E 104

Developing an airport-specific volcanic early warning system for aviation preparedness

〇 Ziyang LIU, Masamitsu ONISHI, Haris RAHADIANTO

1. Introduction

A VEI 4 eruption of Eyjafjallajökull in 2010 April paralyzed European airspace for almost one week, making it the costliest disruption to aviation in history. Until now, Japan has never experienced a severe aviation disruption from volcanic ash, but Japan can never take it lightly. Sakurajima may erupt massively in the next 30 years [1]. Still worse, simulation reveals that as far as Tokyo is under threat. However, Japan does not have a volcano alert level system for aviation nor a detailed volcanic hazards mitigation plan. In acknowledgement of weaknesses of current aviation volcanic hazard management, we are collaborating with stakeholders from airlines, authority, volcano observatories and academic researchers from multiple disciplines to explore new strategies to enhance the aviation section's level of preparedness.

2. Methodology

The roadmap to design the early warning are as follows: Alert level design, airport classification, and trigger events designation.

(1) Alert level design. We decided to develop an action-based alert level system as the interface of our early warning system to communicate volcanic risks to end-users, which should minimize confusion on the airlines end and prompt quick actions. This design is supported by both airlines and volcanologists. We designate four levels: Green, Yellow, Orange, and Red, indicating Safe, Prepare, Reduce, and Evacuate. When the airport is safe, no attention is required; when the airport is at Level Yellow, we recommend airlines and airports to prepare for nighttime standby. When the airport is at Level Orange, airlines should reduce risk exposures. We recommend airlines cancel arrival flights to reduce risk exposure at this stage. When the airport is at Level Red, the airport is under imminent threat and we suppose airlines should evacuate aircraft to safe airports and cancel risky departing and arriving flights.

(2) Airport groups. We implement an airport-specific early warning system because heterogenous characteristic of volcanic risks between airports means differing level of uncertainty tolerance, thus targeted actions are worthwhile. To make the system more practical, we categorize Japan's airport into six action subgroups. Group A and Group B require nighttime standby, Group C airports are also threatened by volcanic risks but nighttime standby is unnecessary, and Group D airports are largely safe according to simulations. To be specific, Group A contains airport where aircraft evacuation should start before the eruption onset while for Group B airports such decision makings can wait until the eruption onset. Group B is further subdivided into three subgroups: B1, B2, and B3, based on the availability of detailed VAFF and 2^{nd} round of detailed VAFF.

(3) Trigger events and indicated actions. Notably, the decision making regarding to nighttime standby should be made at 9am, if simulation warns ashfall of 0.2mm or above. In this research, we incorporate JMA-managed VALS Ground Hazard, which is intended to warn residents of volcanic risks, not for aviation purpose. However, it can be utilized as a good indicator of volcanic unrests. The assignments are shown in Figure 1.

3. Workshop Validation

We organized a face-to-face workshop inviting stakeholders from airlines, authority, Sakurajima Volcano

Observatory, to validate our proposed early warning system, and every assumption we made when developing the system is carefully examined. The workshop concluded that firstly our proposed volcanic early warning system, which focuses on preparedness and pre-event retreat from risky airport is valuable because the potential negative cost is unbearable and early response increases airlines resilience against volcanic risk which is fraught with uncertainty. Secondly, participants acknowledged our design as innovative and practical. However, airline stakeholders advised us to take seasonal disparity into consideration in the future.

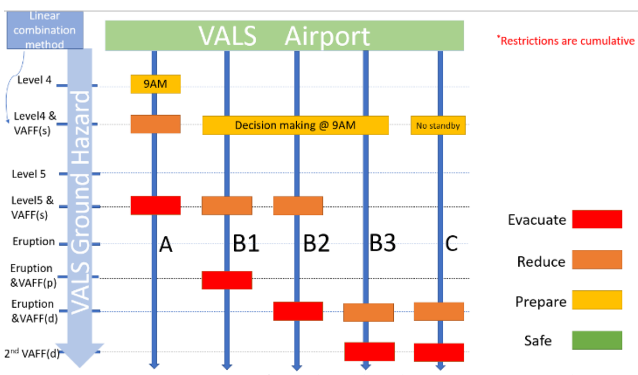

Figure 1 Trigger events for alert levels. JMA-managed VALS Ground Hazard serves to communicate level of volcanic activities. Volcanic ashfall forecast (VAFF) communicates ashfall risk at each airport. Linear Combination Method monitors the ejectable volume of ash, an input for VAFF.

4. Quantitative Assessment

The assessment reveals that our early warning can reduce the hazard loss by 87% given the eruption onsets at 10pm and more reliable in winter seasons. However, in the worst cases, the early warning can only prevent roughly 11% losses. We further find that typhoon activities only have a marginal contribution to the system dysfunction but failure at any hub airport can significantly compromise the early warning. Distance and ashfall being close to the 0.2mm threshold are found to have a negative impact on the system performance (Figure 2, Figure 3).

5. Conclusion

In this interdisciplinary early warning research, we developed an airport-specific volcanic alert level system for managing aircraft evacuation under threat of a large-scale eruption. To make the airport-specific system and phased response practical, we deliberately divide airports into six subgroups, taking advantage of the varying ash arrival time. Trigger events and indicated actions of the system are also proposed and validated by stakeholders. We also quantitatively assessed the effects of uncertainty associated with wind forecast and eruption onsets. Additionally, we found that distance can explain the disparity of performance between airports, implying longer ash travel time may reduce the warning sensitivity, which may further explain more missed alerts in June and October, when ash travel time is longer due to weak westerlies.

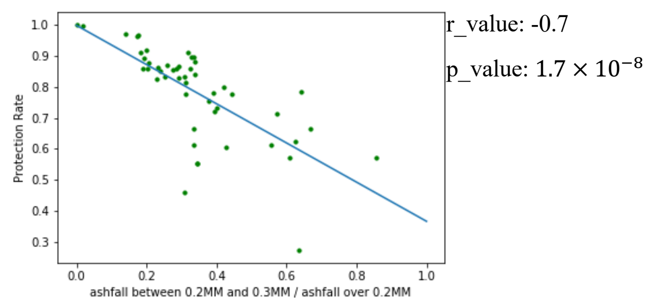

Figure 2 Airports where unsafe amount of ashfall (over 0.2mm) are more likely to fall between 0.2mm and 0.3mm are associated with lower protection rate. (Protection rate: the portion of scenarios with ashfall over 0.2mm that are correctly alerted)

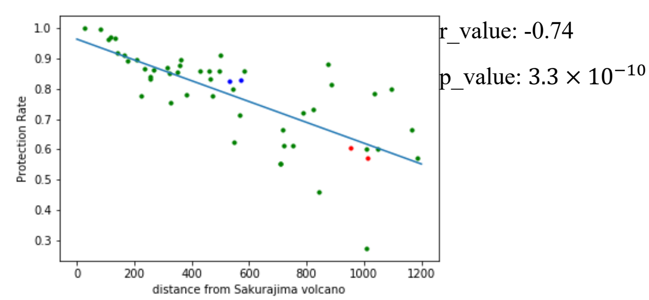

Figure 3 Remote airports have a lower protection rate. Blue dots are both Osaka airports and Red dots are both Tokyo airports.

Reference:

[1] Hickey, J., Gottsmann, J., Nakamichi, H., & Iguchi, M. (2016). Thermomechanical controls on magma supply and volcanic deformation: application to Aira caldera, Japan. *Scientific reports*, *6*, 32691.