A310

Dynamic Volcanic Ash Hazard Maps of the Sakurajima Taisho Eruption Scenario for Evacuation Decision Support

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The municipal government of Kagoshima City has commenced the Model City Framework of Volcanic Disaster Risk Reduction policy in anticipation of the potential large-scale explosive eruption (*cf.* Taisho eruption) in Sakurajima volcano. This plan includes a procedure for a city-wide evacuation during enormous ash fallout resulting from such an eruption. The heavy ash deposits in residential areas can damage buildings, hinder the transportation system's service, and threaten people's health. Therefore, it is necessary for the population in affected areas to evacuate before the disaster.

Massive ash fallout in residential areas requires the creation of large evacuation zones, which may include citizens living outside areas affected by the eruption's direct consequences. These evacuation zones are often determined by applying specific damage thresholds, such as the risk of building collapse or loss of infrastructure services. Authorities need to determine evacuation areas in advance of a disaster in order to prevent loss of life. However, due to the complex and dynamic nature of volcanic ash, it can be challenging to determine precise evacuation zones before an eruption. Additionally, the infrequency of large explosive eruptions makes it difficult to develop effective emergency management and preparedness plans. As a result, the policy for formulating effective evacuation plans in anticipation of volcanic ash hazards is not well-established yet. Furthermore, it is also critical to consider circumstances that can arise during an eruptive period.

Acquiring a more profound knowledge of the complete consequences of volcanic ash hazards is vital. Such knowledge is necessary to understand how evacuation zones will be identified and enforced. Unfortunately, the spatio-temporal complexities in the ash dispersal process can produce biased forecasts. Such errors can lead to inaccuracies in pre-impact assessments, which are crucial for decision-making, impacting affected communities directly. Accordingly, relying solely on prediction results to establish evacuation zones is insufficient for reducing loss of life during a volcanic ash disaster. It is, therefore, critical to developing effective criteria for determining evacuations for all people at risk and minimising false alerts in unnecessary areas.

Unfortunately, the authorities can only rely on the ashfall forecast output 24h before the eruption, provided by the Japan Meteorological Agency (JMA), when making evacuation decisions. This mechanism was enacted due to the time-consuming process of mobilising all people at risk to safer locations, as it is currently estimated that it will take 24h to 30h. However, it is important to note that precisely predicting the start of an eruption is extremely challenging, and the quality of wind forecasts can decrease sharply the longer the time lead. Therefore, the evacuation zones designated a day before an eruption are expected to contain a fair amount of wrongly judged areas likely. Incorrectly assigned evacuation zones can result in unexpected casualties and false alerts to communities outside exposure areas.

In the current initiative, the residents of Kagoshima City will be instructed to evacuate after obtaining the possibility of an eruption in a day. This evacuation process will occur when it is expected that there will be strong easterly winds during the eruption. Such a policy was specifically drafted due to the position of Kagoshima City, located on the western side of the Sakurajima volcano. However, the probability of ash affecting the city side is low as winds are primarily westerly throughout the year.

Additionally, the initiative promotes the Zero Victim Goal (no casualties) in the event of a major Sakurajima eruption. In order to achieve this goal, Kagoshima City has divided the city side into six sectors based on wind direction to ease traffic congestion during evacuation. However, this division is only intended to avoid congestion when leaving the city and to provide safer destination options to the north or south of the prefecture without considering the effectiveness and efficiency of evacuation orders. Nevertheless, the authorities will issue evacuation orders to all sectors if conditions are met. This can lead to discrepancies in the actual communities at risk in the event of irregular weather patterns. Underestimating the evacuation zones can result in more casualties while overestimating the evacuation zones can result in more people being forced to evacuate despite living in safe areas.

In this study, we consider the spatio-temporal evolution of the Taisho eruption of the Sakurajima volcano to understand when and how impacts from volcanic ash hazards could manifest and influence evacuation decision-making for city-side residents. We produce temporal volcanic ash hazard maps based on the Taisho eruption scenario that will explain the dynamic changes in ash coverage. To explain the complete probable impacts of a large-scale explosive eruption in Sakurajima volcano, we produce the maps following the eruption transition every six hours for two days. Furthermore, to provide input to the decision-makers about the enhancement that can be done for evacuation decision-making, we also produce the dynamic volcanic ash hazard maps from the day before the assumed eruption until just before it starts. The information presented in both dynamic hazard maps will contribute as a knowledge base for the disaster risk reduction strategies anticipating future eruptions.

To our knowledge, continuous information updates on the ground deposit output from ash dispersal simulations can support decision-makers decisively. While this technique is still in its early stages, the feasible solution presented in this study has the potential to make a valuable contribution to the development of overall strategies for managing volcanic ash hazards and to provide constructive input to comprehensive volcanic disaster risk reduction.