ESTIMATION OF STRONG GROUND MOTION PARAMETERS OF INITIAL PART OF P-WAVE FOR EARLY WARNING SYSTEMS IN THE AZARBAYJAN REGION

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ABSTRACT

Two recent earthquakes that struck the Azarbayjan region, NW-Iran, on 10 August 2012 (Mw=6.2 and 6.1) caused major concern about future earthquake occurrences in Azarbayjan Region.

In order to improve the capability of NW-Iran earthquake early warning system for giving early warning of a damaging earthquake in the Azarbayjan Region, we explored an alternative approach with the use of a period parameter (tc) and a high-pass filtered displacement amplitude parameter (Pd) from the initial 3 s of the P wave forms. The empirical relationships both between τ_c and moment magnitude (Mw), and between Pd and peak ground parameters (PGA, PGV and PGD) for the this region are presented. These relationships can be used to detect a damaging earthquake within seconds after the arrival of P waves, and can provide on-site warning in the Azarbayjan Region.

INTRODUCTION

Rapid magnitude estimation is at the heart of Earthquake Early Warning Systems (EEWS). The challenge is to use only a few seconds of the P wave data from a limited number of stations to quickly determine a useful estimate of the earthquake magnitude. Effective Early Warning Systems for natural hazards are now increasingly perceived as an integral component of disaster risk reduction programs. EEWS, already in operation in several countries around the world, have been using mainly two approaches; regional warning and on-site warning. In the first approach, the traditional seismological method is used to locate an earthquake, and determine the magnitude from stations at close epicentral distances, and estimate the ground motion at other distant sites. This approach has already been used in Japan (Nakamura, 2004), Mexico (Espinosa et al., 1995) and Taiwan (Wu et al., 2003). In the second approach, the beginning of the ground motion (mainly P waves) observed at a site is used to predict the ensuing ground motion (mainly by S- and surface waves) at the same site. On-site warning is usually based on individual sensors, while regional warning requires seismic networks. Therefore the regional warning approach is more reliable but requires more time, and cannot be used for the sites at short distances. In contrast, the second one is less reliable, but it is very fast and could provide early warning to sites even at very short distances, where an early warning is most necessary. In the second approach, it is necessary to make rapid estimation of the nature of the progressing earthquake or the ground motions at an early stage of its rupture process (Kanamori, 2005).

In this paper, we explore the use of the second approach, namely τ_c and Pd methods (Kanamori, 2005; Wu and Kanamori, 2005) for seismic early warning purposes in the Azarbayjan region using the accelerograms from the Iranian strong motion networks operated by Building and Housing Research Center (BHRC). Fig. 1 shows the stations distribution of the networks in the northwestern part of Iran.

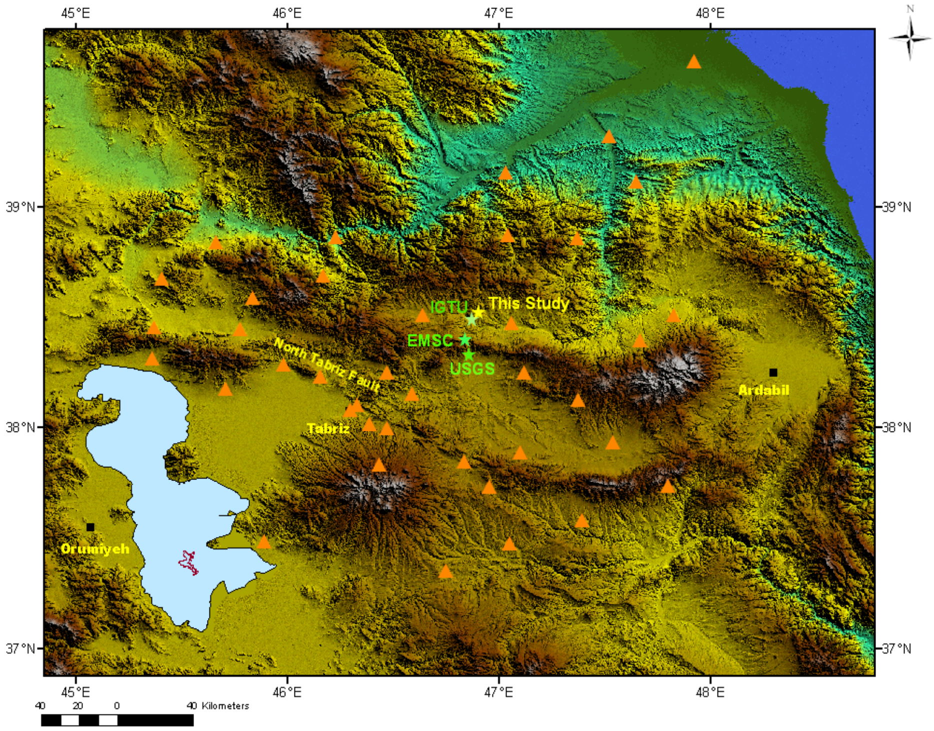

Figure 1.Triangles show the strong ground motion stations and epicenter distribution of the earthquakes (stars) used in this study

τ_c AND Pd METHODS

For an earthquake early warning system, it is important to estimate the size of anearthquake. Wu and Kanamori (2005) developed a method to estimate the magnitude of an earthquake from the first few seconds of strong motion records, by extending the method of Nakamura (1988) and Allen and Kanamori (2003). In this method, the τ_c parameter, which characterizes the average period of ground motion during the initial t_o second after the arrival of the P wave is calculated by using vertical component records to estimate earthquake magnitude, although the value of magnitude is not directly used for on-site early warning purposes. A high- pass filter is applied to remove the drift of the displacement records after double integration of the accelerograms (Kanamori et al,. 1999). Since the relationship involving these parameters depends on the specific filter used, it is important to use the same filter consistently (Wu and Kanamori, 2008a and 2008b). The calculation of τ_c is given by the following equation:

$$\tau_c = 2\pi / \sqrt{[\int_o^{to} U'^2(t)dt]/[\int_o^{to} U^2(t)dt]} \qquad (1)$$

where τ_c is in seconds, u is the high-pass filtered displacement of the vertical component ground motion, and U' is the velocity differentiated from the displacement U. Another element of EEWS is to estimate the strength of shaking at asite from the first few seconds of the P wave.Wu and Kanamori (2005) showed that the Pd parameter, which is the maximum displacement amplitude can be used to estimate the PGV, and proposed that if Pd is equal or greater than 0.5 cm, the event is most likely damaging. Thus, the magnitude ands haking intensity can be estimated for early warning purposes within 3 s after the P wave arrival is detected. If τ_c>1 s and Pd>0.5 cm, then the potential of a damaging earthquake is quite high (Wu and Kanamori, 2008a). They also demonstrated that the combination of the τ_c and Pd methods can provide reliable threshold warnings within 10 s after the occurrence of a large earthquake (Wu and Kanamori, 2005), depending on the stations density of the seismic network.

DATA ANALYSIS

The τ_c and Pd methods have been studied to determine linear relations for the Azarbayjan region between τ_c and M_w, and between Pd and PGA, PGV, PGD parameters (Wu and et al., 2007). We used 149 of 262 strong motion records, including the events with magnitudes 4.5 and larger, recorded by BHRC.

All the P wave arrivals were picked manually. Then, we used the peak displacements and velocity amplitudes of the first 3 s of the P waveforms on vertical components. The acceleration signals are integrated to velocities and displacements, which are recursively filtered with a Butterworth band-pass filter with a cut-off frequency of 0.7-25 Hz for removing the low- frequency drift after the integration process (Shieh et al., 2008).

RESULTS AND DISCUSSION

The relation between τ_c and M_w for the Azarbayjan region was tested in off-line mode, and the following relationship is obtained:

$$M_w=5.2*log(\tau_c)+7.08\pm0.1 \tag{2}$$

where τ_c is in seconds. Fig. 2 shows the average τ_c plotted as a function of M_w. The scatter is large, and the average period parameter (τ_c) values, in general, are higher than those determined by other studies especially for small earthquakes. From the early warning point of view, small amplitude data are not of interest. The threshold level for τ_c calculated in this study is about 2 s, and is greater than that calculated for Taiwan (τ_c =1 s), for the events with M_w =6. This may be due to the difference in S/N ratio, especially for smaller earthquakes. The noise in the strong motion data at long periods is always a critical issue. Shieh et al. (2008) studied this issue by applying different number of poles for the0.075 Hz high-pass Butterworth filter, one (1) through six (6) poles, and examined the relationship between M_w and τ_c. They pointed out that small number of poles had larger slope but larger scatter. Contrarily, large number of poles resulted in a smaller slope but in a smaller scatter. We used a filter setting with four (4) poles.

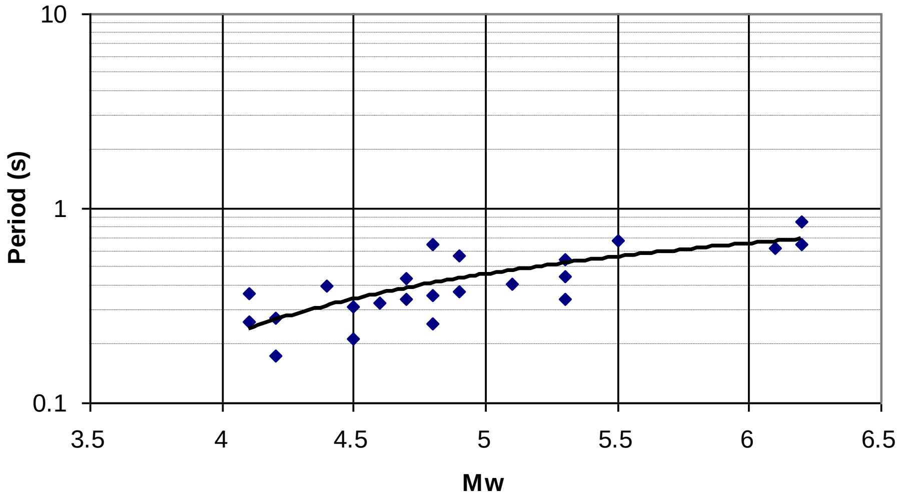

Figure 2. τ_c and M_w relationship obtained using Kanamori's (2005) procedure which is modified from the method used by Nakamura (1988). Solid line indicates the least-square fit.

Pd is an important and robust parameter for rapid recognition of damaging earthquakes, since it is more characteristic of the earliest stage of an earthquake's rupture process, and also less affected by the scattering due to the complex velocity structure than the other types of arrivals in estimating magnitudes (Wu et al., 2007, Wu and Kanamori, 2008). The relationship between Pd and PGA, PGV, PGD for the149 records with the epicentral distances lessthan100km are:

$$Log(PGA)=0.648\ Log(Pd)+1.88\pm0.31 \quad (3)$$

$$Log(PGV)=0.668\ Log(Pd)+0.363\pm0.11 \quad (4)$$

$$Log(PGD)=0.758\ Log(Pd)-0.487\pm0.329 \quad (5)$$

where PGV is in meters per second and Pd is in meters. PGV values increase with Pd approximately linearly as observed in the other results from Taiwan and Japan (Wu and Kanamori, 2005). If we take the Pd equal to 0.5 cm as a threshold level, the corresponding PGV would be about 30 cm/s, showing that the potential of a damaging earthquake is high. As can be seen the damaging earthquakes with M_w=7.2 and 7.5 have the Pd values greater than 0.5 cm.

CONCLUSIONS

The implemented warning system will provide only warnings regarding the severity of impending strong motion. No information regarding the characteristics of the ground motion is given, and at present, EEWS is still in progress. The other approaches to earthquake early warning with the use of τ_c and Pd methods are explored in off-line mode. As a consequence, empirical relationships both between τ_c and M_w, and between Pd and PGA, PGV, PGD for the Azarbayjan region are derived and proposed (Eqs. (2)–(5)). These empirical relationships can be used to detect a damaging earthquake within seconds after the arrival of P waves, and can provide on-site warning in the NW-Iran.

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