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Combining Volcano Monitoring Timeseries Analyses with Bayesian Belief Networks to Update Hazard Forecast Estimates

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Volcanic hazard assessments must combine information about the physical processes of hazardous phenomena with observations that indicate the current state of a volcano. Incorporating both these lines of evidence can inform our belief about the likelihood (probability) and consequences (impact) of possible hazardous scenarios, forming a basis for formal quantitative hazard assessment. However, such evidence is often uncertain, indirect or incomplete. 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 thus becomes increasingly complex. In practice, interpreting many timeseries requires an individual to be familiar with the idiosyncrasies of the volcano, monitoring techniques, configuration of recording instruments, observations from other datasets, and so on. In making such interpretations, an individual must consider how different volcanic processes may manifest as measureable observations, and then infer from the available data what can or cannot be deduced about those processes. We examine how parts of this process may be synthesised algorithmically using Bayesian inference.

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 strands of evidence (e.g. observations, model results and interpretations) and their associated uncertainties in a methodical manner. BBNs are 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 from the long-lived eruption at Soufriere Hills Volcano, Montserrat. We show how our method provides a route to formal propagation of uncertainties in hazard models. Such approaches provide an attractive route to developing an interface between volcano monitoring analyses and probabilistic hazard scenario 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 timely volcanic crisis decision support.