Geophysical Research Abstracts
Vol. 18, EGU2016-9888, 2016
EGU General Assembly 2016
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Location and wavefield attributes of long-period signals at Villarrica volcano (Chile) determined by array and polarization-moveout analysis

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Villarrica Volcano is the most active volcano in Chile whose latest eruption occurred in March 2015. Increasing the knowledge on its processes, structure and behavior is thus crucial to an effective monitoring and hazard assessment. In this context, long-period volcanic signals (LP) are considered to be a key to the understanding of fluid dynamics and volcanic plumbing systems, accessible by seismological observations. However, standard seismological location tools usually fail due to the emergent onset of the signal and its serious distortion caused by attenuation and scattering in a complex geology. Therefore, alternative methods are needed.
In March 2012, a dense seismic network was installed at Villarrica for two weeks with 50 stations covering the volcanic edifice including 6 subarrays. About 400 LP events were identified. LP-events recorded on crater stations look similar to typical earthquakes arrivals with distinguishable P- and S-wave onsets indicating a source near the crater. But with increasing source distance waveforms gradually change into typical LP-events.
To investigate how to locate these LP-events we tested two approaches at the basis of a show-case event. In a first trial, records of the subarrays were used to determine backazimuths and slowness by beamforming in the time domain. The analysis was performed in a moving window, using semblance to measure the beam quality. The epicenter was derived by intersecting azimuthal rays. It locates ca. 1 km southeast of the summit crater. Slownesses range from 0.5 s/km up to 2.0 s/km. At frequencies above 2 Hz, additional maxima appear in the semblance distribution of near-summit arrays which can be interpreted as side-scattered signals.
Since the crossing points of the backazimuth rays showed some scattering we tested polarization analysis (applied to the subset of 3-component stations) as an alternative location method. Although the direct interpretation of the backazimuths was unreliable, we identified two characteristic patterns within the time series of rectilinearity that can be interpreted as “onsets”: the starting point of a 2 to 10 s long time interval of almost constant rectilinearity (value of 0.7 to 0.9 indicating elongated elliptical to almost linear polarization), and a follow-up minimum (with rectilinearity at 0.0, indicating circular polarization). Both patterns can be clearly identified on several stations. The corresponding arrival times show nearly linear moveouts of 550 m/s and 270 m/s, respectively. At corresponding frequencies and stations, similar apparent horizontal velocities are found by the beamforming. A grid search approach was performed to find the epicenter of the LP event by fitting the “onset”-times. The resulting epicenter lies 2 km southeast of the crater thus close to the one found by beamforming.
The good accordance in the results of the new polarization and the conventional beamforming method makes the moveout approach, at least in the case of this data set, a promising amendment to the existing LP-location toolbox. A thorough test of its general applicability is planned.