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Young volcanoes in the Chilean Southern Volcanic Zone: A statistical approach to eruption prediction based on time series

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Forecasting volcanic activity has long been an aim of applied volcanology with regard to mitigating consequences of volcanic eruptions. Effective disaster management requires both information on expected physical eruption behaviour such as types and magnitudes of eruptions as typical for the individual volcano, usually reconstructed from deposits of past eruptions, and the likelihood that a new eruption will occur within a given time. Here we apply a statistical procedure to provide a probability estimate for future eruptions based on eruption time series, and discuss the limitations of this approach.

The statistical investigation encompasses a series of young volcanoes of the Chilean Southern Volcanic Zone. Most of the volcanoes considered have been active in historical times, in addition to several volcanoes with a longer eruption record from Late-Pleistocene to Holocene. Furthermore, eruption rates of neighbouring volcanoes are compared with the aim to reveal possible regional relations, potentially resulting from local to medium-scale tectonic dynamics. One special focus is directed to the two currently most active volcanoes of South America, Llaima and Villarrica, whose eruption records comprise about 50 historical eruptions over the past centuries. These two front volcanoes are considered together with Lanín Volcano, situated in the back-arc of Villarrica, for which the analysis is based on eight eruptions in the past 10 ka.

For Llaima and Villarrica, affirmed tests for independence of the repose times between successive eruptions permit to assume Poisson processes; which is hampered for Lanín because of the more limited availability of documented eruptions. The assumption of stationarity reaches varying degrees of confidence depending on the time interval considered, ameliorating towards the more recent and hence probably more complete eruption record. With these pre-requisites of the time series, several distribution functions are fit and the goodness of their fits is evaluated. The mixture of exponentials distribution (MOED), adopted from Mendoza-Rosas and De la Cruz-Reyna (2008), facilitates statistical evaluation of non-stationary eruptive regimes. Despite providing the least good fit of the data, the MOED proves particularly useful for Lanín Volcano, where stationarity can not be assessed because of possible gaps in the eruption record. In general, the Weibull, exponential and log-logistic distributions imply a higher likelihood of future eruptions within a given time, while the Bayesian and MOED analyses predict lower hazard probabilities.

This study does not take into account the complexly interacting geophysical and geochemical processes triggering volcanic eruptions. Our aim is to contribute this statistical prediction to the integrative hazard assessment currently performed in the area by the SFB 574 (“Volatiles and Fluids in Subduction Zones”), complementing regional recording of seismic activity and quiescent gas release, as well as tectonic and geochemical characteristics of the investigated volcanic centres.