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A wavelet coherence array processing procedure for mapping Long-Period (LP) and Very Long-Period (VLP)seismicity at active volcanoes

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LP and VLP signals are the most characteristic features of the seismic activity at volcanoes. Their study can provide important information on the physical processes which occurr in the magmatic and hydrothermal systems. These events are characterized by sharp spectral peaks, related in many cases to resonance effects in fluid-filled cavities, by emergent onsets and by a lack of clear S waves. These latter features make the classical methods of hypocenter determination by arrival time inversion inoperative. Here we propose a processing procedure based on Continuos Wavelet Transform of multichannel data to define the kinematic parameters of broad-band signals recorded in volcanic environments. The major improvements of using wavelet transform in multichannel analysis consists in the high resolving power of wavelets toward time-frequency localization of signals. In wavelet analysis the trade-off between frequency bandwidth and time duration, also known as Heisenberg inequality, can be overcome. The use of a fully scalable modulated window solves the signal-cutting problem of Windowed Fourier Transform. Our method consists of two separate steps: a) An array-averaged wavelet coherence analysis to obtain highly-resolved estimates of the time-frequency location of coherent signals crossing the array. This measure of correlation as a function of both time and frequency is obtained from averaging the time-scale smoothed wavelet coherence estimates calculated for all the independent channel pairs; coherent signals propagating across the array results in high-coherence patches spanning the analysed time-scale domain. b) For each time-frequency localized signal, the signal's parameters are then estimated by using a wavelet-based MUSIC (MUltiple SIgnal Characterization) algorithm. In this approach, we derive the elements of the spatial cross-spectral matrix using the time-series of complex wavelet coefficients associated with the time-scale regions where coherence analysis indicated presence of correlated wavetrains. This procedure greatly facilitates the detection and processing of signals which dominant frequencies may range over a wide frequency interval. The method is first tested against synthetic waveforms using both plane- and spherical-wavefront models using 2D and 3D arrays, respectively. For the former case, the technique allows retrieving the two components of the slowness vector, which in turn provides estimates of the azimuth and apparent velocity with which plane waves propagate across the array. In the second case, the technique allows retrieving the location of the source in a cartesian 3D volume. The method is eventually applied to LP and VLP signals recorded at Stromboli volcano using data from (a) a short-period, small aperture array, and (b) a large-aperture, broad-band network. In both cases, our method provides a precise estimates about the signal's localization in the time-scale plane. Data from the small-aperture array are analysed under the plane-wave assumption, allowing for stable and robust estimates of vector slowness associated with LP components. Conversely , we use the spherical wavefront model to analyse VLP signals from the sparse network, thus obtaining source location estimates which are fully compatible with those retrieved from application of more traditional time-domain techniques such as the Semblance method.