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Inversion of GPS data for spatially variable slip-rate on the San Andreas Fault near Parkfield, CA

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Abstract. We analyze GPS data collected from 1991-1998 at 35 sites near the Parkfield segment of the San Andreas Fault. Inverting the resultant site velocities for the distribution of interseismic slip-rate on the San Andreas reveals an area of low slip-rate on the fault extending from between Middle Mountain and Carr Hill to southeast of Gold Hill. This slip-rate pattern is similar to that found by *Harris and Segall* [1987] using trilateration data collected between 1966 and 1984. We infer a deep slip-rate (33 mm/yr) and depth of the transition between seismogenic and non-seismogenic slip (14 km) that agree better with independent geologic evidence than those found in the 1987 study. In contrast to *Harris and Segall* [1987], we find no evidence of fault-normal contraction.

Introduction

The Parkfield segment of the San Andreas fault (figure 1) forms a transition between the creeping segment to the northwest [*Savage and Burford*, 1971], and the locked section that last ruptured in the M 8 1857 Fort Tejon earthquake [*Sieh*, 1978] to the southeast. At least 5 historic earthquakes of $\sim M$ 6 have occurred in this area, in 1881, 1901, 1922, 1934, and 1966, although other San Andreas events may have occurred near Parkfield in 1877 and 1908 [*Toppozada*, 1992]. Seismograms from the 1922, 1934, and 1966 events indicate that these earthquakes had similar hypocenter, moment, and focal mechanism [*Bakun and McEvilly*, 1984]. These authors described the Parkfield events as "characteristic" and predicted the next earthquake would occur in 1988 $\pm$ 5 years. However, to date the most recent $\sim M$ 6 event here was in 1966. Others have noted the Parkfield earthquakes are not strictly characteristic [e. g., see *Roeloffs and Langbein*, 1994]. *Segall and Du* [1993] inferred from geodetic data that the 1966 event ruptured further to the southeast and may have had a larger moment than the 1934 earthquake.

Harris and Segall [1987] inverted trilateration data collected between 1966 and 1984 for the distribution of slip-rate on the Parkfield segment of the San Andreas. They found a "locked patch" extending NW from the 1857 rupture zone to the area below Middle Mountain. This patch of low slip-rates roughly coincides with the aftershock zone from the 1966 earthquake. *Harris and Segall* [1987] also found that a systematic misfit between data and model prediction could be reduced by including a small component of fault-normal shortening. More recent data [*Dong*, 1993; *Shen and Jackson*, 1993], however, do not show this shortening.

The U. S. Geological Survey has used the Global Positioning System (GPS) to make repeated position measurements of sites in the Parkfield area since the late 1980s [*Davis et al.*, 1989]. These data are methodologically and temporally independent of the earlier trilateration data. In our study, we assess whether the inferred locked patch persists by inverting the GPS data for interseismic slip-rate distribution.

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Data collection and processing

Between 1991 and 1998 the USGS conducted 15 GPS campaigns involving 35 sites in the Parkfield area. We processed these data with GIPSY-OASIS II software using a bias-fixed, precise point positioning technique [*Gregorius*, 1996; *Zumberge et al.*, 1997]. We incorporated the National Geodetic Survey (NGS) phase center calibrations to correct for multiple antenna types. We treated the wet zenith troposphere delay as a stochastic random walk parameter with a tropospheric drift parameter of 9.5 x 10^{-8} km/$\sqrt{sec}$ [*Gregorius*, 1996]. Analysis of continuous GPS measurements in the Parkfield area showed that this value minimizes the short-term scatter in the daily solutions. We used non-fiducial satellite orbits and clock corrections produced by NASA's Jet Propulsion Laboratory (JPL). After processing, we applied JPL's date-specific Helmert transformations to transform the position solutions from each day's nonfiducial reference frame to an ITRF96 frame.

Assuming steady state deformation, we solved for constant station velocities using weighted least squares (figure 1). The formal position errors were scaled so that the mean square error of the velocity estimate was approximately one. Typical rms values about the best fitting lines are 6.4 mm (east), 5.8 mm (north), and 19 mm (up).

Inversion

We assumed that the surface displacements observed in the Parkfield area arise from right lateral strike slip along the San Andreas fault, which we modeled as a dislocation in a homogeneous, linear, elastic half-space. Discretizing the model fault into a grid of uniformly sized blocks (3 km long by 2 km high) and taking the time derivative of *Okada's* [1985] expressions, we expressed the surface velocities as the sum of contributions from slip across each of the blocks.

For a specified fault geometry, the inversion for slip-rate is linear. The orientation of the San Andreas fault near