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Afterslip detection from normal-mode data

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Afterslips of large earthquakes from the analysis of normal modes may provide useful information for earthquake source process as its frequency band fills the gap between geodetic data and higher-frequency (> 3 mHz) seismic data. Recent large earthquakes, such as the 2010 Chilean earthquake (M=8.8), the 2004 Sumatra earthquake (M=9.3) and the 2005 Nias (N. Sumatra) earthquake (M=8.6), provide us historically unparalleled opportunities to test such an idea because of availability of broadband seismic instruments.

In this study, we focus on amplitudes of multiplets between 0.2 and 1.85 mHz. There are 20 spectral peaks in this frequency range, some of which are simple multiplets like 0S2 and 0S3 but others consist of more than one multiplet like 1S3+3S1 and 2S5+1S6. Amplitudes of these peaks are the basic information of our approach. We first calculate synthetic seismograms for these peaks and calculate amplitude ratios between data and theory. These ratios as a function of frequency give us insight into the existence of possible afterslips (or multiple sources). If we compute modal amplitude ratios for the 2004 Sumatra earthquake, the amplitude ratios of data to synthetic spectra for the CMT solution is about 2.5 at about 0.3 mHz, i.e. 0S2 (Stein and Okal, 2005). The ratios at frequencies of twenty spectral peaks show systematic, decreasing trend toward 1 at about 2 mHz. The ratio of 1 indicates that the CMT solution is a good solution for seismic data for frequencies higher than 2 mHz.

Application of our technique to the 2010 Chilean earthquake shows that the modal amplitude data are mostly explained by the Global CMT solution with the exception of about 10 percent moment deficit. Amplitude ratios for the CMT solution are about 1.1 at lower frequency end (0.3 mHz). If we search for an additional source to improve the fit these ratios, we get a solution with the moment of about 11 percent of the CMT solution (Mo=1.84x10**29 dyne cm) and the source duration of 80 seconds.

For the N. Sumatra earthquake (Nias) in 2005, the afterslip must have the moment approximately 20 percent of the CMT solution with the rise time of about 100 seconds, although constraints on rise time is not tight.

For the Sumatra-Andaman earthquake in 2004, we modified Tsai et al.'s (2005) five point-source solution and were led to the sixth solution that indicated slow afterslip in the northern part of the Andaman arc.

Somewhat unusual resutls were found for the 2001 Peru earthquake and the 2003 Tokachi-Oki earthquake with no requirement for afterslips. As we know the Tokachi-oki earthquake had afterslips, derived from geodetic data, we must conclude that the afterslip for the Tokachi-oki earthquake occurred very slowly, meaning that the slip was so slow that it did not excite normal modes in the range 0.3-3 mHz.

We will discuss the details of our approach, the underlying assumptions and results for afterslips of large events (Mw >8.0) in the past decade.

Keywords: normal mode, source process, afterslip