Tremor-based real time monitoring and early warning on Etna volcano (Italy): technical aspects and methods

Marcello D'Agostino [1], Giuseppe Di Grazia [1], Ferruccio Ferrari [1], Horst Langer [1], Alfio A. Messina [1][2], Danilo Reitano [1], Salvatore Spampinato [1]

[1] Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Etneo - Sezione di Catania, Piazza Roma 2, 95125, Catania, Italy
[2] Istituto Nazionale di Geofisica e Vulcanologia, Sezione Roma 2, Via di Vigna Murata, 605, 00143,Roma, Italy

Twenty-five lava fountains occurred on Mt Etna from January 2011 to April 2012. In summer 2012 volcanic activity resumed in a milder form within the Bocca Nuova crater, before it came to an essential halt in August 2012. All these unrests offer rich material for testing automatic procedures of data processing and alert systems, running 24/7, in the context of volcano surveillance. We focus on the seismic background radiation – volcanic tremor – which plays a key role in the monitoring of Mt Etna. Since 2006 a multi-station alert system has been established in the INGV operative centre of Catania exploiting STA/LTA ratios. Besides, also the spectral characteristics of the signal, which change correspondingly to the type of volcanic activity, can be exploited for warning purposes. Here we apply Self Organizing Maps and Fuzzy Clustering which offer an efficient way to visualize signal characteristics and its development with time. All these techniques allow to identify early stages of eruptive events, and automatically flag a critical status before this becomes evident in conventional monitoring techniques.
Changes of tremor characteristics are related to the position of the source of the signal. The location of the sources exploits the distribution of the amplitudes across the seismic network. The locations were extremely useful for warning, throughout both the flank eruption in 2008 as well as the 2011 lava fountains, during which a clear migration of tremor sources towards the eruptive centres could be noticed in advance. The location of the sources completes the picture of an imminent volcanic unrest, and corroborates early warnings flagged by the changes of signal characteristics.
Real time data processing requires computational efficiency, robustness of the methods and stability of data acquisition. The amplitude based multi-station approach is not sensitive to the failure of single stations and therefore offers a good stability. The single station approach, exploiting unsupervised classification techniques, limits logistic efforts, as only one or few key stations are necessary. Both strategies have proven to be insensitive to disturbances (undesired transients like earthquakes, noise, short gaps in the continuous data flow). False alarms were not encountered so far.
Stable data acquisition and processing come with a properly designed data storage solution. The reliability of data storage and its access is a critical issue. A cluster architecture has been realized for failover protection, including a Storage Area Network system, which allow easy data access following predefined user policies. We present concepts of the software architectures deployed at INGV Osservatorio Etneo in order to implement this tremor-based multi approach system. We envisage the integration of seismic data and those originating from other scientific fields (e. g., volcano imagery, geochemistry, deformation, gravity, magneto-telluric). This will facilitate cross-checking of evidences encountered from the single data streams, in particular allow their immediate verification with respect to ground truth.