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Forecasting volcanic eruptions using Voight's relation

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Voight's relation $d^2\Omega/dt^2 = K(d\Omega/dt)^\alpha$ between the acceleration and rate of earthquakes or other geophysical parameters Ω has been proposed as a falsifiable hypothesis for precursory signals prior to volcanic eruptions (K and α being empirical constants). Importantly, models based on Voight's relation may permit forecasting of eruption time. However, in existing retrospective analyses it is common to find examples of (1) inappropriate techniques for fitting these models to data and (2) inappropriate data selection that fails to account for the complexity of pre-eruptive processes. Here we test the two main competing hypotheses based on Voight's relation - exponential and power-law acceleration – using maximum likelihood techniques and an information criterion for model choice, based on a Poisson process with variable rate. For examples from Mt Etna and a laboratory brittle creep-to-failure experiment, the power-law is clearly the best model, both in terms of the fit and the resulting error structure, which is consistent with the Poisson approximation. At Kilauea, a spectrum of precursory behaviour is observed indicating different mechanisms controlling the approach to volcanic events. When these are accounted for, an exponential is clearly the best model for all 7 of the appropriate sequences. Deviations from the models most likely reflect local interactions and/or non-stationary loading processes not captured by the mean-field approach inherent in Voight's relation. In addition, we use simulations to demonstrate an inherent problem with model preference, in that a power-law model will only be preferred if failure or eruption occurs close to the singularity. Consequently, even under ideal conditions, a power-law trend may only be observed a short time ahead of an eruption. We conclude that prospective mode model testing is essential for quantifying the predictability of volcanic eruptions using Voight's relation.