Relationships between corridor morphological variables and avalanche deposits volumes

2003-2017, Haute-Maurienne valley, Savoie, France

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OBJECTIVES OF THE AVALANCHE DEPOSIT STUDY

- **Few studies on deposits** (i.e: Jomelli and Bertran, 2001; Mc Clung D.M., Gauer P., 2018) : uncertainties in deposit volume, shape and stratigraphy control factors

→ **Factors driving the volumetric characteristics of deposits still largely unknown**

- **Deposit characteristics** determine the potential **damage and disturbance**

Figure 1: Picture of an avalanche cutting a road (Bessans/2018/data-avalanche.fr)

Figure 2: Picture of a trench in the avalanche deposit of the Brion path in Bessans on 08/01/2018 (data-avalanche.fr)

MAIN ISSUE

What is the influence of the morphological characteristics of the corridors on the volume of avalanche deposits?

- → **Determine the corridors geomorphological characteristics influence on avalanche deposits volumes**
- → **Explore the corridor annual frequency influence on the avalanche deposits volumes**

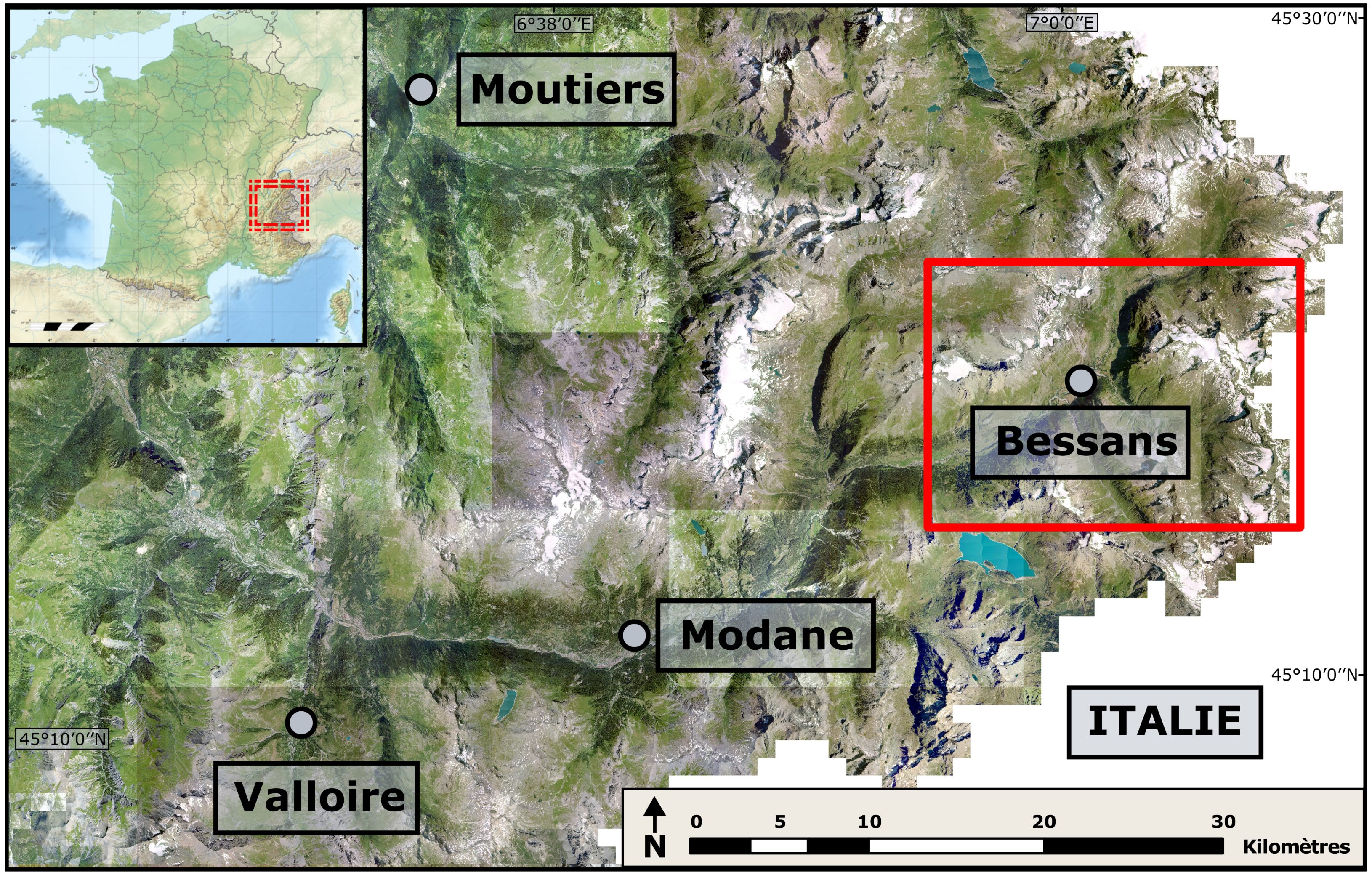


Figure 3: Location map

AVALANCHE DESCRIPTION DATA

- Data obtained from a preliminary work of correction and completion of the **Permanent Avalanche Survey (EPA) database**
- The EPA corridors are well **known, delineated and mapped**
- Database listing nearly **1491 events** described by **75 variables** between **2003 and 2017** for the Study Area
- **79 corridors studied:** large variety of sizes and shapes

Estimation of the deposit volume reported for each event

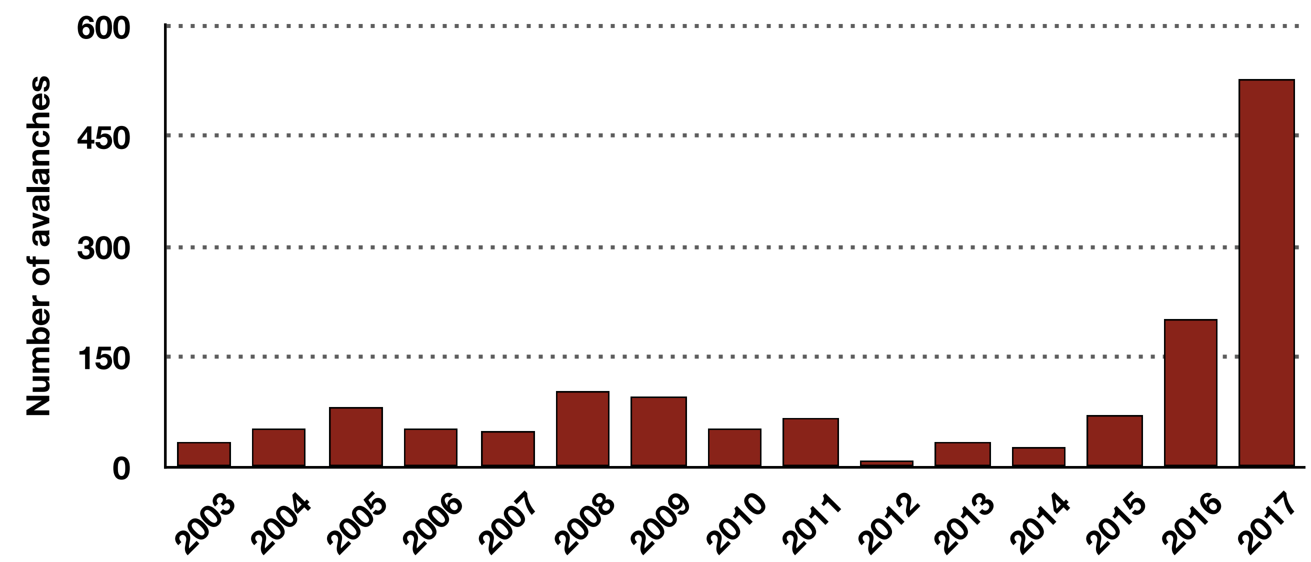


Figure 4: Number of avalanches recorded per year

Figure 5: Method for visually estimating the deposit volume (Bessans/2019/INRAe)

Applied methodologies

- **Corridors morphometric variables** were calculated using **GIS** from a metric accuracy DEM

- Two elements of the corridor are characterized:
  - the presumed preferential avalanche flow path (PPFP) within the corridor
  - the corridor itself

Table 1 : descriptive statistics of avalanche corridors

Variable	Mean	Std. deviation	Range
Length (m)	1515	615	594-2860
Minimal elevation (m a.s.l.)	1781	123	1461-2313
Maximal elevation (m a.s.l.)	2731	397	2120-3731
Mean elevation (m a.s.l.)	2281	260	1936-2942
Vertical drop (m)	950	395	331-1887
Area minimmal slope (°)	3	4	0-15
Area maximal slope (°)	82	81	39-89
Area mean slope (°)	39	7	26-49
Surface area (ha)	36	39	3-172

- **Spearman correlations coefficients** were calculated between each descriptive variable of corridor morphology and the transformed deposition volume data

$$\rho = 1 - \frac{6 \sum d_i^2}{n(n^2 - 1)}$$

→ Useful because of the **asymmetric distributions** with inclusion of **extreme values**

A STRONG AVALANCHE ACTIVITY AND A HIGH SPATIAL VARIABILITY

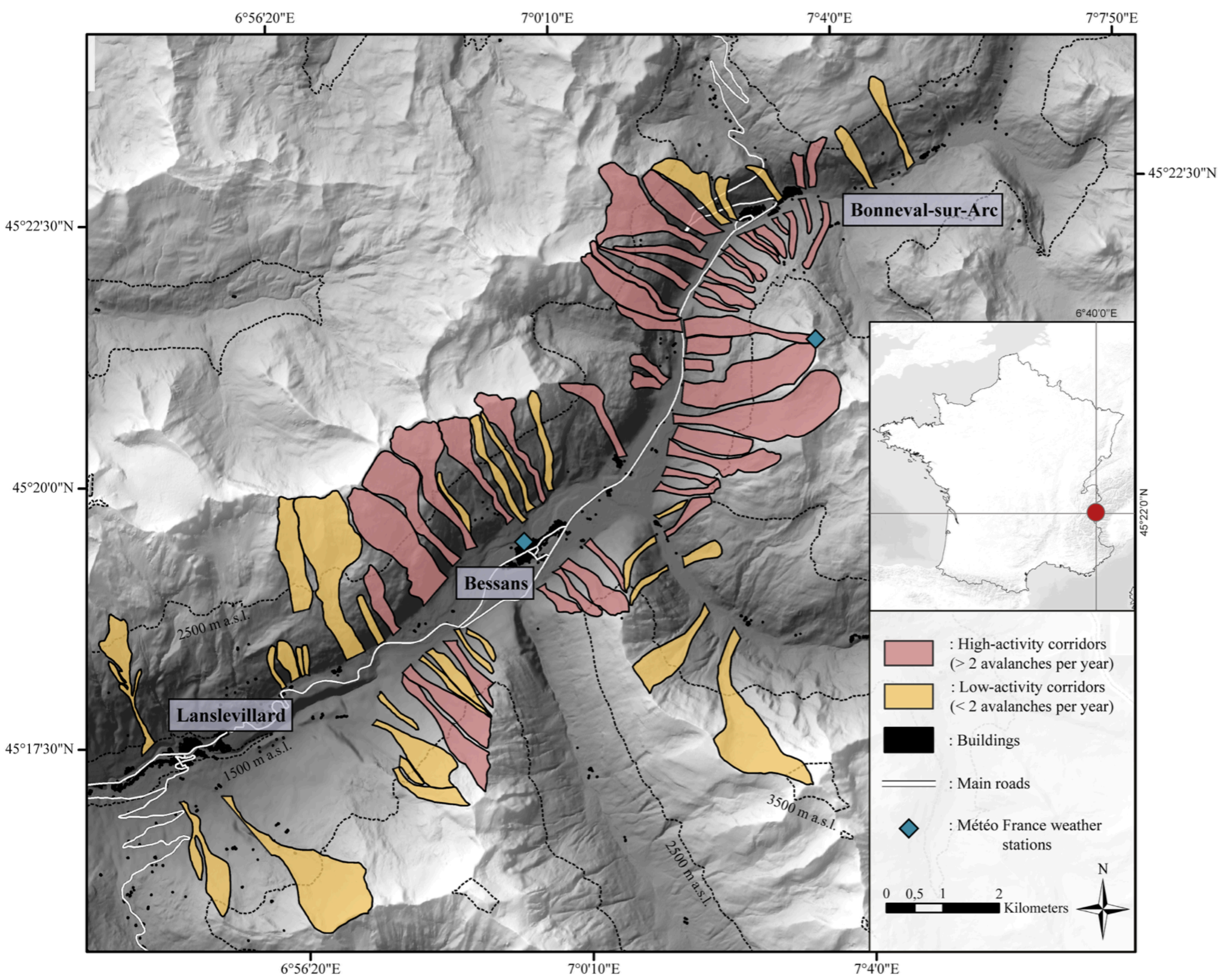


Figure 6: Avalanche activity in the upper part of the Maurienne Valley corridors between 2003 and 2017

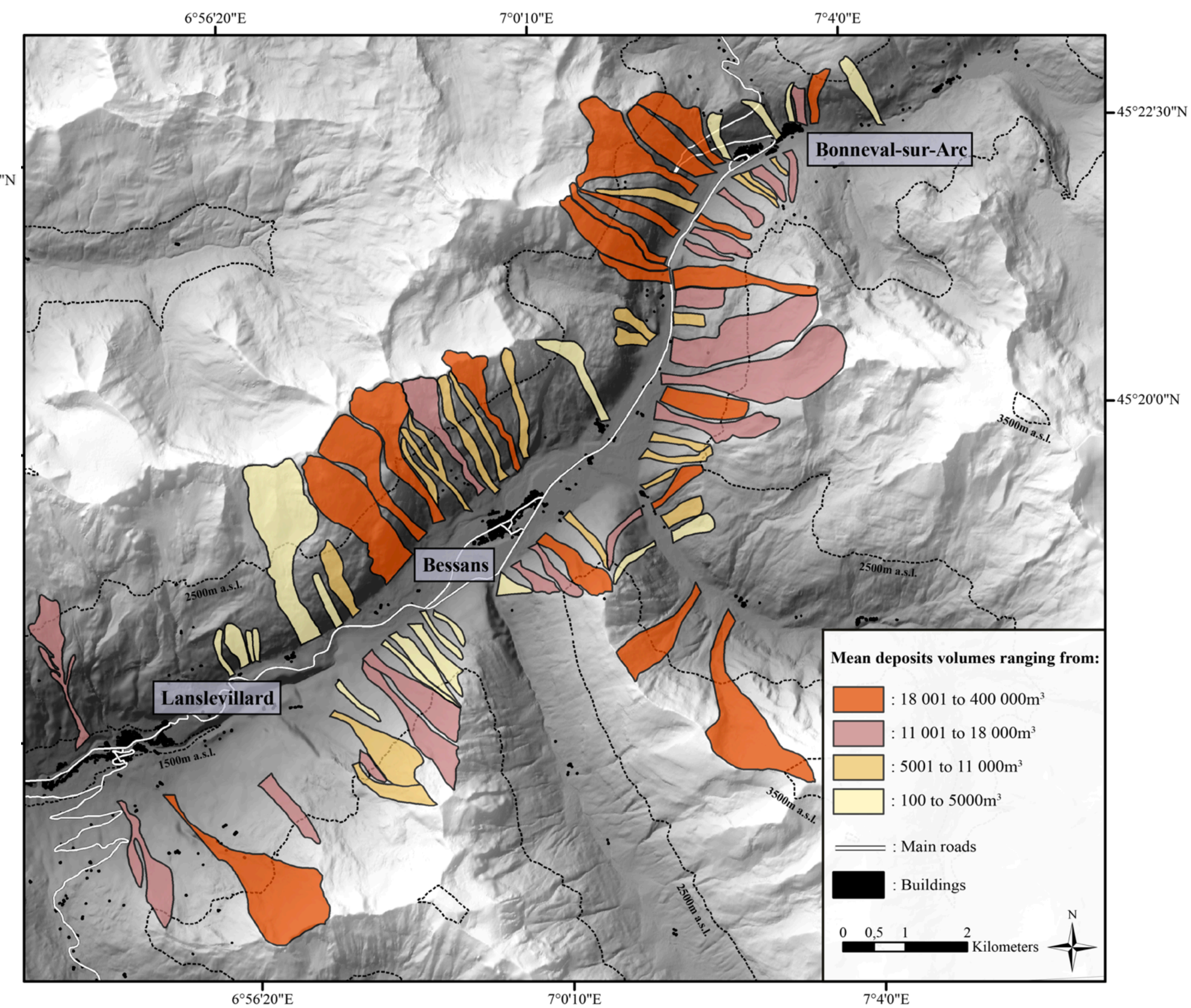


Figure 7: Location map of the EPA corridors depending on mean deposit volumes

CORRIDOR MORPHOLOGICAL VARIABLES CONTROLLING DEPOSIT VOLUMES

- The surface area of the corridors and two elevation variables are **particularly correlated with deposit volumes**
- **Complex interaction** between deposit volumes and **slope variables**
- **PPFP** characteristics **not correlated** with deposit volumes
- No influence of the **corridor mean orientation**

→ **Deposit volumes mainly influenced by three variables**

Table 1: Corridor morphological variables correlated with deposit volumes

Variables		Signs of correlation
Corridor area	Maximal elevation	+
	Mean elevation	+
	Surface area	+
	Vertical drop	+
	Area min slope	+
	Area max slope	+
	Minimal elevation	-
	Area mean slope	-
	Mean orientation	-
PPFP	Length	-
	Minimal slope	-
	Maximal slope	-
	mean slope	-

= **Highly significant** ($\rho > 0{,}5$ et $P < 0{,}001$)

= **Significant** ($\rho = [0{,}3;0{,}5[$ et $P < 0{,}05$)

= **Not significant** ($\rho < 0{,}3$ et/ou $P > 0{,}05$)

STRONG INFLUENCE OF THE MEAN ANNUAL CORRIDOR ACTIVITY ON DEPOSIT VOLUMES

- **The number of avalanches per year and per corridor is controlled by slope variables**

- **Counter-intuitive result** for the relation between the size of **deposit volumes and the annual activity of the corridors**

→ The largest deposits are observed in corridors that show high annual avalanche frequency

→ Deposit volumes occurring in corridors with a low annual frequency correlate more strongly with the corridor morphology

→ **The slope variables are, through the annual frequency, an indirect and complex controlling factor of the deposit volumes**

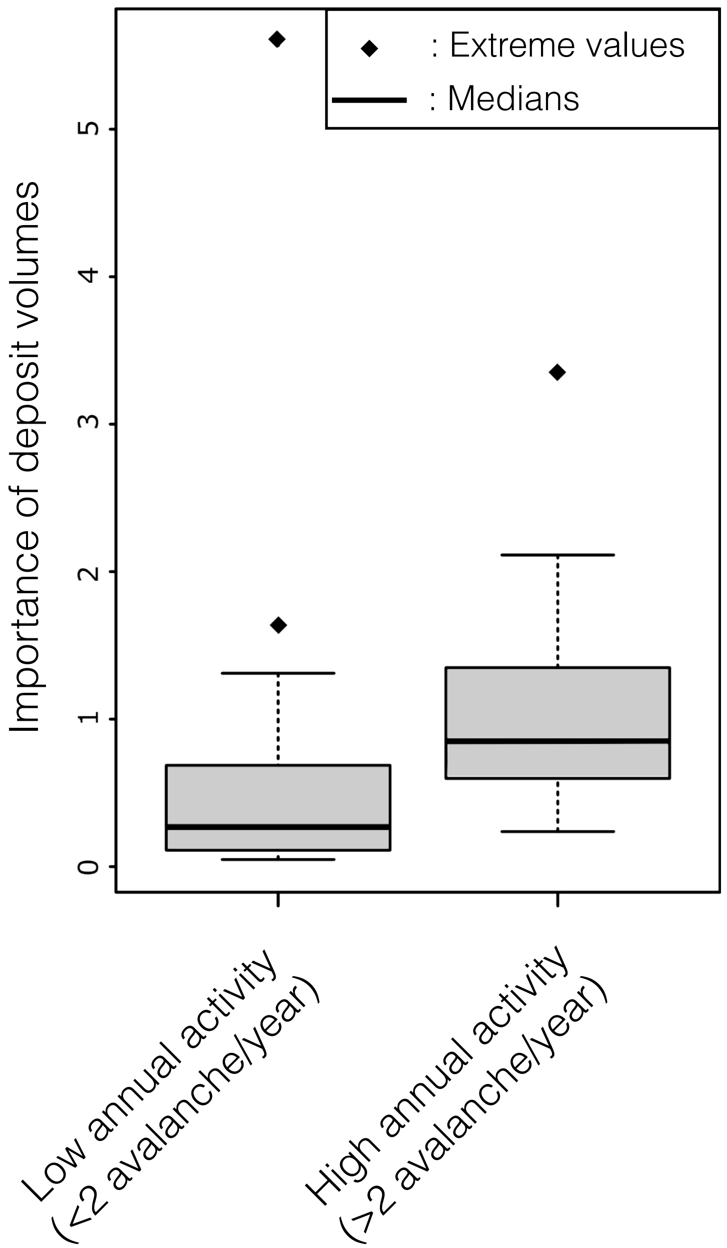
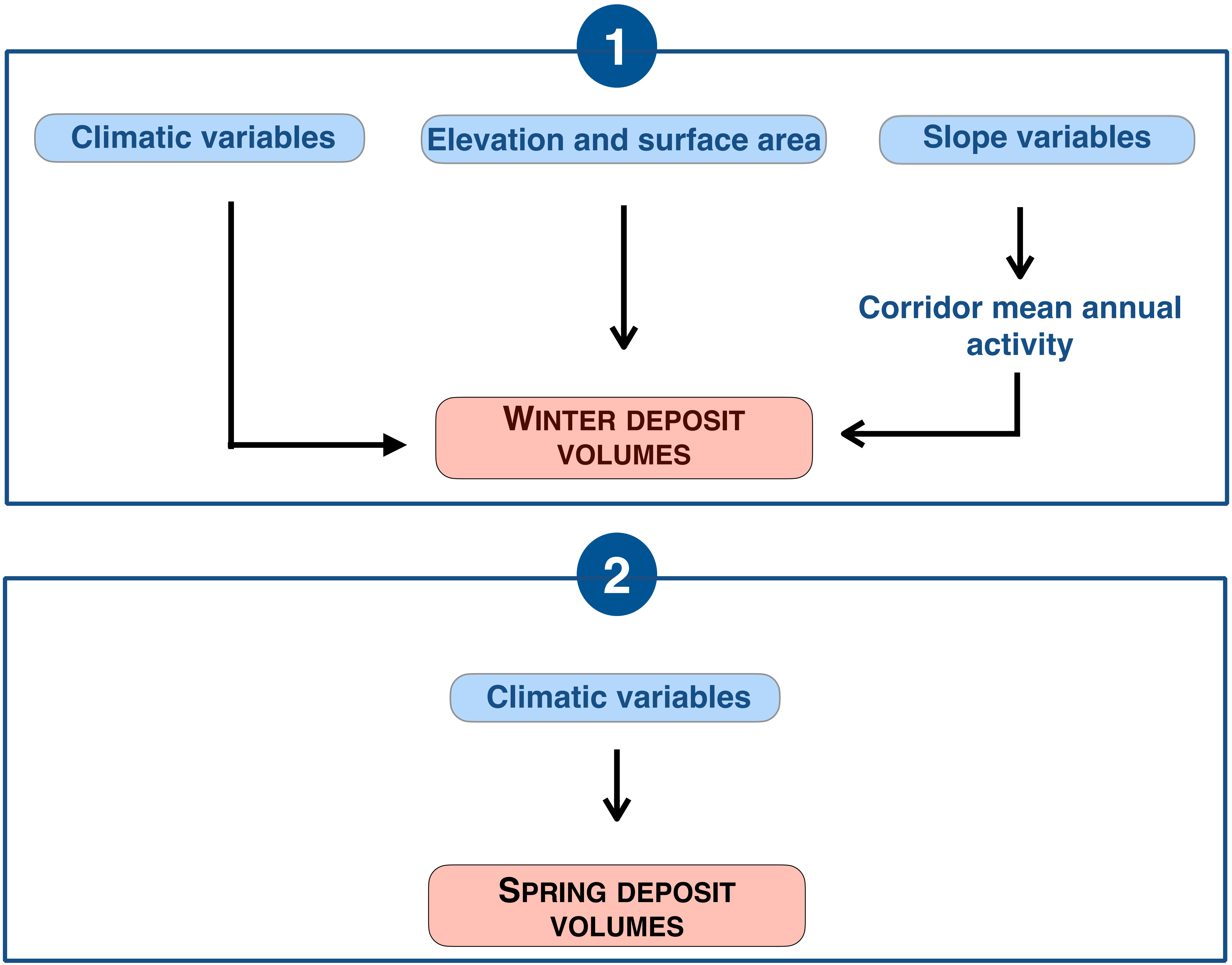


Figure 8: Deposit volume by class of mean annual activity

ONLY WINTER DEPOSIT VOLUMES ARE CORRELATED WITH CORRIDORS MORPHOMETRIC VARIABLES

- **No correlation** between corridor morphological variables and **spring deposit volumes**
- **A one-way ANOVA** conducted on deposit volumes for both seasons shows a **statistically significant difference** ($F(1,123) = 6.681$, $p = .010$) between **the winter and spring subsamples.**

→ **spring deposit volumes may be more climate-controlled**


1
Climatic variables
Elevation and surface area
Slope variables
Corridor mean annual activity
WINTER DEPOSIT VOLUMES
2
Climatic variables
SPRING DEPOSIT VOLUMES

OUTLOOK

1

- Improve the results with the use of a **logit model**
  - ➡ **A richer comprehension** of relationships for sub-sets
  - E.g: Corridor with a mean annual activity higher than 2 events per year

Table 2: Results of logit models for the corridors with a mean activity >2 /year

annual activity > 2/ year	Source	Value	Standard Error	Wald Khi²	Pr > Khi²	Wald infimium (95%)	Wald supremum (95%)	% correct 0	%correct 1	% correct
	Z_Min	1,247	0,391	10,189	0,001	0,481	2,013	86,96 %	86,36 %	86,67 %
	Max_Slope	-0,824	0,398	4,301	0,038	-1,604	-0,045			

➡ Deposit volumes (> 2 events per year) = 1 / {1 + EXP[-(-109,3+0,062*Z_Min*-0,002*Max_Slope*)]}

2

- Contribution of the **climatic factors to the study** of the dimensions of the deposits
- Study of the **road network vulnerability** to avalanches

Avalanche deposit field work in Bessans (2020, INRAe)

Thank you

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