Assessing volcano state from multi-parameter monitoring data streams and other evidence using Bayesian belief networks

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Changes in the eruptive state of a volcano affect the potential for hazardous activity. When volcanoes exhibit unrest, risk-managing authorities often seek science-based decision support. Evidence available to scientists about a volcano's internal state is typically indirect, secondary or very nebulous. Approaches to volcano monitoring have advanced substantially in recent decades, increasing the variety and resolution of multi-parameter timeseries data recorded at volcanoes. Interpreting these multiple strands of parallel, partial evidence has thus become increasingly complex. In practice, interpreting timeseries typically requires familiarity with idiosyncrasies of the volcano, monitoring techniques, configuration of recording instruments, observations from other datasets, and so on. Assimilation of this knowledge is necessary in order to select and apply the appropriate statistical techniques needed to extract the required information.

Bayesian Belief Networks (BBNs) use probability theory to treat and evaluate uncertainties in a rational and auditable scientific manner, but only to the extent warranted by the strength of the available evidence. The concept is a suitable framework for marshalling multiple observations, model results and interpretations - and associated uncertainties - in a methodical manner. The formulation is usually implemented in graphical form and could be developed as a tool for near real-time, ongoing use in a volcano observatory, for example. We explore the application of BBNs in analysing volcanic data, the uncertainties of inferences, and how they can be updated dynamically. Such approaches provide an attractive route to developing an analytical interface between volcano monitoring analyses and probabilistic hazard analysis. We discuss the use of BBNs in hazard analysis as a tractable and traceable tool for fast, rational assimilation of complex, multi-parameter data sets in the context of volcanic crisis decision support.