SOURCE PARAMETER DETERMINATION USING A SPARSE BROADBAND NETWORK

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MEE06020

ABSTRACT

We determined P-wave moment magnitude M_{wp} introduced by Tsuboi for M 3-7 events. We compared M_{wp} obtained by this study with M_w of NIED CMT solutions. In the case where we use correction factor $\alpha = 0.2$ for radiation pattern, the calculated M_{wp} is slightly larger than M_w of NIED CMT solutions. This may be caused by the effect of the velocity structure which is not considered for calculating M_{wp}. We also determined the moment magnitude Moment Tensor Inversion using the program by Yagi. We assumed the same velocity structure as that used by NIED. Values of M_w obtained by this study are very similar to M_w obtained by NIED. We can conclude that the Yagi program can be used for the moment tensor determination for local events of M3-7. As to the events which are larger than M 7, the point source approximation can not be held. Therefore, it is difficult to determine the moment tensor using the program by Yagi for local events larger than M 7. However, for distant events larger than M 7, we could determine M_{wp} which are close to those of Harvard CMT solutions.

Keywords: P-wave moment magnitude, Moment tenser inversion, Moment magnitude

INTRODUCTION

Myanmar lies on the earthquake belt of Himalayan range. The northeastern part of the Indian plate subcontinent is seismically active. The motion of the Indian (IN) plate with respect to that of the Eurasia (EU) plate is highly oblique to the margin. The seismic records show that there have been at least 16 major earthquakes bearing magnitude $M \geq 7.0$ within the territory of Myanmar for the past 170 years. Monitoring of earthquakes in Myanmar is an urgent subject for earthquake disaster prevention.

Now Myanmar is planning to expand the number of seismic stations by using 10 digital broadband seismic stations. Myanmar will have a network of 6 VSAT telemetry broadband seismometers by the end of this year. Since our broadband seismic network is under construction, we can not use our seismic data. Therefore, we use the broadband seismograms from F-net in Japan. In the present study we adopted a technique to determine earthquake magnitudes using the broadband P-wave seismograms (Tsuboi et al., 1995; 1999), which is called broadband P-wave moment magnitude M_{wp}. This P-wave moment magnitude M_{wp} scale has been utilized at the Pacific Tsunami Warning Center (PTWC) and the West Coast/ Alaska Tsunami Warning Center WC/ATWC. We also determined the moment magnitude using the program by Yagi (2004). Then, we compare the P-wave moment magnitude with moment magnitude. These methods will be applied later after the establishment of new sets of broadband digital seismogram in Myanmar.

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DATA

The data used in this study was obtained from the F-net by the National Research Institute for Earth Science and Disaster Prevention (NEID). We used 6 broadband seismic stations; Abuyama, Aogashima, Nishitosa, Watarai, Yasaka and Toyota operated by the NIED in this study. We selected 22 earthquakes from the F-net of 2007, March to July which occurred in our study areas (Japan). The magnitude of the selected events ranges from 3 to 7. We chose the earthquake whose epicenters lie within 30◦ – 38◦ N 128◦ – 142 ◦E. First of all, we need information about an earthquake, its location (latitude and longitude in degrees) and hypocenter depth. We show the epicentral distribution of events and the location of stations in Figure 1.

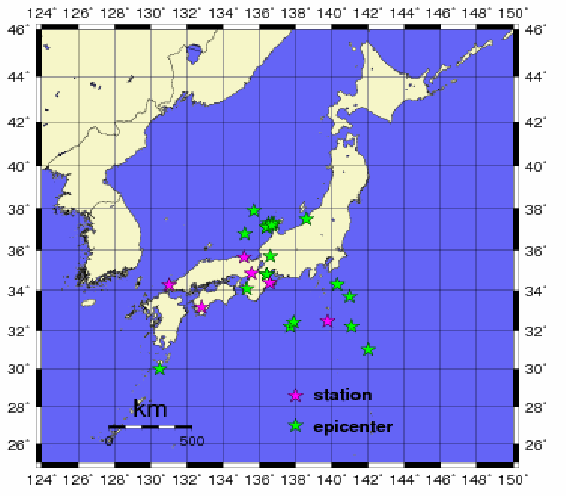

Figure 1 The epicentral distribution of events

METHOD

In this study, we used two methods for data analysis.

1. Determination of Broadband P-wave Moment Magnitude
2. Determination of Moment Tensor

Determination of Broadband P-wave Moment Magnitude

Following Tsuboi *et al.* (1995, 1999). The P-wave moment magnitude, M_{wp} is calculated from the vertical component of far-field P-wave displacement and by using the following equation to calculate the approximate seismic moment M_0:

$$M_0 = \max\left(\int u_z(x_r, t)dt\right)\frac{4\pi\rho\alpha_p^3 \ r}{F^p} \qquad (1)$$

where u_z is the vertical component record, x_r is the station location, ρ is the density, α_p is the P-wave velocity, r is the epicentral distance. F^p is the P- wave radiation pattern. Then, we used the standard moment magnitude formula (Kanamori, 1977) to calculate the moment magnitude:

$$\mathrm{M}_w = \frac{1}{1.5}\left(\log M_0 - 9.1\right) \qquad (2)$$

For the last step, effect of radiation pattern was taken into account and the following formula was used.

$$\mathrm{M}_{wp} = \mathrm{M}_w + \alpha \qquad (3)$$

$$\alpha = \{\log (15/4)\}/3 \approx 0.2$$

For calculating M_{wp}, we use the method by Kanjo et al. (2006).

where α is correction for radiation pattern (Tsuboi 1995). This P-wave moment magnitude M_{wp} scale has been utilized at the Pacific Tsunami Warning Center (PTWC) and the West Coast/ Alaska Tsunami Warning Center WC/ATWC.

Determination of Moment Tensor

We used the code developed by Yagi (2004) for obtaining M_w by moment tensor inversion. We can treat source and propagation process as linear operators. The moment tensor can be described as double-couple. Therefore, it is possible to construct observed waveform by summing the moment tensor weighted displacements for each moment tensor (convolution of Green's function and Source time function). The number of independent components of moment tensor for double-couple is five.

$$u(t) = \sum_{i=1}^{5} m_i \times Green_i(t) * Source(t) \quad (4)$$

where Green(t) and source(t) are to calculate the Green's function. We can assume the structure and depth of hypocenter. We can also assume the source time function is delta function. Then, the observation waveform ($\emptyset$) can be expressed as

$$\emptyset = \mathbb{G}\, m \quad (5)$$

$$\emptyset = \begin{bmatrix} u_{ud}(t_1) \\ u_{ud}(t_2) \\ \vdots \\ u_{ns}(t_1) \\ \vdots \end{bmatrix}, \quad \mathbb{G} = \begin{vmatrix} G_{ud}^{m_1}(t_1) & G_{ud}^{m_2}(t_1) & \cdots & G_{ud}^{m_5}(t_1) \\ G_{ud}^{m_1}(t_2) & G_{ud}^{m_2}(t_2) & \cdots & G_{ud}^{m_5}(t_2) \\ \vdots & \vdots & \ddots & \vdots \\ G_{ns}^{m_1}(t_1) & \vdots & & G_{ns}^{m_5}(t_1) \\ \vdots & \vdots & \cdots & \vdots \end{vmatrix}, \quad \mathbf{m} = \begin{bmatrix} m_1 \\ m_2 \\ m_3 \\ m_4 \\ m_5 \end{bmatrix}$$

$$G_{ud}^{m_1}(t) = Green_{iud}^{m_1}(t)$$

If we know the observation waveform ($\emptyset$) and green's function ($\mathbb{G}$), then we can solve the above matrix equation using least-square approach, which is exactly Moment Tensor Inversion.

RESULT

Relationship between M_w (NIED), M_w (this study), M_{wp} (this study, α = 0.0 and α = 0.2) and M_{jma}

In the Figure 2, we compare M_{wp} obtained in this study with those by the NIED. Here we take into account α = 0.2. In this case M_{wp} (this study) are larger than moment magnitude M_w (NIED). However, in the Figure 3, we take α = 0.0. We can see that there is a good agreement between M_{wp} (this study) and those by the NIED. According to the result, we can say that for the local earthquake, it is not necessary to add α = 0.2.

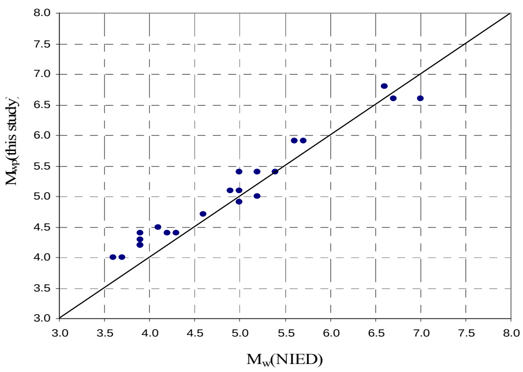

Figure 2 Comparison of M_w (NIED) and M_{wp} (this study, α = 0.2)

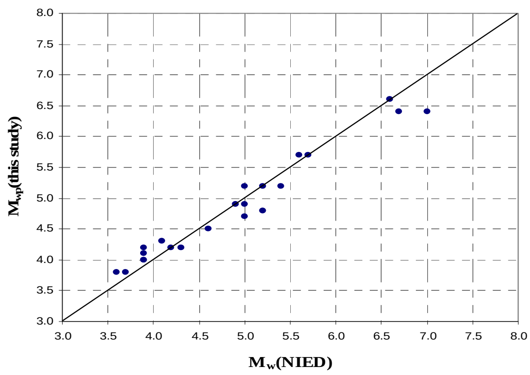

Figure 3 Comparison of M_w (NIED) and M_{wp} (this study, α = 0.0)

Next, we made comparison between moment magnitude (NIED) and moment magnitude (this study) as shown in Figure 4. We obtained the good correlation between M_w (this study) and M_w (NIED). According to the figure, we can conclude moment magnitude by using moment tensor inversion provided by Yagi (2004) and that of NIED result which are very close.

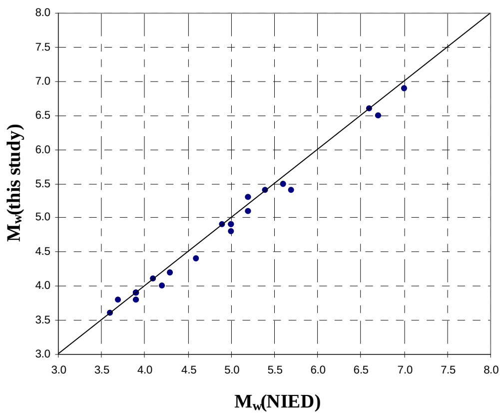

Figure 4 Comparison of M_w (this study) and M_w (NEID)

In Figure 5, we compared M_{wp} (this study, α =0.0) and M_w (this study). We obtained the good correlation between M_{wp} (this study) and M_w (this study).

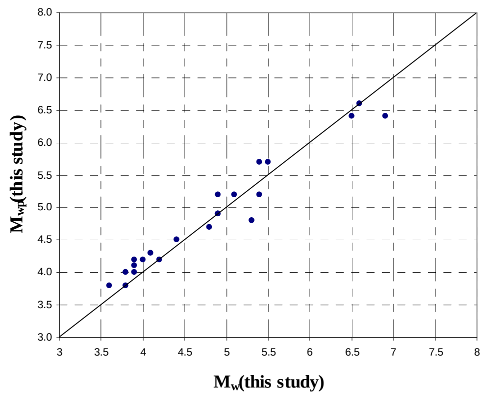

Figure 5 Comparison between the M_{wp} (this study, α = 0.0) and M_w (this study)

Finally, we compared the M_w (this study) and M_w (NIED) with M_{jma}. We found that M_{jma} gave larger values than obtained from moment magnitude adopted by Yagi (2004) and M_w by NIED.

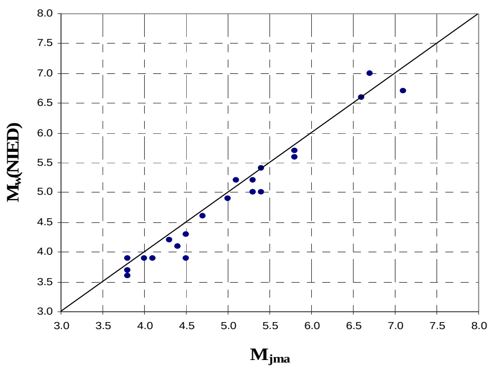

Figure 6 Comparison of M_{jma} and M_{wp} (this study, α = 0.2)

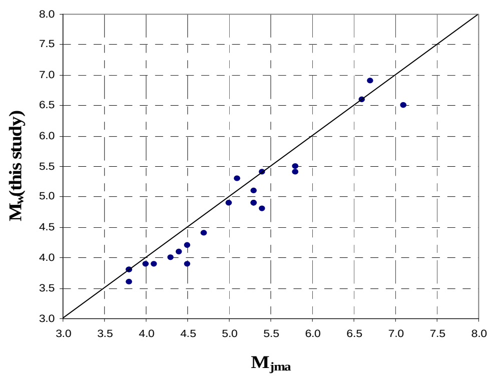

Figure 7 Comparison of M_{jma} and M_w (this study)

Determination of M_{wp} for Larger Events (M_w > 7.1)

We analyzed 4 events that occurred in Japan (2003-2007) with moment magnitude more then 7.1. We retrieved the digital waveforms from broadband seismometer of F-net. We obtained the P-wave moment magnitude using the Tsuboi (1995, 1999) method for each event. Then, we compared their values with the magnitude obtained from M_{jma}, M_w (NIED) and M_w (CMT), respectively, by plotting the M_{wp} of this study against the moment magnitude. We obtained that M_{wp} (this study) is larger than the M_w (NIED). On the other hand, the M_{wp} obtained in this study is very close to the M_{jma} and M_w (CMT).

We could not determine moment tensor inversion because in the program the source of earthquake is assumed to be a single point source. For the local event we can determine the moment tensor for the event less than M7.

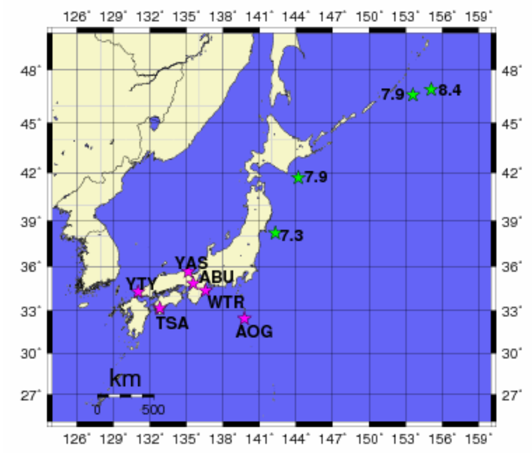

Figure 8 Location of stations and epicenter of large events

DISCUSSION AND CONCLUSIONS

First, we determined M_{wp} for M 3-7 events. We compared M_{wp} obtained by this study with M_w obtained by NIED. In the case where we use correction factor $\alpha = 0.2$, the calculated M_{wp} is slightly larger than M_w obtained by NIED. For the calculation of M_{wp}, an elastic half-space is assumed. Therefore, it may be necessary to change the values of correction factor α, considering a velocity structure. For example, in the case $\alpha = 0.0$, there is a good agreement between M_{wp} (this study) and M_w obtained by NIED.

We also determined the moment magnitude using the program by Yagi (2004). We assumed the same velocity structure as that used by NIED. Values of M_w obtained by this study are very similar to M_w obtained by NIED. This indicates that we can determine the moment tensor using the program by Yagi (2004). By comparing M_{wp} with M_w obtained by Yagi's program, we can determine a correction factor, α for M_{wp}.

As the events which are larger than M 7.1, the point source approximation can not be held. Therefore, it is difficult to determine the moment tensor using the program for local events by Yagi (2004). Actually, we tried to determine the moment tensor of the large events which occurred at subduction zones. But we failed to determine the moment tensor. However, we could determine M_{wp}, although the number of analyzed events is small, we could obtain values of M_{wp} which are closer to those of CMT solutions.

We used the seismograms from the stations of which distribution is very similar to our future seismic network. The noise level of our network will be much greater than that of F-net since the sensor of our network is located at the surface. Although and large. We cannot say that we will be able to determine the M_{wp} and M_w for small events such M3 and M4 using our future seismic network. But we will be able to determine the M_{wp} and M_w for middle events. We will also be able to determine M_{wp} for the distant large subduction zone events.

ACKNOWLEDGEMENT

I am thankful to the National Research Institute for Earth Science and Disaster Prevention (NEID), Japan because they provided me with the waveform data for my study.

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