Japan Geoscience Union Meeting 2012
(May 20-25 2012 at Makuhari, Chiba, Japan)

SVC51-05 Room:102B Time:May 21 16:30-16:45

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 (+/-6.5 years) for the mu parameter and 0.51 (+/-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