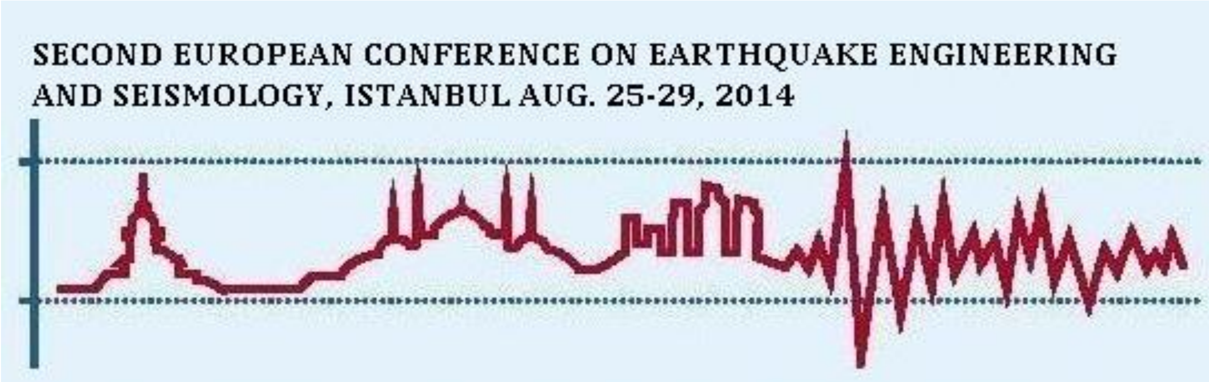

INVESTIGATION ON THRESHOLD BASED EARLY WARNING SYSTEM

Y. Gokhan DURGUN[1] and H. Serdar KUYUK[2]

Earthquake Early Warning Systems (EEWS) are currently helping thousands of people in many countries around the world. In 2011, the magnitude 9.0 Tohoku earthquake demonstrated the effectiveness of the nascent Japanese EEWS. By the usage of these EEWS algorithms, people can reach secure areas and protect themselves. The public transports such as trains, metros can be stopped securely and the engineers can stop their production lines in factories. Many companies have already started to use public national warning system in Japan and a few companies in California, USA such as Bay Area Rapid Transit and Google. Furthermore, some companies such as Miyagi-Oki Semiconductor Company, in Sendai Japan, even started to build up their own early warning system based on pure threshold level of ground motion. Whether it is simple threshold or complex seismic network based, EEWS uses a simple idea of the time span between the P-wave detection at one or more EEW sensors and the arrival of S- or surface waves at the user site.

Many EEWS uses three seconds of (P-wave) data from one or couple of stations to identify location and magnitude of earthquakes (Kuyuk et al., 2013a). Therefore, it takes some time (Kuyuk et al.,2014) to process data for collecting, transmitting, filtering, integrating, and solving location (inverse problem) optimizing and giving final alarm. The loss in time for processing information cause S-wave to propagate around epicentre which result in an area, blind zone, where EEWS information cannot reach (Kuyuk and Allen, 2013b). This fact considers many of the EEWS users especially engineers (Copley, 2012) who think that waiting to calculate location and magnitude is a waste of time, because these information generally does not mean anything to them. Rather they wonder if the threshold of acceleration would exceed some level which might cause damage to their machinery in their workspace. For example this happened in 2009 with L'Aquila earthquake M_w 6.3. Offline evaluation of EEWS in Italy showed that time need to release warning take a few seconds where blind zone is calculated about 32 km. This is the area which actually affected the people and buildings most, around the epicentre (Zollo, 2014). Therefore the people needed the EEWS most, would missed the vital information since they lived in the blind zone.

For benefiters of EEWS who live very close to hypocentre of earthquakes would like to use basic threshold based algorithm rather than current sophisticated EEWS because they do not want to wait until epicentre and magnitude are determined. However, defining the optimum threshold, based on the first stations' acceleration time histories have not been studied in literature, comprehensively. In this study, we have investigated the acceleration amplitude levels of very close stations (less than 15 km) that have available data around epicentre within the three seconds of P-wave onset at the closest station. This approach is based on pure threshold that does not involve complications of signal processing such as real-time filtering, P-wave detection (STA/LTA optimization), calculating frequencies of P-wave and all the complexity of EEWS such as magnitude and location determination.

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METHODOLOGY

The approach we have conducted is based on readings of acceleration amplitudes of closest stations to hypocentre of an earthquake. We have defined maximum amplitudes as;

$$A_{max}(t) = \frac{1}{n}\sum_{1}^{n} \max\left(\left|\nabla_1(t), \nabla_2(t), \nabla_3(t)\right|\right) \quad (1)$$

where n is the number of stations available within three seconds of closest station P-wave onset, ∇ is a component of recorded acceleration time histories. Investigation of the first three closest stations of Mid-Niigata Prefecture (M_w 6.8 in 2004) earthquake showed that within the three seconds of P-wave onset of NIG019 stations, maximum amplitudes were 525, 87 and 30 cm/s/s consecutively (Figure 1).

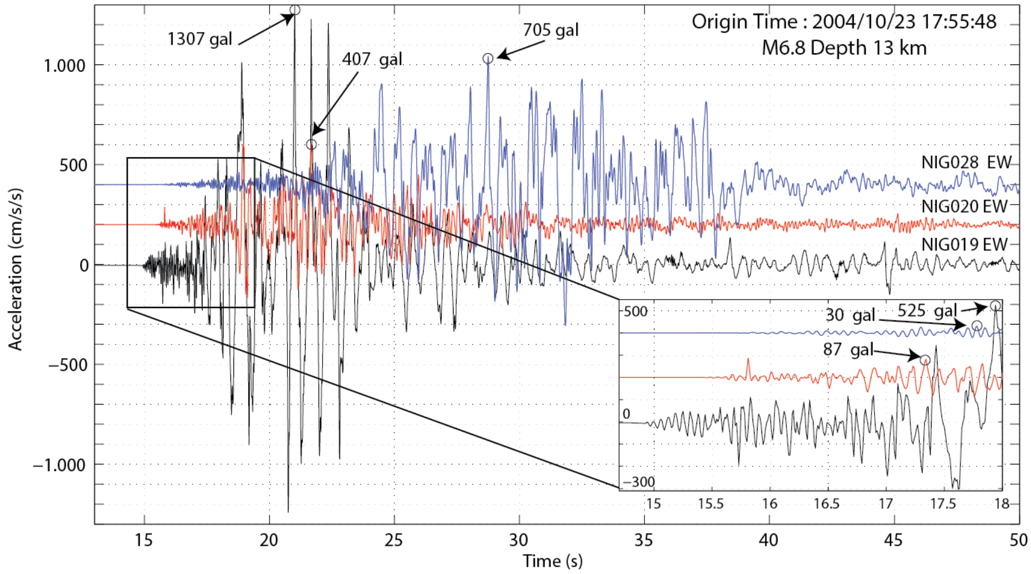

Figure 1. Waveforms of first closest three stations of Mid-Niigata Prefecture Earthquake at 2004/10/23. Waveforms are East-West component of NIG019, NIG020 and NIG028 stations. Figures in right below are zoom of the first three seconds of records.

We assume that three component of records are available at the same time. Rather than using only U-D component of waveforms (like most of existing EEWS such as Onsite, (Böse et al, 2009) and Elarms2 algorithms, (Kuyuk et al, 2014)), we considered using three components from stations. In this case, maximum absolute amplitudes become 739, 312 and 87 cm/s/s (gal) for NIG019, NIG020, and NIG028, respectively which are the closest three stations in the vicinity of Mid-Niigata earthquake epicentre (Figure 2).

DATA

To test our approach, we have compiled 23 inland earthquakes occurred in Japan recorded by Kyoshin Strong Motion Network (K-Net) between 1997 and 2013. Kyoshin network is a nation-wide strong-motion seismograph network, which consists of more than 1,000 observation stations distributed every 20 km uniformly covering Japan. K-Net has been operated by the National Research Institute for Earth Science and Disaster Prevention (NIED) since 1996. At each K-NET station, a seismograph is installed on the ground surface with standardized observation facilities. For this study, minimum and maximum magnitudes (M_{JMA}) of 4.8 and 6.9 with a depth between 10 and 15km are used. Records from stations belong to corresponding earthquakes are within 15 km epicentral distance.

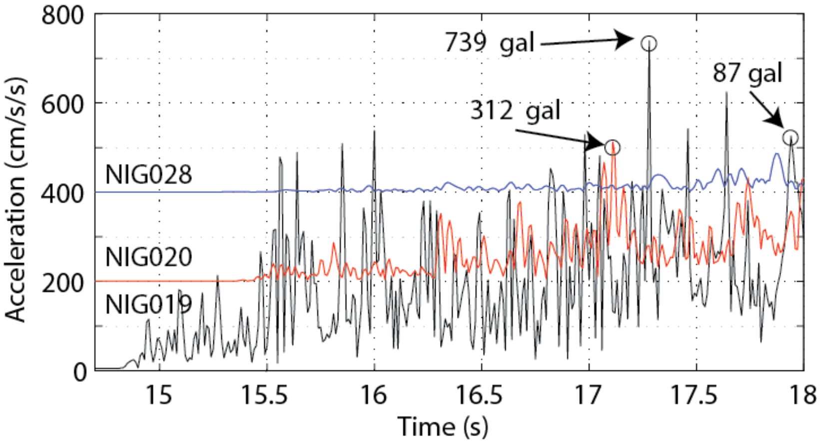

Figure 2. Absolute maximum records of three components of the three stations

RESULTS

Correlation between mean peak acceleration amplitudes with magnitude between M_{JMA} 4.8 and 6.9 for 23 earthquakes is shown in Figure 3. Amplitude levels of acceleration increase with magnitude up to 700 gal for M_{JMA} 6.9 earthquake. We observed a threshold, 100 gal for earthquakes larger than M_{JMA} 5.3. We have found 23 earthquakes except for three, exceed 100 gal amplitude in the first three seconds of first station P-wave onset.

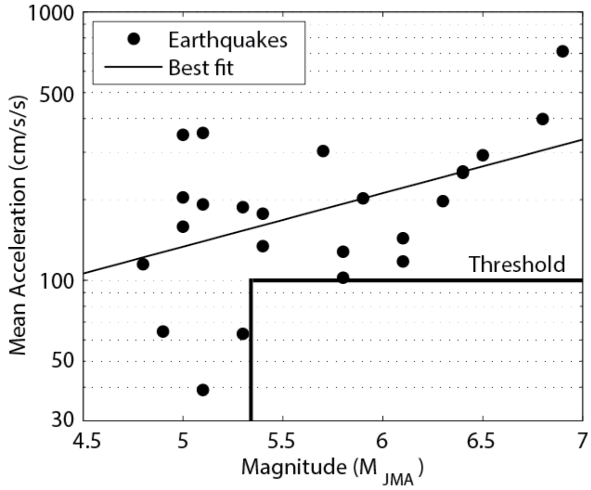

Figure 3. Correlation between M_{JMA} 4.8 and 6.9

REFERENCES

Böse M, Hauksson E, Solanki K., Kanamori H, and Heaton TH, (2009) "Real-Time Testing of the On-site Warning Algorithm in Southern California and Its Performance During the July 29 2008 Mw5.4 Chino Hills Earthquake," *Geophys. Res. Lett*., 36, doi:10.1029/2008GL036366

Copley K, (2012, December). Personal Communication

Kuyuk HS, Allen RM (2013a) "A global approach to provide magnitude estimates for earthquake early warning alerts",*Geophysical Research Letters*, 40(24): 6329-6333

Kuyuk HS, Allen RM (2013b) "Optimal Seismic Network Density for Earthquake Early Warning: A Case Study from California", *Seismological Research Letters*, 84(6):946-954

Kuyuk HS, Allen RM, Brown H, Hellweg M, Henson I, and Neuhauser D (2014) "Designing a Network Based Earthquake Early Warning Algorithm for California: ElarmS-2", *Bulletin of the Seismological Society of America*, 104(1): 162-173

Zollo A, (2014, February). Personal Communication