SEISMIC INPUT ENERGY (E_I) OF GROUND MOTIONS DURING THE 2004 (M6.0) PARKFIELD, CALIFORNIA EARTHQUAKE

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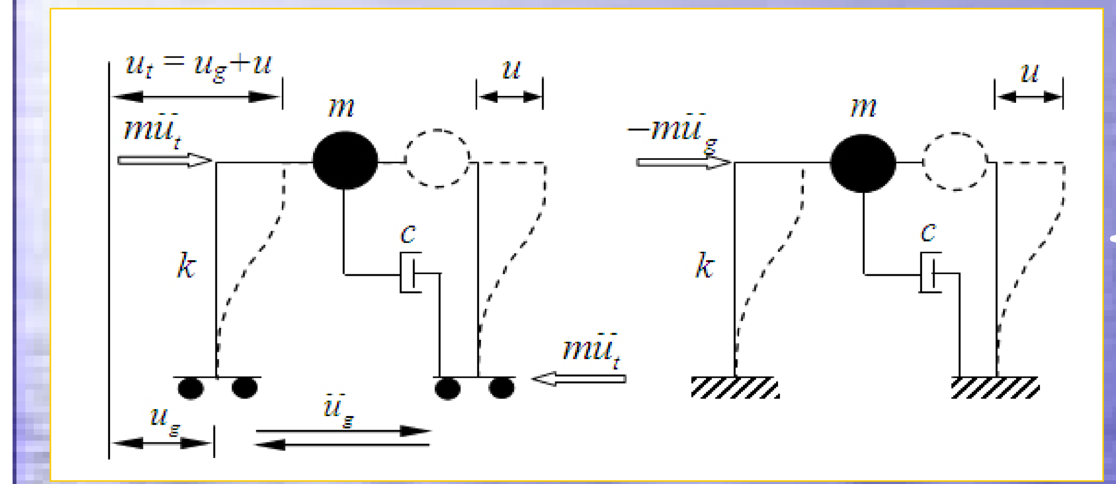
Abstract

Ground motions recorded in the vicinity of fault-rupture may contain coherent long-period velocity pulses. These pulses are generated either due to succession of high frequency acceleration peaks or integration of distinguishable acceleration pulses. In this study, spectral seismic input energy contents of near-fault records from the 2004 (M6.0) Parkfield earthquake are compared and contrasted. The findings of this study are also compared with the results obtained from worldwide earthquake near-fault recordings.

Seismic Input Energy



Idealized mathematical models of SDOF system used for absolute (Left) and relative energy formulations (Right).

Basic Seismic Input Energy Formulations

The equation of motion of a damped SDOF system : $m(\ddot{u}_t) + c\dot{u} + f(u) = 0$

where m is the mass, c is the damping coefficient, $f(u)$ is the restoring force (= ku for linear systems), u_t ($u_t = u+u_g$) is the absolute (total) displacement, ug is the ground displacement, and u is the relative displacement of the system with respect to the ground.

Integrating equation of motion with respect to u_t over time gives the absolute energy formulation of a viscous damped SDOF system subjected to horizontal motion as follows:

$$E_K + E_\xi + (E_S + E_H) = E_I$$

$$\frac{m(\dot{u}_g + \dot{u})^2}{2} + \int c\dot{u}du + \int f(u)du = \int m(\ddot{u}_g + \ddot{u})du_g = \int m(\ddot{u}_g + \ddot{u})\dot{u}_g dt$$

As a corollary, integration of equation of motion with respect to u results in the relative energy formulation of a fixed-based SDOF system:

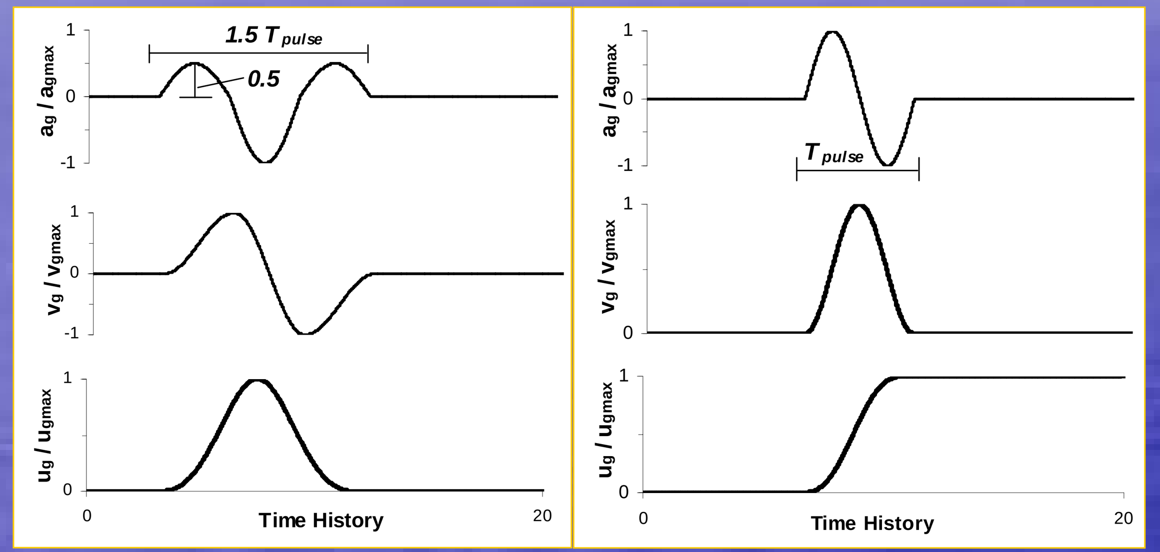
$$E_K^{'} + E_\xi + (E_S + E_H) = E_I^{'}$$

$$\frac{m(\dot{u})^2}{2} + \int c\dot{u}du + \int f(u)du = -\int m\ddot{u}_g du = -\int m\ddot{u}_g \dot{u} dt$$

Difference between absolute and relative energy : $E_I - E_I^{'} = E_K - E_K^{'} = \frac{1}{2}m\dot{u}_g^2 + m\dot{u}_g\dot{u}$

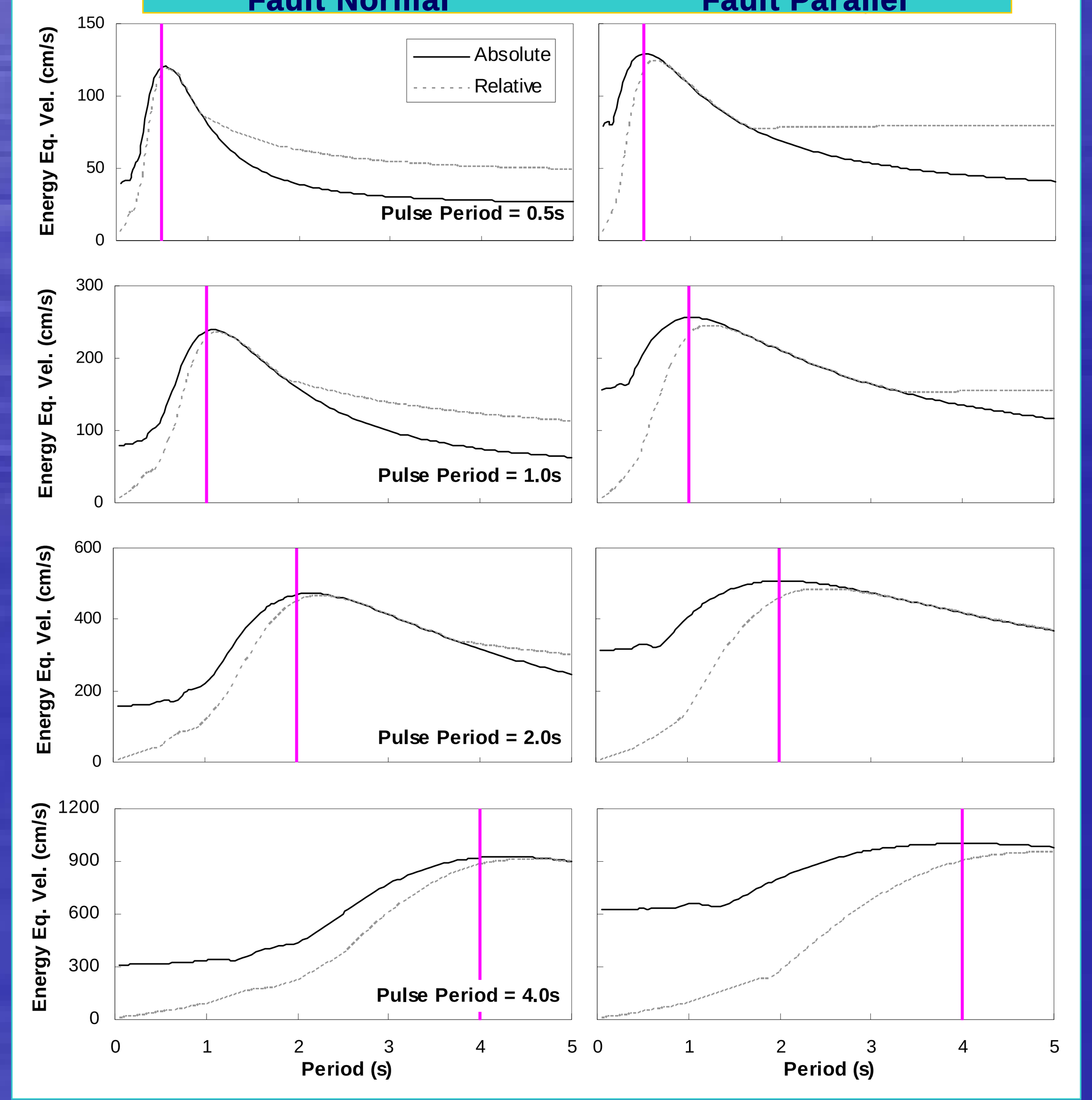
Energy Computation Using Simple Wave Forms

Sinusoidal wave forms to simulate near-fault fault normal pulse (Left) and fault parallel pulse (fling-step) (Right).



Energy equivalent velocity: $V_{EQ} = \sqrt{2E_I / m}$

ENERGY SPECTRAL RESPONSE



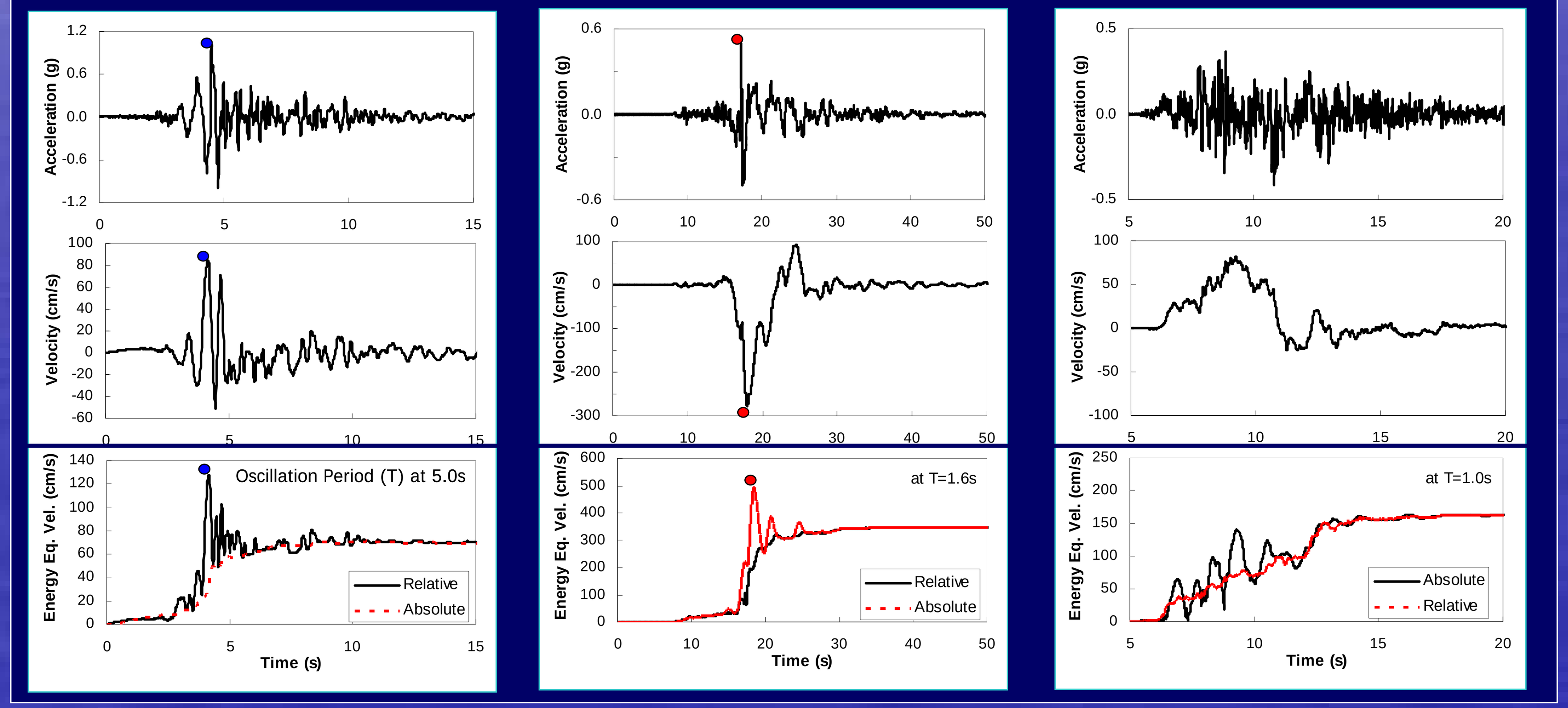
Comparisons of energy-spectra show that simple pulse models consistently impart larger absolute energy than relative energy for periods less than the pulse period (Tp). Conversely, relative input energy becomes larger for periods larger than about 2 Tp for forward directivity and about 3 Tp for fling records. In the period range of Tp to 2 Tp for forward directivity and Tp to 3 Tp for fling, both energy notations generate similar results.

Comparison of equivalent velocity spectra (5% damping) computed using absolute and relative energy formulations for forward directivity (Left) and fling (Right) pulse models (Vertical line in energy spectrum indicates the pulse period).

Energy Computations using Parkfield Data

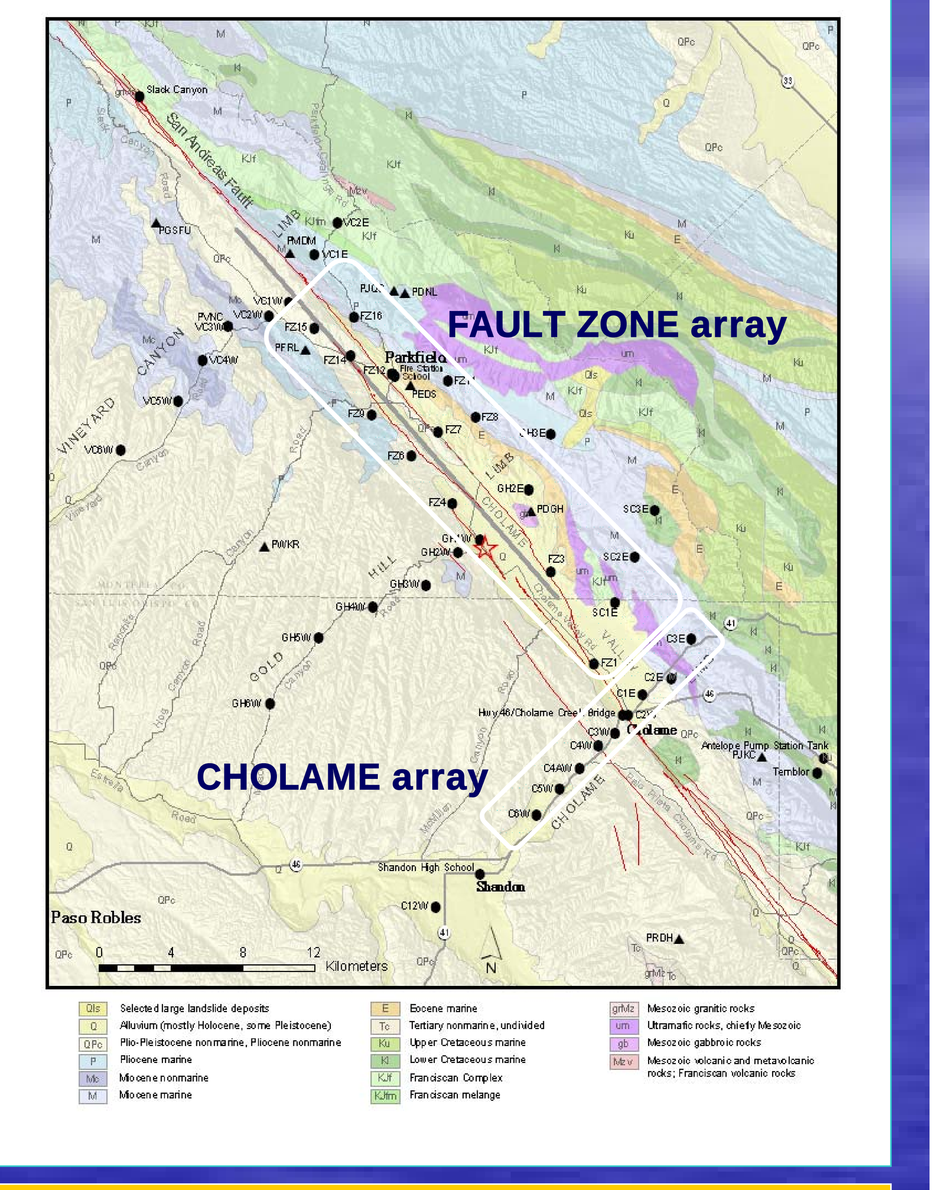
Each individual horizontal component was rotated into fault normal and parallel directions considering estimated strike angle of 137 degrees.

Forward Directivity from 2004 Parkfield EQ.	Fling from 1999 Chi-Chi EQ.	Fling from 1999 Kocaeli EQ.
Fault Zone 12 (FZ12) Fault Normal Comp.	TCU068	Sakarya (EW)



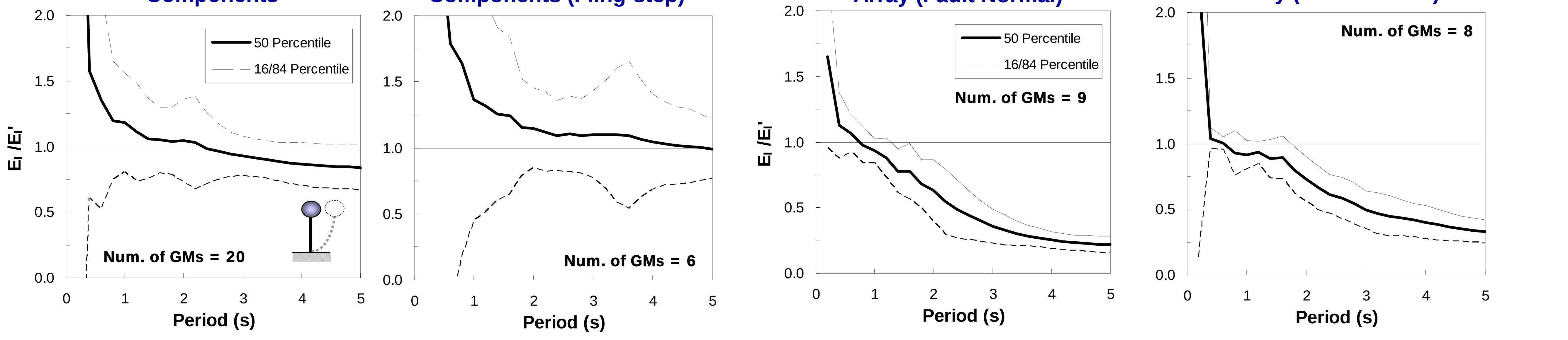
Forward directivity (FN) and fling-step (FP) records may generate sudden energy input which is larger than the accumulated energy at the cessation of motion. These energy jumps arise due to existence of distinct acceleration pulses associated with long period velocity pulses contained in the near fault records. However, records having high frequency acceleration peaks rather than distinct acceleration pulses do not generate significant energy increase, instead they create gradual energy built-up over ground motion duration. For such records, absolute and relative energy difference become almost negligible.

Stations in the Parkfield array plotted on a map of geology (Jennings, 1977)



Statistical variation of absolute and relative energy ratio for spectral periods

World-wide Fault Normal Components | World-wide Fault Parallel Components (Fling-step) | Parkfield CHOLAME Array (Fault Normal) | Parkfield FAULT ZONE Array (Fault Normal)



Concluding Remarks: Parkfield ground motions rotated in Fault Normal direction is well agree with previous results obtained for worldwide forward directivity records in which relative energy becomes larger than absolute at longer periods. However, fling records produce larger absolute energy than relative. No significant fault parallel records were obtained during the Parkfield EQ. for correlation.