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Testing the application of Permutation Entropy to characterize the precursory phase of volcanic eruptions

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Permutation Entropy (PE) has been 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. The application has been used in the biomedical and econophysics fields and recently was adopted to find precursors of volcano eruptions and to identify tremor episodes. However, in the different eruption cases, the temporal variation of PE was found behaving in different ways. For example, a gradual drop of PE was observed few days prior to the 1996 Gjalp eruption while it remained high prior to the 2012 Copahua eruption. Our final aim is to quantify what features in the PE can be interpreted as eruption precursors and whether this is applicable to different eruptions from the same or different volcanoes. In calculating the PE, the determination of two key inputs, namely the delay time and the embedding dimension, is crucial as PE depends strongly on those parameters. Here we present several tests on different types of synthetic signals with different signal to noise ratios to determine the most suitable input parameters. We found that when the delay time is much shorter than or equal to the dominant period of the signal, the value of PE will be strongly influenced by the noise. Thus, the value of the delay time should be chosen in between. Furthermore, the embedding dimension should not be smaller than 5 to be able to identify the characteristic of the underlying signal. Finally, we show the application of this method to the seismic data during the dike formation and the effusive eruption at Holuhraun, Iceland, in 2014-2015.