Monitoring of Teide volcano (Canary Islands) through a seismic network covariance matrix analysis

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Abstract

We develop an automatic network-based method for detecting and locating all kind of seismo-volcanic signals. Seismic data of the island of Tenerife continuously recorded by the Red Sísmica Canaria, a permanent monitoring network composed of 16 broadband stations operated by the Instituto Volcanológico de Canarias (INVOLCAN), are analysed. The method is based on the analysis of eigenvalues and eigenvectors of the seismic network covariance matrix, the equivalent in the frequency domain of the cross-correlation matrix. First, the width of the network covariance matrix eigenvalues distribution is used to detect events. Then, the first eigenvector of the covariance matrix corresponding to each event is used to locate it. Our main hypothesis is that, by representing the principal component of the recorded wavefield, this first eigenvector characterizes the dominant event excluding the information related to the noise. Obtained locations are successfully compared with locations from a standard approach based on manual phase picking. Conversely to this latter traditional approach, the developed method has the advantage of not requiring a priori knowledge, to be fully automatic and to be able to analyse large amounts of data.

Keywords: volcano monitoring, network covariance matrix

Most of pre- and co-eruptive processes within volcanic systems are accompanied by seismicity, whose characterization constitutes a key aspect of volcano monitoring and eruption forecasting. In Canary Islands, the volcanic activity is partly monitored by the Red Sísmica Canaria, a permanent seismic network operated by the Instituto Volcanológico de Canarias (INVOLCAN). This network is currently spread in all the islands of the archipelago, except Fuerteventura and La Gomera. In the island of Tenerife, where the Teide volcano is located,

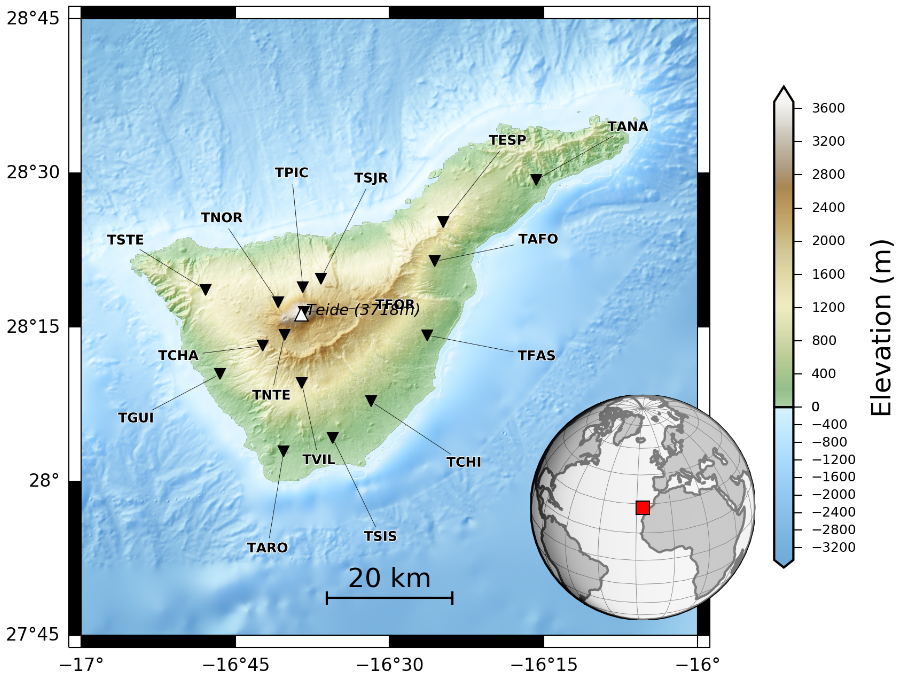

Figure 1: Seismic network (stations: black inverted triangles) operated by INVOLCAN in the Island of Tenerife to monitor the Teide volcano (white triangle). The island of Tenerife is located by a red square on the Earth globe.

the network is currently composed of 16 broadband seismic stations (Figure 1). Each station being recording soil vibrations in three spatial components (two in the horizontal plane and one in the vertical axis) at a sampling frequency of 100 Hz, this network generates a large amount of data: about 1.6 GB per day or 0.6 TB per year.

The observed seismicity contains signals from tectonic, volcanic, oceanic and anthropogenic origins. Interesting signals for volcano monitoring range from sharp to emergent onset single events, and from high amplitude to barely visible changes in the continuous signal. With this complexity of seismo-volcanic signals, traditional seismological approaches are now showing their limitation for detecting events and identifying characteristic patterns dealing with such large amounts of data. Indeed, many traditional approaches are largely based on the visual inspection of seismic records. But with continuously growing monitoring networks and associated data fluxes, this way of analysing data is problematic and it becomes necessary to use data-intensive systematic and automatic methods.

Nowadays, a lot of seismo-volcanic approaches allow to better understand volcanic processes occurring over time and space, and then to mitigate the impact of volcanic activity on our society. The method presented in this work, designed to automatically detect and locate all kind of seismo-volcanic events, is one of them. Following Seydoux et al. (2016), the proposed approach exploits the coherence of seismo-volcanic signals across the network, that is derived from the network covariance matrix, the equivalent in the frequency domain of the cross-correlation matrix. The method is based on the analysis of the eigenvalues and eigenvectors of the seismic network covariance matrix. Events are detected through the time

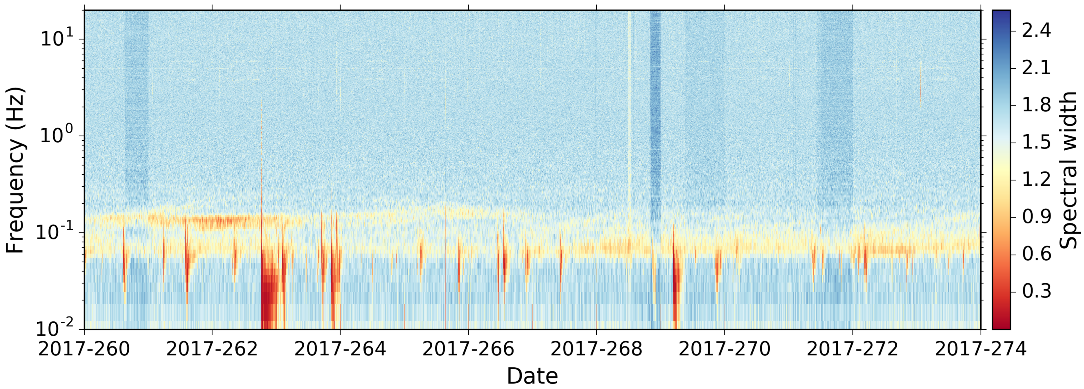

Figure 2: Spectral width of the network covariance matrix. Each pixel of this graph represents the width of the eigenvalues distribution of the cavariance matrix calculated at one time and one frequency. Detected events correspond to low values of the spectral width.

evolution of the width (here called spectral with) of the network covariance matrix eigenvalues distribution, which is a proxy of the number of acting sources (Seydoux et al., 2016). An example of such events detection is shown in Figure 2, that represents the colour-coded value of the spectral width as a function of time (x-axis) and frequency (y-axis). During this two weeks period of time, a lot of different seismic sources are detected (low value of the spectral width). Each detected event can then be located through a cross-correlation based location method using the corresponding first eigenvector of the covariance matrix (Soubestre et al., 2018). The final goal of this method is to automatically improve the completeness of the catalogue of manually detected and located seismo-volcanic events.

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