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# The instability of the $M_W$ and $M_L$ comparison for earthquakes in Greece for the period 1969 to 2007

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**Abstract** We use 576 earthquakes of magnitude,  $M_w$ , 3.3 to 6.8 that occurred within the region 33° N–42.5° N, 19° E–30° E in the time period 1969 to 2007 to investigate the stability of the relation between moment magnitude,  $M_w$ , and local magnitude,  $M_L$ , for earthquakes in Greece and the surrounding regions. We compare  $M_w$  to  $M_L$  as reported in the monthly bulletins of the National Observatory of Athens (NOA) and to  $M_L$  as reported in the bulletins of the Seismological Station of the Aristotle University of Thessaloniki. All earthquakes have been analyzed through regional or teleseismic waveform inversion, to obtain  $M_w$ , and have measured maximum trace amplitudes on the Wood–Anderson seismograph in Athens, which has been in operation since 1964. We show that the Athens Wood–Anderson seismograph performance has changed through time, affecting the computed by NOA  $M_L$  by at least 0.1

magnitude units. Specifically, since the beginning of 1996, its east–west component has been recording systematically much larger amplitudes compared to the north–south component. From the comparison between  $M_w$  and  $M_L$  reported by Thessaloniki, we also show that the performance of the sensors has changed several times through time, affecting the calculated  $M_L$ 's. We propose scaling relations to convert the  $M_L$  values reported from the two centers to  $M_w$ . The procedures followed here can be applied to other regions as well to examine the stability of magnitude calculations through time.

**Keywords** Magnitude · Local magnitude · Moment magnitude · Aegean · Earthquake

## 1 Introduction

The wide use of the local magnitude ( $M_L$ ) scale continues nowadays despite the introduction of other more robust magnitude scales (i.e., the  $M_w$  scale) and the progressive abolition of the analog Wood–Anderson instruments in which the original  $M_L$  scale was developed (Richter 1935). Today, seismologists continue to measure the “maximum trace amplitude” but on synthetic Wood–Anderson waveforms. Among the reasons for the continuous use of  $M_L$ , despite the changes in metrology in the digital era, are the ensuring

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of continuity in seismicity catalogs and the importance of  $M_L$  in engineering practice, as many buildings have resonant frequencies near 1 Hz, close to that of a Wood–Anderson seismograph. On the other hand,  $M_w$  is widely recognized as the best single measure of the size of an earthquake. It is therefore of great importance to continue using both scales and to calibrate accurately one against the other.

The goal of this study was to compare  $M_w$  values derived from regional or teleseismic waveform inversion and  $M_L$  values reported by the two longest operating seismological institutes in Greece, the Geodynamic Institute of the National Observatory of Athens (NOA) and the Seismological Station of the Aristotle University of Thessaloniki (SS-AUTH). Until few years ago, moment magnitudes for earthquakes in Greece were available, on a routine basis, for moderate-to-large magnitude events (usually for  $M_w > 5.5$ ) mainly through the Harvard centroid moment tensor (CMT) solutions. During the past decade, several groups started computing routinely moment tensors of earthquakes in the Mediterranean and thus in Greece, facilitating this type of studies. Firstly, we present a brief review of  $M_L$  computation methods followed by these two Greek seismological centers during the last four decades. Then, we show our results from the comparison of  $M_w - M_L$  values that have been reported for earthquakes in Greece and its surroundings since 1969 up to 2007, which is a benchmark year for the reported  $M_L$ 's in Greece. At the end of 2007, four seismological networks in Greece were unified to form the Hellenic Unified Seismological Network, and the reported  $M_L$ 's are based on simulated Wood–Anderson waveforms. A comparison of these magnitudes with those reported so far will be the subject of a future work.

## 2 Background on $M_L$ computation in Greece

### 2.1 Computation of $M_L$ in the Geodynamic Institute of NOA in Athens

$M_L$  estimates have been reported by the Geodynamic Institute of the NOA for earthquakes in Greece and its surroundings since 1964 based

on the maximum trace amplitudes on the two horizontal components of the Wood–Anderson (WA) seismograph in Athens (station ATH).

For the period 1964 up to November 2007, NOA has been using the Richter (1935, 1958) nomogram, applicable to the strongly attenuating crust of southern California, i.e., the calibration function ( $-\text{Log}A_0$ ), to calculate  $M_L$ 's for earthquakes in Greece. These magnitudes and trace amplitudes are reported in the monthly bulletins. It should be noted, however, that in the online earthquake catalog of NOA (<http://www.gein.noa.gr/services/cat.html>), magnitude is always characterized as  $M_L$ , even though for some smaller magnitude events the actual reported magnitude is a duration magnitude ( $M_D$ ), calibrated against  $M_L$ . This can be easily detected from the NOA bulletins (no WA amplitudes or  $M_L$  values are reported for smaller events).  $M_D$  is in some cases reported for larger magnitude events, as well because of amplitude clipping at the Athens WA seismograph.

Since November 2007 up to present, NOA has been computing  $M_L$  from synthetic WA seismograms that are derived from appropriate transformation of digital waveforms recorded on an STS-2 instrument collocated to the original Athens WA in station ATH. In this case, the Hutton and Boore (1987) relation is used to scale amplitudes with distance.

### 2.2 Computation of $M_L$ at the Seismological Station of AUTH network

The Seismological Network of the Aristotle University of Thessaloniki has been in full operation since January 1981. Initially, the network consisted of 12 stations in northern Greece, equipped with three component short-period S13 Teledyne-Geotech seismometers. This was the network configuration when the network was calibrated for magnitude calculation (Kiritzi 1984). No Wood–Anderson seismograph was ever installed in Thessaloniki. Thus, the calibration of the network for magnitudes was performed against the  $M_L$  magnitude calculated from the Athens WA seismograph using the appropriate calibration function (Kiritzi and Papazachos 1984) applicable to Greece. These calibrated  $M_L$ 's (Kiritzi

1984) were based on the total signal duration (Kiritzi and Papazachos 1985) and the ground amplitudes (Kiritzi and Papazachos 1986). SS-AUTH started reporting  $M_L$  for earthquakes in Greece and the neighboring region in July 1985.

In practice, for the period July 1985 up to August 2006 in the bulletins of the Seismological Station of the Aristotle University of Thessaloniki, the reported magnitudes (equivalent to  $M_L$ ) were calculated using the following empirical relations:

- (a) Calculated from the ground amplitudes ( $\alpha$ , inferred from the maximum trace amplitudes recorded on the vertical component)

For distances  $\Delta \leq 10$  km (Scordilis 1985):

$$M_L = \log \alpha + 2.736 + C_s \quad (1)$$

For distances  $10 \text{ km} < \Delta \leq 100$  km (Scordilis 1985):

$$M_L = \log \alpha + 1.199 \times \log \Delta + 1.268 + C_s \quad (2)$$

For distances  $>100$  km (Kiritzi 1984; Kiritzi and Papazachos 1985):

$$M_L = \log \alpha + 2.32 \times \log R - 1.07 + C_s$$

for  $3.0 \leq M_L \leq 6.0$  (3)

where  $\alpha$  (in microns) is the ground amplitude corresponding to the maximum peak-to-peak trace amplitude,  $\Delta$  is the epicentral distance, in kilometers,  $R$  is the hypocentral distance, in kilometers (in practice,  $\Delta$  has been used instead of  $R$  in SS-AUTH computations), and  $C_s$  appropriate station corrections.

- (b) Calculated from signal duration (dur)

For distances  $\leq 100$  km (Scordilis 1985):

$$M_L = 2.14 \times \log(\text{dur}) + 0.0038 \times \Delta + C_s \quad (4)$$

For distances  $>100$  km (Kiritzi 1984; Kiritzi and Papazachos 1985):

$$M_L = 1.97 \times \log(\text{dur}) + 0.0012 \times \Delta + C_s$$

for  $3.0 \leq M_L \leq 6.0$  (5)

where dur is the signal duration, in seconds, from the  $P$  onset till the point where the

peak-to-peak amplitude drops and remains below 2 mm on the paper recordings,  $\Delta$  is the epicentral distance, in kilometers, and  $C_s$  appropriate station corrections. The final  $M_L$  reported in SS-AUTH bulletins is the mean of all individual computations [(number of  $M_L$  computations from amplitudes + number of  $M_L$  computations from durations) / total number of computations].

For the period September 2006 to 31 July 2008,  $M_L$  was calculated from synthetic Wood–Anderson amplitudes using an unpublished empirical relation which was developed at SS-AUTH (Scordilis E., personal communication). This formula was calibrated against the  $M_L$  values of NOA reported on the online catalogue, thus against  $M_D$  values for smaller magnitude events.

For the period 01 August 2008–present,  $M_L$  is being calculated from synthetic Wood–Anderson seismograms using the relation of Hutton and Boore (1987), and the amplitude is the arithmetic mean in the two horizontal components.

Summarizing the above, we draw the following conclusions for  $M_L$  values reported by the two largest seismological institutes in Greece.

1. NOA has been reporting  $M_L$  since 1964 using the calibration function of Richter (1935, 1958). To the best of our knowledge, until the end of November 2007, there has not been a known change in the computation method of  $M_L$  from this institute, and therefore, its catalog is expected to be homogeneous for magnitude. We point out, however, that  $M_L$  values should be extracted from the monthly bulletins and not from the online catalog of the institute where  $M_L$  is mixed with  $M_D$  for smaller magnitude events and, in more rare cases, for larger magnitude events as well. It must also be noted that Richter’s (1958) distance correction factors used by NOA were proposed for southern California and are not optima for use in Greece due to differences in attenuation of seismic waves between the two regions. For this reason, Kiritzi and Papazachos (1984) used the original amplitudes from the WA seismograph in ATH station (data for the period 1966 to 1980) and

calculated calibration functions ( $-\text{Log}A_o$ ) applicable to Greece, proposing the formulae:

$$M_L = \log A + 2.00 \text{Log}(R/100)$$

for strong ( $M_L > 3.7$ ) events (6)

$$M_L = \log A + 1.58 \text{Log}(R/100)$$

for moderate ( $M_L \leq 3.7$ ) events (7)

where  $A$  (in microns) is the mean of the maximum zero-to-peak trace amplitude readings at the horizontal components of the Wood–Anderson seismograph and  $R$  is the hypocentral distance, in kilometers. These equations predict that the attenuation of amplitudes with distance in Greece is less compared to southern California (for example for an earthquake at an epicentral distance of 500 km, the nomogram of Richter predicts  $-\text{Log}A_o = 4.5$ , while Kiratzi and Papazachos (1984) predict  $-\text{Log}A_o = 4.25$ ). The above formulae have never been adopted in the routine analysis in NOA; thus, the reported  $M_L$  magnitudes were overestimated for  $R > 200$  km (see Fig. 6 in Kiratzi and Papazachos 1984).

2. The magnitude values reported in SS-AUTH bulletins until the end of July 2008 are  $M_L$  equivalent (calibrated against the  $M_L$  of NOA using the calibration functions of Kiratzi and Papazachos 1984). The computation method of the reported magnitudes has undergone significant changes which occurred in parallel to the upgrade of SS-AUTH network during the last 4 years. Its original short-period (S13) seismometers were gradually replaced by modern broadband instruments (mainly CMG-3ESP) and new stations were added to the network.

### 3 Data sources

Our dataset consists of 576 events, of the period 1969–2007, within the region  $33^\circ \text{N} - 42.5^\circ \text{N}$ ,  $19^\circ \text{E} - 31^\circ \text{E}$  with magnitudes  $3.3 \leq M_w \leq 6.8$ , 516 of which are shallow ( $h \leq 40$  km) and the rest

60 are intermediate-depth earthquakes ( $40 < h \leq 170$  km) that fulfill the following two criteria:

1. have been analyzed through teleseismic or regional waveform inversion and have reported  $M_w$  or seismic moment values
2. have been assigned maximum trace amplitudes measured on the Wood–Anderson instrument operated in the National Observatory of Athens (station ATH) and these original amplitudes were published in the bulletins.

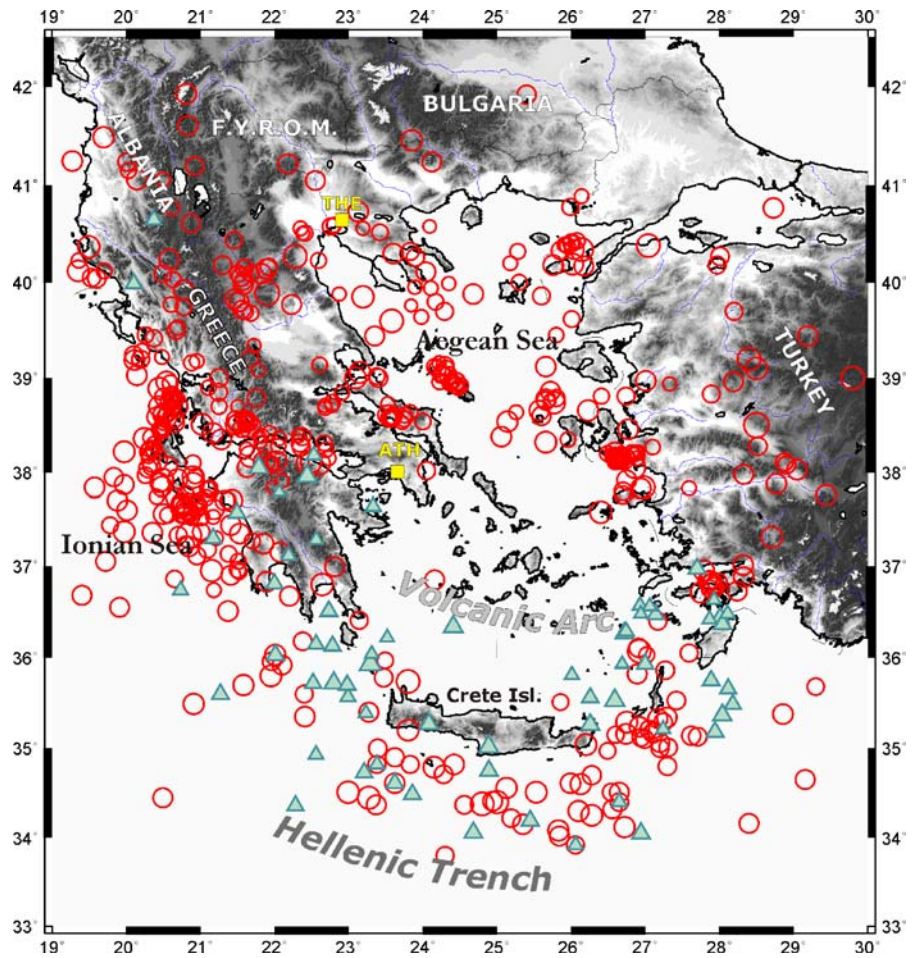
The distribution of epicenters within the study area is shown in Fig. 1, and the basic source parameters of these events are listed in Table 1. Figure 2a shows the number of the reported  $M_w$  values per year, and presumably after 2003, there is an impressive increase in the number of available data. This increase refers to smaller magnitude events as can be concluded from (Fig. 2b) where the mean  $M_w$  per year is shown.

$M_w$  values were collected from the published literature. For the earthquakes with  $M_w$  from various sources, for this specific work, we preferred to retrieve  $M_w$  from the Harvard Global CMT database (<http://www.globalcmt.org/CMTsearch.html>). We did that because CMT methods, in principle, should give a better estimate of  $M_o$  than the body wave methods because they use longer periods, which are a more stable indicator of moment. We also searched the moment tensor database of NOA (<http://bbnet.gein.noa.gr/MT.htm>) and the web page of the European–Mediterranean Seismological Institute (<http://www.emsc-csem.org>) where other institutes have been reporting fast moment tensors, and thus  $M_w$  values, during the last few years. Our final dataset includes also  $M_w$  estimates from moment tensor calculations performed by SS-AUTH (Roumelioti et al. 2009), the Swiss Seismological Survey (ETHZ), the Italian National Institute for Geophysics and Volcanology, the Kandilli Observatory (KOERI) of Turkey, and the University of Patras Seismological Laboratory. Moment tensor solutions from the latter four institutes are considered as published on the web page of the European–Mediterranean Seismological Institute.

It must be noted that we chose to calibrate  $M_L$  against  $M_w$  since the latter has been repeatedly



**Fig. 1** Regional map with the distribution of epicenters of 516 shallow,  $h \leq 40$  km (circles) and 60 intermediate-depth,  $40 < h \leq 170$  km (triangles) earthquakes included in the dataset (Table 1). The location of the station ATH (location of the Wood–Anderson seismograph) and the central station (THE) of the Seismological Station of Thessaloniki Network are also depicted as solid squares



proven to be the most robust magnitude determination (e.g., Pasyanos et al. 1996). For events used in this study, independent  $M_w$  computations from different sources exhibit consistency, with differences between them (if any) being of the order of 0.1 (e.g., Roumelioti et al. 2008a, b). Thus, although various computation methods from various institutes may lead to slightly different  $M_w$  estimates, the effect is not significant to distort the  $M_L$ – $M_w$  comparisons presented herein.

**4 The performance of the Wood–Anderson seismograph in ATH station through time**

During the gathering of our data, we noticed that after some point in time, the reported amplitude

for the east–west component ( $A_e$ ) is systematically much larger than the amplitude reported for the north–south component ( $A_n$ ). To further investigate and quantify this first observation, we plotted the  $A_e/A_n$  ratio versus time and the results are shown in Fig. 3. The ratio of the two amplitudes appears to be rather stable on average for the first 154 points of our dataset. In fact,  $A_n$  appears to be systematically larger than  $A_e$  on average ( $A_e/A_n$  is less than unity and approximately equal to  $0.95 \pm 0.26$ ). After the 155th point, which corresponds to an intermediate-depth event of  $M_w = 5.4$  that occurred on April 26, 1996 in southeastern Aegean,  $A_e$  becomes systematically larger than  $A_n$ , while scatter increases significantly. On average,  $A_e$  is  $1.7 \pm 0.5$  times larger. It is thus obvious that in the end of 1995–beginning of 1996, there was a change in the operation of the Athens

**Table 1** Source parameters of the 576 earthquakes used in the present study to calibrate  $M_w$  against  $M_{L(NO\text{A})}$  reported by the National Observatory of Athens (NOA) and  $M_{L(\text{THE})}$  reported by the Seismological Station of Thessaloniki University (SS-AUTH)

No	Date	Time	Lat (deg)	Lon (deg)	Depth (km)	$M_w$ (mm)	$A_n$ (mm)	$A_e$	Dist (km)	$M_{L(NO\text{A})}$	$M_{L(\text{THE})}$	Reference
1	690323	21:08:41	39.10	28.50	8.0	5.9	18.5	15.5	435	5.8		Eyidogan and Jackson (1985)
2	690325	13:21:32	39.20	28.40	8.0	6.1	17.0	14.7	430	5.7		Eyidogan and Jackson (1985)
3	690328	1:48:28	38.50	28.50	3.3	6.7	56.5	26.0	430	6.6		Braunmiller and Nabelek (1996)
4	690612	15:13:31	34.40	25.00	19.0	6	9.8	15.0	405	5.6		Taymaz et al. (1990)
5	700419	13:29:38	39.00	29.80	9.0	6.1	7.5	7.0	500	5.3		Eyidogan and Jackson (1985)
6	720913	04:13:20	37.96	22.44	80.0	6.1	156.0		120	5.4		Liotier (1989)
7	731104	15:52:14	38.89	20.44	23.0	5.8	26.0	27.2	285	5.4		Baker et al. (1997)
8	731129	10:57:44	35.20	23.80	18.0	5.7	27.0	18.0	315	5.5		Papadimitriou (1993)
9	750327	5:15:06	40.34	26.14	15.0	6.1	29.0	25.0	340	5.7		Taymaz et al. (1991)
10	750922	00:44:56	35.26	26.26	64.0	5.8	8.3	6.5	350	5.1		Taymaz et al. (1990)
11	751231	9:45:45	38.49	21.66	4.0	6.0	31.0	39.0	195	5.1		Kiratzi et al. (2007)
12	770818	9:27:41	35.27	24.08	45.0	5.7	15.0	11.5	296	5.2		CMT
13	770911	23:19:28	34.51	22.99	37.0	5.8	23.0	23.5	340	5.9		CMT
14	771103	2:22:57	41.46	23.85	15.0	5.5	12.5	10.5	420	5.6		CMT
15	771128	2:59:11	35.18	27.94	85.0	5.4	6.0	5.0	410	5.2		CMT
16	780307	22:33:49	34.19	25.45	42.0	5.5	4.5	3.5	405	5.1		CMT
17	780523	23:34:18	39.85	23.19	10.0	5.8	36.5	15.5	300	5.4		CMT
18	780619	10:31:12	40.73	23.13	15.0	5.3	7.0	5.0	290	4.8		CMT
19	780620	20:03:31	39.60	23.58	10.0	6.2	92.0	86.0	310	6.0		CMT
20	790409	2:10:25	41.25	19.27	15.0	5.4	1.1	1.4	570	5.0		CMT
21	790515	6:59:22	34.38	24.80	15.0	6.1	10.0	8.4	380	5.4		CMT
22	790614	11:44:48	37.58	26.40	15.0	5.8	45.0	37.3	260	5.5		CMT
23	790615	11:34:14	34.82	24.42	33.0	5.4	6.5	5.8	355	5.1		CMT
24	790616	18:42:03	38.46	26.77	15.0	5.3	10.0	6.0	270	4.8		CMT
25	790718	13:12:08	39.44	29.19	15.0	5.3	4.5	3.3	485	5.2		CMT
26	790723	11:41:53	35.29	26.75	15.0	5.6	5.0	5.0	380	5.1		CMT
27	790822	20:12:47	35.75	27.89	94.0	5.3	3.0	2.0	405	4.9		CMT
28	800710	19:39:08	39.00	23.09	15.0	5.6	41.5	42.5	155	5.0		CMT
29	800811	9:16:04	39.44	23.35	15.0	5.2	22.0	25.0	160	4.7		CMT
30	810310	15:16:23	38.53	20.64	19.0	5.4	18.2	14.8	305	5.3		CMT
31	810624	18:41:28	37.89	20.45	22.0	5.2	10.4	10.8	325	5.2		CMT
32	810628	17:20:23	37.60	20.01	18.1	5.4	20.5	24.5	310	5.5		CMT
33	810913	23:25:25	34.56	25.13	15.0	5.5	2.4	3.6	395	4.9		CMT
34	811229	8:00:46	38.38	25.06	15.0	5.4	123.0	137.0	130	5.4		CMT
35	820622	3:04:33	37.44	21.41	38.0	5.4	73.0	56.0	250	5.7		CMT
36	821116	23:41:28	40.12	19.35	10.0	5.6	4.5	6.2	442	5.3		CMT
37	830117	12:41:44	38.13	20.38	10.0	6.8	130.0	120.0	304.9	6.2		CMT
38	830119	0:02:14	37.88	20.90	15.0	5.8	37.0	31.0	290.2	5.5		CMT
39	830131	15:27:02	38.35	21.28	28.0	5.4	24.0	11.6	290.5	5.3		CMT

**Table 1** (continued)

No	Date	Time	Lat (deg)	Lon (deg)	Depth (km)	$M_w$ (mm)	$A_n$ (mm)	$A_e$	Dist (km)	$M_{L(NO\text{A})}$	$M_{L(T\text{HE})}$	Reference
40	830221	0:13:08	37.36	20.35	26.0	5.3	11.0	6.4	320.5	5.1		CMT
41	830319	21:41:49	34.75	24.89	65.0	5.6	10.0	11.5	323.3	5.2		CMT
42	830323	23:51:15	37.92	20.48	33.0	6.2	45.9	43.7	291.8	5.7		CMT
43	830324	4:17:36	38.58	20.54	25.0	5.4	12.5	10.2	304.2	5.1		CMT
44	830514	23:13:46	38.06	20.55	15.0	5.4	11.0	10.0	290.7	5.0		CMT
45	830705	12:01:33	40.38	27.04	15.0	6.1	35.0	25.0	390.7	5.9		CMT
46	830714	2:54:26	36.51	21.37	25.0	5.3	18.3	16.8	284	5.2		CMT
47	830826	12:52:10	40.11	24.04	15.0	5.1	3.3	3.9	276.9	4.5		CMT
48	830727	23:59:40	36.97	27.70	170.0	5.4	9.0	6.1	324.8	5.2		CMT
49	831010	10:17:02	40.18	25.76	15.0	5.4	16.0	27.7	311.1	5.4		CMT
50	840211	8:02:54	38.11	21.86	15.0	5.6	52.0	58.5	161.3	5.1		CMT
51	840506	9:12:07	38.66	25.57	10.0	5.4	25.0	22.2	195.2	4.9		CMT
52	840522	13:57:11	36.13	22.78	73.0	5.1	8.0	5.0	246.3	4.7		CMT
53	840617	7:48:08	38.86	25.72	15.0	5.1	50.0	30.0	222.3	5.3		CMT
54	840621	10:43:47	35.74	23.80	34.0	6.2	64.0	77.0	292	5.9		CMT
55	840709	18:57:14	41.05	22.55	10.0	5.2	5.0	5.5	338.8	4.9		CMT
56	850421	8:49:42	35.35	22.41	38.5	5.3	12.0	10.0	292.4	5.1		CMT
57	850430	18:14:16	39.06	23.15	15.0	5.6	88.0	76.0	158.4	5.3		CMT
58	850523	16:02:27	36.99	22.81	22.0	5.2	16.7	10.8	209.1	4.7		CMT
59	850722	21:32:35	34.16	28.40	15.0	5.2	2.3	2.3	582.3	5.3	4.9	CMT
60	850907	10:20:54	37.35	21.53	10.0	5.4	31.0	28.0	232.6	5.2	4.9	CMT
61	850927	16:39:48	34.05	26.94	44.0	5.6	3.0	2.1	445.5	5.0		CMT
62	850928	14:50:20	41.22	22.18	21.0	5.2	2.1	2.1	384	4.7	4.6	CMT
63	851109	23:30:47	41.24	24.12	21.0	5.2	7.5	7.3	349.7	5.1	4.8	CMT
64	851121	21:57:19	41.49	19.69	10.0	5.5	3.7	3.8	512.2	5.3	4.9	CMT
65	860325	1:41:42	38.54	25.14	15.0	5.5	86.5	98.0	131.7	5.2	5.0	CMT
66	860522	19:52:21	34.12	26.72	33.0	5.5	1.8	1.8	426.6	4.8	4.7	CMT
67	860608	4:55:15	36.67	22.20	29.0	5.1	3.8	3.8	297.7	4.6		CMT
68	860913	17:24:34	36.80	22.64	15.0	5.9	132.0	106.0	166.1	5.5		CMT
69	861002	10:12:46	34.65	29.16	15.0	5.2	1.7	1.0	512.8	4.9		CMT
70	861011	9:00:15	37.31	28.71	15.0	5.6	10.6	5.6	465.3	5.5		CMT
71	870227	23:34:55	38.51	21.02	15.0	5.7	30.7	16.0	292.4	5.4	5.2	CMT
72	870412	2:47:16	35.40	23.27	15.0	5.1	9.9	7.7	273.4	4.9	4.9	CMT
73	870529	18:40:34	37.57	21.49	57.0	5.2	35.0	30.0	192.8	5.0	5.0	CMT
74	870610	14:50:13	36.83	21.89	37.0	5.3	17.0	30.1	218.8	5.0	4.9	CMT
75	870619	18:45:42	36.44	28.01	60.0	5.3	1.5	1.3	404.8	4.6	4.6	CMT
76	880109	1:02:48	40.37	19.49	15.0	5.9	2.5	2.5	500.7	5.1		CMT
77	880424	20:49:39	40.77	28.73	15.0	5.3	1.7	1.6	500.7	4.9	5.2	CMT
78	880518	5:17:40	37.70	19.88	23.0	5.3	24.5	17.0	287.5	5.3	5.1	CMT
79	880905	20:03:36	34.51	26.65	15.0	5.2	1.4	1.3	443.5	4.7		CMT
80	881016	12:34:13	37.95	20.90	29.0	5.8	51.0	58.0	242.2	5.5		CMT
81	881120	21:01:09	35.38	28.86	15.0	5.4	1.7	1.5	531	5.0		CMT
82	890219	14:28:54	37.01	28.32	15.0	5.4	1.5	1.2	381.5	4.5	4.2	CMT
83	890224	0:40:45	37.76	29.44	15.0	5.3	1.7	1.2	497.8	4.9	4.8	CMT
84	890317	5:42:53	34.51	25.53	17.0	5.7	2.4	2.5	392.6	4.8	5.1	CMT
85	890319	5:37:02	38.61	23.53	15.0	5.4	98.0	98.0	146.4	5.3	5.8	CMT
86	890328	13:29:14	34.06	24.68	56.0	5.5	3.0	2.2	432.2	4.9		CMT
87	890427	23:06:55	36.71	27.75	15.0	5.5	4.2	3.5	388.9	5.0	5.0	CMT
88	890428	13:30:22	36.95	27.79	15.0	5.5	7.0	3.7	384.1	5.1	4.9	CMT
89	890607	19:45:58	38.05	21.63	25.0	5.2	24.0	24.2	181.7	4.8	4.5	CMT
90	890614	18:06:40	34.30	26.10	15.0	5.5	1.7	1.4	454.8	4.8		CMT



**Table 1** (continued)

No	Date	Time	Lat (deg)	Lon (deg)	Depth (km)	$M_w$ (mm)	$A_n$ (mm)	$A_e$	Dist (km)	$M_{L(NO A)}$	$M_{L(THE)}$	Reference
91	890820	18:32:36	36.95	21.15	15.0	5.8	42.0	39.0	242.8	5.4	5.3	CMT
92	890824	2:13:11	37.05	19.72	15.0	5.2	12.8	10.6	317.6	5.2	5.2	CMT
93	890827	1:21:17	34.25	26.28	15.0	5.6	2.5	2.0	419.8	4.9	4.9	CMT
94	890905	6:52:37	39.12	25.66	15.0	5.4	9.0	9.2	268.3	4.9	4.9	CMT
95	900616	2:16:21	38.70	20.44	15.0	5.5	16.5	28.5	317.8	5.5		CMT
96	901221	6:57:45	40.27	22.28	15.0	6.1	12.0	18.5	349	5.4	5.9	CMT
97	910319	12:09:27	34.60	26.13	15.0	5.5	7.5	7.0	392.5	5.3	5.2	CMT
98	910626	11:43:44	38.42	21.17	31.0	5.3	6.7	4.7	276.7	4.7	4.7	CMT
99	920123	4:24:19	38.22	19.97	15.0	5.6	12.0	9.0	292.2	5.0	4.9	CMT
100	920320	5:37:29	36.85	24.16	15.0	5.2	25.0	20.5	166.7	4.8	5.0	CMT
101	920430	11:44:43	35.04	26.20	33.0	5.7	12.2	12.7	409.3	5.6	5.8	CMT
102	920723	20:12:50	39.88	24.68	15.0	5.4	28.5	17.5	214.7	5.0	5.0	CMT
103	921106	19:08:13	37.84	26.98	25.0	6	46.0	35.0	305.7	5.7	5.4	CMT
104	921118	21:10:48	38.09	22.60	15.0	5.9	124.0	71.0	126.3	5.2	5.4	CMT
105	921121	5:07:25	35.72	22.80	70.0	5.9	54.0	55.0	298.2	5.8	6.1	CMT
106	930305	6:55:10	36.90	21.41	37.0	5.2	38.5	39.8	223.4	5.3	4.8	CMT
107	930318	15:47:06	38.05	21.79	49.0	5.8	40.0	40.0	136.6	4.9	5.0	CMT
108	930326	11:58:20	37.61	21.18	15.0	5.4	34.5	25.0	203.9	5.0	4.8	CMT
109	930613	23:26:42	39.03	20.14	15.0	5.3	18.6	23.0	308.5	5.4	4.8	CMT
110	930714	12:31:54	38.17	21.67	20.0	5.6	42.5	42.5	172.6	5.1	4.8	CMT
111	931104	5:18:41	38.12	22.03	15.0	5.3	17.4	15.0	161.4	4.6	4.9	CMT
112	940111	7:22:52	35.70	21.58	33.0	5.5	28.1	20.0	284.4	5.4	5.0	CMT
113	940128	15:45:32	38.97	27.01	15.0	5.4	11.5	9.3	346.4	5.3	4.9	CMT
114	940225	2:30:55	38.63	20.50	33.0	5.4	23.0	21.2	286.9	5.3	5.1	CMT
115	940523	6:46:19	35.02	24.89	81.0	6	33.5	23.0	299.6	5.6	5.3	CMT
116	940524	2:05:41	38.66	26.23	21.0	5.5	75.0	57.5	241.7	5.6	5.1	CMT
117	941129	14:30:31	38.61	20.49	15.0	5.1	6.0	9.4	294.5	4.9	4.7	CMT
118	950103	22:51:44	34.90	23.62	15.0	5.0	2.0	1.8	321.8	4.4	4.2	Arvidsson and Ekstrom (1998)
119	950107	20:30:47	37.95	19.83	19.0	5.0	4.1	3.0	332.9	4.7	4.6	Arvidsson and Ekstrom (1998)
120	950203	22:29:09	34.22	25.19	15.0	4.9	0.9	1.0	416.2	4.5	4.6	Arvidsson and Ekstrom (1998)
121	950216	13:02:18	34.32	26.56	15.0	5.0	1.0	1.0	476.3	4.7	4.7	Arvidsson and Ekstrom (1998)
122	950330	18:17:15	34.37	24.56	22.0	4.8	1.2	1.4	413.1	4.6		Arvidsson and Ekstrom (1998)
123	950503	21:36:52	40.26	23.90	16.0	4.7	2.0	2.1	289.9	4.3	4.5	Arvidsson and Ekstrom (1998)
124	950503	21:43:25	40.32	23.83	16.0	4.7	3.0	2.9	293.9	4.5	4.6	Arvidsson and Ekstrom (1998)
125	950508	05:11:09	38.27	22.36	17.0	4.6	5.4	5.0	143.9	4.0	4.0	Arvidsson and Ekstrom (1998)
126	950509	01:14:37	40.61	20.87	21.0	4.9	2.2	2.0	398.6	4.7	4.7	Arvidsson and Ekstrom (1998)
127	950504	0:34:15	40.30	23.60	15.0	5.3	11.0	10.0	287.9	5.0	5.3	CMT
128	950513	8:47:20	39.89	21.90	15.0	6.5	97.0	115.0	300.2	6.1	6.1	CMT
129	950513	10:58:34	40.06	21.55	15.0	5.0	1.0	1.2	295.2	4.1	3.9	Arvidsson and Ekstrom (1998)
130	950513	11:43:28	40.14	21.89	28.0	5.3	1.5	1.2	303.7	4.2	4.4	Arvidsson and Ekstrom (1998)

**Table 1** (continued)

No	Date	Time	Lat (deg)	Lon (deg)	Depth (km)	$M_w$ (mm)	$A_n$ (mm)	$A_e$	Dist (km)	$M_{L(NO A)}$	$M_{L(THE)}$	Reference
131	950515	4:14:00	39.80	21.52	15.0	5.2	8.0	9.5	291.6	5.0	4.6	CMT
132	950515	08:16:58	40.44	21.45	21.0	4.5	0.5	1.0	302.9	3.9	4.0	Arvidsson and Ekstrom (1998)
133	950515	09:01:51	40.16	21.92	15.0	4.5	0.5	0.5	303.8	3.8	3.6	Arvidsson and Ekstrom (1998)
134	950515	09:19:42	40.09	21.51	31.0	4.5	1.0	1.2	306.9	4.1	3.9	Arvidsson and Ekstrom (1998)
135	950516	04:37:30	40.18	21.30	29.0	4.8	1.2	1.6	295.8	4.2	4.0	Arvidsson and Ekstrom (1998)
136	950518	03:48:58	40.09	21.82	15.0	5.3	0.5	0.7	286.8	3.8	3.5	Arvidsson and Ekstrom (1998)
137	950519	6:48:56	39.98	21.58	15.0	5.1	6.0	4.5	297.9	4.8	4.6	CMT
138	950520	20:09:30	40.01	21.58	36.0	4.6	1.0	1.1	290.6	4.0	3.8	Arvidsson and Ekstrom (1998)
139	950521	04:04:22	39.70	21.60	15.0	4.4	0.5	0.6	297.0	3.8	3.9	Arvidsson and Ekstrom (1998)
140	950523	04:37:38	40.09	21.68	23.0	4.4	0.7	0.9	302.6	4.0	3.7	Arvidsson and Ekstrom (1998)
141	950524	06:24:06	40.09	21.68	22.0	4.5	1.0	1.1	291.7	4.0	3.9	Arvidsson and Ekstrom (1998)
142	950528	19:56:39	38.08	21.93	15.0	4.8	5.3	5.0	160.5	4.1	4.3	Arvidsson and Ekstrom (1998)
143	950605	05:20:19	39.45	20.26	15.0	4.4	1.4	1.5	343.4	4.4	4.2	Arvidsson and Ekstrom (1998)
144	950611	18:51:46	39.72	21.56	19.0	4.8	2.0	2.2	285.9	4.3	4.3	Arvidsson and Ekstrom (1998)
145	950615	0:15:56	38.10	22.46	15.0	6.5	195.0	154.0	144	5.6	5.8	CMT
146	950615	04:51:18	38.31	22.34	20.0	4.7	6.1	5.6	141.0	4.1	4.1	Arvidsson and Ekstrom (1998)
147	950615	07:00:59	38.38	22.37	24.0	4.6	3.9	4.2	148.4	3.9	3.8	Arvidsson and Ekstrom (1998)
148	950619	15:00:16	39.68	21.68	21.0	4.2	0.9	1.2	281.7	4.0	3.7	Arvidsson and Ekstrom (1998)
149	950717	23:18:18	39.83	21.46	15.0	5.2	7.3	7.3	301.8	4.9	5.0	CMT
150	951207	18:01:01	34.79	24.15	15.0	5.6	2.9	2.2	335	4.6	4.8	CMT
151	951210	3:27:52	34.37	23.37	21.0	5.2	4.2	4.6	338.2	4.8	4.9	CMT
152	960201	17:58:01	37.84	19.57	15.0	5.3	7.9	10.7	348.3	5.2	4.9	CMT
153	960402	7:59:27	37.83	26.94	15.0	5.4	10.9	10.8	278.1	5.0	4.5	CMT
154	960412	15:39:10	36.47	27.14	152.0	5.2	4.7	5.5	331.6	5.0	4.7	CMT
155	960426	7:01:33	36.37	28.04	128.0	5.4	3.2	8.5	416.4	5.3		CMT
156	960720	0:00:47	36.07	26.92	15.0	6.2	33.0	46.0	361.7	5.9	5.5	CMT
157	960722	1:44:42	36.11	26.91	15.0	5	2.2	3.8	408.2	4.9	4.0	CMT
158	960726	18:55:55	39.92	20.77	15.0	5.3	3.0	6.0	350.3	4.9	4.5	CMT
159	970121	20:47:50	37.98	28.33	18.0	5.2	2.0	1.1	457.6	4.8		CMT
160	970516	7:00:54	41.06	20.14	21.0	5.3	6.5	10.0	446.6	5.5		CMT
161	970727	10:07:56	35.49	20.91	33.0	5.5	4.0	9.6	385.1	5.2		CMT
162	971105	12:22:58	34.61	23.62	40.0	5.4	2.5	4.0	340.6	4.7	4.9	CMT
163	971105	21:10:32	38.11	22.49	15.0	5.6	42.0	56.5	129.6	4.9	4.8	CMT
164	971114	21:38:55	38.74	25.77	15.0	5.8	62.0	79.0	209.2	5.4	5.1	CMT
165	971118	13:07:52	37.33	20.84	23.0	6.6	112.0	116.0	295.3	6.1	6.1	CMT
166	971202	19:22:46	36.68	19.40	15.0	5.2	1.2	2.1	445.2	4.8	4.6	CMT

**Table 1** (continued)

No	Date	Time	Lat (deg)	Lon (deg)	Depth (km)	$M_w$ (mm)	$A_n$ (mm)	$A_e$	Dist (km)	$M_{L(NO A)}$	$M_{L(THE)}$	Reference
167	980110	19:22:00	37.21	20.84	36.0	5.4	10.0	22.0	280.4	5.2	4.9	CMT
168	980309	11:21:20	35.66	28.12	54.0	5.1	1.2	3.5	475.6	5.0	4.8	CMT
169	980429	3:30:42	36.03	22.01	40.0	5.5	22.5	53.0	269.3	5.5	5.1	CMT
170	980501	4:00:19	37.56	20.50	33.0	5.3	4.0	5.0	302.4	4.8	4.7	CMT
171	980930	23:43:00	41.93	20.81	18.0	5.3	3.0	5.5	516.3	5.4	4.6	CMT
172	981006	12:27:49	37.85	20.48	15.0	5.4	16.0	37.0	245.8	5.2	4.8	CMT
173	981007	18:47:38	34.02	25.84	22.0	5.1	0.8	1.2	486.8	4.7	4.4	CMT
174	990417	8:17:59	35.60	21.27	44.0	5.3	7.0	13.0	266.9	4.9	4.7	CMT
175	990611	7:50:19	37.30	21.17	59.0	5.2	11.2	33.1	233	5.1	4.5	CMT
176	990725	6:56:56	38.96	28.19	15.0	5.2	3.4	5.8	383.9	5.0	4.6	CMT
177	991005	0:53:30	36.73	28.24	33.0	5.2	4.6	7.5	482	5.4		CMT
178	991222	9:06:17	41.61	20.83	15.0	5.1	0.9	1.7	499.8	4.8	4.2	CMT
179	000222	11:55:31	34.15	25.35	33.0	5.3	2.0	5.1	392.7	5.0	4.9	CMT
180	000405	4:36:58	34.08	25.83	15.0	5.5	2.9	5.5	452	5.2		CMT
181	000524	5:40:42	35.80	21.95	38.0	5.7	19.0	50.0	266.2	5.4	5.0	CMT
182	000524	10:01:44	35.92	22.10	15.0	5.2	3.6	5.5	264.9	4.6	4.4	CMT
183	000526	1:28:28	38.96	20.54	15.0	5.5	15.0	24.0	293.3	5.3	4.8	CMT
184	000613	1:43:21	35.16	26.74	15.0	5.4	3.0	6.4	444.4	5.2	4.8	CMT
185	000615	21:30:36	34.45	20.49	15.0	5.1	0.6	1.4	535.3	4.8	4.7	CMT
186	010409	17:38:45	39.99	20.10	51.0	5	4.3	14.0	366.2	5.3	4.7	CMT
187	010501	6:00:57	35.33	27.17	33.0	5.2	2.4	3.5	432.2	5.0		CMT
188	010529	4:44:03	35.49	28.18	46.0	5.1	2.1	4.1	448.6	5.1	4.4	CMT
189	010610	13:11:04	38.32	25.66	34.0	5.6	35.0	51.0	172.9	5.1	4.8	CMT
190	010623	6:52:48	35.37	28.04	58.0	5.7	2.5	4.5	491.7	5.2	4.9	CMT
191	010721	12:47:38	39.04	24.28	14.0	4.3	11.0	33.0	133.3	4.6	4.3	Benetatos (2007)
192	010725	15:43:13	39.04	24.25	14.0	4.6	7.0	10.0	131.7	4.2	4.0	Benetatos (2007)
193	010726	1:48:40	38.96	24.39	18.0	4.4	12.4	17.0	124.3	4.4	4.5	Benetatos (2007)
194	010726	2:01:53	39.10	24.31	8.0	4.4	18.0	19.0	135.5	4.5		Benetatos (2007)
195	010726	2:06:38	38.96	24.45	18.0	4.6	22.5	40.0	127.2	4.7		Benetatos (2007)
196	010726	2:09:51	38.96	24.45	16.0	4.8	31.0	47.0	126.9	4.8	5.2	Benetatos (2007)
197	010726	2:26:30	39.03	24.34	14.0	4.6	10.0	11.0	126.6	4.2		Benetatos (2007)
198	010726	4:31:37	38.95	24.37	20.0	4.4	7.0	17.5	124.5	4.3	4.5	Benetatos (2007)
199	010726	4:49:47	38.96	24.37	10.0	4	4.0	10.0	123.2	4.1		Benetatos (2007)
200	010726	4:53:37	39.03	24.34	14.0	4.7	19.5	26.0	133.4	4.6	5.1	Benetatos (2007)
201	010726	14:24:34	39.10	24.20	10.0	4.5	17.5	30.0	135.3	4.6	4.6	Benetatos (2007)
202	010730	16:38:24	39.05	24.25	8.0	4.4	10.0	13.5	135	4.3	4.4	Benetatos (2007)
203	010808	13:12:04	38.92	24.45	6.0	4.3	11.0	20.0	123.5	4.4	3.8	Benetatos (2007)
204	010810	7:47:09	38.96	24.23	28.0	4.1	6.0	10.0	123.7	4.1	3.3	Benetatos (2007)
205	010827	21:43:43	39.12	24.16	16.0	4.1	7.9	15.5	138.1	4.3	3.7	Benetatos (2007)
206	010916	2:00:52	37.24	21.85	15.0	5.4	43.5	59.5	182.9	5.2		CMT
207	011126	5:03:26	34.49	23.86	48.0	5.2	3.5	7.0	357.6	5.0	4.7	CMT
208	020122	4:53:55	35.53	26.59	90.0	6.1	49.5	40.0	378.9	6.1	5.3	CMT
209	020521	20:53:34	36.34	24.41	100.0	5.9	25.0	51.0	164.7	5.1	5.1	CMT
210	020606	22:35:44	35.56	26.26	110.0	5.2	4.5	13.5	340.8	5.2	4.7	CMT
211	020728	17:16:37	37.93	20.69	22.0	5.3	6.4	17.0	261.4	4.7	4.5	CMT
212	020930	19:58:12	37.83	21.12	16.0	4.1	2.0	4.5	228.5	4.2	3.9	Roumelioti et al. (2004)
213	021012	5:58:55	34.61	25.99	15.0	5.4	3.0	5.5	403.4	5.1		CMT
214	021202	4:59:01	37.70	21.42	15.0	5.6	30.0	44.0	226.7	5.3	4.9	CMT
215	021203	0:38:57	37.82	21.12	17.0	4.1	1.5	3.5	230.2	4.1	3.9	Roumelioti et al. (2004)

**Table 1** (continued)

No	Date	Time	Lat (deg)	Lon (deg)	Depth (km)	$M_w$ (mm)	$A_n$ (mm)	$A_e$	Dist (km)	$M_{L(NOAA)}$	$M_{L(THE)}$	Reference
216	021204	22:35:15	37.84	21.13	9.0	3.8	0.8	1.7	228.1	3.8	3.7	Roumelioti et al. (2004)
217	021209	9:35:06	37.87	19.97	15.0	5.2	3.0	6.5	349.8	4.9		CMT
218	021211	15:52:17	38.27	27.10	8.5	4.0	0.5	0.8	318.2	3.9		Zhu et al. (2006)
219	021213	1:19:47	37.83	21.09	8.0	4	1.0	2.2	231.6	3.9	3.6	Roumelioti et al. (2004)
220	021231	20:28:32	39.00	21.25	15.0	4.9	3.3	11.0	243.5	4.6	4.2	Adamova et al. (2008)
221	030130	20:20:05	36.40	27.17	18.8	4.7	1.2	2.0	359.3	4.5		Pondrelli et al. (2007)
222	030224	20:22:26	39.42	20.37	17.9	4.5	1.0	2.0	322.8	4.3	4.1	Pondrelli et al. (2007)
223	030301	04:06:03	34.82	23.83	25.2	4.6	1.8	2.4	327.9	4.5		Pondrelli et al. (2007)
224	030410	0:40:21	38.05	26.86	15.0	5.7	27.0	26.5	268.3	5.3	5.0	CMT
225	030410	01:16:16	38.21	26.87	5.0	3.8	0.6	1.0	275.5	3.8		Zhu et al. (2006)
226	030410	01:32:19	38.21	26.88	5.0	3.8	0.6	1.0	270.7	3.8		Zhu et al. (2006)
227	030410	03:03:52	38.19	26.85	5.0	3.6	0.5	0.9	277.4	3.8		Zhu et al. (2006)
228	030410	18:04:34	38.22	26.82	8.2	3.7	0.5	0.9	263.5	3.7		Zhu et al. (2006)
229	030411	10:57:18	38.15	26.89	25.0	3.8	0.5	0.6	265.3	3.6		Zhu et al. (2006)
230	030411	23:53:52	37.28	22.56	70.0	4.5	10.5	13.5	101.6	4.3	4.1	Pondrelli et al. (2007)
231	030417	22:34:29	37.92	26.75	15.0	5.2	11.0	10.5	280.1	5.0		CMT
232	030429	1:51:27	36.81	22.00	56.0	5.1	11.0	26.0	218.2	5.0	4.6	CMT
233	030504	11:00:33	38.21	26.89	5.0	4.2	1.2	1.6	293.1	4.2	4.0	Zhu et al. (2006)
234	030609	22:05:56	38.94	27.33	13.6	3.6	0.4	0.5	345.5	3.9		Zhu et al. (2006)
235	030609	7:06:46	39.77	22.23	15.0	5.2	12.4	18.0	248.8	5.0	4.6	CMT
236	030609	17:44:04	40.18	27.97	15.0	4.7	1.0	1.5	425.5	4.6	4.7	Pondrelli et al. (2007)
237	030613	16:06:34	38.58	23.59	4.0	4.3	11.0	21.0	70.2	4.1	4.0	Benetatos et al. (2004)
238	030613	16:30:29	38.58	23.58	5.0	4.3	10.0	18.0	67.5	4.0	3.7	Benetatos et al. (2004)
239	030613	20:22:02	38.57	23.55	8.0	4.4	4.0	9.5	70.6	3.7	3.2	Benetatos et al. (2004)
240	030616	15:18:57	38.58	23.57	5.0	4	3.5	7.2	69.8	3.6	3.5	Benetatos et al. (2004)
241	030618	5:25:02	38.60	23.60	5.0	4.7	35.0	35.0	72.5	4.4	4.2	Benetatos et al. (2004)
242	030619	1:00:04	38.57	23.56	5.0	4	13.7	21.0	69.7	4.1	3.6	Benetatos et al. (2004)
243	030619	1:03:56	38.57	23.58	5.0	4.3	8.5	16.0	72.1	4.0	3.9	Benetatos et al. (2004)
244	030619	3:38:22	38.57	23.58	4.0	3.6	12.5	19.0	69.3	4.0	4.1	Benetatos et al. (2004)
245	030621	3:29:19	38.58	23.59	4.0	3.6	3.2	4.5	73.5	3.4	3.2	Benetatos et al. (2004)
246	030622	23:46:29	39.70	28.20	25.0	4.7	1.1	1.6	409.5	4.6	4.3	ETHZ
247	030626	13:45:58	38.57	23.74	4.0	4.4	16.0	20.0	71.4	4.1	4.1	Benetatos et al. (2004)

**Table 1** (continued)

No	Date	Time	Lat (deg)	Lon (deg)	Depth (km)	$M_w$ (mm)	$A_n$ (mm)	$A_e$	Dist (km)	$M_{L(NOAA)}$	$M_{L(THE)}$	Reference
248	030701	6:22:50	38.58	23.54	5.0	4.3	9.0	19.5	73.3	4.0	3.8	Benetatos et al. (2004)
249	030704	3:24:36	38.58	23.55	5.0	4	5.3	7.5	72.7	3.7	3.5	Benetatos et al. (2004)
250	030705	13:00:13	38.58	23.55	4.0	3.6	4.0	5.0	70.9	3.5	3.2	Benetatos et al. (2004)
251	030705	21:58:30	40.43	26.08	16.0	4.3	0.8	0.9	348.4	4.2	4.0	Karabulut et al. (2006)
252	030706	19:10:33	40.19	26.02	15.0	5.7	15.0	16.0	339.7	5.4	5.0	CMT
253	030706	19:39:50	40.41	26.00	19.0	4.2	0.5	0.5	332.3	3.9	3.9	Karabulut et al. (2006)
254	030706	20:10:19	40.17	26.17	15.0	5.2	2.5	3.1	333.3	4.6	4.7	CMT
255	030706	20:48:53	40.41	26.01	20.0	4.7	0.6	0.6	332.9	4.0	4.0	Karabulut et al. (2006)
256	030709	22:01:57	40.39	25.91	13.0	3.8	0.5	0.7	336	4.0	3.8	Karabulut et al. (2006)
257	030709	22:31:42	40.33	25.86	18.0	4.8	2.2	3.0	324.2	4.6	4.5	CMT
258	030713	6:32:08	40.39	25.92	14.0	4	0.4	0.6	329.5	3.9	3.9	Karabulut et al. (2006)
259	030723	4:56:07	37.88	28.77	15.0	5.3	2.5	2.7	454.9	5.0	4.6	CMT
260	030726	01:00:56	38.08	28.91	5.0	4.6	1.0	0.9	440.6	4.5		Zhu et al. (2006)
261	030726	8:36:55	38.03	29.05	15.0	5.4	3.0	2.5	445.3	5.0		CMT
262	030726	13:31:36	38.11	28.88	5.0	4.6	1.5	1.5	445.3	4.7		Zhu et al. (2006)
263	030814	5:15:08	38.70	20.67	15.0	6.2	80.0	80.0	290.8	5.9	5.7	CMT
264	030814	7:06:35	38.44	20.48	5.0	4.1	0.6	0.6	291.1	3.8		Benetatos et al. (2005)
265	030814	8:41:39	38.82	20.61	10.0	4.7	4.5	10.1	291.3	4.9	4.2	Benetatos et al. (2005)
266	030814	9:03:06	38.78	20.61	5.0	4	0.6	0.8	287.1	3.8	3.6	Benetatos et al. (2005)
267	030814	10:01:15	38.75	20.60	7.0	3.8	0.6	0.8	290.8	3.9	3.7	Benetatos et al. (2005)
268	030814	11:52:56	38.75	20.65	5.0	3.8	0.6	0.7	289	3.8	3.4	Benetatos et al. (2005)
269	030814	12:04:58	38.95	20.59	8.0	4.1	0.7	1.2	297.4	4.0	3.8	Benetatos et al. (2005)
270	030814	12:18:19	38.59	20.41	15.0	5.1	8.5	17.0	280.3	5.1	4.6	CMT
271	030814	16:18:07	38.58	20.63	15.0	5.5	13.8	22.3	279.8	5.2	4.7	CMT
272	030814	16:37:39	38.76	20.58	8.0	4.6	2.2	4.5	288.8	4.5		Benetatos et al. (2005)
273	030814	16:55:21	38.79	20.68	10.0	4	0.8	0.8	285.9	3.9	3.8	Benetatos et al. (2005)
274	030814	20:46:50	38.80	20.50	18.0	4.7	3.8	5.3	289.4	4.7	4.2	ETHZ
275	030814	21:52:22	38.70	20.64	9.0	3.6	0.5	0.7	283.3	3.8		Benetatos et al. (2005)
276	030815	3:41:23	38.46	20.45	8.0	3.8	0.6	0.6	303.1	3.8	3.7	Benetatos et al. (2005)
277	030815	16:10:52	38.43	20.45	13.0	3.8	0.5	0.6	286.8	3.7		Benetatos et al. (2005)
278	030816	22:38:16	38.44	20.45	12.0	3.8	0.6	0.8	297.1	3.9	3.6	Benetatos et al. (2005)

**Table 1** (continued)

No	Date	Time	Lat (deg)	Lon (deg)	Depth (km)	$M_w$ (mm)	$A_n$ (mm)	$A_e$	Dist (km)	$M_{L(NO\text{A})}$	$M_{L(THE)}$	Reference
279	030816	14:49:12	38.62	20.55	15.0	4.3	1.2	2.2	285.9	4.2	3.8	Benetatos et al. (2005)
280	030817	16:56:23	38.46	20.45	13.0	4.1	1.0	1.5	291.1	4.1	3.7	Benetatos et al. (2005)
281	030817	15:37:15	38.48	20.48	17.0	4.5	1.7	2.2	289.6	4.3	4.1	Benetatos et al. (2005)
282	030818	6:32:02	38.47	20.47	12.0	3.7	0.5	0.5	287.1	3.7		Benetatos et al. (2005)
283	030819	5:34:16	38.46	20.50	12.0	3.6	0.7	0.7	289.7	3.8	3.7	Benetatos et al. (2005)
284	030822	11:33:14	38.52	20.50	9.0	3.7	0.7	0.6	285.9	3.8	3.3	Benetatos et al. (2005)
285	030831	13:38:50	37.83	27.59	5.0	3.8	0.6	0.6	328.4	4.0		Zhu et al. (2006)
286	030913	13:46:14	35.93	27.00	160.0	5.2	1.8	2.7	319.4	4.6	4.6	CMT
287	031017	12:57:11	36.51	22.73	75.0	5.3	25.0	25.0	259.2	5.3	5.0	ETHZ
288	031029	21:15:48	40.58	22.76	16.0	4.5	1.6	1.6	312.8	4.3	4.0	Pondrelli et al. (2007)
289	031124	15:51:07	34.41	24.94	31.0	5.1	1.5	2.4	360.6	4.6	4.5	ETHZ
290	031219	09:51:27	35.96	21.96	15.8	4.8	2.5	4.5	275.7	4.5		Pondrelli et al. (2007)
291	040116	17:10:25	38.58	23.56	4.0	4	8.0	8.0	69.8	3.7	3.8	Benetatos et al. (2004)
292	040207	21:17:26	35.82	26.89	16.0	5.1	6.0	4.5	356.6	5.0	5.1	CMT
293	040209	3:48:16	36.18	22.38	20.0	4.9	6.0	8.0	241.8	4.6	4.9	CMT
294	040211	00:52:29	35.68	29.30	23.8	4.5	0.5	0.4	539.5	4.5		Pondrelli et al. (2007)
295	040301	0:36:01	37.15	22.07	12.0	5.1	33.0	46.5	164	5.0	5.1	CMT
296	040317	5:21:03	34.45	23.27	12.0	6	33.0	51.0	391.6	6.0	5.8	CMT
297	040328	14:54:48	35.57	22.99	55.0	4.7	1.9	3.1	280.7	4.4	4.8	CMT
298	040407	1:32:34	40.65	20.37	47.0	5	1.0	2.0	420.7	4.7	4.6	CMT
299	040412	22:29:05	35.97	23.49	20.2	4.4	1.7	3.5	205.7	4.0	4.2	Pondrelli et al. (2007)
300	040525	5:34:32	35.86	27.27	17.0	4.8	1.6	3.1	382	4.7		CMT
301	040530	06:59:12	37.13	21.38	22.7	4.3	5.0	11.5	219.1	4.6	4.7	Pondrelli et al. (2007)
302	040530	21:23:30	38.10	20.90	15.0	4.2	1.0	1.6	264.7	4.0	4.3	Pondrelli et al. (2007)
303	040531	06:30:41	36.94	21.52	15.0	4.2	6.0	7.6	217.6	4.5	4.5	Pondrelli et al. (2007)
304	040615	12:02:42	40.34	26.04	12.0	5.2	1.9	2.9	317.7	4.5	5.0	CMT
305	040627	15:31:47	40.78	25.99	4.0	4.5	0.9	1.1	363.8	4.3	4.6	
306	040629	02:11:53	40.89	26.14	6.0	3.9	0.5	0.5	358.9	4.0	3.9	
307	040712	21:33:32	34.71	24.28	15.0	4.8	0.5	0.6	365.6	4.1		ETHZ
308	040724	19:01:03	35.78	23.47	12.0	4.8	1.8	2.2	289.3	4.3	4.0	CMT
309	040803	05:33:38	36.75	27.88	15.0	4.7	1.2	1.0	368.9	4.4	4.5	Pondrelli et al. (2007)
310	040803	13:11:35	36.77	27.93	12.0	5.2	1.6	2.6	368.9	4.6		CMT
311	040804	3:01:10	36.80	27.88	12.0	5.5	10.0	12.5	372	5.4	5.4	CMT
312	040804	4:19:50	36.82	27.97	12.0	5.2	2.5	4.0	369.3	4.8	5.1	CMT
313	040804	14:18:53	36.81	27.91	12.0	5.3	4.5	8.0	368.2	5.1	5.2	CMT



**Table 1** (continued)

No	Date	Time	Lat (deg)	Lon (deg)	Depth (km)	$M_w$ (mm)	$A_n$ (mm)	$A_e$	Dist (km)	$M_{L(NO A)}$	$M_{L(THE)}$	Reference
314	040818	23:06:36	36.05	27.59	17.6	4.6	1.0	1.3	395.2	4.5	4.4	Pondrelli et al. (2007)
315	040820	11:12:19	36.42	27.87	70.9	4.5	1.0	3.0	408.5	4.8	4.7	Pondrelli et al. (2007)
316	040824	12:38:50	38.58	23.59	15.0	4.6	20.0	60.0	68.5	4.4	4.3	ETHZ
317	040921	14:15:06	35.13	27.71	27.0	4.9	1.2	2.0	467.9	4.8	5.0	CMT
318	040926	3:06:00	38.02	24.05	18.0	4.6	25.0	43.0	55.3	4.2	4.3	CMT
319	041005	10:41:24	36.74	20.73	88.0	4.7	4.0	7.5	306.8	4.8	4.9	INGV
320	041007	1:05:15	36.27	26.72	130.0	5.5	5.8	14.6	319.1	5.2	5.1	CMT
321	041007	7:16:51	36.15	22.56	47.0	4.8	4.1	8.5	177.6	4.3	4.5	CMT
322	041008	0:47:54	41.20	20.92	12.0	4.6	1.0	1.4	444	4.6	4.5	CMT
323	041104	6:22:39	35.70	22.98	92.0	5.2	15.0	15.0	238.2	5.0	5.2	CMT
324	041122	19:13:33	38.60	25.60	18.0	5	10.0	21.0	170.4	4.6	4.7	ETHZ
325	041123	2:26:17	40.24	20.58	18.0	5.4	7.5	17.5	377.4	5.4	5.1	CMT
326	041211	21:03:20	39.21	21.67	12.0	4.5	2.0	5.0	227.0	4.2	4.3	ETHZ
327	041220	23:02:16	36.88	28.33	12.0	5.3	3.2	4.5	416.8	5.1		CMT
328	050103	21:44:28	37.64	23.33	114.0	4.8	13.0	22.0	49.6	4.5	4.5	ETHZ
329	050108	14:18:54	37.18	21.09	21.0	4.7	2.5	2.5	248.0	4.2		ETHZ
330	050110	23:48:52	36.84	27.87	15.0	5.4	2.8	2.5	396.6	4.8	5.1	CMT
331	050111	4:35:57	36.84	27.84	12.0	5	3.6	5.1	371.8	5.0	5.0	CMT
332	050128	0:17:24	33.80	24.30	10.0	4.7	1.2	1.4	403.1	4.6		ETHZ
333	050131	1:05:35	37.37	19.97	12.0	5.7	23.5	40.0	324	5.7		CMT
334	050331	14:35:08	35.51	25.86	6.0	4.4	1.0	1.1	335.4	4.2	4.4	ETHZ
335	050514	18:00:28	37.33	20.70	24.0	4.6	1.8	2.0	275.1	4.2	4.5	ETHZ
336	050524	05:50:54	37.57	20.88	27.0	4.4	1.5	2.5	253.9	4.1	4.1	ETHZ
337	050529	8:55:34	38.18	22.53	115.0	4.8	9.0	19.0	92.7	4.5	4.5	CMT
338	050530	9:20:09	33.92	26.06	40.0	4.7	0.6	1.0	444.7	4.5	4.8	CMT
339	050618	16:13:50	38.85	21.24	39.0	4.7	2.5	2.0	236.9	4.1	4.3	ETHZ
340	050623	22:44:16	37.80	26.70	18.0	4.7	1.5	1.7	261.7	4.1	4.4	ETHZ
341	050702	17:35:17	34.80	27.30	25.0	4.8	1.0	1.5	459.0	4.7	4.6	ETHZ
342	050703	16:15:27	36.03	27.02	9.0	4.2	1.0	1.9	362.1	4.5		ETHZ
343	050703	22:39:26	35.21	27.05	21.0	4.7	1.2	1.9	455	4.8	4.5	CMT
344	050707	11:45:09	36.41	23.14	24.0	4.6	5.0	9.5	180.4	4.3	4.6	ETHZ
345	050708	18:08:22	35.20	27.12	18.0	4.3	0.8	0.8	431.5	4.4		ETHZ
346	050711	17:20:31	36.48	28.11	63.0	4.5	0.5	0.5	423.8	4.2	3.8	ETHZ
347	050725	04:38:24	37.37	21.01	12.0	4.5	2.5	4.7	247.8	4.4	4.3	ETHZ
348	050801	13:35:03	36.29	26.74	150.0	4.8	2.1	2.5	312.6	4.6	4.7	CMT
349	050804	5:47:39	39.00	23.40	31.0	4.8	23.5	29.5	118.0	4.6	4.4	ETHZ
350	050804	10:45:28	34.70	26.28	31.0	5	1.2	2.0	418.2	4.7		CMT
351	050824	3:06:25	39.86	25.60	23.0	4.7	5.5	11.0	248.1	4.7		CMT
352	050919	22:17:21	38.04	20.29	19.0	4.8	2.1	3.8	305.8	4.6	4.7	CMT
353	051011	5:44:31	35.53	27.42	20.0	4.9	1.8	2.0	426.4	4.8		CMT
354	051017	4:31:27	38.15	26.63	10.0	3.9	0.9	1.2	247	3.8	3.8	Benetatos et al. (2006)
355	051017	5:45:24	38.21	26.59	15.0	5.5	48.0	45.0	256.5	5.5	5.3	CMT
356	051017	6:16:07	38.17	26.66	12.0	3.9	1.0	1.5	264.4	4.0		Benetatos et al. (2006)
357	051017	7:05:49	38.16	26.63	18.0	4.1	1.5	2.0	254.6	4.1	4.0	Benetatos et al. (2006)
358	051017	8:07:30	38.17	26.65	16.0	3.8	0.6	0.9	263.7	3.8		Benetatos et al. (2006)

**Table 1** (continued)

No	Date	Time	Lat (deg)	Lon (deg)	Depth (km)	$M_w$ (mm)	$A_n$ (mm)	$A_e$	Dist (km)	$M_{L(NO\text{A})}$	$M_{L(T\text{HE})}$	Reference
359	051017	8:28:54	38.18	26.65	18.0	4.3	1.7	2.5	260.3	4.2	4.3	Benetatos et al. (2006)
360	051017	8:34:45	38.14	26.63	11.0	4.2	1.5	2.5	245.9	4.1	4.3	Benetatos et al. (2006)
361	051017	9:47:00	38.15	26.66	12.0	5.8	34.0	43.0	252.1	5.4	5.4	CMT
362	051017	9:55:36	38.16	26.59	18.0	5.2	11.5	11.5	254.7	4.0	5.0	CMT
363	051017	11:20:27	38.18	26.68	6.0	3.9	1.0	1.4	256	3.9		Benetatos et al. (2006)
364	051017	12:43:30	38.15	26.65	8.0	4	1.5	2.0	264	4.1	4.1	Benetatos et al. (2006)
365	051017	13:16:43	38.18	26.66	5.0	3.9	1.2	1.5	271.1	4.1	3.8	Benetatos et al. (2006)
366	051017	13:22:51	38.17	26.64	11.0	3.8	1.0	2.0	259.1	4.1	3.9	Benetatos et al. (2006)
367	051017	14:53:22	38.13	26.69	17.0	3.4	0.9	1.0	280.3	3.9	3.6	Benetatos et al. (2006)
368	051017	23:13:17	38.15	26.64	10.0	3.9	1.0	1.2	263.1	3.9	3.8	Benetatos et al. (2006)
369	051018	11:54:50	40.09	20.49	30.0	4.6	1.0	1.5	361.9	4.4	4.4	NOA
370	051018	15:26:05	37.62	20.81	16.0	5.7	46.0	66.0	256.3	5.6	5.3	CMT
371	051018	15:36:33	37.56	20.76	14.0	5	6.0	12.0	242.8	4.7	4.6	CMT
372	051018	16:00:49	38.17	26.64	22.0	4.2	1.7	2.5	258.5	4.2	4.0	Benetatos et al. (2006)
373	051018	16:15:06	37.77	20.80	23.0	4.4	2.0	4.0	243.1	4.3	4.1	INGV
374	051018	18:43:08	36.86	20.65	37.0	4.5	2.5	5.0	250.1	4.4	4.4	INGV
375	051018	22:49:28	38.16	26.71	19.0	3.9	0.9	1.0	274.7	3.9		Benetatos et al. (2006)
376	051019	10:11:31	38.18	26.67	15.0	4.6	2.0	3.5	261.1	4.3	4.2	Benetatos et al. (2006)
377	051020	21:40:07	38.15	26.71	13.0	5.8	45.0	55.0	255.2	5.6	5.6	CMT
378	051021	0:34:15	38.11	26.61	20.0	3.8	1.0	1.3	258.5	3.9	3.6	Benetatos et al. (2006)
379	051021	11:11:35	37.65	20.97	35.0	4.6	4.0	5.7	247	4.5	4.4	NOA
380	051021	11:47:38	38.18	26.60	10.0	4.3	2.0	2.0	258.7	4.2	4.2	Benetatos et al. (2006)
381	051021	16:34:40	38.20	26.84	13.0	3.7	0.6	0.7	294.2	3.8	3.5	Benetatos et al. (2006)
382	051022	7:21:03	38.16	26.77	12.0	3.7	0.5	1.0	282.6	3.8		Benetatos et al. (2006)
383	051022	15:35:26	38.18	26.63	19.0	3.7	0.5	0.7	286.6	3.8		Benetatos et al. (2006)
384	051022	18:00:08	38.19	26.56	20.0	3.6	0.5	0.7	245.9	3.6		Benetatos et al. (2006)
385	051023	14:59:38	38.11	26.59	17.0	4	1.5	2.0	261.5	4.1	4.0	Benetatos et al. (2006)
386	051024	16:55:39	38.16	26.57	12.0	3.6	0.7	0.8	254.7	3.7	3.7	Benetatos et al. (2006)
387	051024	21:15:38	38.17	26.61	18.0	3.9	1.0	1.4	252.3	3.9	3.8	Benetatos et al. (2006)
388	051026	17:48:08	38.13	26.58	13.0	3.8	0.6	1.0	258.3	3.8	3.9	Benetatos et al. (2006)

**Table 1** (continued)

No	Date	Time	Lat (deg)	Lon (deg)	Depth (km)	$M_w$ (mm)	$A_n$ (mm)	$A_e$	Dist (km)	$M_{L(NO\&A)}$	$M_{L(THE)}$	Reference
389	051029	10:17:02	34.93	22.56	67.0	4.6	0.7	1.6	336.6	4.3		INGV
390	051029	14:48:42	38.13	26.61	14.0	4.2	2.1	3.6	247.5	4.3	4.2	Benetatos et al. (2006)
391	051031	5:26:40	38.14	26.64	16.0	4.9	5.4	7.0	260	4.7	4.6	Benetatos et al. (2006)
392	051031	6:48:22	38.13	26.65	12.0	4.2	1.2	1.7	259.1	4.0	4.2	Benetatos et al. (2006)
393	051103	13:59:06	37.60	20.94	25.0	4.1	1.1	1.8	245.5	4.0	4.1	NOA
394	051112	21:52:10	38.28	22.05	25.0	4	1.2	2.0	150.5	3.5	3.9	NOA
395	051115	5:51:32	40.32	25.28	10.0	4.1	0.9	1.2	293.4	4.1	4.2	NOA
396	051116	9:55:53	37.91	22.10	3.0	3.6	1.3	2.7	136.3	3.6		NOA
397	051118	16:57:43	39.22	20.48	22.0	3.9	0.7	1.0	305.5	4.0	3.6	NOA
398	051120	17:56:43	38.39	21.83	10.0	3.7	1.4	3.0	169.2	3.8	3.8	NOA
399	051120	21:20:58	35.21	27.24	65.0	4.4	0.4	0.9	427.4	4.3		NOA
400	051125	9:31:01	34.73	23.21	54.0	5.2	7.0	14.0	329.1	5.2		CMT
401	051209	14:33:25	35.29	27.24	26.0	4.8	0.9	1.5	433.4	4.6	4.7	CMT
402	051219	17:44:48	39.16	20.88	3.0	4.1	0.8	2.0	273.9	4.1	4.1	NOA
403	051219	17:48:15	39.18	20.95	13.0	3.9	0.9	1.5	278.3	4.0	3.8	NOA
404	051222	9:13:10	35.93	26.69	70.0	4.1	0.4	1.0	357.9	4.0		NOA
405	051223	7:09:57	35.39	23.23	95.0	4.5	2.0	4.5	293.8	4.6	4.5	NOA
406	051224	0:14:26	39.02	23.38	25.0	4.3	6.5	21.0	120.6	4.3	4.0	NOA
407	051224	3:56:08	38.83	27.89	30.0	4.7	1.0	1.5	370.7	4.4	4.5	NOA
408	051226	5:53:32	41.15	20.03	13.0	4.1	0.5	1.0	442.3	4.4	4.3	NOA
409	060107	5:11:21	38.25	20.31	18.0	4.1	0.9	1.5	300.9	4.1	4.1	NOA
410	060107	13:12:53	38.17	20.30	10.0	3.7	0.5	1.0	296.1	3.9		NOA
411	060108	11:35:00	35.93	23.29	64.0	6.7	499.5	499.5	197.1	6.3	6.4	CMT
412	060111	10:34:48	36.04	23.31	45.0	4.3	4.3	6.5	199.9	4.3	4.2	NOA
413	060116	6:43:43	37.74	20.41	22.0	3.8	0.5	1.0	286.1	3.9	3.7	NOA
414	060220	17:20:08	41.92	25.40	32.0	5	0.8	1.3	434.4	4.6	4.6	KOERI
415	060221	7:30:36	39.13	24.30	20.0	4.7	13.0	19.5	134.2	4.5	4.4	NOA
416	060222	5:38:22	35.12	26.94	34.0	4.7	1.0	2.0	421.8	4.7	4.3	KOERI
417	060308	4:18:58	41.06	20.49	10.0	3.8	0.3	0.7	437.5	4.1	3.8	NOA
418	060323	5:05:25	38.90	21.11	20.0	4	1.0	3.0	248.4	4.1	3.8	NOA
419	060403	0:49:46	37.67	20.76	22.0	5	7.0	14.0	247.6	4.8	4.8	CMT
420	060404	22:05:10	37.66	20.74	20.0	5.5	17.0	37.0	248.6	5.2	5.0	CMT
421	060409	23:27:22	35.34	27.29	26.0	5.3	2.0	2.8	431.1	4.9	4.9	CMT
422	060410	21:21:37	38.79	21.75	31.0	4.8	1.6	3.0	244.6	4.2	4.4	INGV
423	060411	0:02:46	37.64	20.75	21.0	5.5	19.0	31.0	248.6	5.2	5.0	CMT
424	060411	17:29:33	37.60	20.83	22.0	5.5	27.0	59.0	249.4	5.4	5.1	CMT
425	060412	16:52:06	37.63	20.74	21.0	5.7	29.0	50.0	247.5	5.4	5.0	CMT
426	060413	16:18:34	38.20	26.49	8.0	4.2	1.1	2.0	244.7	4.0	3.9	KOERI
427	060415	21:15:16	37.73	20.66	26.0	4.9	8.0	15.5	241.9	4.8	4.8	CMT
428	060418	3:54:33	37.53	21.00	16.0	4.7	3.5	6.3	243.9	4.5	4.6	Roumelioti et al. (2009)
429	060419	5:40:36	36.57	26.93	143.0	4.6	1.0	1.5	320.7	4.3	4.1	INGV
430	060419	15:16:30	37.65	20.76	21.0	5.4	6.0	10.5	248.1	4.7	4.9	CMT
431	060505	6:16:11	38.31	22.67	10.0	4.1	9.5	24.0	101.7	4.3	4.1	NOA
432	060510	7:01:43	40.52	23.42	6.0	4.4	1.2	2.0	282.4	4.0	4.3	Roumelioti et al. (2009)
433	060511	1:47:47	36.22	23.52	75.0	4.3	1.5	3.2	199.2	3.9	4.1	NOA
434	060515	4:22:41	35.81	26.01	50.0	4.5	1.0	3.0	317.8	4.5	4.4	NOA

**Table 1** (continued)

No	Date	Time	Lat (deg)	Lon (deg)	Depth (km)	$M_w$ (mm)	$A_n$ (mm)	$A_e$	Dist (km)	$M_{L(NO\&A)}$	$M_{L(THE)}$	Reference
435	060515	7:51:28	38.68	22.68	27.0	3.7	1.7	3.6	129.1	3.7	3.6	NOA
436	060518	2:25:29	40.23	22.59	8.0	4.2	1.0	2.0	270.9	4.1	4.0	Roumelioti et al. (2009)
437	060525	23:14:41	36.55	19.91	23.0	5.2	6.0	3.5	323	4.8	4.9	CMT
438	060608	14:38:37	38.61	23.75	8.0	4.2	9.0	22.5	72.8	4.1	4.0	Roumelioti et al. (2009)
439	060612	8:07:05	38.18	26.68	6.0	3.9	1.0	1.4	257.2	3.9	4.1	KOERI
440	060613	2:25:59	37.79	22.06	110.0	4	0.9	2.1	156.7	3.6	4.1	NOA
441	060617	2:20:23	38.71	22.77	8.0	3.7	4.5	10.0	116.3	4.0	3.7	Roumelioti et al. (2009)
442	060624	2:49:31	38.37	20.34	18.0	4.7	3.5	5.0	285.2	4.3	4.7	CMT
443	060626	0:51:43	34.97	26.49	25.0	4.4	0.6	1.0	395.8	4.3	3.9	NOA
444	060701	14:36:48	38.73	23.53	8.0	3.6	4.2	14.0	86.1	4.0	3.4	Roumelioti et al. (2009)
445	060709	3:12:56	36.56	27.06	90.0	4.4	1.0	0.7	349.9	4.3	3.5	NOA
446	060712	13:35:14	38.39	22.32	15.0	3.7	1.5	4.0	134.2	3.7	3.7	NOA
447	060712	14:40:57	38.81	26.74	37.0	4.7	1.5	2.0	276.1	4.2	4.3	NOA
448	060713	15:13:33	35.15	26.60	32.0	4.5	1.2	2.7	386.7	4.7	4.4	KOERI
449	060714	9:57:13	37.11	22.19	47.0	4.5	2.0	4.5	147.6	3.9	4.1	NOA
450	060720	15:57:39	37.70	21.37	10.0	4.1	1.5	2.0	209.1	3.8	4.1	Roumelioti et al. (2009)
451	060730	4:04:11	37.53	21.17	21.0	3.9	1.3	2.0	241.1	4.0	4.2	UPSL
452	060803	7:23:54	37.96	20.93	25.0	4	1.3	2.0	243.5	4.0	3.9	UPSL
453	060806	7:49:48	40.05	19.53	16.0	4.8	2.5	5.0	442.4	5.1	4.8	CMT
454	060808	21:20:12	40.04	19.60	20.0	4.8	2.4	4.0	419.1	5.0	4.8	CMT
455	060816	18:56:40	38.54	24.00	12.0	4.4	10.5	30.0	58.3	4.1	4.1	Roumelioti et al. (2009)
456	060817	4:27:31	40.56	23.19	25.0	3.7	0.5	1.0	291.6	3.9	3.6	NOA
457	060818	10:12:35	40.12	19.70	8.0	4.1	0.6	1.0	427.9	4.4	4.1	Roumelioti et al. (2009)
458	060822	9:23:22	35.17	27.11	12.0	5.1	1.0	2.0	430	4.7	4.3	CMT
459	060822	12:15:50	37.66	20.94	9.0	3.7	0.8	1.3	248.4	3.8	3.8	UPSL
460	060828	22:49:00	38.06	20.34	10.0	4.6	1.5	2.5	296.9	4.3	4.2	Roumelioti et al. (2009)
461	060829	2:43:18	38.70	21.25	15.0	4.1	0.5	2.0	226.5	3.8	3.6	NOA
462	060831	9:41:20	38.38	21.79	10.0	3.5	1.5	2.5	171.9	3.7	3.7	UPSL
463	060910	4:40:52	38.15	22.73	5.0	3.9	5.0	13.5	90	4.0	3.9	NOA
464	060916	20:46:54	37.67	20.94	6.0	3.7	1.0	1.5	250.0	3.9	3.8	UPSL
465	060918	16:57:28	37.55	20.78	10.0	4.3	2.0	2.2	250.5	4.1	4.2	Roumelioti et al. (2009)
466	060930	22:46:10	36.96	21.50	35.0	4.3	1.7	4.6	224.8	4.2	4.3	NOA
467	061003	15:58:11	39.53	20.69	12.0	4	1.0	1.7	319	4.3	4.6	Roumelioti et al. (2009)
468	061019	12:35:26	37.84	21.98	18.0	3.5	1.5	2.0	159.4	3.6	3.5	UPSL
469	061020	18:15:25	40.27	28.01	10.0	4.8	2.0	2.5	438.6	4.9	5.1	NOA
470	061024	3:39:32	35.06	27.20	34.0	5	1.2	1.4	429.0	4.6	4.5	KOERI
471	061123	13:21:42	40.03	20.63	35.0	4.2	1.4	3.0	358.5	4.5	4.2	NOA
472	061124	17:16:59	37.05	21.51	30.0	4.2	2.5	4.1	209.1	4.1	4.3	NOA
473	061125	11:45:06	39.14	22.61	13.0	4	1.5	4.5	163.6	3.9	4.0	NOA
474	061130	18:45:37	36.48	26.94	95.0	4.1	0.5	0.6	331.3	4.0	3.8	NOA
475	070101	14:55:38	38.70	21.50	20.0	3.5	2.0	1.0	210	3.8	3.5	NOA

**Table 1** (continued)

No	Date	Time	Lat (deg)	Lon (deg)	Depth (km)	$M_w$ (mm)	$A_n$ (mm)	$A_e$	Dist (km)	$M_{L(NO\text{A})}$	$M_{L(THE)}$	Reference
476	070107	14:47:05	38.42	21.93	5.0	3.9	2.0	3.0	153.7	3.8	3.8	NOA
477	070108	3:35:46	39.45	25.80	7.0	4	1.0	1.8	244.5	3.9	4.2	NOA
478	070110	1:54:55	38.64	23.83	30.0	4	11.0	24.0	71.5	4.1	4.0	NOA
479	070111	16:06:58	39.94	24.11	10.0	3.8	0.9	1.5	221.4	3.7	4.3	NOA
480	070118	22:25:15	34.36	22.28	49.0	5.1	2.5	3.0	359.7	4.7	5.2	INGV
481	070123	21:22:01	38.28	28.52	13.0	4.9	1.0	1.5	428.6	4.6	4.5	CMT
482	070125	21:09:44	34.82	23.38	40.0	4.7	1.2	1.5	232	4.3	4.7	INGV
483	070126	10:44:56	39.80	24.17	5.0	4.3	3.5	4.4	203.8	4.2	4.0	NOA
484	070202	12:06:28	39.50	20.67	8.0	4.6	1.8	2.5	314.3	4.4	5.0	Roumelioti et al. (2009)
485	070203	13:43:21	35.72	22.52	60.0	5.1	7.5	15.5	261.3	5.0	5.9	NOA
486	070221	1:41:00	40.51	22.38	4.0	3.6	0.5	0.5	308.3	3.8	4.1	Roumelioti et al. (2009)
487	070221	2:04:39	40.51	22.41	4.0	4.1	0.5	1.0	301.8	3.9	4.5	Roumelioti et al. (2009)
488	070224	14:46:59	40.56	22.35	5.0	3.9	0.5	0.5	310.3	3.8	4.3	Roumelioti et al. (2009)
489	070228	0:25:16	39.95	23.89	12.0	3.6	1.5	2.3	220.4	3.9	4.6	Roumelioti et al. (2009)
490	070303	14:56:25	40.23	19.36	4.0	4	0.6	0.5	452.9	4.3	4.5	Roumelioti et al. (2009)
491	070304	16:14:32	40.00	25.30	3.0	4.1	1.0	1.5	263.2	4.0	4.6	Roumelioti et al. (2009)
492	070319	20:53:59	38.36	22.06	7.0	3.9	1.0	2.5	151.5	3.6	4.2	Roumelioti et al. (2009)
493	070320	15:54:42	38.74	22.78	8.0	4.4	19.0	37.0	117.0	4.6	4.8	UPSL
494	070325	13:58:04	38.36	20.24	12.0	5.7	17.5	42.5	291.9	5.5	5.9	CMT
495	070325	18:57:19	38.22	20.30	6.0	4.7	2.5	4.5	301.3	4.6	5.1	Roumelioti et al. (2009)
496	070326	2:19:34	38.25	20.37	6.0	4.5	2.5	4.5	295.3	4.6	5.1	Roumelioti et al. (2009)
497	070409	23:27:16	38.51	21.62	6.0	4.4	2.5	4.5	193.2	4.1	4.7	Roumelioti et al. (2009)
498	070410	3:17:59	38.52	21.50	14.0	5	13.5	19.5	191.8	4.7	5.3	CMT
499	070410	4:29:58	38.54	21.61	6.0	3.6	0.5	1.0	192.1	3.4	3.8	Roumelioti et al. (2009)
500	070410	4:47:18	38.54	21.62	6.0	3.5	0.5	0.8	199.4	3.3	3.8	Roumelioti et al. (2009)
501	070410	6:03:39	38.57	21.64	7.0	3.8	1.0	1.5	195.1	3.6	3.9	Roumelioti et al. (2009)
502	070410	7:13:04	38.53	21.65	6.0	4.7	5.0	12.0	190.4	4.4	4.9	Roumelioti et al. (2009)
503	070410	7:14:12	38.57	21.62	12.0	4.4	3.5	5.0	199.1	4.2	4.9	Kiratzis et al. (2007)
504	070410	7:15:43	38.50	21.47	14.0	5.1	9.5	15.0	196	4.6	5.3	CMT
505	070410	8:13:45	38.53	21.61	7.0	3.8	0.9	1.5	193.6	3.6	4.3	Roumelioti et al. (2009)
506	070410	9:59:01	38.56	21.62	12.0	3.5	0.5	1.0	197.9	3.4	3.8	Kiratzis et al. (2007)
507	070410	10:34:48	38.55	21.61	14.0	3.3	0.5	0.7	197	3.3	3.8	Kiratzis et al. (2007)

**Table 1** (continued)

No	Date	Time	Lat (deg)	Lon (deg)	Depth (km)	$M_w$ (mm)	$A_n$ (mm)	$A_e$	Dist (km)	$M_{L(NO\&A)}$	$M_{L(THE)}$	Reference
508	070410	10:41:05	38.55	21.48	12.0	5.2	16.0	20.0	195.8	4.8	5.3	CMT
509	070410	12:55:17	38.54	21.62	13.0	3.3	0.5	0.8	193.4	3.3	3.6	Kiratzzi et al. (2007)
510	070410	13:51:01	38.56	21.61	18.0	3.6	1.0	1.9	197.4	3.7	4.2	Kiratzzi et al. (2007)
511	070412	3:38:06	38.82	20.59	9.0	4.1	1.2	2.5	288.5	4.3	4.5	Roumelioti et al. (2009)
512	070415	2:16:33	38.57	21.58	4.0	4.1	2.0	4.5	198.2	4.0	4.7	Roumelioti et al. (2009)
513	070416	7:38:55	41.24	20.01	15.0	4.9	1.2	2.5	518.9	5.0	5.2	Roumelioti et al. (2009)
514	070416	16:18:42	38.30	20.37	4.0	4	0.9	1.5	295.9	4.1	4.5	Roumelioti et al. (2009)
515	070419	10:15:45	39.70	24.29	5.0	4.6	14.0	25.0	198	4.8	5.4	Roumelioti et al. (2009)
516	070501	0:27:13	37.30	21.21	12.0	3.8	0.5	1.0	234.1	3.6	4.2	Roumelioti et al. (2009)
517	070501	4:08:53	39.88	22.87	12.0	3.7	0.4	0.8	219.8	3.4	4.0	Roumelioti et al. (2009)
518	070501	11:07:13	39.34	21.72	10.0	3.6	0.5	0.8	222.7	3.5	4.2	Roumelioti et al. (2009)
519	070503	5:41:16	40.20	25.18	6.0	3.9	0.8	1.5	279.9	4.0	4.3	Roumelioti et al. (2009)
520	070507	1:34:43	37.67	20.95	20.0	4.6	5.0	11.0	235.3	4.6	5.1	NOA
521	070509	1:46:01	38.25	21.62	12.0	3.7	1.0	2.5	183.6	3.7	4.2	Roumelioti et al. (2009)
522	070515	7:57:26	39.08	21.78	7.0	3.5	0.5	0.8	208.9	3.4	3.9	Roumelioti et al. (2009)
523	070521	16:39:11	35.14	27.62	18.0	5	0.9	1.5	487.5	4.8	5.0	CMT
524	070521	19:59:05	34.40	26.65	40.0	4.8	1.0	1.5	456.2	4.7	5.5	KOERI
525	070525	9:17:37	40.77	20.62	8.0	3.9	0.5	0.6	424.2	4.3	4.3	Roumelioti et al. (2009)
526	070602	1:02:38	38.71	22.68	7.0	3.7	3.2	6.2	125.3	3.9	4.0	Roumelioti et al. (2009)
527	070605	11:50:23	38.47	21.56	17.0	4.9	10.0	20.0	193.7	4.7	5.4	CMT
528	070607	19:24:26	37.11	20.95	7.0	4.6	2.2	4.0	249.7	4.3	4.9	Roumelioti et al. (2009)
529	070624	8:53:03	38.84	22.91	5.0	3.9	2.0	5.0	122.3	3.7	3.9	Roumelioti et al. (2009)
530	070624	10:31:52	37.23	20.80	10.0	4.5	1.0	2.5	277	4.2	4.6	Roumelioti et al. (2009)
531	070629	18:09:15	39.19	20.11	12.0	5.4	7.5	11.0	333.5	5.2	5.8	CMT
532	070629	22:21:18	39.24	20.10	14.0	4.8	2.5	5.0	334.9	4.8	5.1	CMT
533	070706	19:01:47	38.24	22.69	6.0	4	7.5	14.3	98.6	4.1	4.3	Roumelioti et al. (2009)
534	070717	18:23:20	40.15	21.59	13.0	4.7	4.0	8.5	303.2	4.9	5.4	Roumelioti et al. (2009)
535	070718	19:09:29	40.59	22.80	5.0	4	0.6	1.0	301.2	4.0	4.7	Roumelioti et al. (2009)
536	070719	04:25:26	40.17	21.59	11.0	3.7	0.6	1.2	297.9	4.0	4.3	Roumelioti et al. (2009)



**Table 1** (continued)

No	Date	Time	Lat (deg)	Lon (deg)	Depth (km)	$M_w$ (mm)	$A_n$ (mm)	$A_e$	Dist (km)	$M_{L(NO\text{A})}$	$M_{L(THE)}$	Reference
537	070726	09:03:59	39.77	20.60	15.0	4	0.5	1.3	329.1	4.1	4.5	NOA
538	070802	11:04:12	38.76	25.71	13.0	3.4	0.5	1.0	193.9	3.4	4.2	Roumelioti et al. (2009)
539	070802	20:43:46	40.58	24.09	8.0	3.5	0.5	0.8	291.9	3.8	4.0	Roumelioti et al. (2009)
540	070803	21:08:14	35.60	22.40	25.0	4.7	2.0	2.0	321.3	4.4		ETHZ
541	070807	22:23:30	37.44	19.78	34.0	4.4	0.8	1.0	346.7	4.3	4.8	Roumelioti et al. (2009)
542	070810	19:03:25	39.28	20.21	6.0	4.1	0.6	0.8	333.2	4.0	4.5	Roumelioti et al. (2009)
543	070812	11:20:42	39.20	20.19	6.0	4.6	1.5	2.5	335	4.5	4.8	Roumelioti et al. (2009)
544	070814	06:09:31	38.53	23.72	10.0	3.6	7.4	10.0	59.2	3.7	4.2	NOA
545	070817	21:55:34	38.64	25.26	12.0	3.8	9.5	4.5	154.2	4.2	4.2	Roumelioti et al. (2009)
546	070820	18:52:24	39.76	23.84	7.0	3.4	0.8	1.2	198	3.5	3.8	Roumelioti et al. (2009)
547	070827	6:29:03	38.25	20.33	12.0	4.6	2.5	4.5	298.4	4.6	5.1	Roumelioti et al. (2009)
548	070827	15:29:53	38.32	21.81	4.0	3.4	0.5	1.0	169.8	3.3	2.3	Roumelioti et al. (2009)
549	070828	12:44:51	40.38	25.95	6.0	4.2	0.7	1.3	327.9	4.2	4.8	Roumelioti et al. (2009)
550	070829	14:26:59	39.99	24.35	8.0	3.6	0.7	0.7	245.4	3.6	4.0	Roumelioti et al. (2009)
551	070905	17:37:50	39.64	23.98	6.0	3.9	1.3	1.9	187.1	3.7	4.2	Roumelioti et al. (2009)
552	070909	2:42:37	36.74	21.18	5.0	3.9	1.0	1.0	273	3.9	4.3	NOA
553	070909	5:14:58	38.81	26.41	10.0	4.2	1.0	2.5	251.8	4.1	4.6	Roumelioti et al. (2009)
554	070916	2:48:27	38.09	21.97	7.0	3.8	1.5	2.5	152.9	3.7	4.1	NOA
555	070922	20:04:54	35.00	27.20	14.0	4.7	0.8	1.0	428.6	4.5	4.6	ETHZ
556	070923	0:54:33	35.24	26.92	18.0	5.3	3.0	4.0	427.5	5.1	5.6	CMT
557	070924	18:12:33	35.00	23.39	25.0	4.8	1.5	2.5	360.1	4.6	5.1	NOA
558	070930	19:00:50	38.92	24.51	8.0	4.1	11.5	21.5	126.5	4.4	4.4	Roumelioti et al. (2009)
559	071001	10:11:39	38.89	24.48	10.0	3.7	9.0	12.5	124	4.3	4.2	Roumelioti et al. (2009)
560	071006	3:34:31	37.27	21.70	19.0	4.1	2.2	2.5	186.5	3.9	4.5	NOA
561	071010	10:14:12	37.97	20.26	8.0	4.4	2.0	2.8	305.6	4.5	4.6	Roumelioti et al. (2009)
562	071010	21:27:50	36.63	27.93	85.0	4.2	0.5	1.0	404.2	4.3	4.8	NOA
563	071011	12:00:35	38.90	24.46	6.0	3.7	8.5	11.0	122.8	4.2	4.3	Roumelioti et al. (2009)
564	071012	3:02:38	39.16	24.22	7.0	3.6	3.5	5.0	136.2	3.9	4.2	NOA
565	071014	9:18:11	34.51	26.54	20.0	4.7	0.5	1.0	460.8	4.5		Roumelioti et al. (2009)
566	071018	14:52:27	37.55	20.56	8.0	4.2	0.8	1.2	301.1	4.1	4.5	Roumelioti et al. (2009)
567	071025	11:38:37	39.74	20.77	10.0	4.3	1.5	2.0	28.1	4.4	5.1	Roumelioti et al. (2009)

**Table 1** (continued)

No	Date	Time	Lat (deg)	Lon (deg)	Depth (km)	$M_w$ (mm)	$A_n$ (mm)	$A_e$	Dist (km)	$M_{L(NO\text{A})}$	$M_{L(THE)}$	Reference
568	071027	5:29:43	37.70	21.33	28.0	5.1	12.0	21.0	215	4.8	5.5	CMT
569	071028	12:03:17	35.10	26.99	25.0	4.8	1.0	1.8	397.3	4.6	4.8	INGV
570	071102	8:55:43	37.73	21.07	6.0	4.1	1.9	2.2	234.5	4.0	4.6	Roumelioti et al. (2009)
571	071109	1:43:09	38.78	25.66	15.0	5.2	32.0	31.0	200.1	5.1	5.5	CMT
572	071109	7:07:38	38.79	25.80	16.0	4.5	6.0	20.0	194.3	4.6	4.9	NOA
573	071109	7:11:58	38.76	25.66	20.0	4.9	6.5	21.0	196.4	4.7	5.1	CMT
574	071228	21:14:01	39.62	26.01	11.0	4.3	3.5	3.7	261.4	4.4		NOA
575	071230	6:42:41	37.54	20.87	25.0	4.9	7.9	9.2	249.1	4.8	5.4	NOA
576	071231	10:40:10	38.35	25.96	17.0	4	1.4	1.1	206.7	3.7	4.2	NOA

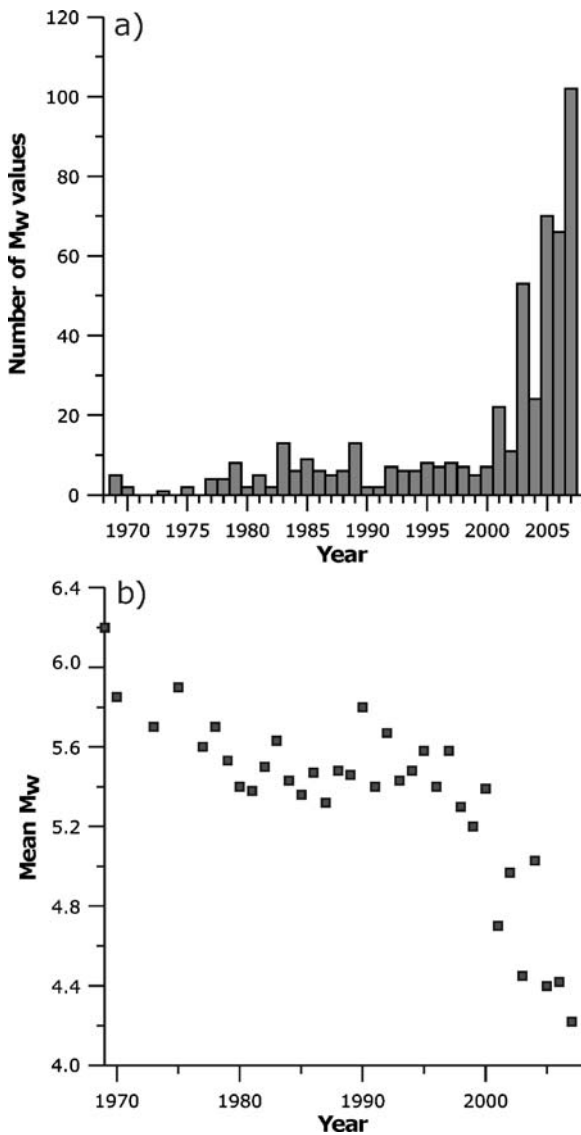
The WA maximum trace amplitude values were taken from the monthly bulletins of NOA. Other source parameters (epicenter coordinates, focal depth) were taken either from event-specific references, if available, or from the monthly bulletins of NOA and SS-AUTH. Maximum trace amplitudes on the Athens WA instrument are also shown for the NS ( $A_n$ ) and the EW ( $A_e$ ) component. The last column of the Table includes the reference for each  $M_w$  value

WA. Information about technician’s intervention in late 1995 was not verified by the directorship of NOA. Therefore, we are not in the position to explain this change.

To investigate how the change in  $A_e/A_n$  ratio may have affected  $M_L$  reported in NOA bulletins, we recalculated  $M_L$  using Richter’s (1935, 1958) relation and  $A_e$  and  $A_n$  independently and plotted the computed values against  $M_L$  reported by NOA [ $M_{L(NO\text{A})}$ ]. The results, for data after April 26 1996 [ $M_{L(A_n, A_e)\text{recent}}$ ], are presented in Fig. 4a, b, while corresponding plots for the entire dataset [ $M_{L(A_n, A_e)\text{all}}$ ] are shown in Fig. 4c, d. In each plot, we have also drawn the 1:1 line (continuous line) and the least-squares fit to the data (dashed line). In the first two subplots of Fig. 4, the difference between the computed values and those reported by NOA appears to be almost constant throughout the entire magnitude range for both components. Assuming a slope of 1.0 for the least-squares fit line and if we consider the NS component solely in  $M_L$  calculation (Fig. 4a),  $M_L$  values reported by NOA after 1996 appear underestimated by 0.12 magnitude units on average. In the opposite case, where we consider the EW component solely (Fig. 4b),  $M_L$  values reported by NOA after 1996 appear overestimated by 0.07 magnitude units on average. The difference in larger magnitude events is smoothed out when we look at the entire dataset (Fig. 4c, d), while it is still evident in smaller magnitude ranges (<5.0–

5.5). This is due to the fact that most of the larger events of the dataset are dated before 1996 (see Fig. 2) when the Athens WA presented a more “stable” operation, while the vast majority of smaller magnitude events occurred within the last few years.

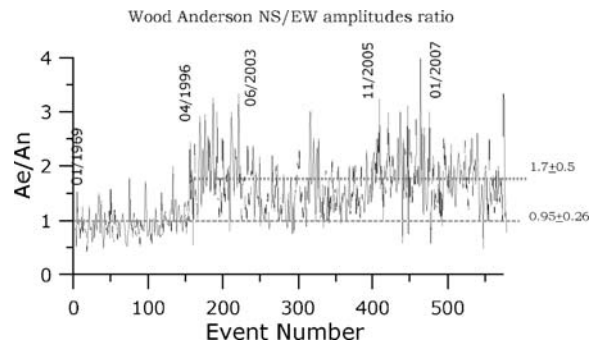
A question arising is which of the two components of the Athens WA is more reliable after 1996, if not none. We tried to resolve this issue by comparing  $M_L$ , computed independently for each one of the horizontal Athens WA components, to  $M_w$ . Since the parallelism between the two compared magnitudes has never been shown for smaller magnitude events in Greece, we performed this comparison for only larger magnitude earthquakes ( $M_w \geq 5.0$ ). The comparisons for the two WA components are shown in Fig. 5. In each subplot, we have also drawn the least-squares fit (continuous line) and the best-fit line assuming a slope of zero (dashed line). For the NS component (Fig. 5a),  $M_w$  appears to be systematically larger by  $\sim 0.41$  magnitude units, and this difference is practically constant throughout the entire time range. In the EW component plot (Fig. 5b) and at first glance, there is a trend with time, which, however, is attributed to a “break” around point 155 (April 1996) of the dataset (note: number of points is the same as in previous plots, although points that correspond to events with  $M_w < 5.0$  are not shown). Prior to 1996,  $M_w - M_L$  is  $\sim 0.45$  (as has been previously noted by Kiratzi 1984;



**Fig. 2** **a** Number of events ( $M_w$  values) per year used to calibrate  $M_w$  against  $M_L$  in Greece and **b** mean  $M_w$  of these events per year. Note the increase after 2003 in the number of available data (**a**) and that this increase refers to smaller magnitude events (**b**)

Papazachos et al. 1997; Margaris and Papazachos 1999; Papazachos et al. 2002), and from then on, it becomes  $\sim 0.23$  (best fit, zero slope lines are also presented separately for the two time intervals in Fig. 5d).

Based on the above results, we draw the conclusion that since late 1995–early 1996, the performance of the Athens WA has significantly changed and this change has mostly affected the



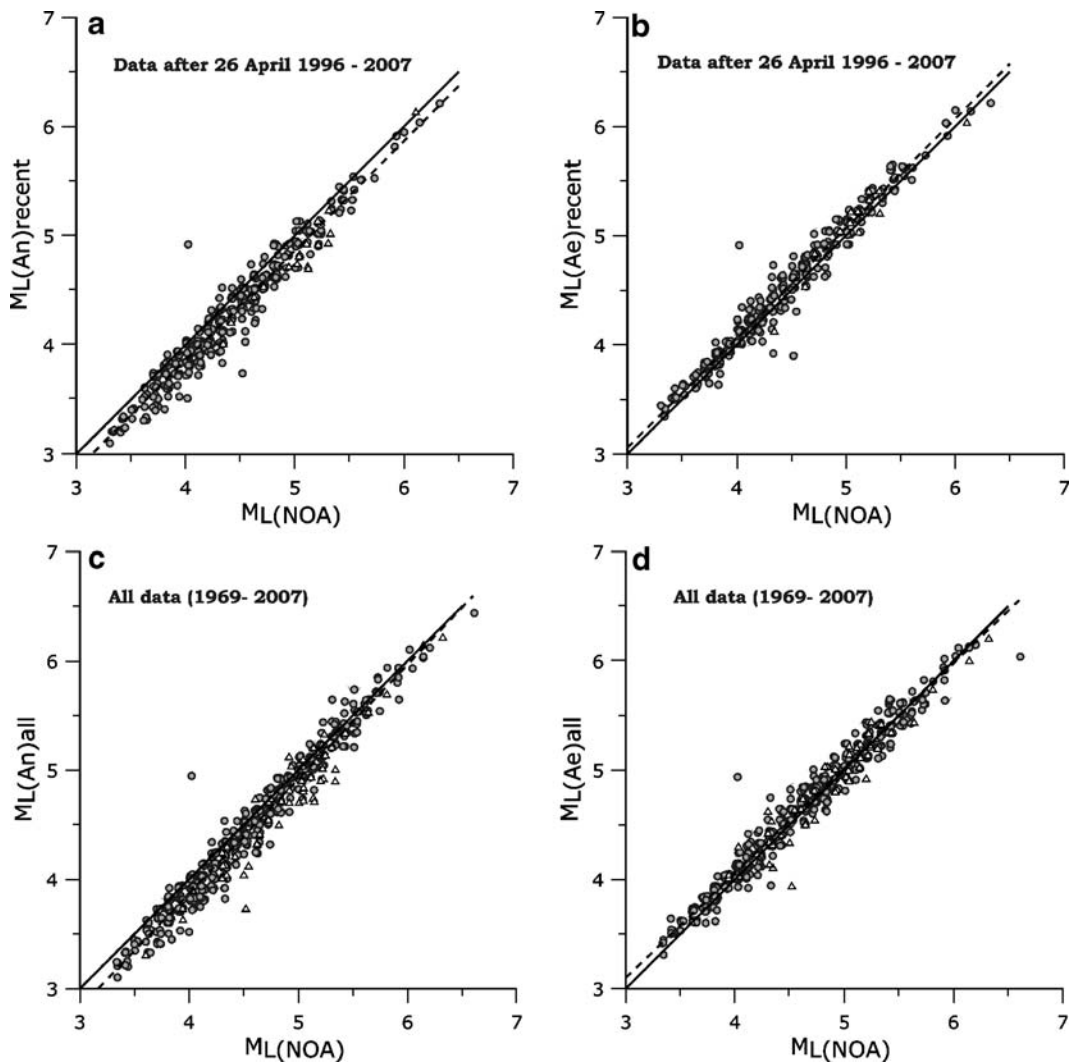
**Fig. 3** Ratio of the maximum recorded amplitudes on the two horizontal components of the Athens Wood–Anderson instrument ( $A_e/A_n$ ) versus event number. Events are numbered chronologically as in Table 1. Note that ratio appears to be rather stable (close to 1) for the first 154 points, and there is an increase after the 155th point (April 1996).  $A_e$  becomes systematically larger than  $A_n$ , while scatter increases significantly. On average,  $A_e$  is  $1.7 \pm 0.5$  times larger

EW component of the instrument, although a very small effect (small deviation of the best-fit line from zero slope line) is also evident for the NS component as well. This means that after 1996,  $M_L$  reported in NOA bulletins is overestimated, on average, by  $\sim 0.1$  magnitude units, since the effect on the two horizontal components is averaged out when the arithmetic mean of the two amplitudes is used.

## 5 $M_w - M_L$ comparison

### 5.1 Comparison of $M_w$ with $M_L$ of NOA

In Fig. 6a, we compare  $M_w$  (Table 1, from waveform modeling) with  $M_L$  values as reported in NOA bulletins. The comparison shows a gradual increase in the difference between the two magnitudes from  $\sim 0.1$  (at  $M_w = 3.5$ ) to  $\sim 0.4$  for the largest magnitude events of the dataset. The agreement in small magnitude ranges is not real but is due to the overestimation of  $M_L$  in NOA since 1996. In Fig. 6b, we show an analog comparison between the two magnitudes, although in this case,  $M_L$  values for events that occurred after April 1996 have been recalculated using the amplitude recorded on the north–south component solely and the calibration function of Richter



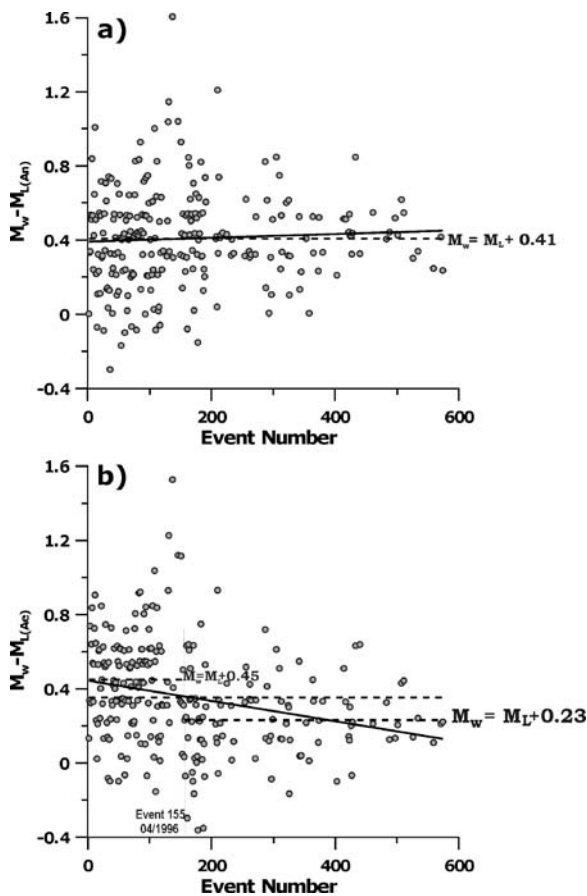
**Fig. 4**  $M_L$  computed for each one of the two horizontal components of the Athens Wood–Anderson instrument independently: **a**  $M_L$  for the NS component and for events that occurred after April 1996 (see text for the choice of date), **b**  $M_L$  for the EW component and for events that occurred after April 1996, **c**  $M_L$  for the NS component and for the entire dataset (including events before April

1996), and **d**  $M_L$  for the EW component and for the entire dataset. Equality (1:1) lines (*continuous*) and least-squares fits (*dashed lines*) are also drawn in each subplot. Shallow events and intermediate depth events are shown with *different symbols* (*open circles and solid triangles*, respectively)

(1935, 1958). From this plot, we conclude that  $M_L$  is smaller than  $M_w$  throughout the entire examined magnitude range and by an almost constant amount of 0.29 (assuming a slope of 1.0).

The value of the practically constant difference between  $M_w$  and  $M_L$  in Greece for the time period 1969–2007 depends on the adopted calibration function for  $M_L$  computation. We concluded this dependence by recalculating  $M_L$  based on

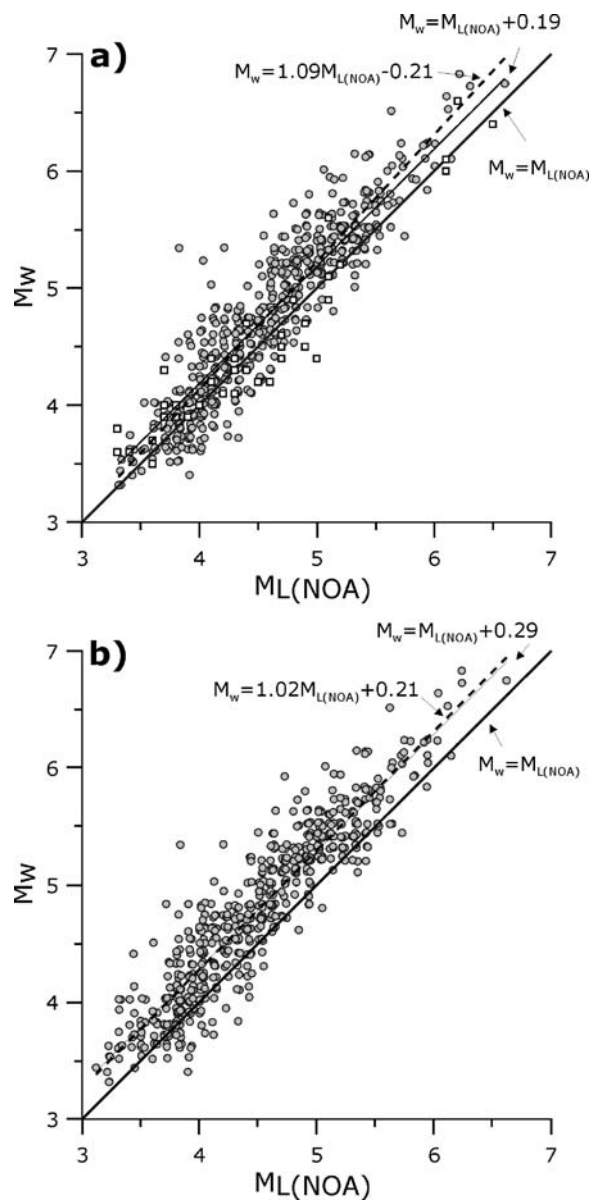
the WA amplitudes in station ATH using (a) the calibration function of Kiratzi and Papazachos (1984) applicable to Greece which gives  $M_w = M_L + 0.42$  and (b) the calibration function of Hutton and Boore (1987) which has been recently adopted for synthetic  $M_L$  computation by most Greek seismological centers in 2008, which gives  $M_w = M_L + 0.38$ . In all three tested relations (the third one being the calibration function of



**Fig. 5**  $M_w - M_L$  versus event number for events with  $M_w \geq 5.0$  from Table 1: **a** when  $M_L$  is computed from the maximum recorded amplitude on the NS component of the Athens Wood–Anderson instrument and **b** when  $M_L$  is computed from the corresponding amplitude on the EW component. Least-square fits (*continuous lines*) and best-fit lines assuming a slope of zero (*dashed lines*) are also shown. Note that for the NS component  $M_w$  appears to be systematically larger by  $\sim 0.41$  magnitude units and this difference is constant throughout the entire time range. For the EW component prior to 1996,  $M_w - M_L$  is  $\sim 0.45$ , and from then on, it becomes  $\sim 0.23$

Richter mentioned in the previous paragraph for which the constant difference was calculated at 0.29),  $M_w - M_L$  differences were plotted against distance and no significant dependence was found (slope of least squares fit lines  $< 0.001$ ).

The major question about the linear increase in the difference between the two compared magnitudes is whether this difference is due to physical properties of the earthquake sources (e.g., low stress drop of earthquakes in the Aegean) or to



**Fig. 6**  $M_w$  versus  $M_L$  of NOA: **a**  $M_L$  values are exactly as reported in NOA bulletins. *Squares* correspond to data gathered within the first 6 months of 2008. **b**  $M_L$  values are the originally reported in NOA bulletins until April 1996 and from then on recalculated using the maximum trace amplitude of the NS component of the Athens WA solely. The 1:1 equality line (*thick continuous*), least-squares fit (*dashed*), and best-fit line of slope 1.0 (*thin continuous*) are also depicted

inadequacies in the modeling of the attenuation or in the way  $M_L$  is being measured in Greece. If the static magnification of the Athens WA instrument was responsible for this difference, then we would

**Table 2** Source parameters of the 44 earthquakes used in the present study to check  $M_w$  against  $M_L$  in Greece after January 2008, i.e., after the abolition of the Athens Wood–Anderson seismograph

Date	Time	Lat (deg)	Lon (deg)	Depth (km)	$M_w$ (mm)	$A_n$ (mm)	$A_e$	Dist (km)	$M_{L(NO A)}$	Reference
071228	21:14:01	39.62	26.01	28.0	4.3	0.0	0.0	261.4	4.4	NOA
071230	6:42:41	37.54	20.87	23.0	4.9	0.0	0.0	249.6	4.8	NOA
071231	10:40:10	38.35	25.96	38.0	4.0	0.0	0.0	206.7	3.7	NOA
080105	5:11:00	38.58	27.09	22.0	4.0	0.9	0.5	278.6	3.8	NOA
080106	5:14:19	37.1	22.82	86.0	6.0	600.0	600.0	126.5	6.1	NOA
080111	12:56:23	37.12	22.82	76.0	4.1	8.0	8.7	137.5	4.3	NOA
080112	15:06:45	38.87	26.1	24.0	4.5	10.8	10.1	224.7	4.7	NOA
080112	17:17:29	38.89	26.01	23.0	3.6	0.5	0.6	221.9	3.4	AUTH
080113	21:15:31	38.9	26.02	27.0	3.9	1.2	0.9	222.6	3.7	SS-AUTH
080115	7:44:25	38.86	25.96	31.0	4.0	1.8	2.0	240.1	4.0	NOA
080124	2:22:05	36.36	26.97	44.0	4.3	0.4	0.4	316.4	3.7	NOA
080126	2:29:04	38.08	20.25	7.0	3.9	0.7	0.5	303.0	3.8	NOA
080129	15:16:53	37.67	23.61	20.0	4.2	72.0	102.0	49.1	4.6	NOA
080204	20:25:11	38.05	21.94	27.0	4.5	29.6	38.3	158.2	4.9	NOA
080204	22:15:38	38.05	21.97	25.0	4.4	38.0	49.5	156.3	5.0	NOA
080206	15:46:11	39.07	19.72	16.0	3.7	0.2	0.3	345.8	3.6	NOA
080214	10:09:23	36.41	21.64	41.0	6.6	288.5	301.3	236.7	6.2	NOA
080214	12:08:56	36.22	21.8	38.0	6.1	83.3	229.8	261.5	6.1	NOA
080219	23:15:40	36.08	21.72	22.0	5.1	16.0	18.3	262.6	5.1	NOA
080220	18:27:06	36.19	21.74	25.0	6.1	141.0	100.0	266.3	6.1	NOA
080222	4:57:48	37.76	21.02	24.0	4.7	4.7	4.8	235.8	4.4	NOA
080226	10:46:10	36.01	21.67	5.0	5.2	13.9	17.7	286.6	5.2	NOA
080226	16:10:39	36.15	21.86	15.0	4.7	8.4	9.0	272.1	4.9	NOA
080228	4:54:37	36.02	21.78	11.0	4.6	6.5	5.0	280.5	4.7	NOA
080301	0:07:08	35.27	26.17	22.0	4.2	0.6	0.6	378.3	4.1	SS-AUTH
080301	7:01:09	37.88	26.81	22.0	4.2	1.4	1.9	268.7	4.1	SS-AUTH
080301	9:28:25	38.42	21.98	10.0	3.8	0.7	1.2	158.2	3.3	SS-AUTH
080302	5:41:38	36.05	21.77	12.0	4.4	3.2	2.1	265.8	4.3	NOA
080305	16:11:37	36.16	27.4	21.0	4.4	1.8	2.1	383.6	4.7	NOA
080305	16:14:42	36.16	27.41	22.0	4.5	2.2	2.2	384.2	4.7	NOA
080328	0:16:20	34.77	25.31	50.0	5.6	6.2	5.6	359.4	5.1	NOA
080411	8:01:41	37.72	27.03	20.0	4.4	2.0	1.9	282.9	4.3	NOA
080505	20:48:01	37.78	27.01	15.0	3.6	0.3	0.2	281.0	3.3	SS-AUTH
080513	14:19:34	39.35	24.05	32.0	3.5	1.8	1.6	155.5	3.6	SS-AUTH
080605	2:10:28	38.33	20.45	16.0	3.9	0.8	0.7	289.6	3.9	NOA
080605	18:12:41	38.23	20.42	16.0	4.3	2.3	1.8	292.5	4.3	NOA
080608	12:25:30	37.98	21.48	25.0	6.4	1010.0	713.0	193.8	6.5	NOA
080608	16:10:09	38.01	21.54	26.0	3.9	2.4	2.5	194.3	3.9	NOA
080608	21:10:25	38.01	21.57	27.0	3.6	0.7	0.6	188.3	3.3	NOA
080612	3:15:36	38.02	21.51	25.0	3.7	1.0	1.4	185.8	3.6	NOA
080618	1:58:45	37.69	22.7	83.0	4.9	3.1	4.0	88.8	5.1	NOA
080625	20:59:44	38.73	22.88	21.0	4.2	23.7	22.9	111.8	4.5	NOA
080627	5:18:57	38.04	21.57	14.0	4.1	4.8	4.1	190.4	4.2	NOA
080630	13:40:11	39.35	20.85	55.0	4.4	1.3	1.8	295.1	4.1	NOA

Synthetic maximum trace amplitudes at station ATH are also shown for the NS ( $A_n$ ) and the EW ( $A_e$ ) component. The last column of the table includes the reference for each  $M_w$  value  
 SS-AUTH Seismological Station–Aristotle University of Thessaloniki (<http://seismology.geo.auth.gr>), NOA National Observatory of Athens (<http://bbnet.gein.noa.gr>)

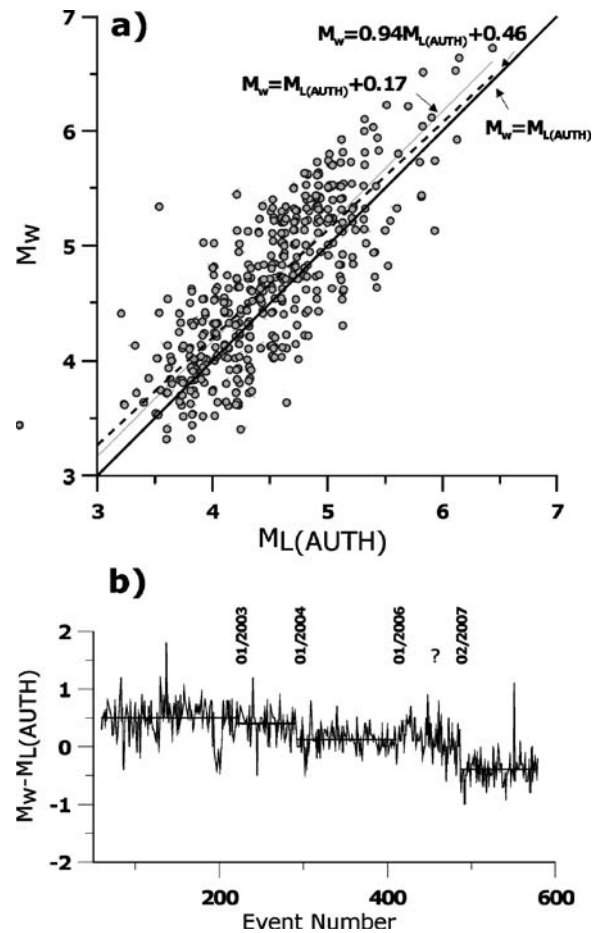


expect to see it disappearing after December 2007, i.e., the date after which the Athens WA stopped being the basis for  $M_L$  computation in Greece and only synthetic WA amplitudes are used in the procedure. In Fig. 6a, we have superimposed more recent data (after December 2007, solid square symbol). Moment magnitudes have been taken from fast MT computations of either NOA or SS-AUTH and  $M_L$  values from the online manual solutions database of NOA (<http://orfeus.gein.noa.gr/cgi-bin/mandbsearch.pl>). Source parameters for the 2008 events are summarized in Table 2. As can be concluded from Fig. 6a, most recent data fall closer to the 1:1 equality line, and this observation favors the consolidated opinion that the Athens WA was not functioning properly. Nevertheless, the number of most recent events is relatively small to draw safe conclusions.

## 5.2 Comparison of $M_w$ with $M_L$ of SS-AUTH

In Fig. 7a, we compare  $M_w$  values with available (after July 1985)  $M_L$  values reported in the monthly bulletins of SS-AUTH. Overall, the two magnitudes correlate relatively well with an almost constant difference of  $\sim 0.17$  throughout the entire magnitude range. Once more,  $M_L$  appears to be smaller than  $M_w$ .

In Fig. 7b, we have plotted the  $M_w - M_{L(AUTH)}$  quantity versus event number to show possible chronological changes in the difference between the two magnitudes. In fact, such changes appear more than once within the time frame covered by our data. For the first 200–220 events of the dataset the  $M_w - M_{L(AUTH)}$  quantity is around 0.5, which is in agreement with the results of Kiratzi and Papazachos (1984). Around point 220 (in the beginning of 2003), the difference between the two magnitudes slightly decreases to  $\sim 0.4$  and during the years 2004–2005 drops around the value of 0.1. Then, a gradual decrease begins until February of 2007 when one can see a clear step of the difference, which ends up being negative by  $\sim 0.39$  magnitude units. These changes in time could be attributed to infrequent calibrations of the short-period instruments operated by SS-AUTH. The abrupt changes (after event 292-01/2004 and after event 487-02/2007) are due to changes of the instrument responses in the



**Fig. 7** **a**  $M_w$  versus  $M_{L(AUTH)}$  as reported in monthly SS-AUTH bulletins. The 1:1 equality line (*thick continuous*), least-squares fit (*dashed*), and best-fit line of slope 1.0 (*thin continuous*) are also depicted. **b** Difference between  $M_w$  and  $M_{L(AUTH)}$  versus time (depicted as event number). Event numbers are assigned in chronological order as in Table 1. Best-fit lines of zero slopes are depicted as *thin continuous lines* for discrete intervals

$M_L$  computation code of SS-AUTH. As a result (Fig. 7b), the catalog that one could derive from the SS-AUTH bulletins is not homogeneous in terms of  $M_L$  magnitude, and therefore, it should not be correlated to any other magnitude, as it is.

## 6 Conclusions

We have compared  $M_w$  computed from regional or teleseismic waveform analysis to  $M_L$  reported by Greek seismological centers for 576 events of  $M_w = 3.3$  to 6.8, which occurred in the broader

area of Greece from 1969 to 2007. The major comparison is against  $M_L$  reported by NOA since all  $M_L$  calibrations performed in Greece are based on  $M_L$  calculated from the maximum trace amplitudes recorded on the Wood–Anderson seismograph operated in Athens (station ATH).

We also studied the performance of the WA seismograph in Athens and found that in the end of 1995–beginning of 1996, the EW component of the instrument started recording much larger amplitudes compared to the NS component. This resulted in a systematic overestimation of  $M_L$  by at least 0.1 magnitude units (assuming that the NS component remained unaffected, which is not strictly true based on Fig. 5a) compared to computations before 1995. Taking into account the change in the operation of the Athens WA after 1996, we composed a hybrid catalog which includes original  $M_L$  values reported by NOA before 1996 and recalculated values using the NS Athens WA component solely after 1996. We compared these values to  $M_w$  and concluded an almost constant difference between the two magnitudes throughout the entire examined magnitude range, with  $M_L$  being systematically smaller than  $M_w$ . The difference ranges from 0.29 to 0.42 and depends on the calibration function used to compute  $M_L$ . Summarizing, assuming that the equality of  $M_w$  to  $M_L$  (Heaton et al. 1986) does hold in Greece, to convert the reported local magnitude by NOA,  $M_{L(NO A)}$  to  $M_w$  for data prior to late 2007, one should use:

$M_w = M_{L(NO A)} + 0.19$  using both WA components and if the Richter (1935, 1958) calibration functions are used ( $M_w = M_{L(NO A)} + 0.29$  using the NS component only);

$M_w = M_{L(NO A)} + 0.38$  if the Hutton and Boore (1987) calibration functions are used;

$M_w = M_{L(NO A)} + 0.42$  if the Kiratzi and Papazachos 1984 calibration functions are used, which are applicable to Greece.

Thus, to convert the original  $M_L$  catalog of NOA to equivalent  $M_w$  (for events before November 2007), one should first choose the most appropriate calibration function (at this point, all aforementioned calibration functions are in use by different institutes and researchers in Greece) and then use the corresponding conversion factor.

The  $M_w - M_L$  difference vanishes after the abolition of the Athens WA in late 2007 when NOA started calculating  $M_L$  from synthetic WA amplitudes. This observation verifies previous studies (e.g., Kiratzi and Papazachos 1984; Margaritis and Papazachos 1999) that attributed the  $M_w - M_L$  to improper operation of the Athens WA rather than to physical properties of the earthquake sources in Greece.

Regarding the  $M_L$  reported in SS-AUTH bulletins, its computation procedure has undergone significant changes through time, and thus, the corresponding catalog is not homogeneous in terms of magnitude. The SS-AUTH  $M_L$  catalog could be converted to equivalent  $M_w$  using the following constant corrections:

July 1985–end of 2002:  $M_w = M_{L(AUTH)} + 0.50$ ;

January 2003–end 2003:  $M_w = M_{L(AUTH)} + 0.41$ ;

January 2004–end of 2005:  $M_w = M_{L(AUTH)} + 0.13$ ;

January 2006–end of 2005: no constant correction can be used;

January 2007–end of 2007:  $M_w = M_{L(AUTH)} - 0.39$ .

We hope that this work will clarify magnitude calculations in Greece and enhance similar studies for other regions as well.

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