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Disaster research in the Toyama Earthquake(1718)

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1,Introduction

Of the destructive earthquakes recorded in Japan over the past approx.1600 years, the only one that caused widespread damage in the southern part of Nagano Prefecture was the Toyama Earthquake of 1718,which had its epicenter at Minamishinano Wada, Iida City. The Toyama Earthquake struck just after 2 pm on August 22, 1718 with a magnitude estimated at 7.0. This earthquake is considered to have occurred along the Median Tectonic Line.

2,Survey Results

I identified 35 places where disasters occurred in each prefecture of Nagano Gifu Shizuoka and Aichi. Among these places, a number of characteristic disaster examples are shown as follows.

(1)Minamishinano Wada,Iida City: Mt.Moriheizan located close to the epicenter of the earthquake, partially collapsed to form the elevated area called Deyama at its foot. A landslide pushing out from Oshidezawa dammed the Toyama River. **(2)Arakida, Anan Town:** The right bank of the Tenryu River is composed mostly of Neogene strata centered on sandstone and mudstone overlaying granite bedrock. The slope at the place called Kibishima collapsed due to the earthquake and dammed the Tenryu River. **(3)Furujo,Anan Town:** Geologically, this area consists of Neogene sandstone and mudstone. In the Furujo district, landslides occurred in 24 places, and fields with place names that are still in use today were damaged or destroyed in 33 places**.(4)Hisawa,Shimojo Village:** There is an oral tradition stating that the local people saw the collapsed state of mountainsides in the Ina and Akaishi Mountains from this district. **(5)Enshu Yokoyama Town** (Yokoyama Town, Tenryu Ward, Hamamatsu City, Shizuoka Prefecture): A document was found stating that the Tenryu River was stopped at a place called Enshu"Teuna". Currently this place name is not used, but there is a place name "Unna", which is also along the Tenryu River, so it was presumed that this was where the river was dammed.

3,Discussion and Consideration

(1)What this survey shows: The distribution of the records concerning this earthquake disaster with its epicenter on the Median Tectonic Line in Minamishinano Wada, Iida City is quite one-sided. Records of damage were found only on the west side of a border marked by the Median Tectonic Line running roughly north-south. Because the Akaishi Mountains on the east side of the border had almost no inhabitants, no records of damage from the earthquake were left there. Also, over the course of the nearly three centuries that have passed since the earthquake occurred, the amount of documentary material has been greatly reduced as a result of natural and human causes. **(2)Geological specificity:** The disasters associated with this earthquake can be divided into three typs according to geological differences and the disaster distribution. The first type involved large-scale landslides and disasters occurring on basement granite. The second type constituted disasters occurring on Neogene strata centered on Anan Town. The third type of disaster occurred on Quaternary terrace gravels and alluvial fan gravels. **(3)Rrelation to the Hoei Earthquake:** In 1707, the Hoei Earthquake struck with an estimated magnitude of 8.6, making it one of the largest earthquakes in Japannese history. The Toyama Earthquake, which struck 11 years later, is considered to be an after-shock of the Hoei Earhquake.

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Keywords: toyama earthquake, the year 1781, earthquake disaster, median tectonic line, hoei earthquake

SSS23-P02 Room:Poster Time:May 1 18:15-19:30

A discussion on improvement of calculation technique for questionnaire survey of seismic intensities

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We compared the seismic intensity from the average intensity with a 1km mesh obtained in the vicinity of the instrumental seismic intensity observation sites. Only in the case of the 2011 off the Pacific coast of Tohoku Earthquake, questionnaire seismic intensities were about 0.5 larger than the instrumental seismic intensities, however, in the cases of other earthquakes, the questionnaire ones were smaller than the instrumental ones. The differences between the instrumental seismic intensity and the questionnaire one are 0.1 to 0.2 at the sites where the instrumental seismic intensities indicate 6 weak. However, at the sites where the instrumental seismic intensities indicate 5 strong, the differences were more than 0.5. Results of the earthquakes of 2008 and 2003 show that the questionnaire seismic intensity is about 0.3 smaller than the instrumental one in the range of 5 weak to 5 strong. Therefore, we compare the method by Inoue et al.(1999) as another method capable in the larger seismic intensity range with the method by Ohta et al.(1998). Inoue et al.(1999) had pointed out that the questionnaire seismic intensity estimated by Ohta et al.(1998) were low in the middle seismic intensity range near about 4.5. They proposed a method capable in large seismic intensity range using the empirical formula to modify the difference without changing the calculating method of Ohta et al. (1979). When questionnaire seismic intensities were calculated using the empirical equation by Inoue et al.(1999), they showed a better correlation with the instrumental seismic intensity for other earthquakes except the 2011 off the Pacific coast of Tohoku Earthquake.

Keywords: Calculation technique for questionnaire seismic intensities, Instrumental Seismic Intensity, Large seismic intensity range

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SATREPS Project on Earthquake and Tsunami Disaster Mitigation in the Marmara Region and Disaster Education in Turkey

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Since 1939, devastating earthquakes with magnitude greater than seven ruptured North Anatolian Fault (NAF) westward, starting from 1939 Erzincan (Ms=7.9) at the eastern Turkey and including the latest 1999 Izmit-Golcuk (Ms=7.4) and the Duzce (Ms=7.2) earthquakes in the eastern Marmara region. On the other hand, the west of the Sea of Marmara an Mw7.4 earthquake ruptured the NAF's Ganos segment in 1912. The only un-ruptured segments of the NAF in the last century are within the Sea of Marmara, and are identified as a "seismic gap" zone. The Sea of Marmara should be focused on through a multidisciplinary research and uncertainty in magnitude, epicenter, recurrence, fault segmentation, and their cross effects should be identified and characterized. To fill the necessity above, a comprehensive multidisciplinary research on earthquake and tsunami disaster mitigation in the Marmara region and disaster education in Turkey in the framework of Science and Technology Research Partnership for Sustainable Development (SATREPS) sponsored by Japan Science and Technology Agency (JST) and Japan International Cooperation Agency (JICA) has been started.

The project is composed of four research groups.

The first is "Earthquake Source Model research" group. Long-term OBS observation, Electromagnetic observation, Seafloor extensometer observation and Trench survey studies will be conducted in order to identify the detailed seismic zone, fault geometry, 3D Velocity structure and reliable crustal deformation beneath the Sea of Marmara.

The second is "Tsunami prediction based on earthquake cycle simulation research" group. In this group earthquake and tsunami occurrence scenarios will be proposed based on especially the research Group 1's outputs and current knowledge on NAF's seismic activities. The outputs will be used for the simulation of strong ground motion, developing of advanced hazard maps and a tsunami early warning system.

The third is "Seismic characterization and damage prediction research" group. This group focuses on modeling of 3D velocity structure, theoretical prediction of ground motion and evaluation of existing structures in the selected urban areas using research outputs of the other groups. Also there will be an attempted of making an urban area model for Istanbul using available data for this area, and to execute earthquake hazard and disaster simulation for various scenarios of a possible earthquake. Improved hazard maps and visual materials for disaster education are expected.

The fourth is "Disaster education using research result visuals from each research" group In group four, effective use of media in the dissemination of disaster information will be examined and disaster management planning through regional disaster prevention community will be encouraged. as well as, using the research visuals a disaster prevention education program will be conducted through media, web, local communities and schools.

Goals of the project are as follows,

1- To develop disaster mitigation policy and strategies based on multidisciplinary research activities.

2- To provide decision makers with newly found knowledge for its implementation to the current regulations.

3- To organize disaster education programs in order to increase disaster awareness in Turkey.

4- To contribute the evaluation of active fault studies in Japan.

Through the project, the research results will be integrated for disaster mitigation in The Marmara region and disaster education in Turkey. The details of SATREPS Japan-Turkey joint research project and latest achievements will be presented.

Keywords: sea bottom observation, earthquake disaster mitigation, tsunami disaster mitigation, disaster education, Turkey, SATREPS

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Fragility curves of buildings during the 2011 Tohoku Earthquake using the damage data in the northern Miyagi Prefecture

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Damage ratios in subdistricts of Osaki and Kurihara cities, northern of Miyagi Prefecture are obtained from the damage data provided by the local City Offices. Ground motions in these subdistricts are estimated by use of source model proposed by Kurahashi and Irikura (BSSA, 2013) and underground velocity structures identified from microtremor H/V spectral ratios. The estimated ground motion indices (PGA, PGV, I_{JMA}, and SI) are used to relate with the damage ratios to construct the fragility curves. It is found that the correlation in small subdistricts is improved, compared with that between the observed ground motion indices and corresponding damage ratios in a wider district.

In addition, we have added some microtremor measurement at plural sites inside each subdistrict, such as Furukawa, and Tajiri, in order to assess the representativeness of ground motions estimated at only one site for the entire subdistrict. We conducted such measurement at or near the preliminary schools inside the subdistricts. The ground motions during the mainshock are estimated with the identified velocity structures from the microtremor H/V spectra ratios. It is found that the variability of ground motions in the Furukawa subdistrict is relatively small. It suggests that the ground motions used for the fragility curves are representative for the entire subdistrict. In contrast, the variability of ground motions in Tajiri is relatively large. It may be caused by the limited numbers of preliminary schools with similar amplification factors.

Keywords: Fragility curve of buildings, microtremor H/V spectral ratio, underground velocity structure, representative of ground motions

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The earthquake vibration observation of the Yasuda auditorium using the IT Kyoshin seismometer

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In order to reduce the seismic disaster, it seems to be the usefulness to investigate the seismic vibration of our familiar buildings such as housing, companies, schools, etc. in small earthquake, examine the weak point and improve the earthquake resistance of these building effectively. For this purpose, we devised IT strong motion seismometer as a new type self install strong motion seismometer.

With this IT Kyoshin seismometer, we continue the vibration observation of some buildings in University of Tokyo from 2006.

The repair work of the Yasuda auditorium will be carried out. We install the IT Kyoshin seismometer and will observe it to confirm an effect of the construction.

We used the high-performance sensor and, in addition to a low cost standard IT Kyoshin seismometer, observed it.

We finish observation before the construction and analyze data now.

After construction was completed, we install the IT Kyoshin seismometer again and are going to compare it.

Keywords: IT Kyoshin (Strong Motion) Seismometer, Structural Health Monitoring

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The effect of torsional and bending vibration on shear-wave velocity extracting from building response by seismic interf

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Because shear-wave velocity correlates with the shear rigidity of buildings, the decrease of it is a indicator of the loss of stiffness, which is possibly caused by structural damage or degradation. Therefore, shear-wave velocity identification is intended for use in health monitoring of upper structures excluding the effect of soil-structure interaction. Shear-wave velocity can be extracted from tracing the propagation of a pulse from normalized cross-correlation of the motion between two points based on the view of response as the wave vertical propagation process. In this study, the reference point is the top of the building (virtual source) instead of the base (physical source) which results in the transfer function including the effect of rigid-body rocking. However, for high-rise and eccentric structures torsional motion and bending motion is inevitable. In practical measurement of horizontal motions with single sensors located on the side not the core of the building plane, it is unavoidable to record the torsional response which mixed with the shear-mode motions. Therefore, the effect of torsional response to shear-wave velocity extraction should be deliberated on to avoid erroneous use of the travel time of torsional wave instead of that of shear wave. Furthermore, the extraction of shear-wave propagation from building vibration generally in bending mode is valid or not should be examined.

In this study, firstly a 3D model with eccentricity is used to calculate the horizontal and vertical impulse response to analyze the effect of torsional and bending response to shear-wave velocity extraction. And the method to eliminate the effects of torsional and bending vibrations to obtain the shear-wave propagation with high resolution is presented. Secondly, a practical use of earthquake records measured in a high-rise building to examine the effect of torsional and bending vibration to shear-wave velocity extraction. Thirdly, velocities of shear wave, torsional wave, and bending wave are extracted separately to evaluate the changes of stiffness before and after the Tohoku earthquake for health monitoring.

Keywords: shear-wave velocity of buildings, deconvolution method, torsional response, seismic interferometry, system identification, Tohoku earthquake

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Global ”strong” ground motions from the 2013 Sea of Okhotsk great deep earthquake

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This study presents the characteristics of global ground motions caused by the Sea of Okhotsk deep earthquake (Mw8.3) of May 24, 2013. The earthquake occurred at a depth of 609 km in the subducting Pacific plate, and it is now the largest deep earthquake ever recorded. According to reports in NEIC, the earthquake was felt at very long distances in the world, including Dubai (˜76 degrees) and Moscow (˜58 degrees). In this study, by using global broadband seismic data from IRIS DMC, we examine ground motions from the earthquake. For the 1994 Bolivia deep earthquake (Mw8.3), which was formerly the largest and were felt in North America, the distant ground motions were examined by Anderson et al. (1995) from the perspective of strong motion seismology. Due to the location, the 2013 Sea of Okhotsk earthquake was recorded by a much better coverage of global stations, compared to the 1994 Bolivia earthquake. This study is an opportunity for exploring the distant ”strong” ground motions from the perspective of Anderson et al. (1995).

Peak ground accelerations (PGA) from the 2013 Sea of Okhotsk earthquake decrease as distance increases out to 120 degrees, and have a peak at a distance of approximately 140 degrees. The variation as a function of distance is similar to that of Anderson et al. (1995) for the 1994 Bolivia earthquake. The values of PGA are a few times larger than those from the Bolivia earthquake. At distances between 30 and 80 degrees, PGA are associated with vertical components of direct P waves, and the values of PGA are often in a range from 0.1 to 1 gal. Peak ground velocities (PGV) vary with distance in a similar way to PGA. The values of PGV at distances between 30 and 80 are lower than 0.1 cm/s.

Large PGA at distances between 30 and 80 degrees are observed in the Eurasian continent. The values of PGA in the western part of the continent are larger than those in the eastern part. Because this difference is also observed for PGA of P waves from an outer-rise shallow earthquake near the Kurile trench, it can be attributed to regional structure in the Eurasian continent. PGA from the 2013 deep earthquake are not low in the southern part of the continent, although from a deep earthquake beneath Sea of Okhotsk that has a different focal mechanism from that of the 2013 earthquake, PGA decrease toward the south as distance increases. The focal mechanism of the 2013 earthquake represents that the P wave radiation is the maximum along a ray toward Karachi, Pakistan. This P wave radiation can account for the observations of PGA in the southern part. Global ”strong” ground motions from the 2013 Sea of Okhotsk deep earthquake are thus likely to be affected by regional structure and P wave radiation, as suggested by Anderson et al. (1995).

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Relation between smallest microtremor amplitudes and largest seismic amplitudes observed at TRIES seismographic stations

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In 1999 TRIES, Tono Research Institute of Earthquake Science, started to establish an observation network of seismographic stations in Tono district, the eastern area of Gifu Prefecture, and completed a 10 stations network at the end of the year. The seismographic station TRIES was the first station, and 9 stations, TOGARI, ENA, MIZUNAMI, AKECHI, IWAMURA, NATAKI, MITAKE, TOKI and INUYAMA were established one by one. In order to investigate the correlation between the smallest spectral amplitudes of microseisms and largest seismic spectral amplitudes, we started spectral analysis of microtremors and seismic waves recorded on the same seismograms. By the discrete Fourier transform we calculated the spectral amplitudes and frequencies from the observed microtremors recorded just before the first arrival of seismic waves in the frequency range from 2.0 to 4.0 Hz. Similarly we calculated the spectral amplitudes and frequencies of seismic waves by the discrete Fourier transform in the frequency range from 2.0 to 4.0Hz. We calculated the ratios of the relative amplitudes of the smallest amplitude of microtremors and largest amplitude of seismic waves to those at the station TRIES. By taking the relative amplitudes of micro tremors and largest seismic amplitudes to those at TRIES we can extract the relative site effects caused by the ground soil to those at TRIES. Since the site effect at TRIES is small, the relative largest seismic amplitudes at TOGARI, for example to those at TRIES simply give multiples of the amplitude at TRIES, at each station. Preliminary results show that the smallest amplitude of microtremors will give the spectral amplitudes of the site effect that will amplify the incident seismic waves from the underlain basements.

Keywords: microtremor, seismic waves, discrete Fourier transform, ground soil, largest amplitude, site effect

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A study on model selection methods for ground-motion prediction equations using synthetic data

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Numerous ground motion prediction equations (GMPEs) have been proposed for the purpose of assessing seismic hazard. However, a critical problem is that how to select appropriate GMPEs for the application of GMPEs to practical engineering problems.

Recently some model selection methods for GMPEs that evaluate the agreement between observed and predicted data have been proposed. In present study, in order to check the properties of model selection methods, we compare the model selection methods by using artificial dataset generated by a known GMPE. As candidate model selection methods, we have chosen three methods, that is, analysis of root mean square residual (RMR), the log-likelihood method (LLH method, Scherbaum et al., 2009, BSSA) and the Euclidean distance-based ranking method (EDR method, Kale and Akkar, 2013, BSSA). The analysis of RMR is one of the simplest methods to evaluate the difference between observed data and medians of GMPE model. On the other hand, the LLH method quantifies the distance between observed data and GMPEs defined as probability density function (both of median and standard deviation), based on information-theoretic perspective. However, Kale and Akkar (2013) points out the problem that the LLH method may favor GMPEs with larger standard deviations. The EDR method considers not only ground-motion uncertainty of model through standard deviation, but also agreement between the median estimations of models and observed data trend (model bias).

First, we assumed a vertical strike-slip fault with moment magnitude 7.0. We randomly chose 200 sites, whose fault distances are up to 200km. Next, we calculated theoretical PGA and response spectral acceleration for 16 periods using ground motion prediction model of Chiou and Youngs (2008, Earthq. Spectra), which is referred to as CY08 hereafter. And, we generated three kinds of synthetic dataset by adding three types of random noise with (1) zero standard deviation, (2) standard deviation of CY08, and (3) twice the standard deviation of CY08, respectively.

We selected five candidate GMPEs, that is, CY08, Abrahamson and Silva (2008, Earthq. Spectra), Campbell and Bozorgnia (2008, Earthq. Spectra), Zhao et al. (2006, BSSA) and Kanno et al. (2006, BSSA), and ranked the performance of candidate GMPEs for each synthetic dataset. In analysis of RMR that does not account for standard deviations of the prediction models, CY08 is stably ranked the best performing model for all kinds of synthetic dataset. The LLH method basically ranked CY08 as the best performing model for synthetic dataset (1) and (2), but it favored GMPEs with larger standard deviations for synthetic dataset (3). It suggests that the standard deviation of model is emphasized more than the median when we apply the LLH method to poor quality data. In the EDR method, in principle, the parameter to measure the level of model bias of CY08 is not able to be calculated for synthetic dataset (1) that does not have random noise. For synthetic dataset (2) and (3), however, the EDR method ranked CY08 as the best performing model both in the point of view of model uncertainty and model bias.

Keywords: attenuation relationship, ground motion predicting equation, root mean square residual, the log-likelihood method, the Euclidean distance-based ranking method

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Seismic hazard assessment using a new ground motion prediction equation

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In the "National Seismic Hazard Map for Japan" by Headquarters of Earthquake Research Promotion of Japan, seismic hazard is evaluated by the ground motion prediction equation (GMPE) of peak velocity by Si and Midorikawa (1999), and conversion from peak velocity to seismic intensity by using an experiential relation. It is indispensable that earthquakes of moment magnitude (Mw) 9 class take into consideration in the present seismic hazard evaluation. However Si and Midorikawa's (1999) equation is obtained from strong motion records of earthquake up to Mw 8.3. In this study we evaluate seismic hazard by using our new GMPE obtained by using strong-motion database including the records of the 2011 Tohoku earthquake and show the comparison it with the National Seismic Hazard Maps for Japan.

The target strong-motion parameters are peak velocity on an engineering bedrock (here, it is considered as the upper surface of Vs=400 m/s layer), and peak velocity and JMA seismic intensity on the ground. The value on the ground is calculated by using the amplification factor obtained from the average S-wave velocity up to 30 m depth based on the 250m-mesh national geomorphologic classification map.

First, we compare the ground motion distributions calculated from two GMPEs. Here we target following 6 assumed earthquake. (1) crustal earthquake on the Itoigawa-Shizuoka fault zone (Mw7.4), (2) crustal earthquake on the Muikamachi fault zone (Mw=6.6), (3) subduction-zone plate-boundary earthquake at Nankai Trough (Mw=9.1), (4) subduction-zone plate-boundary earthquake at Tokachi-oki reigion (Mw=8.1), (5) subduction-zone shallower intra-plate earthquake at Chishima trench region (Mw=8.2), and (6) subduction-zone deeper intra-plate earthquake at Chishima trench region (Mw=7.5). Amplification by the deep sediments layers can be obviously seen in our new result of peak velocity distribution. As the result, amplitude in our new result becomes larger in basin region and smaller in mountain region. On the other hand, the influence of the deep sediments is not so remarkable in result of JMA seismic intensity on the ground. The calculated value from our new GMPE is smaller in the distance area (in general 100 km or more) for subduction-zone earthquakes. Midorikawa and Ohtake (2002) pointed out that Si and Midorikawa's (1999) GMPE overestimates the peak values in distant region earthquake whose focal depth is deeper than 30 km. Our results are consistent with them.

Next, we compare the seismic hazard for the megathrust earthquake occurring at the Nankai Trough. Here we use the model in probabilistic seismic hazard maps by HERP (2013).

Moreover, we use the value of variance in the National Seismic Hazard Maps for Japan as it is. The hazard by our new GMPE decreases especially at the distant area as expected from comparison of above-mentioned strong-motion distribution. However, the decrease does not serve in Kanto and Osaka area where amplification by deep sediments is large. On the contrary, JMA seismic intensity is larger when exceedance of probability is lower at some points. This is considered that that the value of the set-up variation is not in agreement for JMA seismic intensity has influenced.

Keywords: seismic hazard assessment, grount motion prediction equation, variance of ground motion

SSS23-P11 Room:Poster Time:May 1 18:15-19:30

Ground amplification estimates based on very dense seismic array observation in Furukawa district, Osaki, Japan

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On March 11, 2011, a huge earthquake hit the eastern part of mainland Japan. The earthquake caused a huge tsunami that killed more than ten thousand people. Structures were also severely damaged over the area of eastern Japan by the tsunami, ground motions, liquefaction, and so on. We focus on the Furukawa district of Osaki City, where severe residential damages occurred downtown. Ground motion records in the downtown area are available at two stations, MYG006 (K-NET) and JMA Furukawa (JMA). The damage level was different between the areas within several hundred meters from the MYG006 and JMA Furukawa stations, which are about 1km away from each other. The severe damages were concentrated within the area approximately 1x1km2 including the JMA station. This implies that the ground motion characteristics were not uniform in sub-kilometer scale, and the existing two stations are not enough to clarify the damage distribution (Goto and Morikawa, 2012).

In aftermath of the earthquake, we distributed dozens of low-cost seismometers, namely ITK sensor, around the area about $3x2km^2$ in the Furukawa district (Goto et al., 2012). The observed data are sent to the remote server through internet connection in real time. The seismometers were installed beside the volunteers' houses. The volunteers can access the interactive information service, namely on-line viewer system. The observed PGA and PGV values show significant spatial variability that may be correlated to the structural damage caused by the major 2011 event.

We assumed one-dimensional horizontally-layered structure just beneath the stations and estimated ground structure by using the records based on the observation. The results indicate that the area where the severe damages were concentrated is related to the area with the thicker surface layers. The distribution is also indicated by the results obtained from gravity anomaly data.

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Keywords: Ground amplification, Furukawa district, Very dense seismic array observation

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Physics-based decomposition of ground amplification using ground transfer function expansion

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Amplification of earthquake ground motions at actual deposit sites is an important factor to consider when assessing the risk of an earthquake disaster. In order to identify the amplification properties, several preprocessings such as the Fourier transform are required. I propose a series expansion of the amplification with simple ground transfer functions as a new preprocessing. I define a sequence of transfer functions based on a two-layered structure excluding an internal damping, and a function space spanned by the set of the functions. I mathematically prove that the function space is equal to L2 space. This indicates that all the functions belonging to L2 space, i.e., an arbitrary ground amplification, have a unique series expansion.

In practice, the expansion requires the observed ground amplification. It is directly observable from the spectral ratio of the Fourier spectra at the target site to that at a reference rock site (Goto et al., 2013). When the observations are available, the expansion is applicable even for the site response including a 3D basin effect as the preprocessing, whereas it requires a more precise investigation of what the extracted components physically means for the general cases.

I apply the series expansion to the physics-based decomposition of the amplification. The results indicate that the contribution from the given bases can be represented by the absolute value of their coefficients. The contribution may enable direct quantification of the similarity of models. This property potentially has wide applications, e.g., spatial interpolation of the amplifications from the sites where they are reliably determined, stochastic modeling of the amplification as a mixed state of the fundamental simple states, etc. The detailed application is currently under way.

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Keywords: Ground amplification, Function expansion

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Case study on the wavefield in the 3D structure including sedimentary basin and the effect of source depth on it

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It is widely recognized that the existence of sedimentary layers has a great influence on the excitation of surface waves. During the 2011 Fukushima-ken shallow inland earthquake (Mw 5.5, depth = 10.6 km), long-period surface wave was observed at a station in the Niigata sedimentary basin, which is over 150 km away from the epicenter, and its duration reached over 100 s. Long-period surface wave was observed also during the 2012 Fukushima-ken-oki deep interplate earthquake (Mw 5.7, depth = 53 km) at the same station, and its duration reached ˜100 s. Thus, significant difference was not seen between the surface wave duration in the Niigata basin of these two earthquakes despite of large difference of their source depths. This seems inconsistent with the recognition that surface wave is more efficiently excited by shallower source.

This study investigates the effect of source depth on the seismic wave filed in the sedimentary basin based on the numerical simulation using finite difference method for shallow and deep sources. The calculation area is from off the Fukushima Prefecture to the Niigata basin, and the following three simulations are performed.

In the simulation 1, a simple structure model composed of circular homogeneous sedimentary basin and background two-dimensional structure, two cases of source depths: 5 km and 85 km, and source duration of 3 s are assumed. The result shows the duration of the surface wave in the sedimentary basin is ˜50 s for the both shallow and deep sources, and large difference is not seen the two different source depth cases. At the station prior to the basin, wave duration for the shallow source is ˜10 s longer than that for the deep source. This difference of 10 s is shorter than the long duration of 50 s in the sedimentary basin, and this can explain the result that large difference is not seen in the basin.

In the simulation 2, a simple structure model composed of circular homogeneous sedimentary basin and background two-dimensional structure, as in the simulation 1, is assumed, and the case study on the material property values of the homogeneous basin is done. Two cases of source depths: 5 km and 75 km, and source duration of 3 s are assumed. The result shows longer duration of seismic waves is seen in the basin for smaller value of S-wave velocity of the basin medium (˜125 s for Vs = 0.5km/s, ˜90 s for Vs = 1.0 km/s, and ˜40 s for Vs = 2.0 km/s). This is interpreted to be because of larger arrival time difference of S-wave and surface wave for smaller S-wave velocity of the basin.

In the simulation 3, realistic complex three-dimensional structure model is assumed both for the sedimentary basin and for the background structure. We use the three-dimensional model by Koketsu et al. (2012), two cases of source depths: 5 km and 75 km, and source duration of 3 s. Long wave duration of ˜90 s is obtained both for the shallow and deep sources. The maximum amplitude at the station is the sedimentary basin is ˜2 times (for the deep source) and ˜6 times (for the shallow source) larger than that at the station prior to the basin.

Comparing the result of the realistic three-dimensional model case (simulation 2) and that of the simple structure model case (simulation 2), more complex and more continuous wave-packet with long duration is seen in the basin in the former case than that in the latter case. On the other hand, siginificant difference is not seen in the amplitude and duration at the station prior to the basin, both for the shallow and deep sources. This result suggests the wavefield in the sedimentary basin is mainly affected by the basin structure itself, rather than the structure model of the path from the source to the basin.

Keywords: sedimentary basin, surface wave, numerical simulation, source depth

SSS23-P14 Room:Poster Time:May 1 18:15-19:30

Surface wave propagation in the large-scale sedimentary basin: distinct lateral variation of Love wave velocity around m

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By detailed analysis of surface waves recorded at dense seismic arrays in Kanto, sudden change of Love wave velocity for frequency of 0.125-0.25 Hz is found at very narrow, 20 km by 20km, region of southern Saitama.

To clarify cause of such sudden change and characteristics of surface wave propagation in thick sediments, we conducted 3D FDM simulations of seismic wave propagation assuming various basement structure (interface between sediments and bedrock) or velocity structure models in the sediments. Our simulations demonstrated that propagation velocity of Love wave is mainly controlled by shallower velocity structure at depth less than 1.5 km, rather than deeper basement structure. Our results were supported by the analysis of sensitivity kernel of Love wave in the sediments.

We constructed S-wave velocity structure in the sediments of Kanto basin using interpolation technique from 14 boreholes VSP measurements and surface wave analysis in this study. To confirm validity of our modeling, we conducted 3D FDM simulations of seismic wave propagation using constructed velocity structure and compared simulation results with observation. Our simulation results well reproduced peak amplitude and propagation velocity of Love wave for frequency of 0.125-0.25 Hz. Our results indicates that realistic modeling of shallower velocity structure and impedance contrast at the sediments-bedrock interface is important for precise evaluation of long-period ground motion in thick sedimentary basin.

Acknowledgement

We acknowledge the National Research Institute for Earth Science and Disaster Prevention, Japan (NIED) for providing the K-NET/KiK-net waveform data. We also use strong motion data from SK-net. The computations were conducted on the Earth Simulator at the Japan Marine Science and Technology Center (JAMSTEC).

Keywords: long-period ground motion, basin structure, numerical simulation, surface wave

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Long-Period Ground Motion Simulation in the Kanto Basin with/without Accretionary Prism

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Large earthquakes in subduction zones generally excite long-period seismic waves. Once these waves enter into basins filled with thick sedimentary layers, they develop and result in largely-amplified long-period ground motions. Such long-period ground motions have caused damage to large-scale buildings during some earthquakes. For the 2003 Tokachi-oki earthquake (M_w 8.3), long-period ground motions with a dominant period of 7-8 seconds were observed in the city of Tomakomai, located on thick sedimentary layers and at a distance of about 250 km from source region. The long-period ground motions triggered the sloshing in many oil tanks, and two of them caught fire (Koketsu *et al.*, 2005). For the 2011 Tohoku earthquake (M_w 9.0), long-period ground motions were observed at a large distance from source region such as the Osaka and Kanto basins, where some tall buildings shook over about 10 minutes (JMA, 2011).

The large earthquakes along the Nankai trough which are expected to occur in the near future can generate long-period ground motions in the Osaka, Nobi and Kanto basins (Furumura *et al.*, 2008). Along the Nankai trough, a accretionary prism composed of soft materials with a thickness of several kilometers lies near the toe of the Eurasian plate. Such prism does not exist at the Japan or Kuril trench. For this reason, in evaluating the long-period ground motions during the large earthquake occurring along the Nankai trough, we should consider the additional effect of accretionary prism on seismic waves. Yamada and Iwata (2005) simulated long-period ground motions for the Kinki region, and concluded that the existence of accretionary prism reduces the amplitudes of direct S-waves and elongates long-period ground motions. In this study, we performed simulations of the long-period ground motions in the Kanto basin for the foreshock (M_w 7.1) of the 2004 off the Kii peninsula earthquake on 5 September at 19:07 (JST) in order to examine the effect of accretionary prism.

In the simulation, we assumed a point source. Except its depth, its source parameter and source time function were the same as those of Yamada and Iwata (2005). We located the source at a depth of about 16 km, which is slightly shallower than that of Yamada and Iwata (2005), to fit it to the depth of the subducting Philippine Sea plate. We used the Japan Integrated Velocity Structure Model (Koketsu *et al.*, 2008, 2012). We calculated long-period ground motions using the finite element method with voxel meshes (Ikegami *et al.*, 2008). The frequency range of the calculation was 0.05-0.3 Hz, and the time duration of synthetic waveforms was set to be six and a half minutes from the rupture starting time. Our simulation model covered an area of 564 km$\times$198 km and extended to a depth of 61 km. An absorbing boundary with a width of 54 km was also introduced outside the simulation model. According to the velocity structure, the model was discretized by variable voxel meshes with the smallest size of 175 m. We also assumed a velocity structure model without accretionary prism, where the S-wave velocity of accretionary prism (1.0 km/s) is replaced with 3.2 km/s. Then, we calculated waveforms in this model and compared them with those in the accretionary-prism model to examine the effect of accretionary prism.

Our simulation shows that, compared with the velocity structure model without accretionary prism, the long-period ground motions for the accretionary-prism model have smaller amplitudes for direct waves but larger ones for later phases. Our results are consistent with those by Yamada and Iwata (2005). In the accretionary-prism model, the waves trapped in the accretionary prism are continually converted to surface waves, and the incident surface waves to the Kanto basin propagate in the basin. We confirm that this process contributes to the reduction of direct waves and the amplification of later phases in the Kanto basin.

Keywords: Long-period ground motion, Accretionary prism, Nankai trough, Kanto basin

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Semblance analysis for the 2011 Tohoku earthquake using strong-motion and 1Hz GPS data

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Source inversion is well used for the analysis of the earthquake source-process. However in the source inversion some assumptions and constraint conditions are used and there are cases where the settings of these affect the result. On the other hand, array analysis can produce the direct image for the seismic-wave radiation. In this analysis, we investigate the seismic-wave radiation characteristics for the 2011 Tohoku earthquake with the semblance array analysis using strong-motion and 1Hz GPS data.

We use not only the strong-motion data recorded by K-NET, KiK-net, and F-net of NIED and JMA but also 1 Hz GPS data recorded by GEONET of GSI. Additional use of 1 Hz GPS data leads to increase the station density and therefore the number of the available arrays increased remarkably compared to previous work (Kubo & Kakehi, 2013). Except for F-net data, the strong-motion acceleration waveforms are integrated into velocity waveforms. 1Hz GPS data is converted into displacement waveforms using Kinematic PPP as implemented in RTKLIB Ver. 2.4.2 (Takasu, 2013) and they are differentiated into velocity waveforms. These waveforms are bandpass-filtered from 10s to 25s and resampled with a sampling interval of 0.1s. From the comparison of the observed velocity waveforms for the 2011 Tohoku earthquake at the GEONET and strong-motion stations which distance is less than 3 km, we confirmed that the waveform of 1Hz GPS data matches one of strong-motion data at above period-band.

We use the same method of the semblance analysis in Kubo & Kakehi (2013). In this method, we firstly assumed the fault surface model consisting of some subfaults. Then the semblance value for each subfault is calculated assuming spherical-wave incidence when the subfault is the seismic-wave radiation source, and these values are plotted on the fault surface. By doing this analysis with time shift, we can obtain temporal change of the seismic-waves radiation source on the fault surface. The incident waves are assumed to mainly consist of S-wave because the estimated apparent velocity through the semblance analysis assuming plane-wave incidence is approximately 4 km/s and it don ' t have the dispersion. As the velocity structure model for the calculation of the travel time, we use one-dimensional velocity structure model in Asano & Iwata (2012). In this analysis, we constructed nine arrays at Tohoku and Kanto regions, and estimated the snapshot of semblance images at each array for 250s after the synthetic S-wave onset, which is comparable to the rupture starting time. The time length for semblance calculation is 20s and the time shift is 10s. The semblance value is obtained by averaging the three semblance values of the three-component waveforms.

The semblance images at the arrays north of 39^{o}N are different from ones at the arrays south of 39^{o}N. The images at the former arrays demonstrate that the seismic waves were strongly radiated from off Miyagi up to approximately 150s and that then the seismic waves were continued to be weakly radiated from off Miyagi. On the other hand, the images at the latter arrays demonstrate that the duration time of the seismic-wave radiation from off Miyagi is approximately 100s, that subsequently the radiation source moved to off Fukushima and Ibaraki, and that its radiation continued up to approximately 180s. This image difference indicates that the seismic-wave radiation area for the 2011 Tohoku earthquake extended to south approximately 100s after the rupture start and that off Miyagi radiated the seismic-waves during long time (~200s). We will also investigate the spatial variation for the seismic-wave radiation source along dip direction.

[Acknowledgments] The strong-motion data recorded by K-NET, KiK-net, and F-net of NIED and JMA and the 1Hz GPS data recorded by GEONET of GSI were used for this analysis.

Keywords: The 2011 Tohoku earthquake, Seismic-wave radiation characteristics, Semblance analysis, Strong-motion data, 1Hz GPS data

SSS23-P17 Room:Poster Time:May 1 18:15-19:30

Stochastic green function considering 3-D Qs structure-Predicting ground motion of the 2011 Tohoku Earthquake-

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We have developed a method to simulate strong ground motions by combining the stochastic green function (SGF) and 3-D attenuation effects.

The calculation procedures of our method are as follows.

(1) To give Source spectra for sub-fault events.

(2) To calculate basement spectra considering 3-D Qs structure.

(3) To calculate ground surface spectra by multiplication of the site factors to basement spectra.

(4) To make time history of ground motions using ground surface spectra and envelope function (Boore, 1983).

(5) To create main shock ground motion by superimposing the ground motions from sub-fault events considering lapse time: ex. fault ruptures. (Kamae et al.,1991)

In this study, we reproduced strong motions of the 2011 Tohoku Earthquake (M9) by using this method. The fault plane of the 2011 Tohoku Earthquake was divided into 10∗10∗10 element faults planes, and seismic moment of Mo=4E+25 Nm and stress drop 25 MPa are given to the elements uniformly. Target sites to evaluate are ground surfaces of the K-NET and the KiK-net observation stations. The 3-D Qs model and site amplification factors estimated by Nakamura (2009) were used in this study. To show validity of this method, we compared calculation results by using the 3-D Qs model with by a uniform Qs model; $Qs=100f^{1.00}$.

The standard deviation of the logarithmic residual of PGA from the 3-D Qs model is 0.224 and that from the uniform Qs model is 0.231 for the stations with PGA>100Gal and the values are 0.253 and 0.360 respectively for the stations with PGA>1Gal. The difference was more significant for longer epicenter distance area. The response spectra calculated from the uniform Qs model are underestimated in the long distance areas, ex. Kinki and Hokkaido, whereas the response spectra using the 3-D Qs model were well reproduced the observed ones. Seismic wave spreads in deeper part for longer distance travels without attenuating. It is necessary to consider the three-dimensional Qs structure in evaluating the ground motion distribution in a broad area.

We tried to use the complex source model with SMGA. The model with five SMGA segments (Kurahashi and Irikura, 2011)) was adopted for calculation. The waveforms calculated from the uniform source model are like spindle shape generally, but the waveforms from the SMGA model are divided into several wave groups of the corresponding to individual SMGA especially for observation points close to the source. The SMGA model could explain well the observed record shape.

Keywords: 3D attenuation structure, Stochastic green function, Qs, 2011 Tohoku earthquake, Depth dependence, Strong ground motion prediction

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Estimation of Strong Motion Generation Area during the 2008 Iwate-Miyagi Nairiku earthquake using broadband strong groun

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1.Introduction

The 2008 Iwate-Miyagi Nairiku earthquake was an Mw6.7 reverse-fault crustal earthquake that occurred at Iwate prefecture, Japan. Surface ruptures associated with the earthquake were found to distribute near the eastern edge of the southern part of the aftershock zone. Strong ground motions were observed at three stations very near the fault area in addition to the Kik-net and K-NET stations. It is important that strong motion generation areas are estimated using broad-band ground motions to find out the source mechanism generating low-frequency ground motions as well as high strong ground motions.

In this study, we attempt to determine the strong ground motion area (SMGA) of the 2008 Iwate-Miyagi Nairiku earthquake using the broad-band ground motions from the earthquake.

2. The previous studies of the source model for strong ground motions

We presented the SMGA model of this earthquake by forward modeling using the empirical Green's function method by Irikura (1986) in 2008 and 2013.

The model we presented in 2008 was determined to reproduce the observed waveforms around the fault area of the mainshock. We found the first SMGA was located coinciding with large slip area in the southern part of the fault plane obtained by several authors from the waveform inversion analyses using teleseismic body wave data. We clarified to require one more SMGA in the northern part from the hypocenter. However, we realized that the location and geometry of the fault plane we assumed are not so accurate enough according to the aftershock distribution determined from temporary aftershock observation network deployed just after the occurrence of the earthquake (Okada et al., 2012).

We reanalyzed the SMGA model in 2013 using the fault plane determined by the aftershock distribution from the high dense network. In particular, we attempted to simulate the strong ground motions at IWTH25 located very near the fault plane. We obtained one of the best-fitting SMGA models from which simulated and observed ground motions agreed well including the ground motions at a very-near-field station IWTH25. However, it shall be examined whether this model can explain the broad-band ground motions at other near-field stations.

3. Estimation of SMGAs for broadband strong ground motions

In this study, we try to estimate the SMGAs using not only the strong motion records at IWTH25 but other near-field stations, Aratozawa Dam. The observed records at Aratozawa Dam show distinctive strong-motions. This suggests that one of the SMGAs possibly exists near Aratozawa Dam site. On the other hands, the observed records at Aratozawa Dam may have near-field-terms because of very-near-fields from the source area. Therefore, in order to reproduce the mainshock waveform we need to use the empirical Green's functions including the near-field terms, that is ground motion records from an element earthquake occurring very near a source in the fault area. When there is no element earthquake satisfying the near-field condition mentioned above, we use the hybrid Green's functions that have low frequency motions theoretically simulated and high frequency motions empirically obtained. We have no aftershock records at the Aratozawa Dam sites. Therefore, we attempt to simulate the broad-band strong motions at Aratozawa Dam site using only numerically calculated Green's functions to precisely estimate the SMGAs.

Keywords: Iwate Miyagi Nairiku earthquake, Strong Motion Generation Area, broad-band Strong Ground Motion

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Source Model and Strong Ground Motion Simulation for the 2013 Northern Tochigi Prefecture, Japan, Earthquake

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[1]G.R.I., [2]A.I.T.

On February 25, 2013, an inland crustal earthquake (M_{JMA}6.4, Strike-slip type) occurred in the northern Tochigi prefecture, Japan. Strong ground motions with a peak acceleration of 1225 cm/s^2 and a peak velocity of 39 cm/s were recorded at one of the nearest strong motion stations, TCGH07, about 5 km away from the hypocenter. Maeda and Sasatani (2009) showed that a similar large ground motion of 1100cm/s^2, 75cm/s at HKD020 during the 2004 South Rumoi district, Hokkaido, Japan, inland crustal earthquake (M_{JMA}6.1, Dip slip type) is mainly attributable to the source effect, short distance from the strong motion generation area (SMGA) and the forward directivity effect. To investigate how large ground motions at TCGH07 from a source's point of view, we estimate the source model based on the two different approaches.

First, we employ the multi-time window linear waveform inversion method (Sekiguchi et al., 2000) by using the 15 strong motion waveforms (0.1-1.0Hz) recorded by K-NET, KiK-net near the source. A finite extent of the fault plane is assumed referring to the aftershock distribution and moment tensor solution determined by F-net. The fault plane is divided into 84 subfaults of 1.0 km $\times$ 1.0 km. The temporal moment release history from each subfault is expressed by a series of 6 smoothed ramp functions with a rise time of 0.6 sec separated by 0.3 sec. The first time window triggering velocity (FTWTV) was 2.4 km/s. The rise time and FTWTV are given by the smallest misfit solution. The weight of the spatio-temporal smoothing constraint value for inversion was determined based on Akaike's bayesian Information Criterion (ABIC). The velocity structure model for each strong motion station is improved by the downhill simplex method (Nelder and Mead, 1965) using the receiver function. The theoretical Green's function is calculated by using the discrete wavenumber integration method (Bouchon, 1981) with the reflection and transmission matrix (Kennett and Kerry, 1979). To validate the improved velocity structure models, we simulate the aftershock records with a point-source approximation.

The derived rupture model has a large slip area whose maximum slip of 0.98 m in the vicinity of the hypocenter. The rupture mainly propagated from the hypocenter toward the shallower northern part. Seismic moment of the estimated model is 6.67×10^{17}Nm (M_w 5.8). From the contribution of the large slip area to the synthetic waveforms for TCGH07, we find both the SH-wave radiation pattern from the strike-slip fault source and the forward directivity effect toward TCGH07 mainly yield the large pulse velocity waveform (0.1-1.0 Hz) at TCGH07.

Second, the source model is constructed based on the forward simulations using the empirical Green's function method (Irikura.1986) in the frequency range 0.3-10 Hz. One rectangle SMGA is estimated to include the rupture start point, i.e., the hypocenter of the mainshock. The rupture of this SMGA mainly propagates from the hypocenter to shallow side for dip direction, and also propagates to the northward for strike direction. The obtained source model explains the observed acceleration, velocity, and displacement waveforms of this event in the broadband frequency range fairly well. As same as the result from waveform inversion (0.1-1.0 Hz), we also see the large pulse velocity waveform is caused by the forward directivity effect toward TCGH07.

Consequently, we concluded that the main factors generating large pulse velocity waveform at TCGH07 are as follows: 1) the SH-wave radiation pattern from the strike-slip fault source and 2) the forward directivity effect along dip direction toward TCGH07.

Keywords: The 2013 Northern Tochigi Prefecture, Japan, Earthquake, Waveform inversion, Empirical Green's function method, Source model, Strong ground motion simulation

SSS23-P20 Room:Poster Time:May 1 18:15-19:30

Source process of the Feb. 25, 2013 Tochigi Hokubu Earthquake (M 6.3) [2] -Analyses using Empirical Green's Functions-

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INTRODUCTION
An M6.3 earthquake occurred in the northern part of Tochigi prefecture on February 25, 2013. A high acceleration strong motion, over 1 G, was observed at the TCGH07 (Kuriyama-west) of KiK-net, which is situated close to the source region. To explain the reason why such strong acceleration was observed, the author has made the studies using the source process analysis and spectral inversion method to separate site and path effects. However, in the source process inversion, it is difficult to calculate accurate theoretical Green's functions in good enough level, because of the difficulty of making accurate subsurface structures. Consequently, the degree of coincidence between observed and calculated waveforms was not so good.

To overcome such the drawbacks in the source process inversions, the author uses the observed waveforms from a small earthquake as empirical Green's functions (EGF) in this study.

FAULT MODEL and OUTLINE of ANALYSES
Tentative analyses are performed with same fault geometry with Hikima (2013, SSJ fall meeting). The fault model was made using the relocated hypocenters, determined by the DD method, and the F-net mechanism solution. The strike direction is NNW-SSE (165 degree in strike, 80 degree in dip). The fault plane is divided in 1km size for the inversion.

The source process is inverted by the multi time window analysis (Yoshida *et al*. (1996), Hikima (2012)). The velocity waveforms, filtered between 0.03 and 1.5Hz, are used in the inversion analyses. The waveforms at TCGH07 are not used in the inversion, because the station is too close from the fault plain. Only the transverse components are used in this study, to weight the S-wave portion of the waveforms. The waveforms from the Mw 4.0 foreshock, which occurred on 15:26, February 25, 2013, are used as EGFs.

RESULT
Tentative result shows a more concentrated slip distribution than the former results by the theoretical Green's functions (Hikima, 2013). The high moment release area is about 4km *3km. However, the image of the rupture, whose slip propagates to the north, is almost same as former results. The coincidence between observed and calculated waveforms in this study is fairly better than the result by theoretical Green's functions.

Only one result using single EGF has been explained in this abstract. However, many other small earthquakes, which will be candidates for EGFs, occurred in the source area. So the results using other EGFs will be shown and I will discuss the accuracy of resultant slip distributions at the time of the presentation.

Keywords: Source process, Crustal earthquake, Near source, Strong motion, 2013 Tochigi Hokubu earthquake

SSS23-P21 Room:Poster Time:May 1 18:15-19:30

Source rupture process of the 2011 Northern Nagano earthquake (Mj 6.7) based on strong-motion records

SHIBA, Yoshiaki[1]*

[1]CRIEPI

The slip distribution model of the March 12, 2011 Northern Nagano earthquake (M6.7) were estimated by assuming the multiple fault planes model based on the aftershock hypocenters detected from the high-dense seismometer array and the crustal deformation information derived by the interferometry synthetic aperture radar (InSAR). Since the strong-motion record with peak ground acceleration more than 700 gal was obtained at the K-NET station NIG023 near the main shock, it is important to investigate the geometrical relation between the strong motion generation area (SMGA) on the main shock fault and the observation station. Estimated source model displays the largest slip near the K-NET NIG023 and beneath the existing anticlinal structure. The reverse fault motion of this event is considered to contribute the growth of the anticline. On the other hand the secondary fault plane, which was recognized clearly from the crustal deformation data inferred from InSAR, released relatively small or negligible amount of the moment according to our examination. It might have been the deformation caused by the aftershock occurring just after the main shock.

Keywords: 2011 Northern Nagano earthquake, Source process, Strong ground motion, Inversion analysis, InSAR, Anticlinal structure