Geophysical Research Abstracts
Vol. 12, EGU2010-7950, 2010
EGU General Assembly 2010

A volcano-seismic event spotting system for the use in rapid response systems

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The classification of seismic signals of volcanic origin is an important task in monitoring active volcanoes. The number and size of certain types of seismic events usually increase before periods of volcanic crisis and can be used to quantify the volcanic activity. Due to the advantage of providing consistent, objective and time-invariant results automatic classification systems are preferred. Most automatic classification systems are trained in a supervised fashion from a sufficiently large pre-classified data set. The setup of an automatic classification system thus requires the pre-existence of these training data. For a rapid volcano-response team, however, the situation is often different. In the worst case, no prior observations exist (e.g. re-awakening of a dormant volcano). More frequently, archive data exist for a particular observatory network, but no record of seismicity for a high volcanic activity level exists and new seismicity patterns occur. Usually, the networks are additionally sparse and new equipment will be installed for better surveillance during the actual crisis. For the new recording sites again no prior example data is available. Finally, due to the imminent crisis there might be no time for the time-consuming and tedious process of preparing a training data set.

For all these reasons a classification system which allows a "learning-while-recording" approach would be very advantageous for use in rapid response systems. Within this study, we show a novel seismic event spotting approach in order to reduce the dependency on the existence of previously acquired data bases and classification schemes. One main goal is therefore to provide the observatory staff with a robust event classification system based on a minimum number of reference waveforms and thus allowing for a fast build-up of a volcanic signal classification scheme as early as interesting events have been identified.

For implementation issues we make use of the Hidden Markov Toolkit (HTK), a software package which has been developed in the realm of speech recognition research. The training procedure can be described as follows: First, we extract a valuable set of wave field parameters in a sliding window fashion from an unlabeled continuous data stream. Here, we use polarization and spectral attributes as those are well known to provide good discrimination between different seismic event classes. In the following these parameters are used to extract a fixed number of clusters in the feature space. Each cluster corresponds to a mixture component of the overall output distribution which is modeled by Gaussian mixture densities. Based on this general multivariate description of the overall data set we start building particular event classifiers from a single waveform example based on the cluster description learned before. For the classification task we use context dependent hidden Markov models which represent a stochastic description observations and hence are able to handle the great variabilities of volcano-seismic signal characteristics.

To show the capabilities of this new approach tests were performed on two different datasets. Based on the results of the automatic classification process of seismic signals recorded at Soufrière Hills volcano and continuous data recorded at Mt. Erebus volcano we show that the system is able to provide a robust event classification without previously existing training events. For this reason we conclude that the suggested approach is a valuable tool for rapid response action.