Volcano Monitoring System for Long-Term Eruption Forecasting Using Multiple Data Sources

Minoru Luke Ideno[1] *and Takeshi Tsuji*[1, *]

[1]*School of Engineering, The University of Tokyo, Tokyo, 113-8656, Japan*

*Corresponding author

E-mail: tsuji@sys.t.u-tokyo.ac.jp (T.T.)

Abstract

Accurately forecasting volcanic eruptions, particularly sudden phreatic events, remains a significant challenge due to their subtle precursory signals. Here, we develop a long-term eruption forecasting model for Mount Aso by integrating multiple observational datasets—including seismic tremors, magnetic field, crater wall temperature, thermal pool temperature and volune, tilt measurements, and volcanic gas amount—each optimized over specific temporal scales. We systematically identify the optimal temporal scales (look-backward and look-forward windows) for each dataset to maximize prediction metrics. We construct a theoretical framework that quantifies the improvement in predictive performance when combining models derived from diverse data sources, deriving an approximation formula for the ensemble AUC (Area Under the Curve). Our ensemble model enhances eruption predictive metrics, achieving a 0.6 increase in the Matthews correlation coefficient and approximately fivefold improvement in precision compared to short-term, single-data-source models.

Statistical validation confirms the significance of pre-eruption anomalies across datasets. Our findings demonstrate that ensemble multiple data sources over optimized temporal scales, underpinned by a theoretical ensemble framework, enables high-precision, interpretable eruption forecasts months in advance. This approach contributes to effective disaster mitigation planning and offers a versatile forecasting strategy applicable to other volcanic systems.