

Kinematic Rupture Model for the 1966 M_w 6 Parkfield Earthquake with Assessment of Resolution

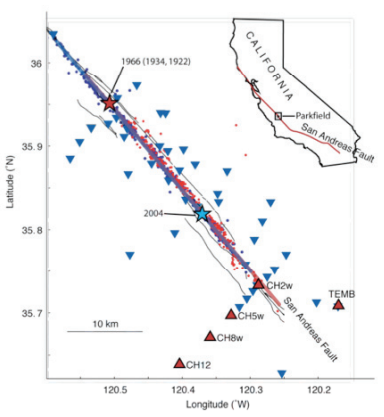
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1. Obtaining a rupture model – kinematic inversion



Parkfield marks the transition between a seismically locked section (SE) and a creeping section (NW) of the San Andreas Fault (SAF). Bakun and McEvilly (1984) noticed that Parkfield experienced moderate - M_w 6 - earthquakes in average every 22 years. They furthermore observed that the waveforms from the 1922, 1934 and 1966 Parkfield earthquakes were similar. Only identical ruptures can produce identical ground-motion. Thus Bakun and McEvilly (1984) proposed that Parkfield earthquakes were "characteristic", i.e., this section of the San Andreas Fault would always rupture in the same epicenter (Middle Mountain) and rupture unidirectionally to the SE. Parkfield characteristic earthquakes would occur with an average recurrence interval of 22 years. However, the next Parkfield earthquake happened in 2004, 38 years after the previous characteristic earthquake (1966). Unlike expected, it nucleated in a different hypocenter (Gold Hill), ~20km SE of Middle Mountain, and the rupture spread toward the NW. From preliminary analysis, it becomes obvious that the 2004 Parkfield was not characteristic. But how similar was it to previous events in terms of slip distribution?

Figure 1. Map of the Parkfield section of the SAF. Blue triangles - stations used in the study of the 2004 earthquake; Red triangles - stations used in the study of the 1966 earthquake; Blue star - 2004 epicenter; Red star - 1922, 1934 and 1966 epicenters; Blue and red dots - aftershocks of the 2004 and 1966 aftershocks, respectively (Thurber, in press); Blue line - projection of the fault plane modeled for the 2004 earthquake; Red line - projection of the fault plane modeled for the 1966 earthquake. The fault planes were chosen in accordance with aftershocks locations.

2. Slip distributions for the 1966 and 2004 earthquakes

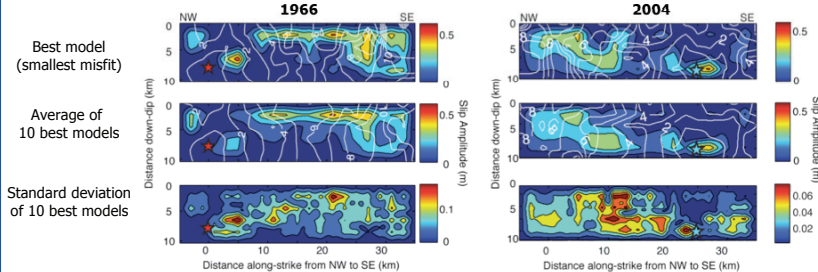


Figure 2. Slip amplitude distribution for the 1966 (1st column) and 2004 (2nd column) Parkfield earthquakes. The 1st row contains the models that generate synthetic ground motion that best fit the observed data. The 2nd row shows the average of the 10 best models, all of which generate synthetic ground-motion that fit the observed data very well. As expected, the average of the 10 best models is very similar to the best model, but the average has less detail. The last row shows the standard deviation of the 10 best models. White lines are 1 sec rupture time contours. The 1966 earthquake rupture model was based on ground-motion recorded at 5 near-fault seismic stations; the 2004 model was obtained based on velocity recorded at 34 near-fault stations.

4. Do the data allow identical slip distributions for the 1966 and 2004 Parkfield earthquakes?

In order to test if the two most recent M_w 6 Parkfield earthquakes could have ruptured identical areas of the fault plane, we inverted the 1966 velocity waveforms once more, but now we constrained the slip amplitude to be the within 20% of the 2004 slip distributions, i.e., we constrained the amplitude of slip of the 1966 earthquake to be very similar to that of the 2004 earthquake.

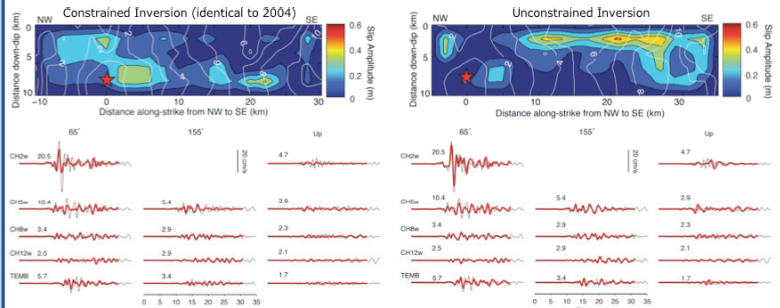
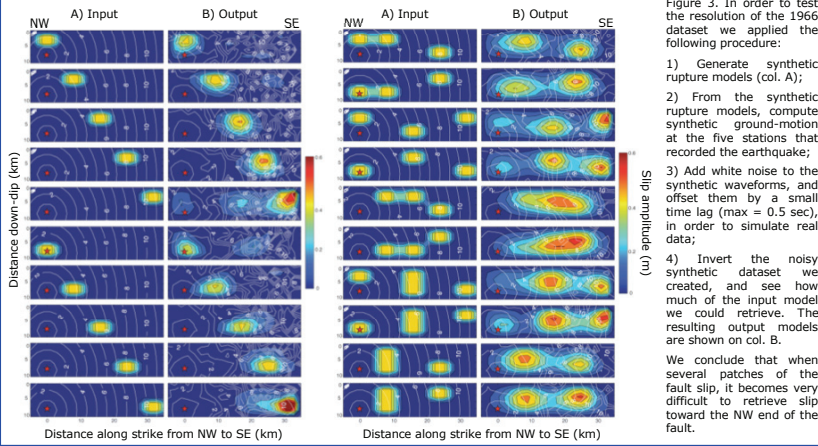


Figure 4. The left-hand side of this figure shows a rupture model for the 1966 earthquake that resembles the 2004 earthquake. This model generates synthetic ground-motion that fits the data adequately in the terms of wave phase (the pulses arrive at the correct time), but not in terms of wave amplitude (the amplitudes of the pulses are strongly underpredicted). The large pulse observed mainly at station CH2W, but also at station CH5W, can only be explained with a rupture model that includes shallow slip toward the SE of the fault plane (right-hand side model). This large pulse close to the fault could also be explained by site effects causing local amplification. However, we corrected the data for local amplification (Liu et al., in press), therefore the large pulses must come directly from the source. Thus, we conclude that the 1966 and 2004 slip distributions must be different.

3. Synthetic tests

The rupture model we infer for the 1966 Parkfield earthquake is based on a very small number of observations. Furthermore, all the strong-motion stations that recorded this earthquake are located on the SE end of the fault. Thus, the 1966 earthquake dataset offers only a partial view of the rupture. In order to understand which features of slip we can retrieve from the available dataset, we performed synthetic tests.



Discussion and Conclusions

The 1966 and 2004 Parkfield earthquakes ruptured areas of the fault that are not identical, but rather complementary. This conclusion agrees well with geodetic inversions (Murray and Langbein, in press), aftershock locations (Thurber et al., in press), and waveform similarity (Bakun et al., 2005). Shallow slip during the 1966 earthquake is supported by the large amplitude of surface waves generated by this earthquake.

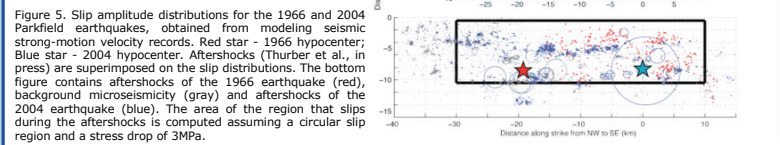


Figure 5. Slip amplitude distributions for the 1966 and 2004 Parkfield earthquakes, obtained from modeling seismic strong-motion velocity records. Red star - 1966 hypocenter; Blue star - 2004 hypocenter. Aftershocks (Thurber et al., in press) are superimposed on the slip distributions. The bottom figure contains aftershocks of the 1966 earthquake (red), background microseismicity (gray) and aftershocks of the 2004 earthquake (blue). The area of the region that slips during the aftershocks is computed assuming a circular slip region and a stress drop of 3MPa.

1) We assume that the ground motion at a given station can be described as a sum of the slip on discrete points of the fault convolved with their Green's function.

2) We use a very fine grid, at which we interpolate both source parameters and Green's functions, to compute synthetic ground motion at each station.

3) We measure the misfit between the computed synthetics and observed data. We compute synthetics for many different sets of source parameters. The goal of our global inversion scheme is to obtain a rupture model that generates synthetics with the smallest misfit to data (Liu and Archuleta, 2004). We include in our analysis an approximation to site effects (Liu et al., in press).

Some assumptions of our model:

- The fault strikes 140° SE and dips 87° SW;
- The rupture was at maximum 40 km long;
- The ruptured area is deeper than 0.5 km (no surface rupture);
- The velocity structure is well approximated by a 1D bilateral model (NE = slow; SW = fast; after Eberhart-Phillips and Michael (1993) and Thurber et al. (2003)).

Source parameters:

- Slip amplitude
- Slip rake (R);
- Average rupture velocity;
- Rise time ($T = T_1 + T_2$).

Green's function

Data Synthetics

0.16Hz < f < 1.1Hz

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