Source Rupture Process of the Sumatra, Indonesia Earthquake (M_W=8.6) of 28 March 2005

Preliminary Results

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Abstract: *The magnitude 8.6 of the 28 March 2005 Sumatra earthquake occurred in the interface between the India-Burma tectonic plates and it was caused by the stress released on the subduction process between this two plates. The hypocenter of this event occurred about 200km southward of the event of December 26th, but at a deepest depth. It was probably triggered by stress variations caused by the December 26 2004 (Mw=9.0) Sumatra mega-earthquake. This work describes the rupture process estimated with data of an azimuthally distribution of 23 teleseismic broad-band waveforms provided by IRIS-DMC stations. The direction and velocity of the rupture were determined from common pulse durations observed in P seismograms using DIRDOP computational code (DIRectivity DOPpler effect) developed by Caldeira (2005). The modified Kikuchi and Kanamori method (2003), based on a finite fault inverse algorithm, has been used to carry out the slip distribution. Based on the subduction geometry, aftershock distribution and CMT were fixed a rectangular rupture plane with 400 km length (along strike direction) and 125 km wide (along dip direction). 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 in two asperities: the largest one located about 90km of the hypocenter, and the other one at 175 km from the hypocenter. Geografically, these two asperities correspond to the most affected area by the event (Nias island) The maximum slip reaches 15 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 as well as horizontal pressure axes in the NNE-SSW direction.*

Introduction

The Indonesian region is one of the most seismically active zones of the earth. After 3 months on the Sumatra mega earthquake (Mw=9.0) last December, the region was affected again by a great event, on the 28^{th} of March, at 16:09 UTC (Borges et al., 2004). This one has a magnitude Mw= 8.6 with the epicentre located at Lat =2.08, Long =97.0, USGS, approximately 200km SE of 26^{th} December's (Fig. 1). This hypocenter is deeper (H=28km) than the previous one.

This earthquake occurred on the interface of the India and Burma plates and was caused by the release of stresses that develop as the India plate subducts beneath the overriding Burma plate (Fig. 1). The complex tectonics of the region involves several plates: Australia, Sunda, Eurasia, India and Burma. This earthquake was probably triggered by stress variations caused by the December 26 2004 (Mw=9.3) Sumatra mega-earthquake.

The aftershock activity 72 hour after the main chock (36 events with M>4.5) suggests a length and width of the rupture of about 400 km and 125 km, respectively (Fig. 1).

This event has generated a moderate tsunami with recorded waves estimated up to 4-5 meters and amplitude up to 2m.

In this preliminary work, the rupture process of the 2005 Sumatra (M_w=8.6) earthquake was determined.

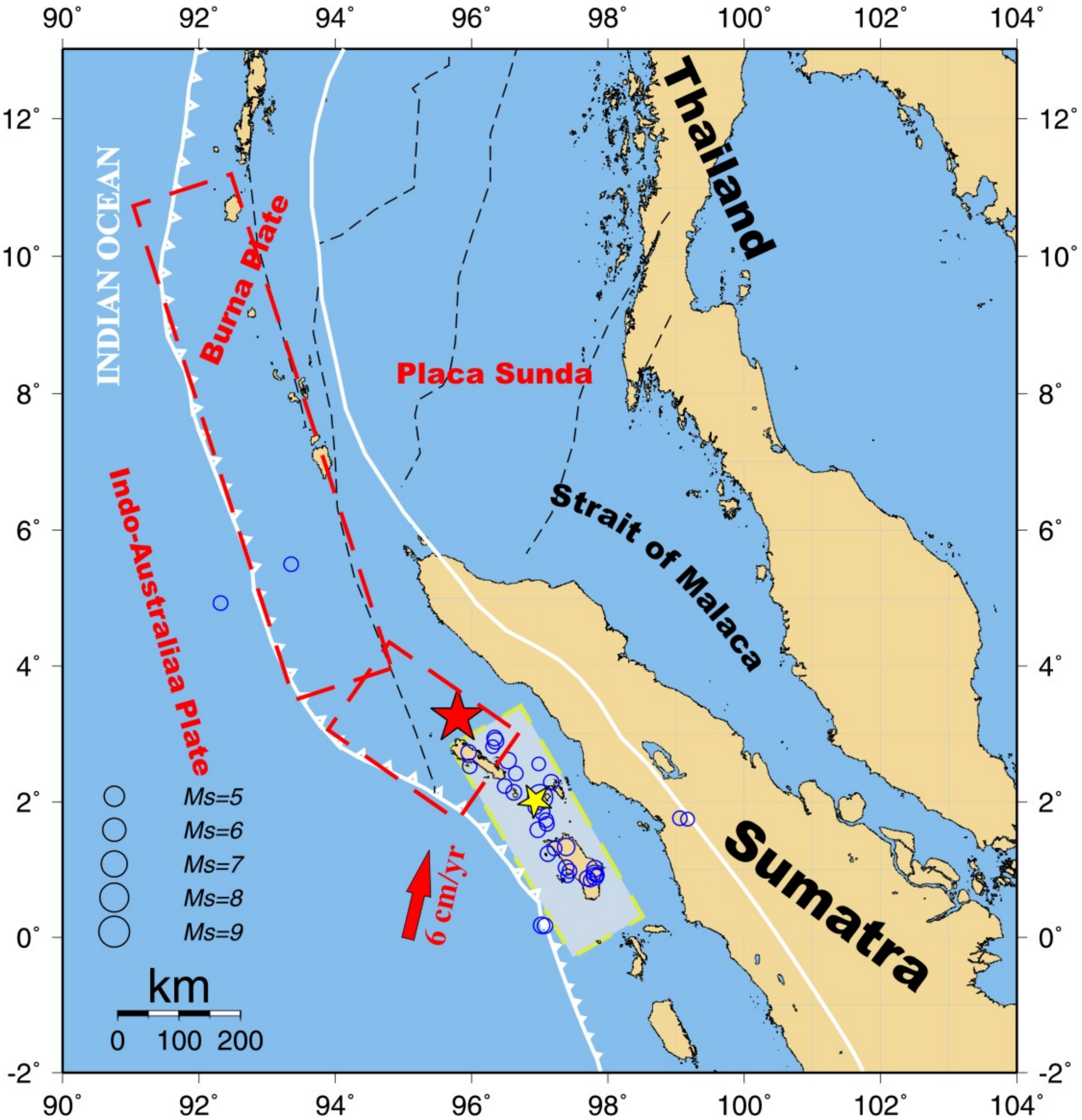

Fig. 1 - Map of the epicentre region with the subduction zone. The yellow star indicates the epicentre of this event and the red star the epicentre of the December 26th 2004 one. The dashed yellow rectangle represent the extent of the fault plane used in the slip inversion of this study (Fig. 3C). Open circles are the large aftershocks (M>4.5; epicentres compiled from USGS). Main tectonic background of the area is plotted. The red arrow indicate direction of the movement between adjacent plates: the India plate moves toward the northeast at a rate of about 6 cm/year relative to the Burma plate.

Data Processing

The source process study has been performed using 23 teleseismic P waveforms data recorded at IRIS-DMC stations (Fig. 2) retrieved via the Internet. Stations were selected from the standpoint of good azimuthal coverage and correspond to seismograms recorded at distances within the range (30^o<D<90^o) in order to avoid problems with the upper mantle wave triplications, and diffractions by the mantle-core boundary.

Directivity

Both rupture direction and velocity were calculated from common pulse durations observed in 23 P waveforms, using Caldeira (2004) DIRDOP computational code (DIRectivity DOPpler effect). Fig. 2 shows azimuth and the rupture velocity obtained for a time interval between 25-60 sec. As we can see the rupture direction points clearly to SSW (N153^{o}E) direction with a velocity of (v_r=3.3±0.6 km/s).

Inversion

The modified Kikuchi and Kanamori (2003) method, based on a finite fault inverse algorithm, has been used to carry out the slip distribution. In agreement with aftershock distribution, CMT and orientation of the subduction a rectangular section with 400 km length and 125 km wide was chosen as the plane of rupture. The length and wide of this plane was oriented along strike and dip directions with 150^o and 10^o, respectively. The rupture velocity was fixed on 3.3 km/s according to the DIRDOP result. A 1D velocity model with 3 layers and 2.5 km water in hypocenter region was used; a global JB model was used for the propagation. On the total 13 teleseismic broad-band P wave data was selected and analysed and a total seismic window of 150 sec length was inverted.

Preliminary Results

The solution obtained shows thrust motion on plane striking on NNW-SSE direction and horizontal pressure axes in NNE-SSW direction. Moreover it is shown that the rupture spreads mainly to the South with slip average vector normal to the strike rupture (Fig. 3 and 4). The spatio-temporal fault slip distribution (Fig. 4) shows the following scenario: in the first stage the rupture nucleated at the hypocenter during the first 15 s as a circular crack; after that, the rupture propagates mostly unilaterally to the SSE direction along 300km, breaking mainly two asperities. The largest one is centred about 90 km and the other one at 175 km from the epicentre. The maximum slip reaches 15 m in the largest asperity and the total scalar seismic moment released is *Mo* = 0.82 x10^{22} Nm (*Mw = 8.6*), which is in agreement with values given by the EMSC and USGS. The total source duration and rupture length are estimated to be above 110 sec and 425 km, respectively.

Conclusion

In this preliminary work 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 scheme of the rupture plan model according with the slip inversion determined in this study is presented in the figure 5.

The rupture process can be explained by 2 asperities distributed at 90 and 175 km SSE from the epicentre where most of the seismic energy was released. Geographically these two asperities correspond to the most affected area (Nias island; Imax=IX according USGS report) The total scalar seismic moment is 0.82 x10^{22} Nm (M_w=8.6) whereas the maximum slip is about 15 m (Fig. 4).

References

- Borges J.F., B. Caldeira and M. Bezzeghoud, 2004. Source Rupture Process of the Great Sumatra, Indonesia Earthquake (M_w=8.9) of 26 December 2004. *Preliminary Results.* http://www.cge.uevora.pt/get_file.php?id=274

- Caldeira B. 2005. *Caracterização espaço-temporal da fonte sísmica. Processo de ruptura e directividade*. PhD thesis, University of Évora, Évora, Portugal, 282 p.

- Kikuchi, M. and H. Kanamori, 2003, *Note on Teleseismic Body-Wave Inversion Program*, http://www.eri.u-tokyo.ac.jp/

Related Links

- EMSC-CSEM: www.emsc-csem.org/
- IRIS: http:/www.iris.edu/
- http://iisee.kenken.go.jp
- US Geological Survey
- International Tsunami Information Center

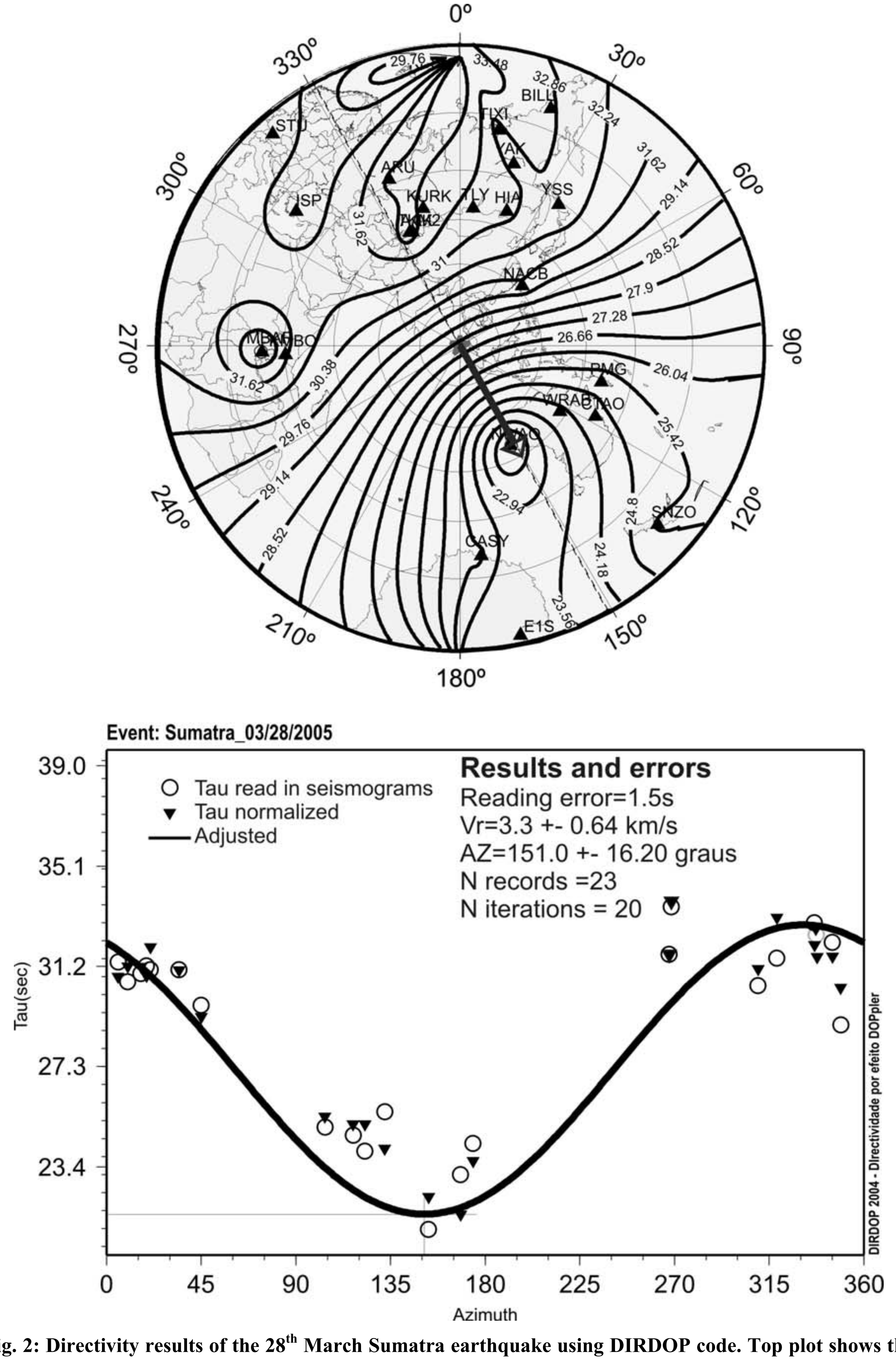

Fig. 2: Directivity results of the 28th March Sumatra earthquake using DIRDOP code. Top plot shows the spatial distribution (isolines) of common time pulses measured in seismograms of the market stations (▲). The blue arrow represents the obtained rupture direction. Lower diagram shows phases-delay versus azimuth of receiver points and the directivity results. Open circles and solid inverted triangles represent measured and normalized time delays, respectively. The solid line represents the predicted time delay obtained by the inversion of the directivity model. Highest correlation coefficient occurred to rupture velocity 3.3km/s and at an azimuth of 151°.

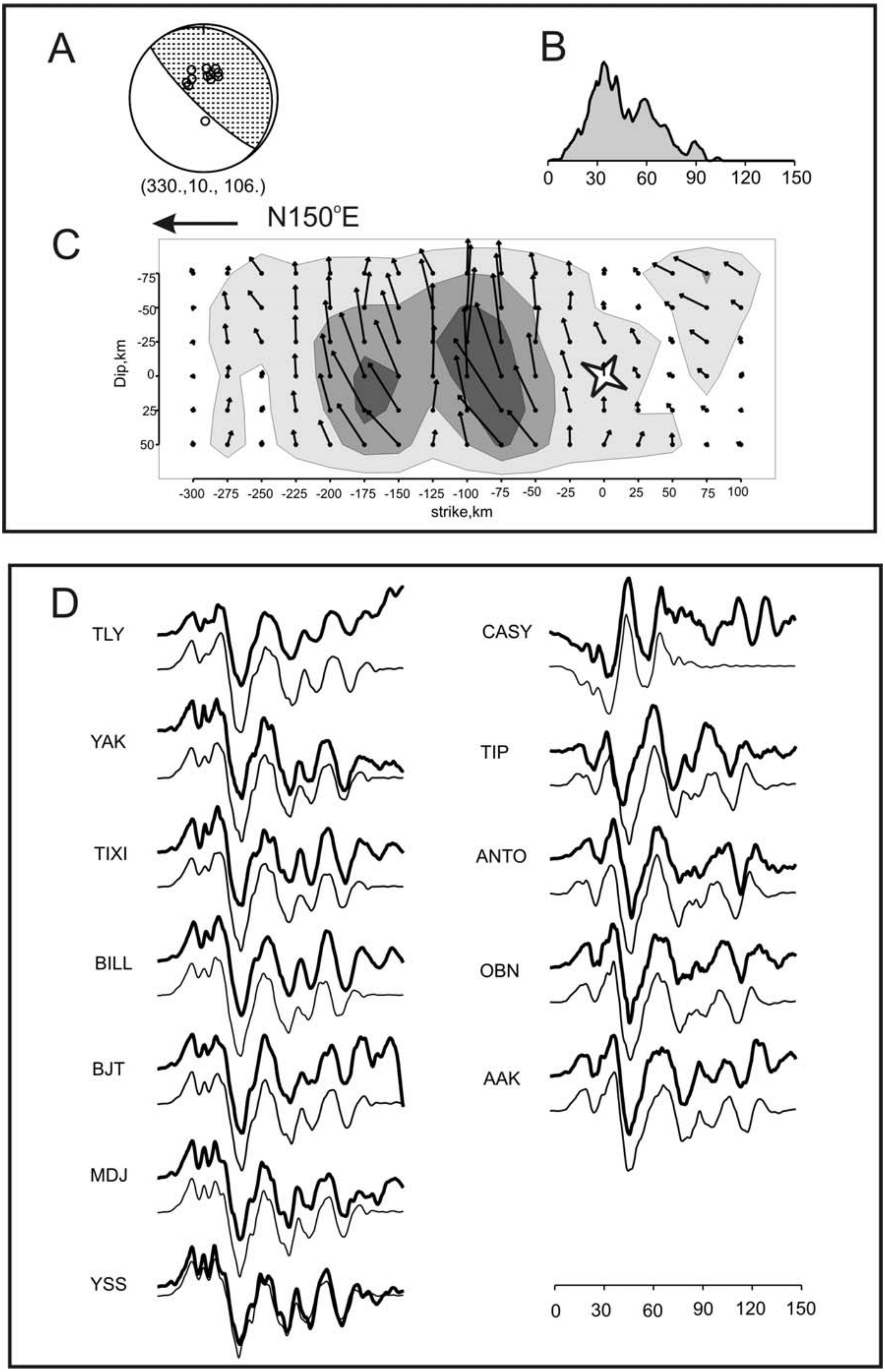

Fig. 3 – Slip distribution model obtained from teleseismic body wave inversion: A) Focal mechanism; B) Source time function; C) Slip distribution along the fault plane; D) P-waveform comparison, solid line represents the observed seismogram and thin line the synthetic seismogram. Star indicates the hypocenter.

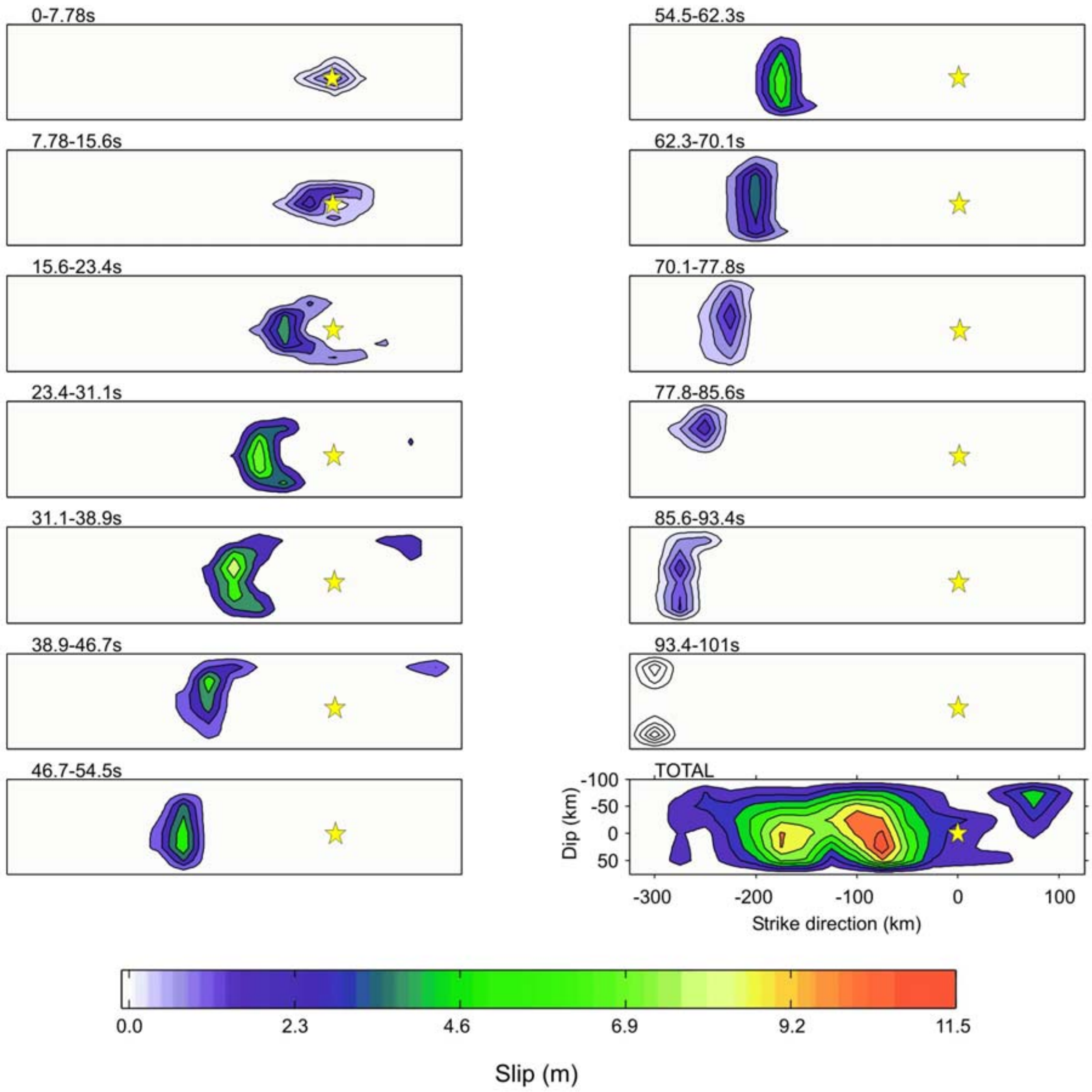

Fig. 4 - Time evolution of the rupture obtained at intervals of 7.8 sec for our preferred model. See text for details (preliminary results).

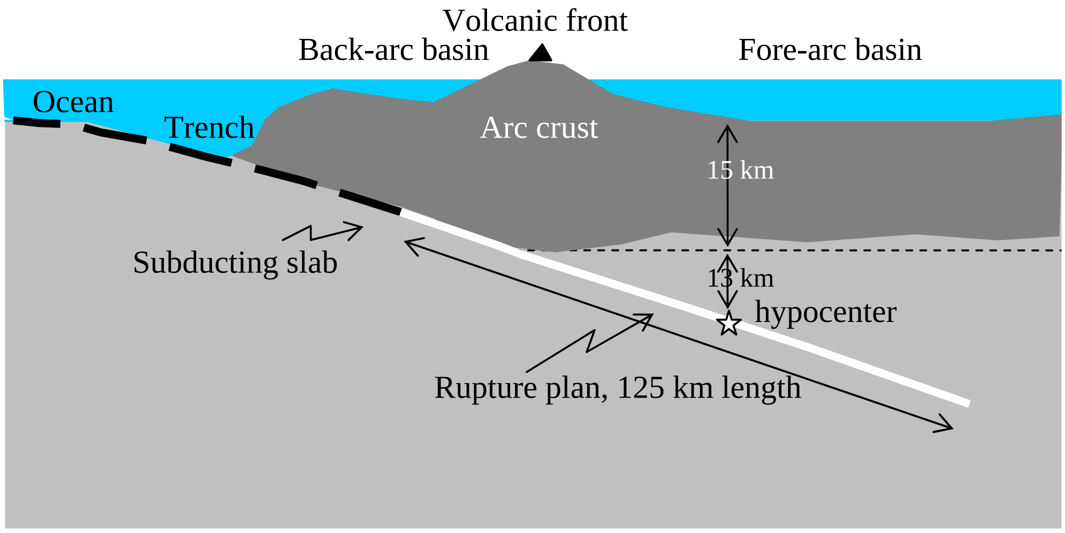

Fig. 5 – Scheme of the rupture plan according with the slip inversion determined in this study (see Figs. 3 and 4).