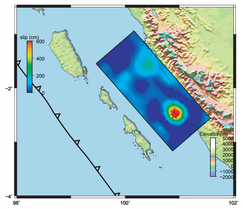
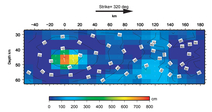
Rupture kinematics of the 2007 South Sumatra Mw7.9 eartquake

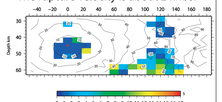
Teleseismic Inversion



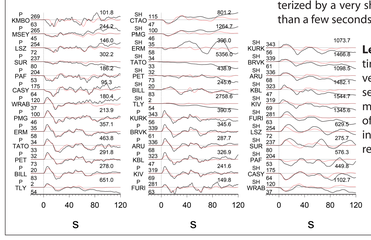
Map view of the slip distribution obtained for the inversion of the teleseismic data.



Above: The solution is characterized by a first pulse of very high slip (~7 m), and a smaller one less than 60 seconds later. The rupture velocity is about 2 km/s.

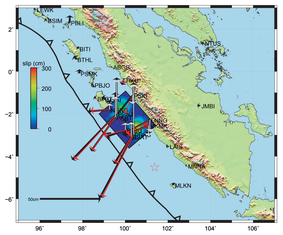


Above: The first patch of slip is characterized by a very short rise-time of less than a few seconds.



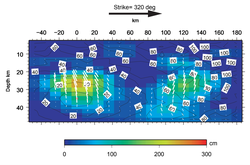
Left: The shortest rise-time allowed for the inversion (2 s.) does not seem to be enough to model the sharp onset of the P waves. Data are in black, and solution in red.

GPS Inversion



Above: Solution obtained from the inversion of GPS data (black arrows) only. The solution (red and grey arrows) fits the data very well, and corresponds to a solution with two patches of slip similar to the teleseismic solution (left box).

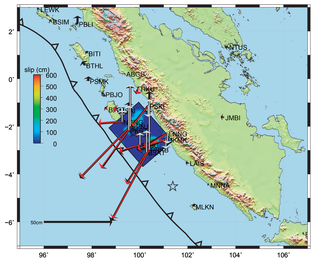
Below: Distribution of slip on the fault plane. The first patch has a much higher slip amplitude (2.5 m) than the second one (~1.5 m), but overall much smaller and distributed than the etleseismic solution alone.

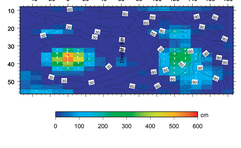


Joint Inversion

Right: Map view of the joint GPS and teleseismic inversion. The epicenter has been shifted from the USGS-NEIC location, to the center of the patch inferred from GPS only inversion in order to accomodate the very sharp pulse at the beginning of the GPS records.

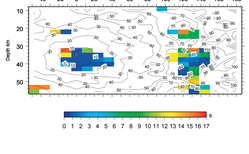
Below: Fit of the teleseismic data obtained from the joint inversion.

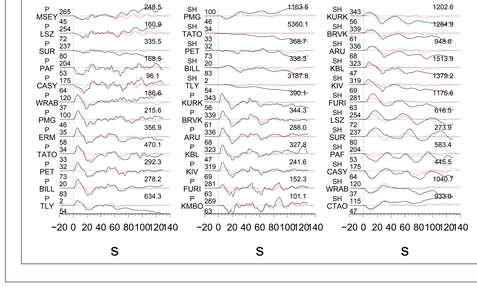




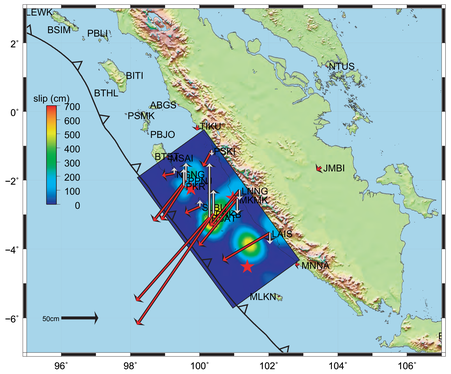
Above: Distribution of slip shows the two slip patches inferred from the separate GPS and teleseismic inversions.

Below: Rise time values for areas of significant slip.

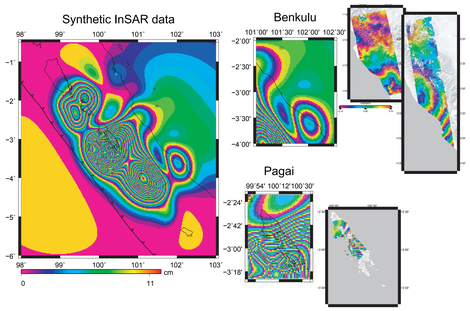




Global Static Solution

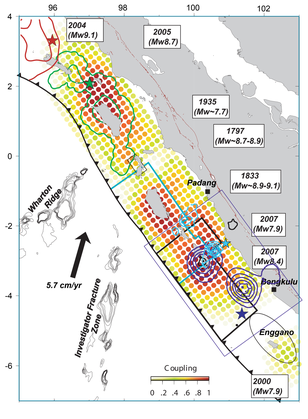


Result of the inversion of the whole GPS series (data vectors are in black, solution vectors in red and grey) , including the M8.4, M7.9 and M7.0 earthquakes (red stars going from South to North). The seismic moment of this solution is about Mo=8.45, that is close to the summation of the seismic moments provided by GCMT.

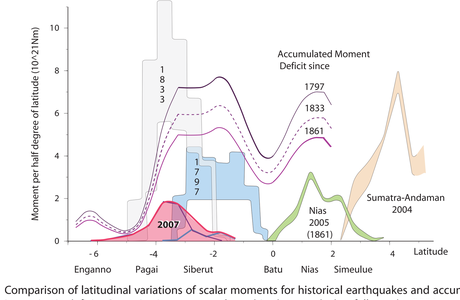


Comparison of the global static (GPS) inversion (left image) with InSAR wrapped images (right). The images in the center are zoom of the left image over the areas for which we have InSAR data. The Benkulu InSAR image confirms the existence of a slip patch below the coast (previously evidenced from only one GPS vector). The agreement is also very good over the Pagai island, espacially considering the sharp variations in the deformation pattern. Including all these data in the inversion process will certainly improve the robustness and the details of our solution.

Comparison with interseismic



Comparison of interseismically locked fault zone with giant ruptures of 1797, 1833 and 2005. The southernmost rupture area of the 2004 Sumatra-Andaman earthquake lies north of our study area and is shown only for reference.



Comparison of latitudinal variations of scalar moments for historical earthquakes and accumulated interseismic deficits. Postseismic moment released in the month that follows the 2004 earthquake and in the 11 months that follows the Nias-Simeulue 2005 earthquake are respectively shown is red and green respectively from Chlieh et al. [2007] and Hsu et al. [2006].

Conclusion

The Mw 8.4 earthquake is a northward unilateral rupture with two main asperities, a deeper one, extending relatively deep beneath Bengkulu coastal area and a shallower one beneath South Pagai Island. The rupture was not impulsive with rise times of the order 10 seconds leading to relatively subdued ground shaking.

The Mw 7.9 event also ruptured two distinct asperities about 130km apart. The seismic waveforms require the first subevent, located near the eastern coast of South Pagai Island, to be extremely impulsive, with a short rise time of a few seconds at most, and a highly peaked slip distribution close to the epicenter. The second subevent is located 130 km to the northwest, along the north-eastern coast of Sipora Island.

Both the 8.4 and 7.9 earthquakes thus seem to consist of sub-events which rupture jointly probably due to dynamic triggering (S waves). By contrast the 12 hour delay between the 7.9 and the 8.4 is more consistent with triggering by static stress change.

The co-seismic slip distributions from both events abuts each other and occurred within the rupture area of the M w~9.0 historical earthquake of 1833. These ruptures also coincide with a well defined patch of the megathrust that had remained locked during the interseismic period. There is however some indication that both ruptures may have extended downdip into the zone that is partly creeping in the interseismic period. This would be an indication that seismic ruptures can indeed propagate in rate-strengthening zones.

Altogether these events released a moment of about 6.e21 N.m that is only a fraction of the 20-50.e21 N.m moment released during the 1833 earthquake. It also amounts to only a small fraction of the deficit of moment that has accumulated since due to interseismic strain build up which is estimated to ~40.e21 N.m.

We conclude that 1-seismic asperities are probably persistent features which arise from heterogeneous strain build up in the interseismic period; 2- the same portion of a megathrust can rupture in different ways depending on whether asperities break as isolated events or cooperate to produce a larger rupture; 3- the state of stress on that portion of the Sumatra megathrust was not adequate for the development of a single major large rupture at the time of this seismic crisis; 4- the breaking of smaller patches tend to be more abrupt, possibility a manifestation of the heterogeneity of megathrust properties which tend to be smoothed out as the rupture area gets larger.