Coseismic and Early Post-seismic Deformation of the Great 2004 Aceh-Andaman Earthquake.

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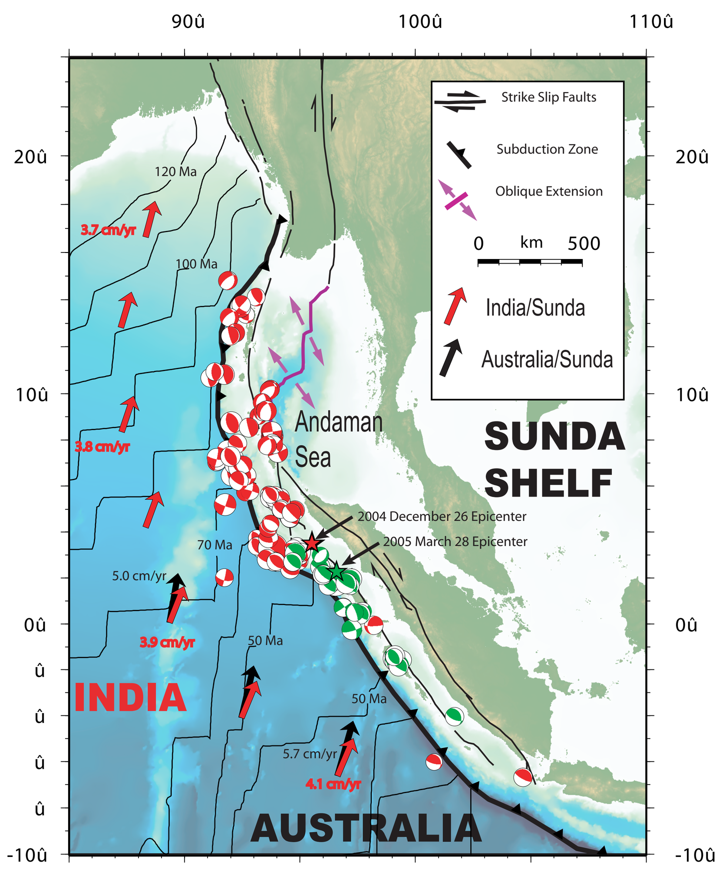
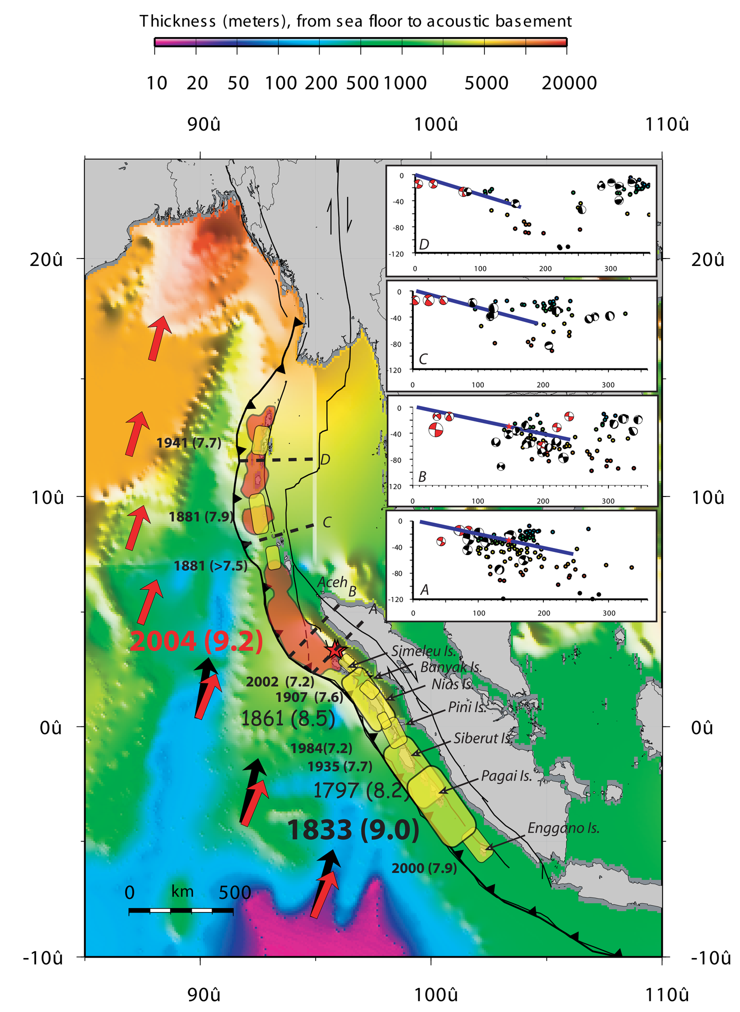
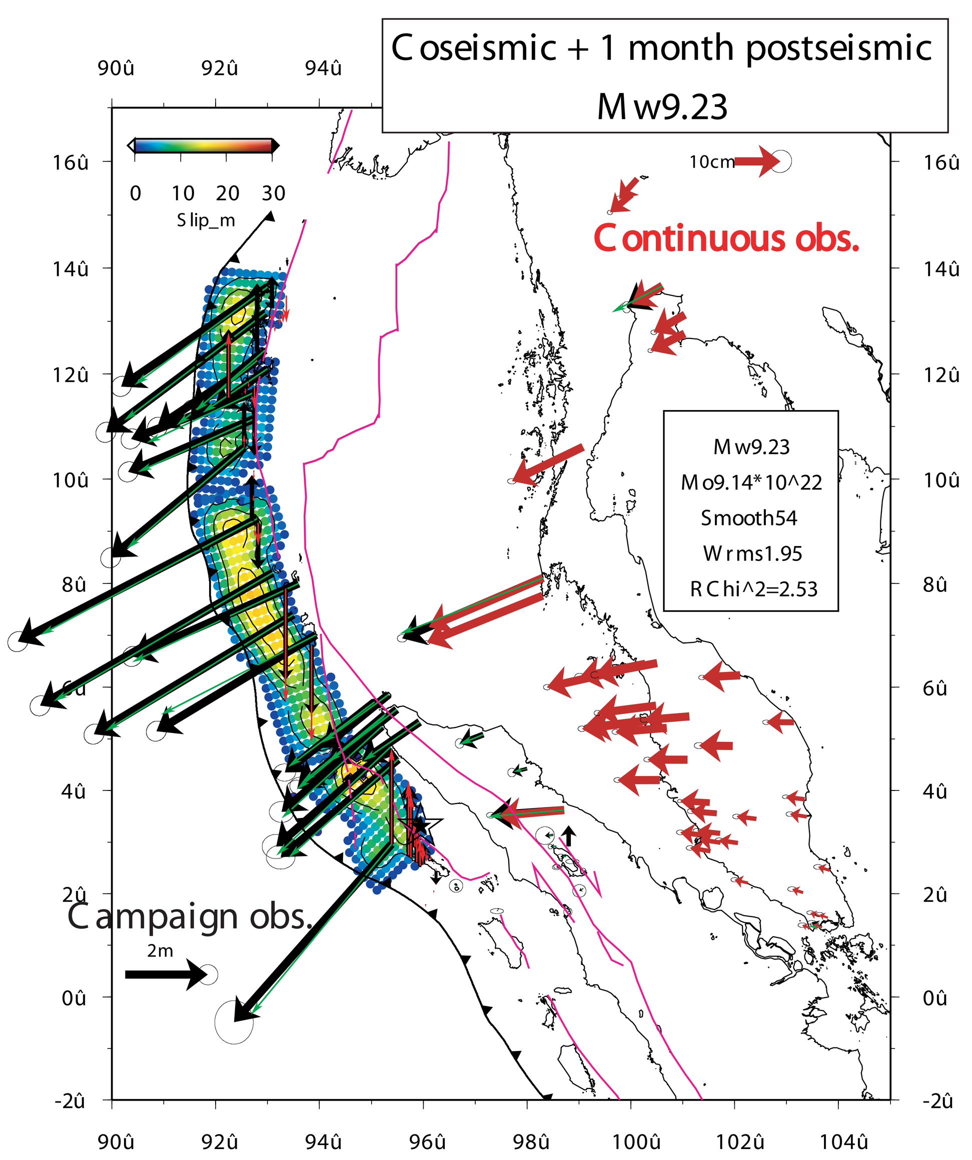


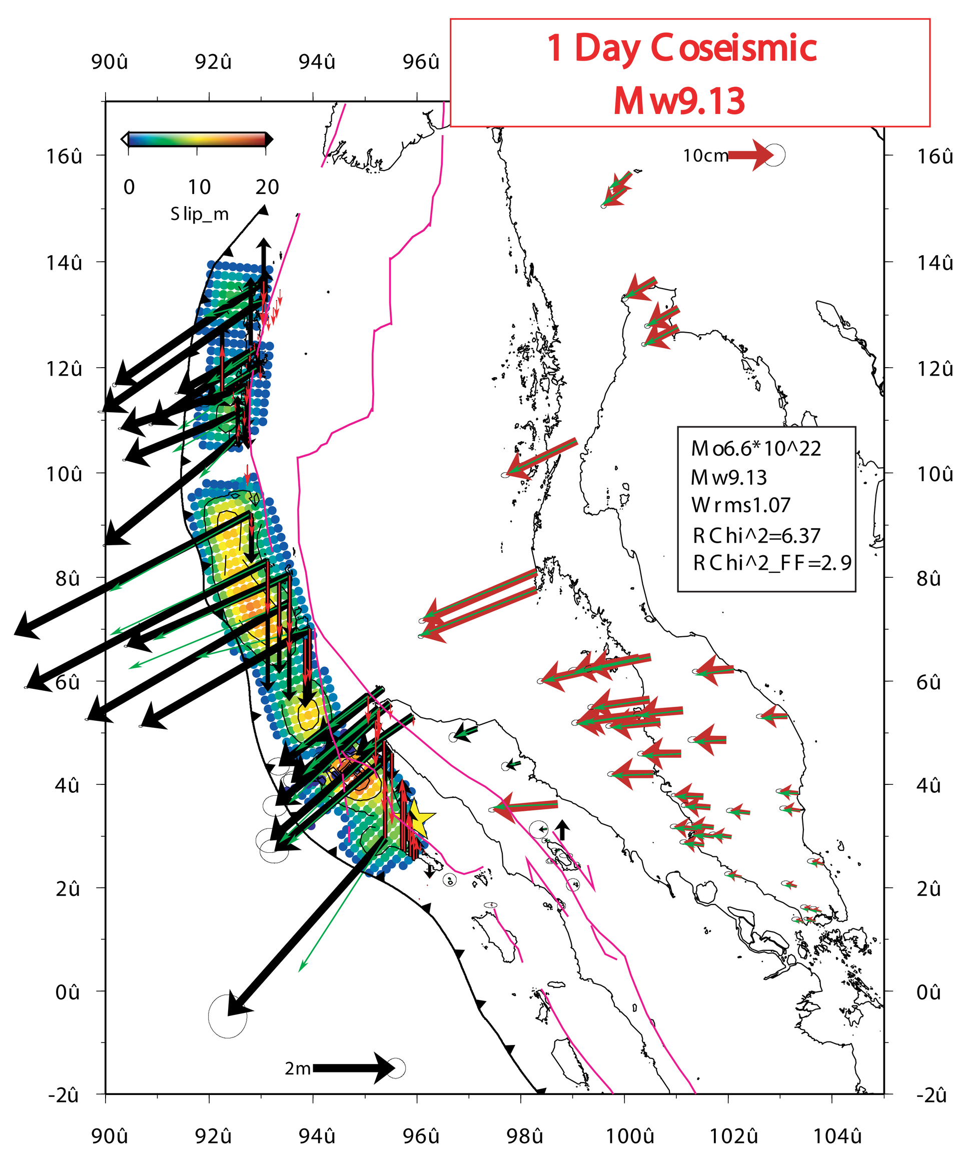
Regional tectonic setting simplified from Curray (2005) and Natawidjadja et al, (2004). Plate velocities of Australia and India relative to Sunda were computed from the regional kinematic model of Bock et al. (2003). The boundary between Australia and India is a diffuse plate boundary with extends approximately between 5°S and 8°N. In this area velocities computed from both Euler poles are shown. Age of the sea floor increases northwards from about 50Ma in the epicentral area to 100Ma at the latitude of Andaman Islands. Epicenter (NEIC) and CMT solutions of aftershocks are shown in red. Epicenter and CMT solutions of aftershocks of the 28 March, 2005 Mw 8.7 earthquake are shown in green.

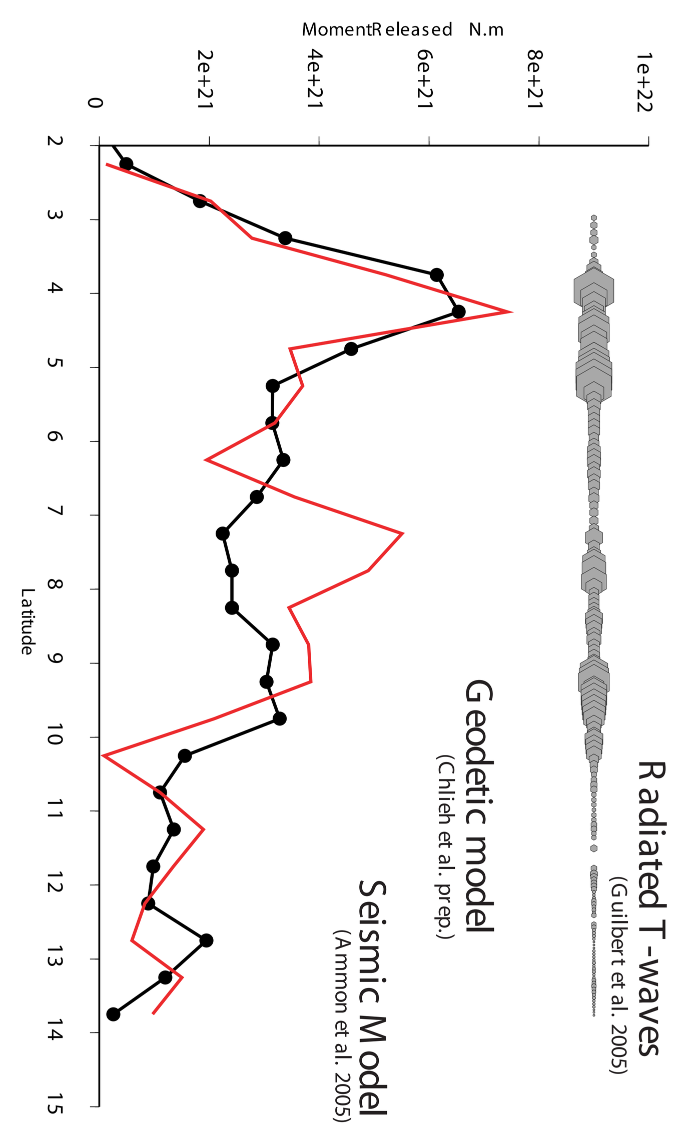
The Sumatra-Andaman earthquake of December 26, 2004 is the first giant earthquake to occur since the advent of modern space-based geodesy and broadband seismology and therefore provides an unprecedented opportunity to investigate the characteristics of one of these most dreadful and rare events. We determine co-seismic and post-seismic deformation over the first month following the main shock using a variety of geodetic data. These include ground displacements from near-field Global Positioning System (GPS) surveys in northwestern Sumatra (Subarya et al, 2005) and in-situ paleogeodetic and remotely sensed observations of the vertical motion of coral reefs (Meltzner et al, 2005), campaign data and continuous GPS measurements from Thailand and Malaysia (Vigny et al, 2005). Our co-seismic model is constrained from co-seismic displacement derived from daily solutions at 34 cGPS stations. It implies that earthquake ruptured the Sunda subduction megathrust over a distance of about 1300 km and a width of less than 150 km releasing a total moment of 6.7-7.0 1022 Nm, equivalent to magnitude Mw 9.15. This moment is slightly in excess of the 6.2 1022 Nm moment released over the first 500s, as estimated from the inversion of seismic records (Model III in Ammon et al, 2005). We also find that the highly variable latitudinal distribution of released moment derived from the two models compare remarkably well. This pattern is also found consistent with the 500s long source time function and rupture velocity derived from T waves recorded in the Indian Ocean (Guilbert et al, 2005). Finally, numerical simulation of the tsunami assuming this co-seismic model are found consistent with altimetric satellite measurements of the tsunami by JASON and TOPEX, as well as with the arrival times of the tsunami as indicated by tide gage records at a number of sites bordering the Indian Ocean and Andaman Sea. We therefore find no need for slow slip or delayed slip as proposed in some early studies (Bilham et al, 2005; Lay et al, 2005). However, the geodetic data postdating the main shock by up to 40 days, require that slip must have continued on the plate interface after the 500s long seismic rupture. The corresponding additional geodetic moment is about 1.5 1022 Nm, representing about 20% of the co-seismic moment release. Comparison with the moment released by aftershocks, which amounts to only 1% over the same period, shows that this deformation was mostly aseismic. Constraints on the depth distribution of afterslip are loose, but it seems that it must have occurred at depths less than about 50km, probably both updip and downdip of the seismically ruptured area. Time evolution of afterslip is consistent with rate-strengthening frictional afterslip. The proportion of aseismic slip is larger to the north, possibly due to the effect of the thick sediment cover entering the trench.

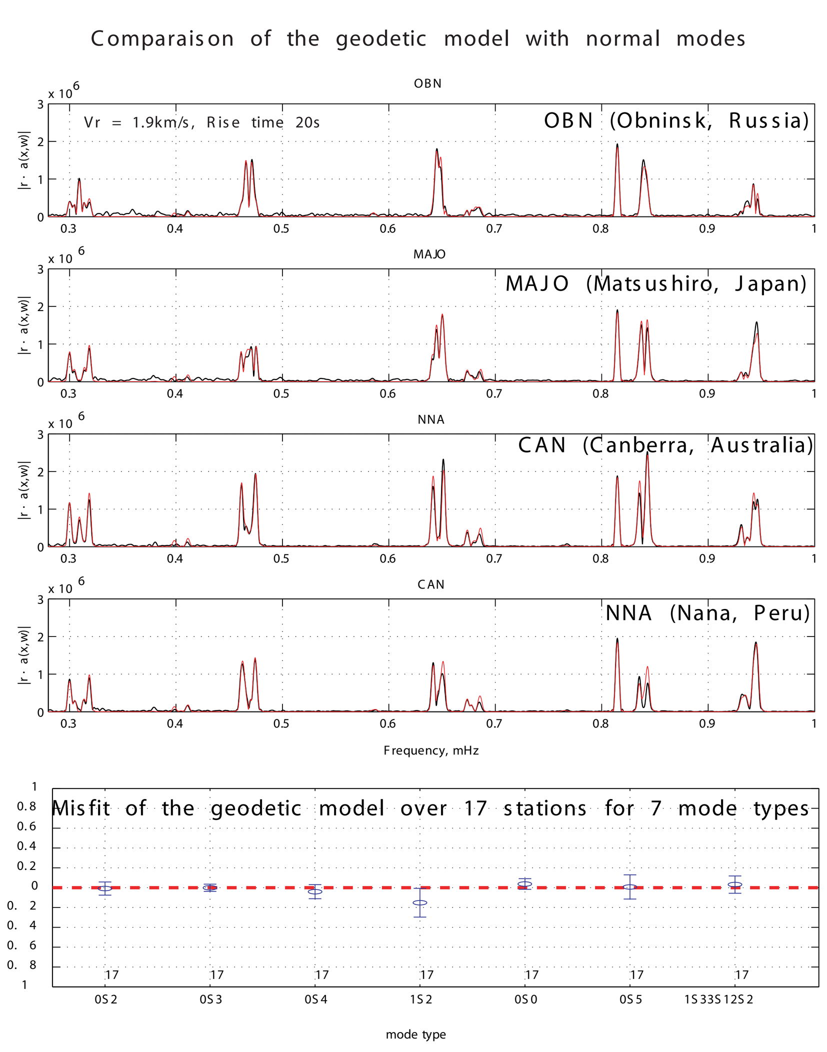


Coseismic Models

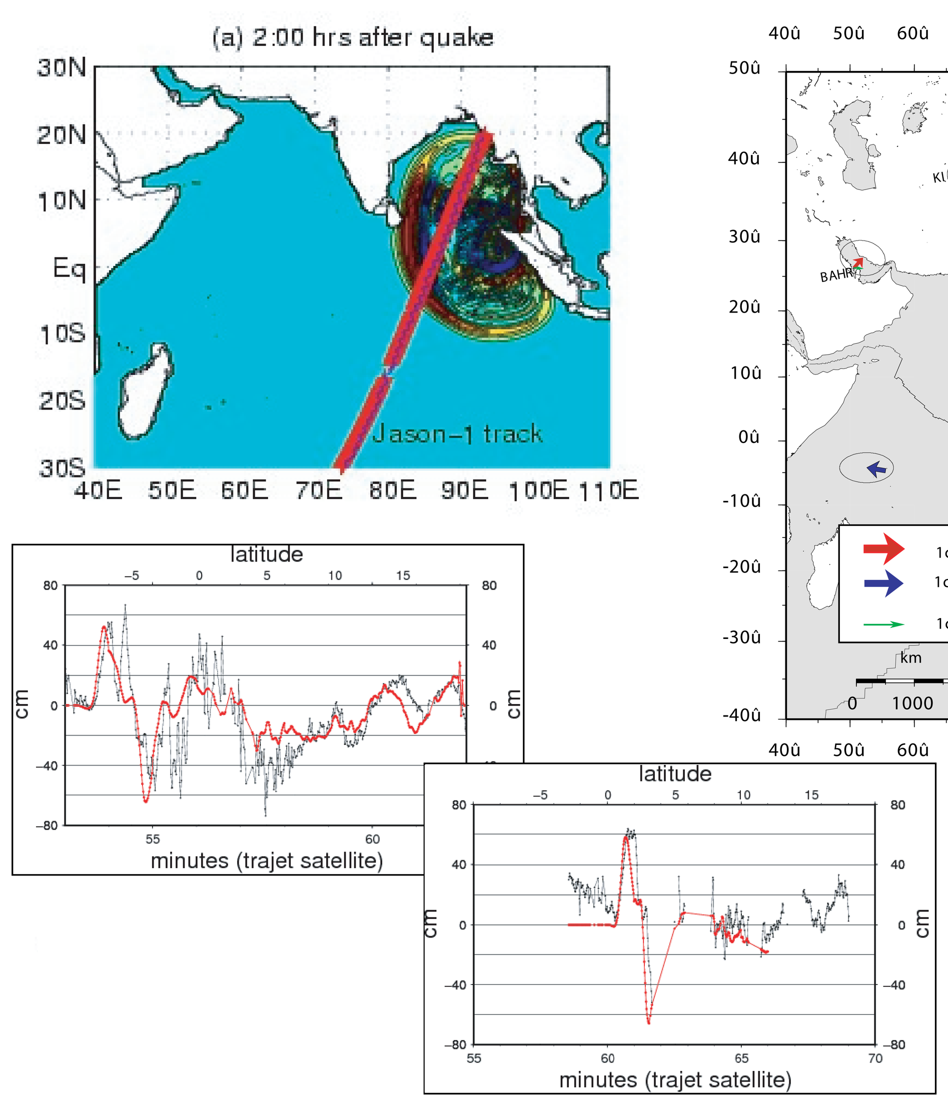


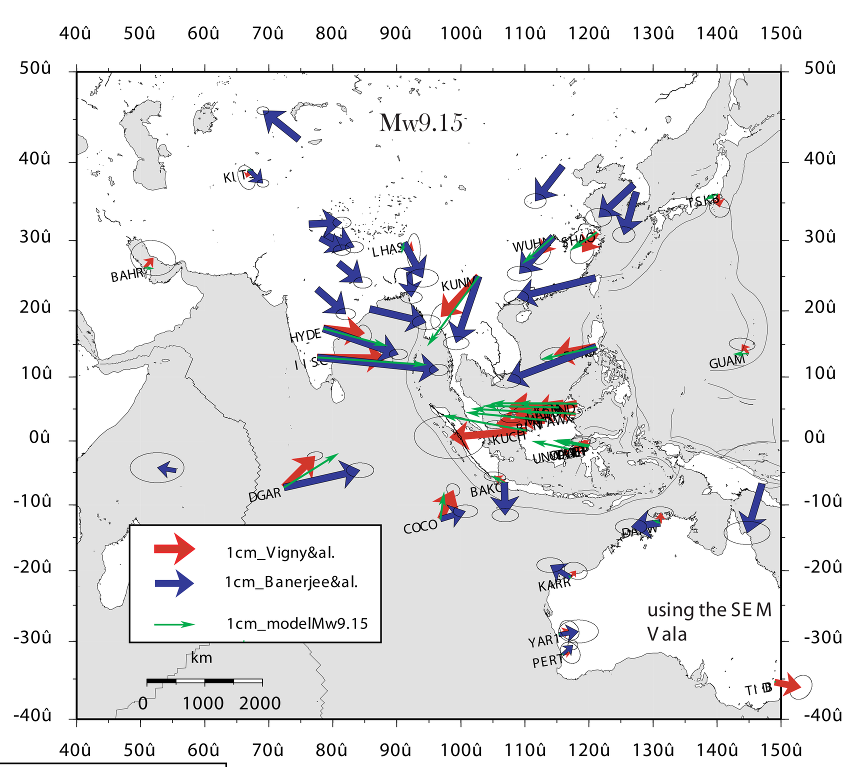


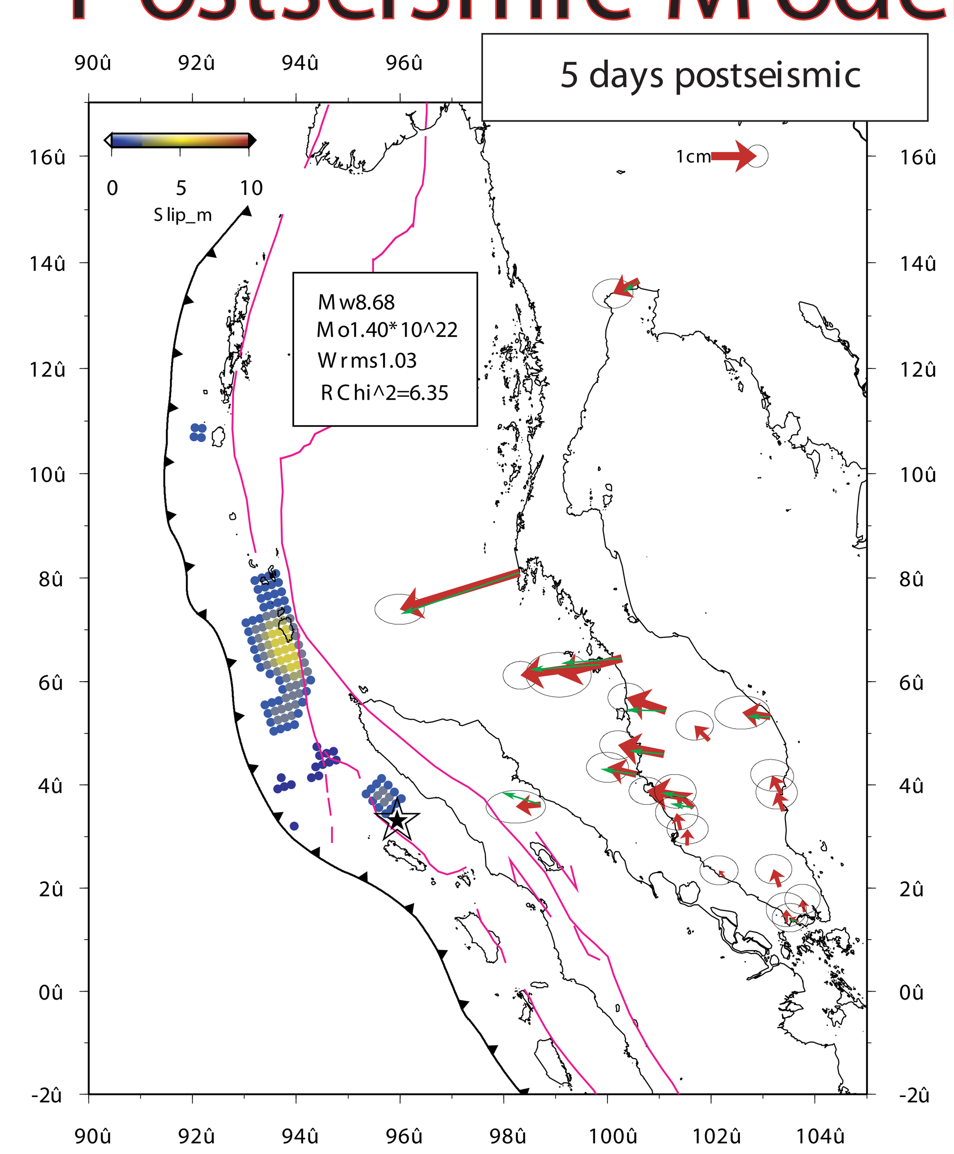


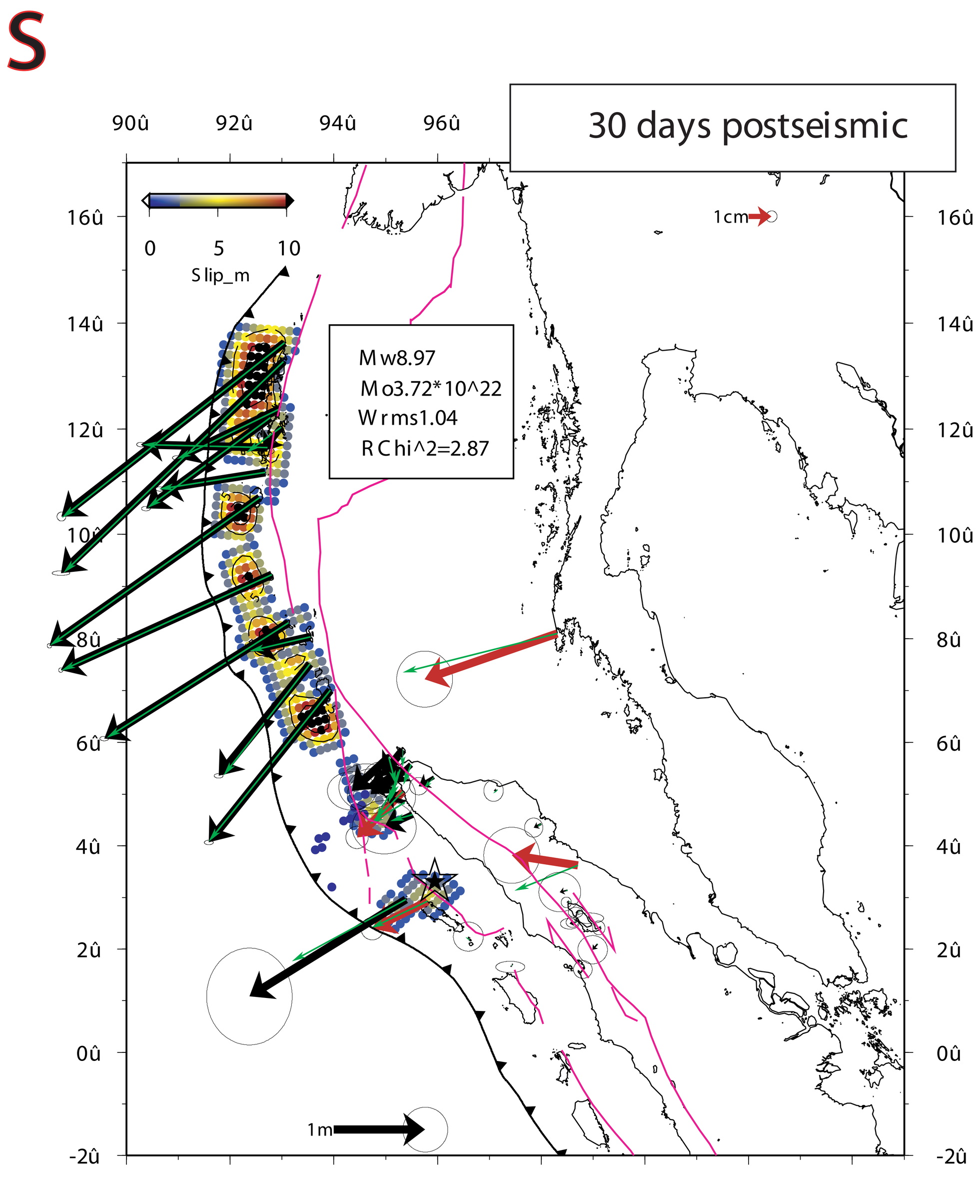


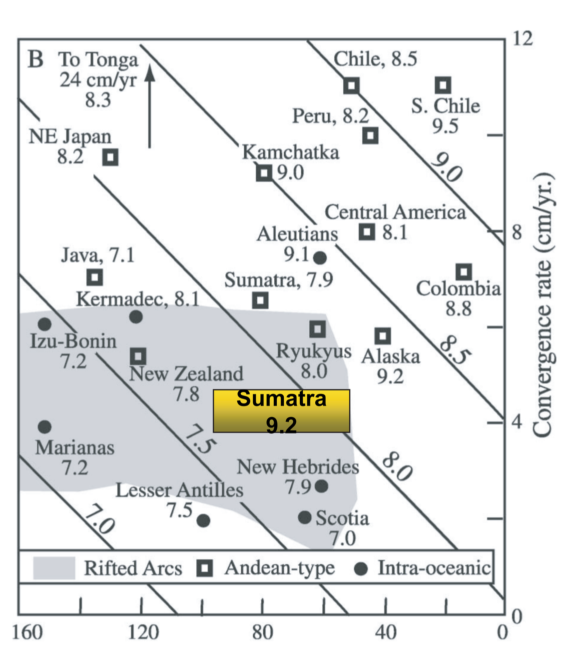
Postseismic Models











These data shed some light on the physical parameters controlling the mode of slip along the plate interface. The ruptured area seems to coincide with the portion of the plate interface shallower than about 40km that was locked before the earthquake, as indicated from the previous background seismicity. The long term slip along the LFZ must be the result of accumulated seismic events with different lateral extent, but possibly characteristic slip and, to some degree, of aseismic slip. The average recurrence interval of giant earthquake along this portion of the Indonesia-Andaman subduction zone could be as low as 240yr, but a more plausible estimate would be 600 to 700yr. Given the >80Ma age of the subducting plate and the <4cm/yr of convergence rate, the Aceh-Andaman earthquake is at odd with the concept that the magnitude of subduction earthquakes increases linearly with convergence rate and decreases linearly with subducting plate age (Ruff and Kanamori, 1980; kanamori, 1983). Neither does it conform to the idea that trench-perpendicular extension, as occurs here, would be diagnostic of low magnitude earthquakes (Uyeda and Kanamori, 1979; Scholz and Campos, 1995). This example shows that there is a need to revisit the physical basis used to estimate the magnitude and recurrence of large events at subduction zone.