A statistical framework to better mitigate avalanche risk with application to land use planning

N. Eckert[1], M. Naaim[1], F. Giacona[1], E. Parent[2], P. Favier[1], M.B. Heredia[1], T. Faug[1] et al.

[1] Univ. Grenoble Alpes, Irstea, ETNA, Grenoble, France

[2] Equipe MORSE, UMR 518 INRA-AgroParisTech, Paris, France

Avalanche deposit on dwelling house © Irstea

Workshop 2.4.B: *Natural hazards assessment – potential, limits and uncertainties of process models and interactions of processes with protection structures and buildings*

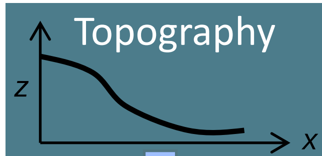
International Mountain Conference 11 September 2019, Innsbruck, Austria.

New paradigms for avalanche risk mitigation

Snow depth distribution and design value for the return period T

Tabulated friction parameters

Topography



↓

Physically-based propagation model

↓

Design values (extension, pressure, etc.) for the return period T

Standard approach to asses risk in land use planning (Salm et al., 1990).

Too many shortcuts and limitations:

- *Friction coefficients without proper calibration;*
- *Improper use of the return period concept;*
- *No consideration of potential non-stationarity;*
- *No consideration of elements at risk and behavior towards risk.*

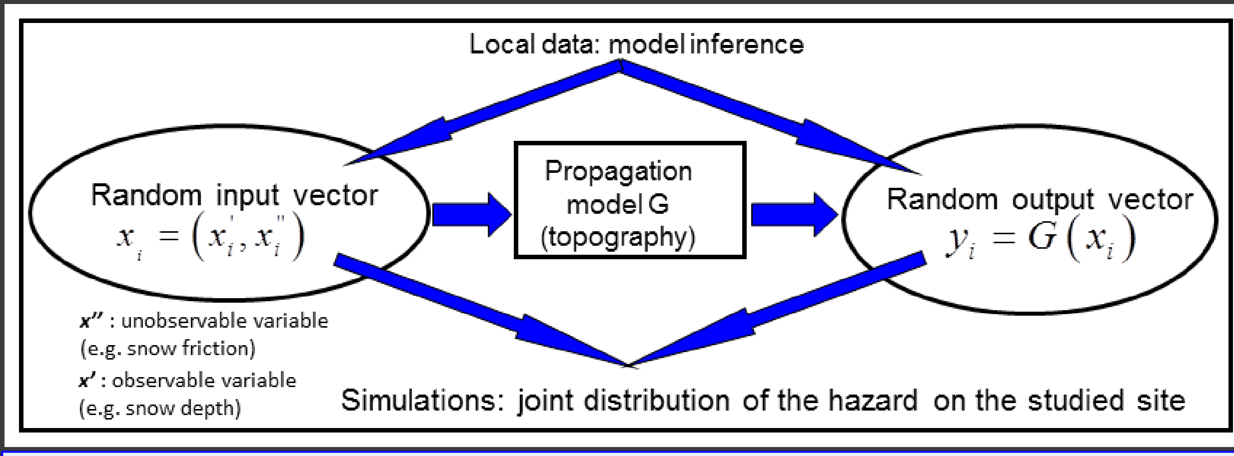
Required paradigm shifts:

Quasi-deterministic physically-based approaches	→	**Probabilistic-physical** approaches handling **uncertainty** sources consistently
Hazard-based approaches	→	**Risk-based** approaches that consider **elements at risk**, their **vulnerability** and **behavior towards risk**
Stationary assumption	→	Risk assessment **accounting for environmental changes**

How?

- **Hierarchical Bayesian modelling** including as much **physics** as possible;
- Merging knowledges and disciplines within a common framework based on **Risk and decision theory**.

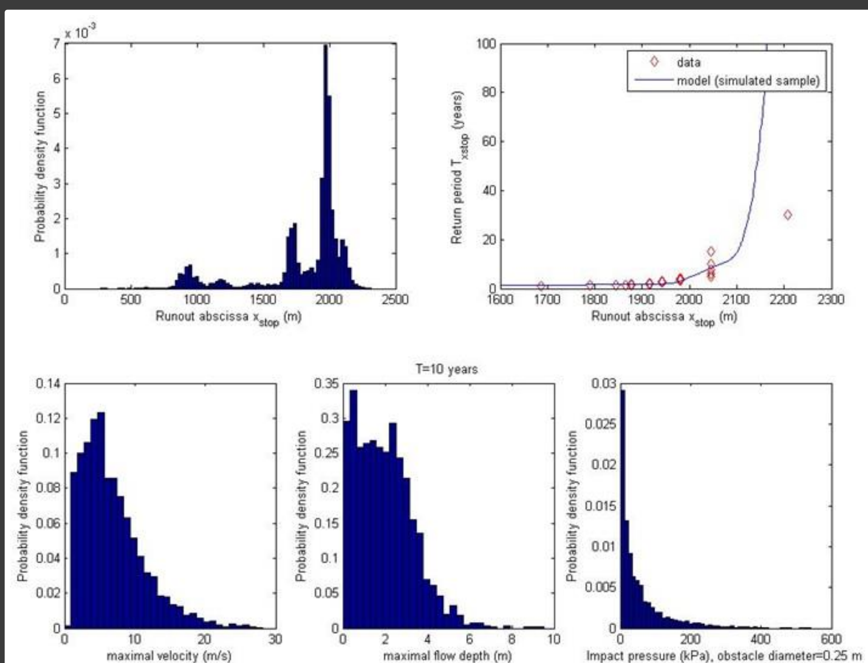
Bayesian numerical-probabilistic hazard modelling



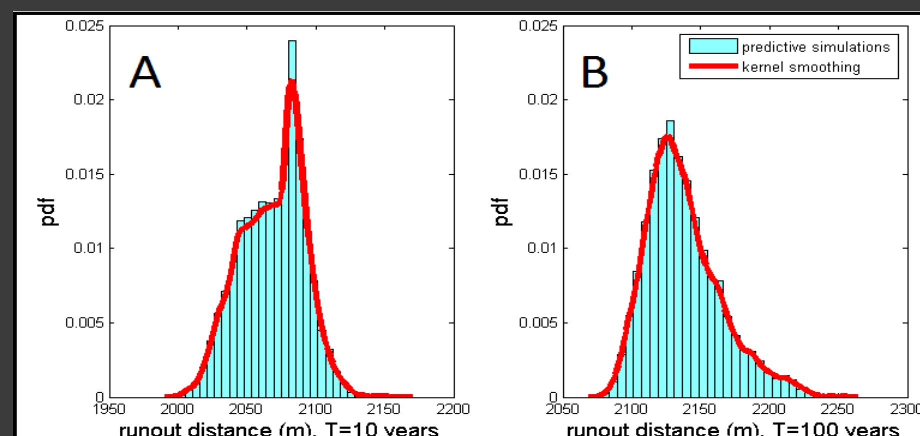
Numerical-probabilistic approach associated with Bayesian inference (Eckert et al., 2007).

Remaining challenges:

- **Integrate the rich and diverse data now available within the calibration**: LIDAR, remote sensing, etc.;
- Find the **best compromise between precision** (numerical model) **and computation times.**



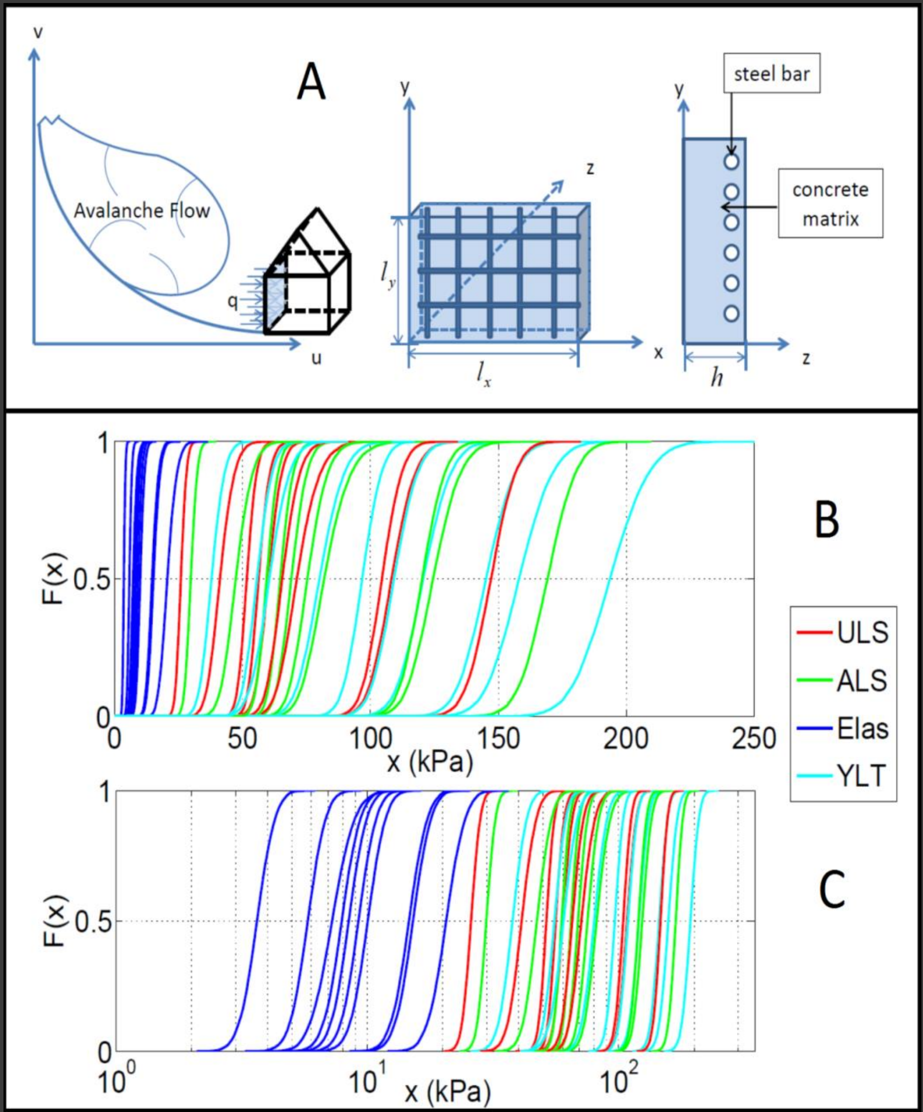
Quantifying variability: Relation between runout distance and return period, and, for each runout distance, distribution of other variables (Eckert et al., 2010)



Quantifying uncertainty : Predictive uncertainty on avalanche runout distances corresponding to return periods of 10 and 100 years ((Eckert et al., 2008).

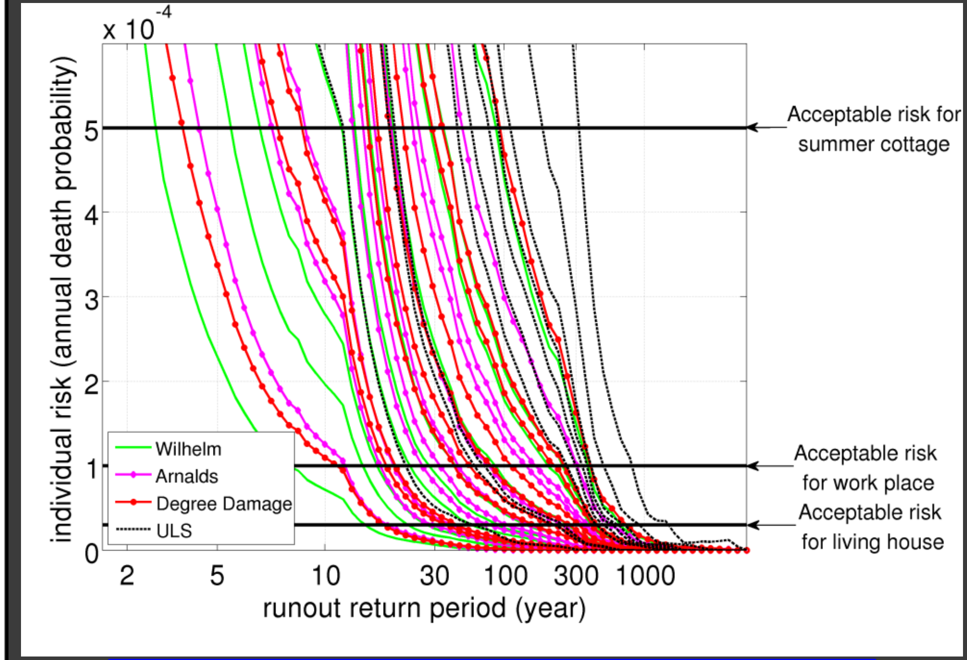
From vulnerability to individual risk

Remaining challenge:
Risk **measures** and **mitigation strategies** alternatives to the "rough" mean expected loss that **consider stakes and behavior towards risk explicitly.**



Evaluation of fragility curves for various types of reinforced concrete (RC) buildings (Favier et al., 2014a).

$$R(x) \propto \int p\left(\Pr \middle| x_{stop}, > x\right) p\left(x_{stop}\right) V\left(\Pr\right) d\Pr dx_{stop}$$

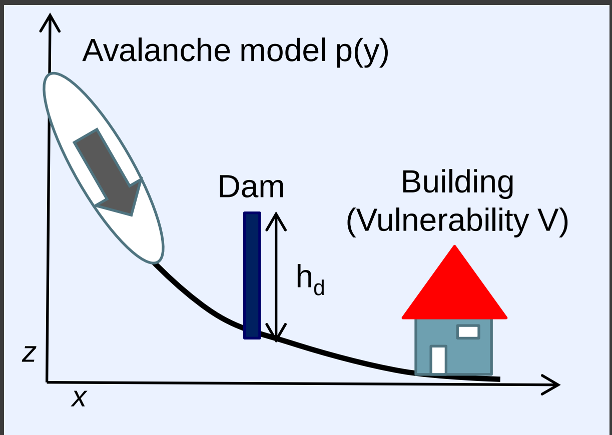


Evaluation of death rates (individual risk) as function of space in the runout zone (Favier et al., 2014b).

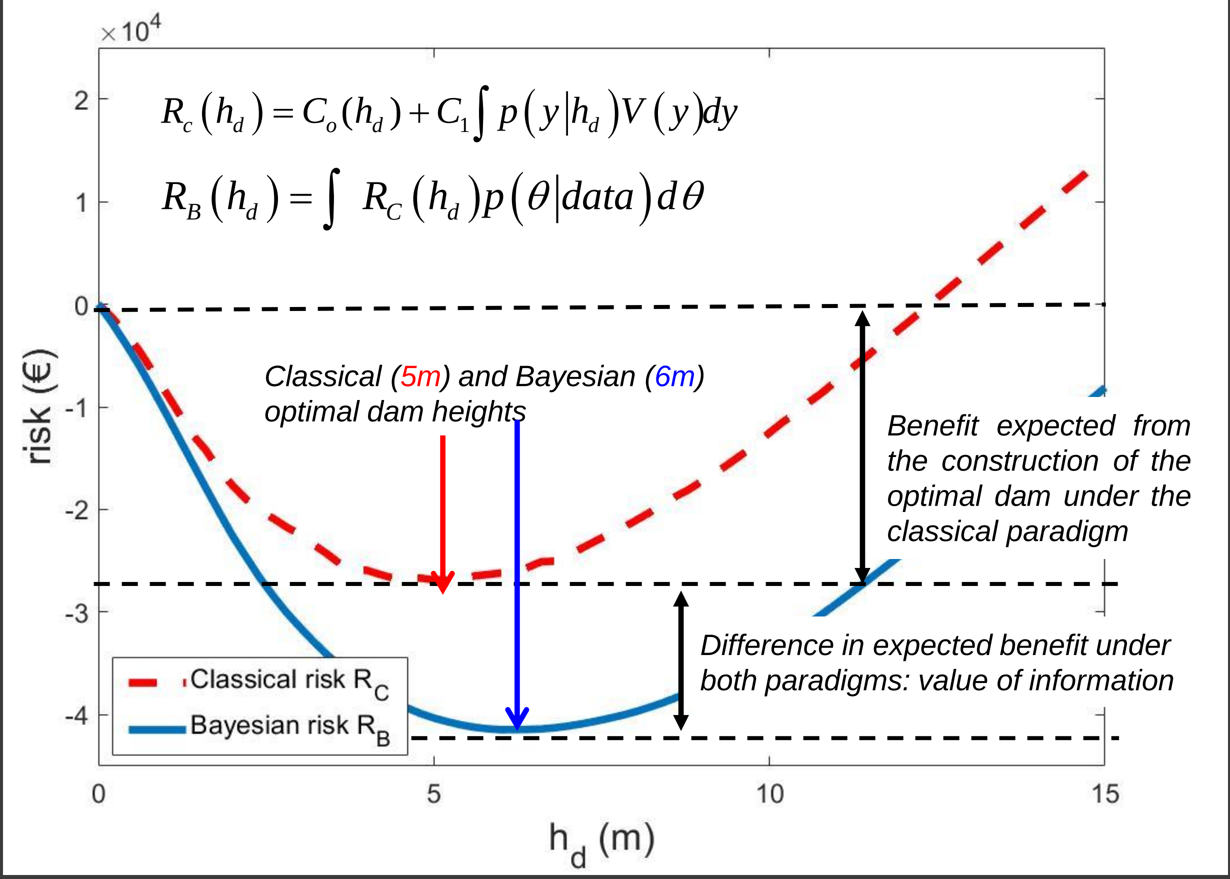
Optimal design of mitigation measures

Remaining challenges:

- Decisional models corresponding to **various operational contexts**;
- **Risk zoning** including defense structures as a **multivariate optimal design problem.**



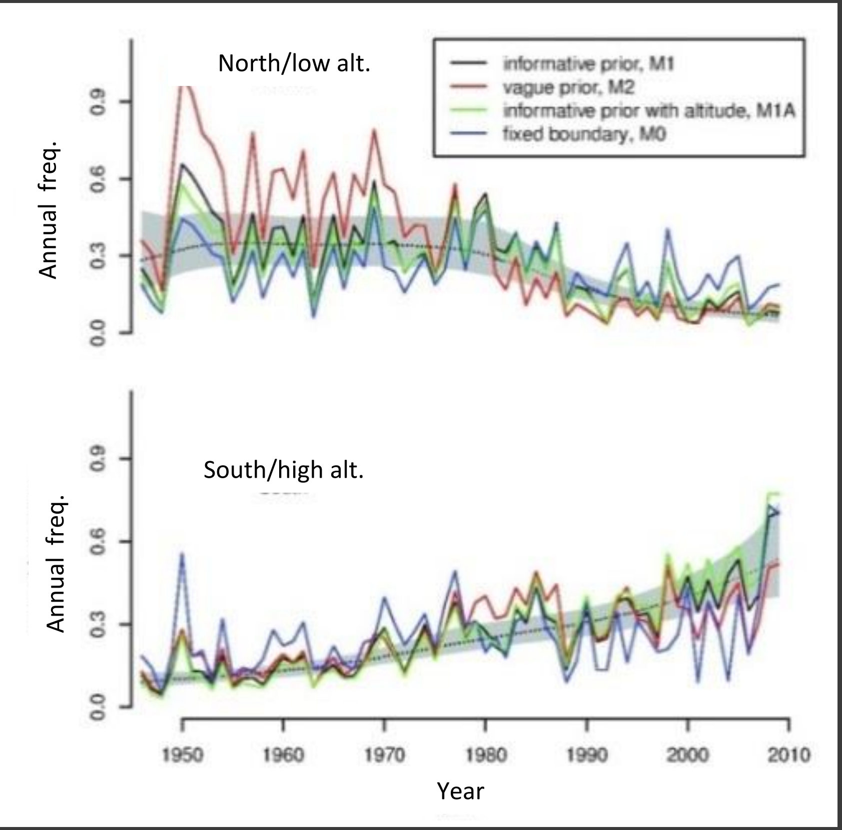
Optimal design of an avalanche dam by total costs minimization (Eckert et al., 2012)



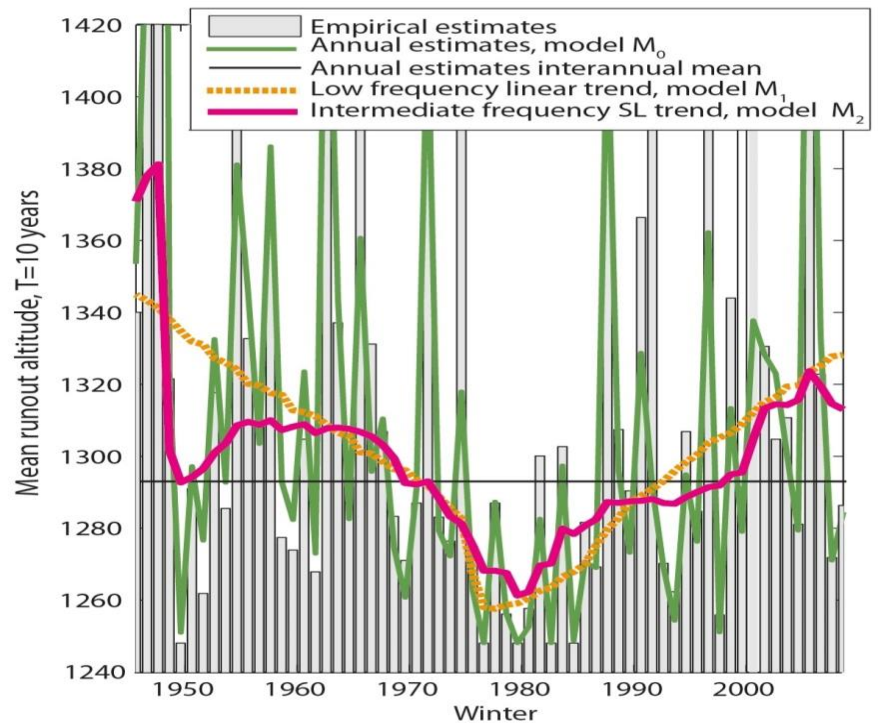
Accounting for non-stationarity in design values

Remaining challenges:

- Better quantifying **evolutions with changing climate/environmental conditions**;
- Methodological developments to adapt the risk framework to non-stationarity.



Avalanche occurrence number per path in the French Alps as function of altitude (Lavigne et al. 2015).



Runout altitude corresponding to a return period of 10 years in the French Alps (Eckert et al. 2013).