Observation and Prediction of Dynamic Ground Strains, Tilts and Torsions Caused by the M6.0 2004 Parkfield, California, Earthquake and Aftershocks, Derived from UPSAR Array observations

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ABSTRACT

The September 28, 2004, Parkfield earthquake (M_w 6.0) and four aftershocks (M_w 4.7 - 5.1) were recorded on 12 accelerograph stations of the UPSAR seismic array, an array of 3-component accelerographs occupying an area of about 1 km^2 located 8.8 km from the closest part of the San Andreas fault that ruptured during the main shock. Peak horizontal acceleration and velocity at UPSAR during the main shock were 0.45 g and 27 cm/s, respectively.

We determined both time-varying and peak values of ground strains, torsions, tilts, torsion rates, and tilt rates by applying a time-dependent geodetic analysis to the observed array displacement time series. Displacements were derived from doubly integrated accelerograms, which were typically band-pass filtered in the 0.1 to 1.4 Hz band. Removal of the lowest frequencies yielded reliable displacement time series and stable differential displacements. Peak torsion and tilt were about 7.4e-5 and 3.1e-5 rad, respectively, for the main shock, and about 1e-5 and 2e-6 rad, respectively, for the aftershocks. Torsion Fourier amplitude spectra agree well with ground velocity spectra, as expected for propagating plane waves.

We compare our Parkfield rotations with rotations during M_w 5 Ito, Japan, events observed on a Systron Donner MotionPak gyro sensor (Takeo, 1998) and with array measurements of the M_w 7.6 Chi-Chi, Taiwan, earthquake rotations (Huang, 2003). Our rotations are consistent with the Chi-Chi rotations, when scaled for magnitude, but our rotation rates are 100 - 1000 times smaller than the Ito measurements.

A simple predictive relation, using predicted peak velocity from the Boore-Atkinson (2007) ground motion prediction relation scaled by a phase velocity of 1 km/s, predicts observed peak Parkfield and Chi-Chi torsions well, but it tends to over-predict peak tilts. It predicts the highly scattered peak torsion rate and tilt rate data poorly