DETERMINATION OF EARTHQUAKE PARAMETERS USING SINGLE STATION BROADBAND DATA IN SRI LANKA

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ABSTRACT

We determined epicenters and magnitudes using data from the single broadband seismic station in Sri Lanka, PALK. First, we analyzed earthquakes to which epicentral distances from PALK were within 40 degree. Most of the events are in and around Andaman and Nicobar Islands in the Indian Ocean. The obtained results show that it is possible to determine epicenters and surface wave magnitudes with acceptable accuracy using a single station method.

We also analyzed an earth tremor in Sri Lanka using data from the PALK station. Despite high frequency noises contained in the data, the epicenter determined by the single station method is consistent with felt reports. The calculated local magnitude is 3.2.

Keywords: Single station method, Epicenter, Surface wave magnitude.

INTRODUCTION

In Sri Lanka, we have not faced with many natural disasters except for landslides based on the known history. In a several decades, there have been implemented preparedness and preventive measures for landslides considering that they are possible natural disasters in the country. When it comes to earthquakes, it is said that Sri Lanka is considered fairly safe and not likely to be prone to major earthquakes. This idea has been changing recently in the society after the Great Tsunami in 2004. Although we are considerably far away from an active plate margin of Sumatra, we suffered from the historical tragedy a several hours after the 2004 M=9 earthquake occurred. This incident proved that seismic activity in subduction zones can transmit a disastrous tsunami for more than two thousand kilometers away from its origin in the Indian Ocean. The seismicity of this area is likely to affect the internal peacefulness of earth in the country. Many off shore earthquakes have made significant shakings inside the country according to the reports after 2004 great earthquake.

A number of inland tremors have been reported by general public within the country in past few years. Most of these tremors were very local, confined to particular region within the country (Fernando et al. 1986). Monitoring of such micro seismic activities is very important and, since there have been recorded a number of tremors within the country, it is essential for us to learn and study local earth dynamics and seismicity.

The great Indian Ocean Tsunami in 2004, reminds us that, although Sri Lanka is located in a relatively stable area, the secondary events like tsunamis can make significant damages. Therefore it is expected to study the seismicity of that particular region using available data resources.

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PALK is the single reliable seismic station in Sri Lanka, data from which was used in the study. We used the software DIMAS to analyze waveform data from 39 regional and teleseismic events and one local event.

DATA

We selected 39 earthquakes recorded at PALK whose moment magnitudes are larger than 6. Although we are mainly interested in events in and around Andaman and Nicobar Islands, some events in other regions are also included in our dataset.

The basic information about events were initially collected using JWEED developed by IRIS data center. The selected events can be further reviewed for the purpose of the study. Once we decide the events of the study, the electronic request is generated and sent to the data center through JWEED. A few minutes later, the requested waveform data are obtained on the client computer and we can save them as mini seed or SAC data formats according to our propose.

METHOD

We used S-P time differences and an assumed velocity structure of the region to find epicentral distances. The P waves and S waves were picked from the vertical component and two horizontal components, respectively. Appling these results with appropriate regional P and S wave velocities in Wadatii diagrams, we can find the epicentral distances quickly. The particle motion of a P wave recorded in all three components can be used to determine the direction of the P wave. Surface wave magnitudes (Ms) were measured using Raleigh waves that were recorded on vertical components. Furthermore, owing to the availability of waveform data, Local Magnitude (M_L) was calculated for a recent local earth tremor.

The software DIMAS (Display, Interactive, Manipulate and Analysis of Seismogram) is used in determination of earthquake parameters in this study (Droznin, 1997). The program has been developed based on the following algorithms.

Origin time

The equation (1) shows the relationship of origin time with arrival time of P wave, S-P time difference and ratio of the velocity.

$$To = Tp - Ts\text{-}p/V, \qquad (1)$$

where

To = Origin Time,
Tp = Arrival Time of P wave,
Ts-p = Difference of arrival times of S-wave and P-wave,
V = (Vp /Vs) -1,
Vp = Velocity of P wave,
Vs = Velocity of S wave.

Epicentral Distance

After finding the P wave travel time, assuming the source depth, the epicentral distance is determined by the travel time table. The program uses the default value for depth, which is set to zero. Depending on waveforms, a user can assume the depth based on depth phases as well. The program uses the travel time table for model iasp91 (Kennett and Engdahl, 1991), and the epicentral distance is calculated based on this table.

Source Azimuth

The azimuth from the station to the seismic source is determined by the investigation of polarization of the initial motion of the P waves. Analyzing the particle motion of the P wave in the first few seconds of the three component records and assuming the lateral homogeneity of the region, the direction of the P wave can be obtained.

Magnitude Calculation

Surface and local magnitudes are calculated by the following formula.

Surface wave Magnitude $$\mathbf{M_S = \log_{10}(A/T) + 1.66\{\log_{10}(delta)\} + 3.33} \quad (2)$$

A – The maximum amplitude of the surface wave (μm)
T – The dominant period of the measured wave (seconds)
delta – The distance from the station to epicenter (degree)

Local Magnitude $$\mathbf{M_L = \log_{10}(A/T) + 2.56\{\log_{10}(dist)\} + 0.67} \quad (3)$$

A – The maximum amplitude (μm)
T – The dominant period of the measured wave (seconds)
dist – The distance from the station to source (km)

RESULTS

Epicenters

Figure 1 shows the epicenters determined in this study and those from the PDE catalog. We found that the quality of PALK data were good enough for epicenter determination. We calculate distances between the corresponding epicenters of this study and the PDE catalog, and their frequency distributions are shown in Fig. 2. The distances for most events are in the range between -1 and 1 degree, from which we may expect relatively good estimates for magnitudes.

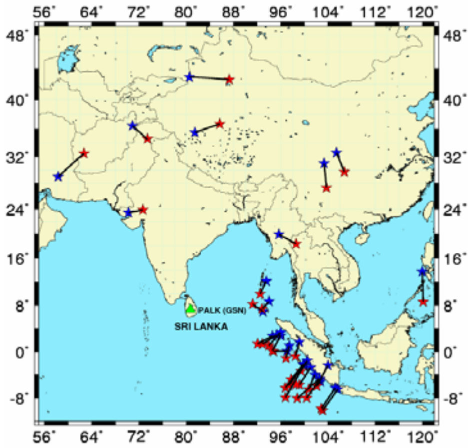

Figure 1. The epicenters determined in the study (red stars) and those from the PDE (blue stars) catalogues are shown, respectively. Corresponding epicenters are connected by solid lines.

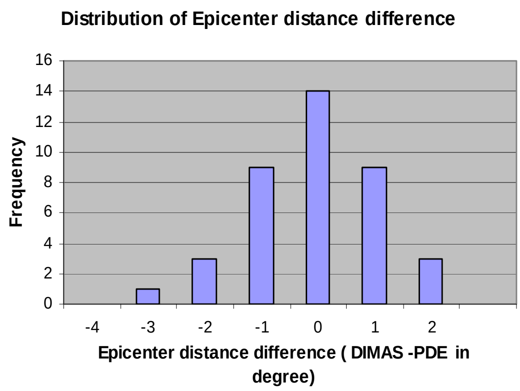

Figure 2. Frequency distribution of distances between epicenters determined in this study and those by the USGS.

Magnitude calculation

Figure 3 shows the comparison between Ms determined in this study and those from the PDE catalog, and Fig. 4 shows the distribution of their differences. We find a good agreement between them for the magnitude range between 6 and 8. Above M=8, their agreement becomes poorer. Their magnitude differences are within ± 0.2 for most of the events.

Figure 5 shows the comparison between Ms determined in this study and Mw from the Global CMT catalog, and Fig. 6 shows the distribution of their differences. Again, we find a good agreement between them for the magnitude range between 6 and 8. Their magnitude differences are within ± 0.3 for most of the events.

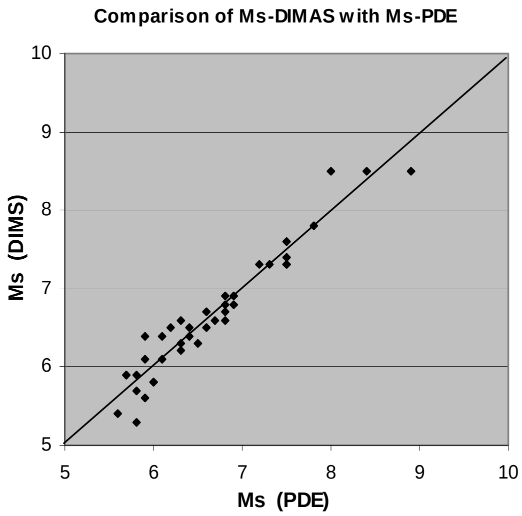

Figure 3. The comparison of Ms obtained from the Study and those from the PDE catalogue.

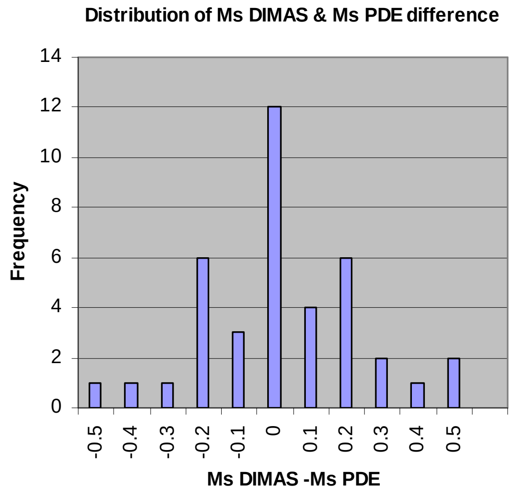

Figure 4. Frequency distribution of differences Ms in the study and those from the PDE catalogue.

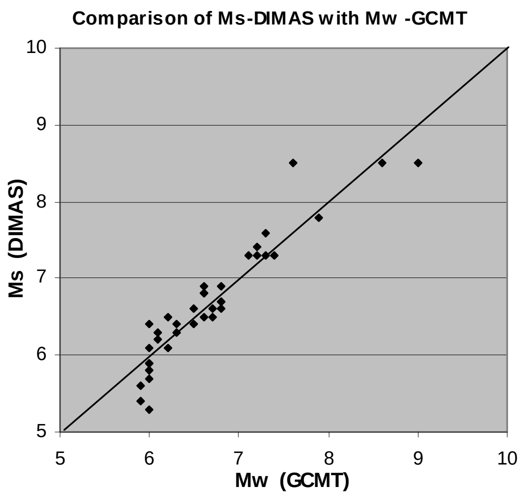

Figure 5. The comparison of Ms obtained in this study and Mw from the Global CMT catalogue.

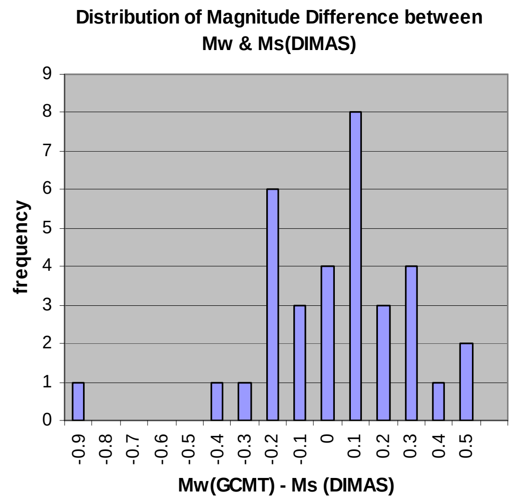

Figure 6. Frequency distribution of differences between Ms of this study and Mw from the Global CMT catalogue.

Analysis of a local tremor

On the April 7, 2008, there was an earth tremor in the central part of Sri Lanka. According to reports from local authorities and public, shakings were felt around Dambulla and Sigiriya in Central Province.

We applied high band-pass filter to the waveform data from PALK, and found a signal around the time where the shakings were felt. This is likely to a record of the earth tremor. Around the time when this local event occurred, there was another regional event in the Indian Ocean. Therefore, the data of the local tremor data has noises of the considerable level. However, using high band-pass filtering, we could analyze this local event.

The latitude and longitude of the estimated epicenter was 7.84 degree and 80.75 degree, respectively. This result is consistent with the felt reports issued by local authorities. The calculated local magnitude of this event was 3.2.

Back azimuths

Figure 7 shows the distribution of differences between the back azimuths in this study and those calculated using the epicenters from the PDE catalogue. They distribute around 10 degree. One of the possibilities for this discrepancy is laterally heterogeneous earth structure. However, this is not likely in this case, because the differences of the back azimuths are observed not only for the events around Andaman and Nicobar Islands but also for the events in other regions.

Another possible reason is inaccurate information on configuration of the seismometer. It will be useful and interesting to use an artificial event, the precise epicenter of which we know, to determine the actual directions of the sensors.

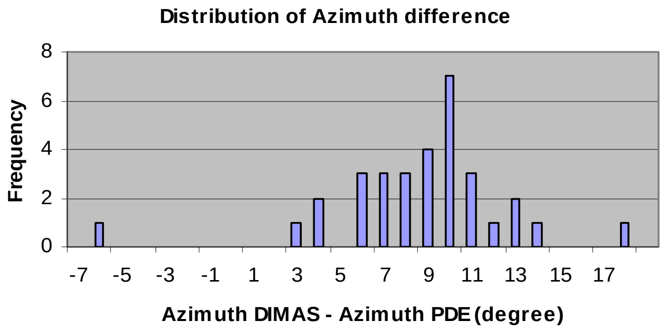

Figure 7. The differences of azimuth values of catalogue (PDE) and calculated in DIMAS

CONCLUTIONS

In this study, we investigated uncertainty of epicenters and surface wave magnitudes determined by a single station method using broadband data from the PALK station. The epicenters obtained in this study agreed well with those of the PDE catalogue in general. The distances between their corresponding events are between –1 and 1 degree for most of the events. We observed the systematic difference of the back azimuths. The plausible reason is likely to be inaccurate information on configuration of the seismometer.

We compared Ms determined in this study to those from the PDE catalogue and Mw from the Global CMT catalogue. In both cases, they agreed well in general in the magnitude range between 6 and 8. Above the magnitude of 8, their differences become larger. One of the reasons may be saturation of Ms for huge events. However, this initial information will be useful and beneficial for tsunami disaster mitigation, because the estimated Ms for the events whose moment magnitudes are larger than 8 are larger than 8, based on which we can consider the possibility of occurrence of devastating events.

We analyzed one local event on the April 7, 2008 using the single station method. Although the data contained considerable noises, the determined epicenter was consistent with felt reports. The calculated local magnitude was 3.2.

RECOMMENDATIONS

The study showed that it was possible to determine epicenters and magnitudes by the single station method using data from PALK with relatively good accuracy. However, uncertainty of these estimates is still large, and it is necessary to enhance earthquake monitoring capability through upgrade and deployment of seismic networks with relevant infrastructures, and establishment of data centers. In addition, it is important to study local and regional seismicity, since many earth tremors has been felt recently in the country. I would like to propose the following suggestions future development.

(1) The current University seismic network, which at present is not working properly, should be upgraded so that it is possible to monitor earthquakes continuously. The upgrade plan was studied and proposed by Thaldena (2008). It is desirable to establish a real-time data transfer between these stations and GSMB National Seismic Data Center.

(2) In order to better understand seismicity in and around the country, another seismic network with sufficient number of short period seismometers is desirable.

(3) The PALK station is governed by international agencies and there are certain limitations for data usage. It is highly desirable to establish our own broadband seismic station. This would be definitely beneficial for earthquake and tsunami disaster mitigation of the nation.

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