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A generic multi-hazard and multi-risk framework and its application illustrated in a virtual city

Arnaud Mignan, Fabian Euchner, and Stefan Wiemer
ETH, Swiss Seismological Service, NO, Zurich, Switzerland (arnaud.mignan@sed.ethz.ch)

We present a generic framework to implement hazard correlations in multi-risk assessment strategies. We consider hazard interactions (process I), time-dependent vulnerability (process II) and time-dependent exposure (process III). Our approach is based on the Monte Carlo method to simulate a complex system, which is defined from assets exposed to a hazardous region. We generate 1-year time series, sampling from a stochastic set of events. Each time series corresponds to one risk scenario and the analysis of multiple time series allows for the probabilistic assessment of losses and for the recognition of more or less probable risk paths. Each sampled event is associated to a time of occurrence, a damage footprint and a loss footprint. The occurrence of an event depends on its rate, which is conditional on the occurrence of past events (process I, concept of correlation matrix). Damage depends on the hazard intensity and on the vulnerability of the asset, which is conditional on previous damage on that asset (process II). Losses are the product of damage and exposure value, this value being the original exposure minus previous losses (process III, no reconstruction considered). The Monte Carlo method allows for a straightforward implementation of uncertainties and for implementation of numerous interactions, which is otherwise challenging in an analytical multi-risk approach. We apply our framework to a synthetic data set, defined by a virtual city within a virtual region. This approach gives the opportunity to perform multi-risk analyses in a controlled environment while not requiring real data, which may be difficultly accessible or simply unavailable to the public. Based on the heuristic approach, we define a 100 by 100 km region where earthquakes, volcanic eruptions, fluvial floods, hurricanes and coastal floods can occur. All hazards are harmonized to a common format. We define a 20 by 20 km city, composed of 50,000 identical buildings with a fixed economic value. Vulnerability curves are defined in terms of mean damage ratio as a function of hazard intensity. All data are based on simple equations found in the literature and on other simplifications. We show the impact of earthquake-earthquake interaction and hurricane-storm surge coupling, as well as of time-dependent vulnerability and exposure, on aggregated loss curves. One main result is the emergence of low probability-high consequences (extreme) events when correlations are implemented. While the concept of virtual city can suggest the theoretical benefits of multi-risk assessment for decision support, identifying their real-world practicality will require the study of real test sites.