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“ESTIMATES OF EPICENTRAL DISTANCE AND MAGNITUDE FROM ONE SEISMIC STATION”

Shayakubova M. Z.
Institute of Seismology of ANRUz, Tashkent, Uzbekistan
muxtabar.muxtabar.shayakubova@mail.ru

Yuldashev E. Sh
Institute of Seismology of ANRUz, Tashkent, Uzbekistan

Annotation

Rapid assessment of episentral distance and magnitude is of fundamental importance for earthquake early detection and warning systems. We present a new method for estimating the epicentral distance from one seismic record in a short time. To quantify the difference in the observed seismic signals, we introduced a simple function of the form Bt•exp(-At) and determined A and B from the point of view of the least squares method, fitting this function to the initial part of the signal envelope. We found that log B is inversely proportional to log Δ , where Δ is the epicentral distance. This ratio is valid regardless of the magnitude of the earthquake. Using this ratio, we can approximately estimate the epicentral distance almost immediately after the arrival of the P-wave. Then we can easily estimate the magnitude from the maximum amplitude observed during a given short time interval after the arrival of the P-wave, using the empirical magnitude-amplitude ratio, which includes the epicentral distance as a parameter.

Keywords: magnitude, amplitude, epicenter, earthquake, seismic signal, envelope signals, distance, focus, linear scale, noise.

Introduction

An important task of earthquake early detection and warning systems is to estimate the magnitude of the earthquake and the epicenter distance in a fairly short time, say, a few seconds after the arrival of the P-wave. The only system that is currently in the stage of practical use may be the system. In the system, the magnitude is first determined based on the prevailing P-wave period, which may become longer with increasing magnitude. The epicentral distance is then derived from the amplitude using an empirical magnitude-amplitude ratio that includes the epicentral distance as a parameter.

On the other hand, the recent development of so-called real-time seismology is remarkable and reflects the recent rapid development of computer and communication technologies and progress in understanding seismology.

Earthquake early warning and damage assessment systems to introduce new technologies and develop new methods. In this article, we present a method for estimating the epicentral distance by recording from a single station. Then the magnitude estimation is easily performed based on the maximum amplitude for a given short time interval after the arrival of the P-wave.

Fitting the Bt•exp(- At) function to the envelope of the observed signal, seismic waves can have different envelope shapes characteristic of the corresponding source and observation conditions, determined by the magnitude, depth of the focus and epicentral distance. We need some attention to display the envelope signal in visual form. The amplitude of the initial movement of the P-wave is usually very small when compared with the later maximum amplitudes of the P and S waves. When amplitudes are displayed on a scale, many of them often go off the scale. To avoid this difficulty, we display the movement of the ground on a logarithmic scale. As a result, we can easily recognize the noise level preceding the arrival of the P-wave, the initial part of the P-phase with a small amplitude and the later phases with a large amplitude together, which

From our logarithmic signals, we find that the initial part of the seismic waves (within a few seconds after the arrival of the P-wave) systematically changes in shape in response to the magnitude of the earthquake and the epicentral distance. The initial low-amplitude part of each seismogram indicates noise, and the slope, sharply or gradually increasing from the noise level, indicates the entry of the P-wave. And another fact is that the amplitude of a strong earthquake gradually increases with time, while the amplitude of a small earthquake decreases shortly after the arrival of the P-wave. These two features are common to other earthquakes [1,2,3].

In order to quantify the difference in the waveform, we introduce the Bt•exp(At) function and determine the unknown parameters A and B by the least squares method, fitting this function to the observed forms of seismic waves. The time of arrival of the P-wave is taken as the beginning of the countdown of time t. The above function is adjusted to the envelope of the original vertical acceleration waveform. The envelope in the present study is constructed simply by preserving the past maximum amplitude at each moment of time. The method of using an approximating curve in the form of Bt•exp(-At) leads to low-frequency filtering (smoothing) of data.

Parameter B determines the slope of the initial part of the P-waves, parameter A is associated with a change in amplitude over time. When A parameter is positive, B/(Ae) gives the maximum amplitude, where Ae means the base of the natural logarithm. This case is typical for small earthquakes, which indicates that the initial amplitude increases sharply and quickly fades shortly after the arrival of the P-wave. When A parameter is negative, the amplitude increases exponentially with time, and this is typical for strong earthquakes.

The previous function is quite simple in form, but it is suitable for characterizing the waveform, since the two parameters A and B are directly related to two specific features of the waveform. This function reduces to a linear function with respect to A parameter with log B. Then A parameter and log B are easily determined by the usual least squares method. A and B parameters are determined for the data in a 3-second window after the arrival of the P-wave. The arrival of P-waves is mechanically identified at the point where the amplitude of the wave exceeds five times the amplitude of the standard deviation of noise for a certain width of the time window.

Estimation of parameter B and estimation of epicentral distance. We estimate parameters A and B for several earthquakes with a magnitude from 3.9 to 7.3, which are class M 6 earthquakes. The least squares method is like the ratio between log B and log D, which we can use to estimate the epicentral distance from parameter B. The accuracy may be acceptable if we take into account that the assessment is made within a fairly short time, say, 3 seconds. after the arrival of the P-wave.

The azimuthal direction of the epicenter can be derived from the ratio of two seismograms with a horizontal component and a vertical component. Then we will be able to estimate the location of the epicenter.

Magnitude estimation. As mentioned above, we find that the epicentral distance can be estimated approximately immediately after the arrival of the P-wave, say, after 3 seconds. In terms of early warning of an earthquake, the size of the earthquake should also be quickly estimated. An earthquake of magnitude is usually estimated by the following formula [4,5].

$$M = a' \log S_{\max} + b' \log \Delta + c', \qquad (1)$$

where Smax denotes the maximum resultant amplitude of seismic recordings, Δ is the epicentral distance, a/ , b/ and c/ are constants related mainly to the characteristics of recording devices. The constant b/ log Δ is a correction for the decrease in amplitude with increasing distance. In our case, we have a good linear relationship between log B and log Δ, therefore, using the formula instead of equation (1); we can estimate the value where Pmax denotes the maximum amplitude of the P-wave within any given short time interval (for example, 3 seconds) after the arrival of the P-wave teeth.

$$M_{\text{est}} = a \log P_{\max} + b \log B + c \qquad (2)$$

The constants a, b and c in equation (2) can be determined for some set of corresponding earthquake data from the point of view of the least squares method.

In order for this formula to be valid for estimating the magnitude, the maximum amplitude of Pmax must change in accordance with changes in the magnitude and B parameter.

The relation between log Pmax and log B for earthquakes of different magnitudes is shown, where Pmax is the maximum vertical acceleration for 3 seconds. after the arrival of the P-wave. We find that the maximum amplitudes decrease almost linearly with the decrease of the B parameter for the corresponding earthquakes, and they are almost parallel to each other. This indicates that the maximum amplitude for 3 seconds. after the arrival of the P-wave decreases with increasing epicentral distance in the same way as expected for the maximum amplitude in the entire recording. Therefore, it can be assumed that the maximum amplitude within 3 seconds after the arrival of the initial P-wave of the earthquake is small enough for magnitude.

The method works well for estimating the magnitude of an earthquake by parameter B and the maximum amplitude is observed for a fairly short period of time from the moment of the arrival of the P-wave. However, some improvements may be required for near earthquakes and for unnatural earthquakes, for which the process of breaking the fault is quite complicated, it consists in repeatedly estimating the magnitude over time as the amplitude increases.

Results and Discussion

We find that the epicentral distance can be estimated a short time after the arrival of the P-wave by analyzing the amplitudes in its initial part. An important fact is the determination of parameter B, does not depend on the magnitude of the earthquake, but depends mainly on the epicentral distance. The initial part of seismic waves is the same in shape, regardless of magnitude, when they come from the source and are smoothed by the non-elasticity property of the medium and wave scattering during propagation [6,7,8]. The initiation of the velocity wave does not depend on the magnitude of the earthquake. A theoretical study of a circular crack expanding at a constant rate under the action of a uniform shear stress shows that the displacement seismogram in the far zone grows as the square of time at its beginning, and thus the velocity seismogram grows linearly with time. Then the acceleration seismogram can behave stepwise at the initial connection point, regardless of the magnitude. This stepwise rise can be smoothed in a real environment due to non-elasticity and wave scattering [9,10,11].

Another important factor that contributes to the reduction of the B parameter with distance is the geometric propagation of waves.

When the amplitude decreases with distance, the initial slope may decrease by the same order of magnitude. This effect does not depend on the magnitude of the earthquake and may be one of the main factors causing a decrease in
Here is an empirical formula for estimating the magnitude of an earthquake based on parameter B and the maximum amplitude within any given short time window (for example, 3 seconds) after the arrival of the P-wave. However, the question arises whether this method is applicable for M 7 and M 8. class earthquakes, where the duration of the focus reaches 10 seconds. and more.

Conclusions

This article describes the basics of the method of rapid assessment of the epicentral distance, additional research is needed for practical application. In a similar analysis for seismograms of moderate and strong earthquake accelerations recorded at standard seismographic stations, the results were obtained and thus we are convinced that parameter B is useful for early detection of earthquakes. We have not discussed the other parameter A, this parameter can be useful for distinguishing surface and deep earthquakes.

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