



## Counterfactual Volcano Hazard Analysis

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The historical database of past disasters is a cornerstone of catastrophe risk assessment. Whereas disasters are fortunately comparatively rare, near-misses are quite common for both natural and man-made hazards. The word disaster originally means 'an unfavourable aspect of a star'. Except for astrologists, disasters are no longer perceived fatalistically as pre-determined. Nevertheless, to this day, historical disasters are treated statistically as fixed events, although in reality there is a large luck element involved in converting a near-miss crisis situation into a disaster statistic. It is possible to conceive a stochastic simulation of the past to explore the implications of this chance factor.

Counterfactual history is the exercise of hypothesizing alternative paths of history from what actually happened. Exploring history from a counterfactual perspective is instructive for a variety of reasons. First, it is easy to be fooled by randomness and see regularity in event patterns which are illusory. The past is just one realization of a variety of possible evolutions of history, which may be analyzed through a stochastic simulation of an array of counterfactual scenarios. In any hazard context, there is a random component equivalent to dice being rolled to decide whether a near-miss becomes an actual disaster. The fact that there may be no observed disaster over a period of time may belie the occurrence of numerous near-misses. This may be illustrated using the simple dice paradigm. Suppose a dice is rolled every month for a year, and an event is recorded if a six is thrown. There is still an 11% chance of no events occurring during the year.

A variety of perils may be used to illustrate the use of near-miss information within a counterfactual disaster analysis. In the domain of natural hazards, near-misses are a notable feature of the threat landscape. Storm surges are an obvious example. Sea defences may protect against most meteorological scenarios. However, if a major storm surge happens to arrive at a high astronomical tide, sea walls may be overtapped and flooding may ensue. In the domain of geological hazards, periods of volcanic unrest may generate precursory signals suggestive of imminent volcanic danger, but without leading to an actual eruption. Near-miss unrest periods provide vital evidence for assessing the dynamics of volcanoes close to eruption. Where the volcano catalogue has been diligently revised to include the maximum amount of information on the phenomenology of unrest periods, dynamic modelling and hazard assessment may be significantly refined. This is illustrated with some topical volcano hazard examples, including Montserrat and Santorini.