Local Magnitude Scale for the Philippines: Preliminary Results

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Abstract

We analysed broadband waveform data from the Philippine Seismic Network in order to obtain a local magnitude formula appropriate for the Philippines. We used data from 162 events that occurred between May, 2012 and March, 2016. We calculated simulated Wood-Anderson seismograms from vertical component waveform data to measure maximum amplitudes. We conducted a grid search to determine the coefficients for the log(r) and r terms of the distance correction function, where r is the hypocentral distance. The preliminary results consist of sets of the coefficients which explain the data relatively well without large hypocentral distance dependence. Compared to the distance correction functions for southern California, central California, and the central United States obtained by previous studies, the distance correction functions of the preliminary results are similar to that for southern California.

Keywords: Local magnitude, distance correction, grid search

1. INTRODUCTION

The Philippine Seismic Network (PSN) has been deployed since 2012. It consists of 29 broadband stations. Ten stations have been deployed in the SATREPS (Science and Technology Research Partnership for Sustainable Development) project by the NIED (National Research Institute for Earth Science and Disaster Prevention) and the Philippine Institute of Volcanology and Seismology (PHIVOLCS) entitled "Enhancement of Earthquake and Volcano Monitoring and Effective Utilization of Disaster Mitigation Information in the Philippines" funded by the JST (Japan Science and Technology Agency) and the JICA (Japan International Cooperation Agency). Nineteen stations have been deployed by the PHIVOLCS.

The SWIFT (Source Parameter determinations based on Waveform Inversion of Fourier Transformed seismograms, Nakano et al., 2008, 2010) system has been implemented for rapid earthquake source parameter determination for earthquakes up to around M_w 4.5 using the PSN data (Bonita et al. 2015).

M_L (Richter, 1935, 1958) is applicable to events smaller than M_w 4.5 and to those up to around M_w 7 (e.g., Hanks and Kanamori 1979; Hanks and Boore 1984). In this study, we analyzed broadband waveform data from the PSN to obtain a distance correction function for M_L for the Philippines following the IASPEI standard procedure for magnitude determination (IASPEI, 2013).

2. METHOD

The IASPEI (2013) recommends a M_L formula based on the distance correction function of Hutton and Boore (1987) 'for crustal earthquakes in regions with attenuative properties similar to those of southern California'. It recommends the calibration of a distance correction function using amplitudes from vertical component instruments 'for crustal earthquakes in regions with attenuation properties that are different from those of coastal California'. Since the attenuation property in the Philippines is not well understood, we tried to determine the distance correction function appropriate for the Philippines using data from the PSN.

Following previous studies such as Bakun and Joyner (1984), Hutton and Boore (1987), Miao and Langston (2007), we adopted the following formula:

$$M_L = \log A + n \log(r/100) + K (r - 100) + 3 + S \quad (1)$$

where A is the maximum amplitude on the vertical component record, r is the hypocentral distance in kilometers, the coefficients n and K are constants to be determined by observed data, and S is a station correction. The sum of the second, third, and fourth terms corresponds to a distance correction function, $-\log(A_0)$, in the Richter's local magnitude.

We performed a grid search to determine these coefficients. The upper and lower bounds and increment for n are set to 0.75, 1.7, and 0.05, respectively. Those for K are set to 0.0008, 0.007, and 0.00005, respectively. For a given pair of n and K, we determined station corrections using the differential scheme of Uhrhammer et al. (1996) with an assumption that the sum of station corrections is zero. Then, we calculated M_L estimates for that pair of the coefficients with the station corrections. We chose a median of M_L estimates for each event as the M_L estimate for that event. We calculated the magnitude residual that is the difference between each M_L estimate and the M_L estimate for that event (i.e., the median). To find an optimal estimate of the parameters, we calculated the root mean square (RMS) of the magnitude residuals and, in addition, investigate the hypocentral distance dependence of the magnitude residuals. For the latter, we fitted a straight line to the magnitude residuals with respect to the hypocentral distance by the least squares method. We evaluated the hypocentral distance dependence by the product of 1000 and the slope of the fitted line, which corresponds to the systematic difference for the range of 1000 km.

3. DATA

In this study, we used waveform data recorded at 18 broadband seismic stations of the PSN considering their operation periods. We selected 162 shallow (up to a depth of 34 km) local earthquakes that occurred in the period from May 2012 to March 2016 for each of which at least six data are available in the hypocentral distance range up to 1000 km. We calculated simulated Wood-Anderson seismograms using the instrument response of the Wood-Anderson seismograph obtained by Uhrhammer and Collins (1990).

4. RESULTS

We performed a grid search to determine the coefficients n and K in eq. (1) by the procedure explained in section 2. As was explained, we evaluated the hypocentral distance dependence of the magnitude residuals by the product of 1000 and the slope of the fitted line. We selected the sets of coefficients n and K under the constraint that the absolute value of the product is less than or equal to 0.02. Figure 1 shows the distance correction functions for the selected sets of the coefficients with those for southern California (Hutton and Boore, 1987), central California (Bakun and Joyner, 1984), and the central United States (Miao and Langston, 2007). The distance correction functions of the preliminary results are similar to that for southern California. The pair of n = 1.70 and K = 0.0013 provides the minimum RMS magnitude residual (0.23). Since the distribution of the data is heterogeneous, it will be necessary to evaluate its effects on the estimation of the coefficients.

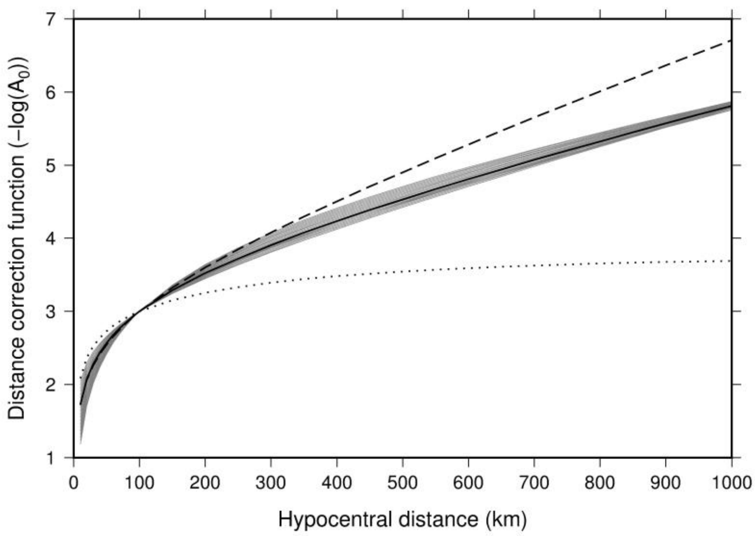

Figure 1. The distance correction functions for the selected sets of the coefficients are shown by gray curves. The black curve, dashed and dotted curves are the distance correction functions for southern California (Hutton and Boore, 1987), central California (Bakun and Joyner, 1984), and the central United States (Miao and Langston, 2007).

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