A Brownian Passage-TIME model for recurrent volcanic eruptions: An application to Miyakejima volcano

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The definition of probabilistic models as mathematical structures to describe the response of a volcanic system is a plausible approach to characterize the temporal behavior of volcanic eruptions and constitutes a tool for long-term eruption forecasting. This kind of approach is motivated by the fact that volcanoes are complex systems in which a completely deterministic description of the processes preceding eruptions is practically impossible. To describe recurrent eruptive activity, we apply a physically motivated probabilistic model based on the characteristics of the Brownian passage-time (BPT) distribution; the physical process defining this model can be described by the steady rise of a state variable from a ground state to a failure threshold; adding Brownian perturbations to the steady loading produces a stochastic load-state process (a Brownian relaxation oscillator) in which an eruption relaxes the load state to begin a new eruptive cycle. The Brownian relaxation oscillator and Brownian passage-time distribution connect together physical notions of unobservable loading and failure processes of a point process with observable response statistics.

The Brownian passage-time model is parameterized by the mean rate of event occurrence, $\mu$, and the aperiodicity about the mean, $\alpha$. We apply this model to analyze the eruptive history of Miyakejima volcano, Japan, finding a value of 44.2 ($\pm$6.5 years) for the $\mu$ parameter and 0.51 ($\pm$0.01) for the (dimensionless) $\alpha$ parameter. The comparison with other models often used in volcanological literature shows that this physically motivated model may be a good descriptor of volcanic systems that produce eruptions with a characteristic size. BPT is clearly superior to the Exponential distribution, and the fit to the data is comparable to other two-parameters models. Nonetheless, being a physically motivated model, it provides an insight into the macro-mechanical processes driving the system.

Keywords: volcanic eruption prediction, probabilistic models, Brownian-passage time model, Miyakejima volcano, periodicity