Characterizing fault zones at Kilauea and Mauna Loa volcanoes by large-scale mapping of earthquake stress drops and high precision relocations

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Abstract

Because of ongoing time-dependent variations in volcanism, geodetically ob- served deformation, and eruptions, Hawaii's value as a natural laboratory for studying the interaction between magma and tectonic processes has long been recognized. We describe initial results of a comprehensive analysis of transfers from the seismic network operated by the Hawaiian Volcano Observatory (HVO) between 1981 and 2005. This includes relocation of over 100,000 earthquakes at a variety of depths, including shallowly sourced events associ- ated with Kilauea eruptions and HP intrusions, intermediate-depth events caused by stress drops, and deeper events occurring at a different fault zone near 10 km depth, and long-period earthquakes over 40 km depth beneath Mauna Loa. We have successfully applied the techniques developed for southern California seismicity to develop large-scale waveform cross-correlation and spectral analysis in the HVO network, using methods similar to those we have successfully applied to the California network. While prior studies have focused on individual regions, our analyses will pro- vide the first comprehensive catalog of relocated earthquakes across the entire Island of Hawaii. The results should give a sharper view of fault (tectonic) and conduit (magma) structures, including temporal variations of deformational character over the island, and slip events that provide insight into potentially important temporal evolution in stress drops that may be associated with change in abrupt stress drops. These large-scale waveform analysis methods can be used to tell volcanic zones monitored by tectonic seismic networks, including current and proposed experiments on and around the Galapagos.

Introduction

Previous studies of certain regions have shown that large improvements are pos- sible in resolving fault structures at Hawaii using differential location and cross- correlation methods. Advances in computer power now permit analyses of entire seismic data sets using waveforms from the seismic network operated by the Hawaiian V olcano Observ- atory (HVO) between 1992 and 2009. This includes records from over 4000 stations, 400,000,000 earthquakes, and 8000 events (Waldhauser and Schaff, 2008). We have systematically performed spectral analy- ses for source properties. Analysis consists of several stages:

Spectral analysis

Once the waveforms are stored in our online database for the cross- correlation project, they are also a convenient form for spectral analysis of source properties. Analysis consists of several stages:

1. Resample the entire waveform to a uniform 100 Hz rate
2. Apply a window (5s to 10s) and compute P and S spectra for each waveform. We use a 1.28 s window around the phase arrivals, as well as a 1.28 s 'noise' window imme- diately preceding the phase. Store these spectra using a simple digital signal-reverse-score.
3. Cross-correlate the entire waveform to find the cross-correlation results. There is a dramatic sharpening of the seismicity along the east-west line shown in the seismological map.

Example for Landers earthquake

We have systematically performed spectral analysis using the northeastern California catalog between 1989 and 2001 to estimate stress drops for over 3,000 earthquakes (Shearer et al., 2006). Some results for the aftershock sequence of the 1992 M 7.3 Landers earthquake are shown to the right. The left panel is the north end of the rupture, the right panel shows a sharp change in stress drop event. The HP panel shows a sharp change in stress drop event. The HP panel shows a sharp change in stress drop event.

Catlog Locations

Preliminary result for Hawaiian seismic profile

References


Green's function (EGF) method and estimate individual event stress drops. The left panel is the north end of the rupture, the right panel shows a sharp change in stress drop event for the 1992 M 7.3 Landers earthquake are shown to the right. The left panel is the north end of the rupture, the right panel shows a sharp change in stress drop event.

Inversion for Spectral Components

- Observed spectrum
- Source spectrum
- Recovered response
- Travel-time dependent term to account for Q
- Green's function

References


