# Testing the influence of snow and meteorological conditions on snow avalanche deposit volumes

## 2003-2018, Haute-Maurienne valley, Savoie & Queyras, Hautes-Alpes France



EGU 2021

**Hippolyte KERN*, Vincent JOMELLI*, Nicolas ECKERT**, Delphine Grancher*, Michael DESCHATRES****

*Université Paris 1 Panthéon-Sorbonne, Laboratoire de Géographie Physique, CNRS-UMR 8591

** UR ETNA, INRAE / Université Grenoble Alpes

## 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, preliminary work highlight a **weak relation between path morphological variables and deposit volumes**

→ **Meteorological and snow 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 meteorological and snow characteristics on the volume of avalanche deposits?**

→ **Determine the meteorological and snow characteristics influence on avalanche deposits volumes**

→ **Consider the paths morphological variables influences within the study of relationships between meteorological and snow characteristics and the volume of avalanche deposits**

## STUDY AREA

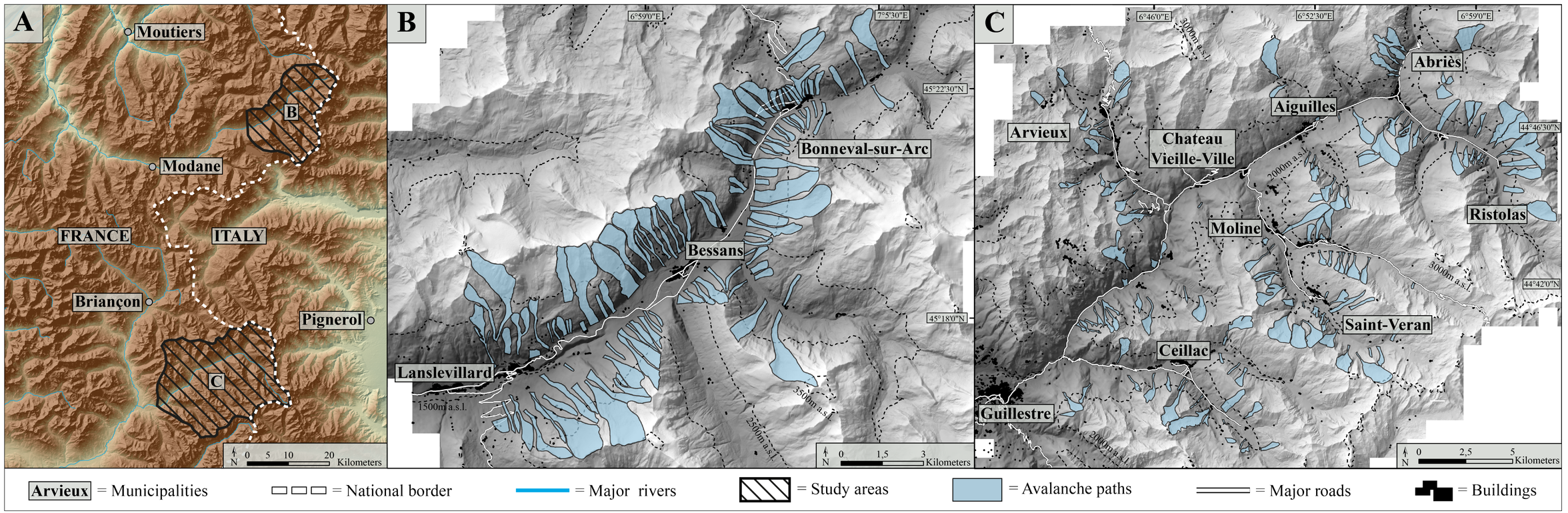



Figure 3: A: Location map of the study areas, B: Snow avalanche paths from the EPA database in the upper part of the Maurienne valley, C: Snow avalanche paths from the EPA database in the Queyras

## AVALANCHE DESCRIPTION DATA

- Data obtained from a preliminary work of correction and completion of the **Permanent Avalanche Survey (EPA) database**
- The EPA paths are well **known, delineated and mapped**
- Database listing **1968 avalanches** described between **2003 and 2018** for the two study areas
- **164 corridors studied:** large variety of sizes and shapes

**Estimation of the deposit volume reported for each avalanche**

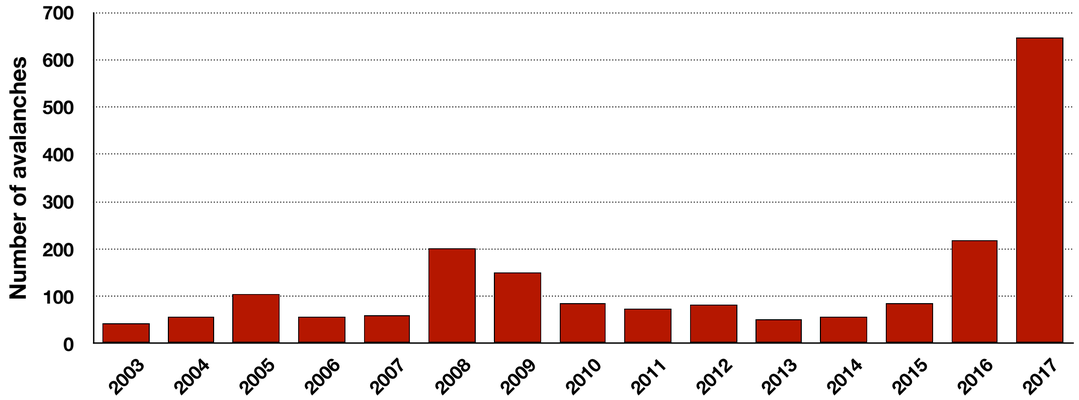



Figure 4: Number of avalanches recorded per year




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

## METEOROLOGICAL DATA

- Data obtained from **re-analyzed meteorological parameters** by Météo France numerical model (SAFRAN)
- **Daily** time steps considered for the 2003-2017 period
- **6 meteorological parameters** relative to the air temperature and snowfall

## SNOW DATA

- Data obtained from **re-analzyded snow depth and characteristics parameters** by Météo France numerical model (CROCUS)
- **Daily** time steps considered for the 2003-2017 period
- **4 snow cover parameters** relative to the snow depth and wet snow depth

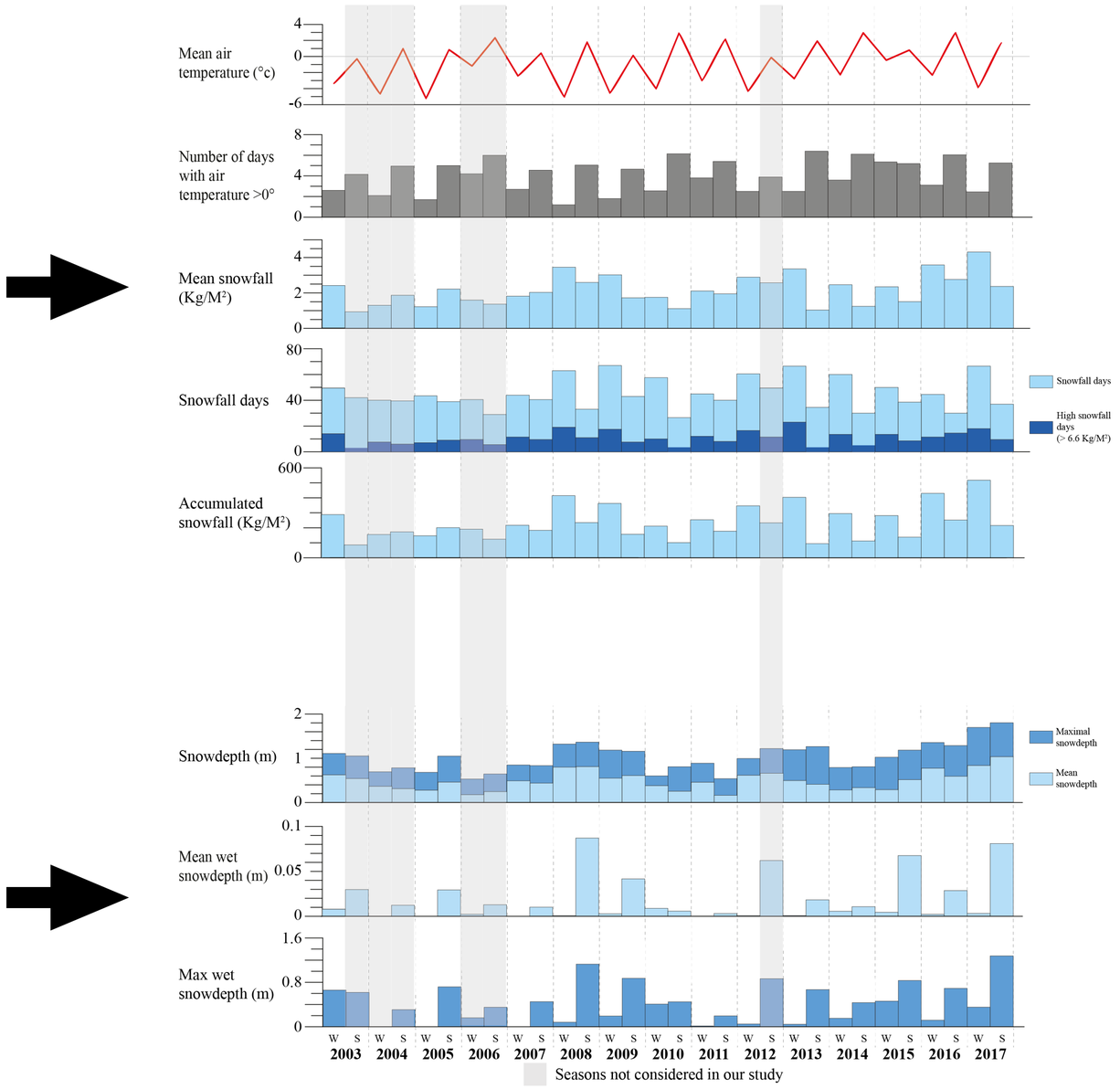



Figure 6: Seasons mean deposit volumes, number of investigated deposits and meteorological and snow data for 2003-2107

# APPLIED METHODOLOGIES

## 1

- **Pearson's correlation ρ** between all pairs of potential meteorological variables **to pre-select meteorological and snow variables**
- **Best linear regressions by adjusting $R^2$** to determine the combination of meteorological and snow variables that best explain the **variability of mean deposit volumes**
- **Distinct linear models** were fitted on the **825 winter (Nov.-Feb.)** snow avalanche deposits and on the **1143 spring (Feb.- May)** snow avalanche deposits

→ **No partition**

## 2

- **A partition of the investigated paths** was carried out considering paths morphological characteristics, the cutoff values used is the **median value of each morphological variable :**
  - Surface area: < or > than 40 ha
  - Mean altitude: < or > than 2220 m a.s.l.
  - Mean slope: < or > than 34°
  - Vertical drop: < or > than 680 m
- **One-way analyses of variance (ANOVA)** to evaluate the significance of each partition
- **Distinct linear models** were fitted on each subsamples considering the different seasons

→ **Partition based on paths morphological characteristics**

# ONLY WINTER DEPOSIT VOLUMES PRESENT A RELATIONSHIP WITH METEOROLOGICAL AND SNOW PARAMETERS

- **No correlation** between meteorological or snow parameters and **annual or spring deposit volumes**

- **Important positive relationship ($R^2$=0.78)** between winter deposit volumes and two snow parameters : mean snow-depth and max wet snow-depth

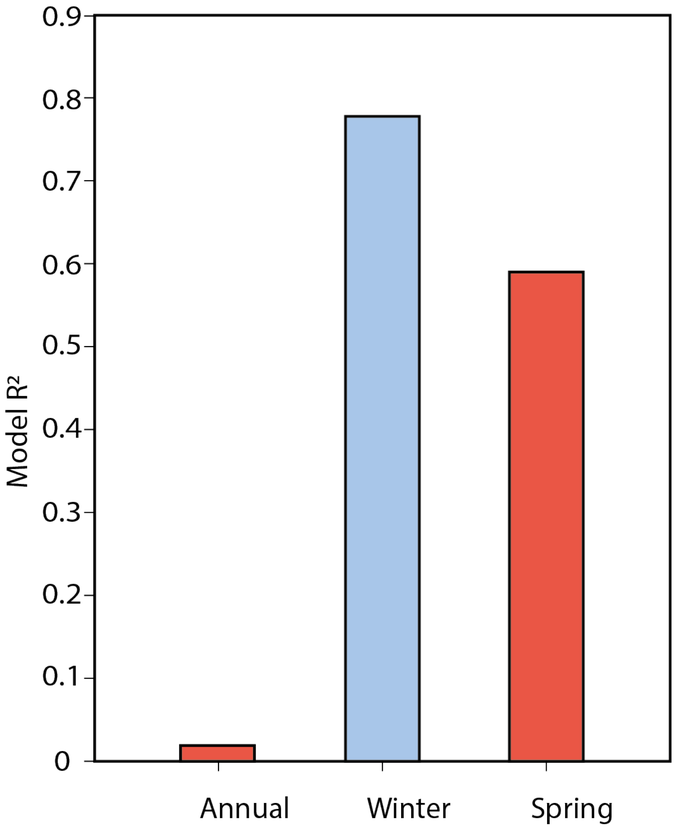



Figure 7: Linear regression $R^2$ between mean deposit volumes and meteorological and snow settings at different seasons

# GEOMORPHOLOGICAL PARTITIONS INDUCED HIGH VARIATIONS

- **A partition of the investigated paths** considering paths morphological characteristics shows **important differences in the linear regression $R^2$ and retained variables.**

- For example, we observe important variations between the two winter linear regressions considering the surface area of the paths:

- **Avalanche paths with a surface area lower than 40 hectares**

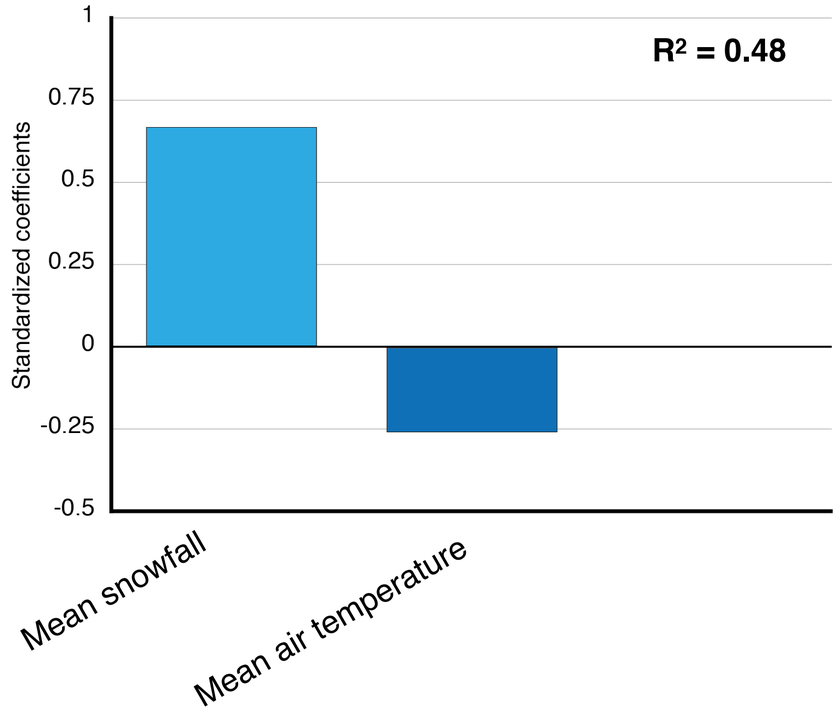



Figure 8: Retained variables by the linear regression model on the winter data from the paths with a surface area < 40ha

- **Avalanche paths with a surface area higher than 40 hectares**

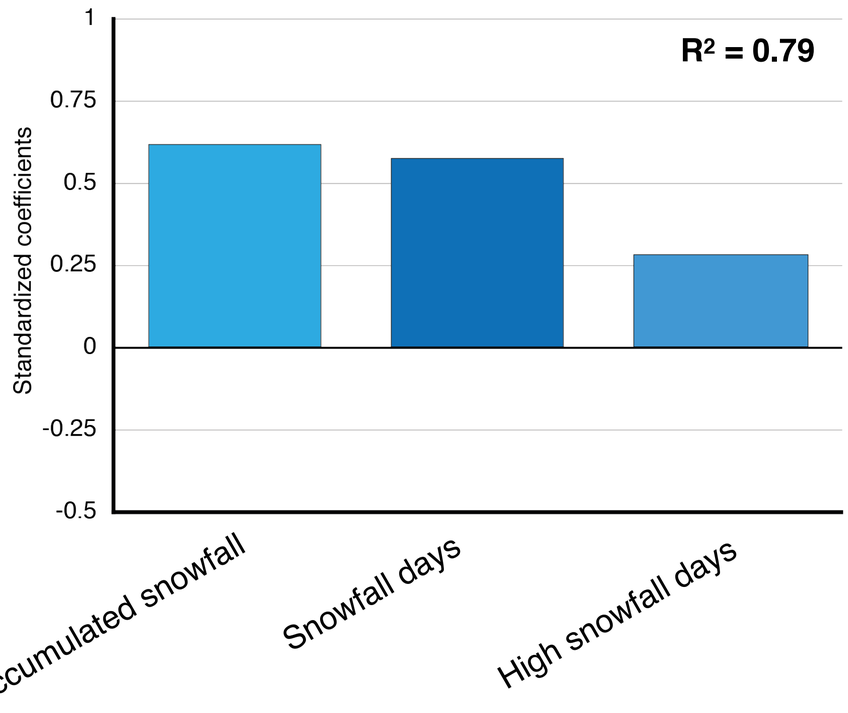



Figure 9: Retained variables by the linear regression model on the winter data from the paths with a surface area > 40ha

# HIGH VARIATIONS BETWEEN THE STUDY AREAS

- **High disparities in the number of investigated deposits :** 75% of the deposits are from the upper part of the Maurienne valley

- **High variations in the linear regression results at local scale:**

- **Avalanche paths from the Maurienne valley**

- 1515 investigated deposits
- Model is only significant for winter season

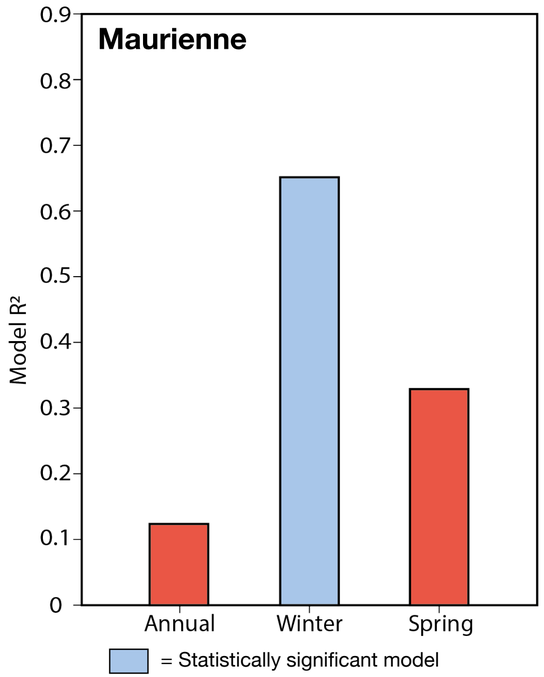



Figure 10: Linear regression $R^2$ between mean deposit volumes and meteorological and snow settings at different seasons for the upper part of the Maurienne valley

- **Avalanche paths from the Queyras**

- 448 investigated deposits
- Models are significant for the three seasons
- Important variations in the retained variables

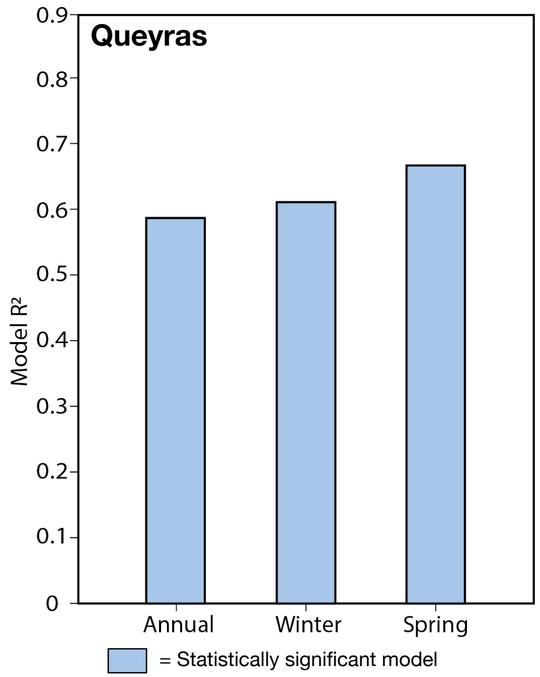



Figure 11: Linear regression $R^2$ between mean deposit volumes and meteorological and snow settings at different seasons for the Queyras

→ **The global results are strongly impacted by the upper part of the Maurienne valley meteorological dynamics**

## CONCLUSION

- **Winter deposit volumes are highly dependent ($R^2$=0.78) of two snow parameters: mean snow-depth and max wet snow-depth**

→ **High variations in the results considering the geomorphological parameters of the paths**

→ **High variations in the results between the two study areas**

## OUTLOOK

- **Expand the study areas to:**
  - **reduce the dependence of results on one area**
  - **investigated more precisely the local specificities**



Avalanche deposit field work in Bessans (2020, INRAE)

Thank you

cnrs
UNIVERSITÉ PARIS 1 PANTHÉON SORBONNE
UFR GÉOGRAPHIE
L.G.P. LABORATOIRE DE GÉOGRAPHIE PHYSIQUE ENVIRONNEMENTS QUATERNAIRES ET ACTUELS UMR 8591
INRAE