Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

SSS23-01 Room:201A Time:May 24 14:15-14:30

The medium-term improvement plan of the JMA EEW system

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The JMA earthquake early warning (EEW) system is a part of the EPOS system, which operates 24 hours a day. So, the improvement must be limited. In other words, the update of the EPOS system will be a good chance to improve the EEW system. We will make a presentation about the medium-term improvement plan of the JMA EEW system.

The main part of the JMA EEW system uses the analysis results at the individual stations. We are making the system more efficient by adding and upgrading the elements of the analysis. For example, we will add the continuous transmission mode to the conventional trigger transmission mode. Using the new mode, we will always be able to grasp the seismic motion field all over Japan. Furthermore, we will introduce the real-time pseudo seismic intensity by Kunugi et al. (2008), by which we will be able to monitor the extent of the strong motion field and to evaluate the calculated hypocenter parameter.

The JMA EEW system has to separate the picking data into the individual events correctly. Then, we only use the phase time data so far, but plan also to use the amplitude data. Moreover, the JMA EEW system also uses the calculated hypocenter parameters by the other methods, including the conventional STA/LTA trigger and AR-AIC method, and we plan also to use the calculated results by the particle filter method (Tamaribuchi, the abstracts of this meeting, 2013).

The JMA EEW system is based on the calculated hypocenter parameter but in the cases of the 2011 off the Pacific coast of Tohoku Earthquake and the aftershocks, the system did not necessarily work well because of the procedure. To overcome the situation, we have the idea of the hybrid method using the conventional method and the real-time pseudo seismic intensities.

As mentioned above, the main part of the JMA EEW system uses the analysis results at the individual stations. Now we use 220 stations over Japan including 5 OBS stations in Tonankai. We have already installed 50 new stations and will use those data after the preliminary surveys. Moreover, we are making the external system which will use the 30 NIED KiK-net stations in the deep boreholes under the southern Kanto area and the 20 JAMSTEC Donet OBS stations off the Kii Peninsula. We will also use those data. Furthermore, we have a plan also to use the real-time pseudo seismic intensities of 400 JMA seismic intensity meters after the next EPOS system.

Keywords: EEW, JMA, seismic intensity, hypocenter determination

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A real-time calculation of seismic intensity and its applications

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With the increasing requirements of earthquake early warning (EEW) system, it is much more obviously that the JMA seismic intensity (Ijma) defined by Japan Meteorological Agency has a real-time delay since the Ijma needs a filtering operation in frequency domain. In order to improve a real-time calculation suitable for the EEW system, National Research Institute for Earth Science and Disaster Prevention (NIED) have proposed a real-time processing method of seismic intensity (Kunugi et. al, 2008), using approximating filters in time domain instead of the original filter in frequency domain. We have also improved upon the accuracy of the approximating filters used for real-time processing of seismic intensity (Kunugi et. al, 2013). The relation between the Ijma and the real-time intensity calculated using the improved approximating filter is examined by using a large number of strong motion records. The results show that the absolute differences between the Ijma and the real-time seismic intensities of 99% of all records are within 0.1.

In this presentation, we introduce the real-time processing method of seismic intensity proposed by NIED. Also its applications for EEW systems are discussed.

Keywords: seismic intensity, real-time processing, earthquake early warning, kyoshin monitor, strong ground motion

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SSS23-03 Room:201A Time:May 24 14:45-15:00

Real-time prediction of earthquake ground motion :application of data assimilation technique for estimation of wavefield

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Aiming at improvement of prediction of seismic intensity in Earthquake Early Warning, we are investigating a new technique for real-time prediction of earthquake ground motion. In this presentation, I will explain the application of data assimilation technique for estimation of current wavefield of ground motion.

In the present EEW of JMA, at first hypocentral location and magnitude, M, are quickly estimated, and then seismic intensity is predicted from the hypocentral location and M. In this method, it is not easy to take into account the effect of extension of source region, and the error of hypocentral and M determination leads directly to the error of the prediction. When multiple earthquakes occurred simultaneously as is the case of aftershocks of the Tohoku Earthquake(M9.0), it is not easy to determine the hypocentral location correctly. For addressing these problems, new method for real-time prediction of ground motion is proposed, in which ground motion is predicted directly from the estimated current wavefield, skipping the process of hypocentral location and M. The boundary integral equation method (Kirchhoff integral) is applied. In the presentation, I will explain the application of data assimilation technique for estimation of current wavefield of ground motion.

Determination of detailed distribution of current wave motion is a key for the method, so that dense seismic observation network is required. Data assimilation is a technique to produce artificially denser network, which is widely used for numerical weather prediction and oceanography. Distribution of current wave motion is estimated from not only the current real observation of u(x, t), but also the prediction of one step before, P(u(x, t-delta_t)). Combination of them produces denser artificial network than the real one. Simulations of the case of large source extent, and the case where multiple earthquakes occurred simultaneously are performed to check the availability of the data assimilation technique.

Combination of the data assimilation technique with the boundary integral equation method and real time correction method of site amplification factors enables us to predict earthquake ground motion more precisely.

Keywords: Earthquake Early Warning, Real-time prediction of ground motion, data assimilation

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SSS23-04 Room:201A Time:May 24 15:00-15:15

Real-time correction of site amplification factors estimated by the coda normalization method

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1. Introduction

Hoshiba (2011, SSJ) proposed a method for expectation of ground motion based on real-time monitoring, in which hypocenter and M are not required. In this method, site amplification factor must be corrected in real-time manner. Iwakiri & Hoshiba (2011, JpGU) concluded that the preciseness will be improved when frequency dependency is introduced into the site amplification correction in comparison with the correction of the scalar values such as average difference between observed and expected seismic intensities. Hoshiba (2012, SSJ) designed a recursive digital filter having similar amplitude property to site amplification factor, and proposed a method for real-time site correction. In this study, we will design the recursive filters for the JMA seismic intensity stations, of which site amplification factors were systematically estimated by the coda normalization method, and test a real-time site correction.

2. Site amplification factor

Aoki & Hoshiba (2012, JAEE) estimated relative site amplification factors of the JMA seismic intensity stations for 11 frequency bands (f=0.75-15.0Hz) by the method of Takemoto et al.(2012, BSSA). In this method, we used average amplitudes (over a time window with 5 s length) of the vector sum of the 3-component band-pass filtered coda waves as a data set. The parameters of source and path effects and those of relative site effects were simultaneously estimated by the least-squares method. 15 sequential time windows were set sliding by 2.5 s after 60 s from the origin time. Only the amplitudes with high S/N (more than 2), of which the lapse time exceeded twice the S-wave arrival time, were used in this analysis. We selected 370 shallow and intermediate depth ($H < 90$km) earthquakes that occurred in the area around Japan from 1996 to 2010 with $4.0 < M < 7.4$ and made use of the amplitude data at the epicentral distance less than 200km. Consequently, we estimated the relative amplification factors for more than 540 sites.

Our results show that the amplification factors in low frequency bands (0.75-2Hz) are in good agreement with the thickness of sedimentary basins, and the regional contrasts tend to weaken in the high frequency bands. There were positive correlations among our results, the values of the station correction estimated from topographic data and those from observed seismic intensities except for the higher frequency bands than 10Hz.

3. Feasibility study of site correction

The filters for site correction [Hoshiba, 2012] are composed by the combination of some 1st order and 2nd order analogue filters, and the parameters of the filters are evaluated by the non-linear least-squares method to fit amplitude property to frequency-dependent site amplification factors. The digital recursive filters are designed by applying the bilinear transform and pre-warping to the analogue filters. While the filter described here is what is called 'convolution filter', which adds characteristic of the site effect to simulate the ground motions on the surface based on the seismograms observed in the ground, the deconvolution filter could be expressed by the reciprocal of the analogue filter. When we evaluate the filter parameters in this study, the site amplification factors in the frequency bands over 15Hz and under 0.75Hz are assumed to equal to those of both ends.

In this test, firstly, a deconvolution filter of each station is applied to each seismogram of an earthquake. Secondly, a common convolution filter is applied to all seismograms due to adding the common site effect. In order to confirm the effect of this correction, we compared the distributions of the seismic intensities before and after the correction. While there were some outliers before the correction, the number of the outliers tended to become small after the correction. These results show the amplification factors estimated in this study are useful for the site correction.

Keywords: Site amplification factor, Coda normalization method, Real-time processing, JMA seismic intensity station, Prediction of ground motion

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Construction of real-time earthquake damage-estimation system J-RISQ

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From the viewpoint of a decision making of the first action to an earthquake, not only the hazard (ground motion) information but also the risk (damage) information evaluated in real-time are important. To meet this need, we developed real-time estimation system (J-RISQ) for exposed population and earthquake damage of buildings. We constructed the system by combining the database developed for J-SHIS and the real-time observation data obtained by strong motion seismograph networks such as K-NET and KiK-net. Database of J-SHIS consists of the site amplification factor, population distribution and the building information (age and structure type) as well as the fragility curves.

To avoid an estimation error of the source location and magnitude, we use only observed seismic intensities as an input of the system. When an earthquake occurs, seismic intensities are calculated in each observation station and sent to the DMC (Data Management Center) in different timing. For rapid estimation, the system does not wait for the data from all the stations but begins the first calculation when the number of the stations observing the seismic intensity of 2.5 or larger exceeds the threshold amount. Estimations are updated several times using all the available data at the moment. Spatial distribution of seismic intensity in 250 m meshes is estimated by the site amplification factor and the observed data. By using this intensity distribution, the exposed population and the numbers of damaged buildings are estimated using population data and the building information, respectively. The results are visualized by WebGIS and can be grasped using an internet browser.

This system is experimentally operated since 2010 and has performed the estimations in real-time for more than 600 earthquakes by the end of 2012. For about 75 % of these earthquakes, it takes less than one minute to send the e-mail of first estimation after receiving data from the first station, and therefore, the rapidity of the system is satisfactory. Though the accuracy of the estimations of exposed population is relatively high, the accuracy of the damage estimations using the fragility curves has some uncertainty. It is important to investigate the effective way to provide and utilize such information, which is potentially useful for mitigating the seismic disasters of ongoing earthquakes in spite of the relatively large uncertainty.

Keywords: earthquake damage-estimation system, real-time earthquake information, earthquake early warning, J-RISQ, K-NET, KiK-net

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Development of new GEONET real-time processing system

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GNSS Earth Observation Network System (GEONET) consists of more than 1,200 continuous GNSS stations operated by Geospatial Information Authority of Japan. The GNSS data are transmitted to GEONET central analysis center in real-time. Advantage of GNSS real-time positioning is better performance in estimating moment magnitude of large earthquake than short-period seismometers. Blewitt and others (2006) demonstrated accurate moment magnitude could be determined within 15 minutes after the 2004 Sumatra earthquake by GPS real-time positioning and contribute to tsunami early warning. It has been suggested that GEONET should be exploited for early warning system especially after the 2011 off the Pacific coast of Tohoku Earthquake by a committee on disaster prevention.

The previous GEONET real-time processing system launched in 2002. However, it has not enough performance to monitor crustal deformations efficiently because of the limited size of analysis network, e.g. number of stations and baseline length should be shorter than 100 km. It was also the problem that the previous system could not detect permanent displacement automatically. The real-time displacements thus were not used instantaneously. Now GSI and Tohoku University are underway to develop new GEONET real-time analysis system to improve the problems described above since 2011.

The goal of the new system is to estimate permanent displacement field and moment magnitude of giant earthquakes and notify that information near real-time. The analysis strategy of the new system is completely different from the previous system. The prototype of the new system implements RTKLIB 2.4.1 (Takasu, 2011) for real-time GNSS positioning. The timing of the extraction of permanent displacements occur are determined automatically by 'RAPiD' (Ohta et al. 2012) or 'EEW' (Kamigaichi et al., 2009) provided by Japan Meteorological Agency. Fault source model inversions are carried out just after the detection of permanent displacements. The automatically derived displacements using RAPiD are cross-checked by comparing the displacements at adjacent stations, which was proved to be effective to reduce false detection of permanent displacements (Kobayashi et al. 2012). The estimated magnitudes are e-mailed to officials of GSI. The prototype has been operated monitoring 143 stations since April 6, 2012.

We present overview of the prototype including some issues to be improved and future plan of the new system to monitor all GEONET stations.

Keywords: GEONET, RTK-GPS, real-time