Rupture process of the recent large Sumatra earthquakes: 26/12/2004 (M_w=9.3) and 28/03/2005 (M_w=8.6)

Bezzeghoud Mourad, José Fernando Borges and Bento Caldeira
Departamento de Física and Centro de Geofísica de Évora, Universidade de Évora - Colégio Luis Verney, Rua Romão Ramalho, 59, 7002-554 Évora – Portugal, mourad@uevora.pt

Abstract

The Sumatra mega-earthquake with magnitude 9.3 of 26 December 2004 was the strongest earthquake in the world since the 1964 Alaska earthquake and the fourth since 1900. The earthquake occurred on the interface of the India and Burma plates and triggered a massive tsunami that affected several countries throughout South and Southeast Asia. The rupture, estimated by the aftershock distribution, start from central Sumatra northward for about 1200 kilometres (Borges et al., 2004). Three months latter in 28 March 2005, about 200 km south of this event, but at a greater depth (28 km) occurred a magnitude 8.6 earthquake. This event was probably triggered by stress variations caused by the December Sumatra mega-earthquake (McCloskey et al., 2005). In this work we describe the rupture process of the both earthquakes estimated from teleseismic broad-band waveform data.

The earthquake of 26 December 2004 (Mw=9.3). The source time function and the rupture were analysed process using 29 teleseismic broad-band data, provided by IRIS-DMC stations,. The rupture direction and velocity were determined from common pulse durations observed in P waveforms using DIRDOP computational code (DIRectivity DOPpler effect) developed by Caldeira (2004). The modified Kikuchi and Kanamori (2003) method, based on a finite fault inverse algorithm, has been used to determine the slip distribution. Two segments of 150 km wide (along dip), 990 km total length with different azimuth were obtained based on the subduction geometry, aftershock distribution and CMT, . Results show that the rupture spreads mainly to the North with an average velocity of 2.7 km/s. The focal mechanism shows thrust motion on a plane oriented on the NNW-SSE direction and a horizontal pressure axis in the NNE-SSW direction. The fault slip distribution shows the following pattern: 1) in the first stage the rupture nucleated at the hypocenter as a circular crack breaking a shallow asperity of about 60 km radius during the first 60 sec; 2) in the second stage, the rupture propagated during ~180 s after the initial break to the NNW and broke a middle large asperity centred at about 360 km from the epicentre; 3) finally, the rupture propagated further to the north and broke a third asperity centred at ~840 km from the epicentre during at least 110 sec. The maximum slip reaches 14 m in the central asperity and the total seismic moment is Mo = 3.0 $x10^{22}$ Nm (Mw = 8.9), which is less than the value given by the ESMC and USGS (the loss of seismic scalar moment was released in a third segment located to the north). The total source duration and rupture length are estimated to be above 350 sec and 990 km, respectively.

The earthquake of 28 March 2005 (Mw=8.7). In this case, the rupture process was estimated using waveforms data from 23 teleseismic broad-band stations provided by IRIS-DMC. The direction and velocity of rupture was determined using the same methodology described above for the 26-12-2005 earthquake. A rectangular rupture plane with 400 km length (along the strike direction) and 125 km wide (along the dip direction) was obtained from the subduction geometry, aftershock distribution and CMT. Results show that the rupture spreads during about 110s in the southwest direction with an average velocity of ~3.3 km/s. Most of the seismic moment was released the break of two asperities: the largest one located about 90km of the hypocenter, and the other one at 175 km from the hypocenter. These two asperities correspond on the surface to the most affected areas by the event (Nias island). The maximum slip reaches

11 m in the largest asperity and the total seismic moment is Mo = 0.82 x10^{22} Nm (Mw = 8.6). The focal mechanism shows thrust motion on a plane oriented on the NNW-SSE direction and horizontal pressure axis in the NNE-SSW direction (Borges et al., 2005).

Conclusion

26 December 2004 Event. The constrained dimension of the fault is nearly 930 km with a maximum rupture velocity of 2.7 km/sec. The rupture process can be explained by 3 asperities distributed between approximately at 5 km and 20 km depths with a total time duration of 350 sec. The total Mo is 3.0 x 10^{22} Nm (Mw=8.9) and the maximum slip is about 14 m located at the second segment where most of the seismic moment was released. The directivity and spatio-temporal slip distribution corroborates the predominant unilateral character fracture propagation- towards the NNW direction- of the Sumatra rupture process.

28 March 2005 Event. The constrained dimension of the fault reaches almost 425 km in length with a rupture velocity of 3.3 km/sec during 110 sec. The rupture process can be explained by 2 asperities located at 90 and 175 km SSE from the epicentre, where most of the seismic moment was released. Geographically these two asperities correspond to the most affected area (Nias island; Imax=IX according USGS report) The total Mo is 0.82 x 10^{22} Nm (Mw=8.6) whereas the maximum slip is about 11,5 m.

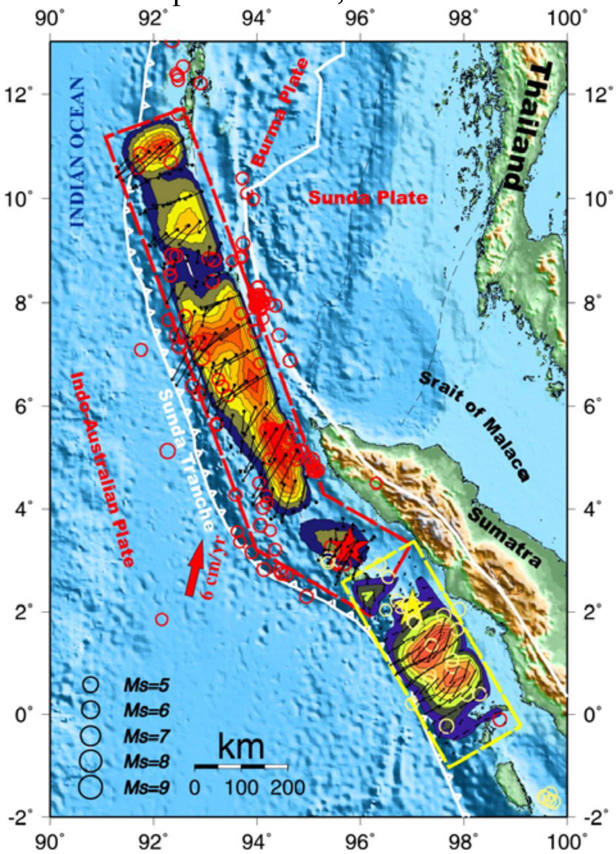

Fig. 1 - Map of the slip distribution with main tectonic background. Red star - epicentre of 26 December earthquake (first event); yellow star - epicentre of 28th March earthquake (second event); dashed red rectangle - extent of the fault plane of the first event; dashed yellow rectangle - extend of the fault plane of the second event; open circle - large aftershocks (M>5.5, epicentres compiled from USGS). Main tectonic background of the area is shown. The thick arrow indicates direction of the movement between adjacent plates: the India plate moves toward the northeast with a rate of about 6 cm/year relative to the Burma plate. Isolines represent the slip distribution of first and second ruptures and thin arrows the slip vectors.

References

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