RAPID DETERMINATION OF MOMENT MAGNITUDE FROM THE NEAR-FIELD SPECTRA: APPLICATION TO THE APRIL 6 2009, L'AQUILA SEISMIC SEQUENCE

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Abstract

On April 6th 2009, a magnitude Mw=6.1 earthquake struck the Abruzzi region in central Italy. Despite its moderate size, the earthquake caused more than 300 fatalities and partially destroyed the city of L'Aquila and many villages in its surroundings. The main shock was preceded by an earthquake swarm that started at the end of 2008, and, by the end of November 2009, more than 16,000 aftershocks with M> 0.5 have been recorded by the INGV seismic network.

Current advances in data transmission and communication yield high quality broadband velocity and strong motion waveforms in near real-time. These data allow for the rapid characterization of earthquake sources in terms of fault geometry, focal depth and seismic moment. Delouis et al. (2009) have developed a methodology for rapid determination of moment magnitude from the near-fields spectra. In this study we test this methodology on the L'Aquila sequence earthquakes for which we have already computed the time domain moment tensor solutions (TDMT, Scognamiglio et al., 2010).

Methodology

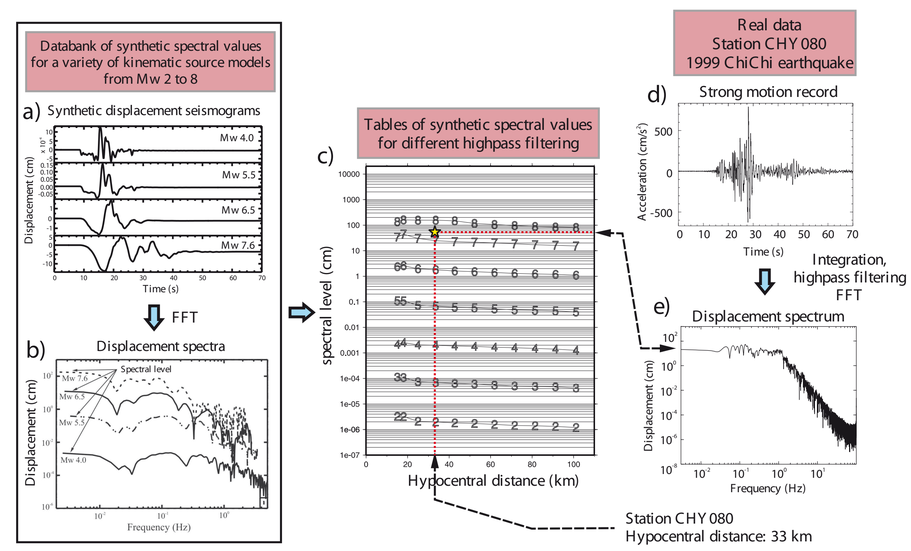
MWSYNTH (Delouis et al., 2009) proceeds in 4 steps. With the first 2 steps a synthetic database is pre computed. Steps 3 and 4 correspond to the processing of the real data and to the actual computing of Mw for the earthquake of interest. Steps 3 and 4 can be implemented in real time.

Step 1: Compute synthetic seismograms for various fault orientations (9 different focal mechanisms), epicentral distances between 1 and 300 km, and magnitude between 2 and 8, using simple rectangular finite source models. Synthetics are computed for a 1D layered earth model with the discrete wave number method of Bouchon, (1981).

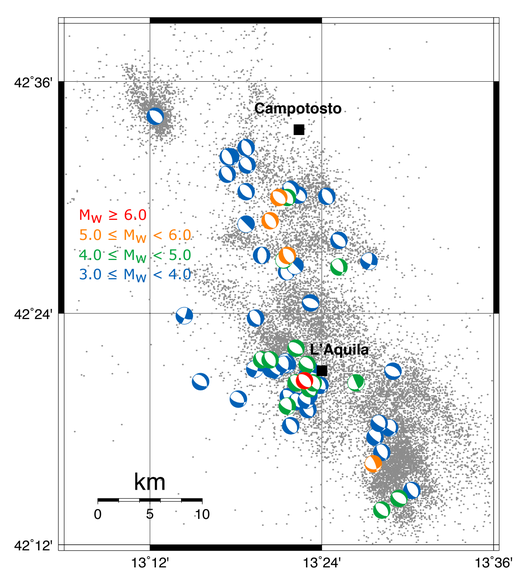
Step 2: Compute the displacement spectra of the synthetic seismograms of step 1, for various highpass filtering, retrieve the spectral level at low frequency (maximum amplitude on the spectra), and average over the different fault orientations. Store the average spectral levels as a function of Mw, hypocentral distance, and filtering (pre-computed tables of spectral levels).

Step 3: Establish the optimal highpass filtering for the real data, compute spectra of the filtered displacement, retrieve spectral levels at low frequency, and compare them with the averaged synthetic spectral levels of step 2.

Step 4: Compute Mw for each seismic station by interpolating spectral levels of real data among the pre-stored synthetic values. The final Mw is the average of the moment magnitudes of the individual stations.



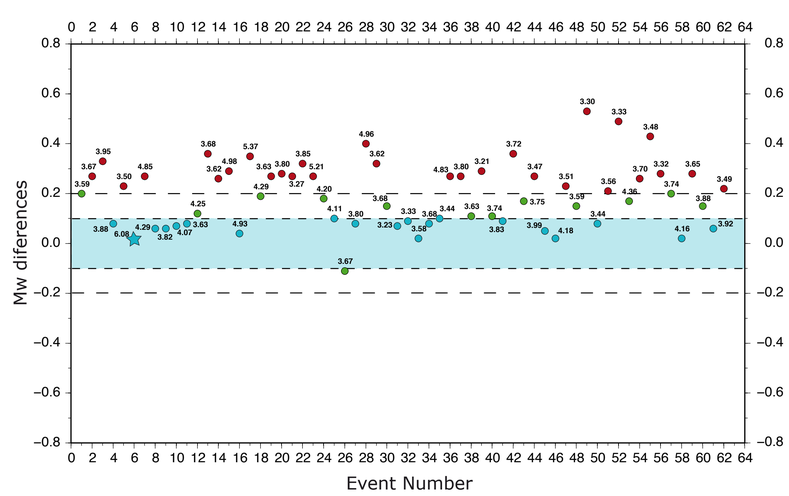
TDMT Solutions

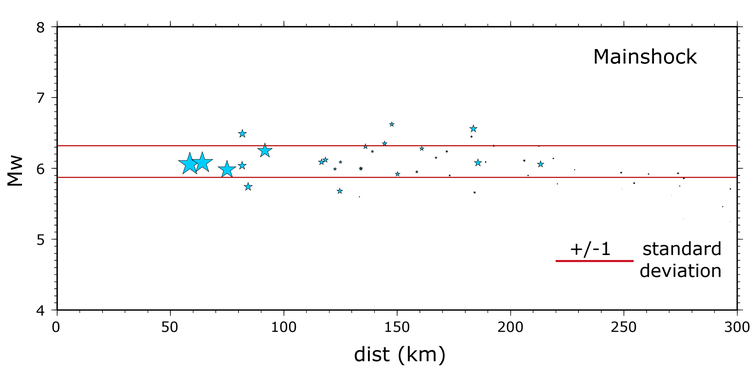


	Origin Time	Longitude	Latitude	Depth (km)	Strike1 Strike2	Dip1 Dip2	Rake1 Rake2	Mw	Rapid Mw
1	2009/03/17 01:12:50	14.021	41.986	7	316 54	88 13	-77 -172	3.59	3.79+/-0.22
2	2009/03/29 08:43:07	14.009	41.989	10	319 89	84 10	-82 -140	3.67	3.94+/-0.18
3	2009/03/30 13:38:38	13.360	42.320	12	117 357	62 47	-129 -40	3.95	4.28+/-0.15
4	2009/04/05 20:48:54	13.382	42.325	10	119 0	62 48	-131 -40	3.88	3.96+/-0.17
5	2009/04/05 22:39:41	13.385	42.329	9	15 124	61 60	-35 -145	3.50	3.73+/-0.21
6	2009/04/06 01:32:39	13.381	42.339	9	139 314	48 42	-87 -94	6.08	6.10+/-0.22
7	2009/04/06 02:37:04	13.340	42.360	9	140 340	53 39	-103 -74	4.85	5.12+/-0.36
8	2009/04/06 03:56:45	13.386	42.335	8	143 330	55 35	-94 -84	4.29	4.35+/-0.20
9	2009/04/06 04:47:53	13.356	42.356	7	129 1	59 44	-123 -48	3.82	3.88+/-0.16
10	2009/04/06 07:17:10	13.383	42.356	7	118 329	59 36	-108 -64	4.07	4.14+/-0.18
11	2009/04/06 10:12:35	13.384	42.317	9	144 339	51 40	-100 -78	3.63	3.71+/-0.17
12	2009/04/06 16:38:09	13.330	42.360	6	138 342	51 42	-106 -72	4.25	4.37+/-0.22
13	2009/04/06 21:56:53	13.323	42.396	5	140 340	46 46	-104 -76	3.68	4.04+/-0.19
14	2009/04/06 22:47:14	13.303	42.326	10	104 332	58 42	-120 -51	3.62	3.88+/-0.17
15	2009/04/06 23:15:36	13.360	42.450	9	154 316	57 34	-80 -106	4.98	5.27+/-0.40
16	2009/04/07 09:26:28	13.387	42.336	9	143 326	63 27	-91 -88	4.93	4.97+/-0.19
17	2009/04/07 17:47:37	13.460	42.270	18	338 93	73 36	-58 -151	5.37	5.72+/-0.29
18	2009/04/07 21:34:29	13.370	42.370	6	310 120	46 44	-83 -97	4.29	4.48+/-0.18
19	2009/04/08 03:00:34	13.462	42.293	9	131 8	73 30	-115 -36	3.63	3.90+/-0.16
20	2009/04/08 04:27:41	13.467	42.305	7	124 355	79 29	-113 -43	3.80	4.08+/-0.18
21	2009/04/08 11:35:57	13.322	42.352	8	107 11	79 63	-152 -13	3.27	3.54+/-0.19
22	2009/04/08 22:56:50	13.364	42.507	7	329 117	47 47	-67 -113	3.85	4.17+/-0.20
23	2009/04/09 00:52:59	13.340	42.480	9	322 149	46 45	-95 -85	5.21	5.48+/-0.25
24	2009/04/09 03:14:52	13.440	42.340	18	156 62	87 30	60 175	4.20	4.38+/-0.18
25	2009/04/09 04:32:44	13.420	42.440	9	122 351	54 48	-124 -52	4.11	4.21+/-0.16
26	2009/04/09 04:43:09	13.373	42.502	7	136 308	55 35	-86 -96	3.67	3.56+/-0.17
27	2009/04/09 13:19:34	13.259	42.341	7	115 325	56 38	-108 -66	3.80	3.88+/-0.14
28	2009/04/09 19:38:16	13.350	42.500	6	137 311	48 42	-86 -95	4.96	5.36+/-0.25
29	2009/04/09 22:40:06	13.312	42.477	8	316 220	90 2	-92 -6	3.62	3.94+/-0.16
30	2009/04/10 03:22:22	13.420	42.463	5	134 311	47 43	-88 -92	3.68	3.83+/-0.17
31	2009/04/10 15:46:17	13.382	42.345	6	120 235	60 53	-44 -142	3.23	3.30+/-0.16
32	2009/04/12 09:48:59	13.386	42.352	7	122 23	74 61	-150 -18	3.33	3.42+/-0.15
33	2009/04/13 13:36:05	13.455	42.445	9	116 15	69 64	-152 -24	3.58	3.60+/-0.17
34	2009/04/13 19:09:49	13.346	42.351	7	126 0	63 41	-122 -44	3.68	3.76+/-0.14
35	2009/04/13 19:17:57	13.341	42.352	8	130 0	61 41	-120 -48	3.44	3.54+/-0.19
36	2009/04/13 21:14:24	13.360	42.500	9	138 327	49 42	-96 -83	4.83	5.10+/-0.27
37	2009/04/14 13:56:21	13.312	42.543	6	332 160	46 45	-95 -85	3.80	4.07+/-0.13
38	2009/04/14 17:27:30	13.313	42.528	7	123 343	50 47	-118 -61	3.63	3.74+/-0.16
39	2009/04/14 19:28:02	13.294	42.535	7	126 345	51 46	-117 -61	3.21	3.50+/-0.17
40	2009/04/14 20:17:27	13.290	42.520	9	137 341	47 45	-107 -72	3.74	3.85+/-0.24
41	2009/04/15 22:53:07	13.312	42.505	7	132 328	49 42	-100 -78	3.83	3.92+/-0.14
42	2009/04/16 17:49:30	13.291	42.535	6	335 150	60 30	-87 -95	3.72	4.08+/-0.15
43	2009/04/18 09:05:56	13.359	42.436	9	311 172	66 31	-110 -53	3.75	3.92+/-0.14
44	2009/04/21 15:44:36	13.371	42.324	9	139 347	54 40	-107 -68	3.47	3.74+/-0.16
45	2009/04/23 15:14:08	13.490	42.240	9	126 302	56 34	-88 -93	3.99	4.04+/-0.19
46	2009/04/23 21:49:00	13.470	42.230	9	133 322	53 38	-96 -82	4.18	4.20+/-0.18
47	2009/04/30 13:01:01	13.358	42.358	9	131 8	60 47	-128 -44	3.51	3.74+/-0.12
48	2009/05/01 05:12:51	13.470	42.280	9	142 347	61 32	-103 -68	3.59	3.74+/-0.20
49	2009/05/10 16:00:07	13.479	42.301	6	125 11	78 27	-115 -27	3.30	3.83+/-0.19
50	2009/05/14 06:30:22	13.406	42.501	7	154 328	48 42	-86 -94	3.44	3.52+/-0.20
51	2009/05/30 02:55:10	13.341	42.356	10	139 345	56 37	-106 -68	3.56	3.77+/-0.14
52	2009/06/07 19:21:34	13.483	42.350	2	303 107	49 42	-79 -102	3.33	3.82+/-0.17
53	2009/06/22 20:58:40	13.356	42.446	18	316 55	88 14	-76 -170	4.36	4.53+/-0.17
54	2009/06/23 00:41:56	13.369	42.441	7	315 201	85 12	-101 -24	3.70	3.96+/-0.14
55	2009/06/25 21:00:08	13.206	42.570	5	143 301	52 40	-76 -107	3.48	3.91+/-0.14
56	2009/07/03 09:43:53	13.361	42.328	9	145 318	54 36	-86 -96	3.32	3.60+/-0.17
57	2009/07/03 11:03:07	13.387	42.409	4	289 111	46 44	-91 -88	3.74	3.94+/-0.14
58	2009/07/12 08:38:51	13.370	42.340	9	138 341	61 31	-101 -71	4.16	4.18+/-0.17
59	2009/07/12 22:14:24	13.398	42.338	10	116 339	60 39	-115 -54	3.65	3.93+/-0.11
60	2009/07/31 11:05:40	13.505	42.247	7	145 333	60 30	-94 -83	3.88	4.03+/-0.17
61	2009/09/24 16:14:57	13.330	42.450	18	178 359	49 41	-91 -89	3.92	3.98+/-0.16
62	2009/10/20 05:07:30	13.240	42.398	4	20 114	81 67	-23 -171	3.49	3.71+/-0.16

Results

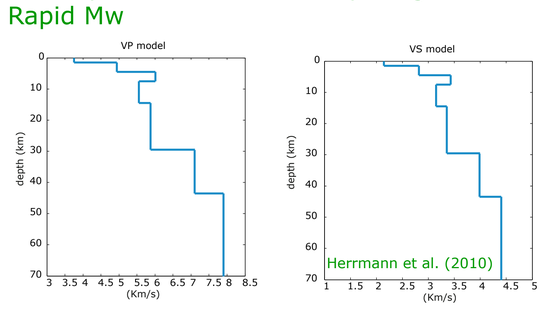
Rapid Mw - Tdmt Mw



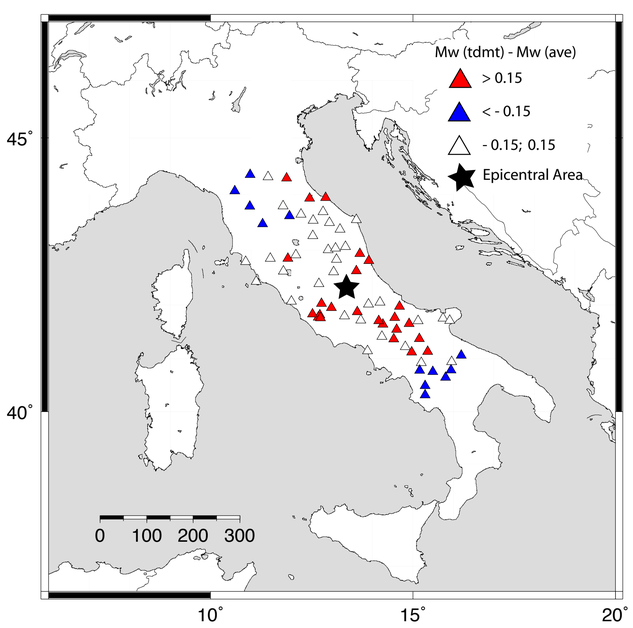


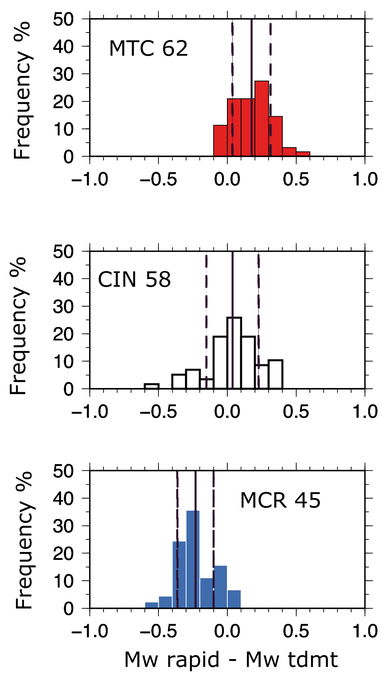
Each star corresponds to a seismic station used to evaluate the Rapid Mw. The stars dimension is proportional to the weight applied in the computation.

Velocity Model used for computing TDMT and Rapid Mw



Stations contributing to the Mw computation





For each station, we have evaluated the average +/- 1 standard deviation of the difference between all the rapid-Mw computed by the station and the relative tdmt-Mw. The Map shows the overall behavior of the 70 stations that have mainly contribute to the 62 magnitude estimation.