Geophysical Research Abstracts
Vol. 20, EGU2018-6396, 2018
EGU General Assembly 2018

Spatio-temporal cluster analyses of landslides causing damage in Switzerland

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Landslides in mountainous regions cause extensive erosions and are responsible of fatalities and high economic losses. In particular, in the Swiss territory landslides are related to the geological, geomorphological and glacial history of the country and are influenced by preparatory factors, such as climate or human activities. A vast literature exists on landslides, especially concerning susceptibility mapping aimed at evaluating the probability of having or not a landslide in a given area. These techniques normally assume that landslides are uncorrelated in space and in time: however, recent studies demonstrated that this assumption is weak.

The present research analyses the spatio-temporal pattern distribution of landslides causing damage in Switzerland in the last twenty years (1995-2015), with the aim of detecting if neighboring events are also closer in time, generating clusters. Data came from the multi-temporal landslide damage database implemented by the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL) on the base of historical information covering a period of 45 years (1972 up to nowadays). We applied the spatio-temporal scan statistics permutation model (STPSS, integrated in the SaTScanTM software), which allowed detecting clusters' location and estimating their statistical significance. STPSS is based on cylindrical moving windows which scan the area across the space and in time counting the number of observed and expected occurrences and computing the likelihood function. The statistical inference (p-value) is evaluated by Monte Carlo sampling and finally the most likely clusters in the real and randomly generated datasets are compared. The spatio-temporal size of detectable clusters is influenced by the radius and the duration of the scanning windows: thus, different values were tested. It resulted that significant clusters were bigger when the maximum allowed radius augmented, while their number decreased.

Although more detailed analyses are required for the determination of cause-effect relationships among landslides and other variables, some relations with the local climatic and meteorological conditions can already be argued. For example, the huge rainfall event of August 2005, which triggered hundreds of landslides, was clearly highlighted using both a large and a small radius, but in this second case the cluster duration was longer (circa 2 years). This could indicate a possible path dependency effect among fore-events and the main event of August 2005. In conclusion, the application of spatio-temporal cluster analysis at various scale allowed the identification of time frames with greater landslide activity. The question of whether this increase in activity depends on changes in climate conditions or land use is still open and request further investigations.

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