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Global Sensitivity Analysis of tephra models for forecasting

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Accurate forecasts are needed to help mitigate the risks of volcanic hazards to society. Current approaches use probabilistic estimates based on sparse data, supplemented with expert judgment, to describe likely future eruption characteristics. These probabilistic eruption characteristics then inform input parameters required by hazard models.

This process requires a lot of simulations with varying input parameters to constrain uncertainty around a future eruption's hazard characteristics. It is also computationally intensive, and the outputs may quantify, but do not reduce eruption uncertainty. As hazard models become increasingly more complex, so do the number of input parameters that need to be estimated, thus increasing the number of sources of uncertainty. As input parameters used for volcanic hazard models are fundamentally uncertain before (and often also after) an eruption, how do they affect the accuracy and utility of forecasts made using these models?

This research explores the input space of volcanic hazard models to understand the interactions between model complexity and robustness of hazard model forecasts. We use the exemplar of volcanic ash distribution models Tephra2 and Fall3D at Mt. Taranaki, Aotearoa-New Zealand (30-50% chance of eruption in the next 50 years). Sampling strategies for Tephra2 and Fall3D were developed to ensure that the input parameter space was fully covered and represent real-world values – both through independent and dependent sampling of parameters. For example, plume height is dependent on the amount of mass ejected during an eruption. A Global Sensitivity Analysis is presented here to investigate the input parameters that significantly influence model output variance. This exploration is conducted through the statistical assessment of Sobol' indices and eFAST (extended Fourier Amplitude Sensitivity Tests) to discern the key parameters that contribute to variations in the model's outputs. The results also shed light on which inputs are vital to robust short-term and real-time hazard forecasting, and ultimately require better understanding/quantification before an event.