Geophysical Research Abstracts,
Vol. 10, EGU2008-A-09548, 2008
SRef-ID: 1607-7962/gra/EGU2008-A-09548
EGU General Assembly 2008

A numerical study on the resolution of source mechanisms of volcano-induced seismic events by moment tensor inversions in a broad frequency range

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During the last years a couple of papers demonstrated the usability of moment tensor inversion for understanding the seismic signature of volcanic events and eruptions, respectively. These papers led to a completely new view of the physical processes creating the recorded signals. The majority of this research is done analyzing so-called Long Period (LP; and follow up signals VLP, ULP), which are seen as strong indicator for fluid flow in the volcanic edifice. However, some volcanoes do not show LP signals before an eruption but the observed seismicity consists mainly of so-called Volcano-Tectonic events (VT) which show much higher frequency amplitudes than LP events. Furthermore, laboratory studies show that magma can be loaded by significant shear stress which is finally released by brittle failure, i.e. an earthquake. This implies that tracing the VT events might provide very valuable information at such volcanoes. The only way to investigate whether recorded VT events are caused by "normal" tectonic stress response or brittle failure within the magma column itself is to invert for the full moment tensor. Up to now this was impossible as the computational cost for computing the Green's functions in a heterogeneous three-dimensional volume including the complex subsurface structure and surface topography up to frequencies as high as 10 Hz was too high. In the advent of new methods in computational seismology, e.g. the discontinuous Galerkin finite-element method, the frequency limit can be shifted even above 10 Hz incorporating the accurate volcano geometry and different rheologies of the assumed subsurface material. However, it remains unclear whether moment tensor inversions are still successful, if the frequency limit is increased up to the 10 Hz band. Starting from 0.5 Hz the seismograms are distorted by local velocity heterogeneities and scattering effects due to topography that might lead to completely wrong inversion results. We perform a numerical study on Merapi volcano using the discontinuous Galerkin scheme to demonstrate the influence of increasingly complex problem setting on the seismic signature and the resulting moment tensor inversion, respectively. While we keep the Green's function relatively simple by considering only the three-dimensional topography and a homogeneous velocity model, we create several data sets of synthetic seismograms using increasingly complex representations of the structure of Merapi volcano. This way, we study the applicability of the moment tensor inversion techniques usually applied and identify their limits.