Afterslip on the Sumatra megathrust following the 2007 Mentawai earthquake sequence

A. P. Kositsky, J.-P. Avouac*, J. Genrich* , J. Galetzka, K. Sieh*, D. H. Natawidjaja, B. Suwargadi*
apk@caltech.edu, avouac@gps.caltech.edu
**1200 E. California Blvd. Mail Code 100-23 Pasadena CA 91125*

Abstract

A magnitude 8.4 and twelve hours later, a magnitude 7.9 earthquake occurred on September 12, 2007 occurred on the Sumatra megathrust in the Mentawai islands area, rupturing partially a patch of the plate interface that had remained locked in the decades preceding the earthquake (Figure 1) [Konca, et al., in press]. Here we analyze the postseismic time series collected at the permanent GPS stations from the Sumatra Geodetic Array (SuGAr) (http://www.tectonics.caltech.edu). Displacements were determined first relative to ITRF200 and then expressed relative to the Australia plate using the pole of [Bock, et al., 2003]. The time series show trenchward displacements amounting to as much as cm over the 120 days after the earthquakes. The stations located on the islands show postseismic subsidence (Figure 2), while these same stations had experienced uplift during the earthquake sequence. This pattern suggests afterslip on the shallow portion of the plate interface updip of the ruptured area as was observed following the Mw 8.6 Nias earthquake of 2005 [Hsu, et al., 2007]. The geodetic times series were inverted for slip on the megathrust using the PCAIM algorithm [Kositsky and Avouac, submitted] (Figure 4). The best fitting model obtained from the inversion 3 first principal components does yield a good fit to the time series (Figure 3), showing that the data are consistent with the hypothesis that postseismic deformation is dominated by afterslip on the megathrust. Moreover the distribution of afterslip is mostly complementary of the co-seismic slip distribution in the area where the data distribution yields some reasonable spatial resolution (Figure 5). Finally, the temporal evolution pattern is consistent with a logarithmic increase of slip as expected from velocity strengthening friction laws (Figure 3). These results suggest that postseismic deformation following the 2007 Mentawai earthquakes is probably reflecting frictional slip on velocity strengthening patches on the megathrust, in particular updip of the rupture area. Afterslip released a geodetic moment of about 1021N.m over the 125 days following the mainshock, equivalent to as much as 15% of the moment released by seismic slip during the earthquake sequence.

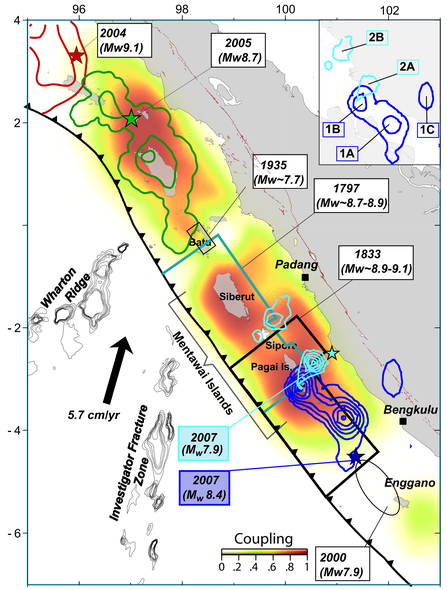


Figure 1: Interseismic coupling on the Sunda megathrust, offshore Sumatra, and rupture area of major recent earthquakes. The pattern of coupling, defined as the ratio of interseismic slip rate to plate convergence rate, is derived from the modeling of geodetic and paleogeodetic data [Chlieh, et al., 2008]. Slip distribution of the 2005 Mw 8.6 earthquake of 2005 is shown with 5 meter contour lines in green Gray and black polygons show estimated rupture areas of the 1797 and 1833 earthquakes. Dark and pale blue lines show the 1 m and 5 m slip contour lines of the Mw 8.4 and 7.9 seismic ruptures of 2007, stars show the epicenters.

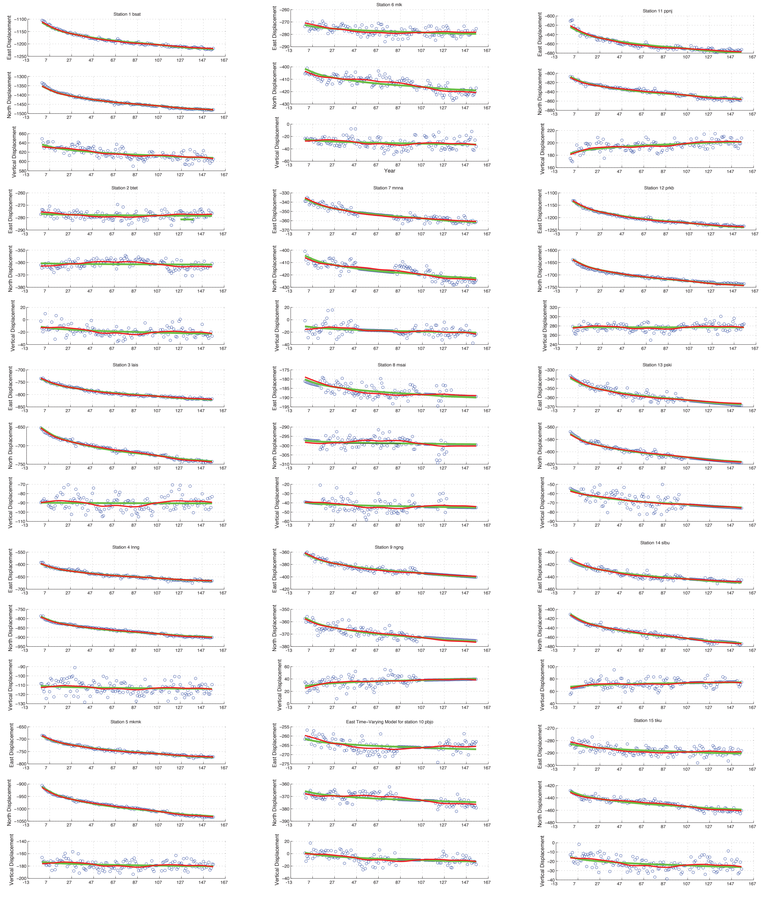


Figure 2: Postseismic displacements at the location of the SuGAr array stations recorded over 125 days after the earthquake sequence of September, 12, 2007.

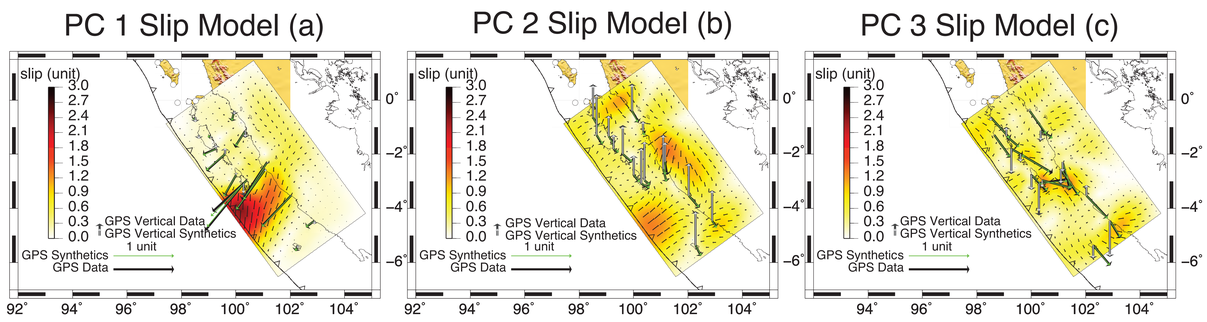
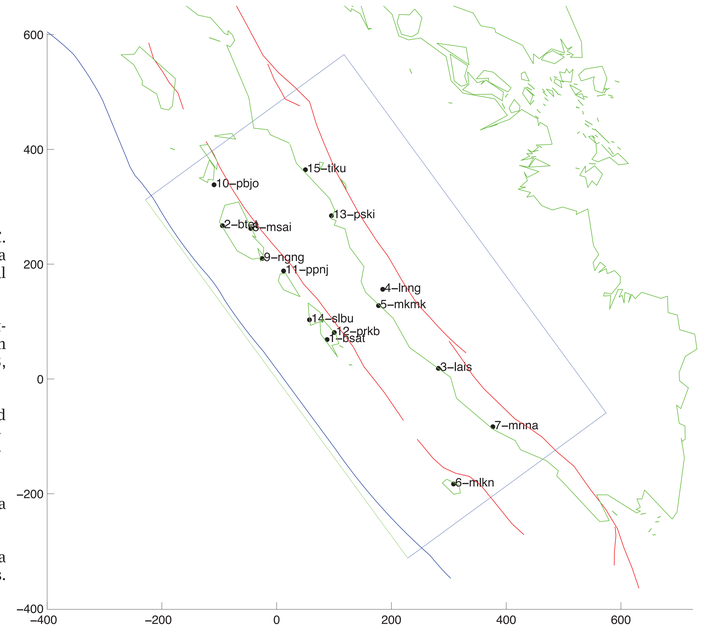


Figure 4: Principal components of the time series.

Figure 3: Geodetic times series at all stations used with model predictions.



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Cumulative slip at depth

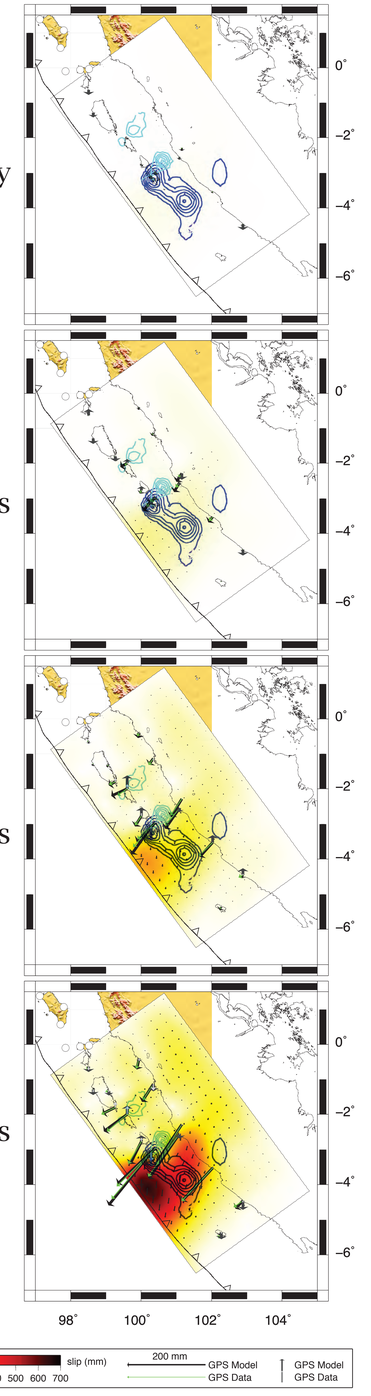

Figure 5: Distribution of afterslip over different time periods obtained with PCAIM