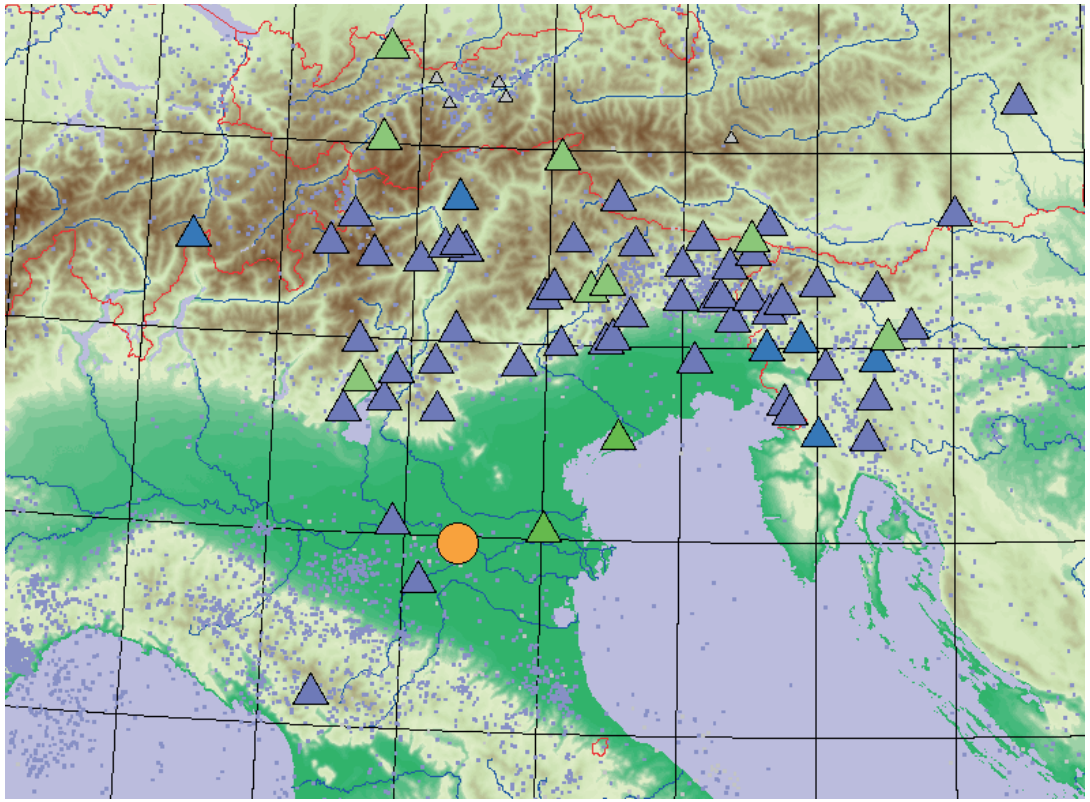
AN AUTOMATIC PROCEDURE TO RECOGNIZE AND LOCATE SEIMIC EVENTS IN NE ITALY



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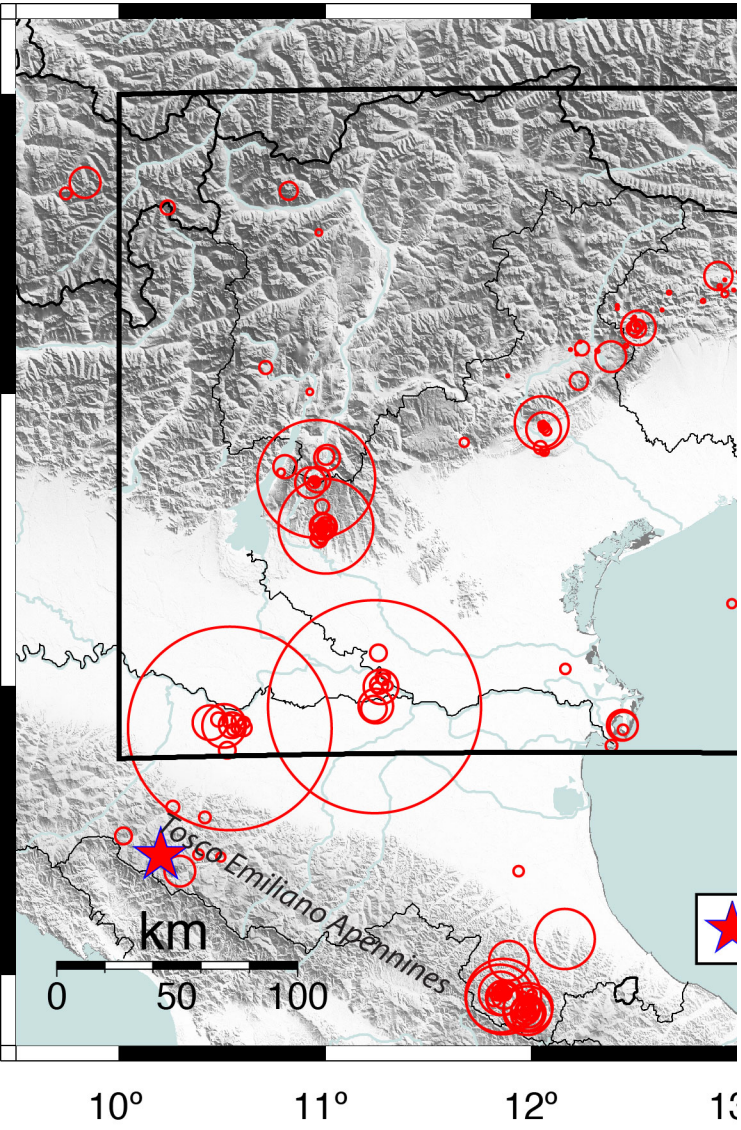
Introduction

- Antelope locates the earthquakes through algorithms that recognize (detect) and locate (assoc) the seismic events; these AUTOMATIC procedures must be opportunely tuned taking into account the characteristics of the seismicity and of the recording networks operating in the studied area (e.g. NE Italy).
- Different aims:
  - The **real-time seismic alarm** (e.g. for Civil Defence purposes): we want to recognize and to locate ALL earthquakes with a magnitude LARGER than a prefixed alarm threshold WITHOUT false events. The microseismicity analysis can be performed later.
  - The **bulletin production**: in this case we want to detect ALL earthquakes, ALSO the microseismicity. The automatic procedure can detect some false events, that will be removed in a manual review.
- The parameters should be settled differently for real-time alarms and the seismological bulletins.

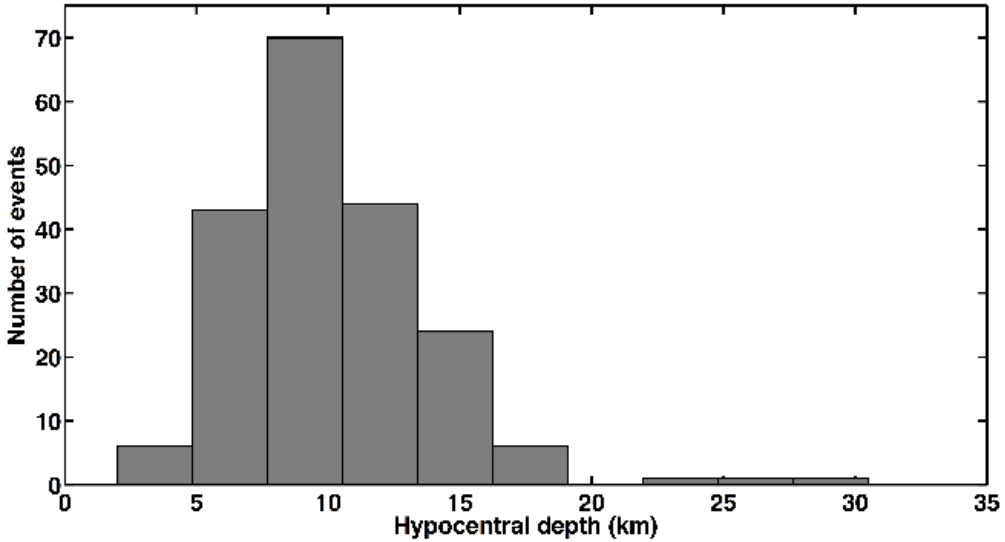
Introduction

- Real-time system:
  - Optimization of the configuration parameters (detect and assoc) by performing several offline tests on a dataset composed by selected seismic events
  - Validation of the procedure on the data recorded in 2011
  - Stress tests: what happens in case of lack of recordings or a malfunctioning in the data broadcasting?
  - Performance of new parameters on the real-time system in 2014
- Bulletin:
  - Optimization of the configuration parameters (detect and assoc) by performing several offline tests on a selected dataset
  - Validation of the procedure on the data recorded in 2011
- Conclusions

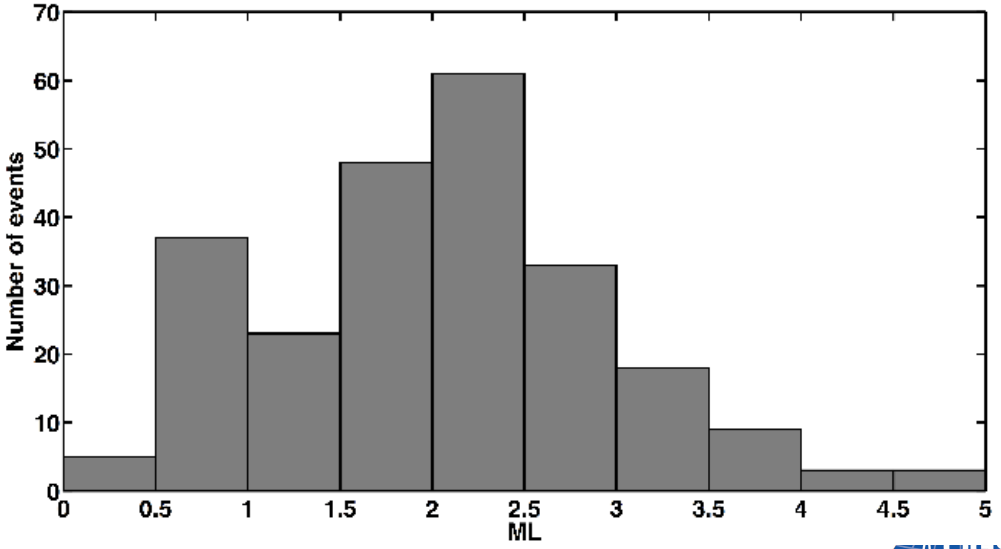
The dataset



(a)



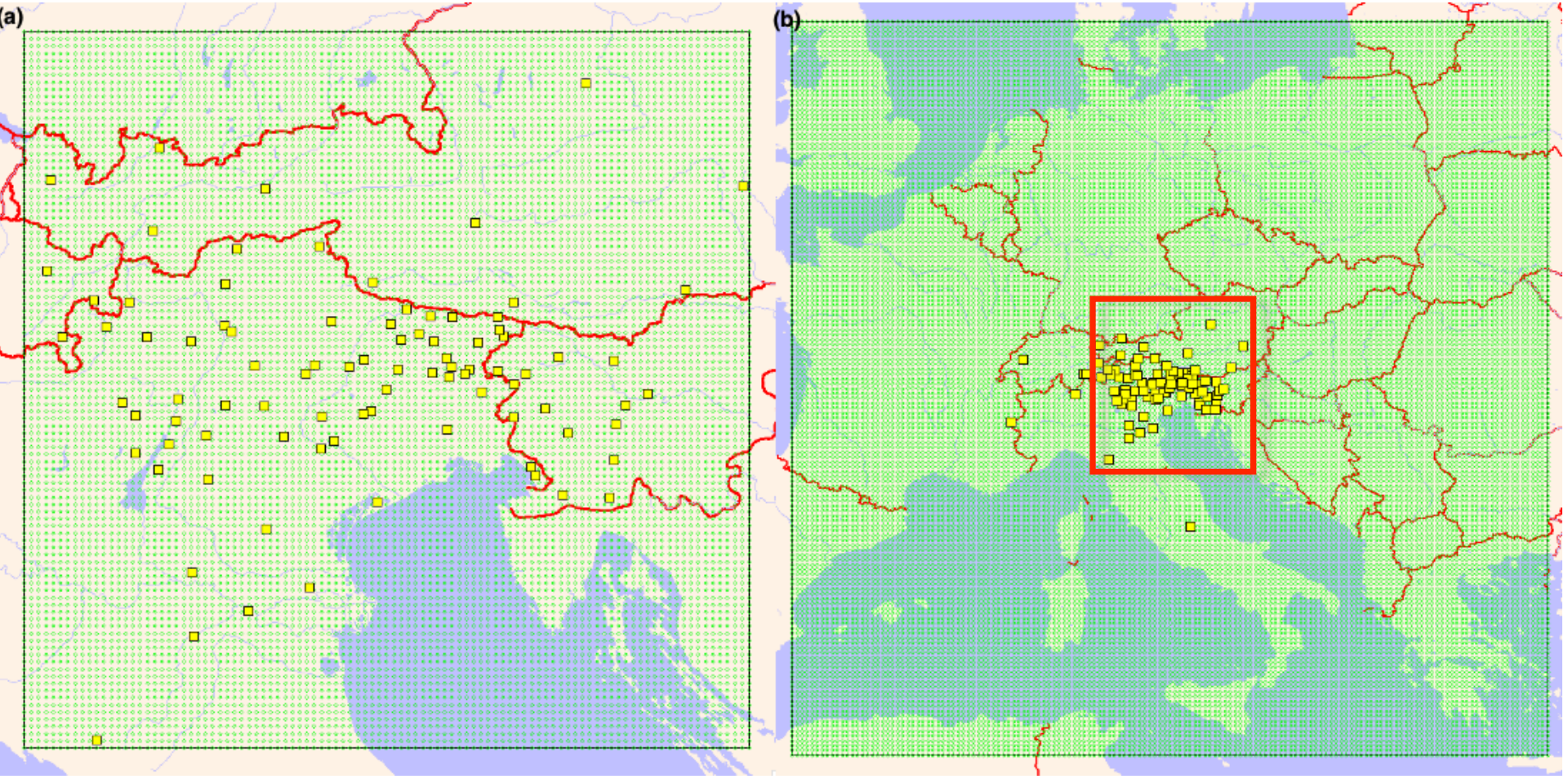
(b)



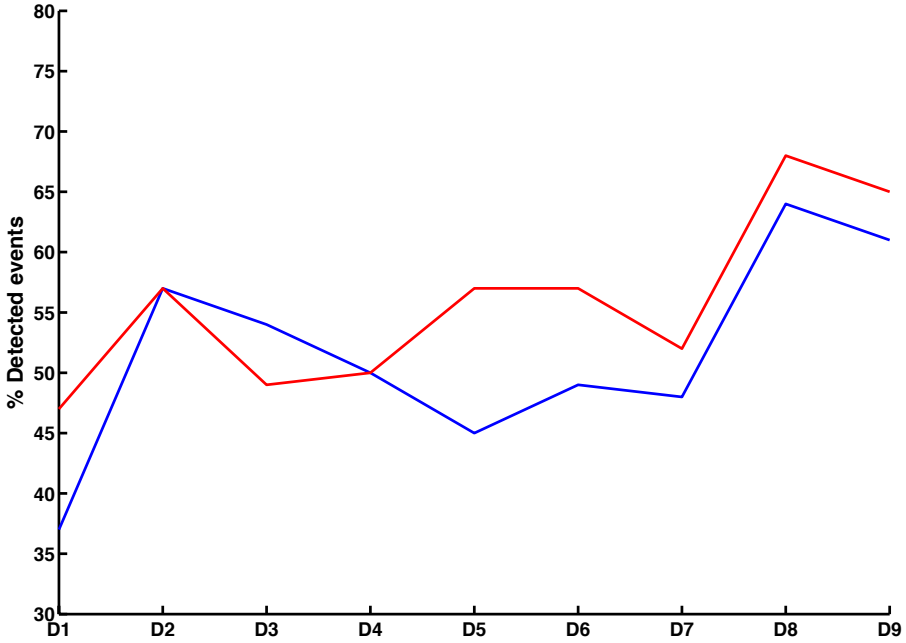
Automatic location by Antelope

- A preliminary step is the definition of the spatial grids where the detection and the association algorithms are running.
- OGS official bulletin is the benchmark.
- The automatic location can be divided in 3 steps:
  - Detection: (real-time) analysis of the signals, SNR computation, comparison with the predefined SNR thresholds.
    - ✓ 9 tests on the frequency ranges utilized for the association to various grids.
  - Grid association: the detections are associated with the predefined arrival times computed on a 3D spatial grid; a preliminary location is obtained.
    - ✓ 20 tests on the minimum number of stations, the length of the time window and the weights (various configurations).
  - Final inversion: an accurate and final location is obtained by performing an inversion that utilizes the results obtained in the grid association as the starting solution (GENLOC by Pavlis et al., 2004).
    - ✓ 7 tests on the velocity models and the weights.
- Indicators: % detected events (%EV) and median of the differences of the epicentral distance (MDE)
- F-test (eg Mayeda et al., 1992; Bianco et al., 2002).

The grids definition

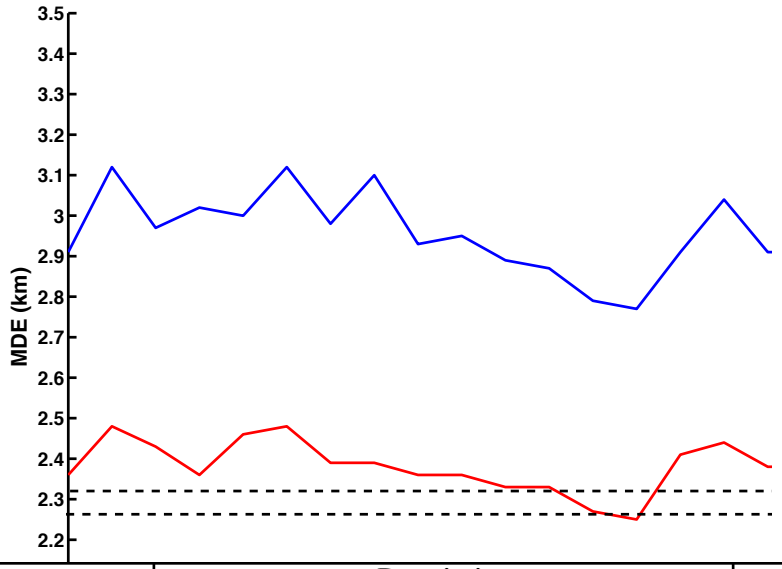


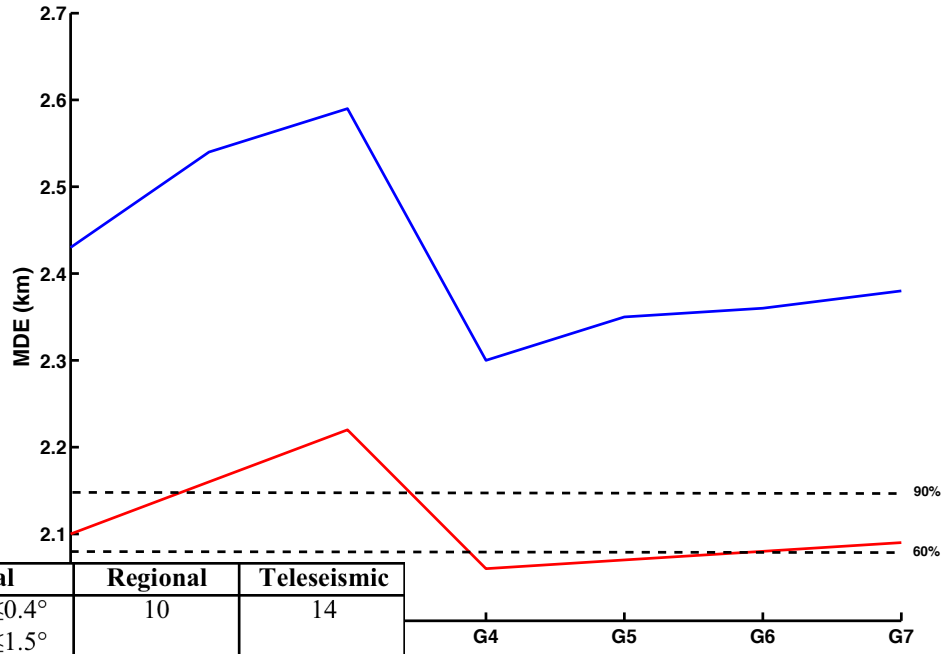
Detection



Parameter	Description	Local	Regional	Teleseismic
sta_twin	short term average time window	1.0	1.0	2.0
sta_tmin	short term average minimum time for average	1.0	1.0	2.0
sta_maxtgap	short term average maximum time gap	0.5	0.5	0.5
lta_twin	long term average time window	10.0	10.0	20.0
lta_tmin	long term average minimum time for average	5.0	5.0	10.0
lta_maxtgap	long term average maximum time gap	4.0	4.0	4.0
nodet_twin	no detection if on time is less than this	2.0	5.0	10.0
thresh	detection SNR threshold	5.0	5.0	5.0
threshoff	detection-off SNR threshold	2.5	2.5	2.5
det_tmin	detection minimum on time	5.0	10.0	20.0
det_tmax	detection maximum on time	10.0	200.0	600.0
filter	Butteworth filter applied to the signals	BP 5.0-25.0	BP 3.0-5.0	BP 0.8-3.0

Association





Parameter	Description	Local	Regional	Teleseismic
nsta_thresh	minimum allowable number of stations to locate an earthquake; in case of local events this parameter is expressed as a function of maximum source-receiver distance in degrees	4 for d≤0.4° 6 for d≤1.5° 8 for d≤2.0° 10 for d≤180°	10	14
cluster_twin	clustering time window in seconds that is used to determine whether an observed arrival associates with a hypothetical event location	1.5	2.0	5.0
try_S	also S travel-times are tried to locate the events	no	no	no
priority	priority to select the association in case of locations falling inside multiple grids	3	2	1
use_dwt	use source receiver distance weighting factor	no	no	no
dwt_dist_near - DN	if use_dwt=yes, the maximum source-receiver distance with weight=1	-	-	-
sta_weight_radius - SR	a radius in degrees that is used to compute a station density weighting factor used to weight picks from each station	no	no	no
closest_stations - CS	use only a selected number of closest stations to a particular source node in the search for defining phases	no	no	no
relocate	run the relocation script (inversion) to refine the final solution	yes	no	no

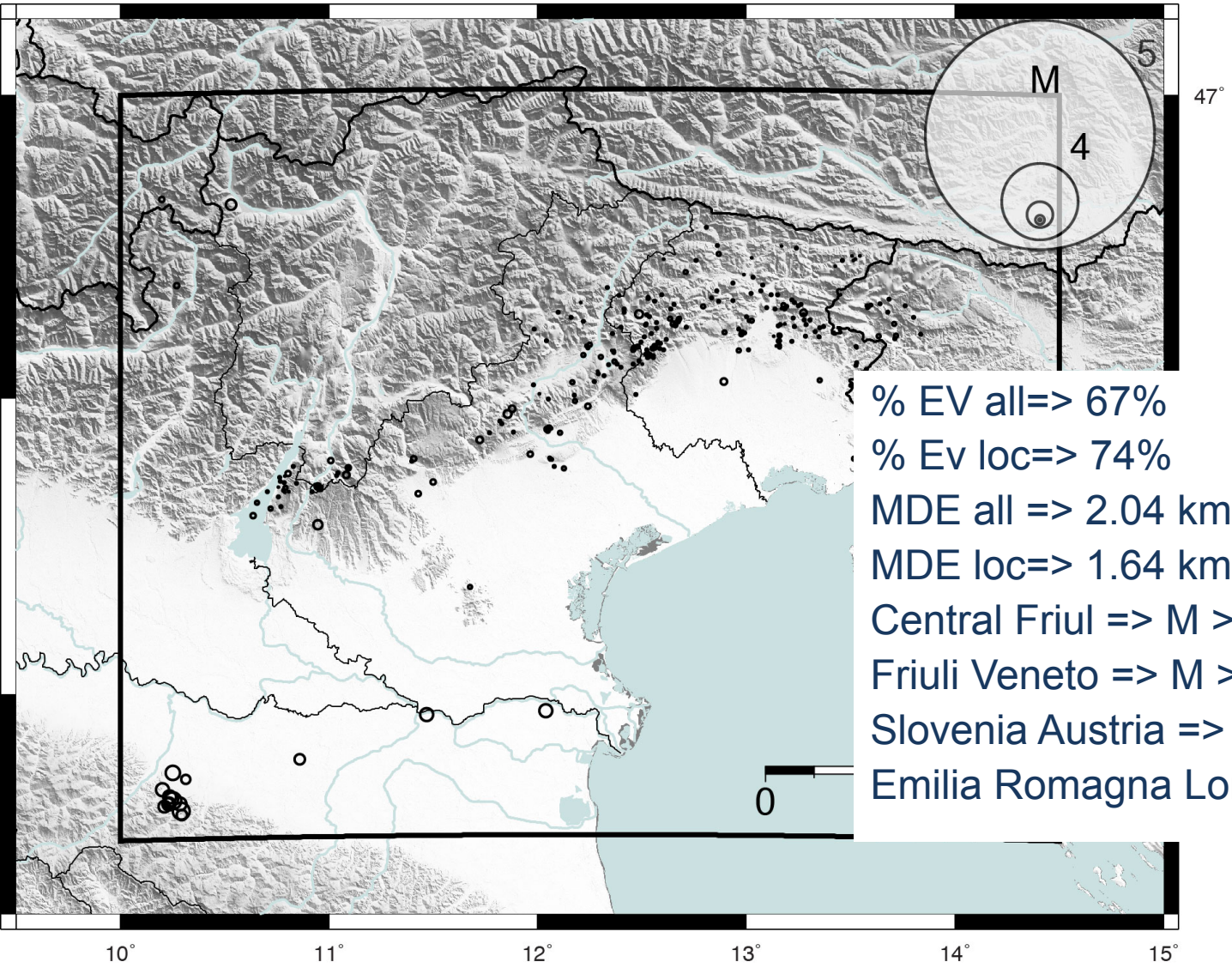
%EV all => 69%

%EV loc => 73%

MDE all => 2.30 km

MDE loc => 2.06 km

Validation on 2011 data



% EV all=> 67%

% Ev loc=> 74%

MDE all => 2.04 km (mean 4.38 km)

MDE loc=> 1.64 km (mean 3.29 km)

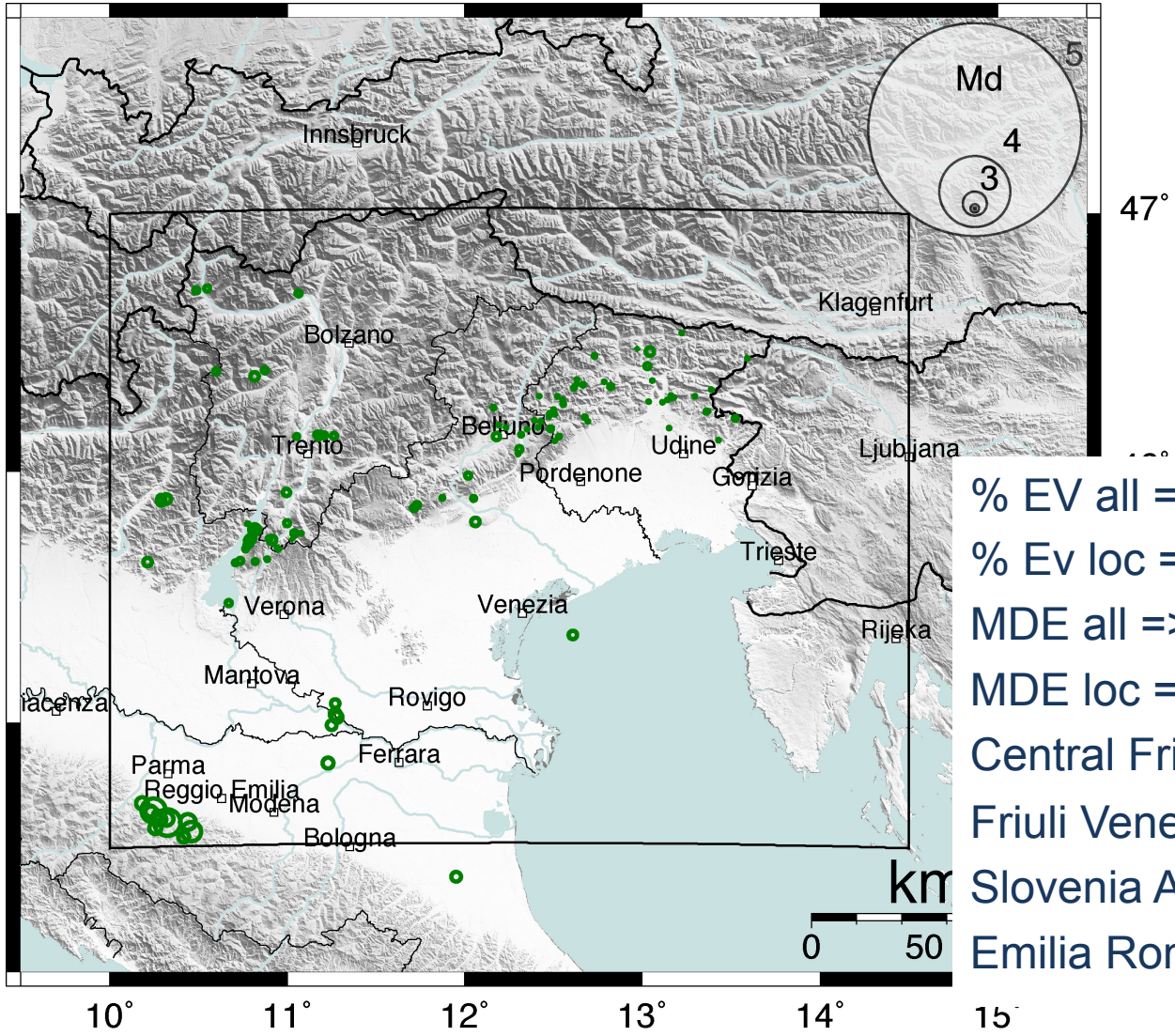
Central Friul => M > 1.5

Friuli Veneto => M > 2.0

Slovenia Austria => M > 1.5

Emilia Romagna Lombardia => M > 2.5

Stress test 1: without SP



% EV all => 51%

% Ev loc => 58%

MDE all => 2.48 km (mean 4.75 km)

MDE loc => 2.06 km (mean 3.61 km)

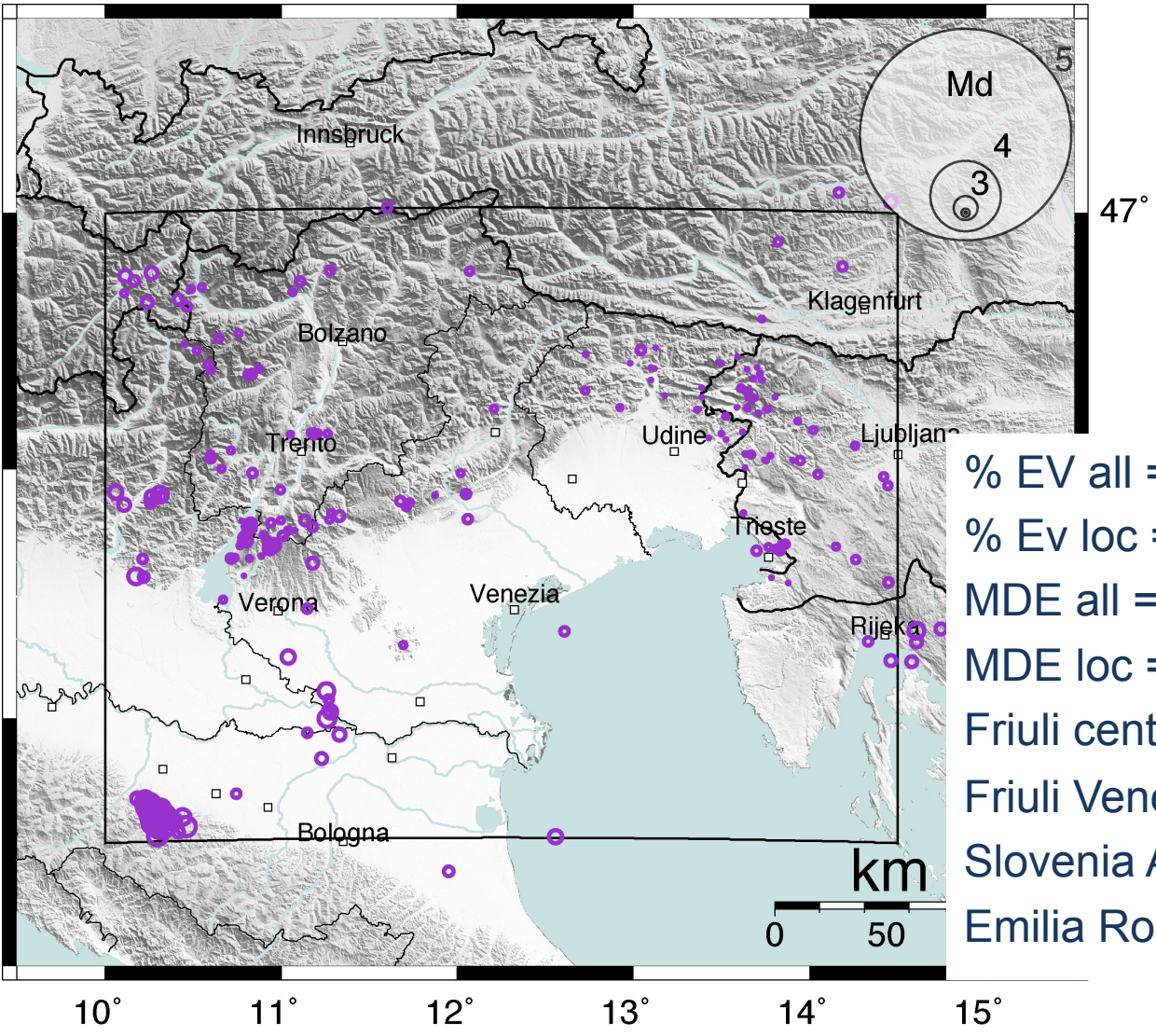
Central Friuli => M > 1.8

Friuli Veneto => M > 2.2

Slovenia Austria => M > 1.5

Emilia Romagna Lombardia => M > 2.6

Stress test 2: only OGS stations



% EV all => 38%

% Ev loc => 43%

MDE all => 1.77 km (mean 5.09 km)

MDE loc => 1.64 km (mean 3.29 km)

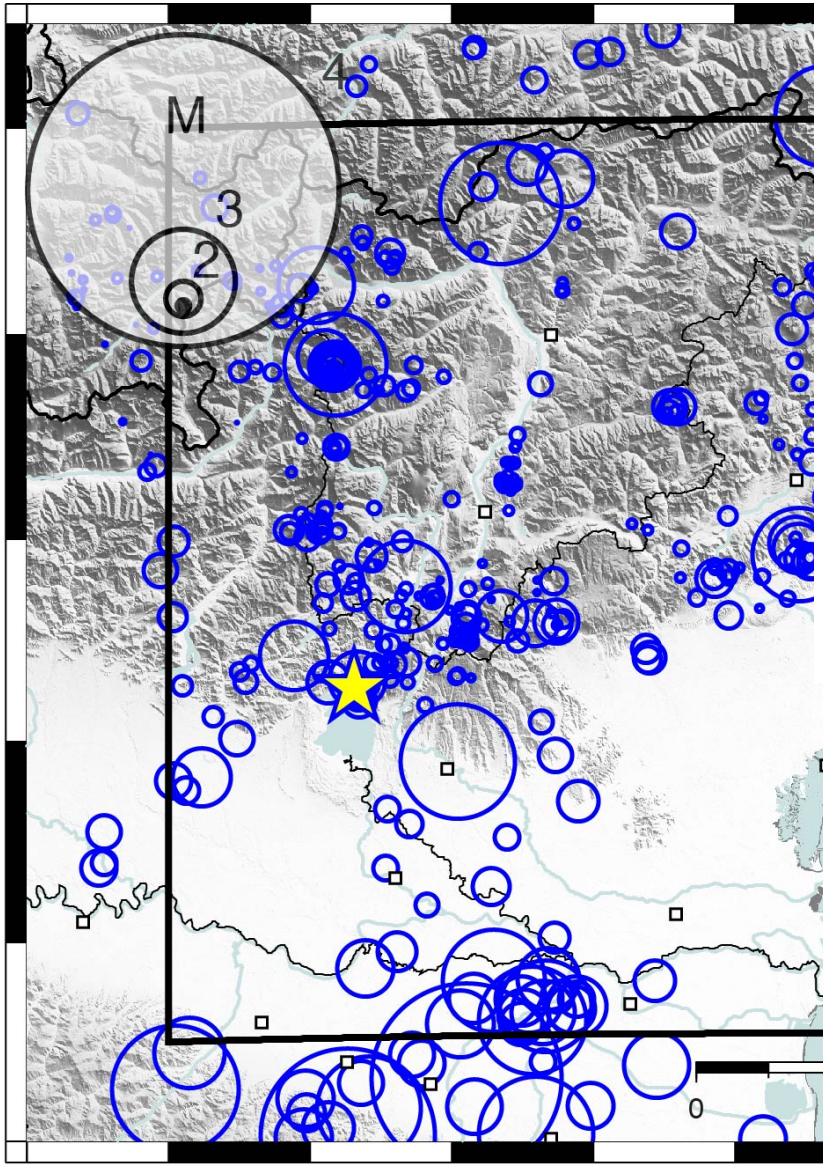
Friuli centrale => M > 1.5

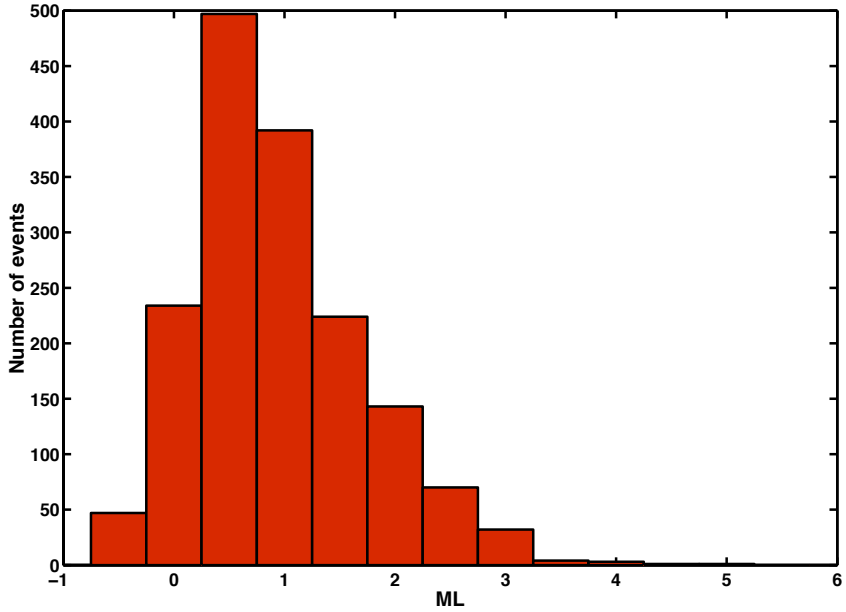
Friuli Veneto => M > 2.0

Slovenia Austria => M > 2.0

Emilia Romagna Lombardia= M > 2.8

2014

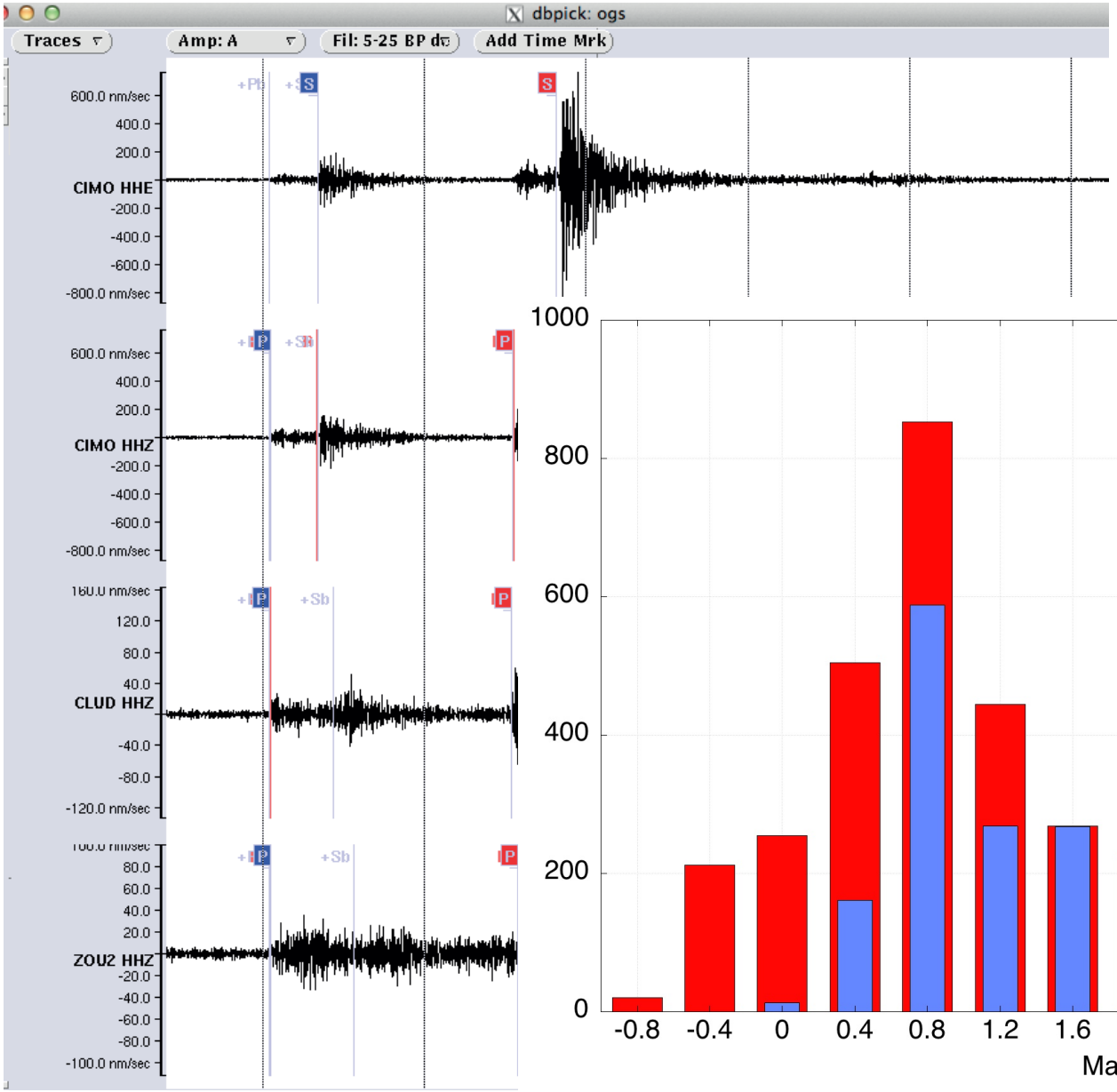

M
4
3
2
0
100
9°30'
10°00'
10°30'
11°00'
11°30'
12°00'
12°30'
13°00'
13°30'
14°00'
14°30'
15°00
45°30'
45°00'


Number of events
ML
500
450
400
350
300
250
200
150
100
50
0
−1
0
1
2
3
4
5
6

Bulletin parameters

Parameter	Description	Local 1	Local 2	Regional	Teleseismic	S phase
sta_twin	short term average time window	1.0	1.0	1.0	2.0	3.0
sta_tmin	short term average minimum time for average	1.0	1.0	1.0	2.0	1.0
sta_maxtgap	short term average maximum time gap	0.5	0.5	0.5	0.5	0.5
lta_twin	long term average time window	10.0	10.0	10.0	20.0	50.0
lta_tmin	long term average minimum time for average	5.0	5.0	5.0	10.0	5.0
lta_maxtgap	long term average maximum time gap	4.0	4.0	4.0	4.0	4.0
nodet_twin	no detection if on time is less than this	2.0	2.0	5.0	10.0	2.0
thresh	detection SNR threshold	5.0	3.0	5.0	5.0	5.0
threshoff	detection-off SNR threshold	2.5	2.5	2.5	2.5	2.5
det_tmin	detection minimum time	5.0	5.0	10.0	20.0	2.0
det_tmax	detection maximum time	10.0	10.0	200.0	600.0	10.0
filter	Butteworth filter applied to the signals	BP 5.0-25.0	BP 5.0-25.0	BP 3.0-5.0	BP 0.8-3.0	BP 1.0-5.0

Parameter	Description	Local 1	Local 2	Regional	Teleseismic
nsta_thresh	minimum allowable number of stations to locate an earthquake; in case of local events this parameter is expressed as a function of maximum source-receiver distance in degree	4 for d≤1.2° 6 for d≤1.5° 8 for d≤2.0° 10 for d≤180°	4 for d≤0.5° 5 for d≤1.0° 6 for d≤1.5° 8 for d≤2.0° 10 for d≤180°	10	14
cluster_twin	clustering time window in seconds that is used to determine whether an observed arrival associates with a hypothetical event location	1.5	1.5	2.0	5.0
try_S	also S travel-times are tried to locate the events	No	Yes	No	No
priority	priority to select the association in case of locations falling inside multiple grids	5	4	2	1
use_dwt	use source receiver distance weighting factor	Yes (for P phases)	Yes (for S phases)	No	No
dwt_dist_near - DN	if use_dwt=yes, the maximum source-receiver distance with weight=1	0.0	0.0	-	-
dwt_dist_max	if use_dwt=yes, the minimum source-receiver distance with weight=0	4.0	0.5	-	-
closest_stations - CS	use only a selected number of closest stations to a particular source node in the search for defining phases	no	no	30	no
relocate	run the relocation script (inversion) to refine the final solution	Yes	Yes	No	No
travel_time_model	velocity model for inversion	Friuli	Friuli	-	-
arrival_residual	weights method	Huber	Huber	-	-


dbpick: ogs
Traces
Amp: A
Fil: 5-25 BP dv
Add Time Mrk
CIMO HHE
CIMO HHZ
CLUD HHZ
ZOU2 HHZ
600.0 nm/sec
400.0
200.0
-200.0
-400.0
-600.0
-800.0 nm/sec
120.0
80.0
40.0
-40.0
-80.0
-120.0 nm/sec
60.0
20.0
-20.0
-60.0
-100.0 nm/sec

2011 NEW Catalogue
2011 OLD Catalogue
1000
800
600
400
200
0
-0.8
-0.4
0
0.4
0.8
1.2
1.6
2
2.4
2.8
3.2
3.6
4
4.4
4.8
Magnitude

Conclusions

- The definitions of the grids with the related frequency ranges for the detections are fundamental to discriminate efficiently between teleseismic, regional and local events; in this context the edges of the grids can be critical.
- SNR is few efficient for ‘doubles’ earthquakes (det_tmax).
- Our seismic network is not spatially homogeneous (the stations are distant 5 km in central Friuli, 50 km in Po Plain); so it is better to avoid the weights in the grid association but they should be utilized in the GENLOC inversion.
- Good performance of real-time system in 2014.
- Bulletin:
  - Computation time: 7 days for 1 year.
  - We redouble the number of events.
  - The false events are 15% of total.
  - A manual review is REQUIRED.