Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

SSS28-P01 Room:Poster Time:May 2 14:00-15:15

New-development of real-time seismic waveform viewing system feeding from DONET

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Jamstec-Ocean seismological database-Integrated byNetwork data (team JOIN) is started since 2012, with the purpose of developing an earthquake research information database through the integration of discrete database, such as real-time earthquake study and lithosphere structure research catalogue. JOIN is consist of three divisions, 1) seismological study using DONET (Dense Ocean-floor Network for Earthquake and Tsunamis) data, 2) sub-structural study for nankai-tonankai earthquake area, and 3) data-management and opent to public for oceanographic data acquired JAMSTEC equipment. These can lead not only scientific but practical outreach, consequently, disaster prevention of each local government.

We have developed web-based real-time monitoring system of strong motion and pressure sensor of DONET observatory network, this is user-friendly tool for servant service of disaster prevention department.

Trial operation with the monitoring system is undergoing for a few government close to nankai-tonankai area, aiming full-scale operation which will start from April 2014.

Technical summary of this system will be introduced.

Keywords: DONET, database, real-time trace view, outreach for local government

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SSS28-P02 Room:Poster Time:May 2 14:00-15:15

Examination of the relative site amplification factor of OBS and their real-time correction: examples of Sagami Bay OBS

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Hoshiba (2013, JGR) proposed a method for real-time prediction of ground motion based on real-time monitoring as the next-generation EEW, in which detection of hypocenter and Magnitude are not required. In this method, site amplification is one of the important factors. Therefore, relative site amplification factor have been evaluated at KiK-net (Iwakiri and Hoshiba, 2011) and at JMA seismic intensity stations (Aoki and Hoshiba, 2013) in the frequency domain. Ocean Bottom Seismograph (OBS) will provide valuable information to grasp ground motion propagation from ocean area. However, it is necessary to correct the site amplification factor of OBS for applying real-time monitoring method. Hayashimoto and Hoshiba (2013, SSJ) reported relative site amplification factor of OBSs at Tonankai region (Tonankai OBS (JMA) and DONET (JAMSTEC)) as a preliminary result. In this study, we evaluate relative site amplification factor of Sagami Bay OBS (NIED, Eguchi *et al*., 1998, MGR) which is close to land stations, and examine the effects of real-time correction to predict ground motion of land station from OBS.

The averaged spectral ratio of a station-pair from many events can be regarded as the relative site factor when the hypocentral distances to station-pair are much larger than the distance of those stations. In this study, we use the waveform data from the Sagami Bay OBSs and adjacent land stations (K-NET and KiK-net, NIED), and select the dataset with the hypocentral distance which is greater than 100km. We compare Fourier spectra from the waveforms of S-wave portion (20s) on OBSs with those on adjacent land stations as the relative site factors. In examples of the relative site factors of OBSs to KNGH23 (KiK-net borehole station), the amplification factor of the horizontal component is greater than that of the vertical component for frequencies 1-10Hz. We conclude that the site effects of OBSs characterized by such a low velocity sediment layers causes those amplification factors.

In order to examine the effect of frequency-dependent relative site amplification factor, we compare the accuracies of predicted seismic intensity using the spectral ratio with those using the average of seismic intensity (frequency-independent factor). We design the causal digital filter (Hoshiba, 2013, BSSA) having similar amplitude property to relative site factor for the station pair. The filter parameters are estimated and applied for both horizontal and vertical components. And we use the real-time processing of seismic intensity (Kunugi *et al*., 2008, Zisin 2) to estimate seismic intensity from observed and predicted waveforms. Both of the techniques are applicable in real-time. We consider the RMS of residual between observed and predicted seismic intensities as the accuracy of site correction of each station pair. In the case of prediction of seismic intensities from OBSs data to land stations, the average RMS of frequency-dependent method are smaller than that of frequency-independent method. Similar results are also obtained at pairs of land station. These results indicate that the frequency-dependent site factor is crucial factor to predict seismic intensity from OBS data, and also show that OBS can be used as front stations in the method for prediction of ground motion based on the real-time monitoring.

Acknowledgments: Strong motion acceleration waveform data were obtained from K-NET and KiK-net of NIED.

Keywords: Earthquake Early Warning, Ocean Bottom Seismograph, Real-time prediction of ground motion, Site amplification factor

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SSS28-P03 Room:Poster Time:May 2 14:00-15:15

Improvement of earthquake early warning system using the extrapolation of wavefield with apparent velocity and direction

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The present early warning system in Japan utilizes the epicenter information preliminary estimated by P-wave arrival times at stations near an event. The present system is still not effective in the following cases, for example, (a) more than one earthquakes occur nearly simultaneously, (b) a deep event whose wave front propagates in a different manner from shallow ones, particularly with very high apparent velocity on the surface, and (c) a large event (M>8) whose finite fault area cannot be neglected. In order to deal with non-circular wave front expansion of these cases, we propose a new approach based on the extrapolation of the early observed wave field alone without determining an epicenter. The idea is similar to the migration method of exploration seismology. The conventional migration method utilizes the wave field on a given wavefront (e.g., Kirchhoff integral migration). In the early warning system, on the other hand, we can obtain the speed and direction of wave field expansion over the surface. Based on the standard representation theorem with a Green's function, we extrapolate wave field outwards or in the future with not only the observed waveform but also its spatial derivative (normal for the wavefront). This enhances the resolution and reliability in the extrapolated wave field in comparison with the conventional approach with the waveform only.

For the extrapolation of wave fields accurately and reliably, we need a reliable Green function in each case. Since the actual wave propagation of P or S waves is very complex or sensitive to details of 3-D velocity structure between a source to each target point on the surface, we shall consider it in a two dimensional manner only focusing on the practical use of the early warning system, that is, a wavefront propagates on the surface with an apparent velocity of P-wave. These apparent velocities vary for events of various depths in different regions. The velocity of shallow events in Hokkaido is about 7.1km/s while that in Nagano prefecture of central Honshuu island is about 5.5km/s. The velocity strongly depends on focal depth: 7.1km/s for the depth of 10km, and 8.9km/s for the depth 100km. The velocity also varies as a function of epicentral distance, particularly for a deep event. We make a table of apparent velocities in different depths, regions and epicenters so that we can pick up an appropriate Green function (apparent velocity) for the wave field extrapolation when an event takes place. We also explain how to estimate the apparent velocity and propagation direction with several early observed wave forms. One key to apply the wavefield extrapolation in the warning system is the good correlation among the seismograms that are observed early as input data. Nevertheless, correlations are generally poor in high-frequency (about 1Hz) seismograms recorded in Japan such as Hi-net data. To enhance the correlation of P waveforms among adjacent stations, we need to correct the site response of each station promptly. Using both shallow and deep events, we first estimated site effect as a function of frequency for Hi-net stations in Hokkaido. We used a rock site station (ONPH) as a reference station for site correction terms for other stations.

For deep earthquakes, a region of anomalous seismic intensity is seen in the Pacific Ocean side of Japan called 'abnormal seismic intensity' , due to a subducting Pacific plate of high velocity and small attenuation. For the earthquake of 590 km deep beneath Vladivostok on 18 February 2010, we examined the direction of P waves propagating in Japan. The apparent velocity is highly anisotropic: fast along the islands but slow perpendicular to them. It is about 7.5km/s in the Souya district in the north of Hokkaido while about 13km/s in the Hidaka district in the south. In our extrapolation scheme, we can model the amplification of wavesin terms of abnormal seismic intensity.

Keywords: earthquake early warning system, extrapolation of seismic wave field, migration, apparent velocity, site effect, abnormal seismic intensity

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SSS28-P04 Room:Poster Time:May 2 14:00-15:15

Early forecasting of aftershocks from seismic energy release rate immediately after the mainshock

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The detection completeness of earthquakes just after a large earthquake becomes very poor because their signals are overlapped each other in seismogram records and are hidden by the large amplitude of coda waves. Currently, the JMA starts to serve the aftershock forecasting at least 24 hrs after the mainshock because long lapse times are necessary before the catalog data becomes available for the forecasting with a certain reliability. Recently, Sawazaki and Enescu (under review) succeeded in estimating temporal change in energy release rate for the mainshock and the early aftershock sequence by using the Hi-net continuous records. In their method, the energy release is not determined for each discrete event, but is estimated as a continuous process like a source time function which sums up energies from all the earthquakes occurring at the same time. Therefore, theoretically there are no missing energies in the energy release rate even just after the mainshock. The estimated energy release rate follows a power-law temporal decay like the modified Omori law from about 40 s after the mainshock, and the deviation of the energy release rate with respect to the temporal regression curve distributes according to a power-law like the Gutenberg-Richter law. Since the current aftershock forecasting is conducted based on these two statistical laws, the energy release rate would be available for the early forecasting of the aftershocks.

We examine the statistical characteristics of energy release rate in the frequency range of 8-16 Hz for three crustal earthquakes took place in Japan. From the energy release rate obtained at the first 1 hr, 3 hrs, and 6 hrs after the mainshock, we estimate the number of energy release rate larger than 10^8 J/s (about M_W4/s) occurring within 24 hrs after the mainshock. For the 2008 Iwate-Miyagi Nairiku earthquake, the ratios of the estimated/observed numbers are 24/35, 12/20, and 20/10 for the forecasting at 1 hr, 3 hrs, and 6 hrs after the mainshock, respectively. Likewise, the ratios are 1524/223, 231/99, and 113/50 for the 2004 Niigata Chuetsu earthquake, and 17/59, 8/59, and 30/21 for the 2007 Niigata Chuetsu-oki earthquake. For the Niigata Chuetsu earthquake, M_J5.9, M_J5.8, and M_J6.3 aftershocks occurred in the first 1 hr, while there are no aftershocks larger than M_J5.5 in the lapse times from 1 to 24 hrs. For the Niigata Chuetsu-oki earthquake, there are no aftershocks larger than M_J5 in the first 3 hrs, while M_J5.7 aftershock occurred 5.4 hrs after the mainshock. Such large aftershocks and their secondary aftershocks may change the pattern of aftershock activity, and causes the over- and under-estimations in the forecasting.

Keywords: aftershocks, early forecasting, energy release rate, modified Omori law, Gutenberg-Richter law

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A method to remove non-seismic long-period pulses for improved estimations of automatic centroid moment tensor solutions

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Non-seismic long-period pulse-like waveforms appear in broadband seismic records when P or S waves arrive (e.g., Delorey et al, Bull. Seism. Soc. Am., 2008). The pulse-like waveforms affect centroid moment tensor (CMT) solutions estimated from waveform inversion, but a method to remove those pulse-like waveforms yet to be established. Broadband seismograph networks were installed in the Philippine and Indonesia region to monitor earthquakes and tsunamis. The pulse-like waveforms appear in those network data frequently. Those data are used for automatic estimations of CMT solutions by SWIFT (Source estimates based on Waveform Inversion of Fourier Transformed seismograms), which was developed by Nakano et al. (Geophys.J.Int, 2008). SWIFT estimates both the CMT and moment function by the use of long-period (50-100 s) waveform data, but sometimes the long-period pulse-like waveforms affect SWIFT solutions. To monitor earthquakes and tsunamis, we have to estimate source parameters rapidly and adequately. In this study, we propose a simple and rapid method to remove long-period pulse-like waveforms from broadband seismic records.

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Japan Meteorological Agency information on long-period ground motion

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An earthquake generates seismic waves with various periods, and earthquakes with larger magnitudes generate stronger long-period ground motions. When the natural period of a high-rise building is close to the predominant period of ground motion, resonance happens and the building is severely shaken longer than surface of the Earth. Today, more and more people spend time in high-rise buildings especially in metropolitan areas. If great earthquake occurs, many people in high-rise buildings will be affected by long-period ground motion.

To notify people of such situations and facilitate effective countermeasures, JMA started to provide information on long-period ground motion from March 28th, 2013. Based on questionnaires to tenants of high-rise buildings, it has become clear that difficulty of people's activities depends on the velocity of floor movement, and we classified the intensity of long-period ground motion into four on the basis of velocity. To get the classification, we use wave forms observed by JMA seismic intensity meters on the surface of the Earth which are automatically sent to the JMA system. To estimate shaking at higher floors from wave forms on the surface of the Earth, we simulate the shaking of buildings by absolute velocity response spectrum of the period between 1.5 and 8.0 seconds which causes a significant resonance of buildings with 45 meters or higher. The information is available on the JMA website, with various kinds of contents such as absolute velocity and acceleration response spectrum.

Keywords: long-period ground motion, strong motion

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Prediction of long-period ground motion intensity for earthquake early warning

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The 2011 Mw 9.1 Tohoku-oki earthquake caused strong shakings of high rise buildings constructed on deep sedimentary basins in Japan. During the earthquake, many people got into difficulty with their movements inside the high rise buildings even on the Osaka basin located at distances as far as about 750 km from the epicentral area. Japan Meteorological Agency (JMA) has started to provide people with information on intensity of long-period ground motions based on the absolute velocity response spectra (1.6 to 7.8 s) of the observed records on the grounds (Aizawa et al., 2013). The intensity scale of long-period ground motions is classified into four: 1, 2, 3, and 4 having spectral values of 5 to 15 cm/s, 15 to 50 cm/s, 50 to 100 cm/s, and more than 100 cm/s, respectively. The spectra were computed at natural periods of 1.6 to 7.8 s using 5% of critical damping. The maximum value of the computed spectra among 1.6 to 7.8 s defines the class of intensity. We have recently constructed empirical prediction equations of absolute velocity response spectra in the period range of 1 to 10s aiming for earthquake early warning application (e.g., Dhakal et al., 2013). The equations use JMA displacement magnitude and hypocentral distance as basic parameters. Earthquakes having JMA magnitude 6.3 or larger and focal depths shallower than 50 km were used. One of the difficulties in empirical prediction of long-period ground motions is to effectively include the effects of local geological structure such as 3-D basin effects in the prediction equations. To simplify this problem, we obtained site correction factors at K-NET and KiK-net strong motion sites as the mean value of the logarithmic residuals. To make predictions possible at sites other than the strong motion observation sites, we derived correction coefficients based on the relationships between the average residuals and depths of deep sedimentary layers, which are available for whole Japan at Japan Seismic Hazard Information Station (J-SHIS). We found that the standard deviations are minimized by corrections using the depth of layer having Vs value of 1.4 km/s.

To define intensity at a site, we obtained the maximum value of the predicted spectra among T=1.6 to 7.8 s using the empirical prediction equations explained above. However, we found that the maximum predicted values were somewhat biased against the observed maximum values. Therefore, we applied an additional correction factor to the maximum predicted values to finally obtain the intensities. When a prediction equation was constructed using the maximum value of the observed spectra as the independent parameter, the additional correction factor was eliminated as the resulting residuals were normally distributed; also, the predicted intensities were almost identical to those obtained based on the regression analysis results for each natural period. In this study, we illustrate and discuss the application of empirical prediction equations for the prediction of JMA intensity of long-period ground motions for earthquake early warning application.

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Keywords: Long-period ground motion intensity, Earthquake early warning, Absolute velocity response spectra, Attenuation relations

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Regional Earthquake Early Warning Applications in Marmara Region Based on KOERI Seismic Network

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KOERI (Kandilli Observatory and Earthquake Research Institute) operates a seismic network in Marmara Sea region (NW Turkey) consisting of 40 broadband and 30 strong motion inland and OBS stations which has a good topology for regional EEW studies. Data transmission between the remote stations and the base station at KOERI is provided both with satellite and fiber optic cable systems. The continuous on-line data from these stations is used to provide real time warning for emerging potentially disastrous earthquakes.

The Virtual Seismologist in SeisComP3 and the PRESTo regional EEW (earthquake early warning) softwares are the two regional EEW algorithms that have been recently setup at KOERI data center to generate the EEW sygnal. Onsite EEW application are underway for more than a decade.

The early warning sygnal is communicated to the appropriate servo shut-down systems of the receipent facilities, that automatically decide proper action based on the alarm level. Istanbul Gas Distribution Corporation (IGDAS) is one of the end users of the EEW signal. IGDAS, the primary natural gas provider in Istanbul, operates an extensive system 9,867 km of gas lines with 550 district regulators and 474,000 service boxes. State of-the-art protection systems automatically cut natural gas flow when breaks in the pipelines are detected. IGDAS uses a sophisticated SCADA (supervisory control and data acquisition) system to monitor the state-of-health of its pipeline network. This system provides real-time information about quantities related to pipeline monitoring, including input-output pressure, drawing information, positions of station and RTU (remote terminal unit) gates, slum shut mechanism status at 581 district regulator sites. The SCADA system of IGDAS receives the EEW signal from KOERI and decide the proper actions according to the previously specified ground acceleration levels. Presently, KOERI sends EEW signal to the SCADA system of IGDAS Natural Gas Network of Istanbul.

The EEW signal of KOERI is also transmitted to the serve shut down system of the Marmaray Rail Tube Tunnel and Commuter Rail Mass Transit System in Istanbul. The Marmaray system includes an undersea railway tunnel under the Bosphorus Strait. Several strong motion instruments are installed within the tunnel for taking measures against strong ground shaking and early warning purposes. This system is integrated with the KOERI EEW System. KOERI sends the EEW signal to the command center of Marmaray. Having received the signal, the command center put into action the previously defined measures. For example, the trains within the tunnel will be stopped at the nearest station, no access to the tunnel will be allowed to the trains approaching the tunnel, water protective caps will be closed to protect flood closing the connection between the onshore and offshore tunnels.

Keywords: EEW sygnal, Virtual Seismologist, PRESTo, end users, IGDAS, Marmaray