Afterslip on the Sumatra megathrust following the 2007 Mentawai earthquake sequence

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. Here we analyze the postseismic time series collected at the permanent GPS stations from the Sumatra Geodetic Array (SuGaR) (http://www.tecnoics.caltech.edu). Displacements were determined first relative to ITRF2000 and then expressed relative to the Australian plate using the rate of Beck et al. (2003). The time series show a jump in the vertical displacements amounting to as much as cm over the 125 days after the earthquake. The stations located on the islands show postseismic subduction (Figure 2), while those same stations had experienced uplift during the earthquake sequence. This pattern suggests that the sum of the process to the interseismic uplift of the stations as observed following the Mw 8.6 Nias earthquake of 2005 (Hsu et al., 2007). The geodetic time 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 of the first principal components does yield a good fit to the time series (Figure 1), showing that the data are consistent with the hypothesis that postseismic deformation is dominated by asperity on the megathrust. Moreover the distribution of slip is mostly complementary to the coseismic 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 long-term increase of slip expected from velocity strengthening friction laws (Figure 3). These results suggest that the postseismic deformation following the 2007 Mentawai earthquakes is probably reflecting frictional slip on velocity strengthening patches on the megathrust, and in particular updip of the rupture area. Afterslip released a geodetic moment of about 10^27 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 Grey and black polygons show estimated rupture areas of the 1797 and 1833 earthquakes. Dark and pale blue lines show the 1 and 5 m slip contours of the Mw 8.4 and 7.8 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 on September, 12, 2007.

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

Figure 4: Principal components of the time series.

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