Eruption forecasting at Strokkur geyser, Iceland: An application of Permutation Entropy

Maria Sudibyo1, Eva P.S. Eibl1, and Sebastian Hainzl2

1Universität Potsdam, Institute of Geosciences, Potsdam, Germany (pujiastutisudibyo@uni-potsdam.de)
2GFZ German Research Center for Geosciences, sec 2.1, Helmholtzstraße 6/7, 14467 Potsdam, Germany

A volcanic eruption is usually preceded by increased seismic activity resulting from magma propagation. Although these precursors can be detected by a modern seismometer, it is still a challenge to answer whether they will be followed by an actual eruption and when the eruption will occur after precursors are detected. The time between the start of volcanic unrest and the actual eruption is crucial. Therefore, there is a need for an assessment tool that is applicable in real-time. Permutation Entropy (PE) has been recently suggested to be a promising tool for the prediction of volcanic eruptions. It is a robust yet simple tool to quantify the complexity of time series. We aim to find out whether there is a distinct feature in the temporal variation of PE that is useful for eruption forecasting. We performed several synthetic tests to understand how PE works and how to choose the optimum input parameters for a signal with certain properties. We then applied this knowledge to calculate PE of seismic data that recorded eruptions of Strokkur geyser, Iceland on the 10th of June 2018. 78 eruptions occurred within five hours of observation. We used this fast-repeating process to check if the eruptions cause a repetitive pattern of PE. The input parameters used for PE calculation are a window length of 1 second, an embedding dimension of 5, and a delay time of 0.067 seconds. Our results show a distinct, repeating pattern of the PE that is consistent with the phases in the eruptive cycle of Strokkur as described by Eibl et al. (2021). The PE drops in the stage of bubble accumulation at depth, then undergoes repeated increasing and decreasing patterns during regular bubble collapses at depth in the conduit, and finally continuously increases as a precursor towards the time of eruption on the surface. The average duration of this precursor to the eruption is about 10 seconds.