Romanian Seismic Network

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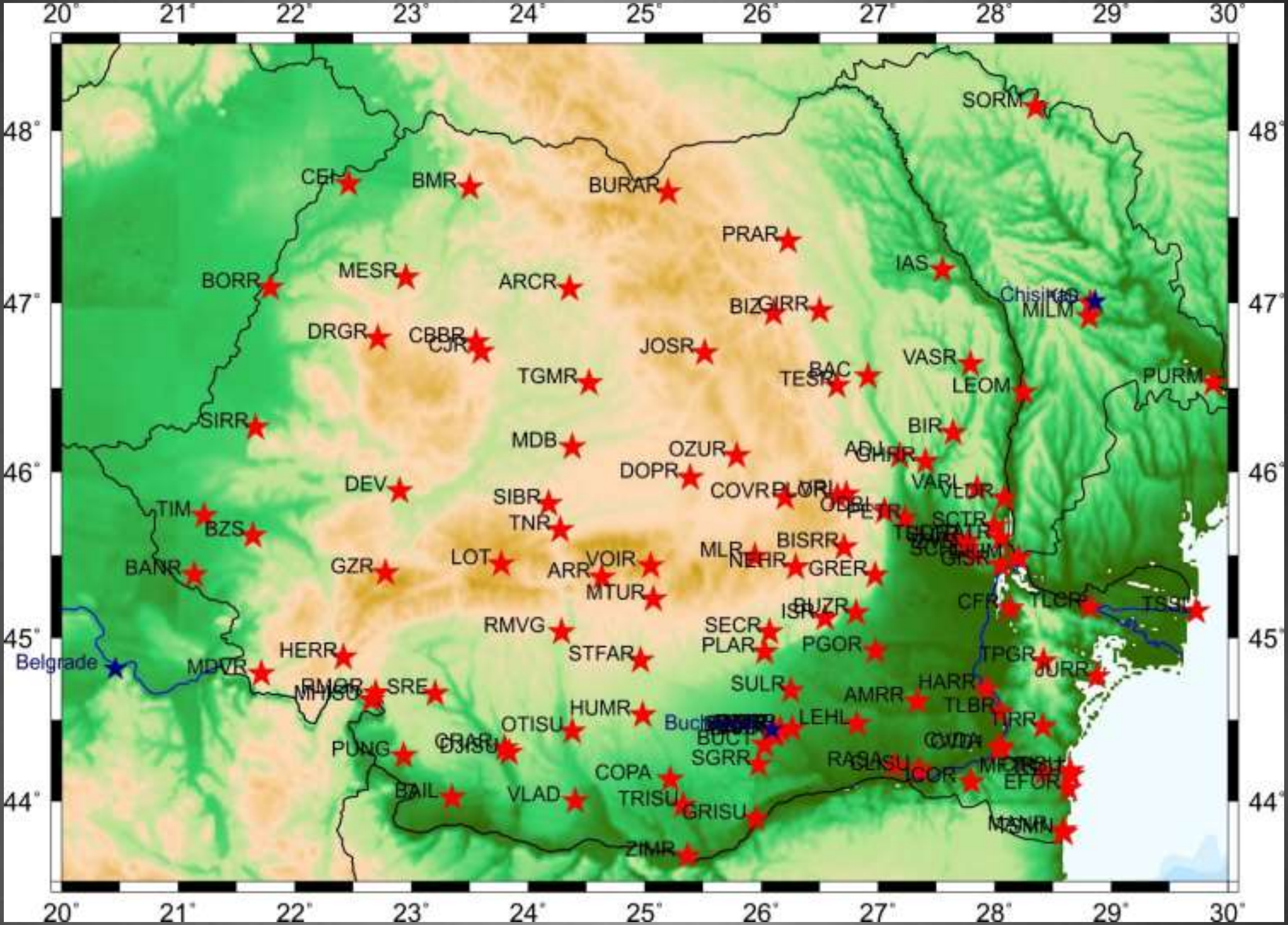
Romanian Seismic Network

- The main seismic survey of Romania is performed by the National Institute for Earth Physics (NIEP).

- The National Institute for Earth Physics operates a real-time digital seismic network.

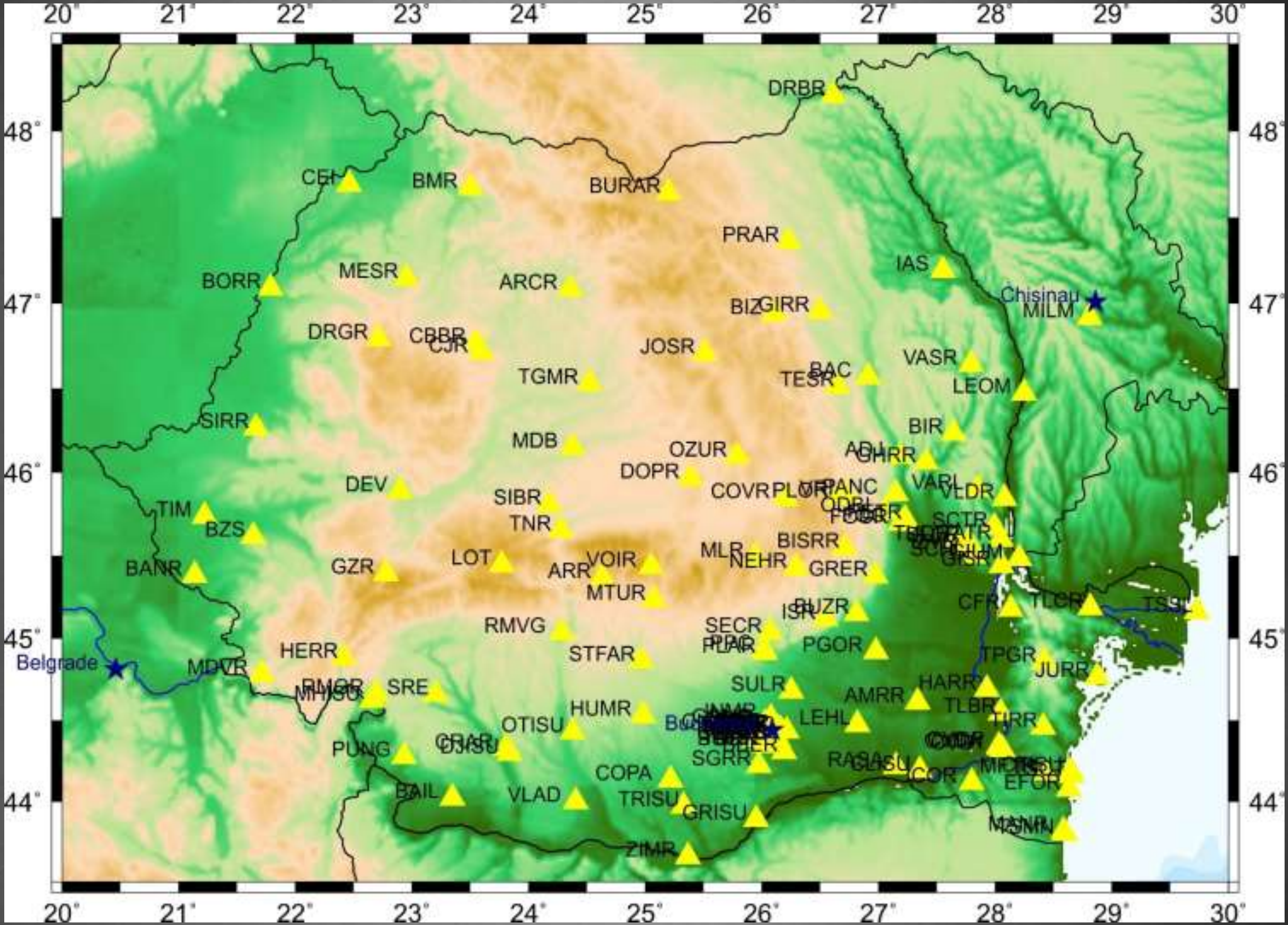
- The network has digital seismic stations equipped with different high quality digitizers (Kinemetrics K2, Quanterra Q330, Quanterra Q330HR, PS6-26, Basalt), broadband and short period seismometers (CMG3ESP, CMG40T, KS2000, KS54000, KS2000, CMG3T, STS2, SH-1, S13, Mark L4c, Ranger, GS21, Mark L22) and acceleration sensors Episensor Kinemetrics.

Romanian Seismic Network



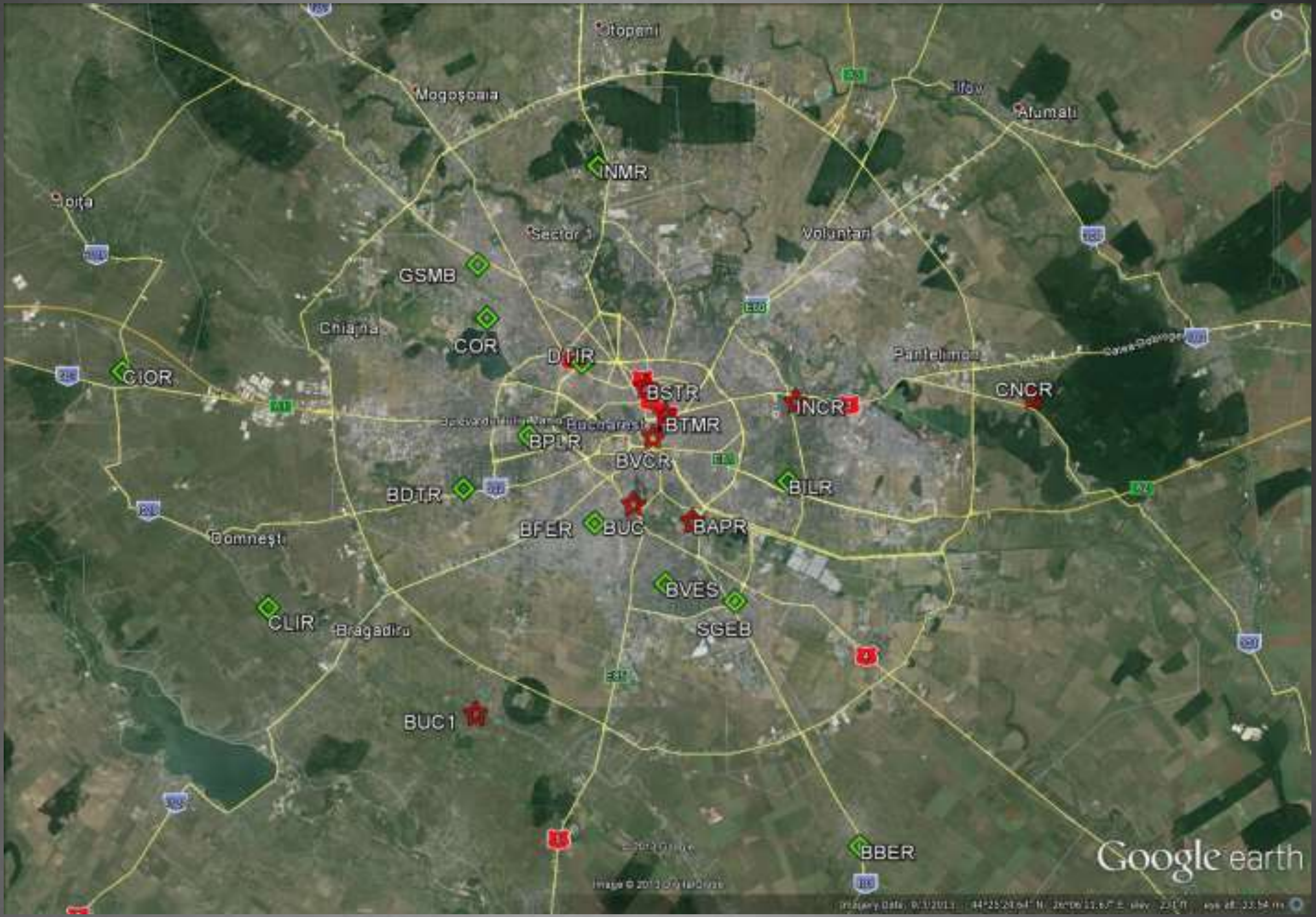
Real time Seismic Network **-** currently consists of 115 stations and two seismic arrays.

Romanian Seismic Network



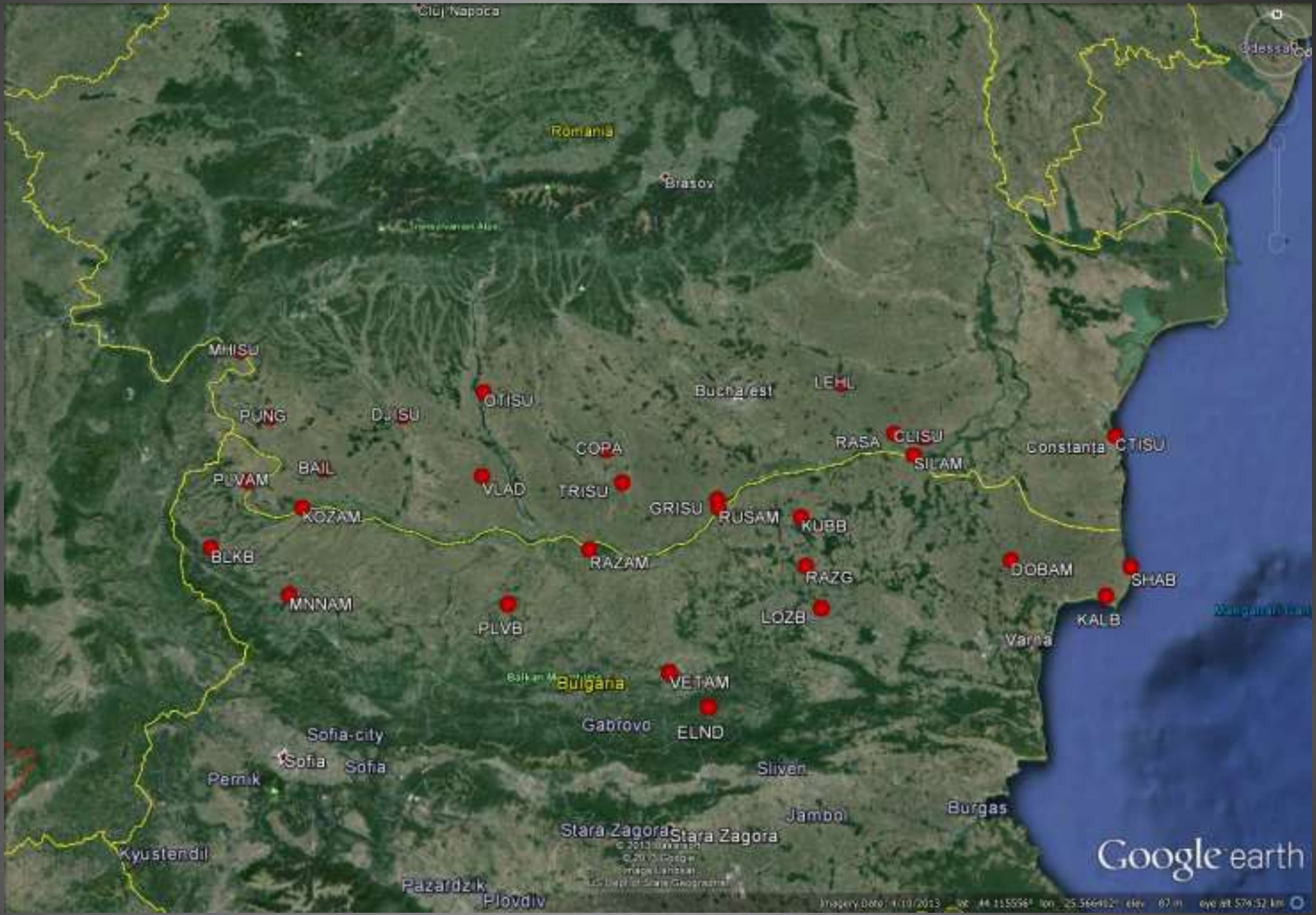
- 132 ***strong motion stations*** using – accelerometers (EpiSensor)

Romanian Seismic Network



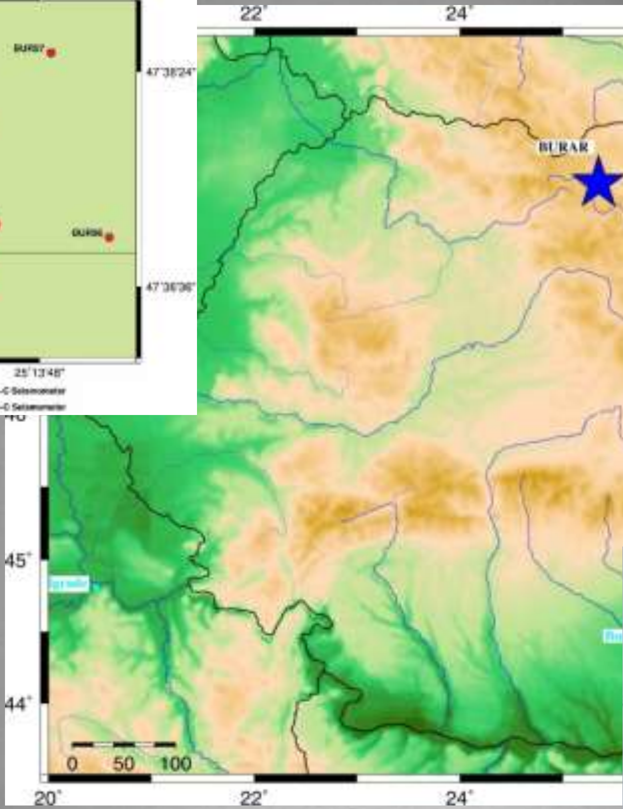
NIEP operates in Bucharest 23 stations: eight of them are in real time (red stars)

Romanian Seismic Network



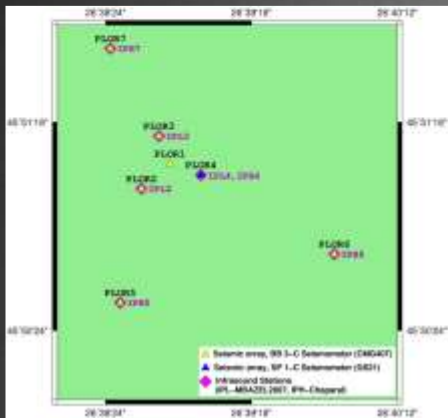
During DACEA project 29 seismic stations were installed

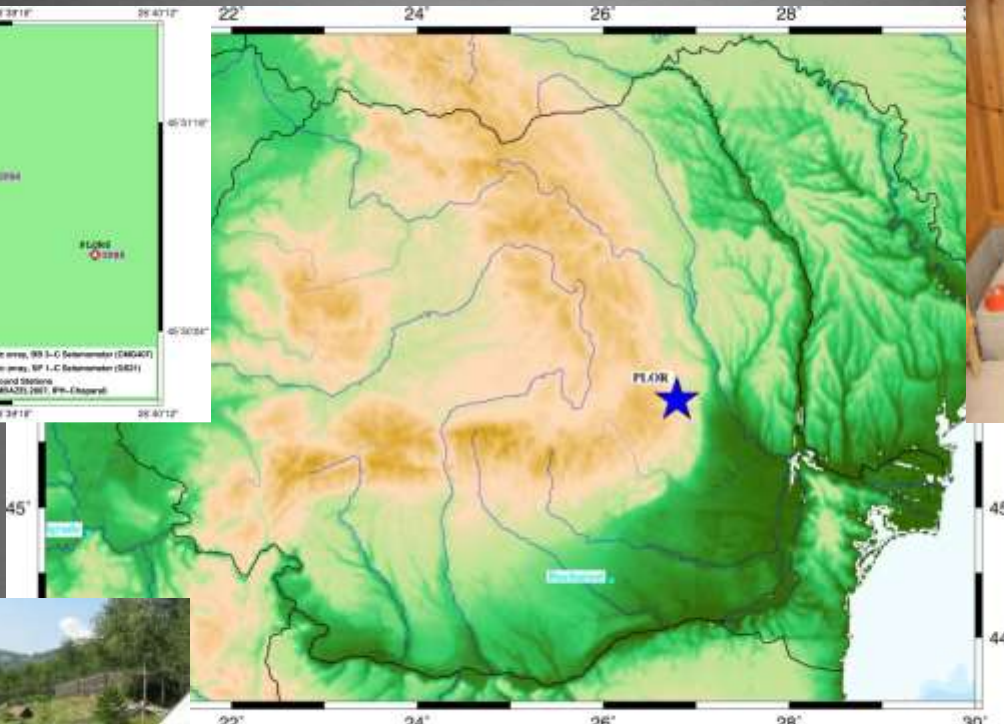
Romanian Seismic Network - Bucovina Array



- The array elements are distributed on an area of 25 square km.
- The Burar Array has 6 broadband sensors, 9 short period sensors and one accelerometer.
- The data from this sensors are transmitted in real time to the National Data Center.

Romanian Seismic Network - Plostina Array



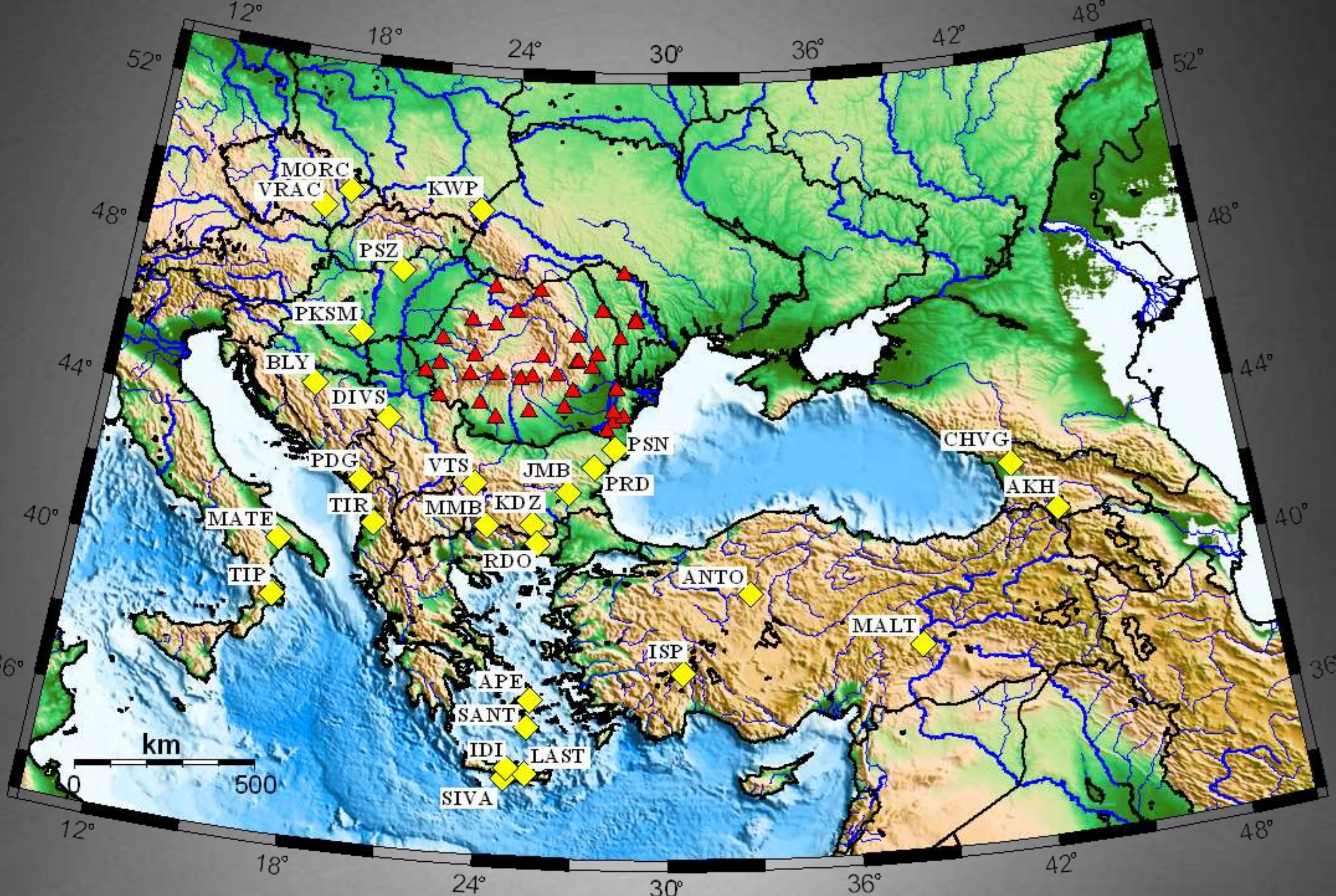


- A seismic array of 7 broadband sensors (yellow triangle)
- distributed on an area of 2 square km
- A short period sensor (blue triangle)
- An infrasound array with 7 elements (purple diamond)
- A GPS station
- In october 2011 a proton processor magnetometer was installed.
- The data from the seismic array and the infrasound stations are transmitted in real time to NDC

Romanian Seismic Network – Seismological Observatories

Romanian network has 8 observatories all around the country, Dobrogea Observatory is the back-up for the NDC and also a monitoring center for Black Sea tsunami events.

Romanian Seismic Network –Data Exchange



Data recorded by RSN, together with real time seismic data from several European stations (Bulgaria, Czech Republic, Greece, Hungary, Italy, Russia, Turkey, Georgia), are sent to the ROM NDC, in Magurele.

Romanian Seismic Network – Data processing

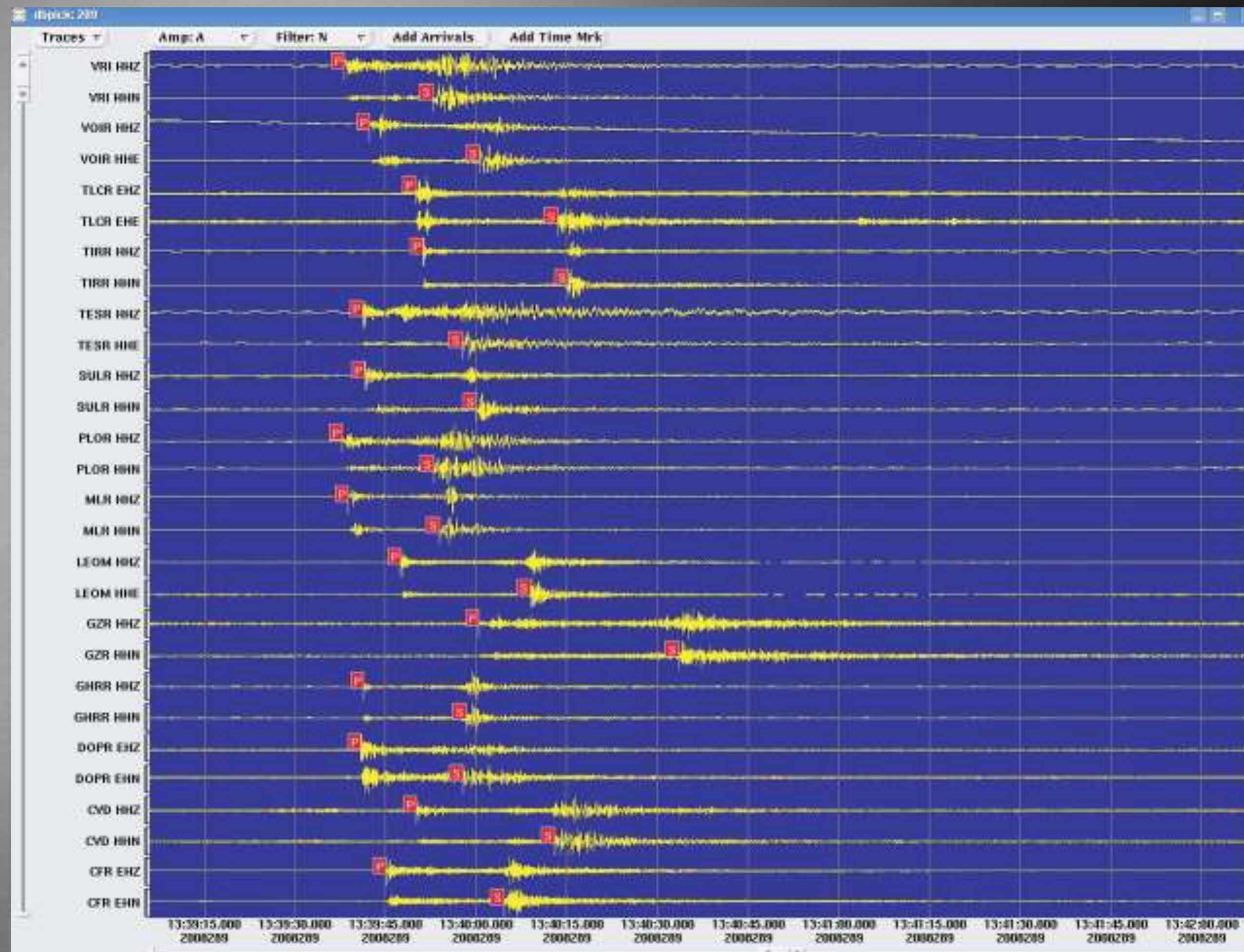
Software Antelope 5.5

Automatic processing:

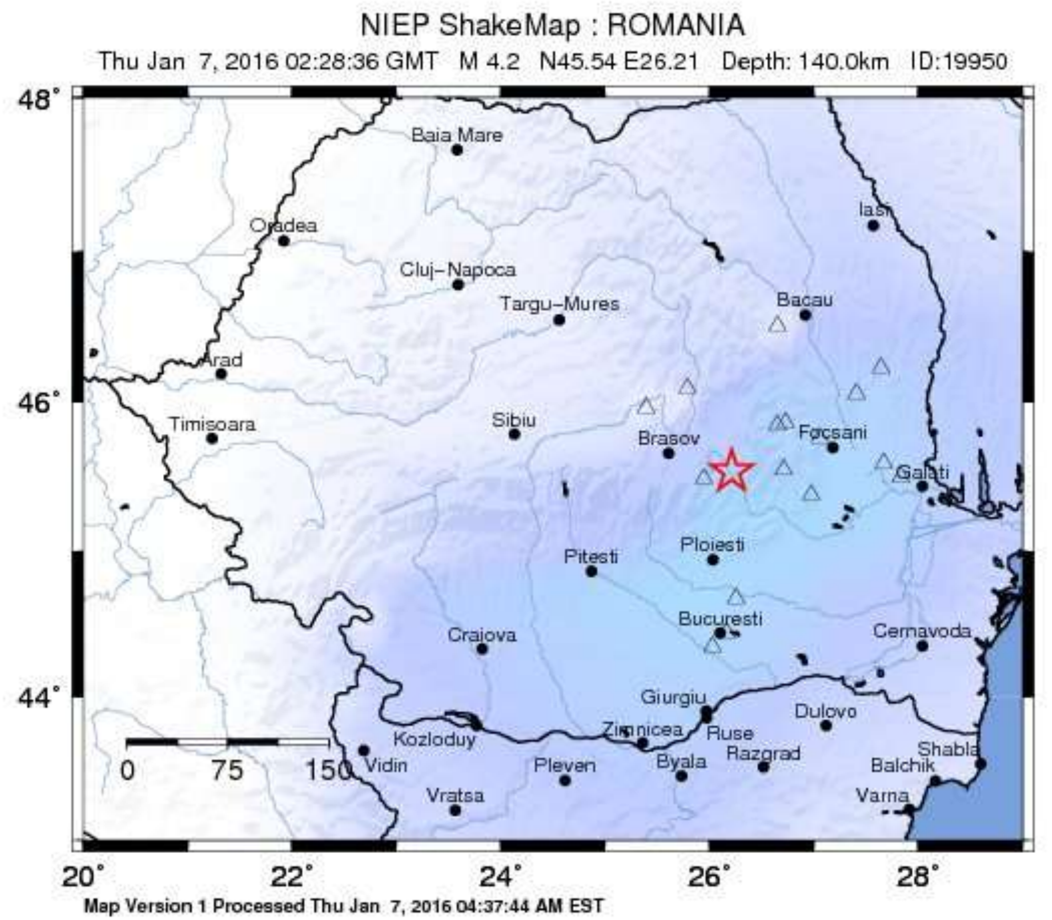
- P-wave picking
- event association
- event location
- magnitude estimation
- sending e-mail / SMS alerts

Manual processing:

- phase picking
- event association
- magnitude estimation
- creation of database
- sending reports/ bulletins

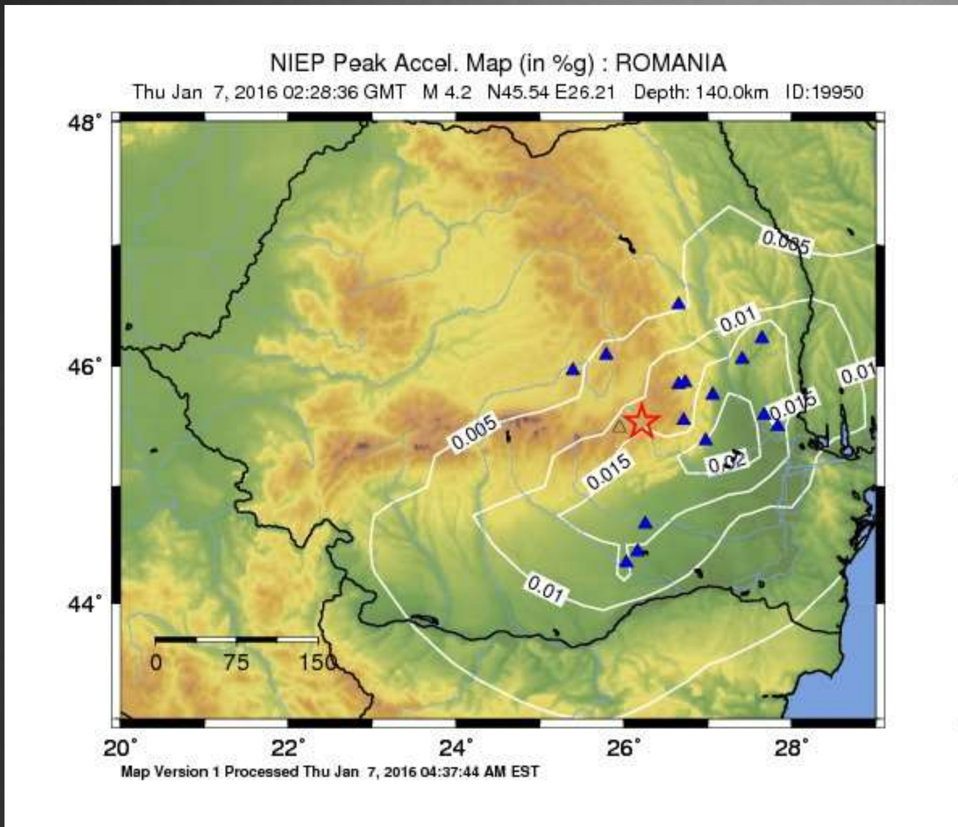


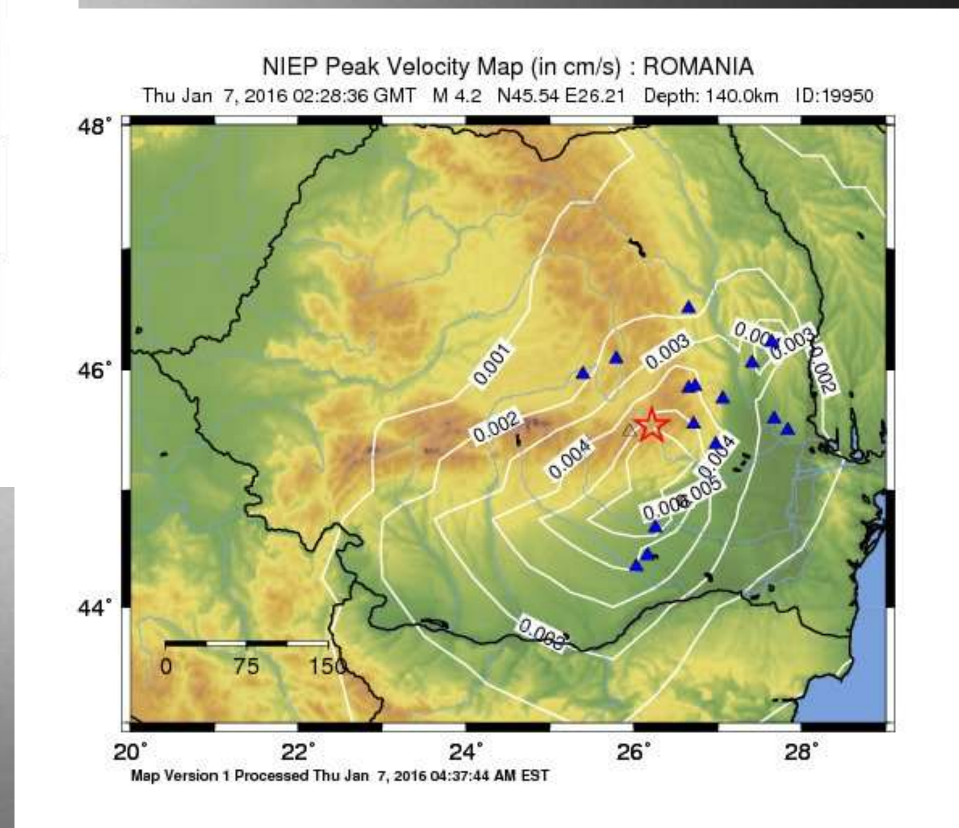
Antelope Products



PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Antelope Products

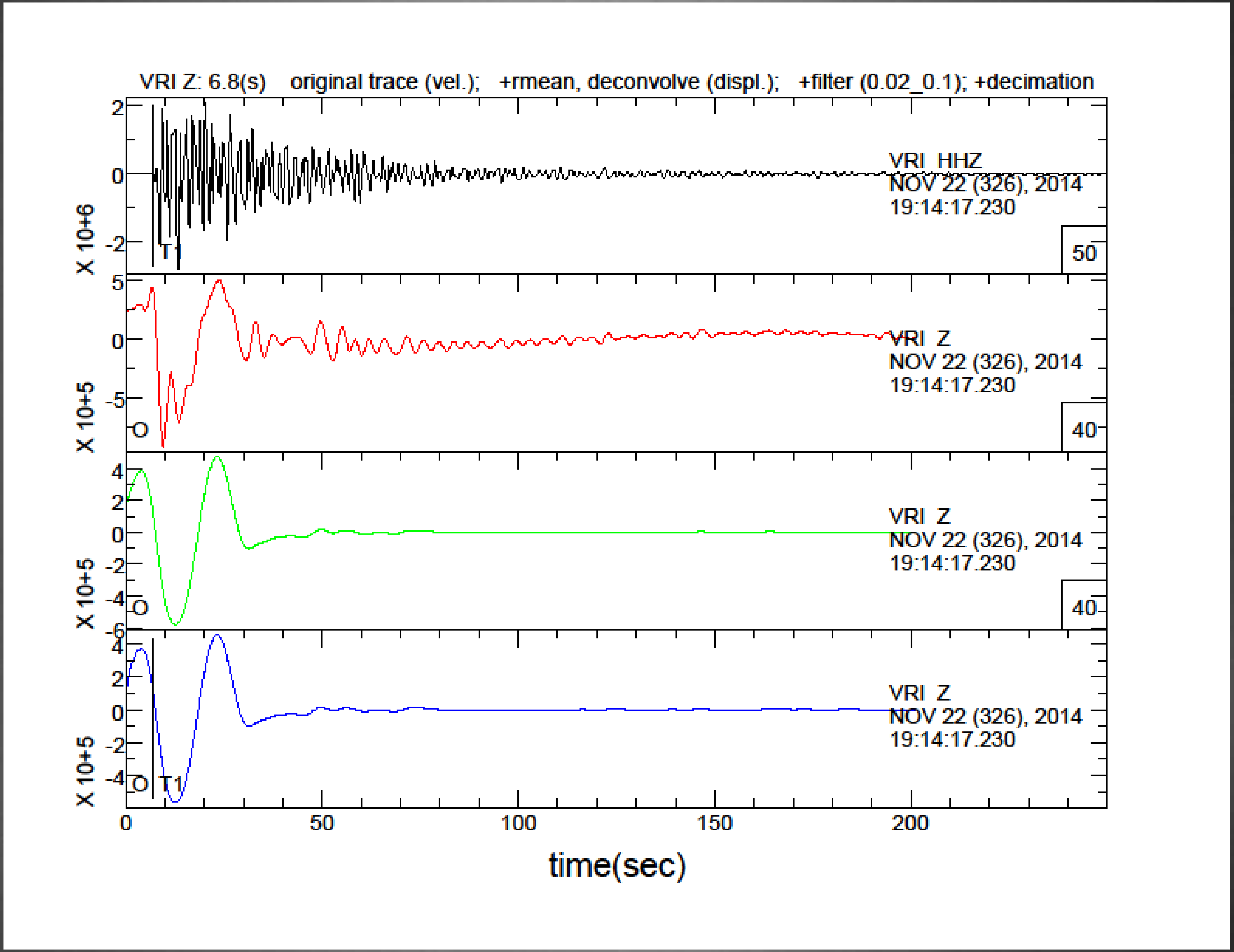




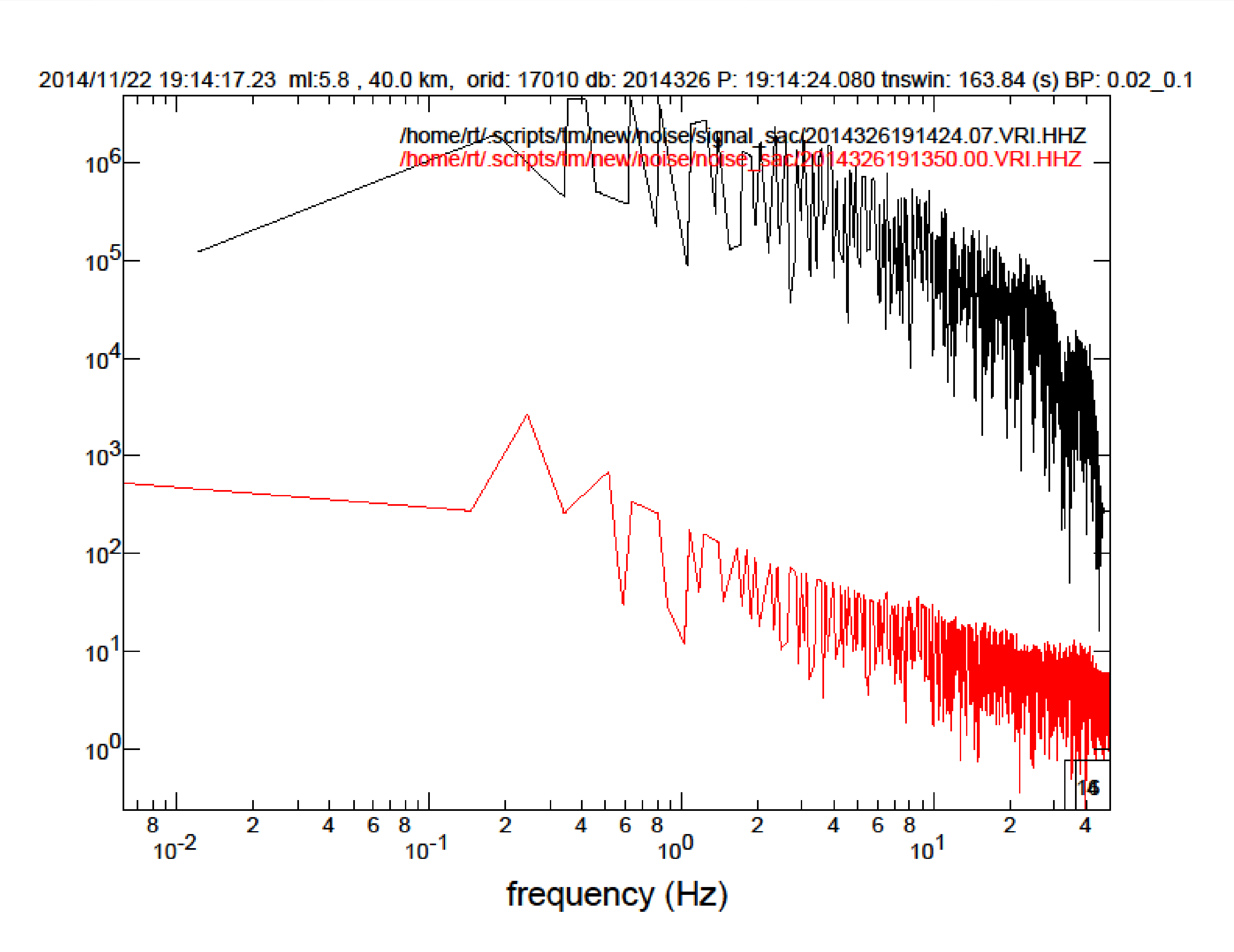
Moment tensor inversion

- SAC – rmean, rtrend, deconvolve,filter (BP 0.02-0.1), decimate, rotate to ZRT
- Assemble SAC files into an Antelope db : orid 1, datatype as, 3 channels/file
- Prepare velocity model files
- Run dbmoment

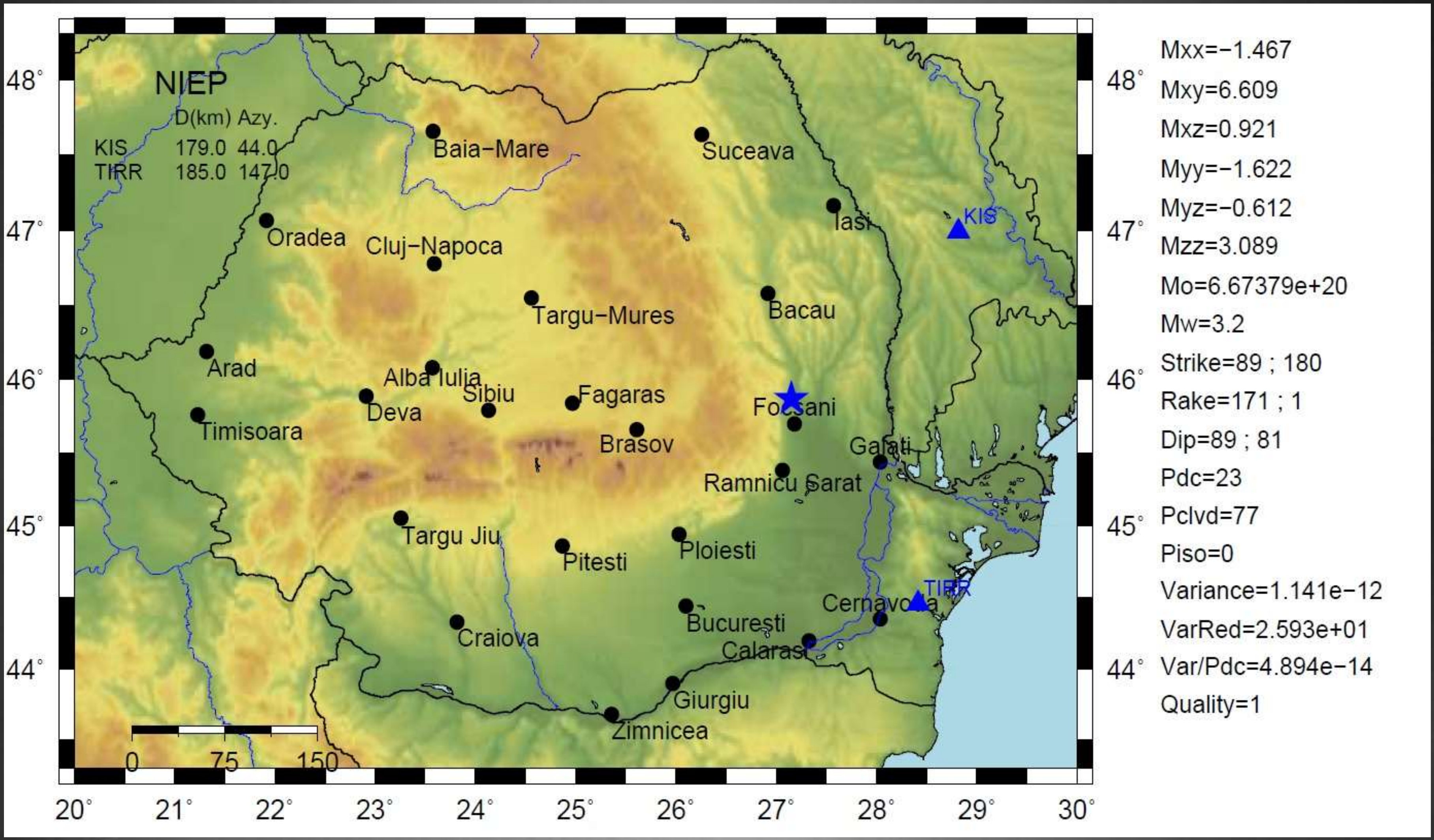
Monitoring waveform processing phases



Monitoring channels noise

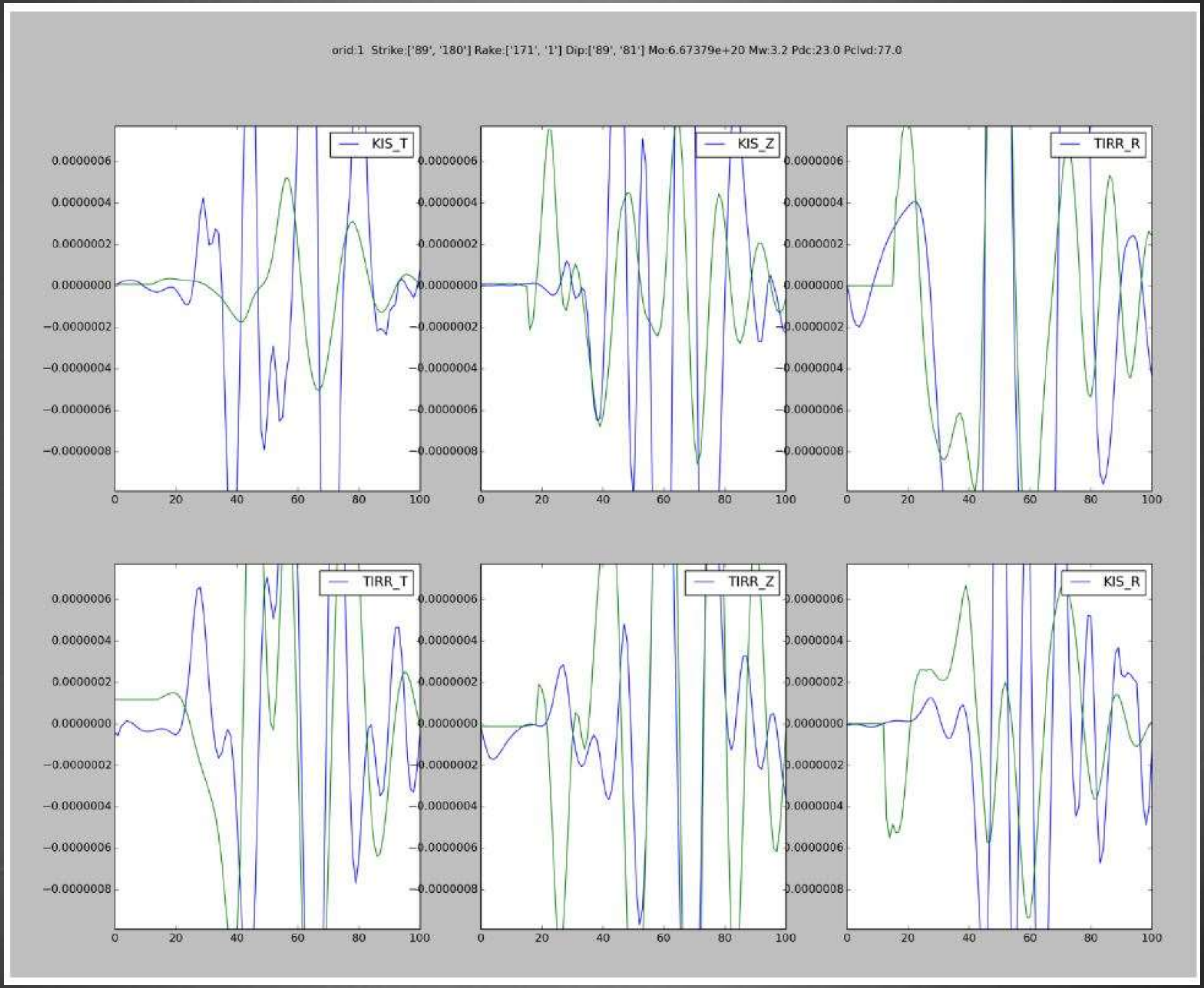


Antelope Products



KIS R=179.0km AZI=44.0 W=1.000 Zcor=11
TIRR R=185.0km AZI=147.0 W=1.034 Zcor=14

Antelope Products



Moment magnitude estimation for local events

Dbmw - Antelope contrib

- ***Acquisition:*** data retrieval from seismic stations and their writing to a digital data base;
- ***Processing:*** locates events, calculates the local magnitude and send this information on the website, SMS and email;
- ***Archiving:*** stores in a database all data retrieved from the seismic monitoring network and the parameters calculated by the software.

Method used to determinate Mw

(Andrews, 1986)

Spectral amplitude at receiver

$$A(f) = D(f)E(f)G(R)$$

Brune (1970) source spectrum

$$D(f) = \frac{M_0}{4\pi k \rho v^3}\left[1 + \left(\frac{f}{f_0}\right)^2\right]^{-1}$$

Attenuation

$$E(f) = e^{-\left(\frac{\pi T f}{Q(f)}\right)}$$

$$Q(f) = 80 f^{(1.1)}$$

Geometrical spreading

$$G(R) = \frac{1}{R}$$

$$SV2 = 2\int_0^\infty V^2(f)\,df \;\Rightarrow\; SV2 = \frac{1}{4}\Omega^2(2\pi f_0)^3$$

$$SD2 = 2\int_0^\infty D^2(f)\,df \;\Rightarrow\; SD2 = \frac{1}{4}\Omega^2(2\pi f_0)$$

$$\Omega = \sqrt{4(SD2)^{3/2}(SV2)^{-1/2}}$$

$$f_0 = \frac{1}{2\pi}\sqrt{\frac{SV2}{SD2}}$$

$$M_0 = 4\pi \rho v^3 \Omega k$$

$$r = \frac{2.34\beta}{2\pi f_0}$$

$$M_W = \frac{2}{3}\cdot \log_{10}(M_0) - 6.1$$

Algorithm dbmw

The S-wave train is identified through an automatic procedure that estimates arrival times.

Average and instrument response are removed and band pass filter is applied

EW and NS component are combined to obtain the transversal one, to minimize wave conversion effects

Signal-to-noise spectral ratio is used to determine the frequency window for strong motion data analysis

Velocities and displacements are obtained by integrating acceleration and velocities

Source spectra are obtained by applying FFT and correcting for geometrical spreading and inelastic attenuation

Seismic moment and corner frequency are estimated following Andrews (1986) method.

The results are stored in several database tables.

Archive events were reprocessed by using Antelope dbreplay

A real time Antelope instance configured to estimate Mw is operational

Results- Mw

Bulletins

Romania - Event 16723 Zona seismica Vrancea

Event local time: Sat Nov 22,2014 21:14:17

Sat Nov 22,2014 19:14:17 GMT N45.87 E27.15 Depth: 40 km ID: 17011

Measurements are based on data extracted and processed by an operator

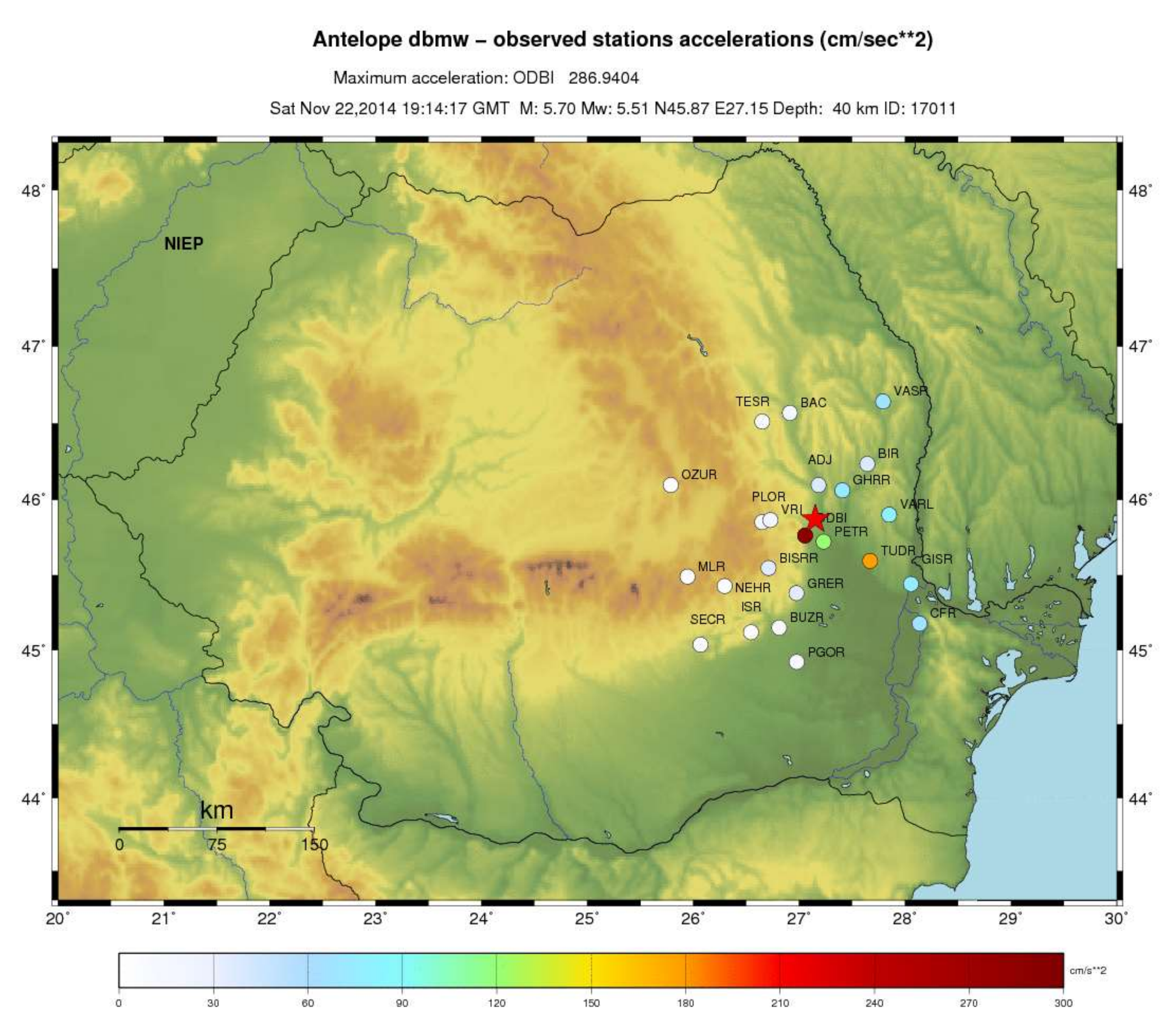
ML: 5.70 Mw: 5.51 netm0: 0.353E+18 netf0: 0.82 neteqR: 1.93 Nsta: 24

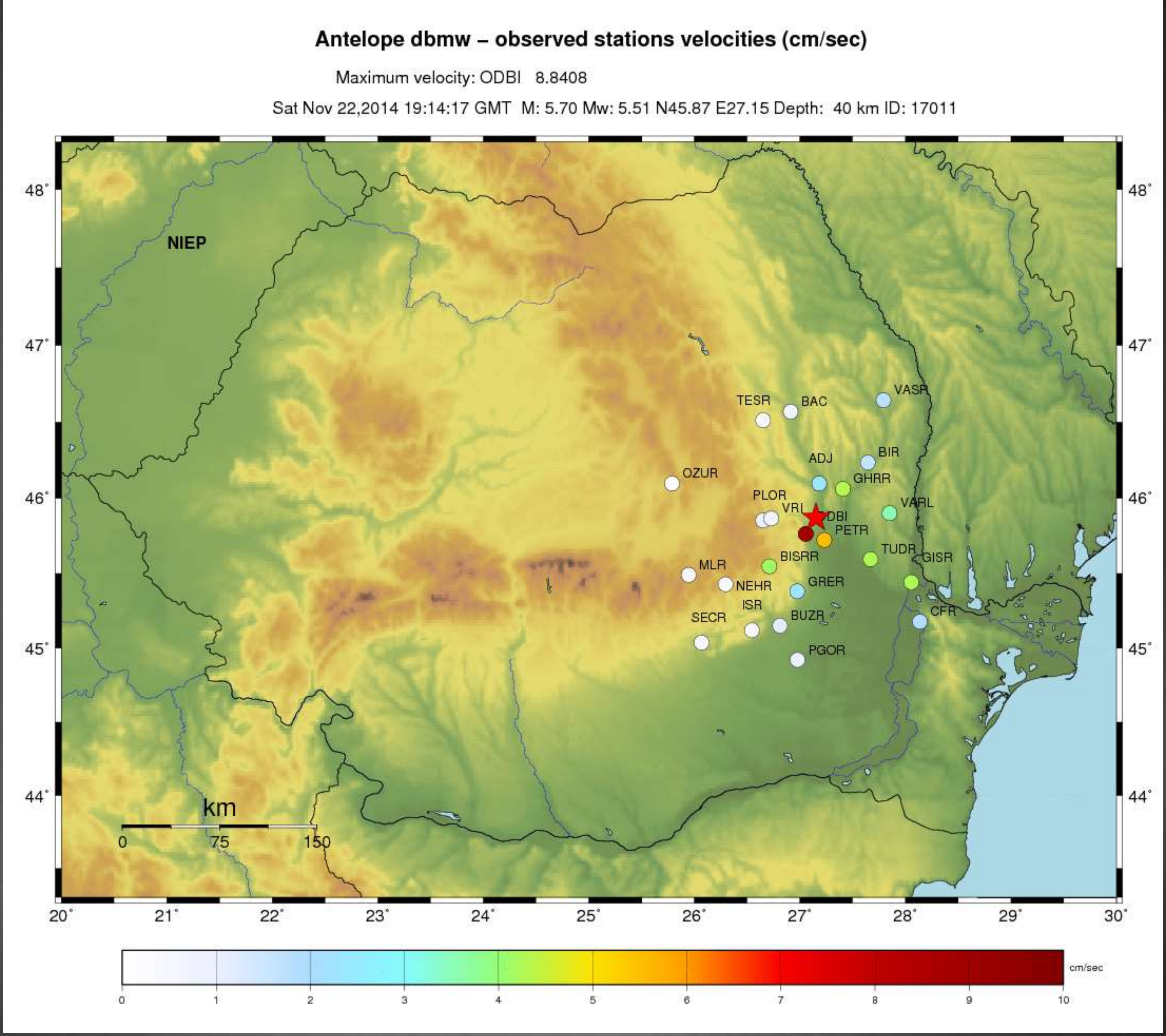
Station moment magnitude estimates - dbmw

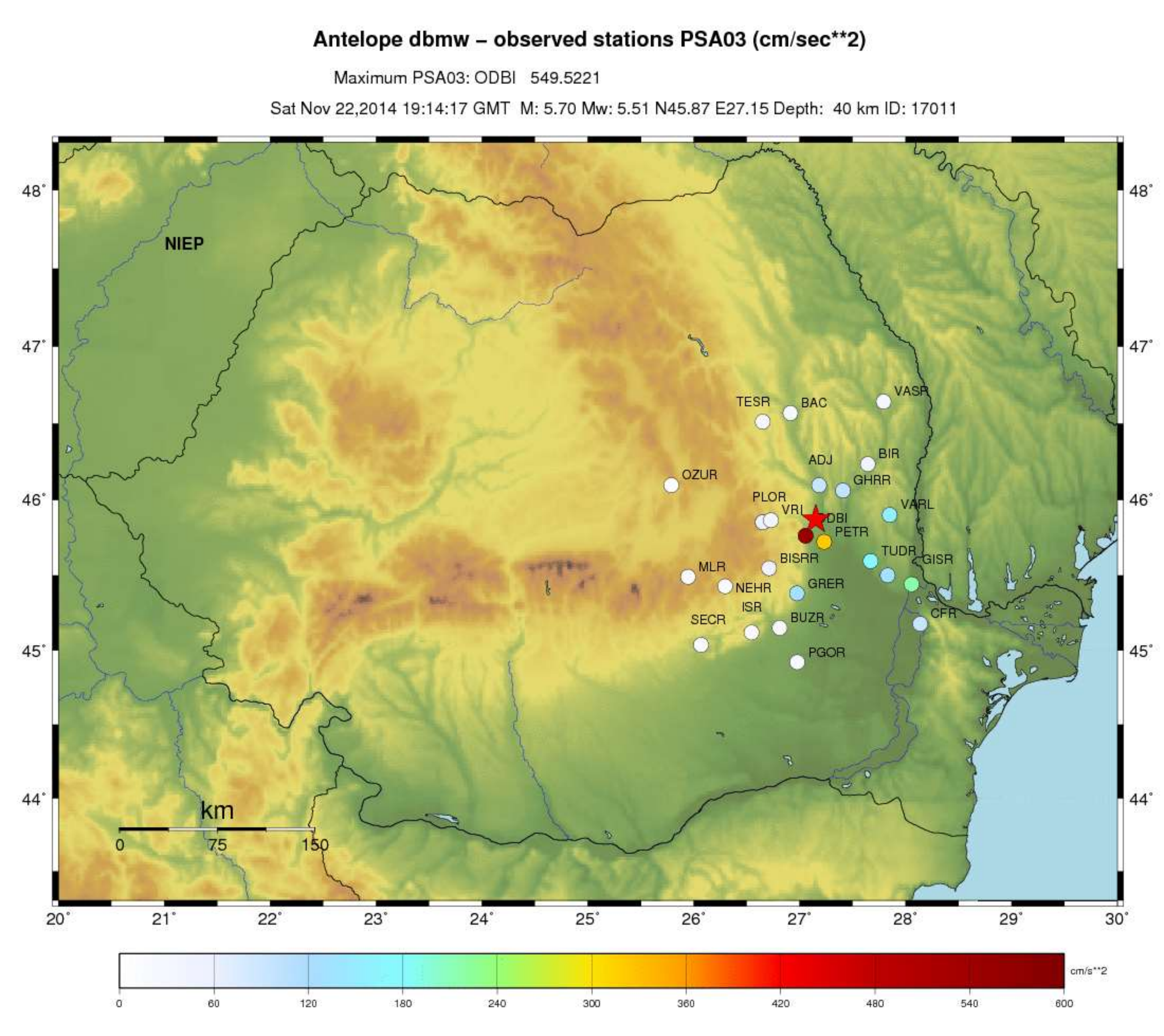
sta	chamw	mw	m0	f0	eqR	timePmw	Pmw	timeSmw	Smw
NEHR	HNT	5.6	0.352E+18	0.46	2.73	19:14:31	synt	19:14:41	synt
PETR	HNT	5.3	0.111E+18	0.67	1.89	19:14:24	synt	19:14:29	synt
GHRR	HNT	5.4	0.196E+18	0.64	1.98	19:14:24	db	19:14:30	synt
MLR	HNT	5.8	0.731E+18	0.44	2.88	19:14:34	db	19:14:46	synt
BUZR	HNT	5.8	0.818E+18	0.50	2.52	19:14:31	synt	19:14:42	synt
SCHL	HNT	5.5	0.225E+18	1.38	0.92	19:14:28	db	19:14:38	synt
GRER	HNT	5.7	0.509E+18	0.74	1.72	19:14:28	db	19:14:36	synt
GISR	HNT	5.7	0.577E+18	1.16	1.09	19:14:31	db	19:14:42	synt
VASR	HNT	5.8	0.720E+18	0.72	1.76	19:14:33	db	19:14:45	synt
PGOR	HNT	5.8	0.601E+18	0.64	1.99	19:14:34	db	19:14:47	synt
PLOR	HNT	5.3	0.127E+18	0.67	1.88	19:14:25	db	19:14:32	synt
ISR	HNT	5.9	0.103E+19	0.45	2.82	19:14:33	db	19:14:44	synt
ODBI	HNT	5.4	0.156E+18	0.77	1.66	19:14:23	db	19:14:28	synt
TESR	HNT	5.3	0.126E+18	0.54	2.35	19:14:30	db	19:14:41	synt
CFR	HNT	5.1	0.673E+17	3.00	0.42	19:14:33	db	19:14:47	synt
VARL	HNT	5.7	0.473E+18	0.81	1.56	19:14:27	synt	19:14:35	synt
BAC	HNT	5.5	0.267E+18	0.57	2.23	19:14:30	synt	19:14:41	synt
BISRR	HNT	5.7	0.520E+18	0.87	1.46	19:14:27	db	19:14:34	synt
ADJ	HNT	5.4	0.201E+18	0.49	2.60	19:14:24	synt	19:14:30	synt
VRI	HNT	5.2	0.765E+17	0.48	2.61	19:14:24	db	19:14:31	synt
PLOR4	HNT	5.3	0.127E+18	0.67	1.88	19:14:26	synt	19:14:32	synt
BIR	HNT	5.4	0.179E+18	0.75	1.69	19:14:27	db	19:14:35	synt
OZUR	HNT	5.4	0.173E+18	0.44	2.90	19:14:34	db	19:14:47	synt
TUDR	HNT	5.3	0.119E+18	1.83	0.69	19:14:26	db	19:14:34	synt

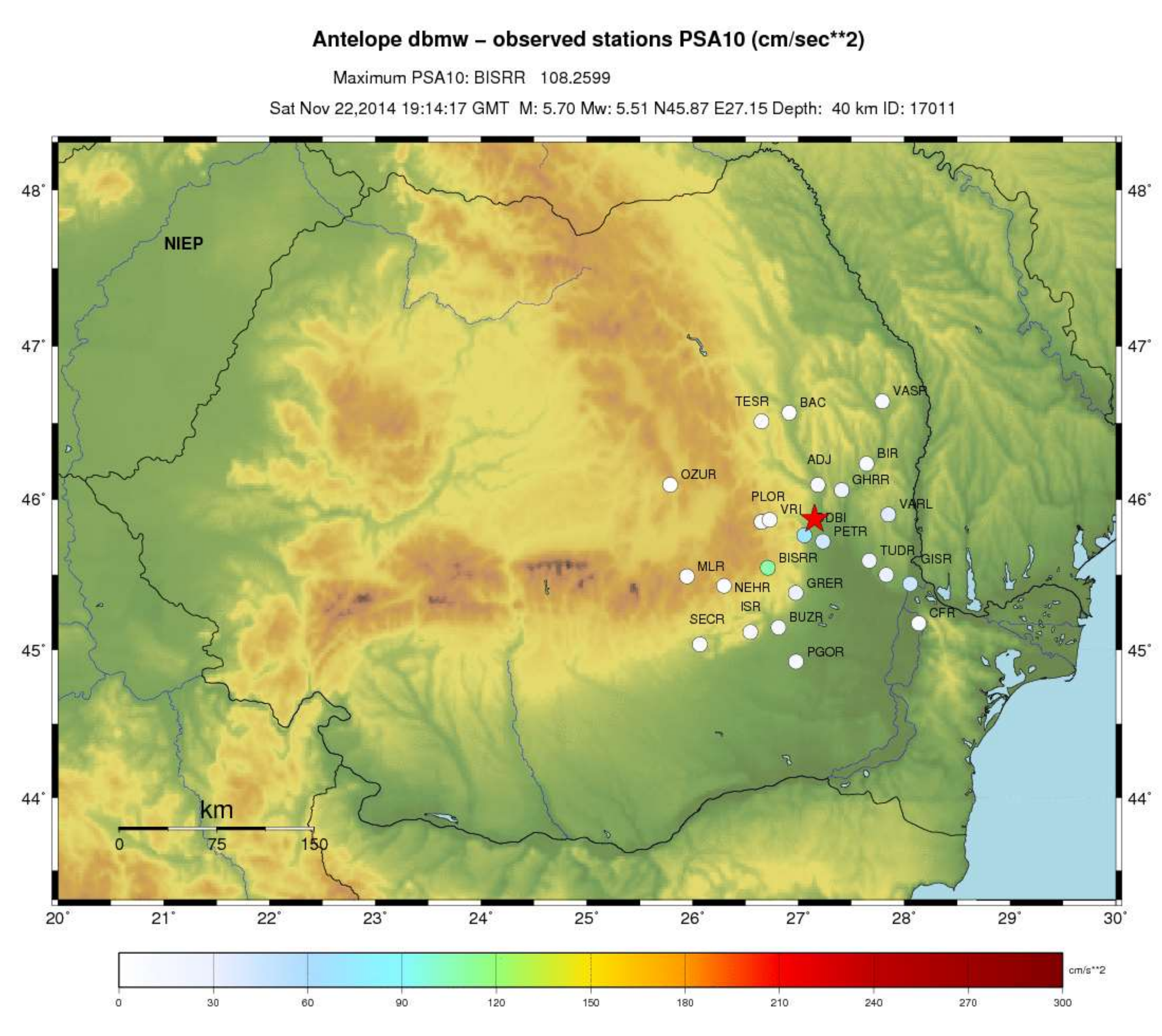
Results

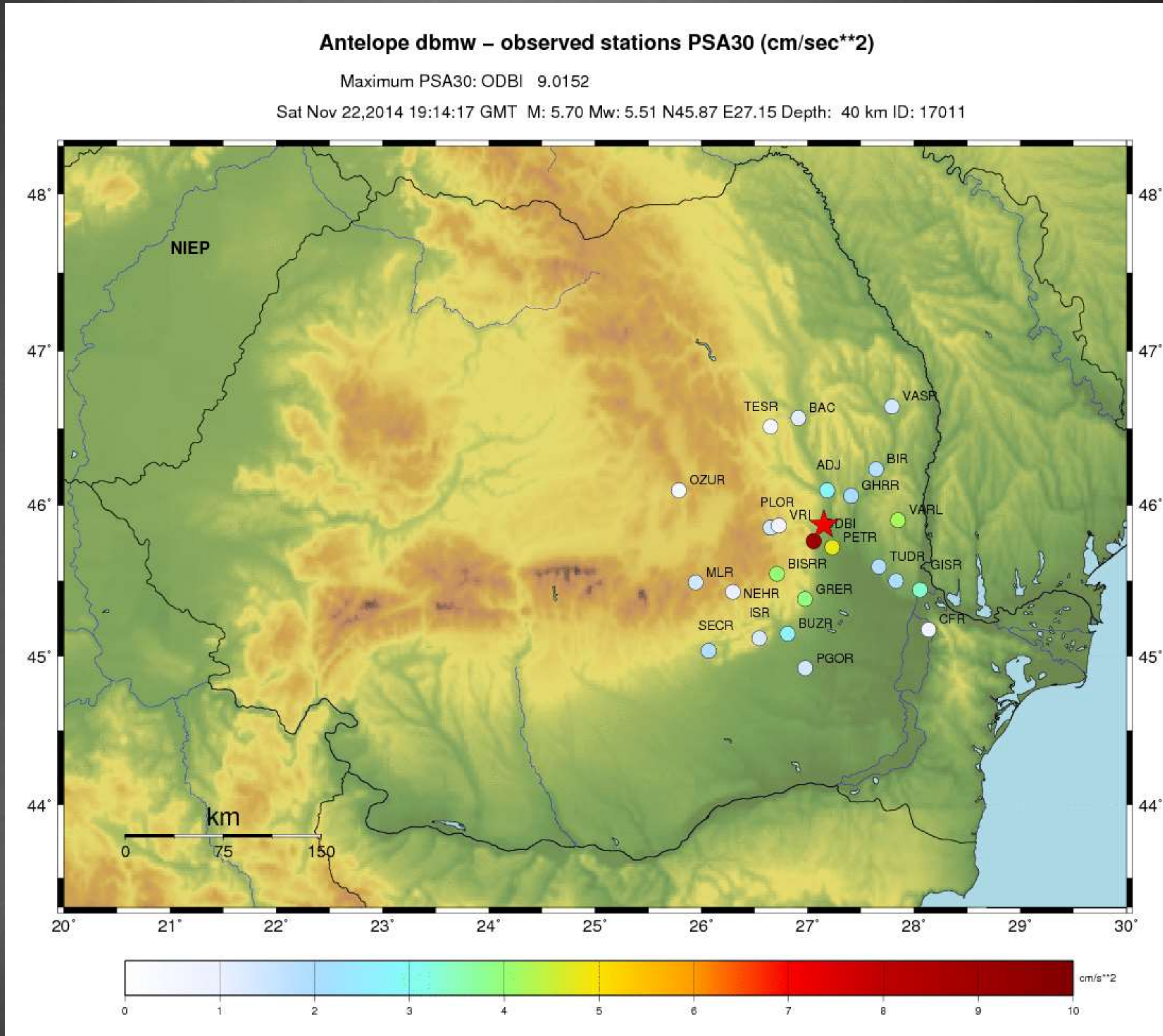
Ground motion parameters




Antelope dbmw – observed stations velocities (cm/sec)
Maximum velocity: ODBI 8.8408
Sat Nov 22,2014 19:14:17 GMT M: 5.70 Mw: 5.51 N45.87 E27.15 Depth: 40 km ID: 17011
NIEP
TESR
BAC
VASR
ADJ
BIR
GHRR
OZUR
PLOR
VRI
ODBI
PETR
VARL
TUDR
GISR
BISRR
MLR
NEHR
GRER
ISR
SECR
BUZR
CFR
PGOR
km
0
75
150
48˚
47˚
46˚
45˚
44˚
20˚
21˚
22˚
23˚
24˚
25˚
26˚
27˚
28˚
29˚
30˚
cm/sec
0
1
2
3
4
5
6
7
8
9
10

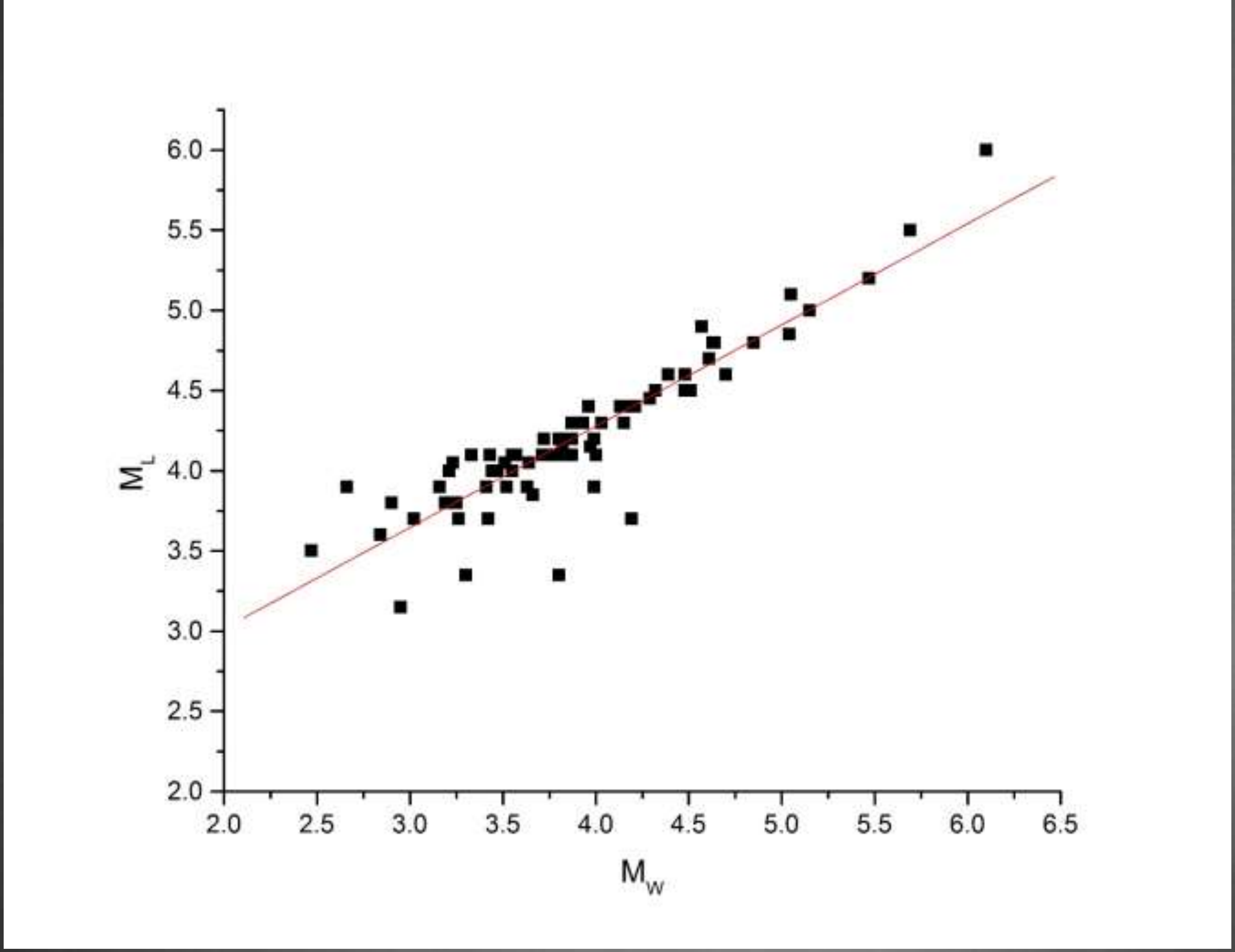

Antelope dbmw – observed stations PSA03 (cm/sec**2)
Maximum PSA03: ODBI 549.5221
Sat Nov 22,2014 19:14:17 GMT M: 5.70 Mw: 5.51 N45.87 E27.15 Depth: 40 km ID: 17011
NIEP
TESR
BAC
VASR
BIR
ADJ
GHRR
OZUR
PLOR
VRI
ODBI
PETR
VARL
TUDR
GISR
BISRR
MLR
NEHR
GRER
ISR
SECR
BUZR
CFR
PGOR
km
0
75
150
48°
47°
46°
45°
44°
20°
21°
22°
23°
24°
25°
26°
27°
28°
29°
30°
cm/s**2
0
60
120
180
240
300
360
420
480
540
600


Antelope dbmw – observed stations PSA10 (cm/sec**2)
Maximum PSA10: BISRR 108.2599
Sat Nov 22,2014 19:14:17 GMT M: 5.70 Mw: 5.51 N45.87 E27.15 Depth: 40 km ID: 17011
NIEP
TESR
BAC
VASR
ADJ
BIR
OZUR
GHRR
PLOR
VRI
DBI
VARL
PETR
TUDR
GISR
BISRR
MLR
NEHR
GRER
ISR
SECR
BUZR
CFR
PGOR
km
0
75
150
48°
47°
46°
45°
44°
20°
21°
22°
23°
24°
25°
26°
27°
28°
29°
30°
cm/s**2
0
30
60
90
120
150
180
210
240
270
300


Antelope dbmw – observed stations PSA30 (cm/sec**2)
Maximum PSA30: ODBI 9.0152
Sat Nov 22,2014 19:14:17 GMT M: 5.70 Mw: 5.51 N45.87 E27.15 Depth: 40 km ID: 17011
NIEP
TESR
BAC
VASR
BIR
ADJ
GHRR
OZUR
PLOR
VRI
ODBI
PETR
VARL
TUDR
GISR
BISRR
MLR
NEHR
GRER
ISR
SECR
BUZR
CFR
PGOR
km
0
75
150
48˚
47˚
46˚
45˚
44˚
20˚
21˚
22˚
23˚
24˚
25˚
26˚
27˚
28˚
29˚
30˚
cm/s**2
0
1
2
3
4
5
6
7
8
9
10

Results

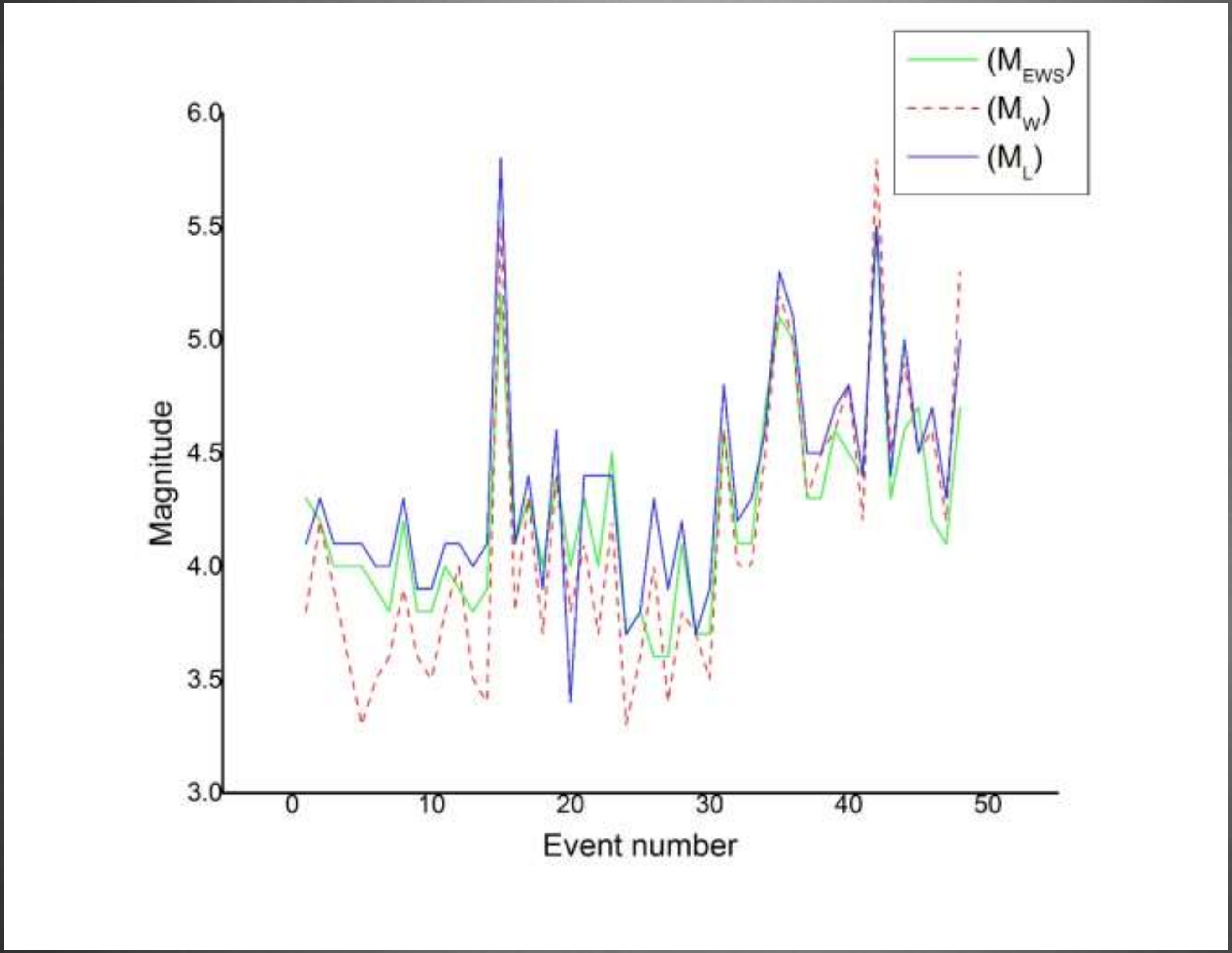
Intermediate depth Vrancea earthquakes - ML vs. Mw



71 seismic events with ML>3.0, recorded during 2004-2016.

Results

Intermediate depth Vrancea earthquakes

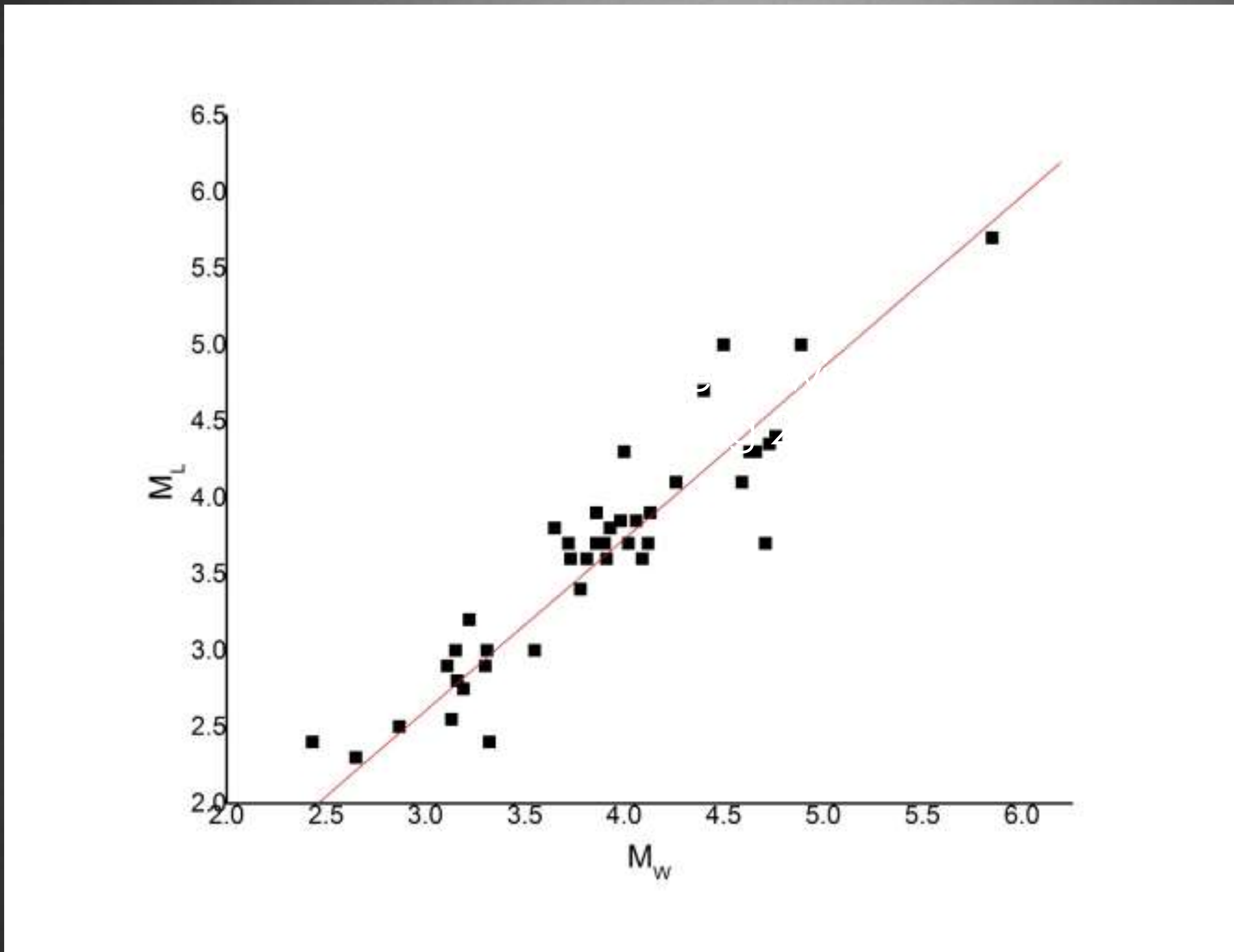


Comparison between Mw, ML and Early Warning System estimations

All these values are obtained from strong motion data

Results

Crustal events ML vs. Mw



46 seismic events with ML>2.3, recorded during 2013-2016

Acknowledgements: I want to make a special thanks to Giovanni Costa and Antonella Gallo for their support and guidance with the dbmw implementation in our Antelope system.

Thank you for your attention !