MOMENT TENSOR AND HYPOCENTER DETERMINATION USING WAVEFORM DATA FROM THE NEW BANGLADESH SEISMIC NETWORK

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ABSTRACT

The Bangladesh Meteorological Department (BMD) has established a new digital seismic observation network in 2007. The data from this digital network have been used to determine a moment tensor using software developed by Dreger (2003). I analyzed the November 11, 2007 Bangladesh-India border earthquake. The obtained focal mechanism is consistent with that of the Global CMT catalog. This result suggests that it is possible for BMD to monitor and investigate the seismic activities by moment tensor determination procedure using data from the newly established Bangladesh Meteorological Department Seismic Network.

I also performed hypocenter determination for the recent three earthquakes. The results for the two events that occurred in Bangladesh are consistent with the USGS hypocenters and felt reports. As for the event in Myanmar, the difference between their depths is large.

Keywords: Moment tensor inversion, Hypocenter.

INTRODUCTION

Seismicity

The north and east parts of Bangladesh is seismically active. The seismicity in these regions is attributed to the collision between the Indian plate and the Eurasian plate, and the subduction along the Indo-Myanmar range. Bangladesh has experienced large earthquakes in its history. Figure 1 shows historical and recent earthquakes in and around Bangladesh. The five historical and recent earthquakes among them occurred in Bangladesh, and the other five events occurred around Bangladesh. This kind of information can be used to evaluate possible damages caused by future earthquakes in and around Bangladesh.

New Digital Seismic Network of Bangladesh

In Bangladesh, the first seismic station was established in Chittagong in 1954. An analog seismometer was deployed at this station. Recognizing the increasing vulnerability for earthquakes, especially in large cities due to high density of population, unplanned infrastructure and their close proximity to India and Myanmar's seismically active areas, the GOB is implementing a project to establish three new seismic stations with upgrading the existing one for earthquake monitoring of in and around Bangladesh in 2007.

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This nation-wide seismic network (shown in Fig. 2) consists of six digital broadband seismometers (two borehole and four vault type), two digital short-period seismometer, six digital triaxial accelerometers with GPS synchronization and five sets of GPS (Geodetic), etc. Networking among these four stations will be done by dedicated digital network for data transmission to the central data collection and processing center in the BMD headquarters in Dhaka.

Figure 1. Some historical and recent earthquakes in and around Bangladesh.
(the data was obtained from the USGS).

Figure 2. The locations of the four stations of the Bangladesh seismic network.

TIME-DOMAIN MOMENT TENSOR PROCEDURE

Software

In this study, time-domain moment tensor inversion was carried out following Dreger and Romanowicz (1994) and Pasyanos *et al.*(1996). The software package of this technique has been used at the University of California, Berkeley Seismological Laboratory (BSL) since 1993 to automatically analyze events (ML>3.5) in Northern California. Also, this package has been implemented at the Japan National Institute for Earth Science and Disaster Prevention (NIED). This time-domain moment tensor inversion software package (TDMT_INV) is available at International Handbook of Earthquake and Engineering Seismology Handbook, part B. Green's functions were computed by using the FKRPROG software developed by Saikia (1994).

Method

The time-domain moment tensor inversion is performed as follows. First, waveform data are processed and prepared by the following steps: (i) baseline correction, (ii) deconvolution to obtain ground velocities, (iii) integration to calculate displacement, (iv) rotatation to obtain transverse and radial components, (v) bandpass filtering, and (vi) re-sampling to 1 sps.

Then, Green’s functions are calculated using the frequency wave number algorithm developed by Saikia (1994). The next step is to calculate time domain Green’s function by the inverse FFT using the result in previous step. Then the bandpass filter with the same passband as was used for the observed data is applied.

Finally, linear least squares for deviatory moment tensor is preformed for a given source depth (both a spatial and temporal point source is assumed). The inversion yields the moment tensor which is decomposed into the scalar seismic moment, a double-couple moment tensor and a compensated linear vector dipole moment tensor. The decomposition is represented as percent double-couple and percent CLVD. The double-couple is further represented in terms of the strike, rake and dip of the two nodal planes. The basic methodology and the decomposition of the seismic moment tensor is described in Jost and Herrmann (1989).

The source depth is determined by finding the solution that yields the large variance reduction, (Dreger and Helmberger, 1993)

$$VR = \left[1 - \sum_i \sqrt{\left(data_i - synth_i\right)^2} \Big/ \sqrt{data_i^2} \right] * 100 \qquad (1)$$

where *data* and *synth* are the data and Green’s function time series, respectively, and the summation is performed for all the stations components.

Another measurement that is useful for determining source depth in regions where explosive events are unlikely is the RES/Pdc, the variance divided by the percent double-couple where,

$$RES / Pdc = \sum_i \sqrt{\left(data_i - synth_i\right)^2} \,/\, Pdc \qquad (2)$$

Dividing the variance by the percent double-couple tends to deepen the minimum.

Crust Model

I selected a crust model from CRUST 2.0 (Bassin, Laske, and Masters, 2000) referring to the positon of the Chittagong station, and used this model for Green’s function computation. CRUST 2.0 is a global crustal model specified on a 2x2 degree grid. Data were gathered from seismic experiments and averaged globally for similar geological and tectonic settings. The model and programs are available at http://mahi.ucsd.edu/Gabi/rem.dir/crust/crust2.html

Data

The event that occurred on the November 7, 2007 (the origin time: 07:10:21.72UTC after USGS) was selected for moment tensor inversion. The nearest station was Chittagong, and we used waveform data recorded at this station for the moment tensor inversion.

Table 1 shows the hypocenters and magnitudes issued by Bangladesh Meteorological Department, USGS, India Meteorological Department, and the Global CMT project (http://www.globalcmt.org/). The focal mechanism of this event in the Global CMT catalog is the strike skip fault.

Result

Figure 3 shows the result of the inversion for a focal depth of 15 km. We used the epicenter from the USGS in inversion, and the frequency band 0.03-0.04 Hz. The determining focal mechanism is a strike slip, which is consistent with the Global CMT solution.

We performed moment tensor inversions for depths of 5, 10, 15, 20, and 25 km, and compared variance reductions and variances divided by the corresponding percent double-couples. While the former is not sensitive to change of depths, the latter is more sensitive, and the focal depth of 15 km provides the smallest value.

Table 1. Hypocenters and magnitudes of the November 7, 2007 earthquake issued by Bangladesh Meteorological Department, USGS, India Meteorological Department, and the Global CMT project (* denotes lack of information).

Organization	Lat (deg.)	Lon (deg.)	Depth (km)	M
USGS	22.15	92.39	28.7	5.5
BMD	22.14	92.38	*	6.0
IMS	22.1	92.5	15	5.3
Global CMT	22.15	92.5	25	5.5

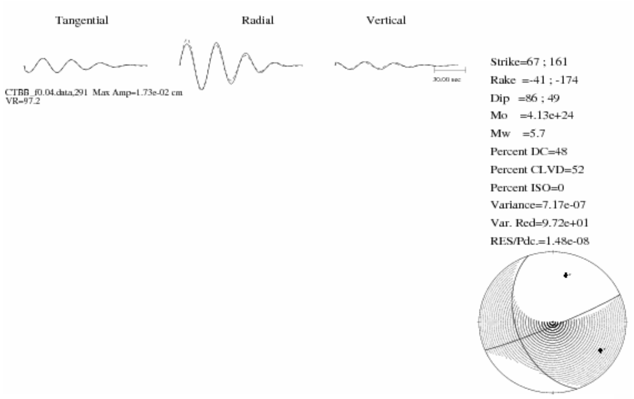

Figure 3. The result of the moment tensor inversion (the focal depth is set to 15 km).

HYPOCENTER DETERMINATION

Data

I performed hypocenter determination to investigate whether it is possible to obtain reliable hypocenters using data from the new Bangladesh seismic network. I selected three events shown in Table 2. The epicenter of the latest event on the July 26, 2008 earthquake is at Mymenshing, and 120 km from the capacital city Dhaka. Its magnitude was 4.9. At least 25 people were injured at Dhaka.

I picked P and S arrival times of the Dhaka, Rangpur and Sylhet stations for the January 12, 2008 event (in the Bangladesh-India border region) and the December 7, 2007 event (in the Myanmar-India border region) using EDSP software. Bangladesh Meterological Department picked P and S arrival times of the Dhaka, Chittagong and Sylhet stations for the July 26, 2008 event (at Mymenshing, Bangladesh).

Table 2. The events selected for hypocenter determination (after the USGS).

Date	Time (UTC)	Lat (deg.)	Lon (deg.)	M	Depth (km)
26th Jul. 2008	18:51:48	24.79	90.51	4.9	1
12th Jan. 2008	22:44:47	22.76	92.33	5.0	33.8
7th Dec. 2007	6:56:34	23.50	94.57	4.8	113.3

Method and Crust Model

I used the program, HYPOCENTER, (Lienert et al., 1986) for hypocenter determination. This is an earthquake location method for locating local, regional and global earthquakes. Since the structures of the crust and upper mantle beneath Bangladesh is not precisely studied, I used model iasp91 (Kennett and Engdahl, 1991) as an earth model in this study. The initial depth guess is set to 0 km.

Result

Table 3 shows the determined hypocenters, and Figure 4 shows comparison between these epicenters and those from the USGS. The results for the events on the July 26, 2008 and the January 12, 2008 are consistent with the USGS hypocenters. As for the former event, the obtained epicenter is also consistent with felt repots. As for the event on the December 7, 2007, which occurred in Myanmar, although the epicenter of this study is close to that of the USGS, the difference between the depths is large. This result suggests the difficulty to locate events outside the network.

In all the cases, data from the three stations are available, and data from one station is missing. It is desirable that data from all of the stations are continuously available.

Table 3. The hypocenters determined in this study.

Date	Lat (deg.)	Lon (deg.)	Depth (km)
26th Jul. 2008	24.98	90.47	10.8
12th Jan. 2008	22.66	92.17	10.0
7th Dec. 2007	23.42	94.24	10.0

Figure 4. Comparison between the epicenters determin study (red stars) and those from the USGS (blue stars).

CONCLUSION

In this study, I applied the moment tensor inversion code developed by Dreger to the waveform data from the new broadband seismic network in Bangladesh. I also performed hypocenter determination of the recent three earthquakes using data from this network.

The focal mechanism solution obtained in this study is consistent with the Global CMT solution for the same event. The results of hypocenter determination for the events in Bangladesh are consistent with hypocenters determined by the USGS.

These results suggest that it will be possible to use both programs for further investigations of events in Bangladesh. Based on the achievements in this study, I am going to perform moment tensor inversion using the procedure of this study. I also plan to relocate previous events using the program HYPOCENTER.

RECOMMENDATIONS

Accurate hypocenter is necessary to perform moment tensor inversion used in this study. At present, there are four stations running in the Bangladesh seismic network. Due to communication problems and unstable power supplies, data from all the stations are not always available. It is desirable to increase the number of stations to enhance the capability of hypocenter determination. Also, data exchange among neighboring countries will be effective to improve accuracy of determination of earthquake source parameters.

To improve moment tensor determination, accurate crust model is necessary. Analyses using phase data and waveform data should be carried out to construct an appropriate crust model for earthquake monitoring. Through these improvements, I believe that our network will successfully work for earthquake monitoring in my country in the near future.

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