Japan Geoscience Union Meeting 2012
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SSS40-01 Room:106 Time:May 21 15:30-15:45

Earthquake Early Warning of JMA - The 2011 off the Pacific coast of Tohoku Earthquake and its aftershocks -

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Japan Meteorological Agency (JMA) started to provide EEW to a limited number of users from August 2006 and to the public through TV and radio in October 2007. The Meteorological Service Act amended in December 2007 defined legally JMA EEW as ”forecast” and ”warning” of strong ground motions caused by an earthquake. ”Warning” is issued when Seismic intensity of 5 or larger (on JMA scale) is expected.

The 2011 off the Pacific coast of Tohoku earthquake (Mw9.0) occurred of Match 11, 2011, caused strong ground motion around northeastern Japan. Before the strong ground motion hit cities, JMA issued EEW announcements to the general public of the Tohoku district. After the mainshock, JMA issued 96 warnings and 3751 forecasts from the mainshock to December 2011 (10 months) for its quite active aftershocks and induced earthquakes. (Note that, from October, 2007 to March, 2011 (41 months), JMA issued 17 warnings and 1928 forecasts).

On the other hand, some inaccurate ”warnings” were issued after the mainshock. From March to December 2011, JMA issued 27 ”false-alarms”, caused by the active seismicity, in which seismic intensity did not exceed 3 everywhere in observation even when seismic intensity 5 lower (or larger) was expected.

The reason of the false-alarms is that multiple earthquakes sometimes occurred simultaneously over the wide source region during the period, the system became confused, and did not always determine the location and magnitude correctly,

In this presentation, we will present evaluation of the performance of EEW issuance, lessons learned from the earthquakes and various efforts and direction to improve EEW of JMA.

Keywords: Earthquake Early Warning, Warning event, The 2011 off the Pacific coast of Tohoku Earthquake

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SSS40-02 Room:106 Time:May 21 15:45-16:00

Prediction of ground motion using real time monitoring -for real time ground motion prediction -

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Earthquake Early Warning (EEW) aims at mitigation an earthquake disaster by giving people enough time to take appropriate safety measures in advance of strong ground shaking. EEW system of the Japan Meteorological Agency(JMA) determines quickly the hypocenter and magnitude (M) of the earthquake, and then predicts seismic intensity using empirical attenuation relation and site amplification factors. During the 2011 off the Pacific Coast of Tohoku Earthquake, the JMA EEW was issued to the Tohoku district as expected, but it was not issued to Kanto district because of the underestimation of seismic intensity. The underestimation can be attributed due to the large extent of the later fault rupture. For several weeks after the mainshock, when earthquakes sometimes occurred simultaneously over the wide source region, the system became confused, and did not always determine the location and magnitude correctly, which leaded to some false alarms.

To solve above problems, Hoshiba(2011) proposed a method for expectation of ground motion based on Kirchhoff Fresnel integral method, in which hypocenter and M are not required. In this method, real time monitoring and estimation of wavefield and propagation direction of the waves are important. The Green function is required beforehand.

In real applications for prediction of ground motion, site amplification factors are important. Though the site amplification factors are scalar values for current JMA EEW system, Iwakiri and Hoshiba(2011) concluded that the preciseness will be improved by 20% when frequency dependency is introduced into the site amplification correction. When the correction can be applied in real time manner, it become possible to synthesize the waveform by combining the application of the Kirchhoff Fresnel integral method, which leads us to real time ground motion prediction.

For ground motion prediction for scenario earthquakes, source parameters such as the location of initial rupture and asperities are assumed and then waveforms are synthesized from the information. For real time ground motion prediction, waveforms are observed in real time manner and then predict based on the information. The real time ground motion prediction is expected to apply to the Earthquake Early Warning.

Keywords: Earthquake Early Warning, Real time, Monitoring, Ground motion prediction

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SSS40-03 Room:106 Time:May 21 16:00-16:15

Real-time fault area location of a massive scale earthquake-Wenchuan Earthquake-

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1. Introduction It's difficult to estimate accurate tsunami heights at a time of a massive earthquake occurrence, since obtained magnitude by Japan meteorological agency are always less than the moment magnitude due to the problem of so-called Magnitude saturation. The Earthquake early warning uses a model of a point source to calculate seismic intensity, causing estimated intensities less than actual ones. Using data of real-time seismic intensity of every one seconds, Horiuchi et al. (2011) developed a method to determine time-and space distribution of fault area of the 2011 Off the Pacific coast of Tohoku Earthquake, and pointed out that these issues can be solved.

In 2008, a massive earthquake of M7.9 with a 280km fault length jolted Wenchuan County of Southwest China's Sichuan province. An estimated number of 80,000 people were found dead or missing in this catastrophic disaster. The length of the fault was so long that beyond the faulting, the destructive shake started 10 seconds after the initiation of the faulting. The development of the real-time location of fault area distribution will help people to effectively escape from the disaster in time, and it would also lighten the predicted damage. The report applied the Horiuchi etc. method to the Sichuan Wenchuan earthquake. An improvement to this method was made to make sure that it would be applicable in China.

2. Real-time location of fault area distribution Shi and Midorikawa(1999), Matsuzaki et al.(2006), showed that the seismic intensity is represented by the function of shortest distance from the seismic fault and determined empirical formulas. Shaking intensity by the empirical attenuation relation is put as,

$$S = S(M,D,H,C) \qquad (1)$$

where, D, H, and C are magnitude, fault distance, depth and site amplification. Assuming S of eq. (1) to be measured seismic intensity of every one seconds, time function of fault distance is

$$D(t) = D(S(t),M,H,C) \qquad (2)$$

Present study, similar with that of Horiuchi et al., determines real-time distribution of fault area by using equation (2) and projecting them onto the line connecting the epicenter and the observation point. We projected them only when calculated seismic intensities by the empirical attention are larger than the observed intensity.

3. Result Obtained direction of the fault is consistent with the result of the aftershock distribution or the results of waveform inversion when using the Shi and Midorikawa (1999)'s empirical equation, but the length of the fault was approximately doubled. The reason is caused by the data of large seismic intensities in a region 200km-500km northeast from the northeastern edge of the fault. There, empirical attenuation relation was changed for Chinese Mainland and was re-calculated. The source region of the results obtained the present study is in good agreement with the results estimated by data of aftershock distribution.

Since the present method is simple and can estimate nearly correct real-time distribution of fault, it can be used for an EEW system in China, which can provide information to eventually mitigate earthquake disaster at a time of a massive scale earthquake.

Keywords: Massive earthquake, Fault area, Real-time estimation, Fault, Seismic intensity, Empirical attenuation relation

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SSS40-04 Room:106 Time:May 21 16:15-16:30

Classification of Simultaneous Multiple Earthquakes for the Earthquake Early Warning System

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The 2011 off the Pacific Coast of Tohoku Earthquake (Mw9.0) caused significant damage over a large area of northeastern Honshu. An earthquake early warning was issued to the public in the Tohoku region about 8 seconds after the first P-arrival, which is 31 seconds after the origin time. There was no blind zone, and warnings were received at all locations before S-wave arrivals, since the earthquake was fairly far offshore.

Over 70 early warnings for strong shaking were also broadcast during larger aftershocks. In general, the system worked well for these smaller events, but there were significant errors caused by event mislocations. Immediately following the earthquake, the waveforms of some large aftershocks were contaminated by long-period surface waves from the mainshock, which made it difficult to identify P-wave arrivals. Also, correctly distinguishing and locating later aftershocks was sometimes difficult, when multiple events occurred within a short period of time.

In this presentation, we propose a new approach to classify simultaneous multiple earthquakes in the current JMA system framework. We introduce a Particle Filter approach, also known as sequential Monte Carlo method, to estimate the most probable event parameter values, which include location, magnitude, and origin time. This approach provides a probabilistic solution to the problem of classifying multiple events. We formulate the likelihood function using the attenuation relationship in the current JMA system, and test the aftershock data of 2011 Tohoku earthquake. The results show that this approach can correctly classify multiple events occurred around the same time in several case studies.

Keywords: Earthquake Early Warning

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SSS40-05 Room:106 Time:May 21 16:30-16:45

GRiD MT with W-phase monitoring system for tsunami early warnin

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The GRiD MT system (Tsuruoka et al., PEPI, 2009) is the real-time monitoring analysis system that continuously monitors long-period seismic wave field at a period of 20-50s recorded by broad-band seismometers. This analysis system automatically and simultaneously determines the origin time, location and moment tensor of seismic events within 3 min of their occurrence without earthquake information such as QED etc. This system has been in operation since April 2003 at the Earthquake Research Institute.

For tsunami early warning purposes, we have implemented a W-phase source inversion algorithm (Kanamori and Rivera, GJI, 2008) into the GRiD MT system (we call this system GRiD MT with W-phase monitoring system) using SeedLink software developed by GEOFON and later adopted by IRIS. W-phase is a very long-period (typically 200-1000s) phase starting after the P-wave arrival, and is suitable for fast source parameter determination for large (Mw>=7) earthquakes. When broad-band seismograms are available at distances (<=30 deg), we can detect seismic events and determine satisfactory mechanism solutions within 15 min after the earthquake occurrence.

We compared GRiD MT with W-phase monitoring results with W-phase source inversion results for events (Mw>=7) occurred from 2005 to 2011 in the World. From the results, (1) this system detects earthquakes and determines the source parameters with a high level of precision and complete automation within 15 min of the earthquake occurrence. (2) The origin time and locations are similar to those of PDE catalogue or GCMT catalogue. (3) The focal mechanism and moment magnitude obtained by two systems are very similar. The preliminary results suggest that this system provides rapid and reliable source parameters useful for tsunami warning purposes.

Keywords: realtime, earthquake analysis system, W-phase, Tsunami

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SSS40-06 Room:106 Time:May 21 16:45-17:00

Improvement of MT/CMT analyses in the AQUA (Accurate and QUick Analysis System for Source Parameters) system

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Quick determination of hypocentral parameters and its transmission to the public are very valuable in the viewoint of disaster mitigation. We have operated an automatic system called the Accurate and QUick Analysis System for Source Parameters (AQUA system) since 2005 (Matsumura et al., 2006). In this system, the moment tensor (MT) and centroind moment tensor (CMT) solutions have been automatically estimated after determination of an initial hypocenter. However, after the 2011 Off the Pacific coast of Tohoku Earthquake, several limitations have been recognized. So, we improved the AQUA system to solve these problems.

The AQUA system could not determine the MT/CMT solutions of the 2011 Off the Pacific coast of Tohoku Earthquake. This is because NIED F-net broadband seismometers were saturated due to large amplitude excited from this earthquake. Furthremore, size of the initial hypocenter was underestimated at the initial stage of rupture process due to short processing time. On the other hand, numerous aftershocks occurred around the outer rise far from the inland seismographic network. Their initial hypocentral depths have large uncertainties and their MT/CMT solutions were not determined accurately.

To solve these problems, we used records from NIED F-net velocity type strong motion seismograph. These types of seismographs provide unsaturated records not only for the mainshock, but also for M>7 earthquakes at closer stations. In the AQUA system, proper parameters are selected according to event size and MT/CMT analyses are repeated at larger stage when larger size is estimated at some stage. We increased maximum number of this repetition of analysis from 1 to 10. We modified parameters such as search range of centroid time, to analyze M9-class earthquake accurately. We used 0.005-0.02 Hz records for M>8 earthquakes, in contrast to 0.01-0.05 Hz records in the original system. We broadened search range of centroid depth for earthquakes far from the seismographic network to process aftershocks around the outer rise.

After above improvement, we re-analyzed the mainshock with the M5-class initial hypocenter and obtained result with moment magnitude Mw of 8.6 after repetition of analyses at each stage. We also re-analyzed M>7 aftershocks. Comparing these results with GlobalCMT (Global CMT Web Page), focal mechanisms, sizes, and centroid depths show good coincidence. Sizes are consistent with those of GlobalCMT within Mw difference of 0.1 except the mainshock. However, difference is large for the mainshock compared to Mw9.1 of GlobalCMT. This might be because a passband of analysis is not adequate for an M9-class earthquake. So, we used 0.0025-0.01 Hz records and obtained result of Mw8.9. This result shows good coincidence with GlobalCMT (Mw9.1) and other results (e.g., Ozawa et al., 2011; Suzuki et al., 2011; Mw9.0). Further improvement is necessary to shorten analyzing time.

Keywords: Centroid moment tensor, Earthquake Early Warning, the 2011 Off the Pacific coast of Tohoku earthquake, outer rise earthquake

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SSS40-P01 Room:Convention Hall Time:May 21 13:45-15:15

Estimation of extended source area during a great earthquake for upgrading the EEW system

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1. Introduction

The seismic intensities predicted by the Earthquake Early Waning are possibly underestimated in comparison with the observed one for great earthquakes. It is caused to the fact that the attenuation-distance relationships of PGV and PGA for such earthquakes are well expressed as a function of not epicentral distance but shortest distance from site to source fault. So far, we have found that the attenuation-distance relationships of both horizontal and vertical PGAs tend to have some saturation near the source faults during large inland earthquakes. We have also found that the time of the saturation of the vertical PGA is generally earlier than that of the horizontal PGA. Based on the above results, we can provide the information about the rupture extension before the arrival of the main motions for large inland earthquake (Kurahashi et al., 2010).

The 11 March 2011 giant earthquake with Mw 9.0 occurred off the Pacific coast of Tohoku, and is one of the historically largest subduction earthquakes in or near Japan. We examined the saturation of the vertical PGAs near the source area of this earthquake. In this study, we try to check the applicability of our methodology to the EEW information for great subduction earthquakes.

2. Procedure

The procedure to calculate seismic intensity using our methodology for great subduction earthquakes is shown as follows.

1: The extent of the source fault is assumed from the distribution of stations where vertical PGAs of more than 200gal are observed. 2: The vertical PGA at each site outside the source extent is calculated using the empirical attenuation-distance relationship of the vertical PGAs and shortest distance from each site to the source fault. 3: The seismic intensity at each site is predicted using the empirical relationship between vertical PGA and seismic intensity.

3. Check the applicability of our methodology

First, we compare source extent estimated from saturation of the vertical PGAs with rupture area from inverted source model. In this study, source area is defined as follows. The source length is diameter of the extent of the observation points where PGA exceeds 200 gal. The source width is assumed as half of the source length. We confirmed that the source area above estimated approximately coincides with the rupture area from the scaling relation of rupture area vs. seismic moment for subduction earthquake by Murotani et al. (2010).

Next, we examined attenuation relationship of the vertical PGAs. The decay of the PGA with distance beyond the saturation extent has almost same tendency independent of seismic magnitude. In this study, the attenuation relationship distance used Nishimura and Horike (2003). Vertical PGAs at target sides outside the source extent are calculated from the attenuation distance relationships.

4. Result and Conclusion

The predicted seismic intensity map obtained from vertical PGAs of Tohoku earthquake is shown in Fig 1. The predicted seismic intensity agrees well with to observed seismic intensity.

We found that vertical PGAs at stations near the source fault of the Tohoku earthquake have some saturation, although the saturation levels are changeable due to site effects. The extent of the source fault is assumed from the distribution of stations where vertical PGAs of more than 200gal are observed. The seismic intensity at each site is predicted using the empirical attenuation-distance relation of vertical PGA and shortest distance to the source fault. This methodology is available as one of updating EEW system.

Keywords: The Earthquake Early Warning, great earthquake

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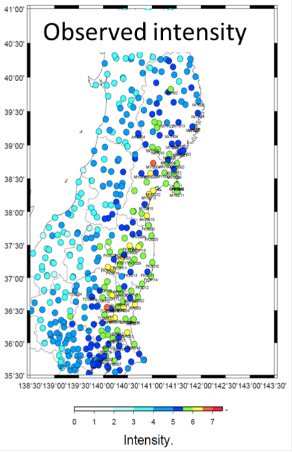

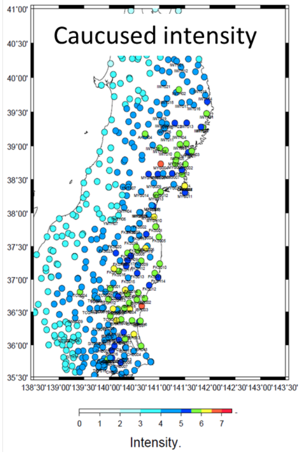

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SSS40-P02 Room:Convention Hall Time:May 21 13:45-15:15

A detection method for large earthquake based on counting a number of seismic intensity observation stations

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An Earthquake Early Warning (EEW) was issued for central Miyagi Prefecture and surrounding areas 8.6 seconds after the 2011 Tohoku Earthquake was detected. The warning times before a seismic intensity corresponding to 5-lower, that was observed at K-NET and KiK-net stations, are about 15 seconds for Miyagi Prefecture, more than 20 seconds for Iwate and Fukushima Prefecture and more than one minute for Ibaraki and Tochigi Prefecture. The EEW played a role in providing information in terms of early warning. On the other hands, a seismic intensity of 5-lower or greater was observed over a wide area from Nakano Prefecture to Aomori Prefecture, so it is clear that the EEW system underestimated the seismic intensity. In addition, the first Tsunami Warning that was issued three minutes after the earthquake occurred also underestimated the height of the actual tsunami. The common factor in these underestimations is mainly the underestimation of the earthquake's size. Therefore in this study, we have developed a detection method for large earthquake based on counting a number of seismic intensity observation stations. The advantage of this method is that it is not always necessary to have information regarding the earthquake source. The method we have developed, counting a number of the seismic intensity observation stations, is a relatively simple method. But we found out that it is effective for detection of large earthquakes that are inland or offshore close to land (fig.1). In addition, when used in combination with the real-time calculation method by Kunugi et al. (2008), there is the benefit of making the real-time processing easier.

Keywords: seismic intensity, earthquake early warning, K-NET, 2011 Tohoku Earthquake

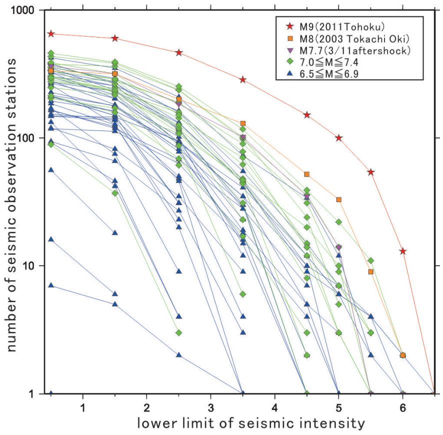

fig.1

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SSS40-P03 Room:Convention Hall Time:May 21 13:45-15:15

Is it possible to be early magnitude estimation of the 2011 Tohoku earthquake from tau_c by increased time window?

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Introduction

The tau_c method has been proposed as one of the algorithms for Earthquake Early Warning system for rapid estimation of eventual M (e.g., Wu and Kanamori, 2005). This method is based on the scaling law that large earthquakes are expected to be relatively richer in low-frequency than small earthquakes. The tau_c, average frequency of the seismic waveform, is calculated from the initial 3 s of the seismic waveform at the stations close to the epicenter, which is used to estimate the eventual M from the empirical tau_c-M relation. Applying the tau_c method to the 2011 Tohoku earthquake (Mw9.0), it would be difficult to estimate that the Mw9.0 event would be larger than the Mw7.3 event (Hoshiba and Iwakiri, 2011).

Is it possible to estimate appropriately M of the huge earthquake from tau_c if we use long time windows or the stations far from the epicenter? Even if as long as 30 s is used for window, or the stations far from the epicenter are analyzed, it would be available in terms of rapidity of the tsunami forecast. Zollo et al., (2011) showed that the M of the 2011 Tohoku earthquake was estimated to be more than 8.5 from tau_c method by using initial 30 s of the P-wave portion at the stations far from the epicenter. This suggests that the tau_c method has possibility of rapid estimate of M of the huge earthquake, even though its inherent rapidity of M estimation would be lost.

In this study, we investigate the possibility of rapid M estimation of the 2011 Tohoku earthquake from tau_c method by increasing time window length and/or by using the stations far from the epicenter.

Data and analysis

The earthquakes used in this analysis were 22 events occurred from January 2000 to December 2011 in and around Japan, in which we analyzed events of Mj>=6.8 and focal-depth<=20km for inland area and Mj>=7.0 and focal-depth<=80km for offshore area. We used the vertical-component accelerograms of the earthquakes recorded at the K-NET and KiK-net (surface). The tau_c is obtained from the ratio of square sum of displacement amplitude to square sum of velocity amplitude in time domain. The accelerogram was integrated and passed through a high-pass filter of 0.075 Hz to obtain the displacement and the velocity waveform. The time windows were used initial 3, 6, 9, 12, 15, 18, 21, 24 and 30 s of P-wave portion. The tau_c of event was the geometric average of more than five stations in the range of 50 km interval of epicentral distance.

Result and Discussion

First, we investigated the dependences of tau_c on time window length and distance. The tau_c tends to increase with increasing time window length, and also with increasing distance. It suggests that tau_c-M relation varies according to time window length and distance. Estimation of tau_c is scattered among the same M.

Based on the tau_c-M relation obtained from 3 s window and stations close to epicenter in previous study, tau_c of the 2011 Tohoku earthquake corresponds to about M8.5 in case that we use 30 s window and stations of the range from 300 km to 350 km. This might be consistent with the result of Zollo et al. (2011) mentioned above in Introduction.

However, when the dependences of tau_c on the time window length and the distance is taken into account, M of the earthquake from tau_c is estimated to be no more than M8, which is against the result of Zollo et al. (2011). The same tendency is obtained when 0.03 Hz or 0.02 Hz high-pass filter and 180 s window are used. This suggests that it would be difficult to recognize obviously that the 2011 Tohoku earthquake would be larger than the M8 event using tau_c, even if the long time window length and the stations far from the epicenter are used. Because the waveforms of the 2011 Tohoku earthquake contained strong high-frequency contents, especially for more than 10 Hz (Iwakiri and Hoshiba, 2011), which deviated considerably from the empirical tau_c-M relation, the M of the 2011 Tohoku earthquake was underestimated in tau_c method.

Keywords: tau_c, the 2011 off the Pacific coast of Tohoku Earthquake

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Examination of a simple method to estimate earthquake magnitude by using the timing of maximum amplitude

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1. Introduction

Earthquake magnitude (M) is significant information, because it is a fundamental parameter for an earthquake early warning, a tsunami warning, a rapid estimation of the disaster damages, and so on. In general, M is determined by short-period amplitude (e.g. Mj). However, it is well-known that M determined by its way is saturated particularly in case of the extremely large events. Mw is often used to determine the large magnitude accurately, however, the long-period records (several tens or hundreds seconds) are necessary for the estimation of Mw. Therefore, it is difficult to determine Mw quickly and easily.

In order to solve this problem, Noda et al. (2011, SSJ fall meeting) proposed a new method which used the lengths of time from the arrival of initial motion (direct P or S) to the timing of the maximum amplitude. They indicated that the estimation accuracy was relatively high in case of using the high frequency (several Hz or more) acceleration data observed at K-NET stations. However, the examination of the method was not enough, because the data of extremely large events were insufficient. On the other hand, it is conceivable from Hara (2007) and Lomax & Michelini (2009) that the data for the near part of direct P-wave of which teleseismic velocity record is filtered for high frequency band (around 1Hz or more) is almost equivalent to the time series of the energy directly radiated from the source. In this study, we conduct the additional examination of the method suggested by Noda et al. (2011) by using the teleseismic data of large earthquakes.

2. Data and Method

We retrieved BHZ channel waveform data recorded by 13 events (Mw7.6 - 9.3) from IRIS DMC. The range of epicentral distance is between 30 and 85 degrees. The events are chosen so as to have no bias in the occurrence region and the type of earthquake.

At first, we manually picked the arrival times of the direct P-wave. Mean of number of the picked data for every event is approximately 42. Next, by following Hara (2007), the retrieved teleseismic velocity data were band-passed for 2-4 Hz. We calculated the lengths of time (T_{maxA}) from the P-arrivals to the timings when the absolute values of the amplitude grow to the maximum. We set the upper limit of the calculation 1.1*log(*tau*). Where, *tau* represents rupture duration indicated by Kanamori & Brodsky (2004).

3. Result and Discussion

At first, we investigate the dependency of T_{maxA} on epicentral distance. As a result, it is found that T_{maxA} is almost independent on distance. This result corresponds to the one shown in Hara (2007). Therefore, the correction by distance is not carried out in the analysis described below.

Next, we calculate the logarithmic mean of T_{maxA} every event, and then compare its mean with the result indicated by Noda et al. (2011). Consequently, it is found out that the result in this study almost corresponds with the one by Noda et al. Thus, it is confirmed that the method proposed by Noda et al. is possible to estimate Mw appropriately even in the case of extremely large earthquakes.

It is concluded that the proposed method is practical enough to determine Mw quickly and simply by using the filter whose high frequency characteristics, regardless of seismogram type (regional or teleseismic; velocity or acceleration). However, it is preferred to use many records which have a proper azimuthal coverage, because T_{maxA} have a certain amount of variance depending on the influence of crustal structure, directivity, relationship of the locations between hypocenter and asperity, and so on. Furthermore, it may be required that the combination of T_{maxA} and intensity of amplitude is used to estimate M (Hara, 2007) especially in middle or small event, because the influence of error of the arrival time is relatively large.

4. Acknowledgement

We would like to thank IRIS DMC for using the waveform records.

Keywords: earthquake early warning, tsunami warning, real-time seismology, magnitude, moment magnitude

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Real-Time Mw Estimation Strategy Using Nationwide Strain Meter Observation Network Data

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The 2011 Tohoku earthquake tsunami killed a lot of residents. One of the reasons why the number of victims was increased seemed to be due to the underestimation of tsunami height by JMA tsunami warning. JMA could not capture size of the Tohoku earthquake at earthquake early warning. This huge disaster suggests that proper estimation of magnitude (M) in the real time is essentially important for tsunami disaster reduction. This study proposes a strategy to estimate Mw in the real time using the nationwide strain observation network data.

Strain represents physical value directly, and the strain meter can measure static and dynamic strain due to fault motion. Strain sensor does not require instrumental response and correction operation and has no mechanical saturation. So it is expected that the real-time Mw estimation using strain data is more effective than that using GPS or broadband seismographs.

We consider following strategies from real-time strain observation data ; 1) The estimating Mw from fault length L using the scaling law (Wells et al., 1996, F.O.Strasser et al., 2010). Spatial distribution of static strain changes may provide rupture spreading in real time. 2) Estimating Mw from source time duration Tau (e.g. Kasahara and Sasatani, 1986) and fault length L derived from real-time epoch-to-epoch principal strain analysis proposed by Okubo (2005). This method can provide information of location and absolute value of moment releasing due to earthquake faulting. Real-time tracking of above trajectory give fault length L and duration time Tau. Mw estimation will be done using scaling relation between Mw and L and Tau. Real-time live broadcasting of Mw growth using above strategies gives conclusive information for near-field tsunami warning with quantitative criterion. Nationwide real-time crustal deformation data exchange system can provide practical facility to be doing this experimental study.

In this study, we target the earthquake which generates huge tsunami every 500 years along the Pacific coast of Hokkaido (Hirakawa, 2000). We are making inspection about usefulness and problems of these proposed techniques using the real observed strain record of 2003 Tokachi-oki earthquake.

Keywords: strain, real-time

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SSS40-P06 Room:Convention Hall Time:May 21 13:45-15:15

Examination of magnitude correction for utilizing ocean bottom seismographs of DONET in EEW

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In ocean areas, the utilization of the ocean bottom seismographs is effective for the rapid detection of the occurrence of an earthquake and also for Earthquake Early Warning (EEW). However, careful handling of these data is required because the installation environment of ocean bottom seismographs may be different from that of land stations. In this study, we examined magnitude correction to utilize the ocean bottom seismographs of DONET for EEW.

In the EEW of JMA, the magnitude is estimated from the maximum amplitude of three dimensional vector summation of the displacement (Kamigaichi (2003)). The magnitude of EEW is determined using two relations: P-wave magnitude and S-wave magnitude (Aketagawa *et al*. (2010), Kiyomoto *et al*. (2010)), whose formulas are as follows:

P-wave M_{eew} = (logA + 1.2*logR + 0.0005*R - 0.005*D + 0.46) / 0.72

S-wave M_{eew} = logA + log(Delta) + 0.0011*(Delta) + 0.0007*D + 1.8

Where A is the maximum amplitude measured in 10 micro-meter units, R is the hypocentral distance in km, Delta is the epicentral distance in km, and D is the focal depth in km. To estimate the magnitude correction for DONET, we determined M_{eew} at DONET stations and compared it with M_j. Waveform data observed in April, 2011 or later were analyzed to determine magnitude, when the maximum amplitude of three dimensional vector summation of the displacement was larger than 50 micrometers. For comparison, M_{eew} of Tonankai ocean bottom seismographs and land stations near the DONET were also calculated. Earthquake catalog of the Japan Meteorological Agency was used as focal parameter.

As a result, we showed that S-wave M_{eew} of DONET was generally larger than M_j by about 0.6. And the differences of S-wave M_{eew} and M_j are independent of a size of Magnitude, epicentral distance, or back azimuth, which is also seen at Tonankai ocean bottom seismographs, as Hayashimoto *et al*. (2011) pointed out. We consider that difference of site-effects cause these differences. Furthermore, distribution of the differences of S-wave M_{eew} and M_j seems to have some regional dependence from trench to coastline. A slight change of the subsurface structure such as the sedimentary wedge (seen in Nakamanishi *et al*. (2002)) may causes these differences. In contrast, the clear differences between P-wave M_{eew} and M_j were not found.

Acknowledgment: We used DONET observation data operated by JAMSTEC.

Keywords: Earthquake Early Warning, OBS, DONET, Magnitude correction

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Orientations of DONET seismometers estimated from seismic waveforms

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DONET is a network of permanent ocean-bottom seismic stations aimed at improving the detection capability and earlier detection of earthquakes and tsunamis off the Kii Peninsula, where the Tonankai mega-thrust earthquake is anticipated to occur in the near future. Real-time DONET data is transferred to the Japan Meteorological Agency and the National Research Institute for Earthquake Prevention and Disaster Mitigation, and used for the earthquake early warning in Japan.

DONET consists of 20 stations each of which seismometers and pressure gauges are installed. At each station a broad-band seismometer and a strong-motion seismometer are installed. The orientation of the horizontal components of the seismometer at each station has been measured by using video of ROV, which is difficult to measure again for the confirmations.

We estimated the orientations of DONET seismometers by using the following methods: (1) correlation of long-period seismic waveforms with observations in land, (2) direction of P-wave first motion from distant earthquakes, and (3) particle motion of airgun signal. The methods (1) and (2) are based on the long-period signals from distant earthquakes, and we used data from broad-band seismometers. The method (3) is based on short-period signals, and we estimated the directions of both the broad-band seismometer and the strong-motion seismometer at each station.

The method (1) is the same as that used for the estimations of the orientations of Hi-net and KiK-net borehole seismometers by Shiomi et al. (2003). We estimated the direction of broad-band seismometers relative to the five F-net stations (ABU, KIS, KMT, NOK, and WTR) installed in the Kii Peninsula. We used data from earthquakes that occurred between May, 2010 and October, 2011, with magnitude larger than 7. We applied a Butterworth filter between 0.008 and 0.01 Hz for the waveforms. We estimated seismometer orientations based on the correlation of the waveforms between DONET and F-net on land.

The method (2) uses the particle motion of the direct P-wave from a distant earthquake. The signal from the direct P-wave appears in the vertical and radial components, both waveforms have positive correlation. We rotated the horizontal waveform components to find the direction that have the largest correlation with the vertical component. The waveforms are from earthquakes that occurred between January and November, 2011, with magnitude larger than 5.5 and the epicentral distance between 30 and 90 degrees.

The method (3) uses airgun signals from the seismic investigations carried out off the Kii Peninsula between September and October, 2011 (KR11-09). The acoustic wave in the water radiated from airgun is converted to seismic waves in the crust at the ocean bottom, and the signal appears in the vertical and radial components in the seismometer records. We fitted the horizontal particle motion with a line, and obtained the seismometer direction from the azimuth computed from the coordinates of the shot and station. The nature of the wave is similar to that used in the method (2), but the waveform may not be well correlated with the vertical motion because the airgun signal is dominated in the frequency components higher than several Hz.

The obtained results from the three methods are well consistent with each other with variations at maximum 5 degrees. The difference from the measurement of the ROV video is about 10 degrees for most stations, but in some stations the difference is about 50 degrees.

Keywords: Ocean-bottom seismometer, Nankai trough, seismic investigations

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An attempt to improve accuracy of a processing method of a real-time seismic intensity.

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We have improved accuracy of the processing method of the real-time seismic intensity proposed by Kunugi et. al (2008). Kunugi et. al (2008) proposed a real-time seismic intensity, whose concept is similarly to the JMA seismic intensity (Ijma) defined by Japan Meteorological Agency. With the increasing requirements of earthquake early warning (EEW) system, it is much more obviously that Ijma 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, the real-time seismic intensity, is defined by using an approximating filter in time domain instead of the original filter in frequency domain. For a small computing system like a strong-motion seismograph, it is easy to process the real-time intensity because the filter has only five stages (it consists of four first-order filters and a second-order filter). In this presentation, we present an attempt to improve accuracy of a processing method of a real-time seismic intensity employing a new filter having more stages.

Keywords: real-time seismic intensity, seismic intensity, instrumental seismic intensity, strong motion, strong-motion seismograph, earthquake early warning