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Long-term evolution of the spectral content of continuous seismo-volcanic signals from a network-based analysis

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Volcanoes are multi-physics systems where different phenomena interact, such as magma transport, degassing, crystallization, and pressure-induced faulting. These interactions create a series of seismic signals, among which we have volcano-tectonic earthquakes, long-period events, and volcanic tremors. Thanks to these signals, there has been an improvement in the comprehension of volcanic systems. However, due to its complexity, there is still a debate regarding the observed seismic signals, i.e., their precise origin and characteristics. In the past, some techniques, such as spectral analysis and simple earthquake location were used. However, these techniques lack the resolution that we currently need. In this regard, network-based methods have been developed to determine the level of wavefield coherence and to classify different seismicity types from complex continuous signals.

In this work, we analyze eight years (from 2011 to 2020) of continuous seismic data of Piton de la Fournaise, la Réunion, France, using a network array including approximately 20 stations. We use a method based on the covariance matrix combining interstation single-component cross-correlations. From the continuous velocity records, we create temporal overlapping windows in which we estimate the covariance matrix in the frequency domain. We then evaluate its rank through the estimation of the width of its eigen-values distribution, in other terms, the number of independent seismic sources. This method allows us to quantitatively measure the presence of coherent sources recorded by the array and to characterize their frequency content.

The resulting distributions of the spectral width show that continuous signals are characterized by multiple narrow spectral peaks clearly observed in the co-eruptive tremors but also during periods without visible volcanic activity. To enhance these peaks, we re-normalize the distribution of spectral width in the frequency and time domains. As a result, we observe in the 1-3 Hz frequency band many spectral peaks that remain nearly constant during very long periods (weeks to months). At the same time, we observe a clear difference in the distribution of these frequencies between the co-eruptive and quiet periods and also some significant variations during long-standing eruptions. We suggest that variations of the spectral lines can be related to the properties of seismo-volcanic sources and eventually to the structural changes and, therefore, can be used in volcano monitoring.