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Seismic moments of Taiwan's earthquakes evaluated from a regional broadband array

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We have taken the seismic moment (M_o) values of 79 earthquakes occurring in the Taiwan region that have been published in the Global centroid-moment tensor (CMT) and regional Broadband Array in Taiwan for Seismology (BATS) catalogues for the period 1996–2005 and compared the values determined from the global and regional networks, respectively. M_{oG} and M_{oB} are used to denote the M_o values published in the Global CMT and regional BATS catalogues, respectively. Our results show that M_{oB} linearly correlates with M_{oG} and that M_{oB} is, on average, approximately equal to $0.37M_{oG}$. This difference may be caused by the use of shorter period seismic waves in BATS for estimating M_{oB}. The moment magnitude evaluated from regional BATS seismograms is about 0.3 less than that estimated from global data.

Key words: Seismic moment, moment magnitude, Taiwan's earthquakes, BATS.

1. Introduction

The double couple force system, which is a combination of two perpendicular force couples, is conventionally considered to describe the earthquake source. The seismic moment, M_o, of each force couple is given by

$$M_o = \mu D A, \quad (1)$$

(Stekettee, 1958; Maruyama, 1963; Burridge and Knopoff, 1964) where μ, D, and A are, respectively, the rigidity of materials in the source region, the average displacement on the fault plane, and the fault area. In a study of source mechanism using an elastic dislocation theory, Aki (1966, 1967) stated that the amplitude of a very long-period wave is proportional to M_o. Aki (1966) first measured the value of M_o of the 1964 Niigata, Japan, earthquake. Ben-Menahem *et al.* (1969) also suggested that the far-field static-strain field is proportional to M_o. From this time onward, the seismic moment has been considered to be a new parameter that specifies the size of an earthquake. Based on M_o, the moment magnitude, M_w, was defined by Hanks and Kanamori (1979) in 1979.

The seismic moment is important not only for understanding earthquake physics but also for mitigating seismic risk. Molnar (1983) estimated average strain from the seismic moment. Hence, it is necessary to evaluate M_o, which is determined and reported by several seismic agencies using teleseismic data, as accurately as possible. Its value can be determined from long-period surface waves and normal modes, geodetic data, or geological data (Kanamori and Brodsky, 2004). In general, the long-period surface waves and normal modes lead to the most accurate evaluations. Dziewonski *et al.* (1981) first suggested the centroid-moment tensor (CMT) method to evaluate the seismic moment. In contrast with the previously moment tensor inversion in which the hypocentral parameters are fixed, the CMT method is used to fit the seismic waveforms of body, surface, and mantle waves for the best point-source hypocentral parameters and six independent moment tensor elements. The body, surface, and mantle waves are low-pass filtered with a cutoff period of 45, 50, and 135 s, respectively. Since 1981, the CMT solutions of the larger sized (on a world scale) earthquakes have been routinely determined. Since the summer of 2006, the main activities of the Harvard CMT Project have become the Global CMT Project conducted by the Lamont-Doherty Earth Observatory (LDEO) of Columbia University. The CMT solutions and the best double-couple seismic moment estimated from the project are published at its web site http://www.globalcmt.org/.

The CMT solution and the best double couple can also be determined from seismograms recorded by regional broadband networks (e.g., Patton and Zandt, 1991; Ritsema and Lay, 1993; Romanowicz *et al.*, 1993; Thio and Kanamori, 1995). For earthquakes with $M_s < 4.5$, the M_o usually cannot be found in the CMT solutions. Hence, it is necessary to evaluate M_o for smaller sized events from a regional array. In general, the value of M_o determined from regional networks is smaller than that from global networks (Thio and Kanamori, 1995; Hwang *et al.*, 2001; Huang and Wang, 2002; Huang *et al.*, 2002; Huang, 2006). Hence, to unify the seismic moment it is necessary to compare the values of M_o determined from these two different types of networks.

Because Taiwan is situated at the colliding boundary between the Eurasian plate and the Philippine Sea plate (Tsai *et al.*, 1977; Wu, 1978; Lin, 2002), seismicity is very high in the region (Wang, 1998). Since late 1994, the Institute of Earth Sciences (IES), Academia Sinica, has operated

Table 1. Seismic source parameters of 79 earthquakes that occurred in the Taiwan region between March 1996 and September 2005. The data are selected from the Global CMT and regional BATS catalogues. The unit of M_o is 10^{25} dyne-cm.

No.	Time	Latitude (°N)	Longitude (°E)	Depth (km)	M_w	NS*	M_{oB}	M_{oG}	Data** type
1	1996/03/29/03:28	23.97	122.33	5.79	5.61	4	0.318	0.520	B
2	1996/08/10/06:23	23.89	122.65	5.65	5.70	5	0.437	0.342	B
3	1996/09/06/11:34	21.69	121.32	19.90	5.19	4	0.076	0.138	B
4	1996/11/26/08:22	24.16	121.7	26.18	4.95	4	0.033	0.077	B
5	1997/01/05/10:34	24.62	122.53	1.13	5.20	5	0.078	0.074	B
6	1997/05/03/02:46	22.54	121.4	3.64	5.02	6	0.042	0.035	B
7	1997/06/22/09:36	22.17	121.38	1.83	4.89	5	0.027	0.076	B
8	1997/07/04/18:37	23.06	120.79	5.16	4.83	6	0.022	0.050	B
9	1997/08/24/12:17	21.64	120.2	41.53	5.15	4	0.066	0.146	B
10	1998/01/18/19:56	22.73	121.09	3.28	5.22	7	0.085	0.073	B
11	1998/07/17/04:51	23.5	120.66	2.80	5.66	4	0.389	0.431	B
12	1998/07/24/18:44	21.63	121.84	6.67	5.94	4	1.029	1.730	B,M
13	1998/09/13/05:34	24.24	123.01	28.11	5.09	8	0.053	0.122	B
14	1998/11/17/22:27	22.83	120.79	16.49	5.25	8	0.093	0.113	B
15	1999/09/10/14:18	22.44	121.82	5.19	5.20	5	0.078	0.144	B
16	1999/09/20/21:46	23.58	120.86	8.57	6.29	3	3.376	4.830	B,M
17	1999/09/22/00:14	23.83	121.05	15.59	6.16	3	2.184	5.030	B,M
18	1999/09/22/00:49	23.76	121.03	17.38	5.66	6	0.386	0.631	B,M
19	1999/09/22/12:17	23.74	120.98	24.02	4.93	7	0.031	0.093	B
20	1999/09/23/12:44	23.93	121.09	18.35	4.97	7	0.035	0.088	B
21	1999/09/25/08:43	23.69	120.95	7.12	5.09	6	0.054	0.051	B
22	1999/09/25/23:52	23.85	121	12.06	6.24	4	2.825	6.010	B,M
23	1999/10/02/17:14	23.96	122.5	6.59	4.84	6	0.023	0.061	B
24	1999/10/22/02:18	23.52	120.42	16.59	5.85	4	0.740	0.695	B
25	1999/10/22/03:10	23.53	120.43	16.74	5.51	4	0.232	0.251	B
26	1999/10/30/08:27	24.02	121.32	14.36	5.07	3	0.051	0.133	B
27	1999/11/01/17:53	23.36	121.73	31.33	6.13	6	1.929	3.290	B,M
28	2000/02/15/21:33	23.32	120.74	14.71	5.14	7	0.065	0.085	B
29	2000/05/17/03:25	24.19	121.1	9.74	5.61	6	0.327	0.161	B
30	2000/06/10/18:23	23.9	121.11	16.21	6.07	5	1.558	5.350	B,M
31	2000/06/19/21:56	23.92	121.09	27.02	4.91	6	0.028	0.092	B
32	2000/07/14/00:07	24.05	121.73	7.19	5.41	5	0.164	0.135	B
33	2000/07/28/20:28	23.41	120.93	7.35	5.65	5	0.365	0.345	B
34	2000/08/23/00:49	23.64	121.63	27.48	5.11	8	0.058	0.113	B
35	2000/09/10/08:54	24.09	121.58	17.74	5.70	8	0.445	0.583	B
36	2000/09/16/23:04	23.92	122.5	15.10	4.99	5	0.038	0.089	B
37	2000/12/12/20:32	23.97	122.68	19.43	5.19	9	0.075	0.157	B
38	2001/03/01/16:37	23.84	121	10.93	5.00	6	0.039	0.089	B
39	2001/06/14/02:35	24.42	121.93	17.29	5.71	6	0.451	0.780	B
40	2001/06/19/05:16	23.18	121.08	6.58	5.00	6	0.040	0.119	B
41	2001/06/19/05:43	23.2	121.1	11.70	4.83	5	0.022	0.058	B
42	2001/12/22/21:40	24.12	122.91	8.73	5.12	4	0.059	0.061	B
43	2001/12/28/00:41	23.99	122.9	9.46	5.05	8	0.046	0.057	B
44	2002/02/12/03:27	23.74	121.72	29.98	5.52	9	0.235	0.379	B
45	2002/03/31/06:52	24.14	122.19	13.81	7.10	4	54.950	54.500	B,M
46	2002/04/03/18:06	24.32	121.87	12.87	4.99	8	0.038	0.100	B
47	2002/05/15/03:46	24.65	121.87	8.52	5.97	7	1.125	1.910	B,M
48	2002/05/28/16:45	23.91	122.4	15.23	5.83	7	0.682	1.490	B,M
49	2002/06/13/20:40	24.78	122.13	8.14	5.04	5	0.045	0.066	B
50	2002/07/11/07:36	23.94	122.41	14.22	5.69	7	0.426	0.652	B
51	2002/07/13/12:07	23.8	122.68	6.26	4.62	4	0.010	0.029	B
52	2002/08/28/17:05	22.26	121.37	12.03	5.39	8	0.153	0.255	B
53	2002/09/01/05:56	23.92	122.43	8.81	5.40	5	0.156	0.183	B
54	2002/09/01/07:07	23.97	122.37	15.56	5.17	8	0.070	0.112	B
55	2002/09/15/01:06	23.92	122.53	11.03	4.88	6	0.026	0.058	B
56	2002/12/21/06:09	21.53	121.37	12.29	4.68	3	0.013	0.056	B
57	2003/05/15/01:17	25.06	122.52	17.58	5.16	4	0.069	0.054	B
58	2003/06/09/01:52	24.37	122.02	23.22	5.61	8	0.328	0.642	B
59	2003/06/10/08:40	23.5	121.7	32.31	5.80	8	0.626	1.041	B,M
60	2003/07/30/18:36	23.92	122.46	12.34	4.82	5	0.021	0.078	B
61	2003/12/10/04:38	23.07	121.4	17.73	6.58	7	9.222	20.030	B,M
62	2003/12/11/00:01	22.79	121.39	33.58	5.29	8	0.109	0.179	B
63	2003/12/17/16:27	22.61	121.31	32.20	5.23	7	0.087	0.121	B

Table 1. (continued).

64	2004/01/01/03:15	23.34	121.71	24.88	5.11	8	0.058	0.069	B,S
65	2004/05/01/07:56	24.08	121.53	21.55	5.04	9	0.045	0.073	B,S
66	2004/05/08/08:02	21.93	121.64	6.61	5.60	9	0.309	0.250	B,S
67	2004/05/16/06:04	23.05	121.98	12.85	5.37	6	0.144	0.262	B,S
68	2004/05/19/07:04	22.71	121.37	27.08	6.11	9	1.821	2.570	B,M
69	2004/07/06/07:32	24.9	122.27	5.96	5.17	5	0.071	0.081	B,S
70	2004/11/08/19:38	23.93	122.51	15.74	4.91	5	0.029	0.069	B,S
71	2004/11/10/14:48	23.97	122.42	14.87	4.86	7	0.024	0.044	B,S
72	2004/11/11/02:16	24.31	122.16	27.26	5.44	7	0.180	0.359	B,S
73	2004/12/16/00:10	23.95	122.41	8.56	4.95	7	0.033	0.049	B,S
74	2005/02/18/20:18	23.34	121.67	15.28	5.33	8	0.122	0.154	B,S
75	2005/03/05/19:06	24.65	121.8	6.95	5.77	9	0.557	0.528	B,S,M
76	2005/04/30/14:48	24.04	121.62	8.45	5.13	9	0.061	0.103	B,S
77	2005/06/07/16:45	23.99	121.74	2.09	4.92	9	0.030	0.036	B,S
78	2005/07/20/13:06	24.75	122.25	7.60	5.10	7	0.056	0.093	B,S
79	2005/09/06/01:16	23.96	122.28	16.76	5.61	5	0.320	0.552	B,S,M

*Number of BATS stations in use for determining M_{oB}.
**Types of seismic waves used in the CMT inversion; "B" for long-period (>45 s) body waves; "S" for intermediate-period (>50 s) surface waves; "M" for long-period (>135 s) mantle waves.

the Broadband Array in Taiwan for Seismology (BATS). There are currently 20 permanent stations in operation, each equipped with a broadband instrument; in most cases, this is the Streckeisen STS-1 or STS-2 seismometer. A detailed description of BATS can be found in Kao *et al.* (1998, 2002). Kao *et al.* (1998) first determined the CMT solutions for larger earthquakes in the Taiwan region from seismograms in the frequency range of 0.02–0.1 Hz (or the period range of 10–50 s) recorded by BATS under the point-source assumption. Since this time, the CMT solutions of larger sized earthquakes in the Taiwan region have been routinely determined using the BATS seismograms (Kao and Jian, 1999, 2001; Kao *et al.*, 2001, 2002; Liang *et al.*, 2003, 2004).

Given the abundance of earthquakes that occur in the Taiwan region, the data on these earthquakes provide a good opportunity to compare the values of M_o determined from global and regional networks. In this study, we have taken the values of M_o listed in both the Global CMT and BATS catalogues and compared these with the aim of assessing the difference between seismic moments determined by global and regional networks, respectively. The results will help us to construct a reliable value of M_o for earthquakes occurring in the Taiwan region (regional M_o). They can also be used to evaluate the moment magnitude, M_w. In addition, we compared regional M_w with global M_w.

2. Data

The CMT solution for earthquakes occurring in the Taiwan region, between a range of 119°E to 123.5°E and 21°N to 26°N, is rapidly determined and then revised—in a two-step approach—using BATS seismograms. To date, the final CMT solutions for more than 1000 events occurring between March 1996 and September 2005 have been determined. We selected a total of 79 events whose seismic moments are listed in both the Global CMT and BATS (final CMT) catalogues. In this study, the symbols 'M_{oG}' and 'M_{oB}' are used to represent the seismic moment published in the Global CMT and BATS catalogues, respectively. The values of M_o of these 79 earthquakes are 2.9×10^{23} dyne-cm $\leqq M_{oG} \leqq 5.45\times10^{26}$ dyne-cm in the Global CMT catalogue and 1.0×10^{23} dyne-cm $\leqq M_{oB} \leqq 5.495\times10^{26}$ dyne-cm in the BATS one. The focal depths of the 79 events range from 1 to 42 km. The values are listed in Table 1, and Fig. 1 shows their locations. Most events were located in eastern

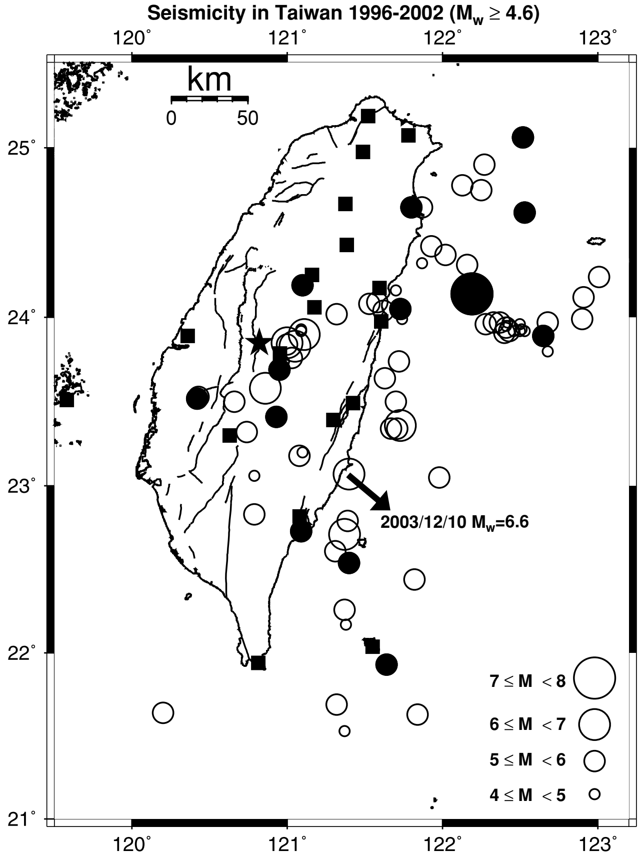

Fig. 1. The epicentral distribution of earthquakes shown in Table 1. The events with $M_{oB} - M_{oG} > 0$ and $M_{oB} - M_{oG} < 0$ are shown, respectively, by filled and open circles. The BATS stations and the epicenter of the 1999 Chi-Chi mainshock are denoted, respectively, by filled squares and a filled star. The different sized circles in the lower-right corner of the figure denotes the different magnitude range.

and offshore Taiwan. Unfortunately, the value of M_o of the 1999 Chi-Chi earthquake (Ma *et al.*, 1999), whose epicenter is denoted by a solid star in Fig. 1, cannot be determined by BATS due to complex regional waveforms caused by complicated source rupture process (Lee *et al.*, 2006).

3. Results

The log-log plot of the M_{oB} versus the M_{oG} of the 79 events is shown in Fig. 2. The dashed line is the bisection line representing $M_{oB} = M_{oG}$. Most of the data points are clearly below the dashed line, thus leading to $M_{oB} < M_{oG}$. Despite the scattering of data points, there is a linear correlation between M_{oB} and M_{oG}. That can be inferred through the least-square method:

$$\log(M_{oB}) = (1.01 \log(M_{oG}) - 0.43) \pm 0.19. \quad (2)$$

Equation (2) is depicted with a solid line in Fig. 2. The M_{oB}-M_{oG} relationship fits the data points comparatively well.

The values of $M_{oB} - M_{oG}$ in an interval of 10^{24} dyne-cm are shown in Fig. 3(a). The M_{oB} is larger than M_{oG} for 13 earthquakes and smaller than M_{oG} for 66 events. For most of the earthquakes studied, the difference is less than $\pm 1.0 \times 10^{24}$ dyne-cm. There are 44 events with $M_{oB} - M_{oG}$ of approximately -1.0×10^{24} dyne-cm and 11 with a $M_{oB} - M_{oG}$ of approximately $+1.0 \times 10^{24}$ dyne-cm. The number of events decreases rapidly with $|M_{oB} - M_{oG}|$. The largest difference is 1.08×10^{26} dyne-cm. The values of $(M_{oB} - M_{oG})/M_{oG}$ are shown in Fig. 3(b). It is quite clear that the values are distributed from -80% to $+30\%$, with an outlier of $+103\%$. Most of the values of $(M_{oB} - M_{oG})/M_{oG}$ fall between -70% and -30%.

BATS has been operative since 1994. Before 1996, there were only five stations, but the number of stations has been increasing steadily, and in 2005, 19 BATS stations were completely functional. A new BATS station was established in March 2006. The cumulative number of BATS stations versus time during the period 1996–2005 is shown in Fig. 4(a). The temporal variation of $M_{oB} - M_{oG}$ is shown in Fig. 4(b). Large $M_{oB} - M_{oG}$ events occurred in 1999 and 2000, with the most noticeable event, the one with the maximum $M_{oB} - M_{oG}$ value ($= -1.08 \times 10^{26}$ dyne-cm), being the 10 December 2003 Chengkung earthquake ($M_s = 6.7$). The M_o values of this event as determined from regional and global networks are 0.92×10^{26} and 2.03×10^{26} dyne-cm, respectively. With the exception of the anomalies, most data points vary around $M_{oB} - M_{oG}$ values of approximately 1.0×10^{24} dyne-cm. Figure 4(c) demonstrates the temporal variation in $(M_{oB} - M_{oG})/M_{oG}$, which ranges from -77% to $+103\%$, with negative and positive average values of -44% and $+21\%$, respectively. The event with the maximum value of $(M_{oB} - M_{oG})/M_{oG}$ ($= +103\%$) is the 17 May 2000 earthquake with $M_w = 5.6$. The M_o values of this event as determined from regional and global networks are 3.27×10^{25} and 1.61×10^{25} dyne-cm, respectively.

4. Discussion

Figure 2 shows that although there were more moderate earthquakes than larger sized ones, almost all of the data points follow the same linear trend. M_{oB} strongly correlates with M_{oG}, with a scaling constant of approximately 1, as

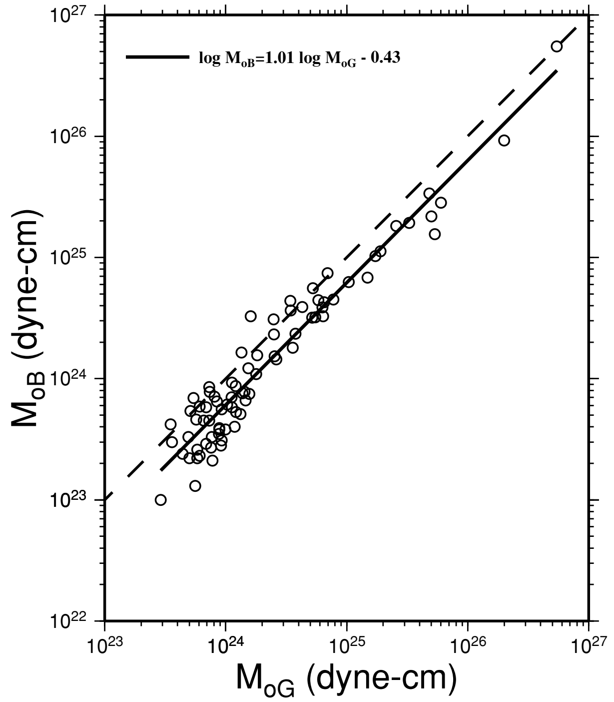

Fig. 2. The plot of M_{oG} versus M_{oB}. M_{oG} obtained from the Global CMT catalogue and M_{oB} from the BATS catalogue. The related regression line is depicted with a solid line, and the dashed line denotes the bisection line.

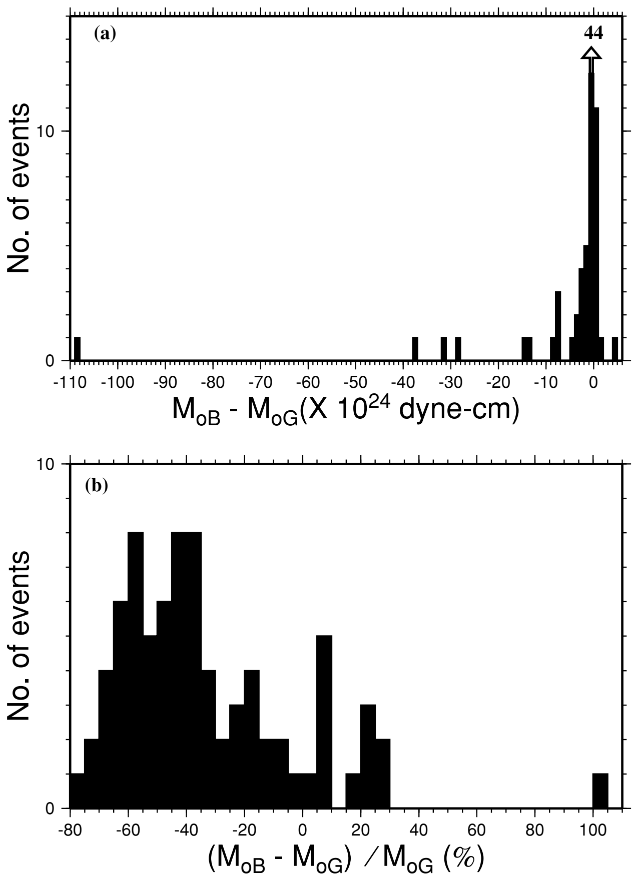

Fig. 3. The plots of (a) the seismic-moment difference between M_{oB} and M_{oG} versus the number of events and (b) the number of events versus $(M_{oB} - M_{oG})/M_{oG}$.

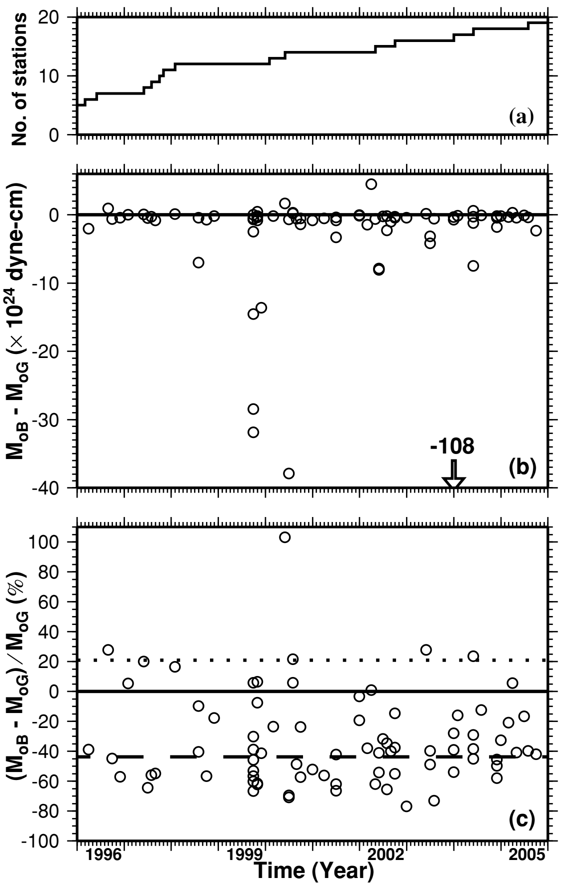

Fig. 4. The plots of (a) the cumulative number of BATS stations versus time, (b) $M_{oB} - M_{oG}$ versus time, and (c) $(M_{oB} - M_{oG})/M_{oG}$ versus time. The dotted and dashed lines denote positive and negative average values, respectively.

shown in Eq. (2). The regression line is almost parallel with the bisection line. The values of the seismic moment listed in the Global CMT catalogue are generally considered to be reliable and accurate because they are determined from the seismic waves of several hundred seconds. Hence, a strong linear correlation between M_{oB} and M_{oG} indicates the high reliability of M_{oB} as determined from the BATS seismograms. However, a correction factor has to be applied to convert the M_{oB} values to M_{oG} values. Equation (2) shows that M_{oB} is, on an average, equal to $0.37M_{oG}$.

Figure 3(a) shows that—for most earthquakes—$M_{oB} - M_{oG}$ is less than $\pm1.0\times10^{24}$ dyne-cm; this includes 44 events with a $M_{oB} - M_{oG}$ value of approximately -1.0×10^{24} dyne-cm and 11 events with a $M_{oB} - M_{oG}$ value of approximately $+1.0\times10^{24}$ dyne-cm. The number of events decreases rapidly with $|M_{oB} - M_{oG}|$, reflecting the small number of larger sized events. Figure 3(b) shows that the values of $(M_{oB} - M_{oG})/M_{oG}$, which are distributed from -80% to $+30\%$, with most of these lying between -70% and -30%. Most values of positive $(M_{oB} - M_{oG})/M_{oG}$ are less than 20%, and the data points with $M_{oB} - M_{oG} > 0$ are close to the bisection line, as depicted in Fig. 2. Our results indicate that the difference between the value of M_o determined from BATS waveforms and that deterimed from the global data is lower for the earthquakes with $M_{oB} - M_{oG} > 0$ than for those with $M_{oB} - M_{oG} < 0$. Figure 3(a) and 3(b) shows that there are 13 events with $M_{oB} - M_{oG} > 0$. These events are indicated with filled circles in Fig. 1. It is clear that no spatial-dependence of $M_{oB} - M_{oG} > 0$ is present, as shown in Fig. 1.

As depicted in Fig. 4(a), the number of BATS stations has been increasing since late 1994. However, the values of $M_{oB} - M_{oG}$ and $(M_{oB} - M_{oG})/M_{oG}$ are both clearly not time-dependent (see Fig. 4(b) and (c)), thus indicating that an increase in the number of BATS stations does not improve the accuracy of determining M_{oB}, primarily due to the fact that M_{oB} is randomly determined from seismograms recorded at—maximally—nine BATS stations (see Table 1). Hence, the total number of stations is less important for determining the M_{oB}. Figure 4(b) shows that in 1999 and 2000, just after the 1999 $M_w = 7.7$ Chi-Chi earthquake in Taiwan, the values of M_{oB} of a few earthquakes were underestimated because they were much smaller than those of M_{oG}, with large negative values of $M_{oB} - M_{oG}$. In addition, the $M_s = 6.7$ Chengkung earthquake of December 10, 2003 has the maximum negative value ($= -1.08 \times 10^{26}$ dyne-cm). However, the $(M_{oB} - M_{oG})/M_{oG}$ values of these two earthquakes lie within the normal range. The factors causing abnormal $M_{oB} - M_{oG}$ values are still unanswered. Only nine of the 79 events studied had $(M_{oB} - M_{oG})/M_{oG}$ values in the range -10% to $+10\%$. The average value of $(M_{oB} - M_{oG})/M_{oG}$ is -33% for the whole time interval in the study time period.

Figures 1–4 all clearly show $M_{oB} < M_{oG}$ for most of the events studied. As had been found by other researchers (Thio and Kanamori, 1995; Hwang *et al.*, 2001; Huang and Wang, 2002; Huang, 2006), we found that the seismic moment determined from a regional network is smaller than that from the global one. This inequality can be explained on the basis of the source model. From the ω^{-2} model proposed by Aki (1967), the source spectral amplitude, $A(f)$, at the frequency f is

$$A(f) = (M_o/\mu)\left\{1 + \left[(\cos\theta/c) - (1/v)\right]^2 (2\pi f/\kappa_L)^2\right\}^{-1/2} \cdot \left[1 + (2\pi f/\kappa_T)^2\right]^{-1}, \quad (3)$$

where μ, θ, c, v, κ_L, and κ_T are, respectively, the rigidity, a polar coordinate, either the P- or S-wave velocity, the rupture velocity, the characteristic length constant, and the characteristic time constant. M_o is clearly the actual seismic moment of an earthquake when it is determined from $A(f)$ at $f = 0$; that is, $M_o = \mu A(0)$. In practice, M_o is evaluated from lower frequency surface waves or normal modes. Based on Eq. (3), the source spectral amplitudes of very low frequency signals are close to $A(0)$. Equation (3) shows that $A(f)$ decreases with increasing frequency. For earthquakes with $M_s > 6$, $A(f)$ obviously departs from $A(0)$ when $f > 0.02$ Hz (see figure 3 in Aki (1967)). In general, three different types of seismic waves are used in the CMT inversion by the Harvard and LDEO groups: long-period (>45 s) body waves, intermediate-period (>50 s) surface waves, and long-period (>135 s) mantle waves. The types of seismic waves used in the CMT inversion for the events of this study are also shown in Table 1. In contrast, as mentioned above, the seismic moment (M_{oB}) is determined from BATS waveforms with $f = 0.02$–0.1 Hz, and, consequently, M_{oB} could be underestimated. Table 1 shows that essentially longer period seismic waves are used by the above-mentioned two CMT groups in comparison to the BATS group, even though most CMT solutions were evaluated from body wave. Hence, M_{oG} must be closer to the actual seismic moment than M_{oB}. This would explain why $M_{oB} < M_{oG}$ holds for most of Taiwan's events.

The moment magnitude, M_w, was originally defined by Hanks and Kanamori (1979) based on the following formula: $M_w = (2/3)\log(M_o) - 10.73$. For Taiwan's earthquakes, this relationship becomes $M_{wB} = (2/3)\log(M_{oB}) - 10.73$ and $M_{wG} = (2/3)\log(M_{oG}) - 10.73$ when M_{oB} and M_{oG} are, respectively, taken into account. This leads to $M_{wB} - M_{wG} = (2/3)\left[\log(M_{oB}) - \log(M_{oG})\right] \approx -0.3$ from Eq. (2) when the standard deviations are ignored. Consequently, the moment magnitude evaluated from regional BATS seismograms is about 0.3 less than that estimated from global data.

5. Conclusions

The values of the seismic moments (M_o) of 79 Taiwan earthquakes published in the Global CMT and regional BATS catalogues from 1996 to 2005 were compared. The designations M_{oB} and M_{oG} were used to denote the values of M_o, respectively, from regional and global networks. The results show that M_{oB} linearly correlates with M_{oG}, with a scaling constant of approximately 1. On average, M_{oB} is approximately equal to $0.37M_{oG}$. The M_{oB} was found to be smaller than the M_{oG} for 66 earthquakes and larger than the M_{oG} for 13 events. There is no space-dependence for positive and negative $M_{oB} - M_{oG}$. In addition, no time-dependence of $(M_{oB} - M_{oG})/M_{oG}$ was found, even though the number of seismic stations increases with time. The moment magnitude evaluated from regional seismograms is approximately 0.3 less than that estimated from global data.

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