SEISMIC SOURCE PARAMETERS OF LOCAL MICRO EARTHQUAKE IN GOIAS STATE BRAZIL BY WAVEFORM INVERSION

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Observatório Sismológico

"Training course in full waveform inversion for moment tensors and multiple source models (ISOLA code)"

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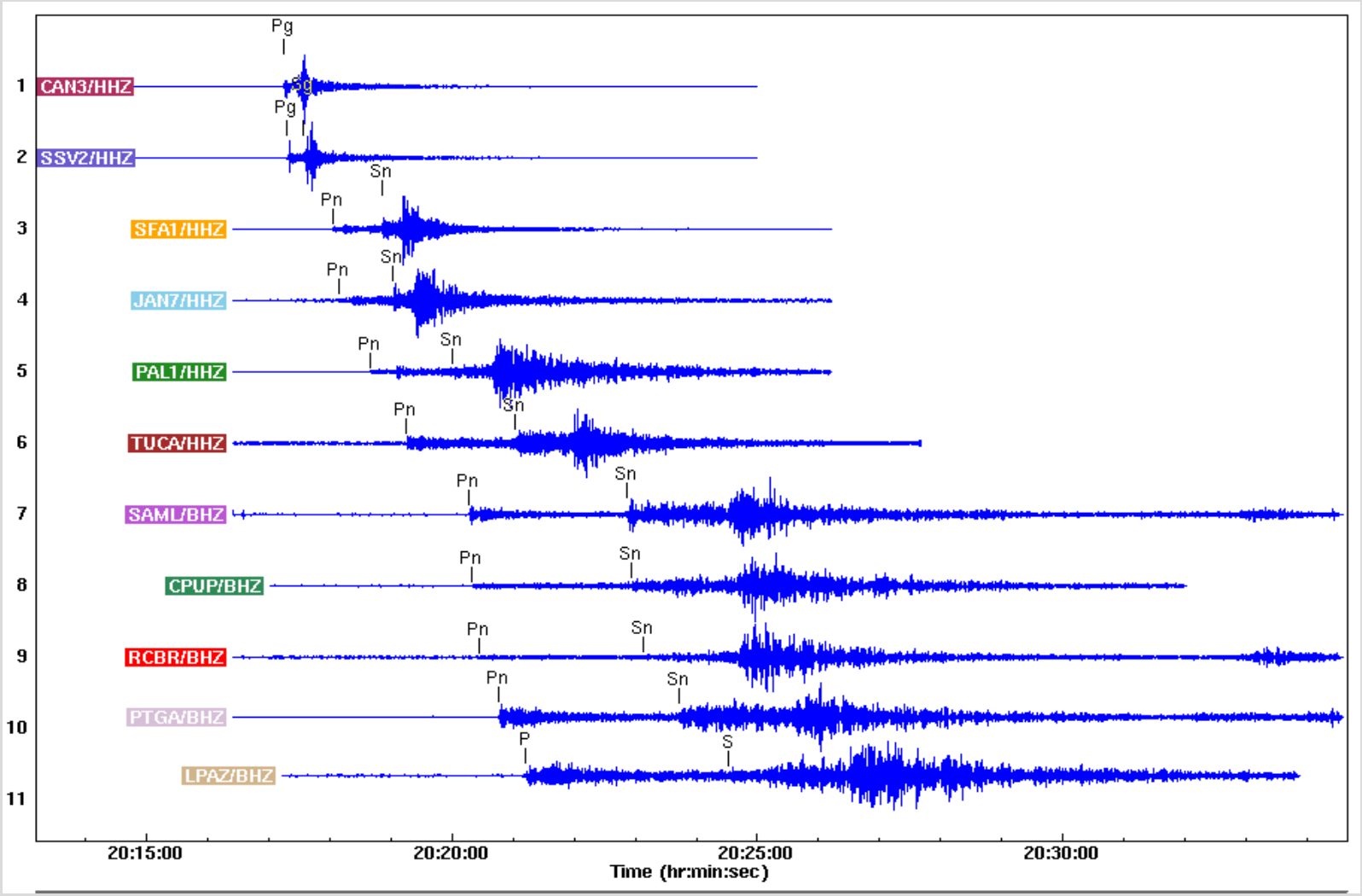
IASPEI

OVSICORI-UNA

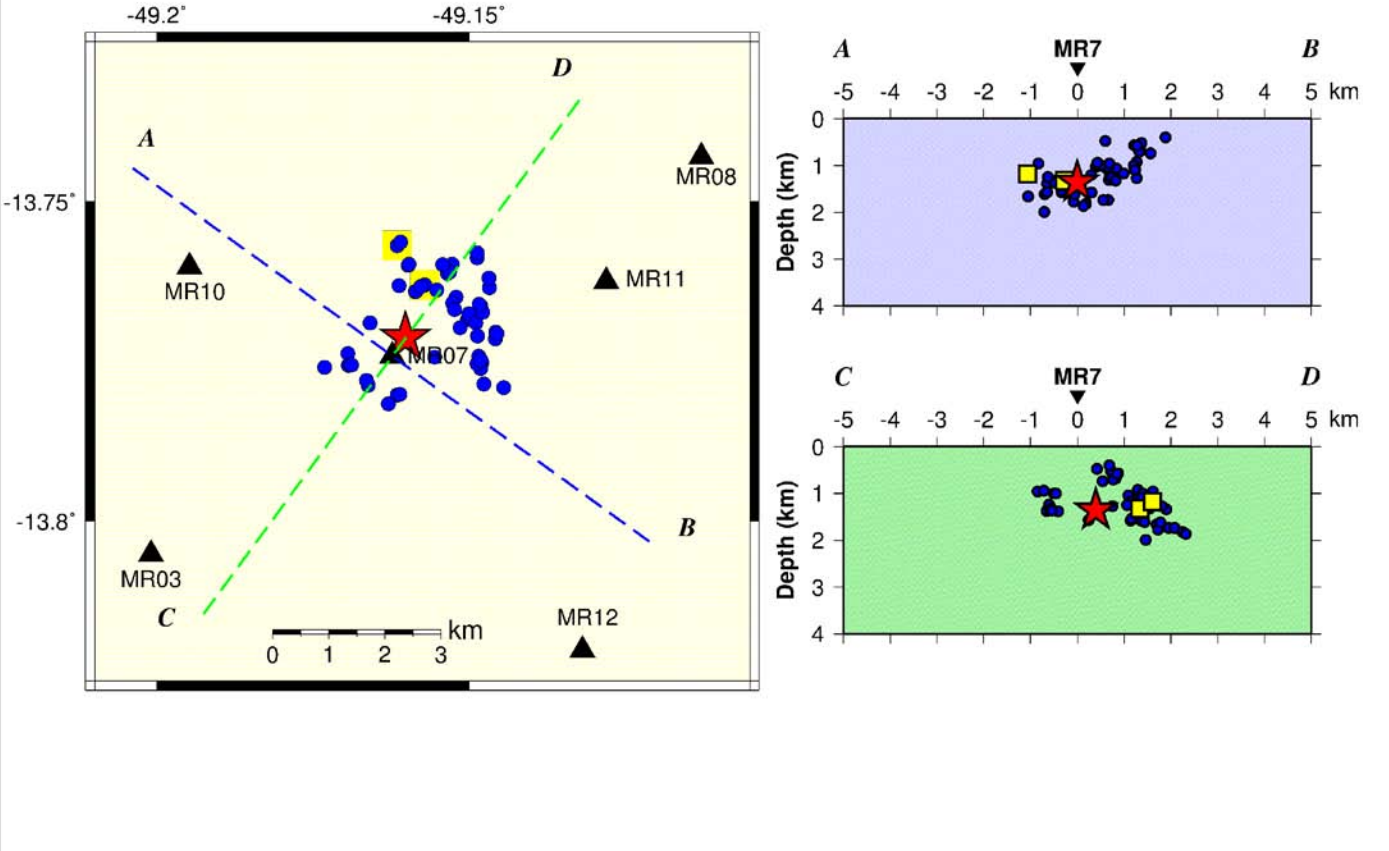
ΠΑΝΕΠΙΣΤΗΜΙΟ ΠΑΤΡΩΝ
UNIVERSITY OF PATRAS

Brasília December 2 - 11, 2013

Central Brazil earthquake, 08/10/2010, magnitude 5.0 mb. Seismograms from local stations up to 2000 km.

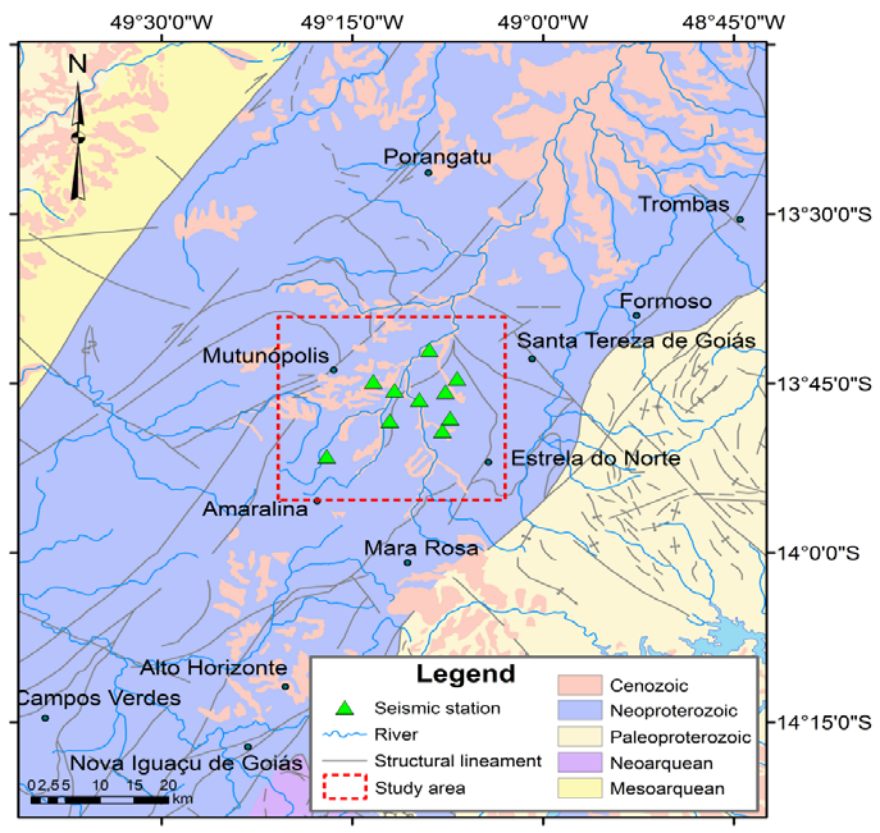


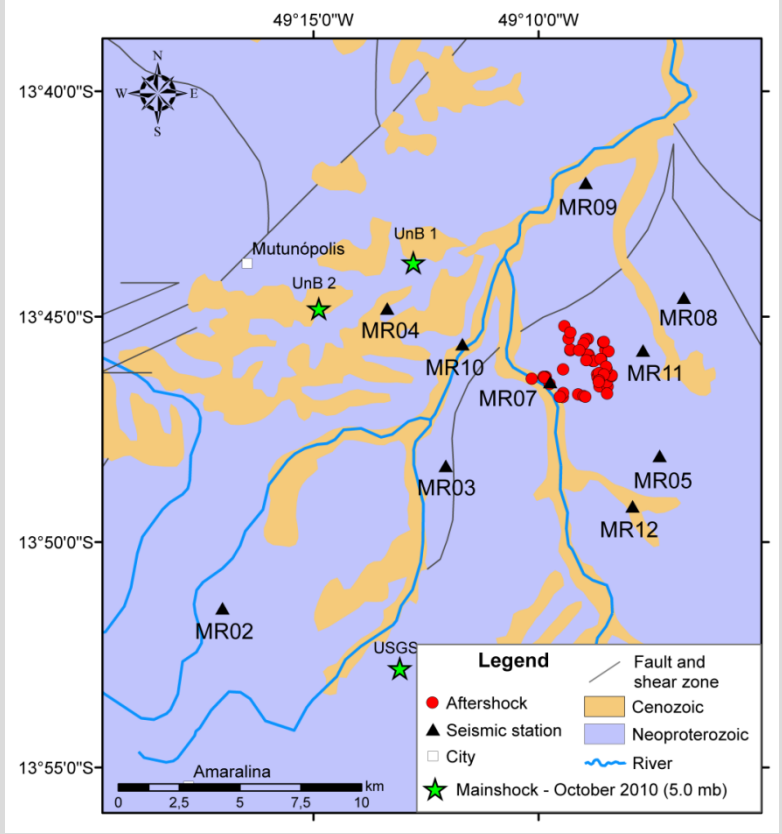
Aftershock location - 62 events with hypoDD



- Red star denotes mainshock location
- Yellow squares denote the reference events for the GT5 calculation (Barros et al., 2013)

Local seismic network

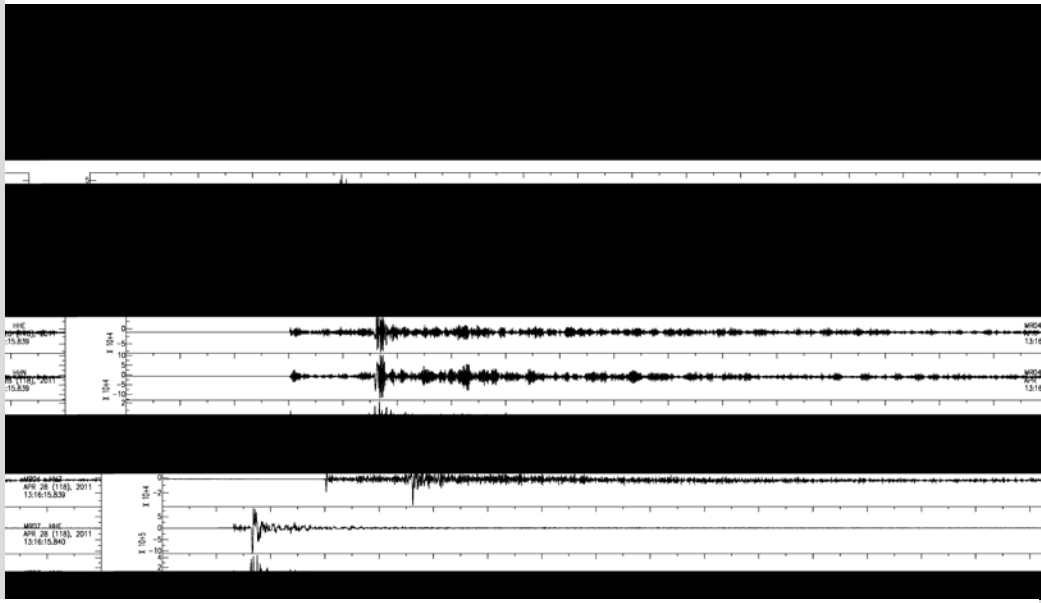




In 2010 Nov a local seismic network with 10 stations was deployed by the University of Brasilia. The hatched box indicates the study area.

The epicenter of the main event indicated by the stars. Location done by the USGS and UnB (1, 2) with a regional network. The red circles indicate the aftershocks located with the use of a local network.

Ev11- April 28th, 2011 MR04, MR07, MR08, MR10



Data selection criteria:

- **Micro-events with magnitudes below 2 M_D**
- **Detected, with quality, by more than 4 stations.**

Table 1

Events selected for this study

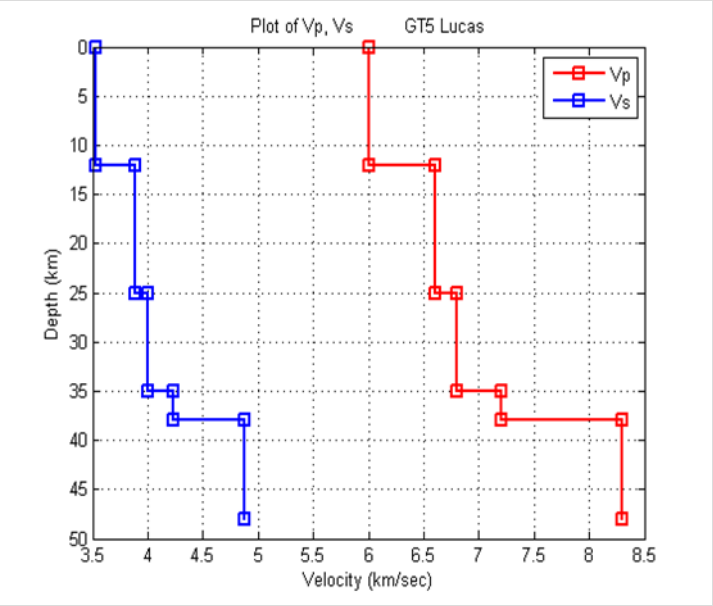
Event Number	Date (yyyy/mm/dd)	Origin Time (UTC)	Coordinate (DDMM)	Depth/Magnitude*	RMS_S
1	2011/03/30	21:40:15.30	-13°46.54 -49°8.88	0.8/1.4	0.03
2	2011/04/03	09:19:49.19	-13°46.11 -49°8.87	1.2/1.3	0.03
3	2011/04/03	15:51:08.60	-13°46.00 -49°9.51	1.4/1.3	0.04
4	2011/04/04	10:19:46.61	-13°45.87 -49°9.54	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.*

Green function

- Green function calculated up to 2.0 Hz.

- One dimensional (1-D) Crustal velocity model (Lucas et al., 2013).



Crustal model GT5 Lucas (vp/vs=1.7)
number of layers
5
Parameters of the layers

depth top(km)	Vp(km/s)	Vs(km/s)	Rho(g/cm**3)	Qp	Qs
0.0	6.00	3.529	2.900	100	50
12.0	6.60	3.882	3.020	100	50
25.0	6.80	4.000	3.060	100	50
35.0	7.20	4.235	3.140	300	150
38.0	8.30	4.882	3.360	300	150

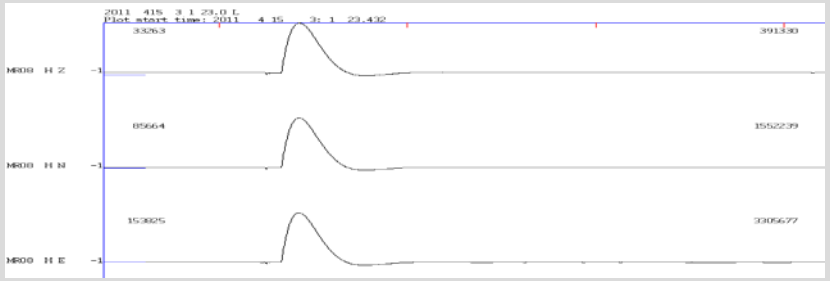
****

- Alternative model: Half-Space Vp=6.0km/s and vp/vs=1.70.

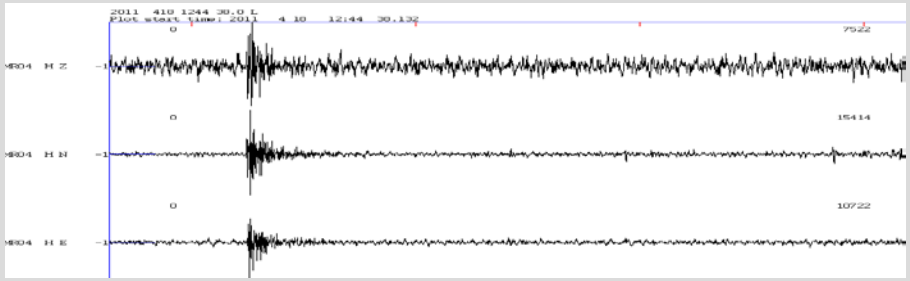
Quality control parameters:

- Variance reduction (VR) – Assess solution quality by measuring the fit between seismograms observed and synthetic. Limitations:
  - i) biased by statios with large amplitudes;
  - ii) high values when few stations are used.
- Condition Number (CN) – Measures the reliability (stability) of the inversion (square root of ratio of maximum to minimum eigenvalues of the least-square matrix).
  - Small eigenvalues indicate the matrix is close to singularity(ill conditioned).
  - Value is relative to the event-station configuration, velocity model and frequency band.
- DC% - In some cases low DC% can indicate problematic inversion results.
- SNR – The higher the better.
- Polarity check – quality check and to resolve the ambiguity of P, T axes reversion (high frequency and narrow band inversion side effects).
- Aftershock location and agreement with local stress.

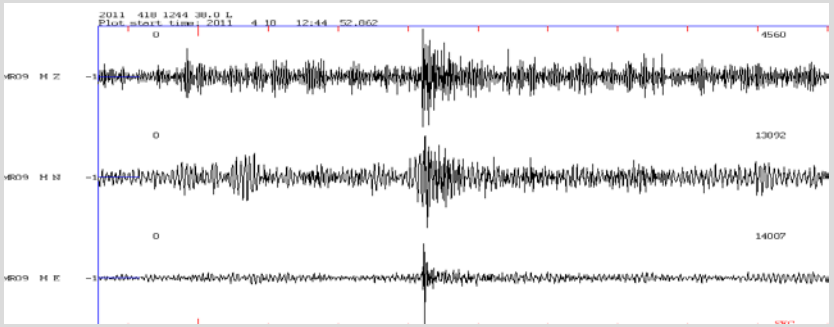
Data quality check



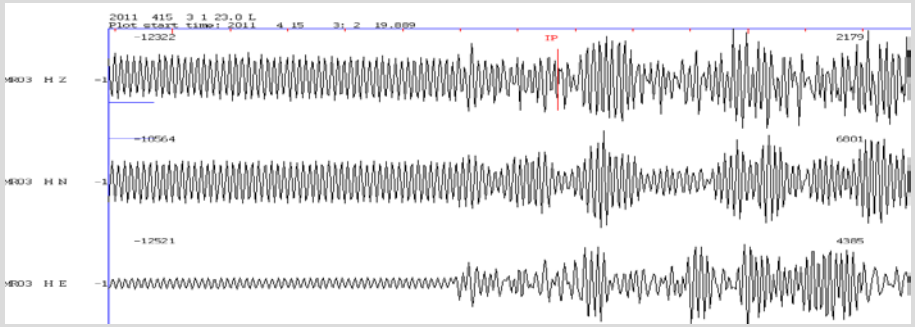
instrumental disturbance (all components)



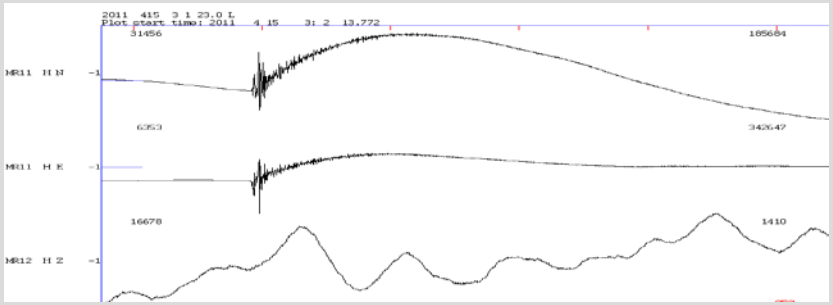
High frequency noise (component Z)



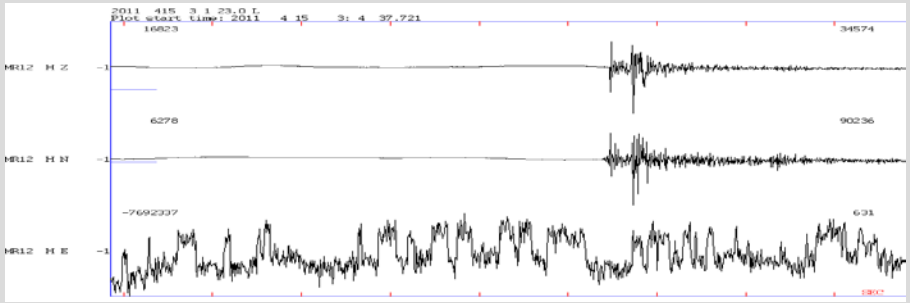
Cultural noise (all components)



Monochromatic noise (all components)

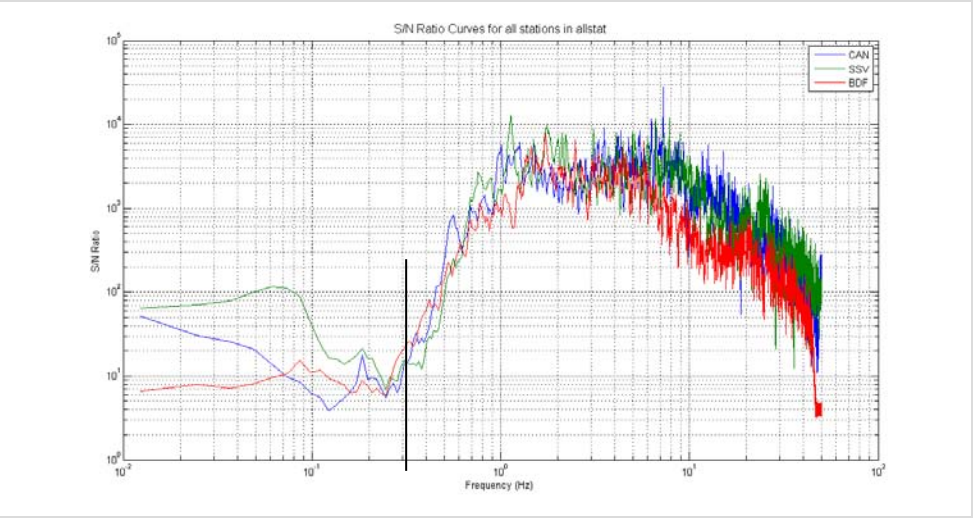


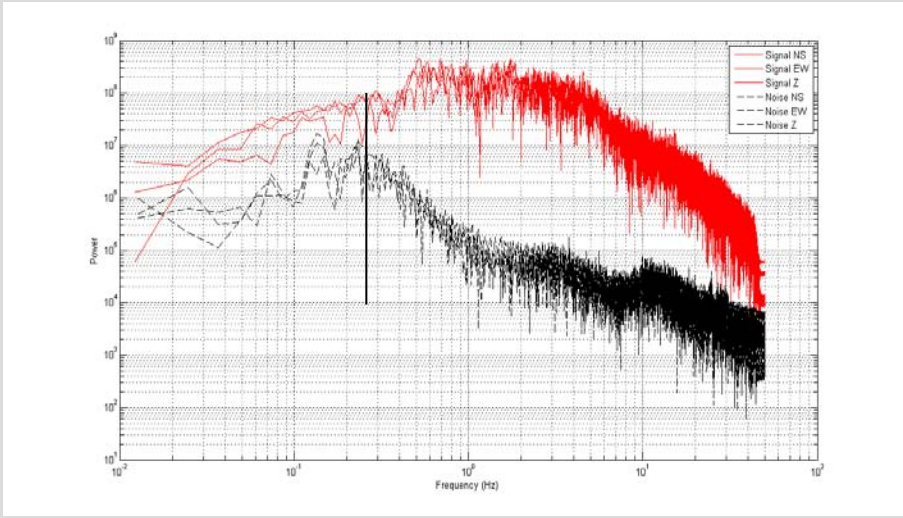
instrumental disturbance 'mouse' (components N and E)

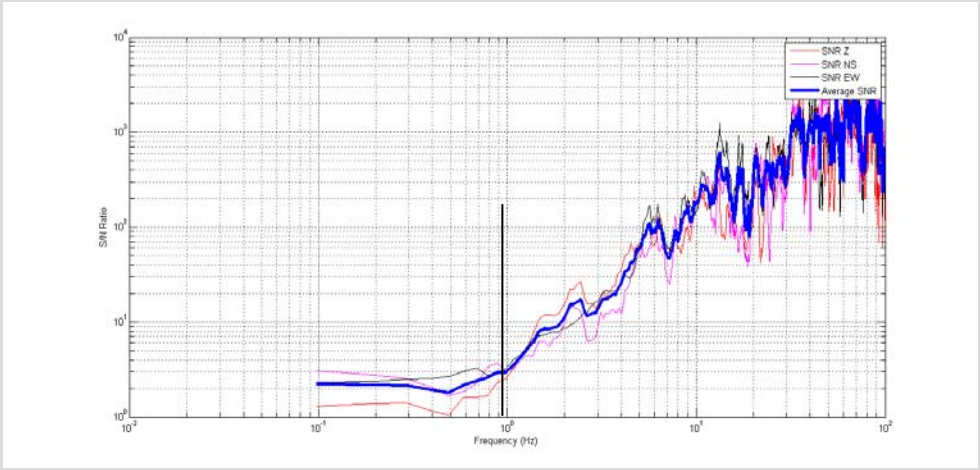


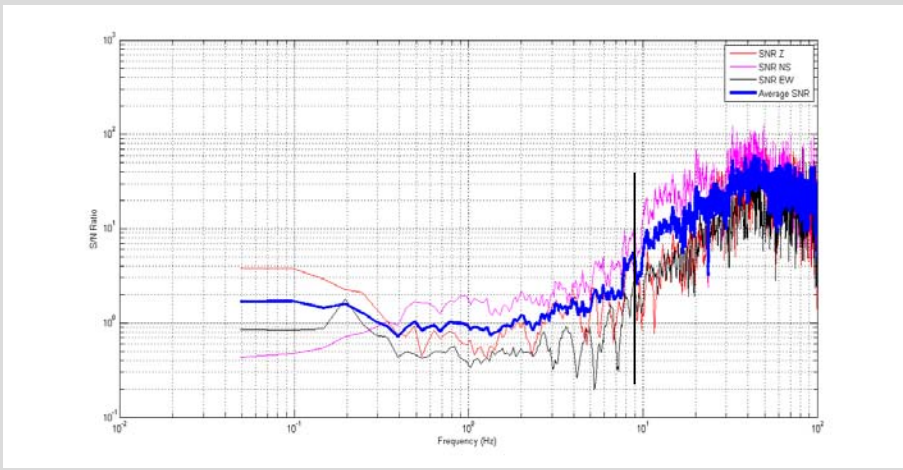
instrumental disturbance (component E)

Data quality check (SNR)



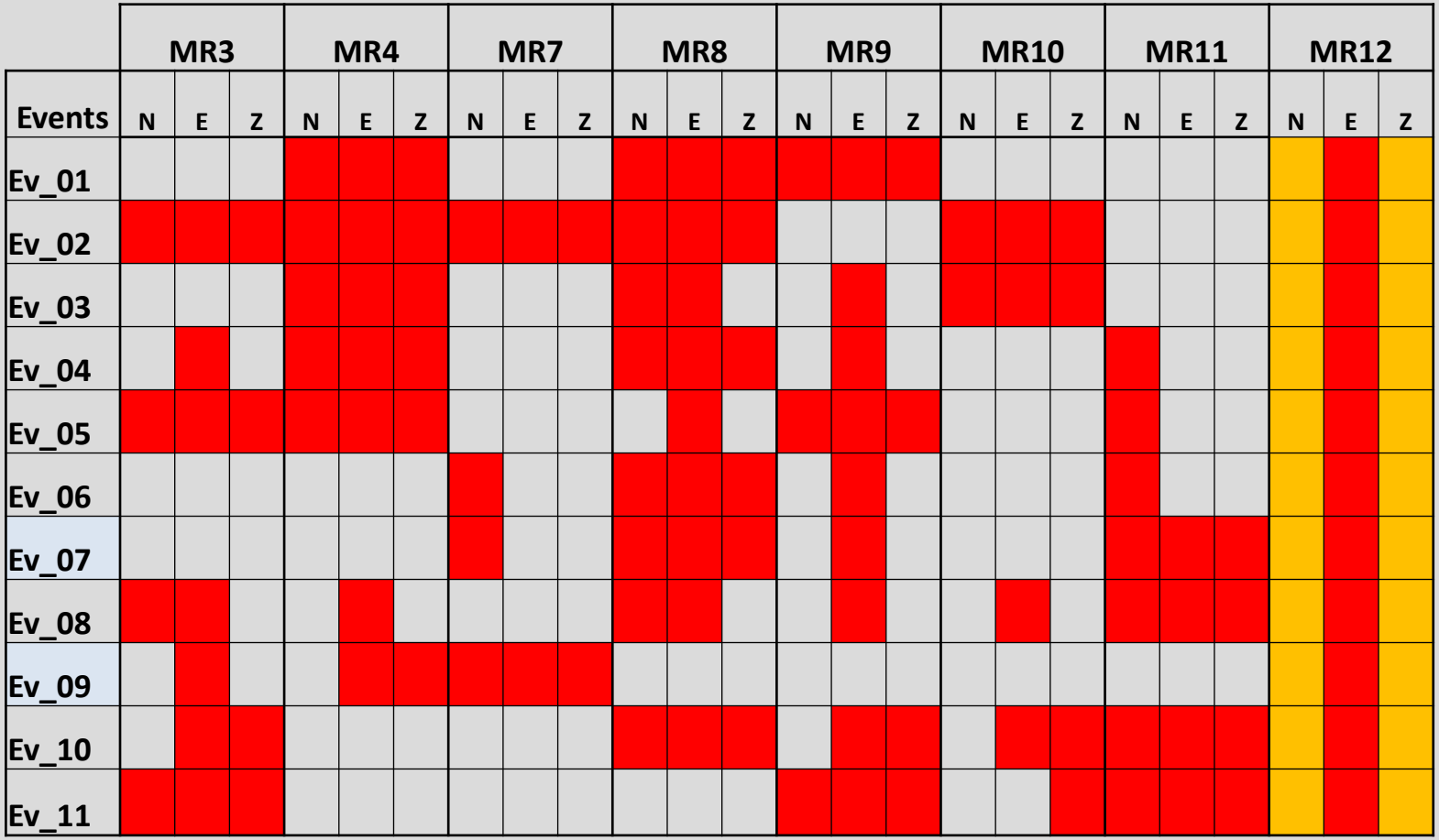






Inversion frequency band definition: F1 is limited by the SNR and F4 by the velocity model resolution and corner frequency. The selected frequency band inversion was from 1.0 to 2.0 Hz.

Data quality check (major and minor problems)



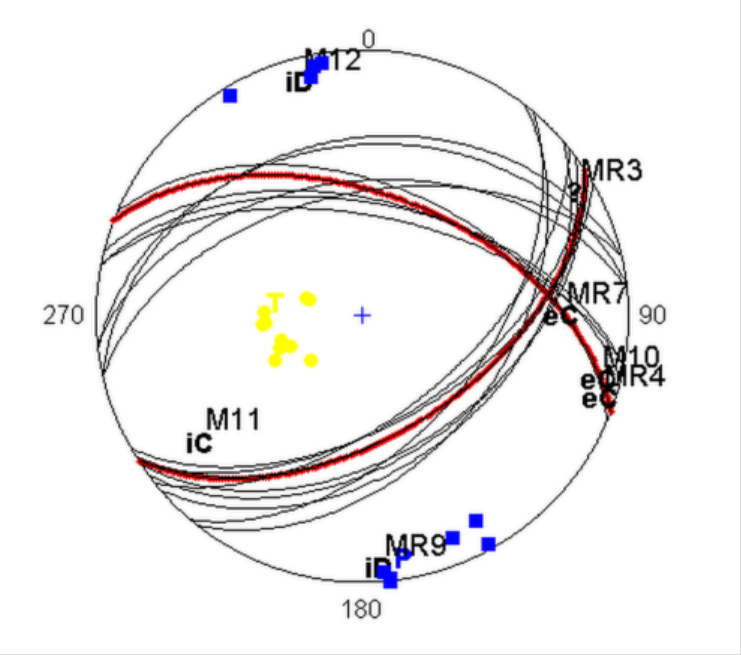
- **Red** = instrumental disturbance, low SNR, cultural noise, etc. Some of this data was removed from the inversion.
- **Orange** = Instrument with time problem. Data removed from the inversion.

Process and tools check (Event 6)

Variations:

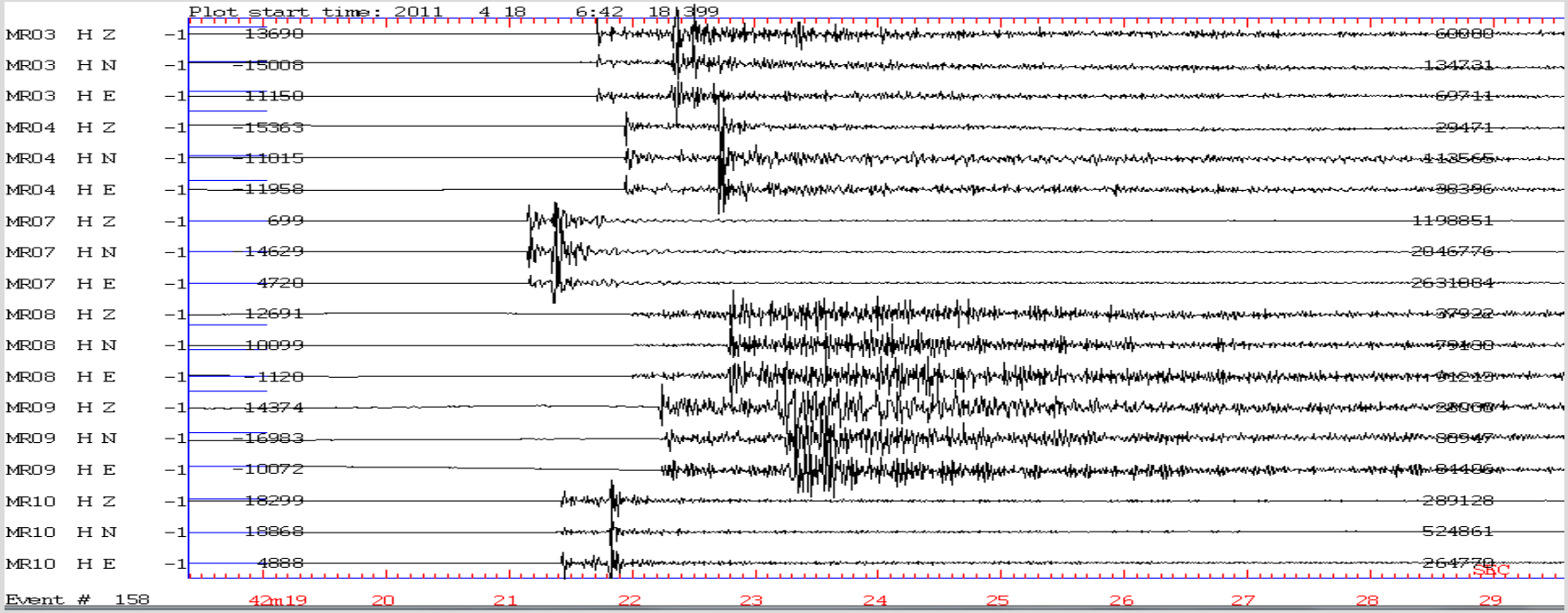
- **- Different setups at the half-space velocity model (vp and vs);**
- **- Few inversions done with different frequency bands from 0.1 to 2.0 Hz;**
- **- Few inversions done with different network geometry scenarios.**

Deselecting one or more 3C stations.

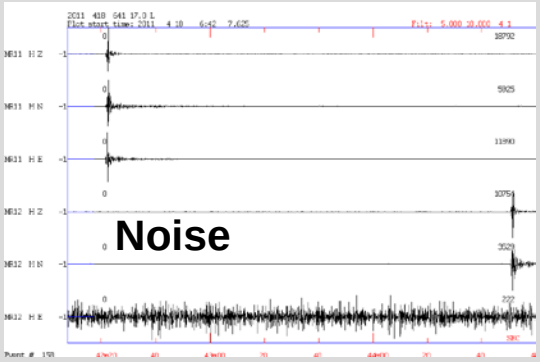


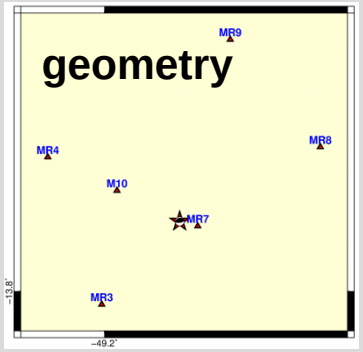
Note: This initial test was done to roughly check the stability of the process/tools and the results showed no drastic changes comparing the several different scenarios.

Data check (Ev9)

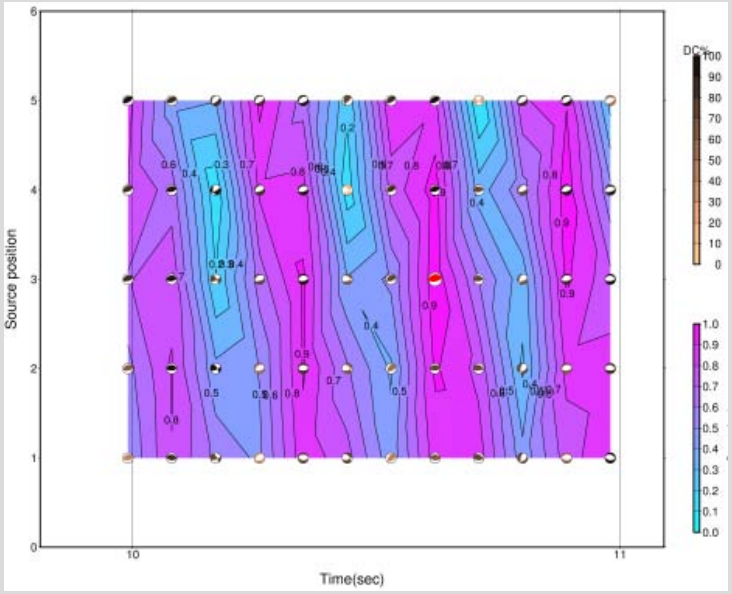


Waveform check

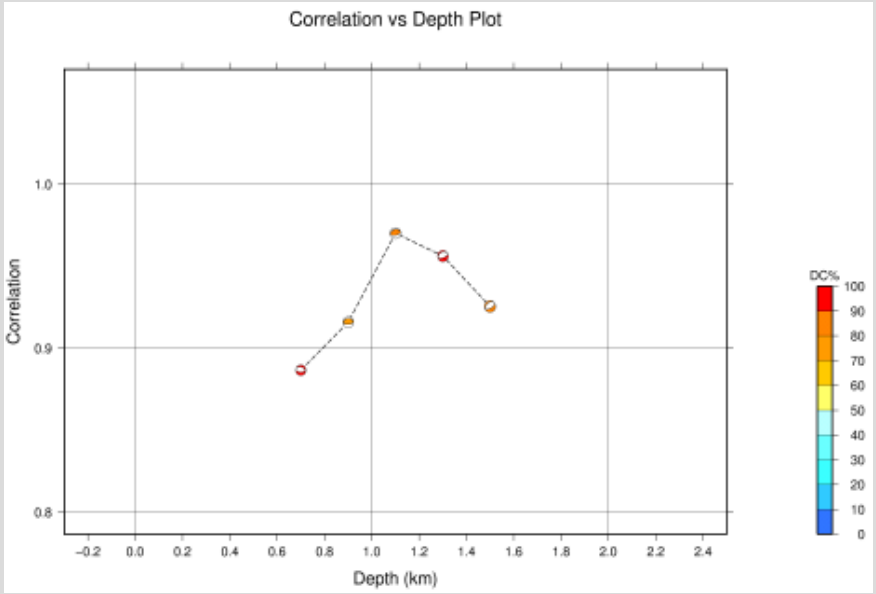




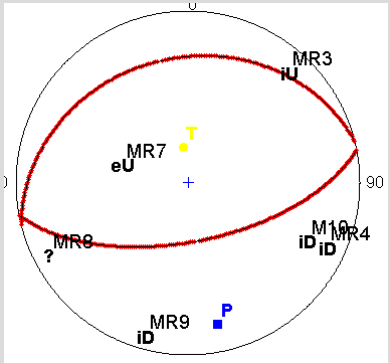
Inversion quality/stability check (Ev9)



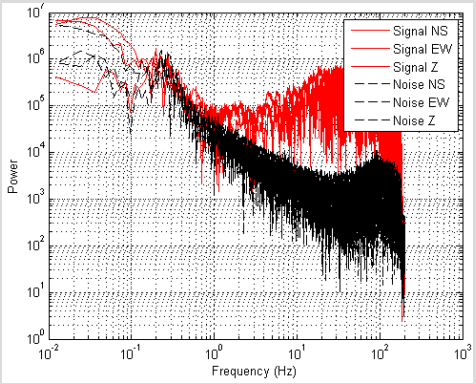
Correlation versus position of trial sources and time



Correlation and DC% versus depth of trial sources



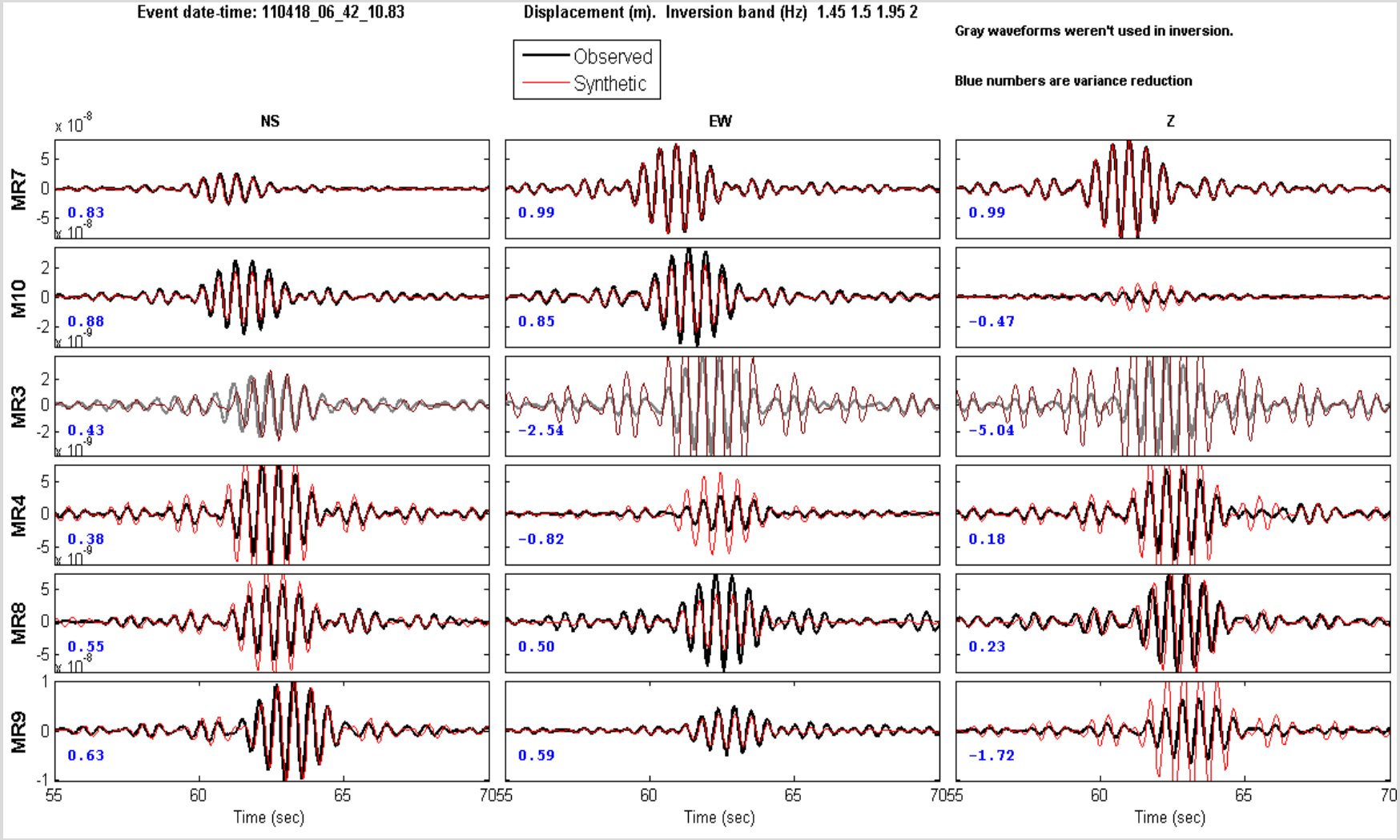
Polarity check



SNR check

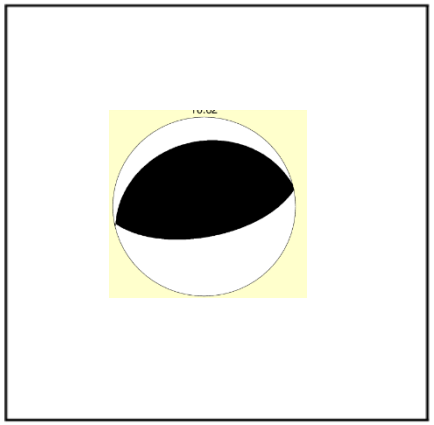
The trial source of about 1.1 km achieved the best correlation and showed to be consistent with the location of the event. This trial depth also satisfied the waveform polarity check.

Inversion quality/stability check (Ev9)



Waveform fit & Variance Reduction

MT Solution (Ev9)



MOMENT TENSOR SOLUTION

HYPOCENTER LOCATION (SIS-UnB)

Origin time 20110418 06:42:10.83
Lat -13.7723 Lon -49.1695 Depth 1.3

CENTROID

Trial source number : 3 (Fixed Epicenter inversion)
Centroid Lat (N)-13.7723 Lon (E)-49.1695
Centroid Depth (km) : 1.1
Centroid time : +10.62 (sec) relative to origin time

Moment (Nm) : 1.400e+011
Mw : 1.4
VOL% :0
DC% :89.3
CLVD% :10.7

		SNR	CN	FMVAR	STVAR
Var.red.:(for stations used in inversion)	:0.94	6	5.6	59±40	0.18
Var.red.(for all stations)	:0.93				

Strike	Dip	Rake
256	28	87
Strike	Dip	Rake
79	62	91

P-axis	Azimuth	Plunge
	168	17
T-axis	Azimuth	Plunge
	352	73

Mrr	Mtt	Mpp
1.203	-1.076	-0.127
Mrt	Mrp	Mtp
0.761	0.130	-0.226

Exponent (Nm): 11

Frequency band used in inversion (Hz)
1.45 - 1.5 -- 1.95 - 2

Stations-Components Used-Distance

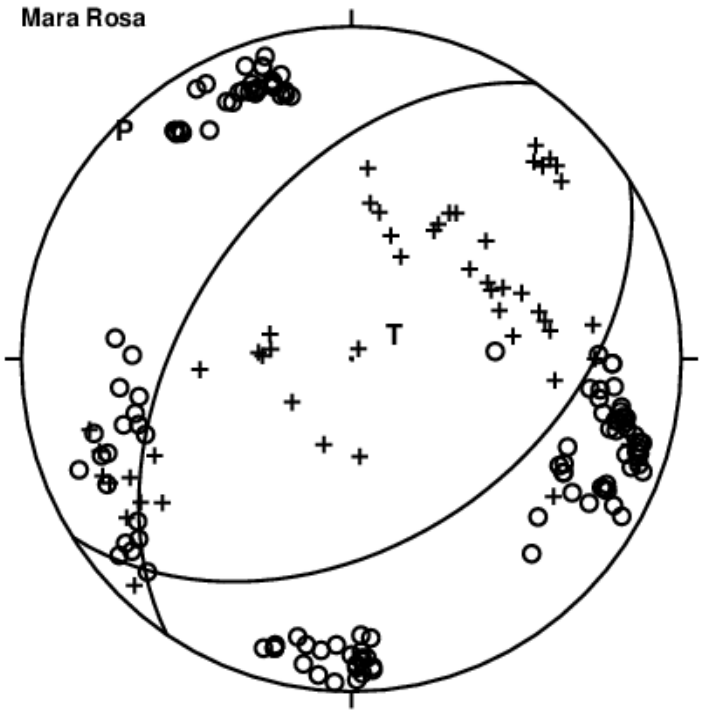
	NS	EW	Z	D(km)
MR7	+	+	+	1
M10	+	+	+	3
MR3	-	-	-	5
MR4	+	+	+	6
MR8	+	+	+	7
MR9	+	+	+	8

Results:

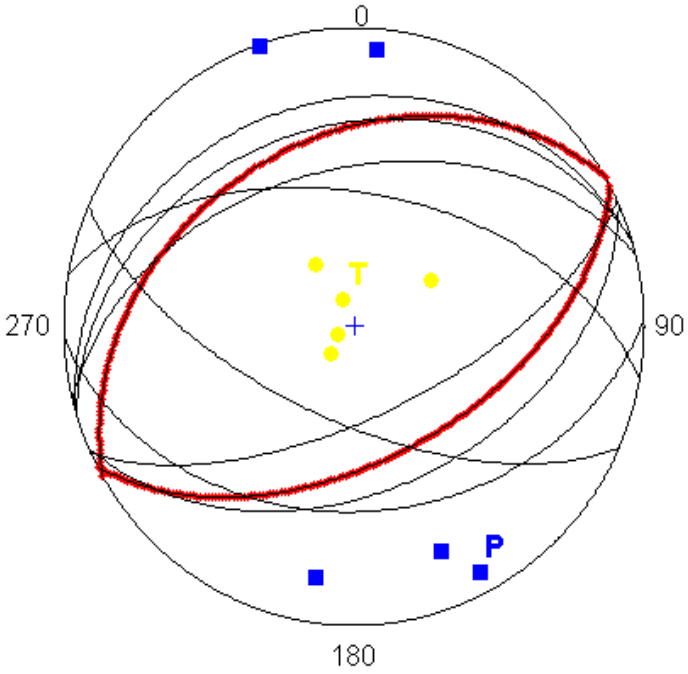
Event	Stations Processed	Frequency band (Hz)	1-S/D/R 2-S/D/R	P-Az/Plg T-Az/Plg	M_D/Mw	depth (Km) Loc/Cent	DC%	CN	VR	STVAR	SNR	Polarity Agreement (Hyp)	Beachball	K-Angle vs source 9	Theoretical uncertainty (C=0.3)	Theoretical uncertainty Plot (C=0.3)
EV1	7, 8, 10, 9 -3	1.5-2.0	265/47/97 76/43/83	351/2 239/85	1.4/0.8	0.8/0.5	97	4.1	0.35	0.10	2	Yes		20	9	
EV2	3, 7, 8, 10	1.5-2.0	254/25/98 65/65/86	158/20 328/70	1.3/1.0	1.2/0.9	99	4.0	0.67	0.12	1	Yes (-1)		13	8	
EV3	3, 7, 8, 9, 10	1.5-2.0	292/87/36 200/54/176	60/22 162/27	1.3/1.3	1.4/3.8	70	2.6	0.05	0.05	2	No		95	9	
EV4	3, 7, 8, 10 -9	1.5-2.0	253/33/104 57/59/81	302/75 153/13	1.2/1.0	1.3/1.7	94	3.9	0.82	0.19	2	Yes		20	9	
EV5	7, 8, 10	1.5-2.0	256/43/97 67/47/84	161/2 278/85	1.5/1.3	1.7/1.7	71	3.8	0.75	0.14	3	Yes (-1)		18	9	
EV6	4, 7, 8, 10 -3, -9	1.5-2.0	280/53/117 60/44/59	249/68 352/5	1.3/1.2	0.6/0.7	78	4.9	0.73		4	Yes(-1)		31	10	
EV7	4, 7, 8, 10	1.5-2.0	280/26/154 34/79/66	143/30 278/50	1.2/0.8	1.4/0.5	94	6.0	0.24	0.18	2	No		47	12	
EV8	3, 4, 7, 8, 9, 10	1.5-2.0	313/65/-20 51/72/-154	274/31 181/4	1.2/0.26	1.0/0.7	77	4.6	0.1		1	No		100	11	
EV9	4, 7, 8, 9, 10 -3	1.5-2.0	256/28/87 79/62/91	168/17 352/73	1.4/1.4	1.3/1.1	89	5.6	0.94	0.18	6	Yes		0	13	
EV10	3, 4, 7, 8, 10 -9,-11	1.5-2.0	215/30/69 58/62/101	140/16 353/71	2.0/0.9	1.2/1.5	90	4.9	0.57	0.21	4	Yes		27	11	
EV11	4, 7, 8, 10 -11	1.5-2.0	188/63/3 97/88/153	146/17 49/21	1.4/1.2	0.9/1.1	99	6.4	0.85	0.12	7	Yes		64	9	

The blue cells indicate problem with the inversion, bad data, k-angle too high, or did not satisfy the waveform polarity check.

Graphical comparison of the composite Focal Mechanism from Barros et al. (2012) and the results from the ISOLA inversion



Composite focal mechanism solution using 62 events detected by 6 to 8 stations (Barros et al., 2012) .
Strike=214 , dip=49 and rake=74



Focal Mechanism plot showing the events 1, 2, 4, 5, 6, 9 and 10. The red line represent the focal mechanism of the event number 4.

Conclusion:

- Events 3, 7 and 8 showed bad results mainly due to low SNR and data problems.
- Events 1, 2, 4, 5 6 and 9 showed focal mechanisms compatible with the regional stress and with the result from Barros et. al, 2012.
- The magnitude of the event 10 (0.9 M_W) is not compatible with Barros et. al., 2012 magnitude 2.0 M_D. The inversion control parameters looks good, but the FM is slightly different from the others.
- The inversion of the event 11 looks ok, but the k-angle showed to be too high.

ISOLA