Deciphering Rainfall and Freeze thaw cycles as long-term preparatory factors for alpine rockfalls

Greta Bajni, Corrado Camera, and Tiziana Apuani
Dipartimento di Scienze della Terra "A. Desio", Università degli Studi di Milano, Via Luigi Mangiagalli, 34, 20133 Milan, Italy
(greta.bajni@unimi.it)

Due to climate change and the strong relationships between landslides and atmospheric variables, the concept of a stationary landslide susceptibility appears limited. However, relating landslides with climatic predisposing and triggering factors is challenging, due to the lack of multitemporal event datasets. Rockfalls are even more challenging in this context, as their reaction to meteorological events is connected to widely variable characteristics (e.g. rock type, in situ stress, fracture network).

By exploiting and homogenizing a multitemporal rockfall inventory and meteorological datasets of the Aosta Valley Region (Western Italian Alps), the general goal of our study was to develop a procedure to decipher the effects of both the short- and long-term action of rainfall and freeze-thaw cycles on rockfalls occurrence, recognized as main forcing climatic variables in the classic literature. Our specific objective was to define synthetic and effective meteorological variables that can act as predictors in statistical landslide susceptibility models.

We analysed 168 rockfall events and meteorological data from 17 stations from 1990 to 2018 (reference period) distributed on an area 670 km^2. The analysis was performed considering:

- Short term (hourly) precipitation expressed both by the intensity-duration characteristics of the single rockfall associated rainfall(1) and by the maximum cumulated rainfall in time intervals from 0.5 to 24 hours before the event(2);
- Long term precipitation (multiple episodes) expressed both by cumulated rainfall in time interval of 1 day to 60 days (3) and by the number of rainfall episodes occurred in 1- to 12-month time intervals before the event(4);
- Number of Freeze-thaw cycles in the year before the event, identified as temperature variation crossing the 0°C value(5).

By comparing the statistical distribution, for the whole reference period, of the above mentioned climatic variables and the meteorological conditions before each rockfall event, we recognized four types of not ordinary climatic conditions. All conditions resulted to be associated to long term conditions of any time interval, while hourly intervals did not result significant. Type-a is associated to cumulated rainfall overcoming the 90th percentile of the historical time series(69 out of 168);

Type-b to a number of rainfall episodes higher than the 75th percentile value(70 rockfalls out of 168); Type–c to a number to a number of freeze-thaw cycles higher than the 75th percentile value(66 out of 168); Type-d to a combination of these factors (47 out of 168). Only 5 rockfalls occurred during ordinary meteorological conditions, whereas the remaining 37 rockfalls could not being analysed due to the absence of complete meteorological data.

Based on these results, we defined a long term Intensity-duration and two episode-duration thresholds, each expressed by a power law equation. The number of times, in the reference period, of exceedance of the selected thresholds represent the synthetic variables to be spatialized by means of geostatistical techniques and tested within a statistical landslide susceptibility model.