thead>
<tr>
<th>Description</th>
<th>Unit</th>
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<tbody>
<tr>
<td>X_{start} (m)</td>
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<tr>
<td>V_{stop} (m^3)</td>
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<td>h_{start} (m)</td>
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<td>L_{start} (m)</td>
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<td>W_{start} (m)</td>
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<td>V_{start eq} (m^3)</td>
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<tr>
<td>X_{stop data} (m)</td>
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</tbody>
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- Description:
  - 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
  - W_{start} (m): width of release zone
  - V_{start eq} (m^3): equivalent release volume
  - X_{stop data} (m): runout distance

Topography and available historical data for the case study. Abriès township, path EPA No. 5.
Bayesian statistical-dynamical model used to calibrate 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.

- From the calibration process, we obtain the posterior distribution of the model parameters.
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 $\mu$ on the forest fraction.
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.

- Forest 1825: \( f = 0.16 \)
- Forest 1948: \( f = 0.24 \)
- Forest 1980: \( f = 0.35 \) (mean)
- Forest 2017: \( f = 0.46 \)
Results overview: return period

Displacement of $X_{rout}$ 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 $P(V_{\text{max}}|X_{\text{stop}}>X)$ of the maximum velocity at $X=1000$ m for $f = 1$, 0.46, 0.35, 0.24, 0.16 and 0.

$$P(V_{\text{max}}>10)= P(V_{\text{max}}>10 \text{ I } X_{\text{stop}}>1000) \cdot P(X_{\text{stop}}>1000)$$

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

No extremum variation in the mean maximum velocity between forest fractions.
Results: evolution of the maximum flow depth:

The graphs below show the evolution of the $P(h_{\text{max}}|X_{\text{stop}}>X)$ 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 extreme variation in the mean maximum snow depth between forest fractions.
## Future work

1. Assess 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 $\xi$. To increase TBF $\xi$ must be decreased.

   b) As a part of both the turbulent friction $\xi$ and the dry–Coulomb friction $\mu$.

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

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