



**HAL**  
open science

## Mapping potential release areas and modelling runout distances of permafrost rock slope failures at a regional scale for hazard assessment

Maëva Cathala, Florence Magnin, Ludovic Ravel, Luuk Dorren, Frédéric Berger, Franck Bourrier, Nicolas Zuanon, Philip Deline

### ► To cite this version:

Maëva Cathala, Florence Magnin, Ludovic Ravel, Luuk Dorren, Frédéric Berger, et al.. Mapping potential release areas and modelling runout distances of permafrost rock slope failures at a regional scale for hazard assessment. 6th World Landslide Forum 2023, Nov 2023, Florence, Italy. . hal-04684170

**HAL Id: hal-04684170**

**<https://hal.science/hal-04684170>**

Submitted on 2 Sep 2024

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Copyright

# Mapping potential release areas and modelling runout distances of permafrost rock slope failures at a regional scale for hazard assessment

Cathala M.<sup>1,2</sup>, Magnin F.<sup>1</sup>, Ravanel L.<sup>1</sup>, Dorren L.<sup>3</sup>, Berger F.<sup>4</sup>, Bourrier F.<sup>4</sup>, Zuanon N.<sup>5</sup>, Deline P.<sup>1</sup>



<sup>1</sup> EDYTEM Lab. (UMR 5204), USMB - CNRS, France  
<sup>2</sup> Alpes Ingé, Saint Vincent de Mercuze, France  
<sup>3</sup> Bern University of Applied Sciences BFH-HAFL, Switzerland  
<sup>4</sup> INRAE, Grenoble, France  
<sup>5</sup> A2 Photonic Sensors, Grenoble INP-Minatec, France

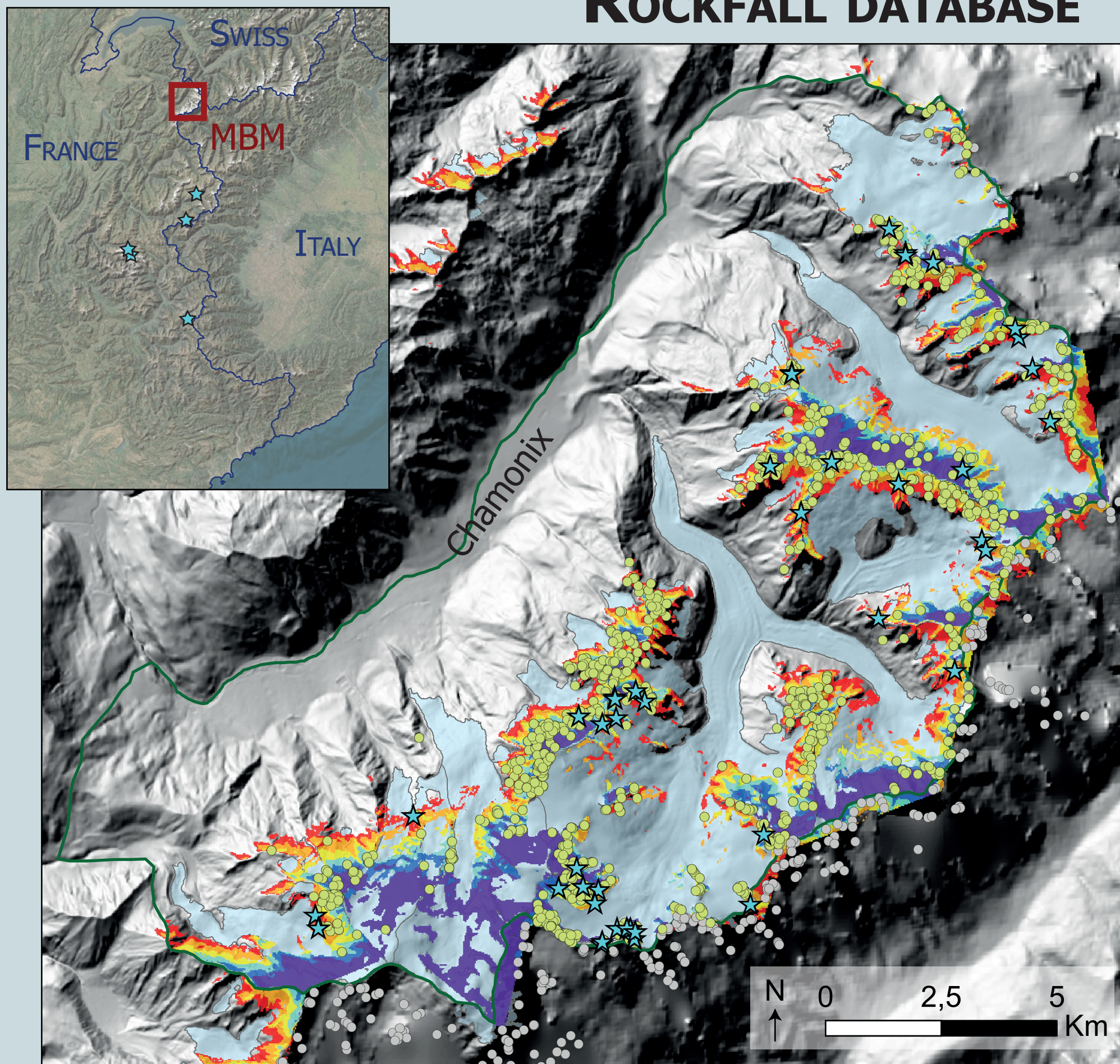


OBJECTIVES

High mountains environments are highly affected by climate change through glacier retreat and permafrost degradation. These phenomena may cause **rock slope failures**, sometimes provoking far-reaching cascading processes threatening human lives and infrastructure. Increasing knowledge on the **triggering mechanism** and **propagation** is therefore required to propose adaptation strategies. In the French Alps, permafrost mapping and extensive rockfall inventories provide relevant data for statistical analysis of their triggering conditions and mobility. In accordance with the GAPHAZ guidelines for hazard assessment (GAPHAZ, 2017), the aims of this study are: (i) to propose a **mapping approach** of susceptible **release areas** of rock slope failures and resulting **runout distances** at a **regional scale** (French Alps), and (ii) to **identify hotspots** for further **hazard assessment**.

METHODS

## ROCKFALL DATABASE



**Mont Blanc Massif (MBM) database**  
 (1389 events >100 m<sup>3</sup>)

- Rockfalls used for statistical analysis
- Rockfalls outside of the raster extent
- Raster extend for MBM database analysis

**High Mountain Database** (48 events)

- ★ Rockfall used to analyse the mobility

**Permafrost: Mean Annual Rock Surface Temperature (MARST; °C)**

- < -2
- -2 to -1
- -1 to 0
- 0 to 1
- 1 to 2
- 2 to 3

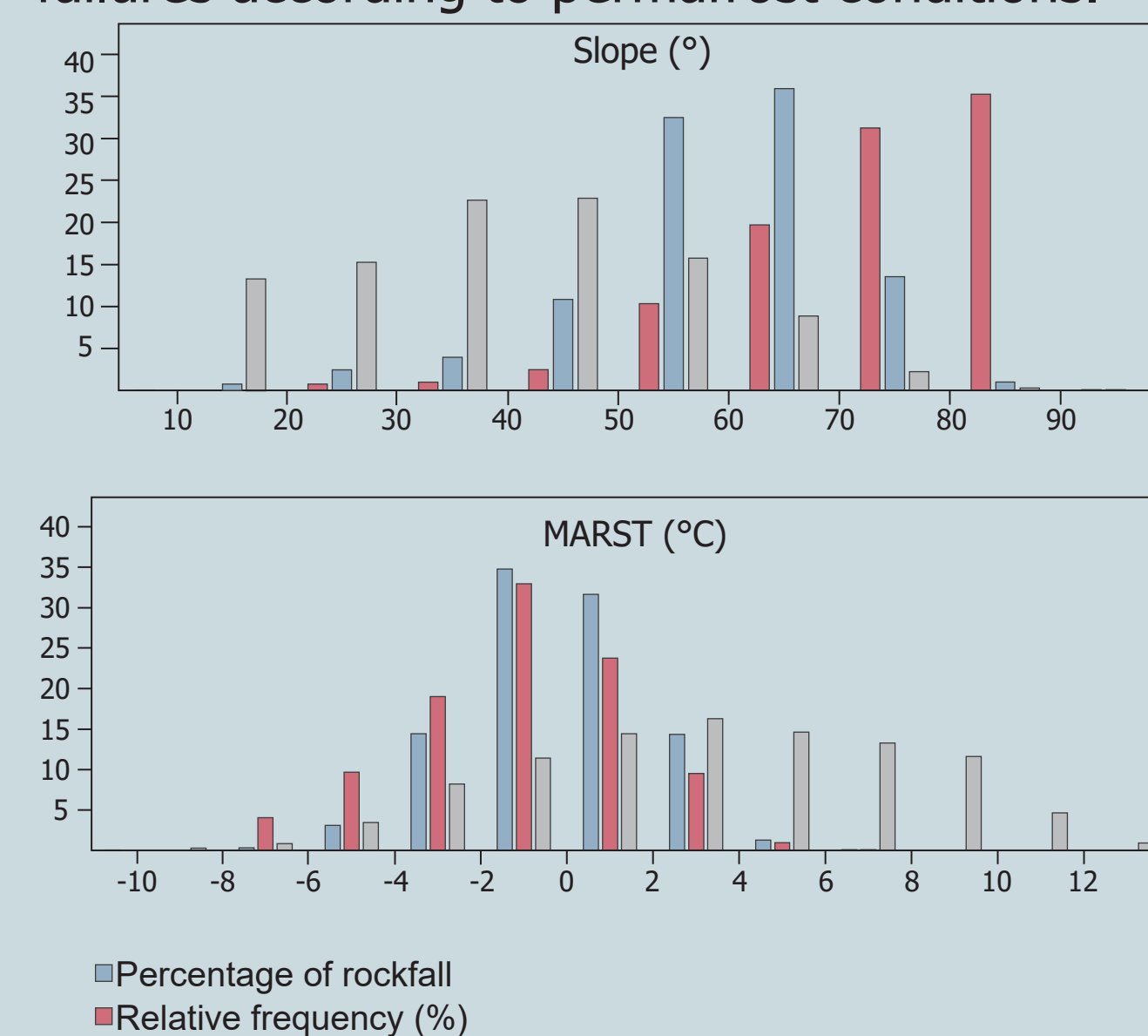
Glacierized areas: ■

The propagation database complete the **3630 events recorded by Rock the Alps** (Interreg Project) in order to calibrate the RockavELA model.

## STATISTICAL ANALYSIS

### Statistical distribution of rockfall according to triggering conditions

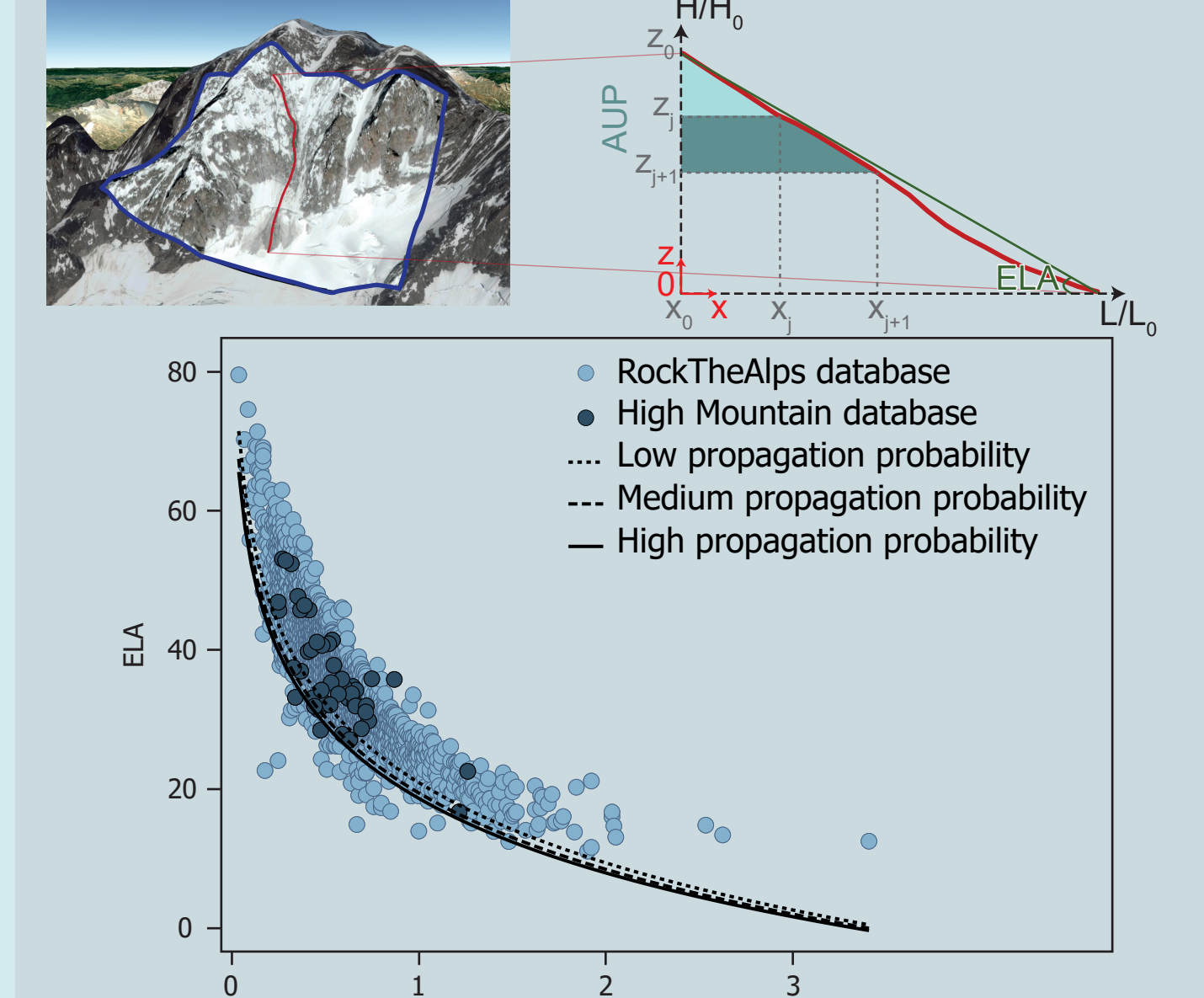
The MBM rockfall database is used to analyse the **distribution of rock slopes failures** according to the **permafrost (MARST)** in the slopes >30°. The results allow to determine the conditions the most prone to trigger rock slope failures according to permafrost conditions.



\*1 The relative frequency is calculated according to the rockwalls area for each slope and MARST classes.

### Propagation analysis

The mobility of each rockfalls of the propagation database and the Rock the Alps database is given by the **Energy Line Angle<sup>2</sup> (ELA) normalize by the dimensionless area under profile<sup>3</sup> (AUP)**



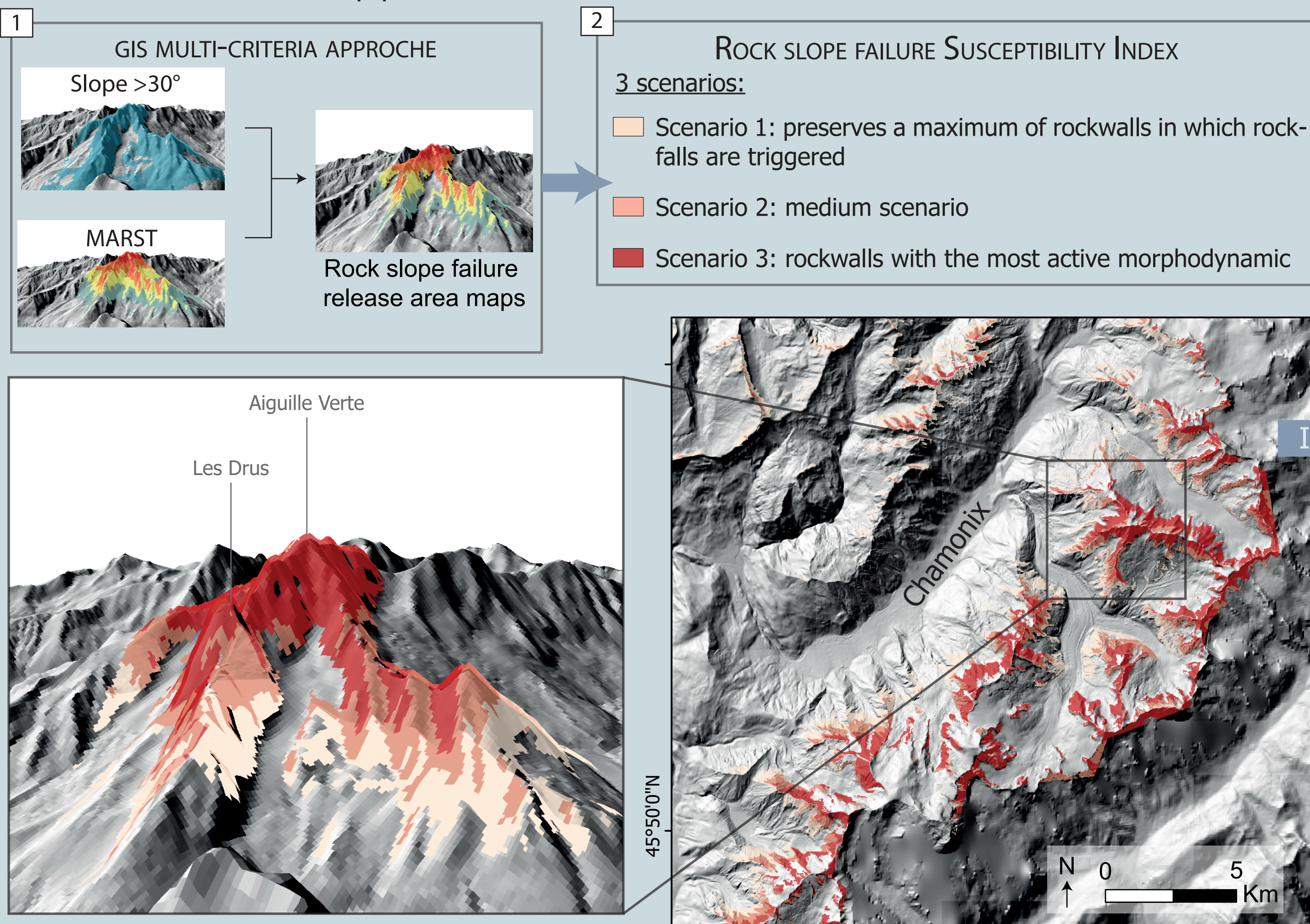
\*2 Angle between the maximum drop height and the maximum horizontal deposition distance (from the top of the scar to the tip of the deposit)

\*3 The dimensionless area is calculated with the area under the profile of each rockfall

RELEASE AREAS AND RUNOUT DISTANCES: REGIONAL MAPPING

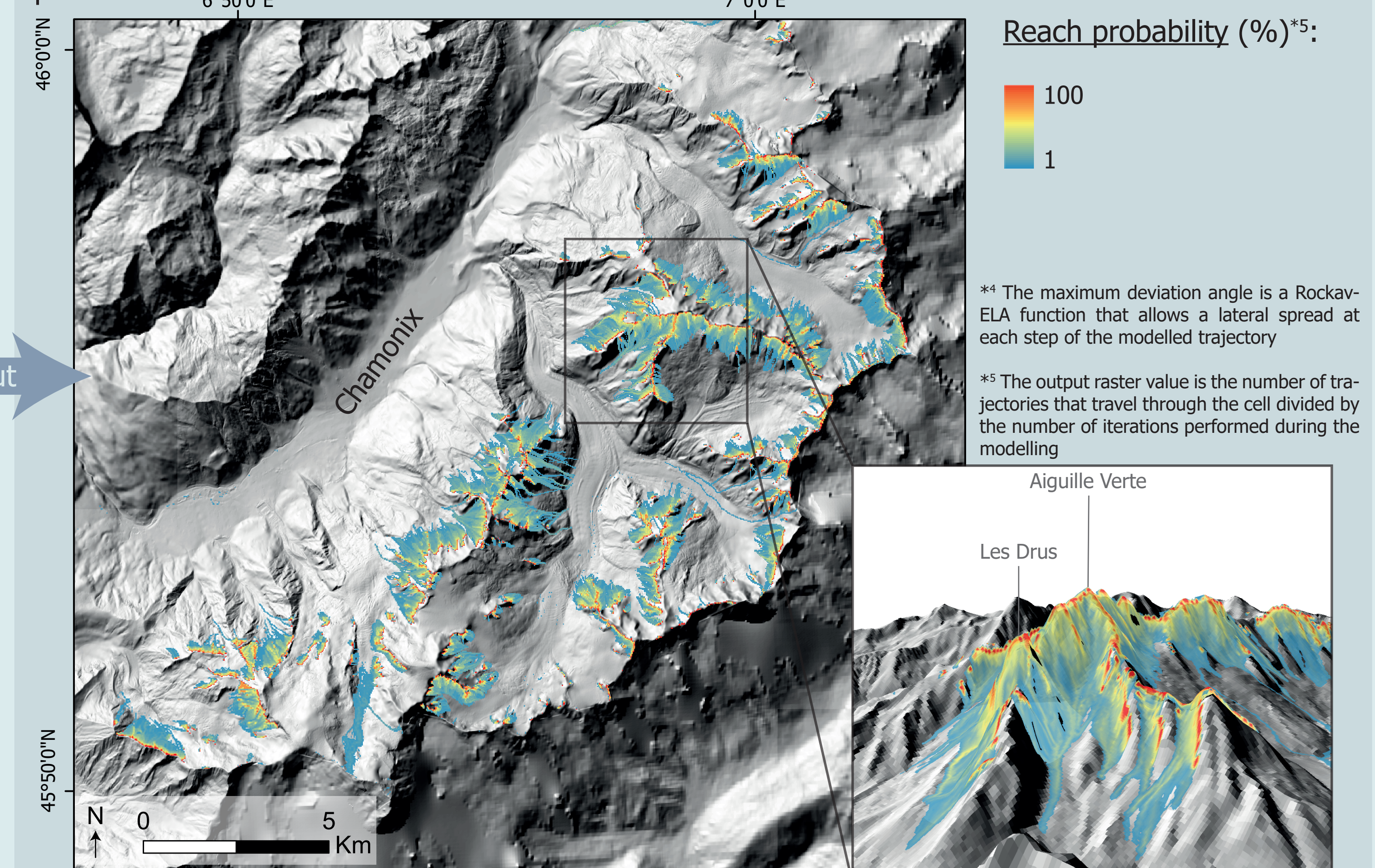
## RELEASE AREAS MAPPING

The statistical distribution of the rockfalls according to slope and MARST are used to set up a multi-criteria GIS scheme to map potential release areas.

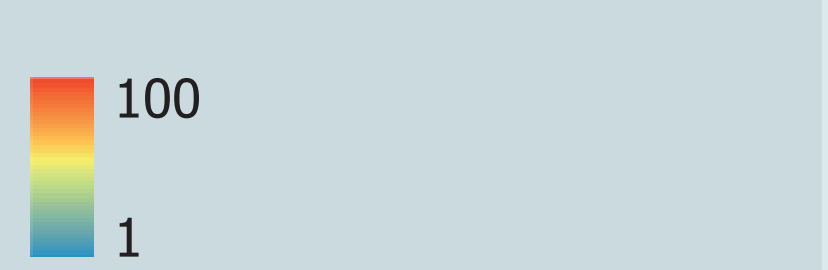


## RUNOUT DISTANCES MODELLING

The RockavELA model (Rock avalanche Energy Line Angle) is used to map at a regional scale the potential runout distances of rockfalls. The model is based on the **Energy Line Angle** and the **Area Under Profile** principles to calculate stopping threshold and a **deviation angle<sup>4</sup>** allows a lateral spread.



Reach probability (%)<sup>5</sup>:



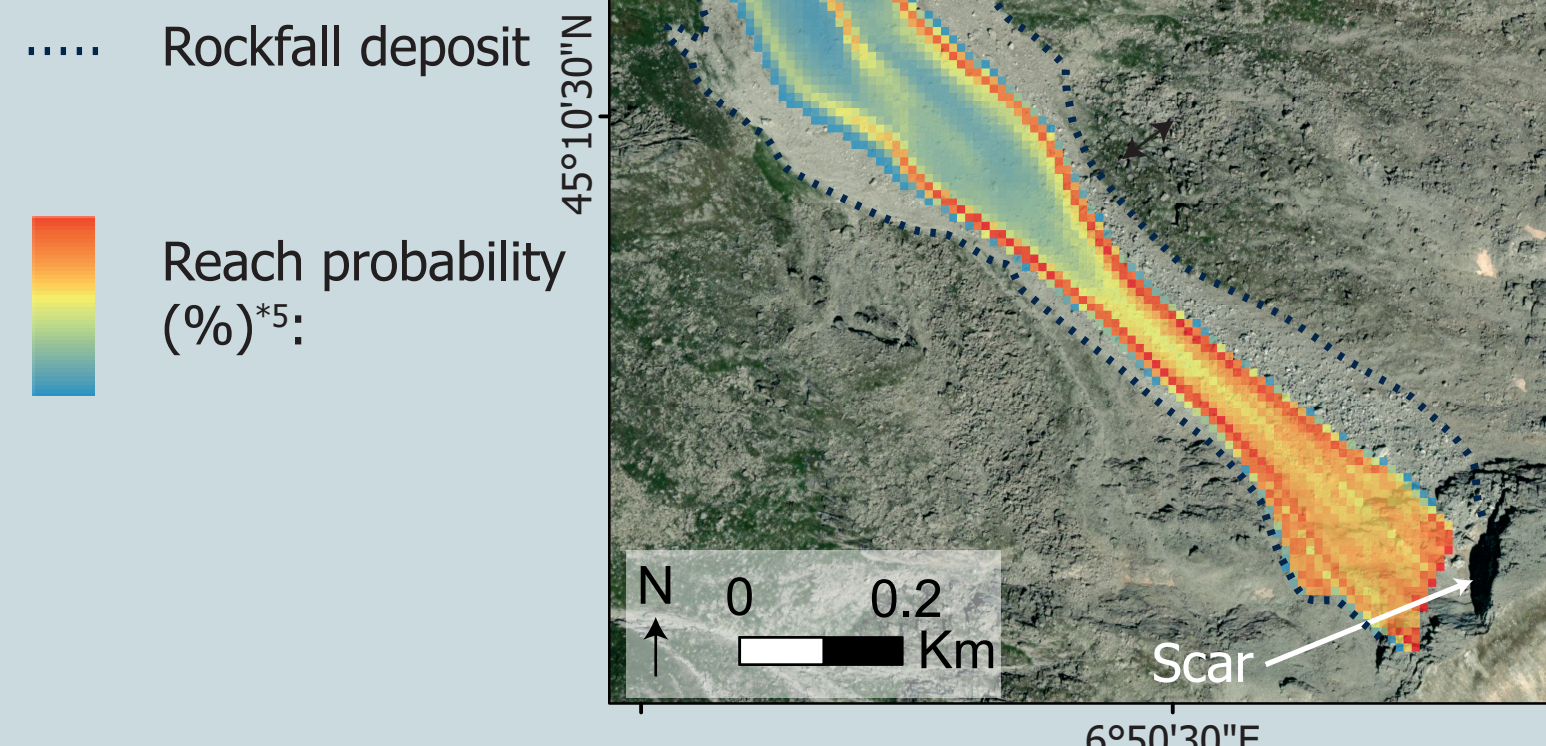
\*4 The maximum deviation angle is a RockavELA function that allows a lateral spread at each step of the modelled trajectory

\*5 The output raster value is the number of trajectories that travel through the cell divided by the number of iterations performed during the modelling

PERSPECTIVES

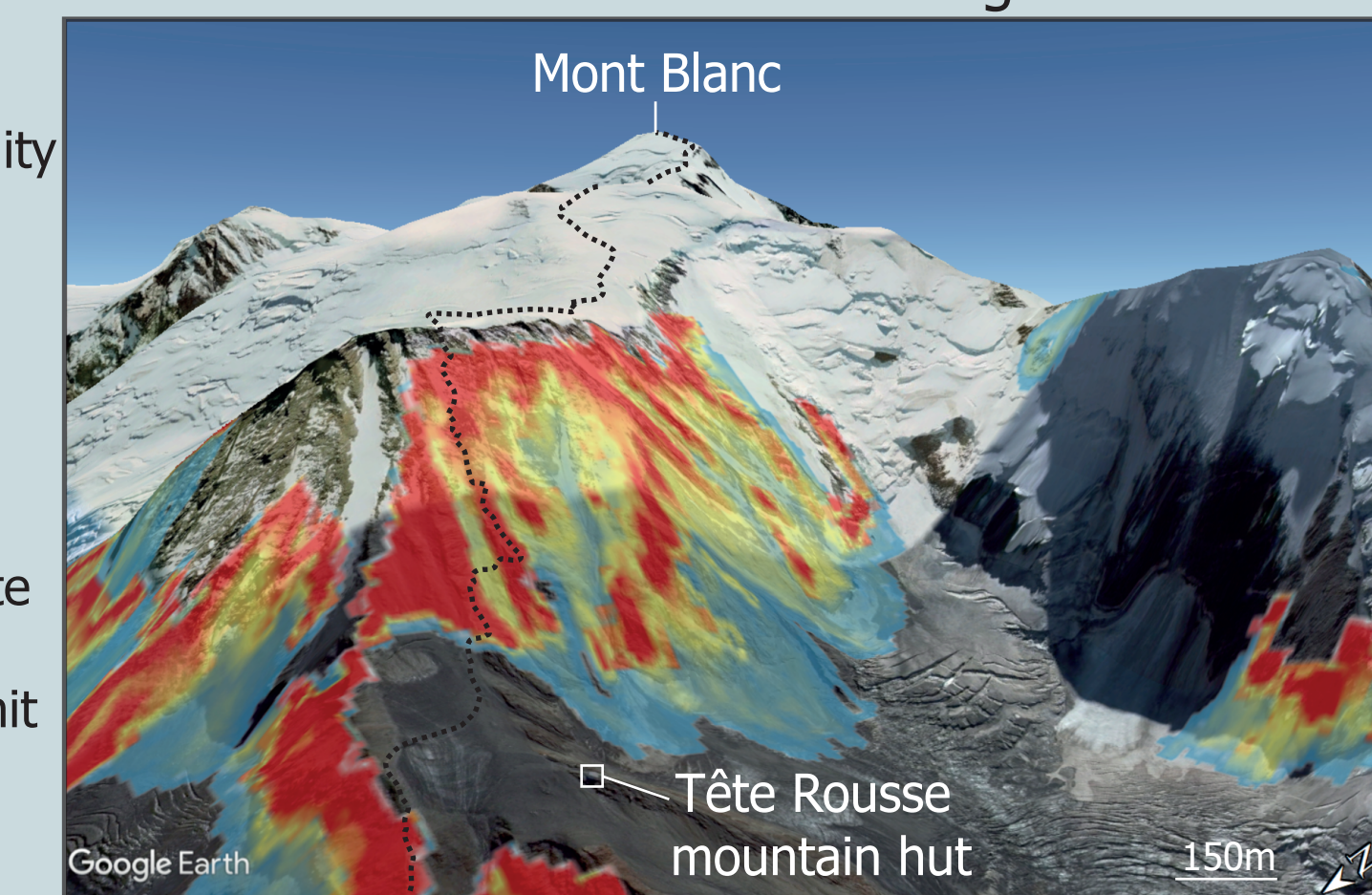
## VALIDATION

The validation of the model will be realised by a **sensitivity study** of the different settings (e.g. lateral spread, segment length) and by measuring the frontal and lateral error (vertical/horizontal distance) between the modelled deposition trajectories rockfall deposit from the propagation database.



## HAZARD ASSESSMENT

This study is a first step to anticipate the location of potential rockfalls trajectory at regional scale and **identify hotspots** where **human issues** (e.g. mountaineering routes, infrastructure, tourism areas) could be impacted. More in-depth studies should be conducted at a local scale for risk mitigation.



## CONCLUSIONS

This work provides a first overview to **assess the susceptibility of rock slope failures and their potential trajectory** at a regional scale for **risk mitigation** in current and future conditions of permafrost degradation. The method presented here is relevant to be reproducible in other mountain ranges and nordic environments.

## REFERENCES

GAPHAZ 2017: Assessment of glacier and permafrost hazards in mountain regions. Prepared by Allen, S., Frey, H., Huggel, C. et al. Standing Group on Glacier and Permafrost Hazards in Mountains (GAPHAZ) of the International Association of Cryospheric Sciences (IACS) and the International Permafrost Association (IPA). Zurich, Switzerland / Lima, Peru, 72 pp.



SCAN ME