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Inflation-deflation cycles of the Mount Etna's 11-13 January 2011 lava fountain episode revealed by tilt analysis at very broadband seismic stations

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The dynamic of small, transient volcanic eruptions are increasingly becoming better understood through the use of very broadband seismometers, allowing for investigation of signals over a wide range of timescales. Very-long-period (VLP) signals have been used to image conduit geometry and unravel the source mechanisms of the volcanic and strombolian eruptions and explosions. For this purpose, recorded signals are used as low as the natural period of the seismic instrument and the component of the signal due to tilt motion is removed from broadband displacement record. However, in some cases, tilt motion recorded by seismographs may be important data for understanding ground deformation. The timescale of the observation can be extended beyond the low corner frequency of the modern, very broadband seismic sensors to explore small ground rotation signals accompanying short lived volcanic explosions. This can be extracted from the horizontal components of broadband seismometers, since these components are highly sensitive to tilt through gravitational acceleration. The ability to extract information about ground tilt with seismometers greatly improves the understanding of volcanic eruptions and explosions, particularly in volcanic areas where more installations of tilt sensors are impossible or difficult.
We propose a novel approach and computational tool for reliable estimation of the tilt motion using the long-period transient signals from broadband seismograms. The method is based on discretizing the (inverse) problem using some basis functions. True tilt motion is modeled as a linear function of a series of basis functions (e.g. triangle functions, bell-curve functions etc). Minimizing the L2-norm, we invert the amplitude of the basis functions that describes complex tilt motion. The method is computationally efficient and numerically stable. Here we report observations of tilt recorded on broadband seismometers associated with lava fountain from Mount Etna, Italy. This work is not only of relevance for understanding the dynamics of volcanic explosions, but also for investigating and potentially monitoring volcanic events like caldera collapses.