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Stochastic Risk Evaluation of Volcanic Ash Fallout from Large Eruptions of Sakurajima Volcano

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The forthcoming decades present an escalating challenge in the field of volcanic risk management, with a high probability of a major volcanic eruption in Sakurajima volcano within the next 25 to 30 years. The magnitude and complexity of such an event necessitate a reevaluation of countermeasure and response strategies. The anticipated eruption is not just a geological phenomenon but a multi-faceted disaster with far-reaching implications. The primary concern stems from the massive ash fallout characteristic of such large eruptions, which can have devastating impacts across various sectors, severely disrupting socio-economic activities and community well-being to all Japan areas. The ash fallout from these eruptions poses significant threats to public health, agriculture, transportation, and infrastructure, not just locally but potentially on a global scale.

The challenges of preparing for these events are compounded by the inherent uncertainties in predicting eruption scenarios. Traditional models and historical data provide some insights, but the unique nature of each eruption, coupled with varying geophysical conditions, makes precise prediction challenging. This uncertainty significantly hinders the development of comprehensive preparation plans, as the range of possible scenarios is vast and the specific impacts of each are largely unknown due to its rarity in the last century. Therefore, there is a critical need for innovative approaches that can enhance our understanding of potential eruption scenarios and their corresponding impacts, thereby enabling more effective planning and mitigation strategies.

To address these challenges, our study adopts a novel approach, utilizing extreme value analysis on extensive monitoring data from continuous eruptions from 1955 until now to derive a range of eruption scenarios. This method is grounded in the statistical analysis of past volcanic activities, providing a basis for predicting future eruptions. The scenarios generated focusing in variability of plume heights of large eruptions, offering a spectrum of eruption intensities, each with its unique implications. These heights are not arbitrary but are calculated based on historical data, current volcanic activities, and geophysical modeling, providing a realistic range of potential scenarios.

Building upon these scenarios, we conducted detailed ash dispersal simulations using a Monte Carlo procedure. This approach is particularly suited to addressing the uncertainties inherent in volcanic ash dispersal. By incorporating randomness in the simulation of various parameters - such as wind speed and direction, eruption start time, and duration - we simulated a wide range of possible ash distribution given the obtained eruption scenarios. This probabilistic approach allows us to capture the inherent variability and unpredictability of ash dispersion patterns in a way that deterministic models cannot.

The results of these simulations are comprehensive and multifaceted, offering significant insights into the potential impacts of different eruption scenarios. We synthesized these results into risk curves and probabilistic maps, which serve as effective tools for visualizing and quantifying the potential impacts.

These outputs illustrate not only the geographical distribution of ashfall but also the probability of different levels of ash deposition under each scenario. The risk curves provide a clear depiction of the likelihood of various impact levels, enabling a better understanding of the most probable scenarios and their potential consequences.

Furthermore, these results have profound implications for the development of ashfall countermeasure strategies. They provide a solid foundation upon which emergency response plans can be developed, ensuring that resources are allocated effectively, evacuation plans are sound, and protective measures are appropriately targeted. For instance, the probabilistic maps can inform the planning of evacuation routes, the positioning of emergency shelters, and the distribution of resources. They also play a crucial role in informing public health advisories, agricultural planning, and infrastructure protection strategies.

In the realm of transportation, the simulation outcomes highlight critical areas where road and airport cleaning would be necessary, thereby aiding in maintaining supply chains and evacuation mechanisms. In agriculture, the results inform strategies for crop protection and livestock safety, essential for mitigating economic losses and ensuring food security.

In conclusion, our study represents an advancement in the field of volcanic risk assessment and preparedness. By employing a Monte Carlo approach to simulate ash dispersal for various eruption scenarios, we aimed to provide a more nuanced and comprehensive understanding of the potential impacts of massive ash fallout from various large-scale eruptions. This approach enables more targeted and effective planning and response strategies, ultimately enhancing the resilience of communities, economies, and ecosystems at risk of volcanic disasters. The methodologies and findings of this study have implications far beyond the immediate field of volcanology, offering insights and approaches that can be applied to a broad range of natural disaster scenarios.