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Usability of ocean-bottom seismograms for broadband waveform tomography

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Recordings made by broadband seismometers on the ocean-bottom are generally noisier than recordings of land stations using the same sensor type. The primary reason is that oceanic recordings are more affected by microseismic noise, which originates in the oceans. A similar drawback applies to data from stations on oceanic islands.

The frequency band between 0.05 Hz and 0.2 Hz is most affected by microseismic noise – unfortunately a large overlap with the band that is most useful in highly-resolving body-wave tomography when using land stations. On the other hand, waveform inversion methods, unlike traditional ray theory, do not necessarily depend on the availability of clean, pulse-like broadband signals across the entire frequency range. For example in finite-frequency tomography, the method of our choice, modelling procedures permit the exclusion of unusable frequency bands on a case-by-case basis. Hence we investigate to what extent seismograms from the ocean-bottom and from island stations can be used for broadband waveform inversion of teleseismic P-waves, as compared to continental land stations.

We have re-analyzed data from one of the largest onshore-offshore, broadband, long-term seismological experiment to date: the Hawaiian PLUME project (Wolfe et al. 2009, Laske 2009). The data quality was studied in eight overlapping frequency bands (dominant periods between 30.0 s and 2.7 s), for year-long records from 62 ocean-bottom stations (January 2005 - June 2007), complemented by seismograms from 74 regional island stations and 236 continental stations from four different networks on the Pacific-rim, recorded in the same time frame.

P-wave seismograms from 103 earthquakes of moment magnitude 6.2 and above, recorded at epicentral distances of 32° to 85° to Hawaii were assessed in this study. The quality of the recorded data was evaluated by calculating the cross-correlation coefficient between the first 1.5 dominant periods of real and predicted waveforms, in eight frequency passbands and on the broadband waveform, after careful correction for source parameters and source time function (Sigloch and Nolet 2006).

As expected, permanent continental stations were quieter than permanent island stations in the Pacific, (independent of frequency band), and island stations were quieter than ocean-bottom stations. Relative data quality for both types of oceanic stations is lowest for dominant periods between 11s and 3 s.

We present statistics for the fraction of usable data, as a function of station type, frequency band, and sensor type. In the lowest frequency band 55%, 71% and 90% of the data recorded by the PLUME stations, island stations and land stations, respectively, can be used for seismic tomography. These values drop with increasing frequency, to a minimum of 12% for the island stations, 8% for OBS stations and 33% for the land stations. We also compare data quality by OBS sensor type (Nanometrics T-40, Nanometrics T-240, Güralp CMG-3T).

We find that frequency bands around 2.7 s and between 20.0 to 30.0 s have low noise levels but have not been used for tomography by the project PIs. A multiple-frequency waveform inversion including these additional bands and wave paths, as well as a larger number of earthquakes (101 versus 97 and 59 used in the original studies by Wolfe et al. 2009 and Wolfe et al. 2011) should be able to improve the resolution of the velocity structure in the upper and lower mantle beneath the Hawaiian hotspot.

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