Seismic source parameters of local micro earthquake in Goiás State Brazil by waveform inversion

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Abstract

The waveform inversion of local seismic events with epicenter in Mara Rosa, in the Goiás State of Brazil was taken to obtain the moment tensor using the package ISOLA. The events are from an aftershock activity of 5.0 m_b main shock and MMI VI in the range of 1.2 to 2.0 mD. The data was band-pass filtered in the frequency of 1.0 - 1.45 Hz. For preliminary results, satisfactory consistency was achieved when we compare the results reached in this work with those obtained by the polarity method.

Introduction

On October 8th, 2010 an earthquake of magnitude 5.0 m_b and intensity VI (MM) startled residents in the northern region of the Goiás state, having also been felt in Brasília and Goiânia which are located about 250 km and 300 km away, respectively. The aftershock activity of this event was studied with a local seismographic network of eight stations that detected more than 600 events of which 110 were located by five or more stations operating simultaneously (Barros et al. 2011). The network operated between October 2010 and June 2011. We selected the strongest events detected by eight stations simultaneously to determine the composite focal mechanism (Snoke, 1984). The nodal plane solution of a reverse faulting with strike of 214°, dip of 50° and a rake of 74° was obtained. The strikes and plunges of the axes of compression (P) and distension (T) are, respectively, 315° and 58°, 3° and 78°. The aftershock epicenter distribution is in agreement with the fault orientation and both are in agreement with the Transbrasiliano Lineament (TL) (Barros et al. 2012).

In this work we present the preliminary results obtained with micro earthquakes waveforms inversion to obtain the moment tensor using the ISOLA package (Sokos and Zahradinik, 2008; Zahradinik et al. 2005).

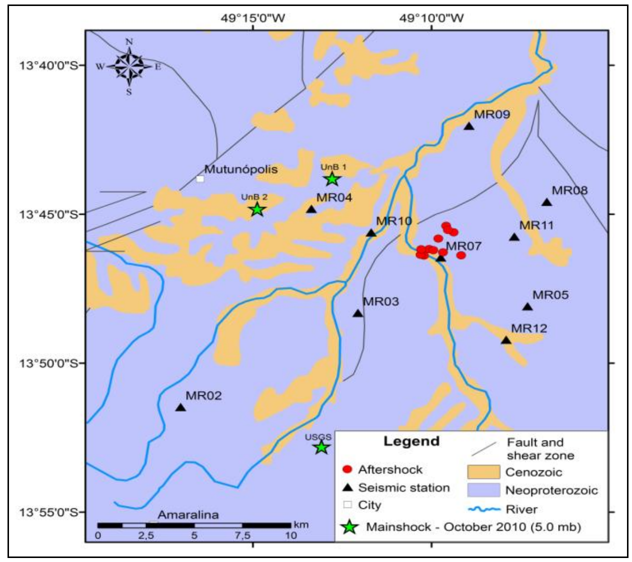

Figura 1. *- Geological map of study area. Stars denote the mainshock epicenters determined by USGS and UnB, using the velocity models of Kwitko and Assumpção, 1990 (UnB1) and the NewBR model by Assumpção et. al. (2010) (UnB2). Red circles denote the best event epicenters (11) detected simultaneously by six or more local stations (black triangles)*

Data

We selected for analysis 11 events detected by six or more stations and with a magnitude between 1.2 and 2.0 (Table 1). The locations were identified with the program Hypocenter (Lienert, 1994) in SEISAN (Havskov & Ottemöller, 2009) using a two layer 1-D velocity model (Table 2). The RMS average of the travel time residuals are in the range of 30 ms and the depths are between 800 m and 1500 m. Data were acquired with GURALP Manufacturer, Model 6TD (30 s - 50 Hz) and DM24/CMG-40T1 (1 - 100 Hz) instruments in a sampled rate of 100 sps. Figure 2 shows the record of April 28th, 2011 event at four stations of the Mara Rosa network (event No. 11 in Table 1).

Table 1
Events selected for this study

Event Number	Date (yyyy/mm/dd)	Origin Time (UTC)	Coordinate (DDMM)	Depth/Magnitude*	RMS
1	2011/03/30	21:40:15.30	-13°46.54 -49°8.88	0.8/1.4	0.03
2	2011/04/03	09:19:49.19	-13°46.11 -49°8.87	1.2/1.3	0.03
3	2011/04/03	15:51:08.60	-13°46.00 -49°9.51	1.4/1.3	0.04
4	2011/04/04	10:19:46.61	-13°45.87 -49°9.54	1.3/1.2	0.04
5	2011/04/09	19:52:13.16	-13°45.96 -49°9.21	1.7/1.5	0.03
6	2011/04/15	03:02:19.25	-13°46.46 -49°8.64	0.6/1.3	0.03
7	2011/04/15	03:05:35.15	-13°46.46 -49°8.64	0.6/1.2	0.03
8	2011/04/16	09:01:07.67	-13°46.29 -49°8.77	1.0/1.2	0.03
9	2011/04/18	06:42:20.83	-13°46.34 -49°10.17	1.3/1.4	0.02
10	2011/04/18	12:45:13.62	-13°46.45 -49°10.14	1.2/2.0	0.02
11	2011/04/28	13:16:36.23	-13°46.14 -49 °9.99	0.9/1.4	0.02

Depth is in km and magnitude is coda duration.

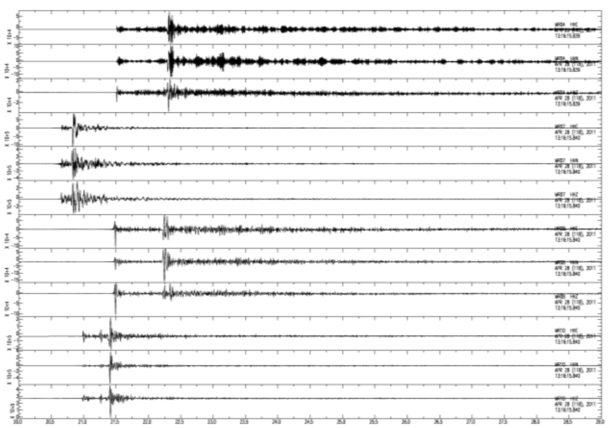

Figure 2. *- Seismogram of April 28th, 2011 event at stations MR04, MR07, MR08 and MR10, whose waveforms were inverted for tensor seismic moment.*

Methodology

The data recorded in GCF format, were converted to SAC, imported into the ISOLA format, corrected to remove the instrumental response and integrated to convert velocity into displacement. The inversion was performed using the ISOLA code (Zahradnik et al, 2005; Sokos and Zahradinik 2008), Matlab, and an iterative method similar to Kikuchi Kanamori (1991). Green's functions were calculated using the 1-D model of Table 2, the NewBR model of Assumpção et al. (2010) and the method of discrete wave number of Bouchon (1981). The events´ waveform deconvolution was calculated using the NewBR model and Table 1 data.

As the location residuals of the events were on the order of 30 ms, i.e., the locations were accurate; the calculations of Green's functions were made with the source position varying only in the vertical, starting at a depth of 1 km up to 5.5 km, in steps of 500 meters.

Table 2
1-D crustal velocity model

Layer	Depth (km)	Vp (km/s)	Vs (km/s)	Qp	Qp
1	0.0	6.0	3.53	300	150
2	15	6.0	3.53	300	150
3	15	7.0	4.10	300	150
4	40	7.0	4.10	1000	500

Results

Using low magnitude local events (1.0 - 2.0 m_D) with epicenters' distances ranging from 1 km to 8 km waveform, inversion was done to obtain the moment tensor. Here we present the preliminary results of the inversion, using the event number 11 of Table 1. Figure 3 shows the observed and synthetic seismograms for this event in the stations MR7, M10, MR4 and MR8. The station M11, which appears in the Figure 3, was not used. As one can see there is reasonable correlation between observed and synthetic seismograms.

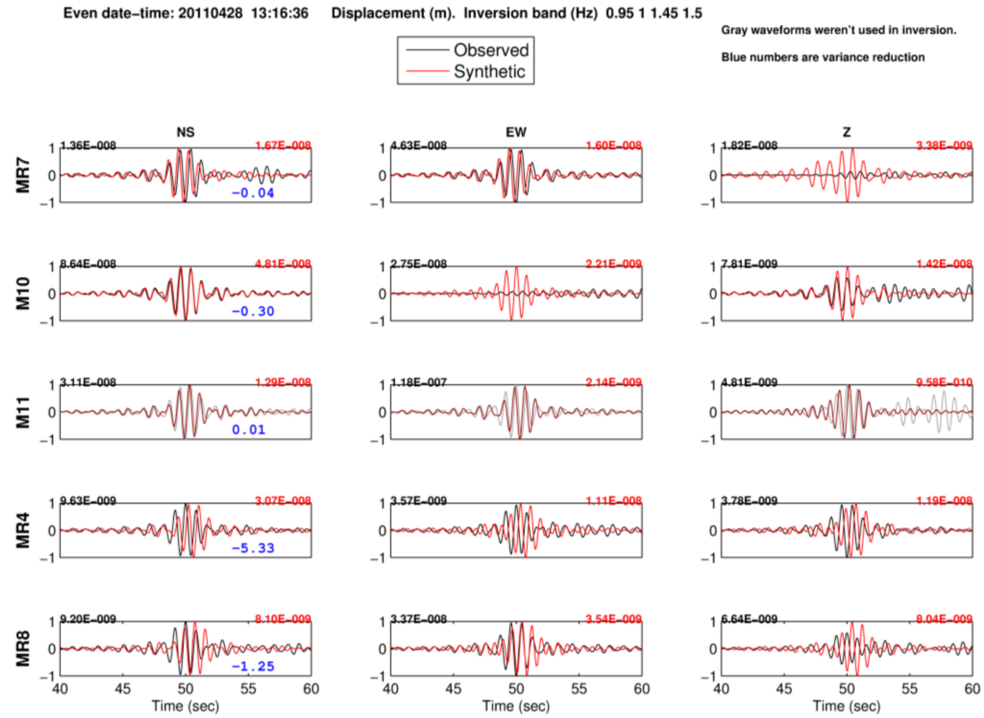

Figure 3. *- Waveform of event number 11 of Table 1 in stations MR7, M10, MR11, MR8 and MR4. Synthetic signal are in red and observed signals are in black. The signals from the station M11 were not used in the inversion process.*

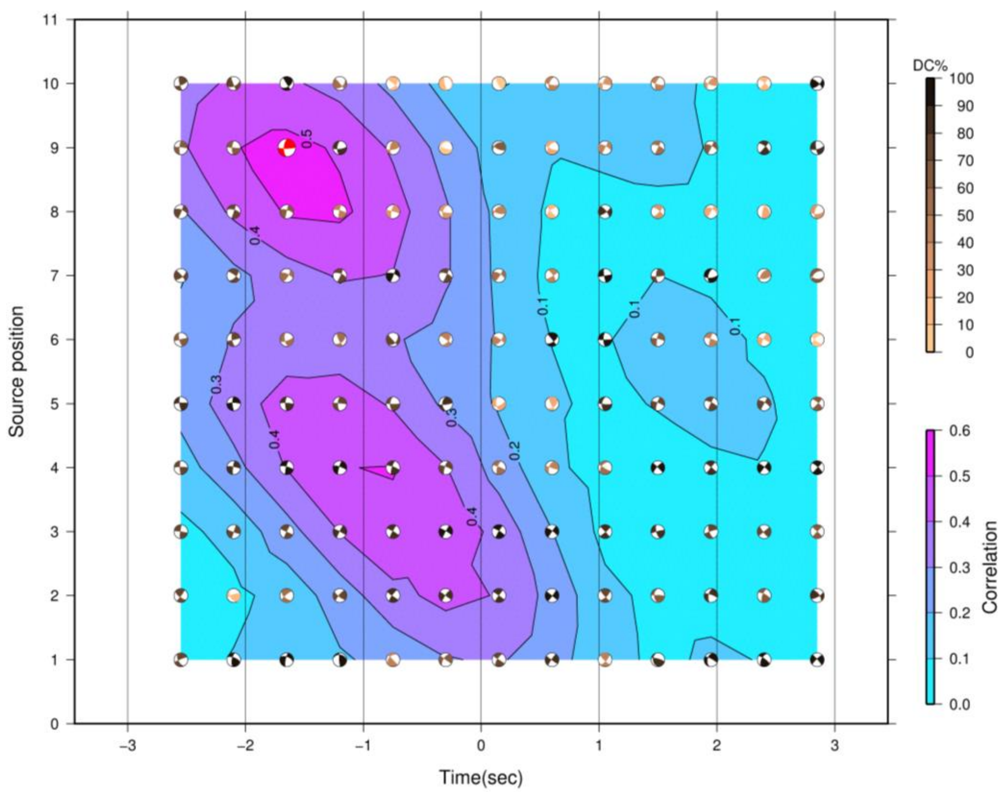

Figure 4. *- Focal mechanism solutions for a point source placed on the vertical axis, at the coordinates 13º46.14S and 49º09.99W (event epicenter), at a depth of 1.0 km and origin time of 13h16m36.23s. The best result was obtained for the* ***Nº****9 source, which corresponds to a depth of 5.0 km and time origin corrected in less than one second.*

In figure 4, which shows the source position versus drift in origin time, two areas with similar correlation were obtained: one at a depth of 2.5 km and another at a depth of 5.0 km (Fig. 5). However, the parameters of nodal planes are different. The solution adopted in this study, with a correlation of 0:53, as shown in Figure 5, is the one that best approximates the results obtained by Barros et al. (2012).

Figure 6 shows all source parameters obtained by the waveforms inversion process of the event of April 28th, 2011, at 13h16m, with magnitude of 1.4 and depth of 0.9 km. In the waveforms inversion of this event a magnitude of 1.6 Mw was obtained with origin time 13h16m36.23s minus 1.65 seconds. The centroid moment tensor is located at the epicenter, since the solutions only investigated vertically variation, given that the locations have good horizontal precision. The source obtained a DC percentage of 80.8.

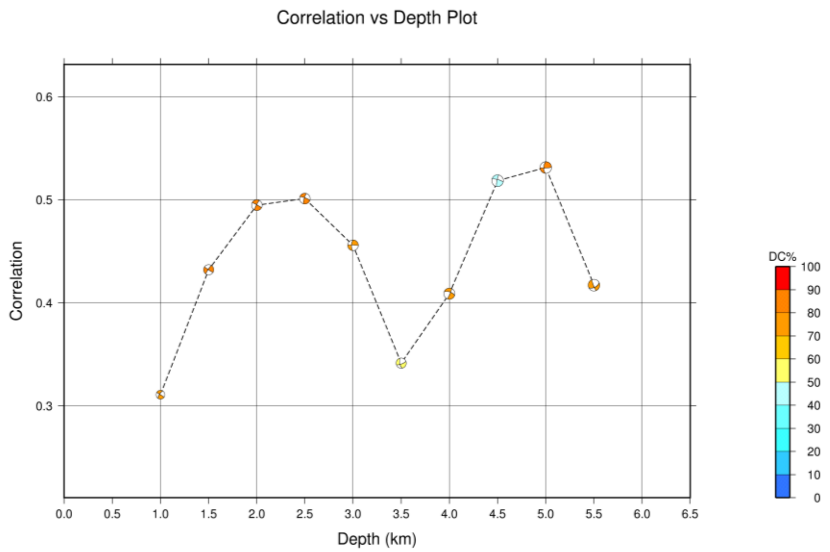

Figure 5. *- Correlation between the focal mechanism solutions obtained and the source depths. The highest correlation, 0:53, was obtained for the source positioned at 5 km depth. The colour of the beach ball reflects the percentage of double-couple (DC%), according to the colour gradient on the left side of the Figure.*

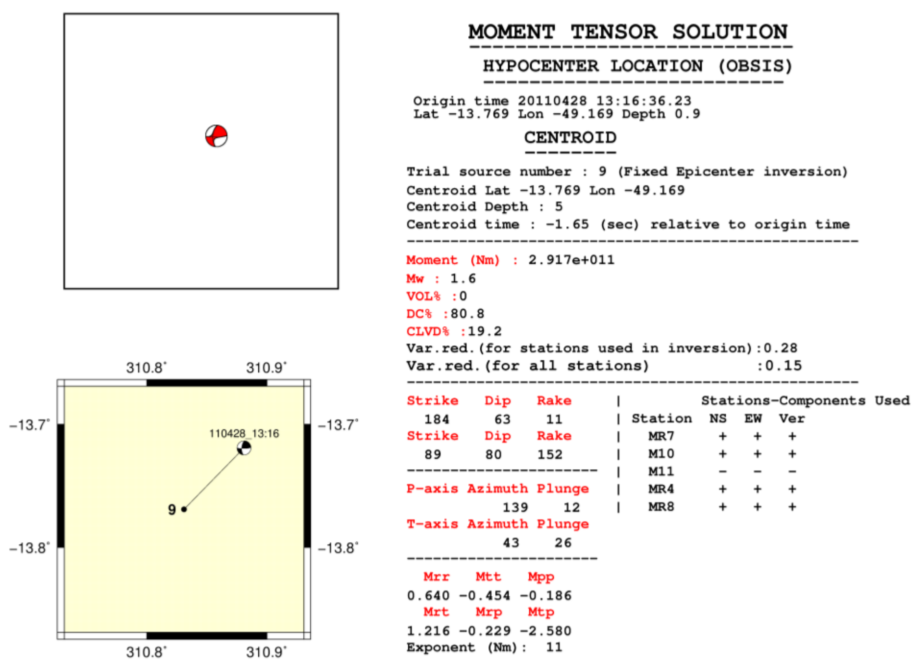

Figure 6. *– All results of the waveforms inversion for the 04/28/2011 event (event 11 in Table 1) at stations MR7, M10, MR4 and MR8.*

Discussion

The thin black line in Figure 7 shows the focal mechanisms obtained by the methods of polarities, whereas the thick red lines show the waveform inversion. As Figure 7 shows, the two faults obtained by both techniques have the same nature, i.e, both have components of inverse faulting. However, the faults parameters differ. For example, comparing the parameters strike, dip and rake obtained by the method of polarity/waveform inversion method we get: strike of 214/184, dip 50/63 and rake 74/11. We believe that these results are reasonable for a preliminary study, although we observed some instability in the solutions obtained for all analyzed events. This instability can be seen in Figure 4, where the solutions vary greatly in positions of neighboring sources. Also the values of correlation and variance reduction are low.

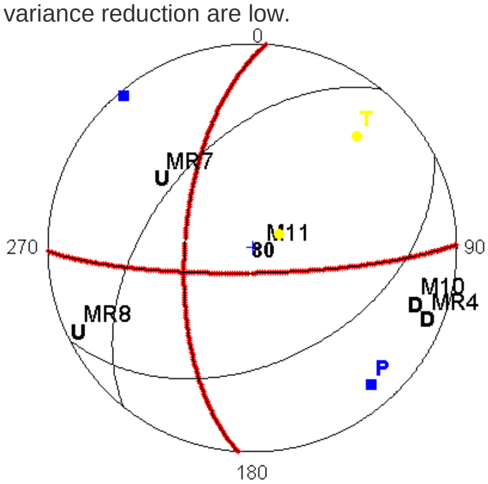

Figure 7. *- Diagram of focal mechanism obtained by P-wave polarities (thin black line) and waveform inversion (thick red line). The letters U and D mean moving up and down, respectively.*

Conclusions

Despite the instability in the results, we conclude that the method implemented in the ISOLA package proved efficient in getting the source parameters by the waveform inversion of band-pass-filtered signals. This conclusion is based on comparing the present results with those obtained by Barros et al. (2012). However, further study is needed, which will be conducted in the future to better understand the case and bring stability to the results.

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