

ISOLA Brasilia 2013

Lucas Moreira

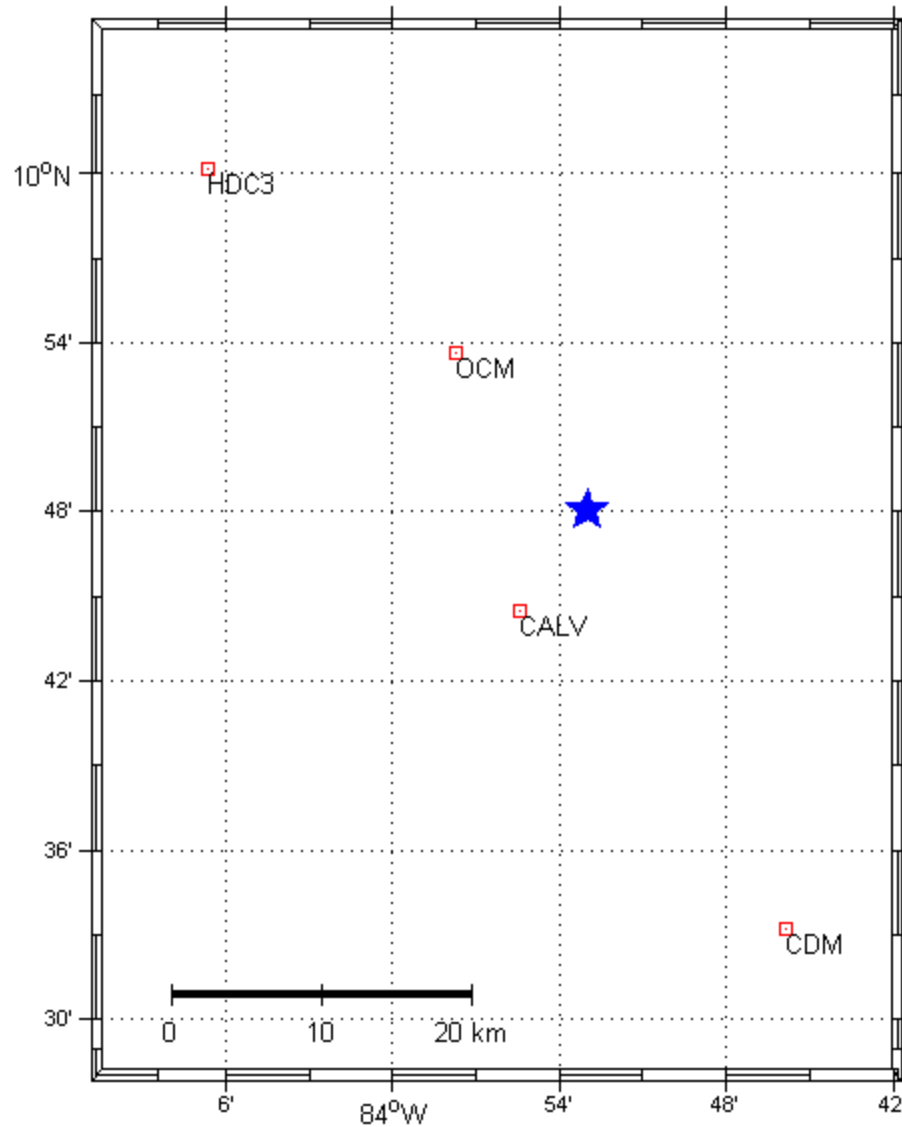
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Scenario

- Costa Rica event recorded by OVSICORI stations
 - Data kindly provided by Dr. Ronnie Quintero
- Magnitude $M = 3.3$
- Depth 3.3 km
- Event recorded by broadband seismometers and accelerometers

Event and stations

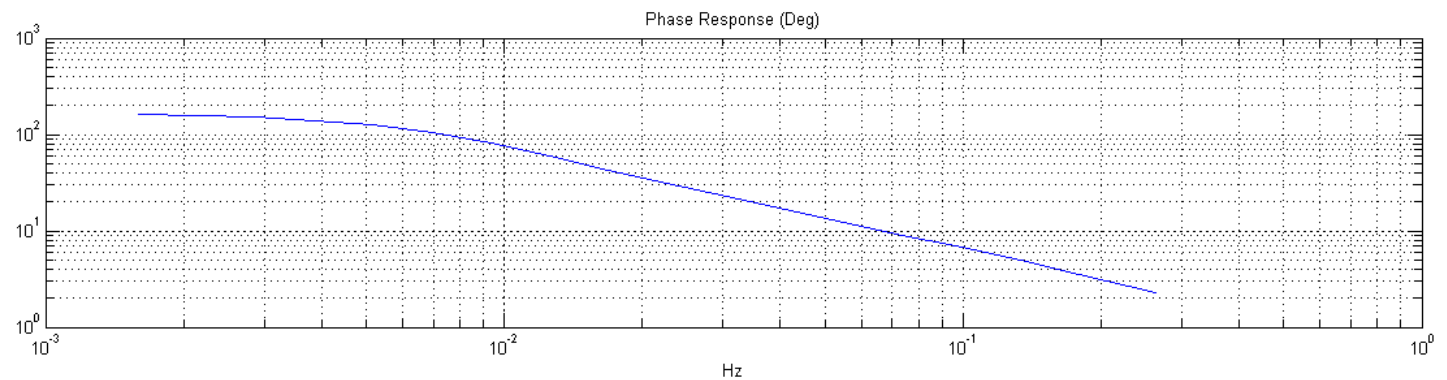
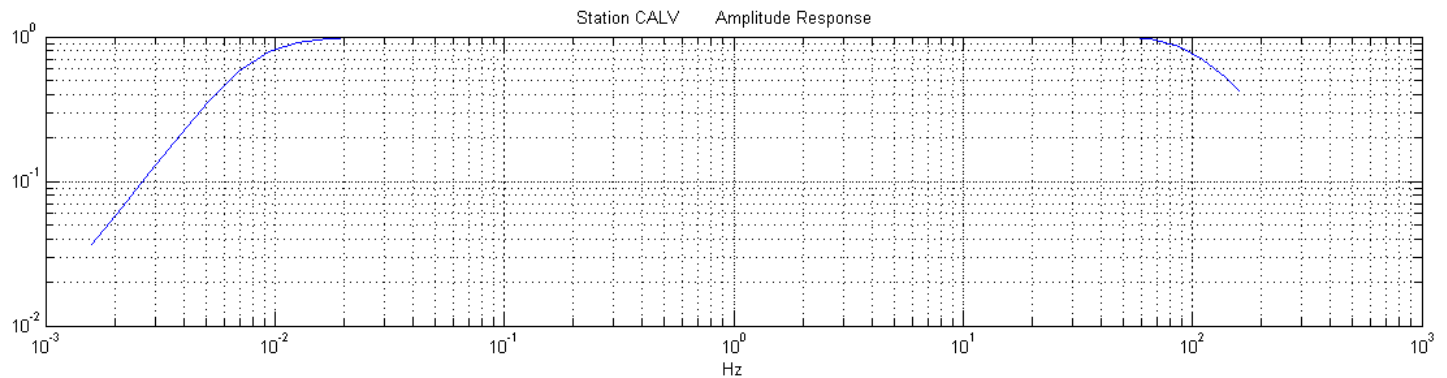


Event information

Date Date (YYYYMMDD) <input type="text" value="20130608"/>		Location		Lat (N) (Dec.Degrees) <input type="text" value="9.8"/>	
Origin Time		Lat (Deg,Min) <input type="text" value="38.00"/> <input type="text" value="50.00"/>		Depth (km) <input type="text" value="3"/>	
Hour <input type="text" value="07"/>		<input type="button" value="DDMM-> DDEG"/>		Lon (E) (Dec.Degrees) <input type="text" value="-83.883"/>	
Min <input type="text" value="50"/>		Lon (Deg,Min) <input type="text" value="21.00"/> <input type="text" value="50.00"/>			
Seconds <input type="text" value="31.00"/>		Comments			
		Magnitude <input type="text" value="3.3"/>		Location agency <input type="text" value="OVSICORI"/>	
Time Window Length (sec)					
<input type="list" value="16.384, 40.96, 81.92, 163.84, 245.76, 327.68, 409.6, 819.2, 1638.4"/>					
The chosen Time Window Length should be large enough to include the travel time from epicenter to stations plus the seismogram duration					

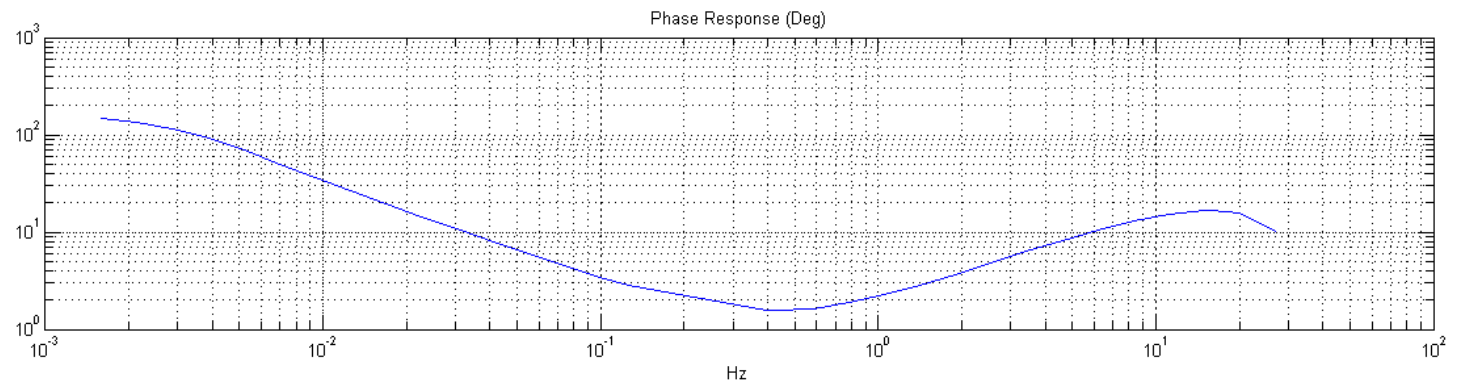
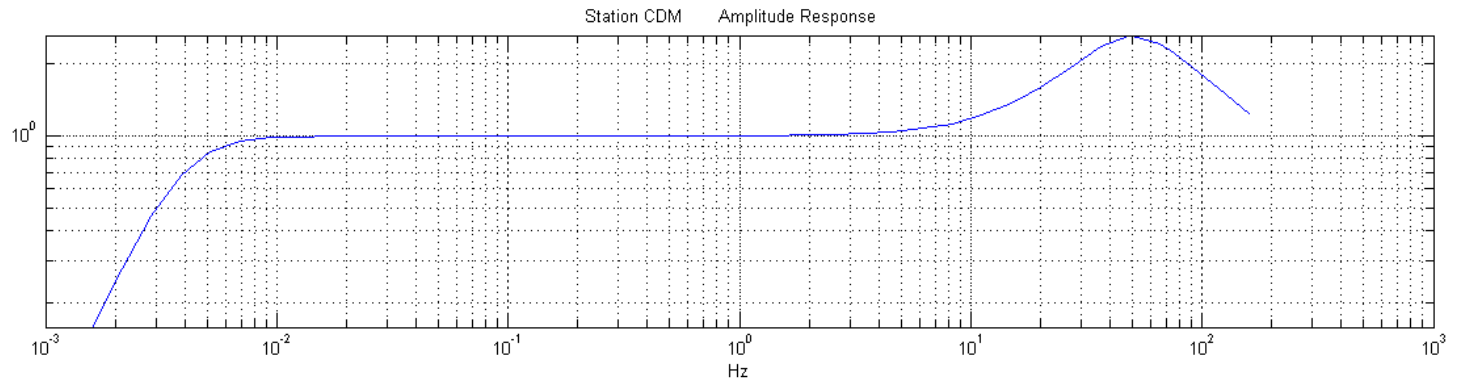
CALV station (Trillium sensor)

```
AO
8.184000E+11
count-->m/sec
3.337422e-09
zeroes
3
0.000000e+00    0.000000e+00
0.000000e+00    0.000000e+00
-4.341000e+02    0.000000e+00
poles
7
-3.6910(
-3.6910(
-3.7390(
-3.7390(
-5.8840(
-5.8840(
-3.7120(
Info: (
```

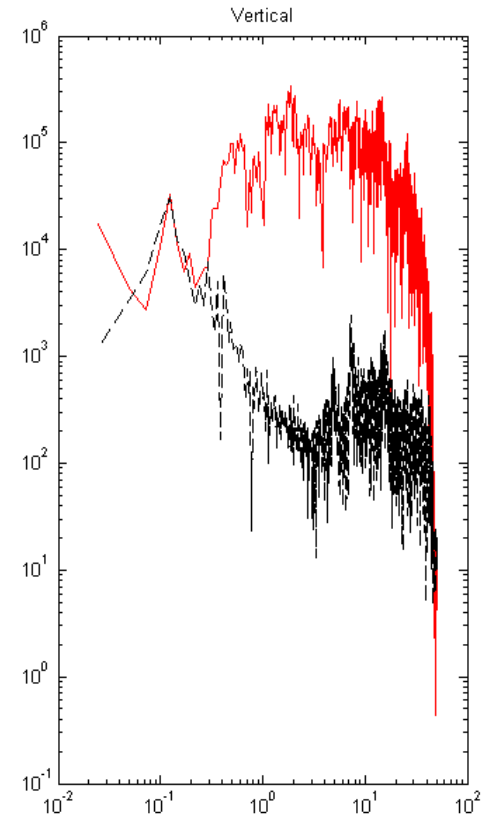
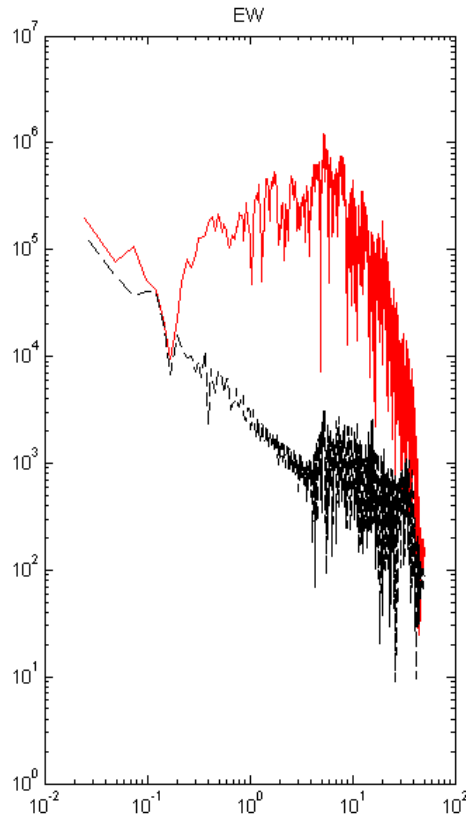
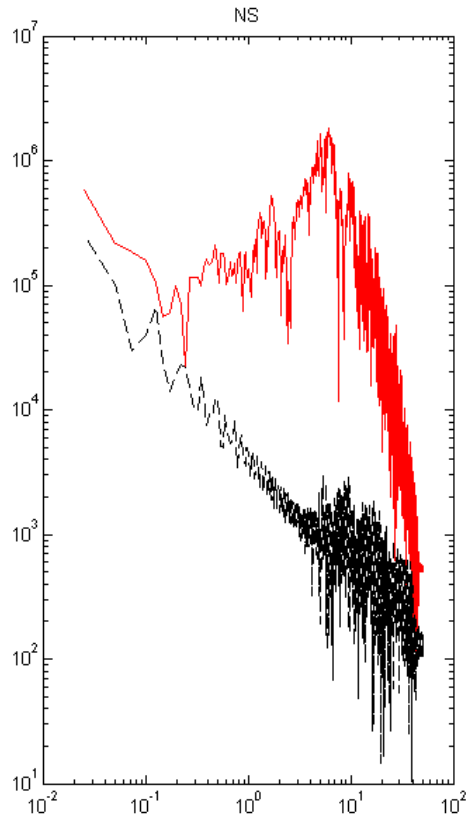


OCM, CDM and HDC3 stations

```
A0
4.517E+05
count-->m/sec
5.101721e-010
zeroes
5
0.000000e+000 0.000000e+000
0.000000e+000 0.000000e+000
-9.166000e+001 0.000000e+000
-1.601000e+002 0.000000e+000
-3.2070
poles
7
-1.7700
-1.7700
-1.2670
-1.9200
-1.9200
-5.5770
-5.5770
Info:
```



Data – CALV station



Data – CALV station

Load Ascii file Exit

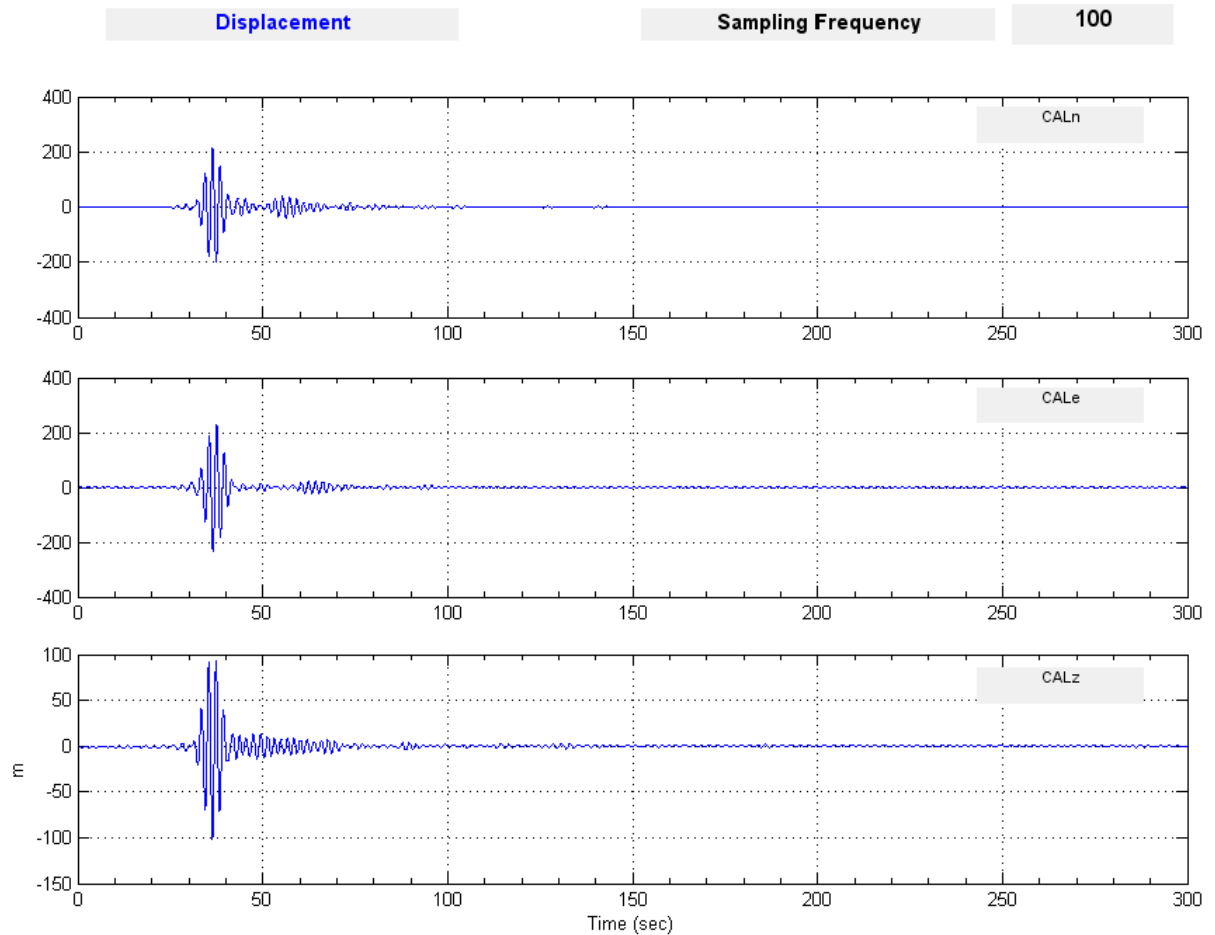
Integrate Restart

Pre-defined filters

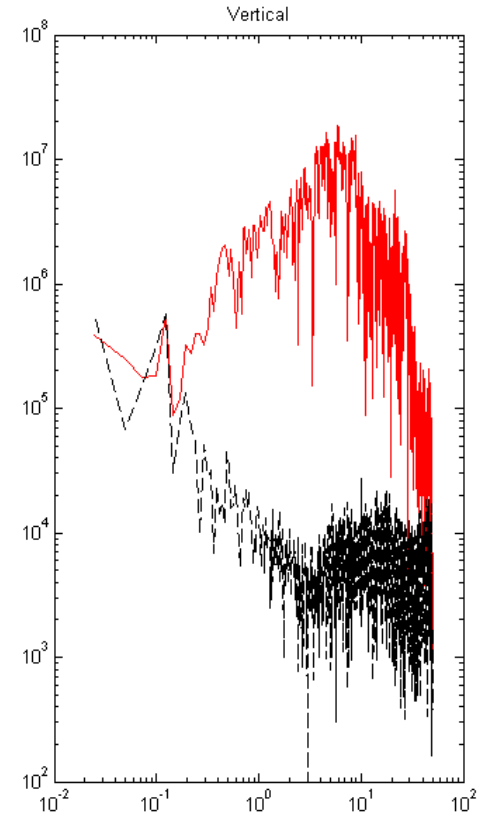
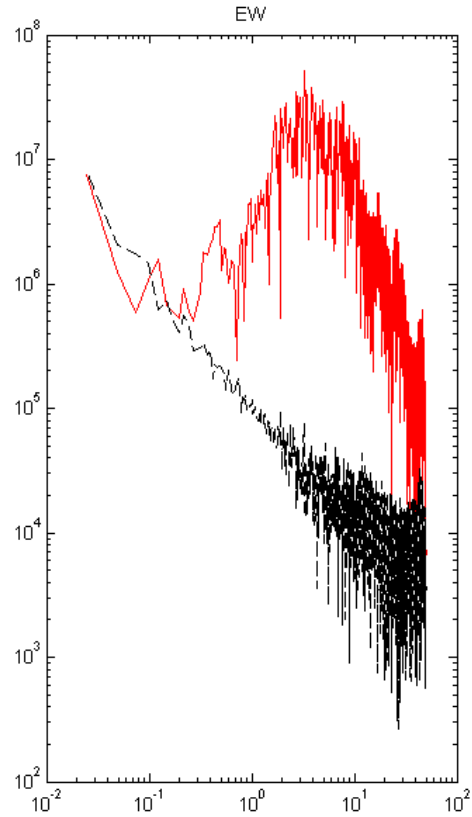
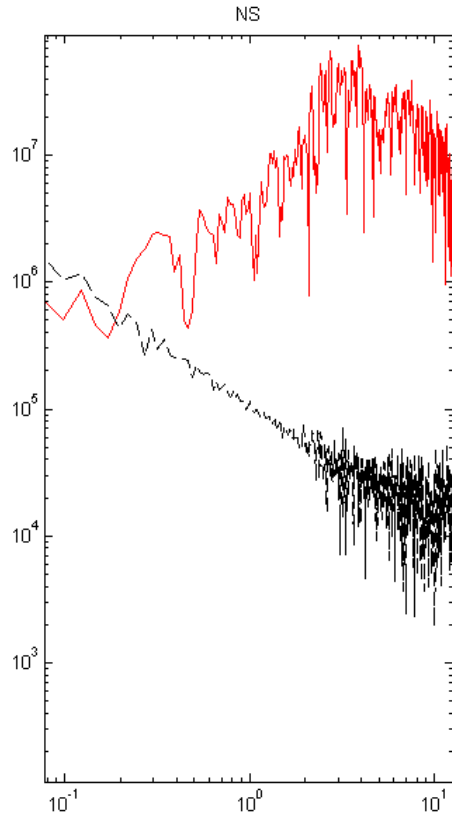
Frequency (Hz)	Period (sec)
1-5	1.0-0.2
0.2-1.0	5.0-1.0
0.08-0.2	12.5-5.0
0.06-0.08	16.5-12.5
0.05-0.07	20.0-14.3
0.03-0.06	33.3-16.5
0.01-0.03	100-33.3

My filter

0.4	(Hz)	0.6
Low		High
2.5	(sec)	1.6667

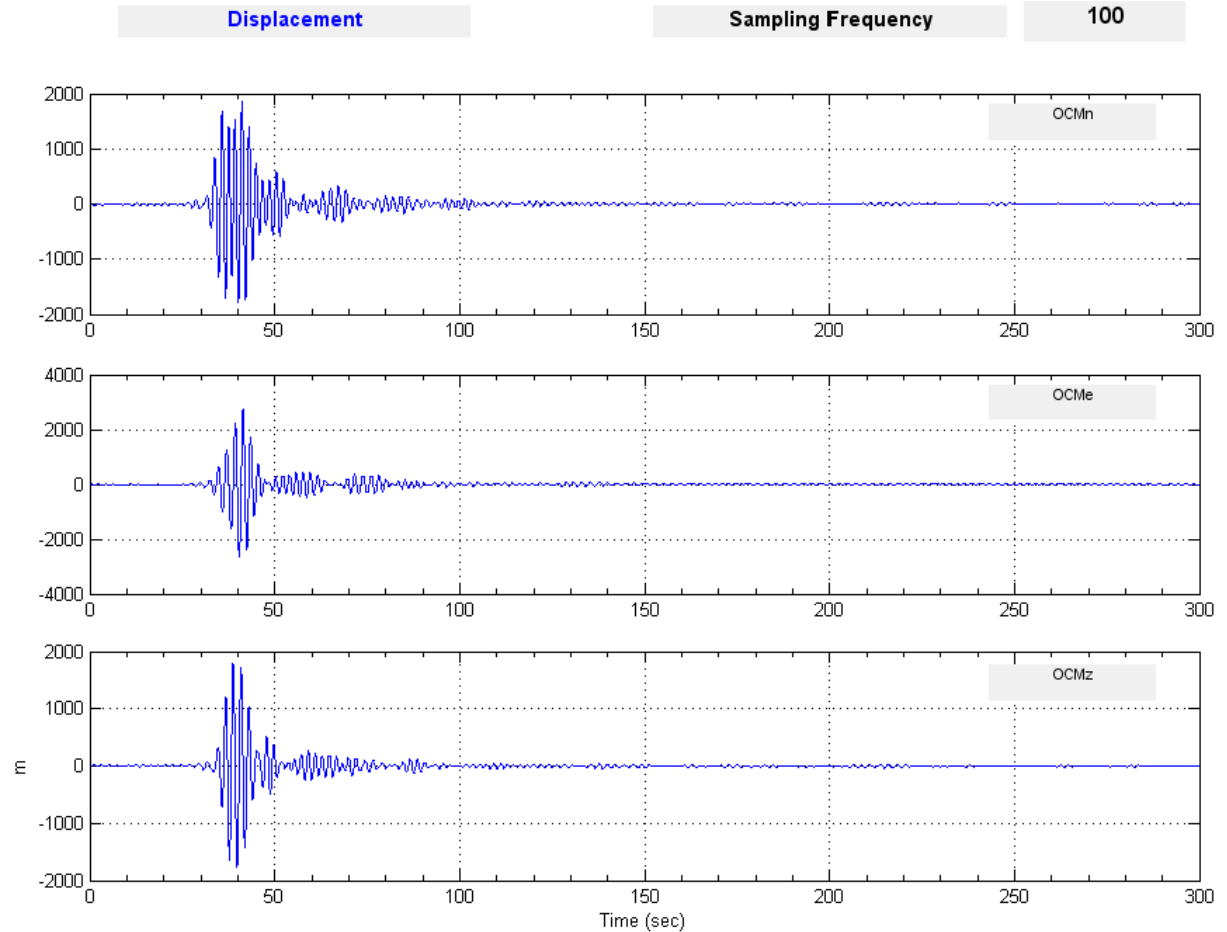


Data – OCM station

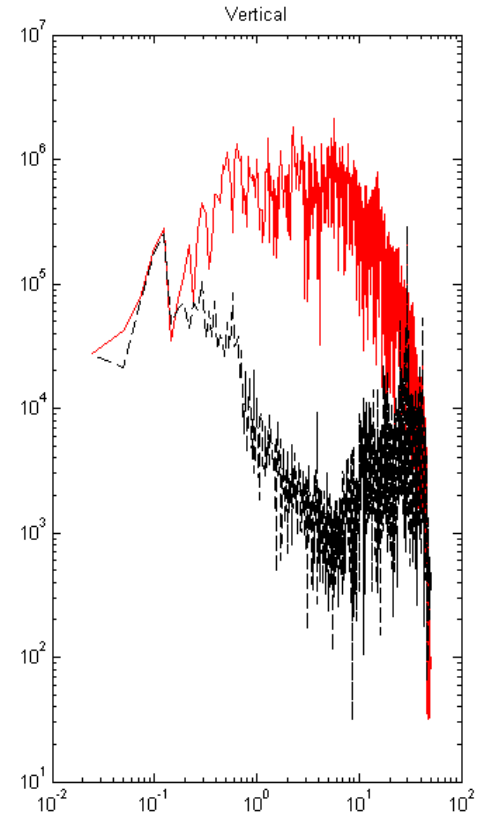
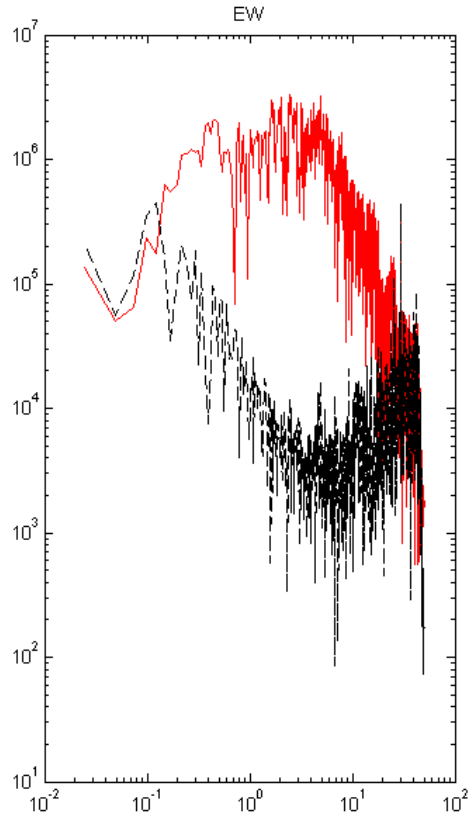
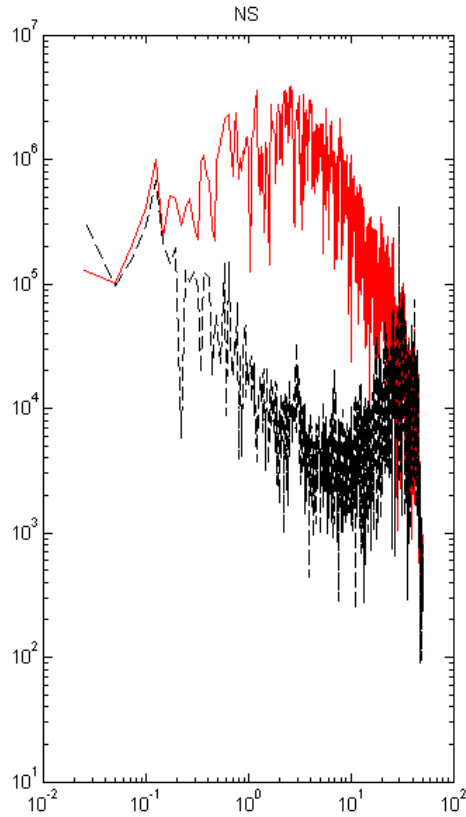


Data – OCM station

Load Ascii file	Exit
Integrate	Restart
Pre-defined filters	
Frequency (Hz)	Period (sec)
1-5	1.0-0.2
0.2-1.0	5.0-1.0
0.08-0.2	12.5-5.0
0.06-0.08	16.5-12.5
0.05-0.07	20.0-14.3
0.03-0.06	33.3-16.5
0.01-0.03	100-33.3
My filter	
0.4 (Hz) Low	0.6 (Hz) High
2.5 (sec)	1.6667 (sec)



Data – CDM station



Data – CDM station

Load Ascii file Exit

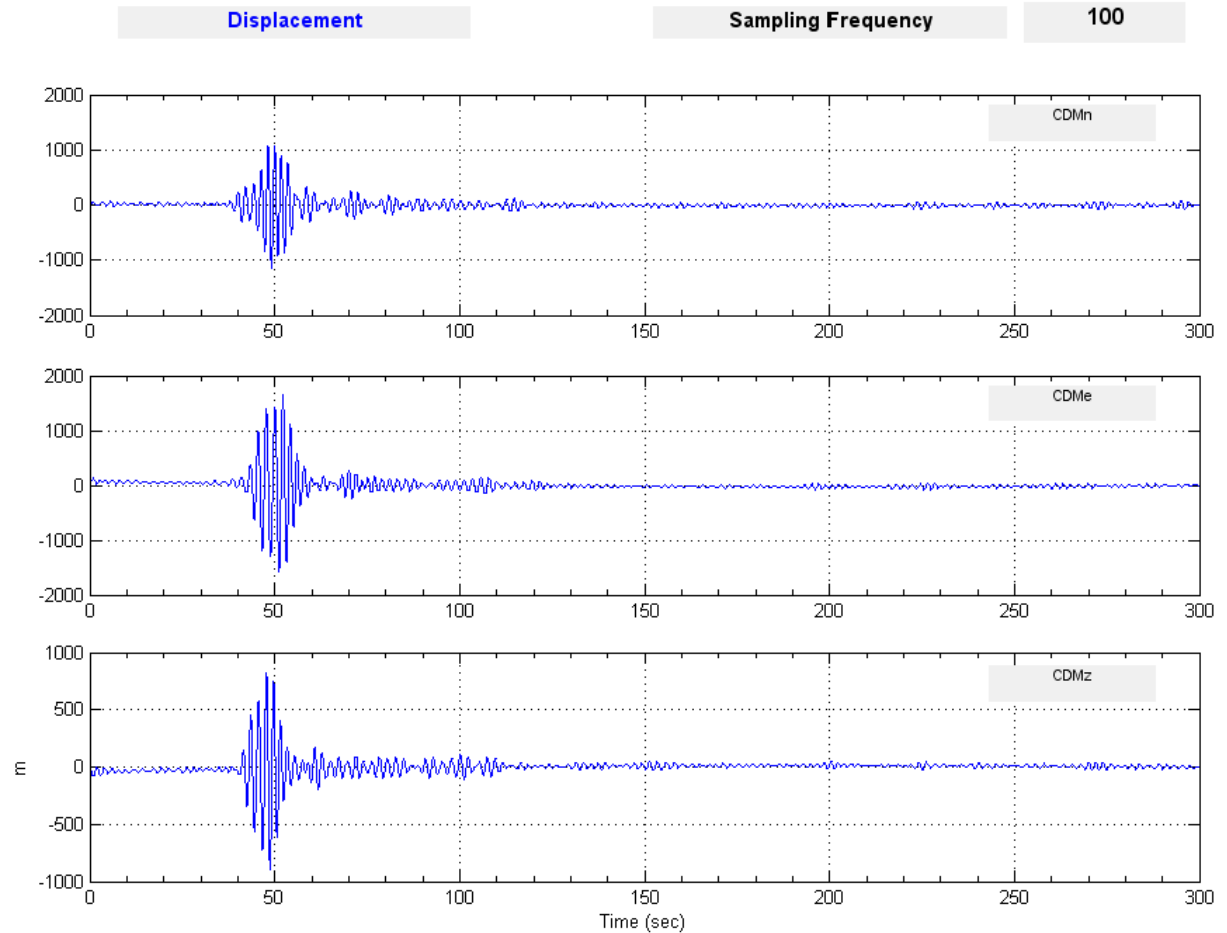
Integrate Restart

Pre-defined filters

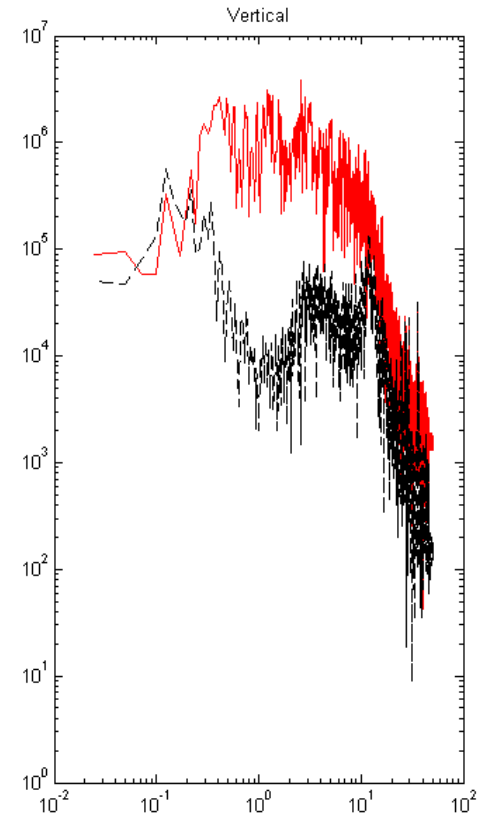
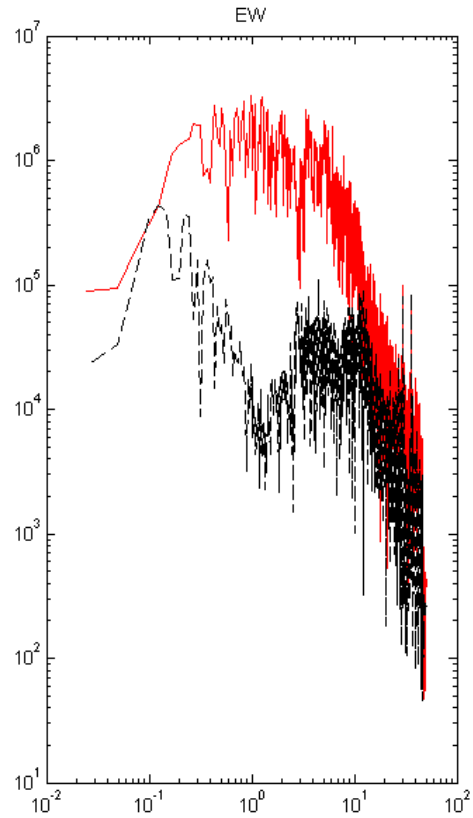
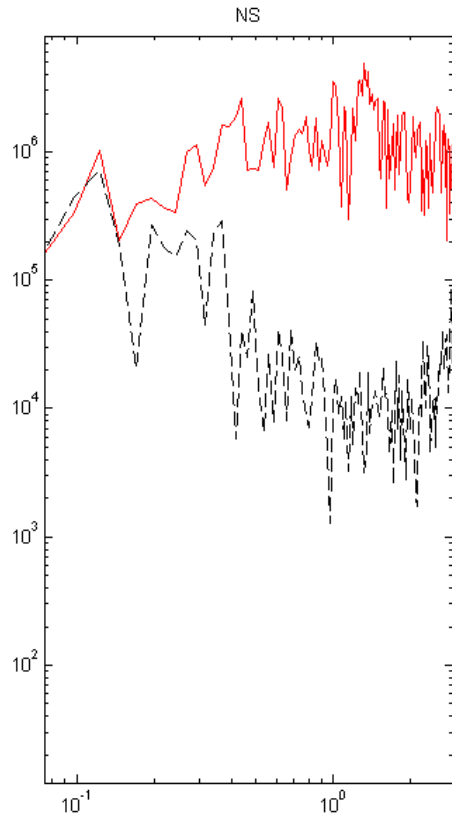
Frequency (Hz)	Period (sec)
1-5	1.0-0.2
0.2-1.0	5.0-1.0
0.08-0.2	12.5-5.0
0.06-0.08	16.5-12.5
0.05-0.07	20.0-14.3
0.03-0.06	33.3-16.5
0.01-0.03	100-33.3

My filter

0.4	(Hz)	0.6
Low		High
2.5	(sec)	1.6667

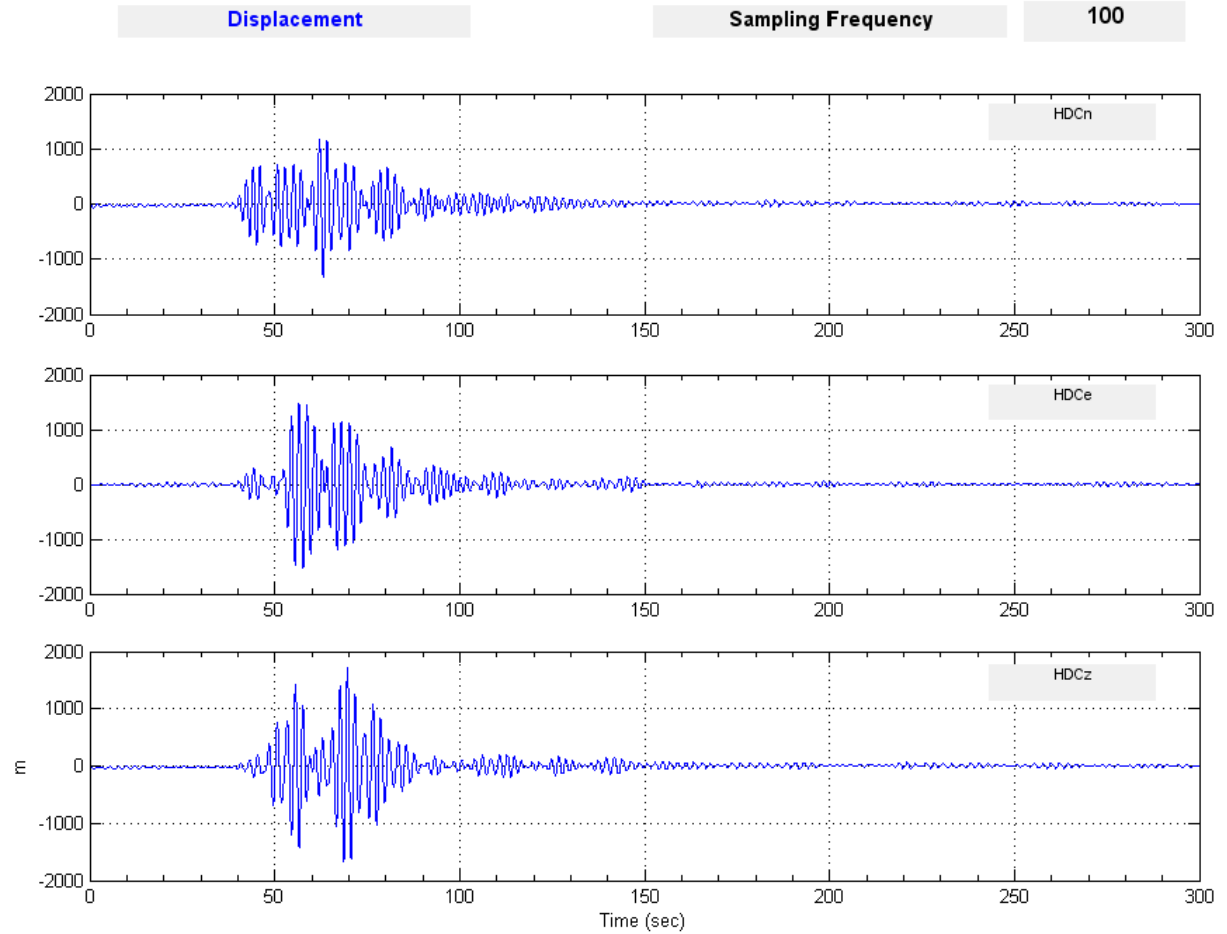


Data – HDC3 station



Data – HDC3 station

Load Ascii file	Exit
Integrate	Restart
Pre-defined filters	
Frequency (Hz)	Period (sec)
1-5	1.0-0.2
0.2-1.0	5.0-1.0
0.08-0.2	12.5-5.0
0.06-0.08	16.5-12.5
0.05-0.07	20.0-14.3
0.03-0.06	33.3-16.5
0.01-0.03	100-33.3
My filter	
0.4 (Hz) Low	0.6 (Hz) High
2.5 (sec)	1.6667 (sec)



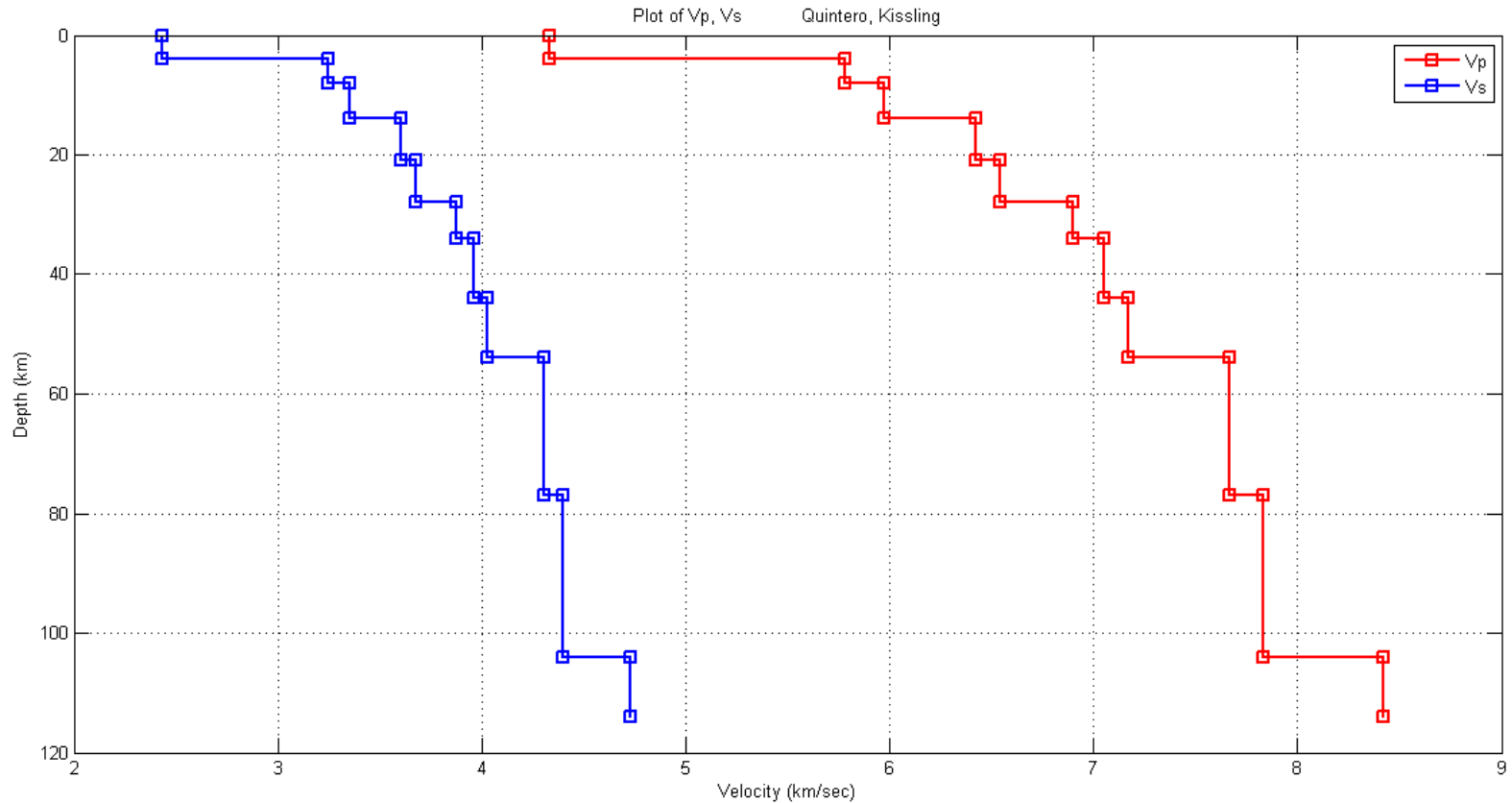
Hypocenter vertical grid search

Starting depth (km)
1.5
Depth step (km)
0.5
No of Sources (< 99)
9

Green function parameters

Maximum Frequency to compute (Hz)	0.89925
Time Function	
<input checked="" type="radio"/> Delta	
<input type="radio"/> Triangle	Duration
	3
Green Function computation parameters	
Time length	245.76
No of Sources	9
No of Stations	4

Velocity model – trial 1



Inversion parameters – trial 1

Info Time Length 245.76 No of Sources 9 No of Stations 4 Min Time shifts (sec) -75 Max Time shifts (sec) 75	Filter (Hz) <input checked="" type="checkbox"/> Common for all stations filter (f1,f2,f3,f4); flat band-pass between f2, f3 cosine tapered between f1, f2 and between f3, f4 f1 f2 f3 f4 <input type="text" value="0.35"/> <input type="text" value="0.4"/> <input type="text" value="0.6"/> <input type="text" value="0.65"/> S/N Ratio using f1 f4 <input type="text" value="32"/> <input type="button" value="Plot S/N curves"/>	<input type="button" value="Select Stations/Freq Band"/> <input type="button" value="Compute Weights"/> <input type="button" value="Reset Weights"/>
Type of Inversion <input type="radio"/> Full MT <input checked="" type="radio"/> Deviatoric MT <input type="radio"/> DC constrained <input type="radio"/> Fixed mechanism Strike <input type="text" value="0"/> Dip <input type="text" value="0"/> Rake <input type="text" value="0"/>	(dt) Time Search (sec) Start <input type="text" value="18"/> Time Step <input type="text" value="0.15"/> End <input type="text" value="24"/> Trial Time shifts <input type="text" value="600"/> <input type="text" value="5"/> <input type="text" value="800"/>	<input type="button" value="Run"/> <input type="button" value="Exit"/>
Number of Subevents <input type="text" value="1"/>		
Time Function <input checked="" type="radio"/> Delta <input type="radio"/> Triangle Duration <input type="text" value="4"/>	<input type="button" value="Plot Correlation diagram"/> <input type="button" value="Plot Correlation on map"/> <input checked="" type="radio"/> Use Source Number <input type="radio"/> Use Distance-Depth <input type="checkbox"/> Plot DC% contours <input checked="" type="checkbox"/> Draw Contours <input type="checkbox"/> Use fixed interval Plot Scale X <input type="text" value="21"/> Plot Scale Y <input type="text" value="18"/> Beachball Scale <input type="text" value="0.35"/> Font size <input type="text" value="10"/> Contour interval <input type="text" value="0.1"/> Beachball cut off % <input type="text" value="0"/> GMT Palette <input type="text" value="cool"/> <input type="checkbox"/> Invert Palette	<input type="button" value="Results for Single source"/> Source Number <input type="text" value="1"/> Time limits <input type="text" value=""/> Source limits <input type="text" value="1"/> <input type="text" value="9"/>

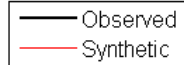
Selected stations – trial 1

Stations	Components				f1	f2	f3	f4
CALV	<input checked="" type="checkbox"/> Use Station	<input checked="" type="checkbox"/> Use NS	<input checked="" type="checkbox"/> Use EW	<input checked="" type="checkbox"/> Use Z	0.35	0.4	0.6	0.65
OCM	<input checked="" type="checkbox"/> Use Station	<input checked="" type="checkbox"/> Use NS	<input checked="" type="checkbox"/> Use EW	<input checked="" type="checkbox"/> Use Z	0.35	0.4	0.6	0.65
CDM	<input checked="" type="checkbox"/> Use Station	<input checked="" type="checkbox"/> Use NS	<input checked="" type="checkbox"/> Use EW	<input checked="" type="checkbox"/> Use Z	0.35	0.4	0.6	0.65
HDC3	<input checked="" type="checkbox"/> Use Station	<input checked="" type="checkbox"/> Use NS	<input checked="" type="checkbox"/> Use EW	<input checked="" type="checkbox"/> Use Z	0.35	0.4	0.6	0.65

Results – trial 1

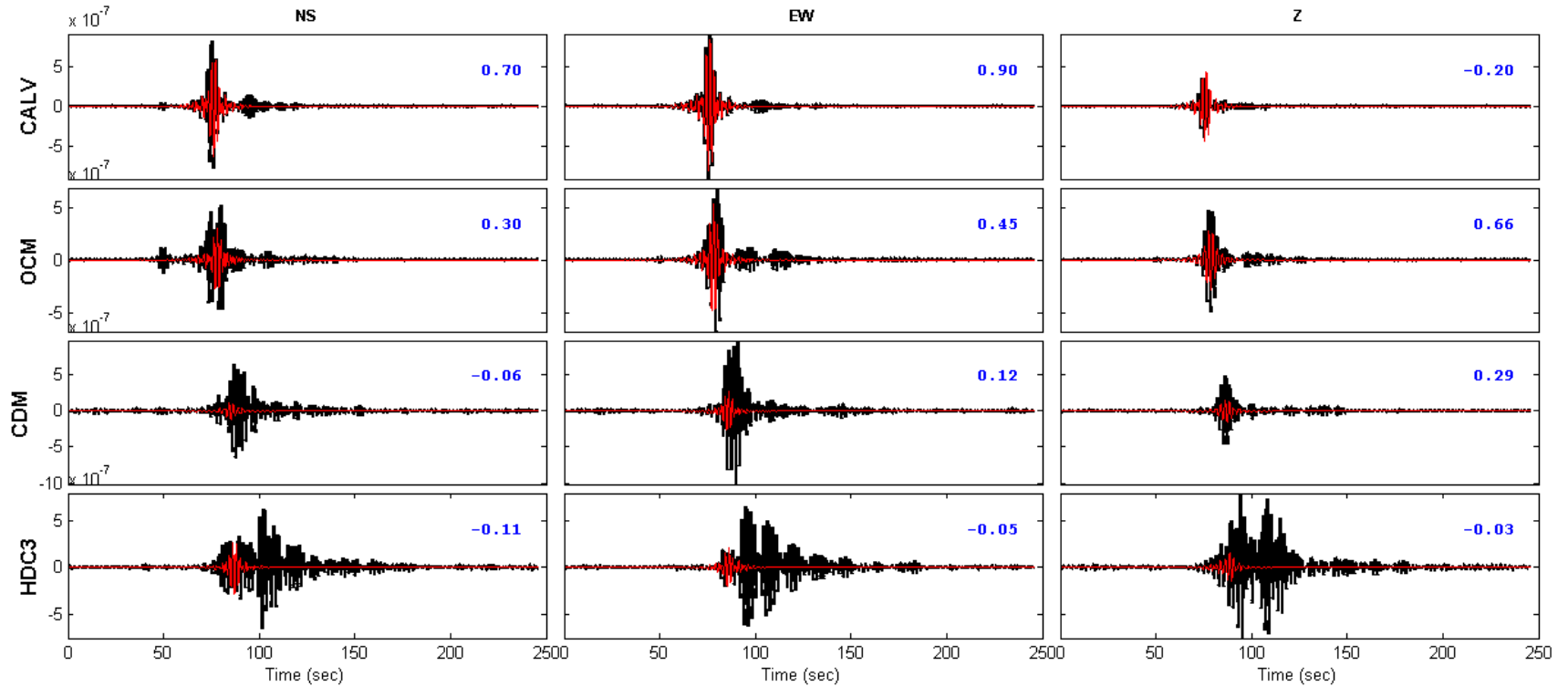
Event date-time: 130608_07_50_31.00

Displacement (m). Inversion band (Hz) 0.35 0.4 0.6 0.65



Gray waveforms weren't used in inversion.

Blue numbers are variance reduction



Results – trial 1

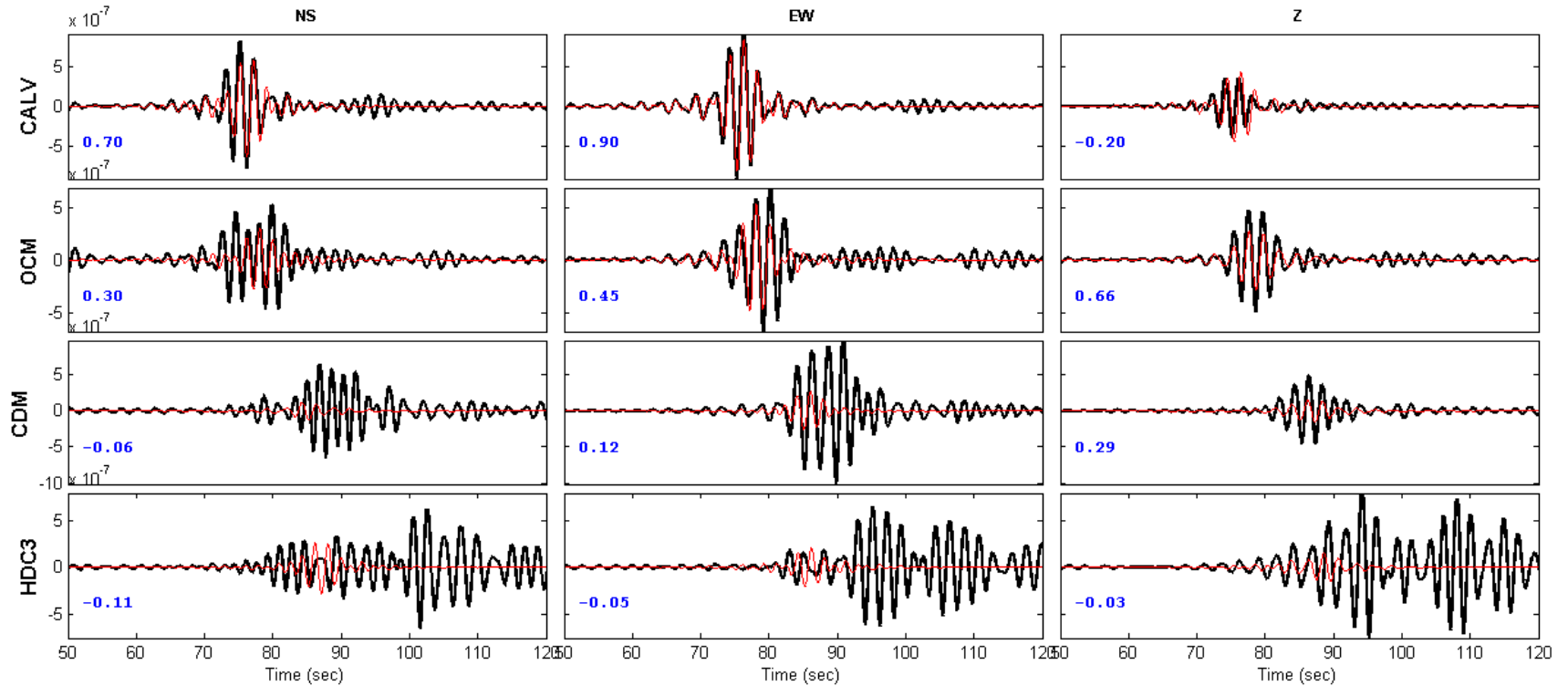
Event date-time: 130608_07_50_31.00

Displacement (m). Inversion band (Hz) 0.35 0.4 0.6 0.65

— Observed
— Synthetic

Gray waveforms weren't used in inversion.

Blue numbers are variance reduction



Results – trial 1

MOMENT TENSOR SOLUTION

HYPOCENTER LOCATION (OVSICORI)

Origin time 20130608 07:50:31.00
 Lat 9.8 Lon -83.883 Depth 3

CENTROID

Trial source number : 6 (Fixed Epicenter inversion)
 Centroid Lat (N) 9.8 Lon (E) -83.883
 Centroid Depth (km) : 4
 Centroid time : +22.65 (sec) relative to origin time

Moment (Nm) : 6.368e+12

Mw : 2.5

VOL% : 0

DC% : 97.3

CLVD% : 2.7

Var.red. : (for stations used in inversion): 0.18 SNR CN FMVAR STVAR
 32 2.3 39±40 0.05

Var.red. (for all stations) : 0.18

Strike	Dip	Rake	Frequency band used in inversion (Hz)
40	69	147	0.35 - 0.4 -- 0.6 - 0.65

Strike	Dip	Rake	Stations-Components Used-Distance
144	59	25	

	NS	EW	Z	D (km)	
P-axis Azimuth Plunge	CALV	+	+	+	8
		94	6		
T-axis Azimuth Plunge	OCM	+	+	+	14
	CDM	+	+	+	30
	HDC3	+	+	+	34

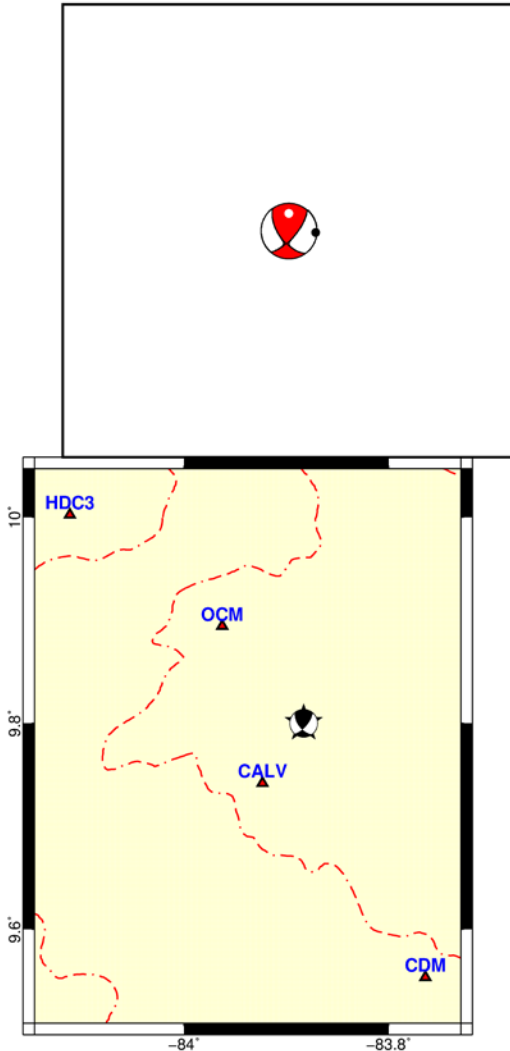
Mrr Mtt Mpp

2.385 3.921 -6.306

Mrt Mrp Mtp

3.075 0.757 -0.346

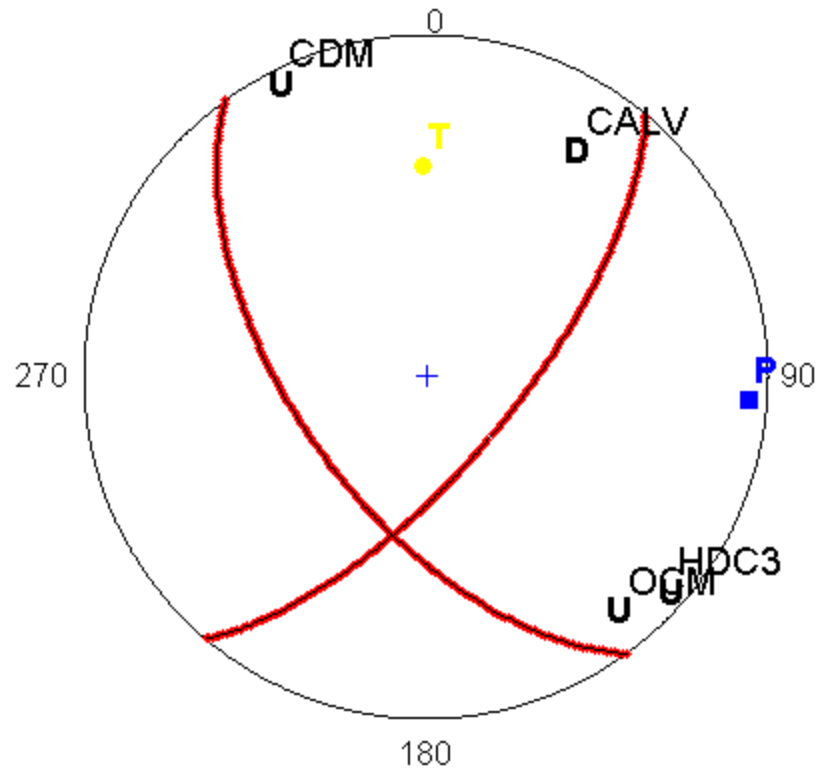
Exponent (Nm): 12



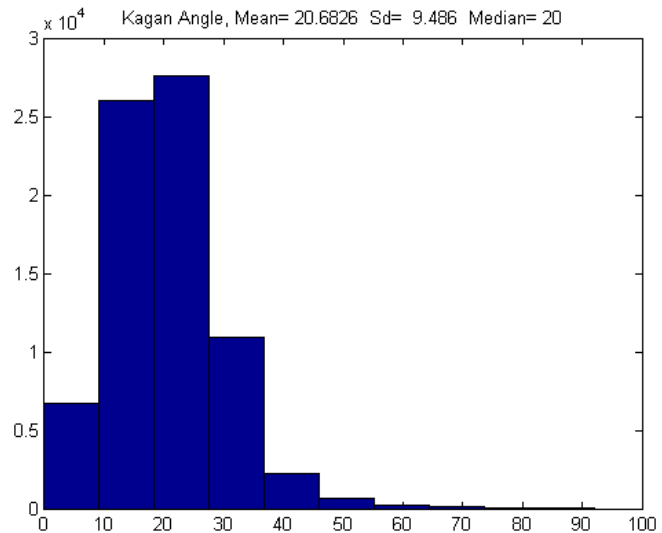
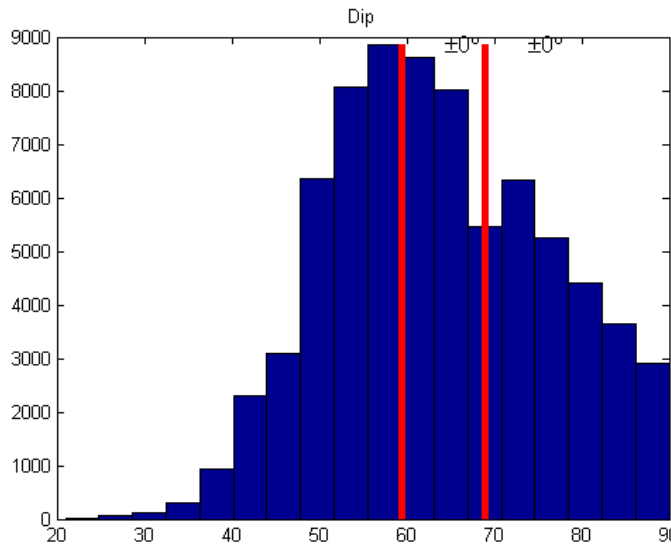
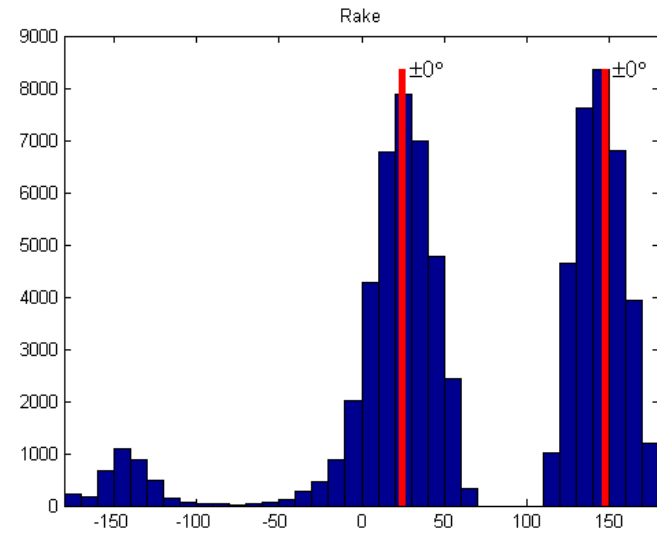
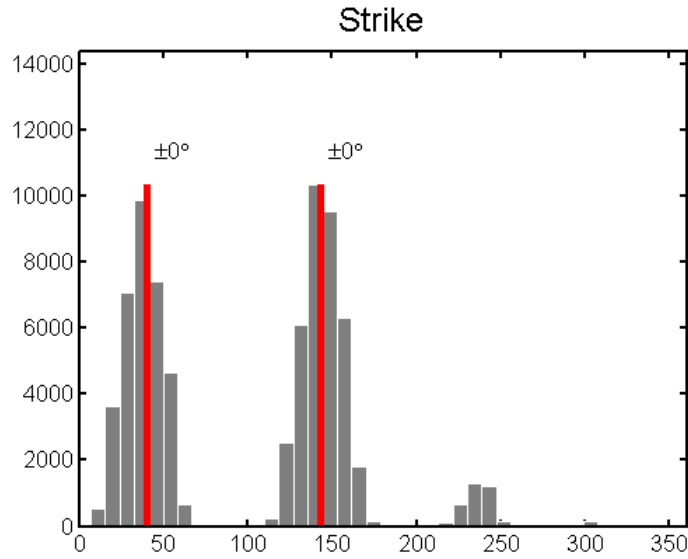
Results – trial 1

Station co-ordinates					
x(N>0,km)	y(E>0,km)	z(km)	azim.	dist.	stat.
-6.4370	-4.4109	0.0000	214.4207	7.8033	CALV D
10.4091	-8.6972	0.0000	320.1200	13.5643	OCM U
-27.2399	13.0975	0.0000	154.3208	30.2251	CDM U
22.3623	-25.0415	0.0000	311.7651	33.5730	HDC3 U

Results – trial 1



Results – trial 1



Results – trial 1



Selected stations – trial 1 (2 stations)

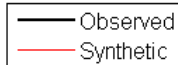
Stations	Components				f1	f2	f3	f4
CALV	<input checked="" type="checkbox"/> Use Station	<input checked="" type="checkbox"/> Use NS	<input checked="" type="checkbox"/> Use EW	<input checked="" type="checkbox"/> Use Z	0.35	0.4	0.6	0.65
OCM	<input checked="" type="checkbox"/> Use Station	<input checked="" type="checkbox"/> Use NS	<input checked="" type="checkbox"/> Use EW	<input checked="" type="checkbox"/> Use Z	0.35	0.4	0.6	0.65
CDM	<input type="checkbox"/> Use Station	<input checked="" type="checkbox"/> Use NS	<input checked="" type="checkbox"/> Use EW	<input checked="" type="checkbox"/> Use Z	0.35	0.4	0.6	0.65
HDC3	<input type="checkbox"/> Use Station	<input checked="" type="checkbox"/> Use NS	<input checked="" type="checkbox"/> Use EW	<input checked="" type="checkbox"/> Use Z	0.35	0.4	0.6	0.65

Results – trial 1 (2 stations)

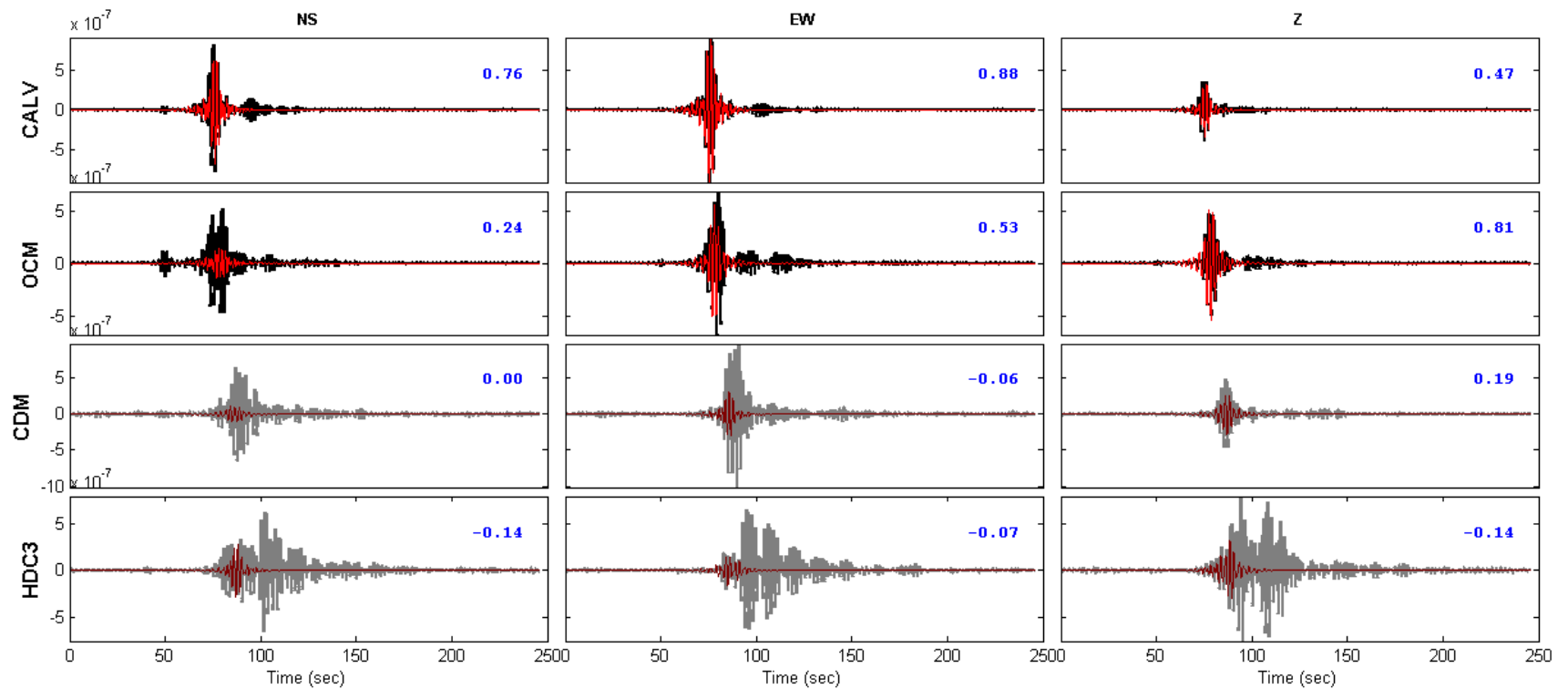
Event date-time: 130608_07_50_31.00

Displacement (m). Inversion band (Hz) 0.35 0.4 0.6 0.65

Gray waveforms weren't used in inversion.



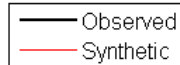
Blue numbers are variance reduction



Results – trial 1 (2 stations)

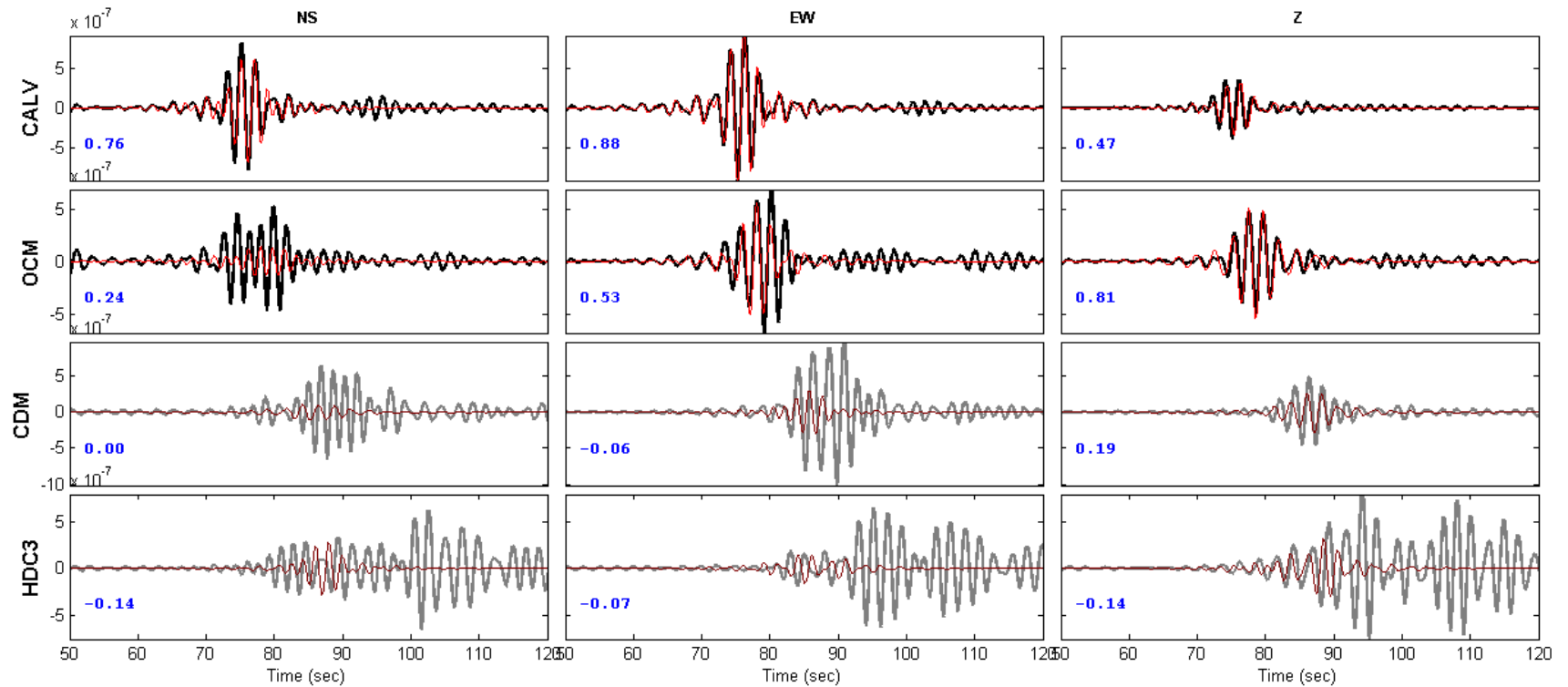
Event date-time: 130608_07_50_31.00

Displacement (m). Inversion band (Hz) 0.35 0.4 0.6 0.65

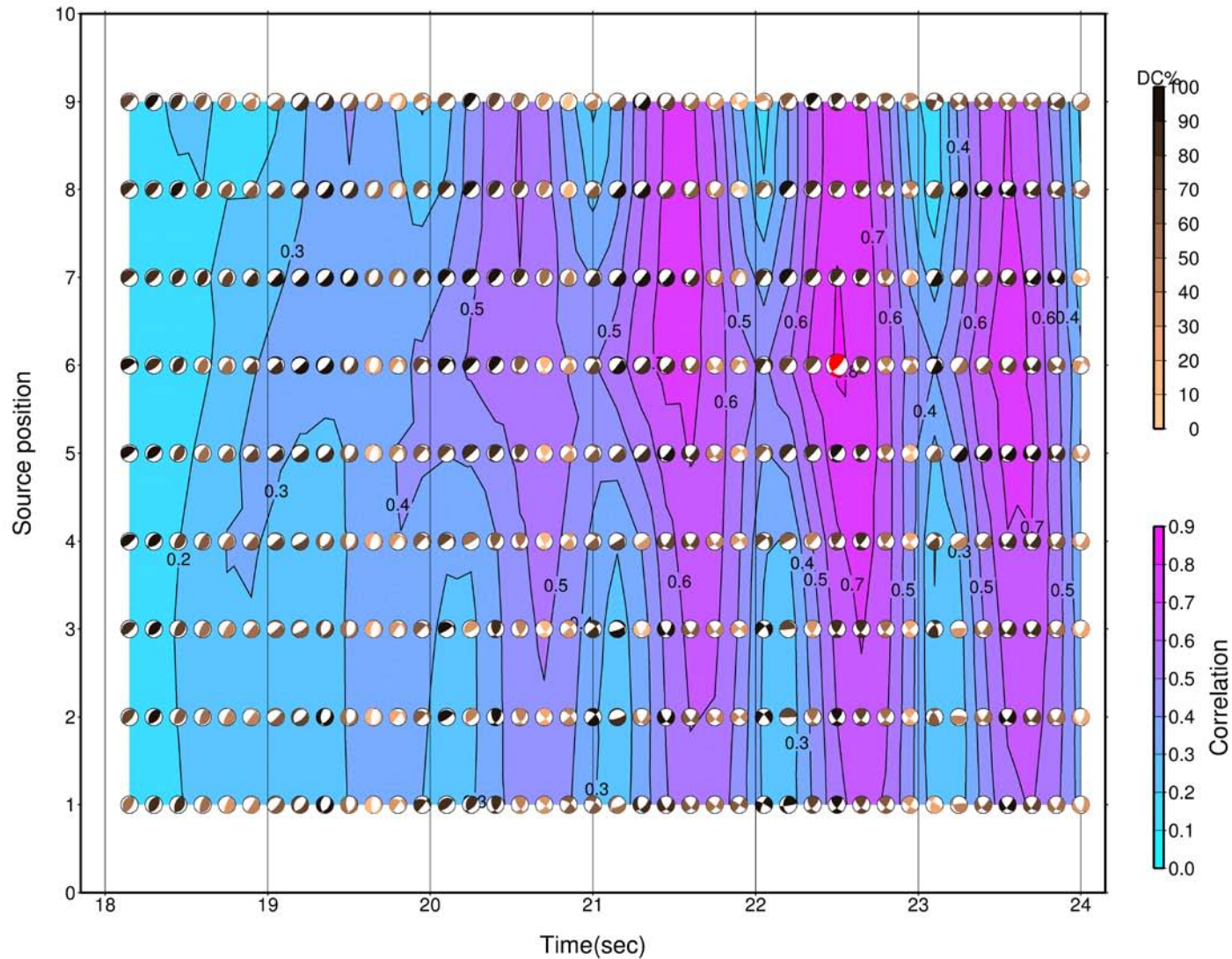


Gray waveforms weren't used in inversion.

Blue numbers are variance reduction



Results – trial 1 (2 stations)



Results – trial 1 (2 stations)

MOMENT TENSOR SOLUTION

HYPOCENTER LOCATION (OVSICORI)

Origin time 20130608 07:50:31.00
Lat 9.8 Lon -83.883 Depth 3

CENTROID

Trial source number : 6 (Fixed Epicenter inversion)
Centroid Lat (N)9.8 Lon (E)-83.883
Centroid Depth (km) : 4
Centroid time : +22.5 (sec) relative to origin time

Moment (Nm) : 7.907e+12

Mw : 2.5

VOL% : 0

DC% : 79.1

CLVD% : 20.9

Var.red.: (for stations used in inversion): 0.66 SNR CN FMVAR STVAR
32 2.6 44±40 0.05

Var.red. (for all stations) : 0.14

Strike	Dip	Rake		Frequency band used in inversion (Hz)
44	77	123		0.35 - 0.4 -- 0.6 - 0.65

Strike	Dip	Rake		Stations-Components Used-Distance
153	35	22		

				NS EW Z D(km)
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P-axis Azimuth Plunge		CALV + + + 8
		OCM + + + 14
T-axis Azimuth Plunge		CDM - - - 30
		HDC3 - - - 34

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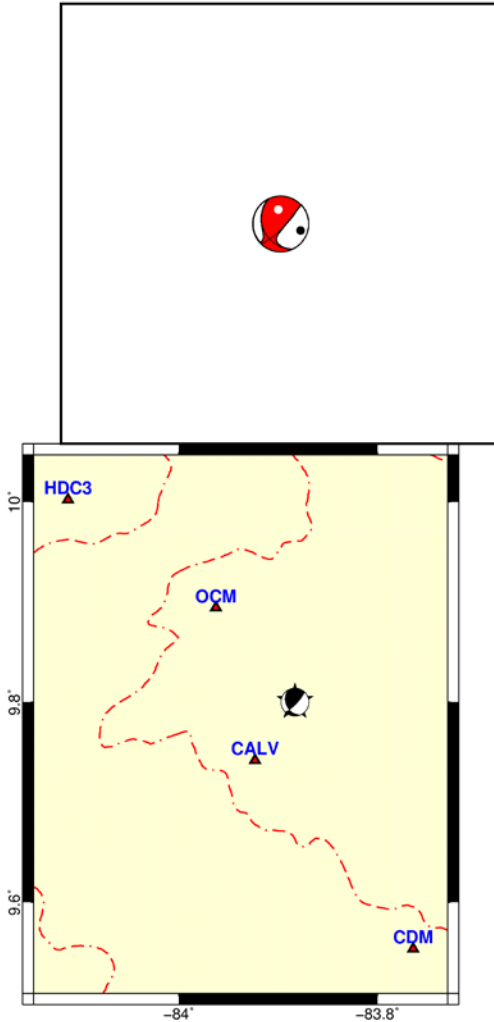
Mrr	Mtt	Mpp
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2.764	3.018	-5.782
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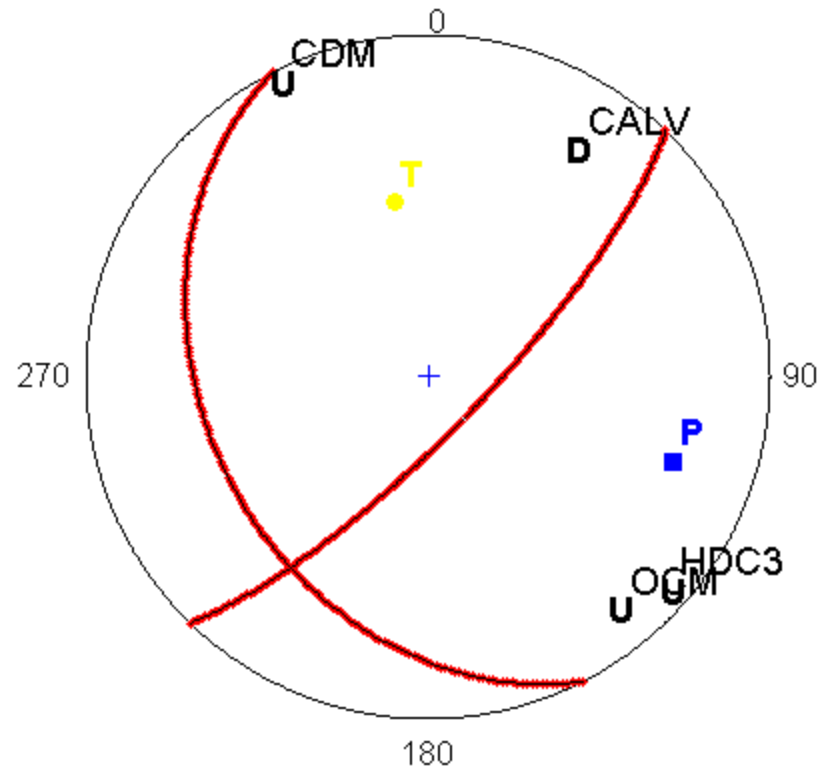
Mrt	Mrp	Mtp
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4.346	3.938	-1.737
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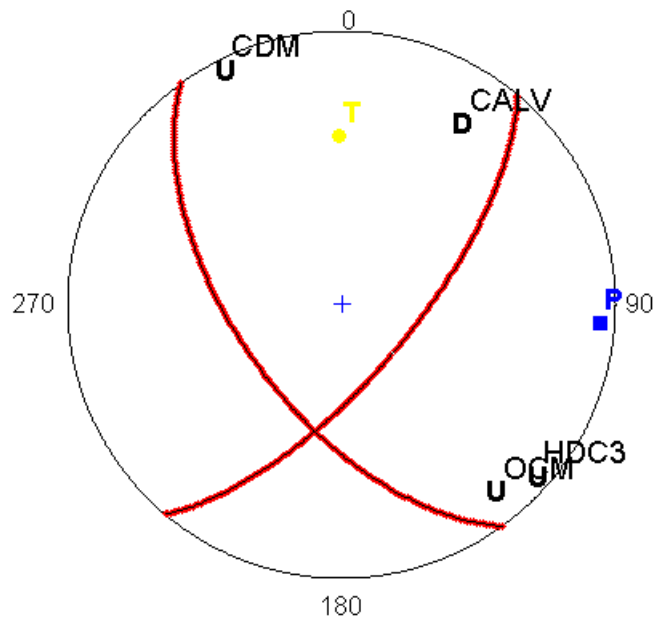
Exponent (Nm): 12



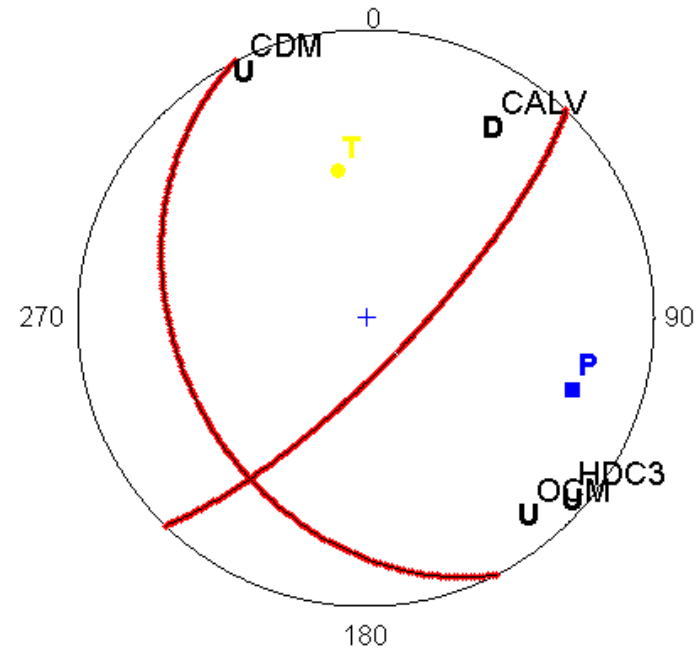
Results – trial 1 (2 stations)



Results – trial 1 (2 stations)



4 stations

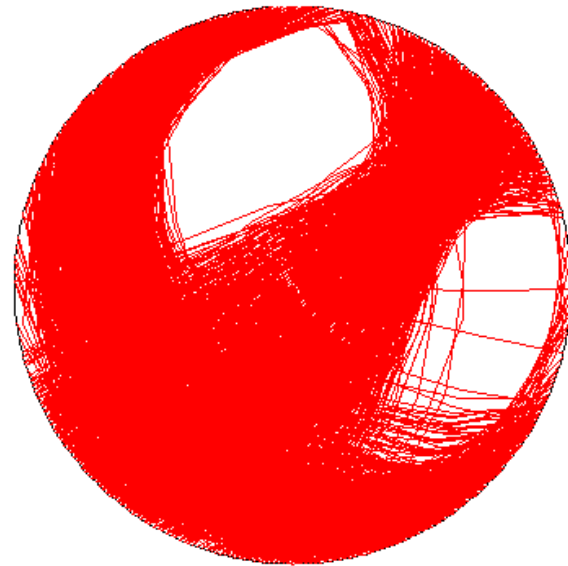


2 stations

Results – trial 1 (2 stations)

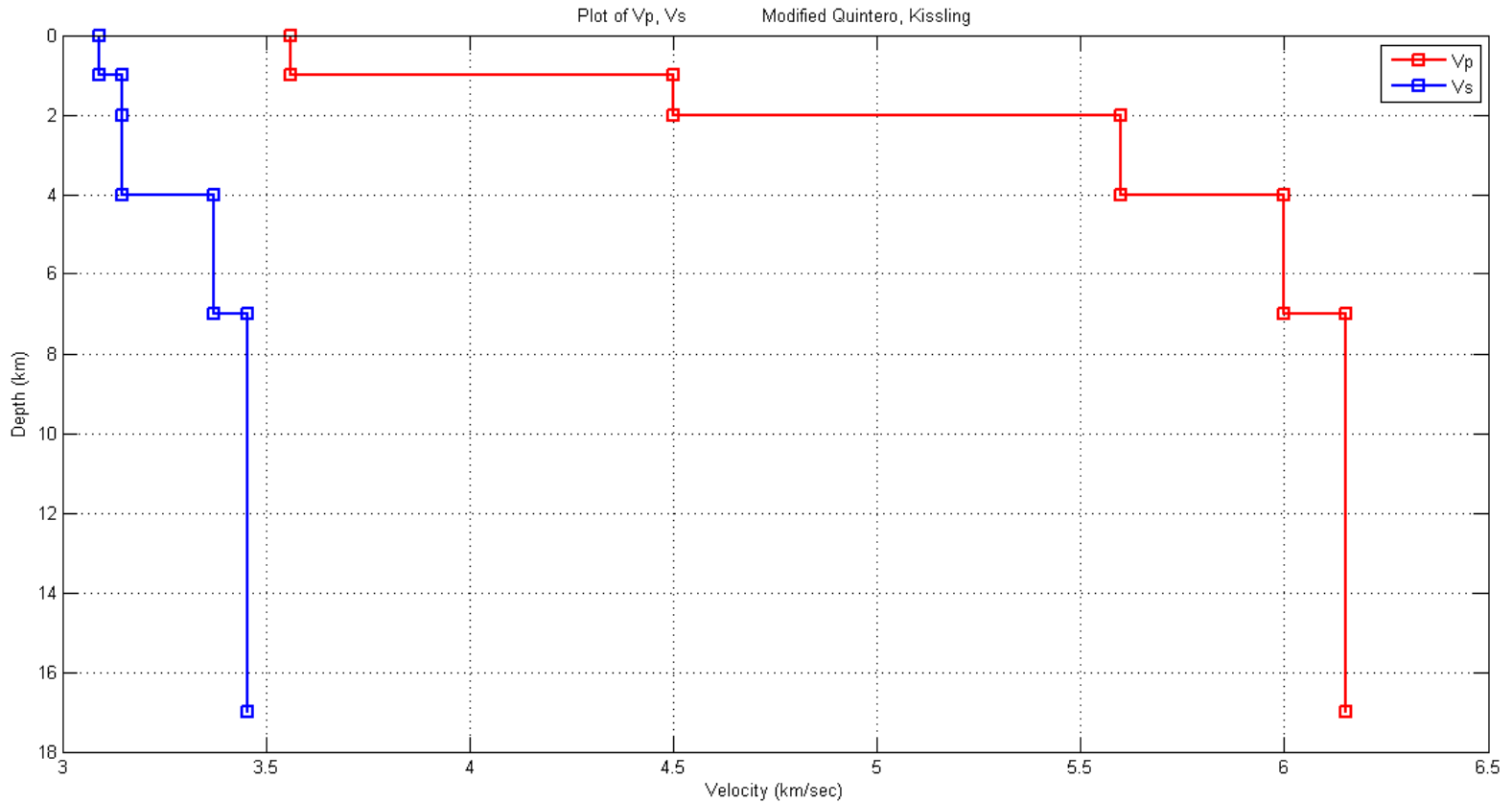


4 stations



2 stations

Velocity model – trial 2

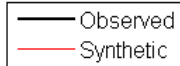


Results – trial 2

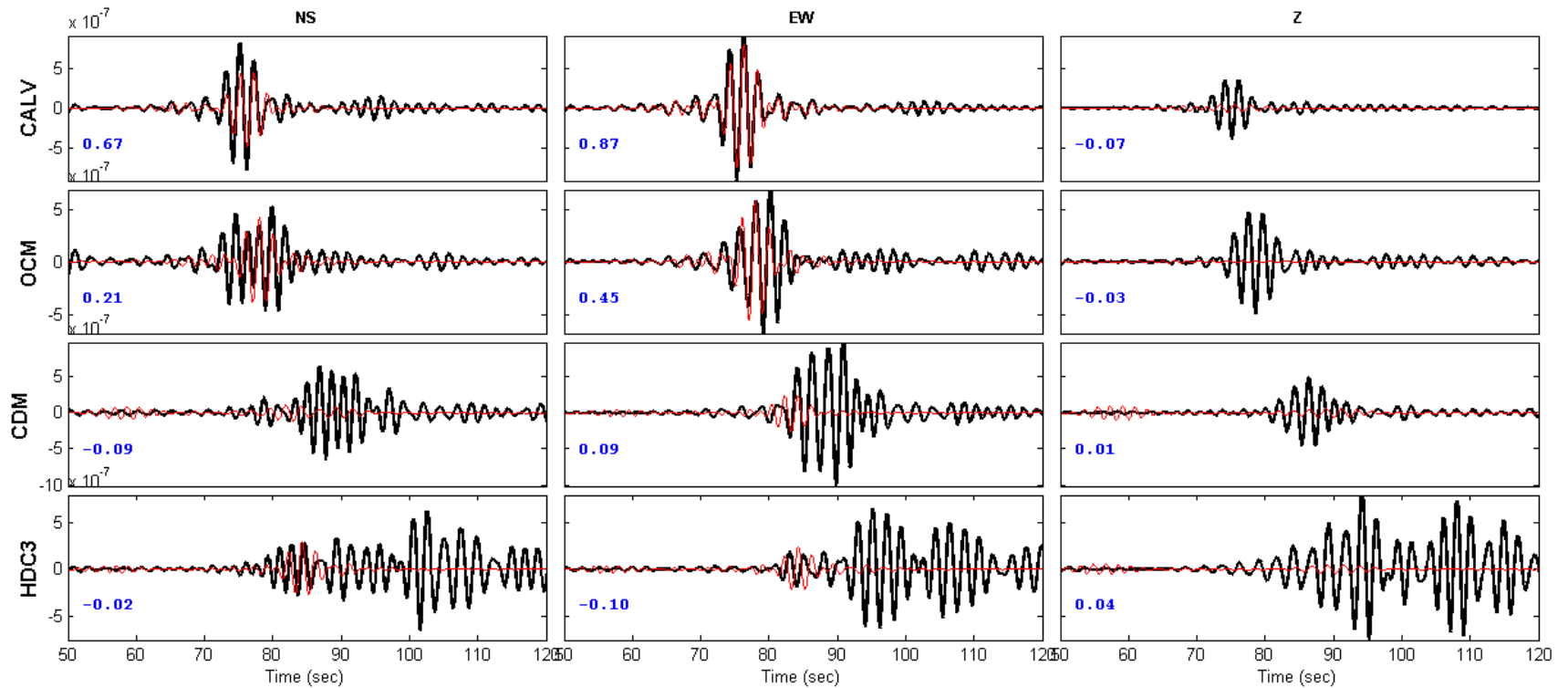
Event date-time: 130608_07_50_31.00

Displacement (m). Inversion band (Hz) 0.35 0.4 0.6 0.65

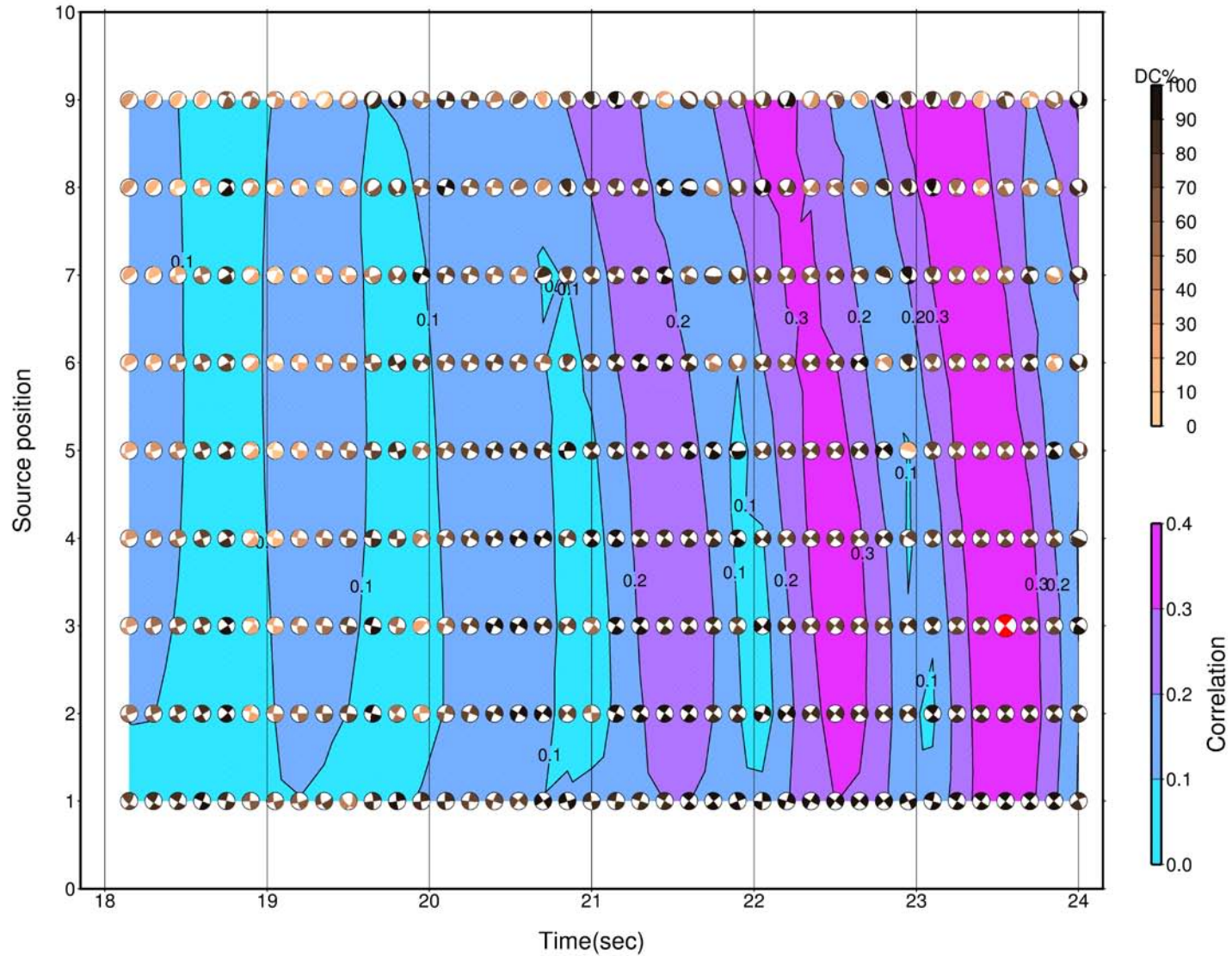
Gray waveforms weren't used in inversion.



Blue numbers are variance reduction



Results – trial 2



Results – trial 2

MOMENT TENSOR SOLUTION

HYPOCENTER LOCATION (OVSICORI)

Origin time 20130608 07:50:31.00
Lat 9.8 Lon -83.883 Depth 3

CENTROID

Trial source number : 3 (Fixed Epicenter inversion)
Centroid Lat (N) 9.8 Lon (E) -83.883
Centroid Depth (km) : 2.5
Centroid time : +23.55 (sec) relative to origin time

Moment (Nm) : 1.005e+13

Mw : 2.6

VOL% : 0

DC% : 73.7

CLVD% : 26.3

Var.red.: (for stations used in inversion): 0.15 SNR CN FMVAR STVAR
NaN 5.1 17±23 0.04

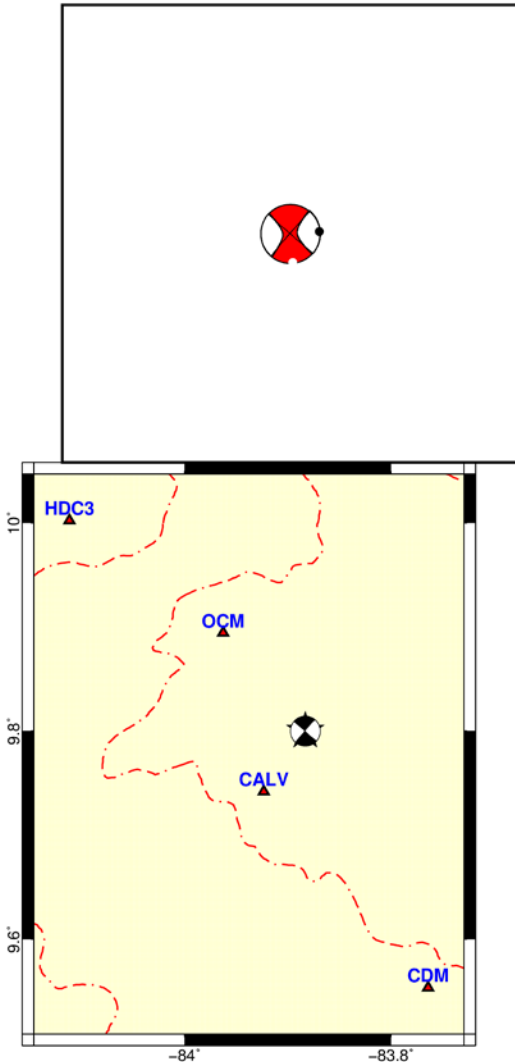
Var.red. (for all stations) : 0.15

Strike Dip Rake | Frequency band used in inversion (Hz)
221 88 -179 | 0.35 - 0.4 -- 0.6 - 0.65

Strike Dip Rake |
131 89 -2 | Stations-Components Used-Distance

----- | NS EW Z D(km)
P-axis Azimuth Plunge | CALV + + + 8
86 2 | OCM + + + 14
T-axis Azimuth Plunge | CDM + + + 30
176 1 | HDC3 + + + 34

Mrr Mtt Mpp
0.139 0.919 -1.058
Mrt Mrp Mtp
-0.011 0.041 0.125
Exponent (Nm): 13



Results – trial 2 (2 stations)

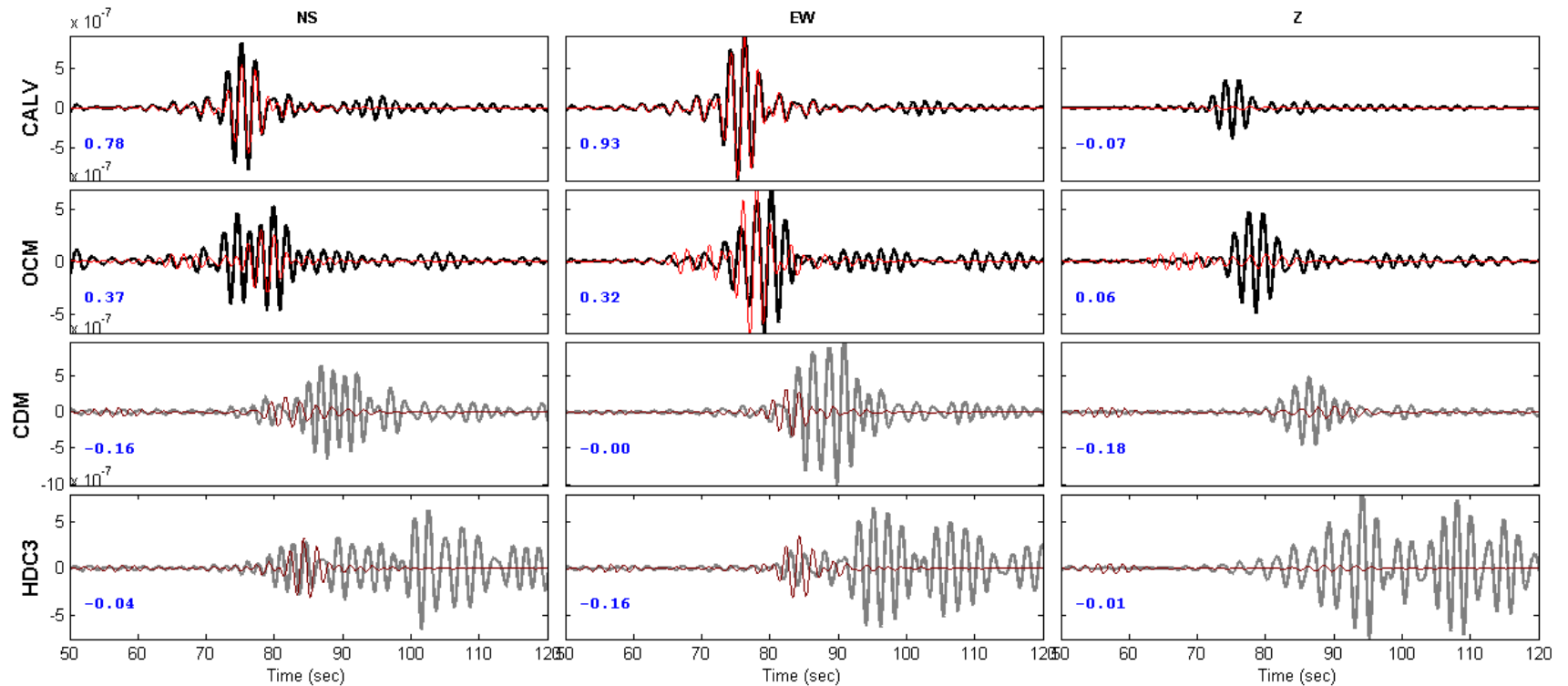
Event date-time: 130608_07_50_31.00

Displacement (m). Inversion band (Hz) 0.35 0.4 0.6 0.65

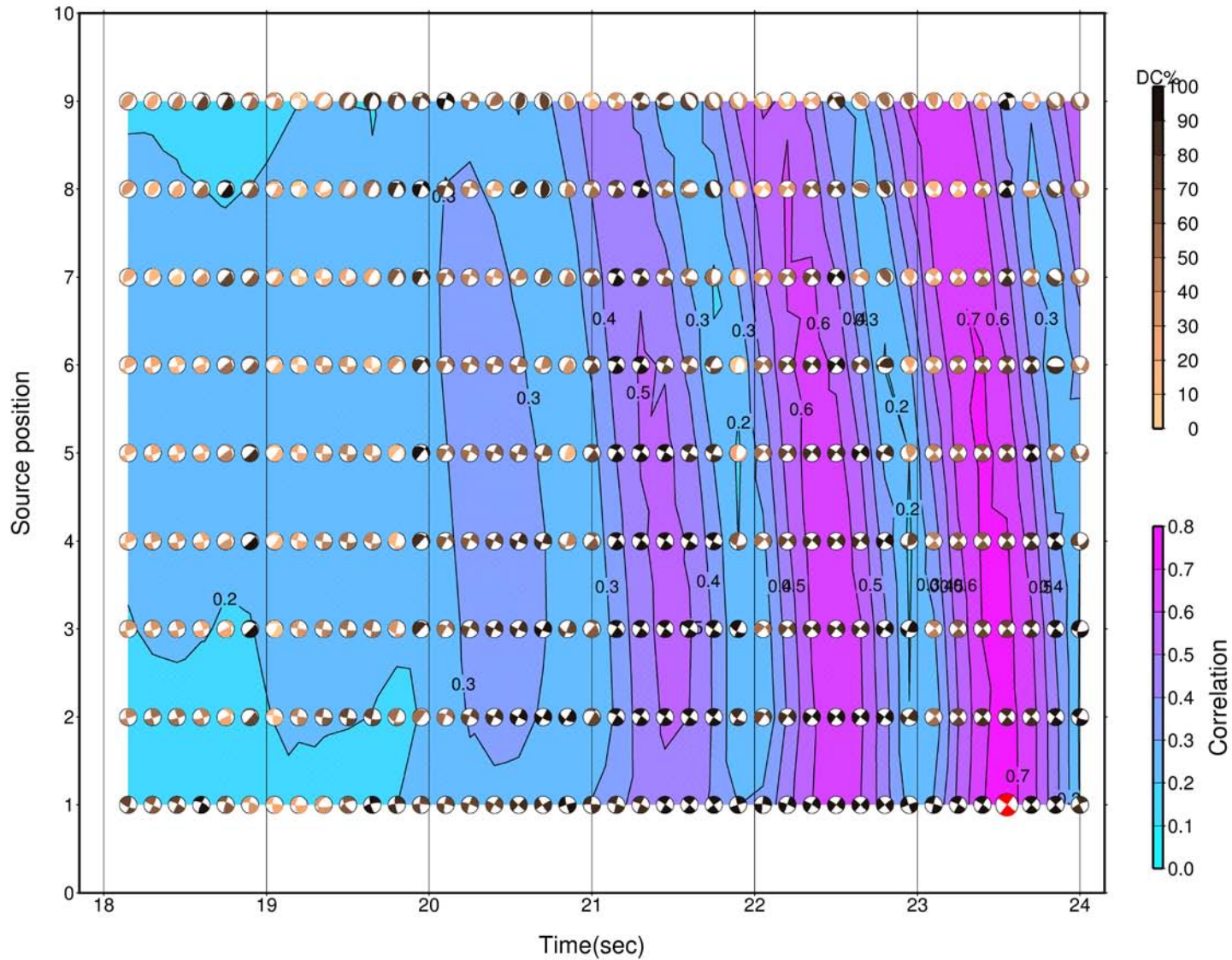
— Observed
— Synthetic

Gray waveforms weren't used in inversion.

Blue numbers are variance reduction



Results – trial 2 (2 stations)



Results – trial 2 (2 stations)

MOMENT TENSOR SOLUTION

HYPOCENTER LOCATION (OVSICORI)

Origin time 20130608 07:50:31.00
 Lat 9.8 Lon -83.883 Depth 3

CENTROID

Trial source number : 1 (Fixed Epicenter inversion)
 Centroid Lat (N) 9.8 Lon (E) -83.883
 Centroid Depth (km) : 1.5
 Centroid time : +23.55 (sec) relative to origin time

Moment (Nm) : 1.108e+13

Mw : 2.6

VOL% : 0

DC% : 99.8

CLVD% : 0.2

Var.red.:(for stations used in inversion):0.55

SNR CN FMVAR STVAR
 NaN 6.3 19±30 0.05

Var.red.(for all stations) : 0.12

Strike	Dip	Rake		Frequency band used in inversion (Hz)
38	90	-177		0.35 - 0.4 -- 0.6 - 0.65

Strike	Dip	Rake		Stations-Components Used-Distance
308	87	0		

				NS EW Z D(km)
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P-axis Azimuth Plunge		CALV	+	+	+	8
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263 3		OCM	+	+	+	14
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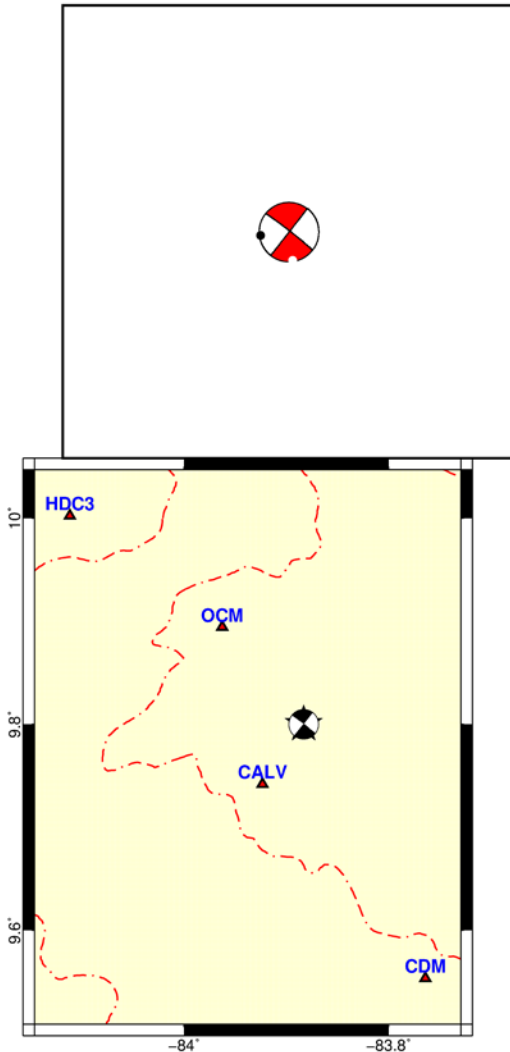
T-axis Azimuth Plunge		CDM	-	-	-	30
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173 2		HDC3	-	-	-	34
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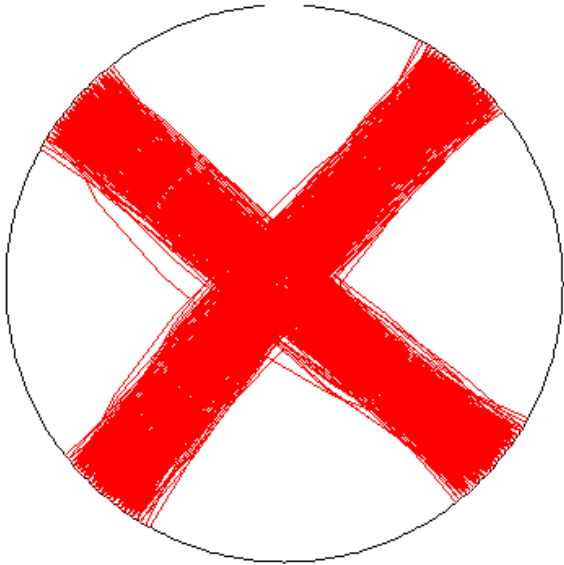
Mrr	Mtt	Mpp
0.000	1.073	-1.074

Mrt	Mrp	Mtp
-0.032	-0.053	0.268

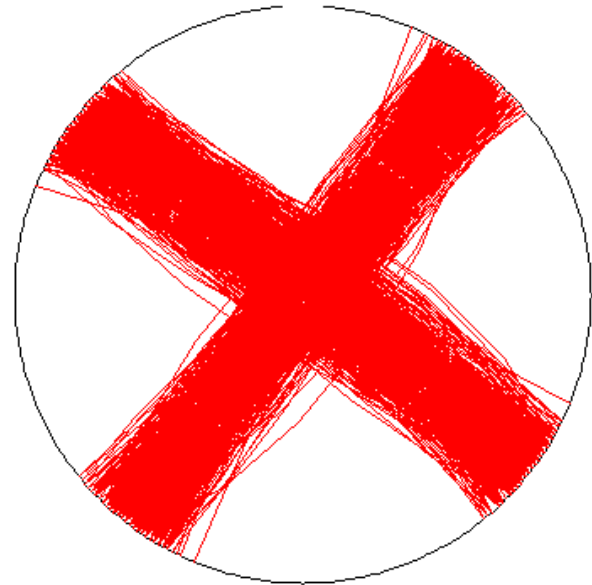
Exponent (Nm): 13



Results – trial 2 (2 stations)



4 stations



2 stations

Conclusions

- Full waveform inversion for moment tensor calculation for frequency range between 0.4 and 0.6 Hz and shallow events is highly sensitive to the seismic velocity model
- Velocity models should not be neglected
- A precise model velocity must be determined prior to the moment tensor parameters assessment