The application of statistical methods in determining volcanic eruption parameters from tephra fall deposits

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An important methodology in determining eruption parameters for historic explosive eruptions is inversion of the properties of tephra fall deposits. We present a range of statistical approaches for determining the uncertainty that is inherent in these methods, in particular focussing on the estimation of erupted volume and eruption column height. We also use statistical tools to make a more general exploration of which areas of a tephra fall deposit contain the most information about the overall deposit structure and the eruption that formed it.

Eruption volume is typically determined by extrapolating thinning trends found from isopach maps drawn for the areas of the deposits that are preserved, a process that can be subjective and variable. We have developed an alternative statistical method to objectively determine the volume of a fall deposit without the production of isopach maps, in which integration of a log-linear regression model for thickness measurements with distance from the vent is applied to the field measurements without any prior interpretation, and data and model uncertainty is accounted for using Bayesian methods. We find that eruption volumes calculated using our method correspond well to those previously determined by alternative approaches for eruptions including Fogo A, Askja D, Pinatubo C1 and Santa Maria 1902.

Eruption column height and windspeed during the eruption can be inferred from measurements of the maximum clast size found at a given distance from the vent. We have used probabilistic, maximum likelihood techniques to determine which of the methods typically used in the field to determine maximum clast size best reconstructs known eruptive conditions. We have simulated the Grain Size Distribution (GSD) of fall deposits for a known volumetric flow rates, and perform inversions on maximum clast sizes from these statistically-produced GSDs at multiple locations to determine the volumetric flow rate and confidence interval. Comparison of modelled volumetric flow rate with the 'known' volumetric flow rate is then used to identify which method for determining maximum clast size gives the most accurate interpretation of eruptive parameters. Confidence intervals for the accuracy of each method will be presented.

The number and distribution of thickness and maximum clast measurements from fall deposits can limit the amount of information gained from the deposit. We have applied a fixed point variogram to field measurements to identify the dependence of the structure of a deposit (referenced to vent location) to different spatial distributions of measurements. Results suggest that measurements from medial and off-axis areas of the deposit are the most informative.