Afterslip on the Sumatra megathrust following the 2007 Mentawai earthquake sequence

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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 80 cm over the first 125 days after the earthquakes, and as much as 120 cm after 451 days. 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 1.5 x 10^21N.m over the 451 days following the mainshock, equivalent to as much as 25% of the moment released by seismic slip during the earthquake sequence.

Geological Context

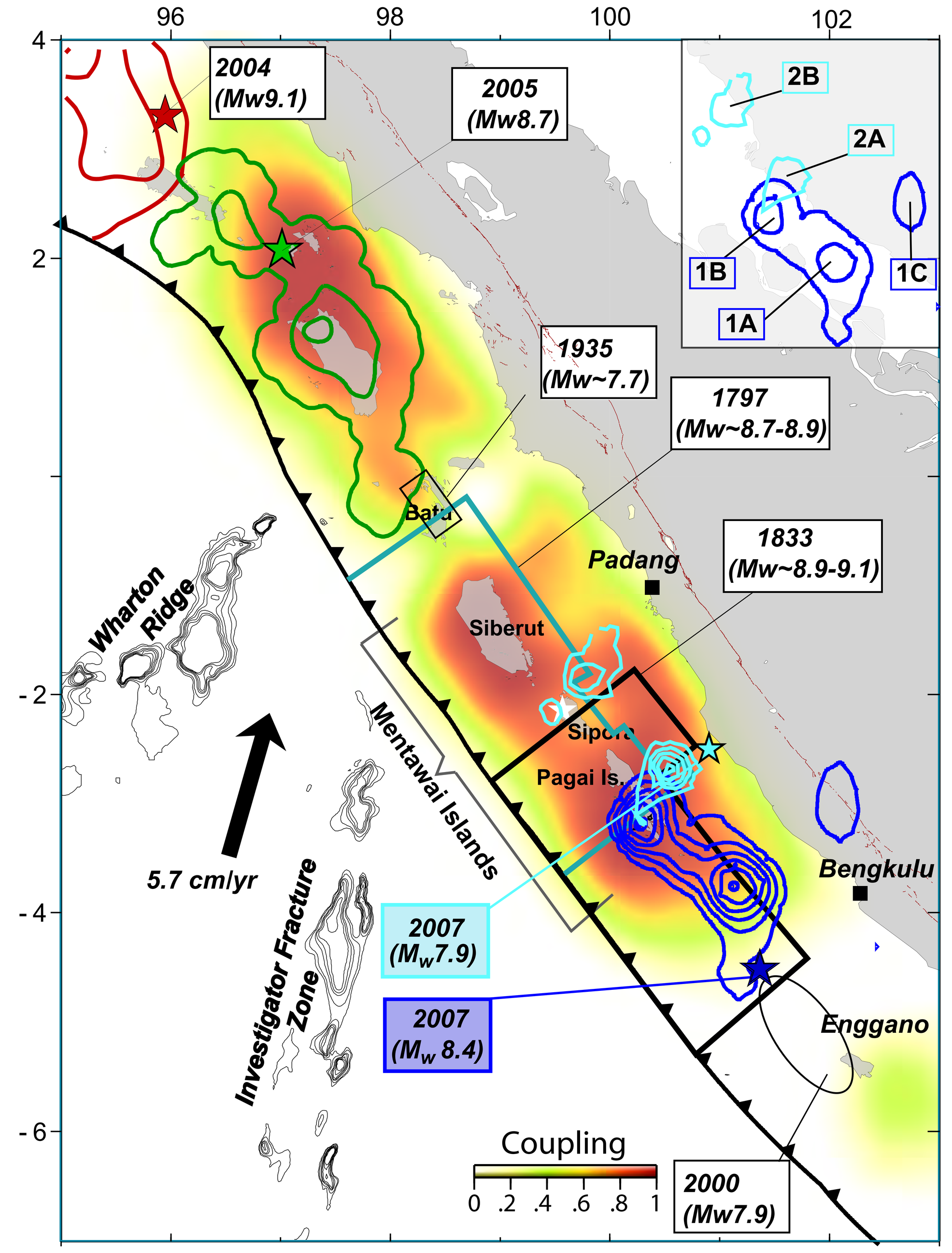

Figure 1: Interseismic coupling on the Sunda megathrust, offshore Sumatra, and rupture area of major recent earthquakes. The pattern of coupling, defined as the ratio of interseismic slip rate to plate convergence rate, is derived from the modeling of geodetic and paleogeodetic data [Chlieh, et al., 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.

Seismicity: 451 Days Post-Mainshock

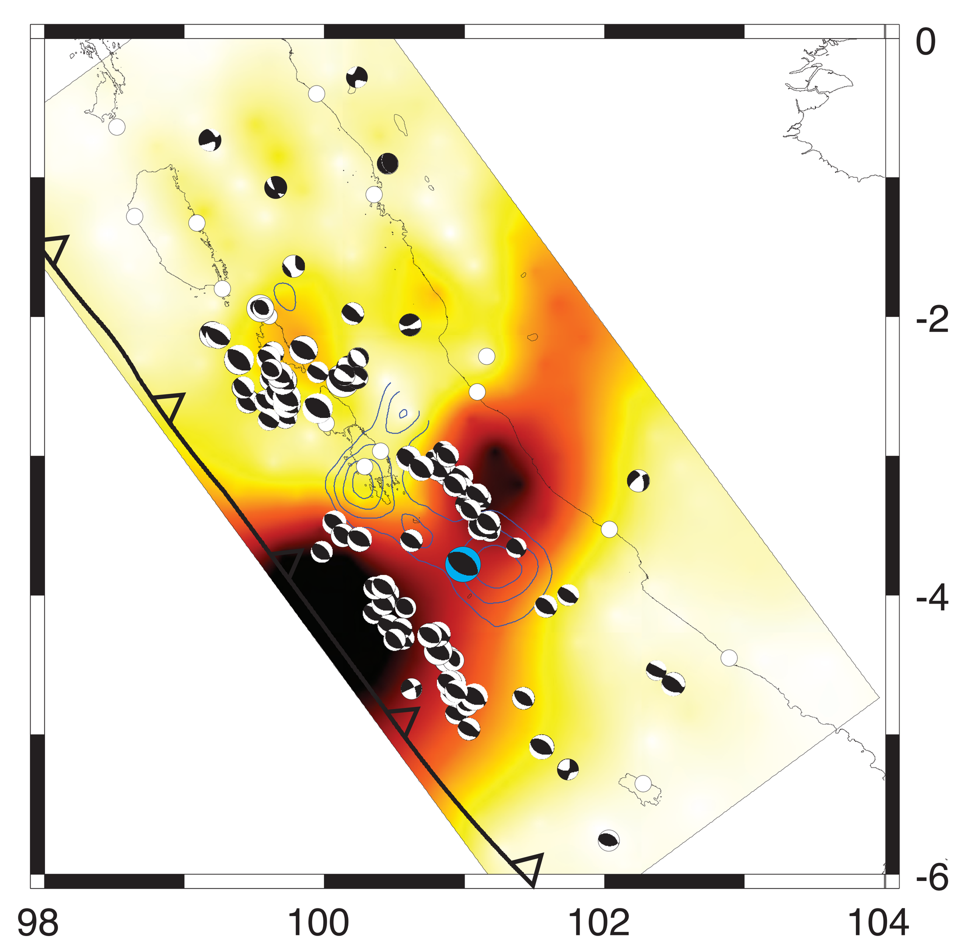

Figure 2: Location of seismicity following the September 12, 2007 mainshocks. Primary shock shown in cyan. Note the three clusters of seismicity, updip, downdip, and to the Northwest ("seismic crisis region").

Model Statistics

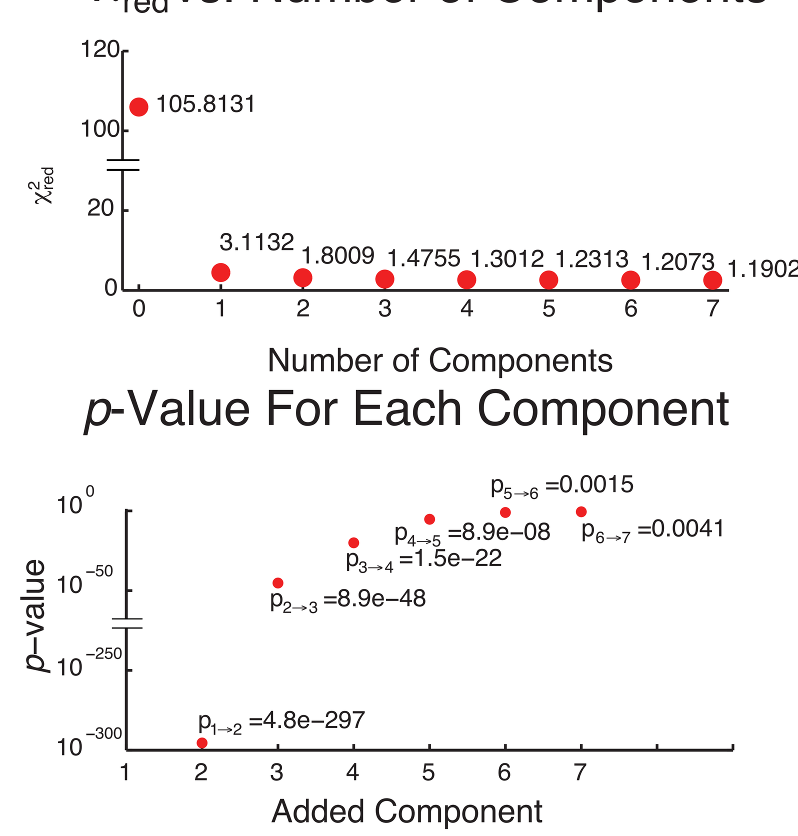

Figure 3: Two measures of the significance of the seven components used. p-values are the chance that the additional ith component explains primarily noise, and χ^2_{red} should be about one.

Slip on Select Patches at Depth

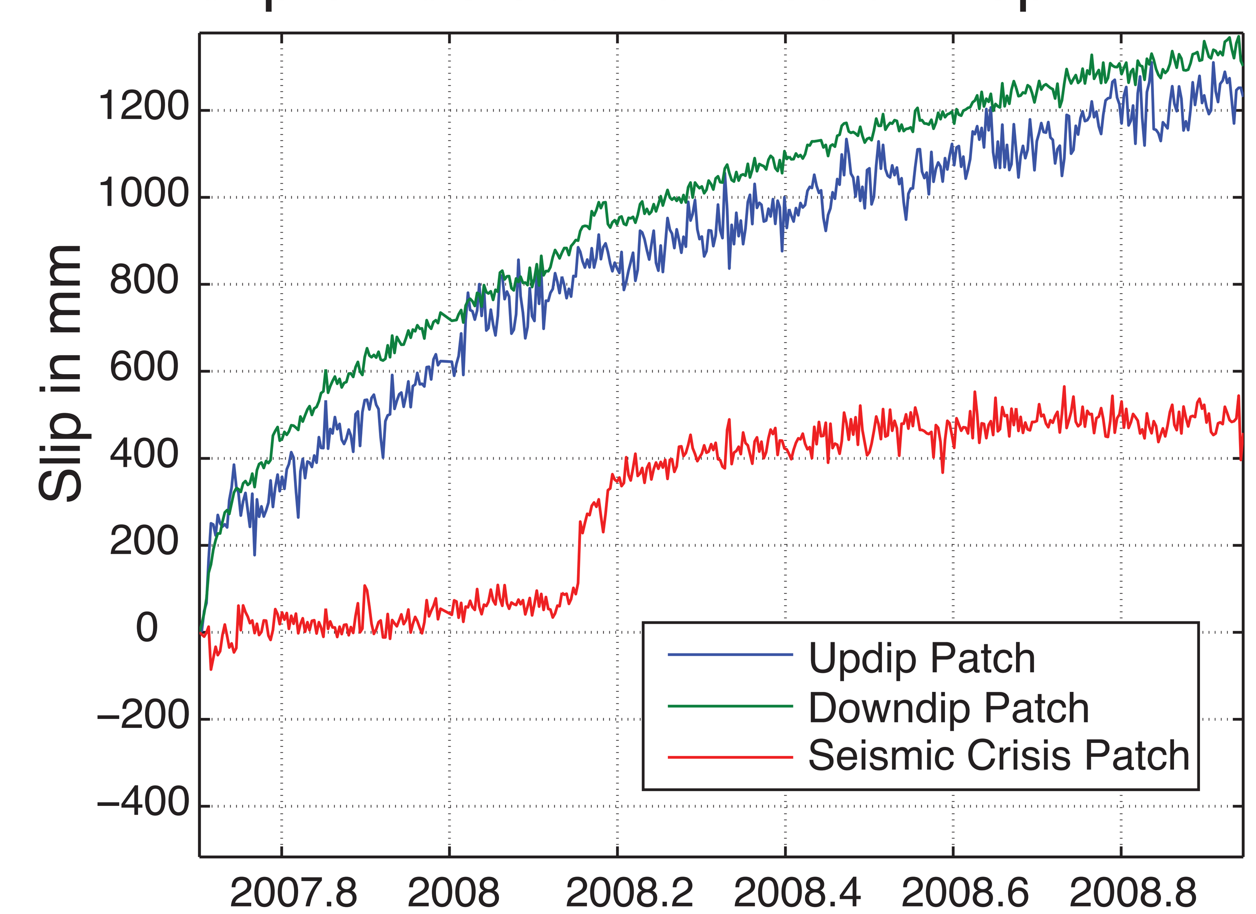

Figure 4: Time variation of slip at depth at the the patches of largest slip within the updip, downdip, and seismic crisis regions. The slip at the seismic crisis region is consistent with the timing of the later earthquakes in that region.

GPS Timeseries and Model Predictions

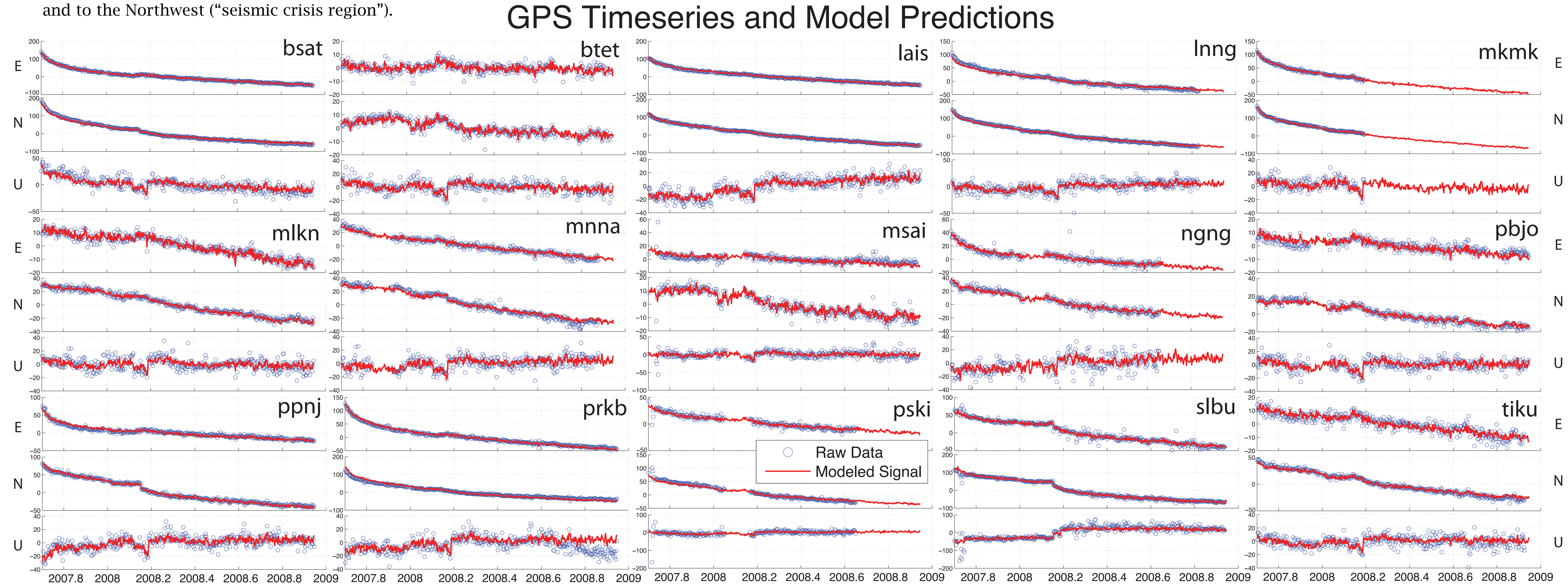

Figure 5: Original GPS imtseries plus model predictions. Most features in most of the timeseries are faithfully represented by the model.

Evolution of Afterslip

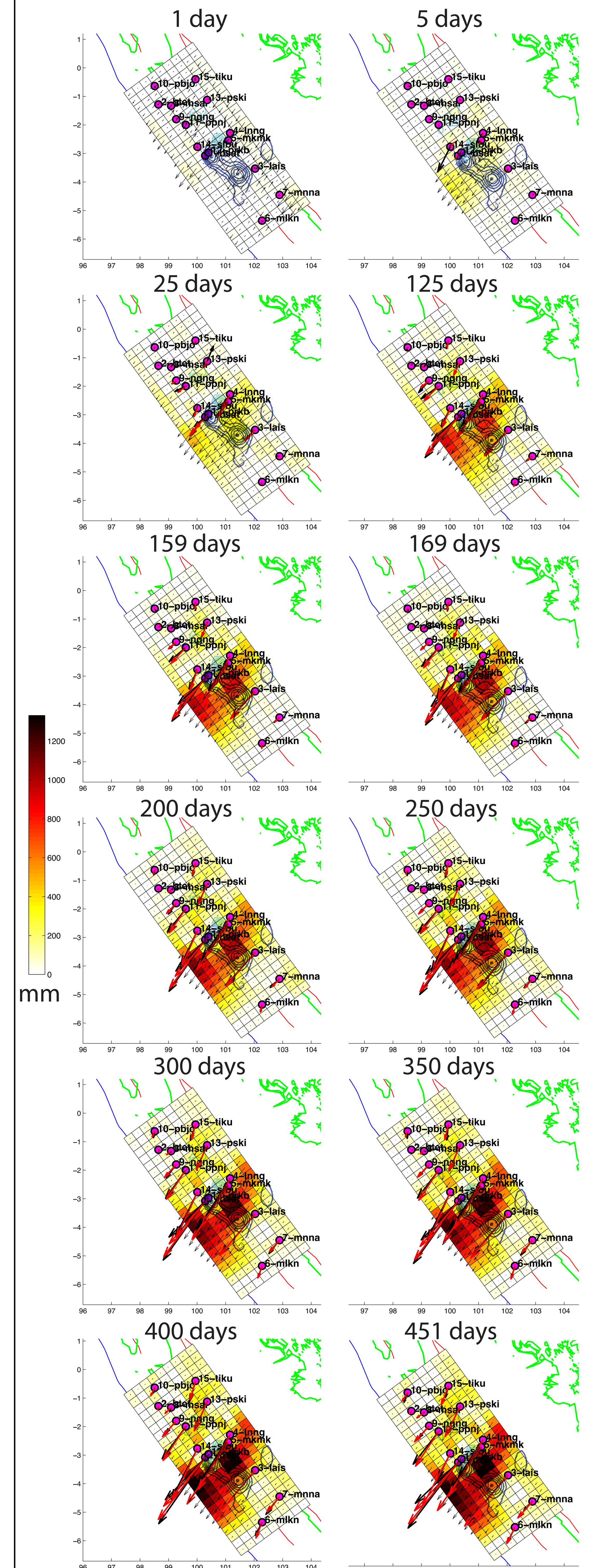

Figure 6: Distribution of afterslip over different time periods obtained with PCAIM. A series of earthquakes occured near slbu near day 159, and the contribtuion of the largest shocks has been removed from slbu using a parametric model. Note the slip shift of slip toward the south during the last ~200 days.

References and Acknowledgements

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