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Multistation alarm system for eruptive activity based on the automatic classification of volcanic tremor: specifications and performance

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With over fifty eruptive episodes (Strombolian activity, lava fountains, and lava flows) between 2006 and 2013, Mt Etna, Italy, underscored its role as the most active volcano in Europe. Seven paroxysmal lava fountains at the South East Crater occurred in 2007-2008 and 46 at the New South East Crater between 2011 and 2013. Month-lasting lava emissions affected the upper eastern flank of the volcano in 2006 and 2008-2009. On this background, effective monitoring and forecast of volcanic phenomena are a first order issue for their potential socio-economic impact in a densely populated region like the town of Catania and its surroundings. For example, explosive activity has often formed thick ash clouds with widespread tephra fall able to disrupt the air traffic, as well as to cause severe problems at infrastructures, such as highways and roads.

For timely information on changes in the state of the volcano and possible onset of dangerous eruptive phenomena, the analysis of the continuous background seismic signal, the so-called volcanic tremor, turned out of paramount importance. Changes in the state of the volcano as well as in its eruptive style are usually concurrent with variations of the spectral characteristics (amplitude and frequency content) of tremor. The huge amount of digital data continuously acquired by INGV's broadband seismic stations every day makes a manual analysis difficult, and techniques of automatic classification of the tremor signal are therefore applied. The application of unsupervised classification techniques to the tremor data revealed significant changes well before the onset of the eruptive episodes. This evidence led to the development of specific software packages related to real-time processing of the tremor data. The operational characteristics of these tools – fail-safe, robustness with respect to noise and data outages, as well as computational efficiency – allowed the identification of criteria for automatic alarm flagging. The system is hitherto one of the main automatic alerting tools to identify impending eruptive events at Etna.

The currently operating software named KKAnalysis is applied to the data stream continuously recorded at two seismic stations. The data are merged with reference datasets of past eruptive episodes. In doing so, the results of pattern classification can be immediately compared to previous eruptive scenarios.

Given the rich material collected in recent years, here we propose the application of the alert system to a wider range (up to a total of eleven) stations at different elevations (1200-3050 m) and distances (1-8 km) from the summit craters. Critical alert parameters were empirically defined to obtain an optimal tuning of the alert system for each station. To verify the robustness of this new, multistation alert system, a dataset encompassing about eight years of continuous seismic records (since 2006) was processed automatically using KKAnalysis and collateral software offline. Then, we analyzed the performance of the classifier in terms of timing and spatial distribution of the stations.