3 Validation of Coda-derived Source Parameters using Strong and Weak Ground Motion Records of the 2008 Wells, Nevada Sequence

Seung-Hoon Yoo, Douglas S. Dreger, and Kevin Mayeda

3.1 Introduction

Well-determined source parameters, such as corner frequency and stress drop, and their scaling relation, can play an important role in assessing the seismic hazard in a specific region, especially in regions where we do not have enough strong ground motion records. In general, ground motions at higher frequencies (1-10 Hz), which may cause damage to surface structures, can be considerably varied depending upon the stress drop of the earthquake, even for events with similar moment magnitude.

Petersen et al. (2011) found that while observed ground motions from the 2008 Wells mainshock are similar to values predicted by the Next Generation Attenuation (NGA) equation by Campbell and Bozorgnia (2008), the ground motion from the M 4.7 (Mw 4.4 from the Saint Louis University Earthquake Center moment tensor catalog, courtesy of R. B. Herrmann and this study) aftershock, which occurred the day after the mainshock, are much lower than values from the NGA equation. However, they estimated this aftershock’s stress drop as 220 bars, which is much higher than typical stress drops observed in the Basin and Range.

In this study, we revisited the 2008 Wells, Nevada sequence to examine a marked discrepancy in the observed strong and weak ground motion with the NGA predictions. We estimated the source parameters of the seismic sequence using the coda spectral ratio method (Mayeda et al., 2007). And, we examined the observed strong and weak ground motion with the derived parameters and self-similar scaling relation.

3.2 Data and Method

We calculated source spectral ratios between the mainshock and the six aftershocks using the coda spectral ratio method (Mayeda et al., 2007). We used a grid-search scheme to estimate the source parameters from the source spectral ratios. The program finds a corner frequency of the mainshock, and the corner frequency and adjusted seismic moment of the aftershocks from a given ratio dataset, simultaneously. To get the optimum source parameters and their errors, we performed bootstrap tests, which sample four event pairs of the six total ratio curves (~67% sampling of a population), then calculated the averages and standard deviations for the results of the 15 possible combinations (Figure 2.4). Next, we calculated theoretical source ratios for periods of 0.2, 0.5, and 1 second using the derived source parameters. And we also calculated the theoretical values based on the self-similar scaling with respect to the mainshock.

The Fourier amplitude spectrum of ground acceleration, A(M0, R, f), can be expressed as

\[ A(M_0, R, f) = C M_0 (2\pi f)^2 S(f) D(R, f) P(f) I(f), \]

where C is a constant of proportionality, M0 is the seismic moment, S(f) is the source spectrum, D(R, f) is an attenuation term as a function of distance R due to the geometrical spreading and anelastic attenuation, P(f) is a high-cut filter, I(f) is a filter used to shape the spectrum to correspond to the particular ground motion (e.g., Boore, 1983). If we calculate a ratio of the ground motions between the two collocated events, the ratio can be simply approximated by a source spectral ratio between the two events.

We computed the 5% damped pseudo spectral acceleration (SA) for the periods 0.2, 0.5, and 1 seconds as a geometric mean of two horizontal components (Figure 2.5a). Then, we calculated the ratios between the mainshock and the aftershocks for a given period and averaged...
of the mainshock in our estimation. (2011), and it is also about five times smaller than that 22 MPa from Fourier spectra analysis by Petersen et al. Aftershock A3, 1.00 (2009), more and less. However, the stress drop of the function finite fault inversion by is consistent with 7.2 MPa from an empirical Green’s functions (Figure 2.6). For all the other event pairs, the theoretical values from coda estimates, than 0.82, 1.02, and 1.36 from the self-similar scaling relation (Figure 2.5). For all the other event pairs, the theoretical values from coda estimates are more consistent with the observations than those from the self-similar scaling (Figure 2.6).

3.3 Results and Discussions

The stress drop of the mainshock, 5.20 (±1.52) MPa, is consistent with 7.2 MPa from an empirical Green’s function finite fault inversion by Mendoza and Hartzell (2009), more and less. However, the stress drop of the aftershock A3, 1.00 (±0.27) MPa, is much smaller than 22 MPa from Fourier spectra analysis by Petersen et al. (2011), and it is also about five times smaller than that of the mainshock in our estimation.

We compared the averaged SA ratio, log (SA_{main}/SA_{after}), with theoretical values from the coda-derived source parameters and the self-similar scaling relation with respect to the mainshock. For the MS/A3 event pair, the observed SA ratios values at 0.2, 0.5, and 1 second periods are 1.31, 1.38, and 1.52, respectively, which are much more consistent with the theoretical values, 1.26, 1.34, and 1.53, from the coda estimates, than 0.82, 1.02, and 1.36 from the self-similar source scaling relation (Figure 2.5). For all the other event pairs, the theoretical values from coda estimates are more consistent with the observations than those from the self-similar scaling (Figure 2.6).

In conclusion, the stress drops of the aftershocks are 2-5 times smaller than that of the mainshock in this seismic sequence. This indicates that weak ground motion of the aftershocks can be overestimated to be higher than the real observation using strong ground motion of the mainshock based on a self-similar scaling relation. Assuming that the scale-dependent stress drop is real, at least in some specific regions, predicting ground motion using weak ground motion records without considering the scaling relation could lead to an underestimate of strong ground motions for future large earthquakes. For the region, considering the differences in the stress drop between the small and large earthquake might help to enhance the prediction capability of the strong ground motion.

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3.5 References

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