Study on long strike-slip fault model with heterogeneous dynamic stress drops on asperities

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Oana *et al*. (2013) has established the long strike-slip fault model for a scenario earthquake along the Median Tectonic Line fault zone using the procedure for evaluating the fault parameters by Dan *et al*. (2011), and has simulated the strong ground motions. On that fault model, the dynamic stress drops on the asperities have been homogeneous. However, this is unnatural because the all stress drops on the asperities must be inhomogeneous in the actual earthquakes. How we consider the heterogeneity of the fault rupture is very important subject on the strong motion prediction, because the heterogeneity will have great effects on the spatial distribution of strong ground motions along a fault, especially along a very long fault. The uncertainty of the fault parameters also should be considered into the evaluation of the fault parameters.

In this study, for the strike-slip fault, the procedure for establishing the fault model which takes into account the heterogeneity of the dynamic stress drops on the asperities is examined, and then the spatial strong ground motions are simulated using the fault model based on the procedure. And also, some fault models with the uncertainty of the rupture starting point, the layout of the asperities, and the relationship between the asperity area and the dynamic stress drop on the asperity are established, and then the spatial strong ground motions are simulated using these fault models.

First, the procedure for establishing the fault model to give each asperity the heterogeneous dynamic stress drop is examined. Concretely, first, the probability density distribution of the stress drop is calculated based on the data of the stress drops on the strong motion generation areas of the past earthquakes by previous studies. And then, the procedure is proposed, that gives each asperity the dynamic stress drop corresponding to the frequency of the midpoint of the probability density distribution which is equally divided by the number of the asperity. Here, to satisfy the all relationships among the fault parameters of the asperity model is impossible. So we preceded satisfaction of the relationship formula of the seismic moment, and allowed an error between the obtained short period spectral level and the relationship formula of the short period spectral level. But the error became smaller than about 6 % of the short-period level of the fault model with the homogeneous dynamic stress drops on the asperities. As one of the ideas, we assumed that the relationship between the ratio of the asperity areas and the ratio of the dynamic stress drops on the asperities is random.

Next, for a scenario earthquake along the Median Tectonic Line fault zone, we established the long strike-slip fault model with the heterogeneous dynamic stress drops on the asperities based on the above proposed procedure, and also simulated the strong ground motions by the stochastic Green's function method. As a result, the deviation for the average of the attenuation relation by Si and Midorikawa (1999) of PGA became 0.20 and that of PGV became 0.16. Each deviation is smaller than 0.25, 0.23, which are derived from Si and Midorikawa (1999). It is concluded that this result is relevant, because the attenuation relation is based on a lot of observed records of various earthquakes and sites, while this study targets for the specific earthquake, the local pass, and the local site condition.

Finally, we examined the effect of the uncertainty of the source parameters for the strong ground motions. In the cases of the various rupture starting points, the deviation for the average of the attenuation relation of PGA became 0.23 and that of PGV became 0.21. In the cases of the various layouts of the asperities, those became 0.22 and 0.17, respectively. In the cases of the various relationships between the asperity area and the dynamic stress drop on the asperity, those bacame 0.20 and 0.17, respectively.

Keywords: Very long fault, Heterogeneity, Strong motion prediction

Establishing procedure of evaluating fault parameters for predicting strong motions from intra-slab earthquakes with M8

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For precise prediction of strong motions from intra-slab earthquakes, it is necessary to establish a new procedure of evaluating fault parameters based on the characteristics of intra-slab earthquakes. Although such studies had been conducted by Sasatani et al. (2006) and Dan et al. (2006), procedures of evaluating fault parameters were not fully validated by reproduction of the actual earthquake records. So, Arai et al. (2013) simulated the ground motions of the intra-slab earthquake that occurred off the coast of Miyagi Prefecture on April 7, 2011, and they pointed out the problem of existing procedures of evaluating fault parameters and suggested the ideas to overcome the problem. Hence, in this study, we simulated the ground motion of the intra-slab earthquakes with M8, the 1993 Kushiro-oki earthquake of January 15 (Mw 7.6) and the 1994 Hokkaido Toho-oki earthquake of October 4 (Mw 8.2), using the procedures of evaluating fault parameter proposed by Arai et al. (2013) and we pointed out the problem of the procedure.

In the case of the intra-slab earthquakes of the 1993 Kushiro-oki earthquake and the 1994 Hokkaido Toho-oki earthquake, there was a possibility that the results of evaluation of strong ground motions using the equation of the short period spectral level proposed by Sasatani et al. (2006) or Dan et al. (2006) became too small. So, we tried to use the procedures of evaluating fault parameter proposed by Arai et al. (2013). But, the fault model of the 1994 Hokkaido Toho-oki earthquake was unnatural because the short period spectral level of the earthquake estimated by Morikawa and Sasatani (2004) was too large. For this problem, we developed the new fault model using a method to reduce the fault area while increasing the short period spectral level. We also developed the fault model using a crack model.

We set fault models of the intra-slab earthquakes of the 1993 Kushiro-oki earthquake and the 1994 Hokkaido Toho-oki earthquake, which were derived from the relationships of intra-slab fault parameters by Sasatani et al. (2006), Dan et al. (2006), Arai et al. (2013), and the procedure developed here. And we also set the fault model using a crack model. By using these five fault models, we evaluated strong ground motions by the empirical Green's function method. As a result, in the case of the 1993 Kushiro-oki earthquake, ground motion evaluation results by using Sasatani et al. (2006) and Dan et al. (2006) were smaller than the actual records. On the other hand, ground motion evaluation results by using the Arai et al. (2013), the procedure developed here, and the procedure of using a crack model showed better agreements with the actual records. In the case of the 1994 Hokkaido Toho-oki earthquake, ground motion evaluation results by using Sasatani et al. (2006) and Dan et al. (2006) were smaller than the actual records. And ground motion evaluation results by using Arai et al. (2013), the procedure developed here, and the procedure of using a crack model were larger than the actual records especially in the period of 0.5 seconds or less. This may result from overestimation of the short period spectral level obtained by estimating the S-wave acceleration source spectrum by Morikawa and Sasatani (2004). Actually, the short period spectral level calculated from the fault parameters by Morikawa and Sasatani (2004) is smaller than the short period spectral level obtained by estimating the S-wave acceleration source spectrum. So, we will reconsider the short period spectral level of 1994 Hokkaido Toho-oki earthquake for setting fault models. In this study, we targeted the intra-slab earthquakes of the Pacific Ocean plate. The study on intra-slab earthquakes of the Philippine Sea Plate remains as a future subject.

Keywords: Intra-slab earthquakes, Strong motion prediction, Fault model

SSS23-03   Room:211   Time:May 1 09:30-09:45

Source effects of the intraslab and interplate earthquakes in Miyagi-ken-oki region based on spectral inversion

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Previous studies showed that intraslab earthquakes generate stronger high-frequency waves than interplate earthquakes. For example, Satoh (2004) estimated the high-frequency levels of acceleration source spectra for seven intraslab earthquakes and four interplate earthquakes in Miyagi-ken-oki region. Their result showed the high-frequency level of intraslab earthquake is 3 to 4 times higher than that of interplate earthquake on the average. On the other hand, Katoh et al. (1999) estimated the excitation strength of high-frequency strong motions for intermediate-depth earthquakes based on the peak ground accelerations (PGA). Their result showed the focal depth is a key parameter controlling the PGA amplitudes rather than the difference of tectonic environments, such as intraslab or interplate earthquakes. Thus, the reason for the excitation strength of high-frequency waves of slab earthquake varies among studies, and this problem requires more precise investigation.

In this study, spectral inversion of NIED K-NET strong motion data is done to evaluate source effects of the intraslab and interplate earthquakes in Miyagi-ken-oki region. Then, seismic moments and corner frequencies are estimated from the evaluated source effects, and the high-frequency levels of the earthquakes are determined.

From the comparison between the intraslab and interplate earthquakes, the high-frequency levels of the former are 2 to 3 times higher than those of the latter. On the other hand, from the viewpoint of source depth, a clear trend is found that deeper earthquakes have higher high-frequency spectral levels. Here, it should be noted that the source depths of intraslab earthquakes are systematically larger than those of interplate earthquakes. Additionally, we find no significant difference between the spectral levels of intraslab and interplate earthquakes that have almost the same source depths. This is also seen for the difference between the spectral levels of upper-plane and lower-plane intraslab earthquakes.

Based on these results, we conclude (1) the trend that intraslab earthquakes have higher- high-frequency level than interplate earthquakes is apparent due to the fact that the former have systematically deeper source depths than the latter, and (2) the high-frequency level does not depend on the difference of tectonic environments, such as intraslab or interplate earthquakes, but on the source depth, and deeper earthquakes have higher high-frequency spectral levels. Difference of 4 times is seen between the high-frequency levels of deeper (~80 km depth) and shallower (~30 km depth) earthquakes for the depth difference of ~50 km.

Finally, we pick up two factors, other than source-originated ones, that may effect the evaluation of the high-frequency level: effect of the waveform difference depending on source depth and depth-dependent Q-value structure. These effects are evaluated quantitatively, and we conclude that they cannot bring such biases as can change the above-mentioned trend of the high-frequency level. Thus, we have successfully enhanced the reliability of our interpretation that deeper earthquakes have higher high-frequency spectral levels.

Keywords: spectral inversion, high-frequency level, intraslab earthquake, interplate earthquake, focal depth

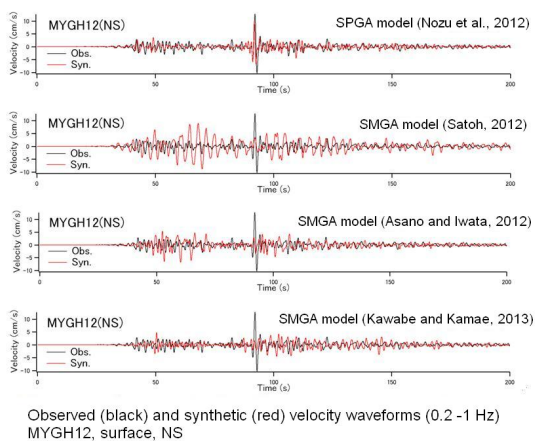SSS23-04　　　　　　　　　Room:211　　　　　　　　　Time:May 1 09:45-10:00

Comparative study of the performance of source models for the 2011 Tohoku earthquake

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The 2011 Tohoku, Japan, earthquake is obviously the first M9 earthquake which was recorded by dense strong motion networks such as K-NET, etc. Several source models have been proposed to explain strong ground motions from this earthquake. It is significantly important to evaluate the relative performance of these models, especially in the frequency of engineering importance. From engineering point of view, the most striking feature of strong ground motions of the Tohoku earthquake is the generation of strong-motion pulses in the frequency range from 0.2 to 1 Hz observed at many sites along the coast of Miyagi through Ibaraki Prefecture. It is significantly important to consider the generation of such pulses in the strong-motion prediction for mega earthquakes, especially when the prediction is aimed at seismic design of structures. To model strong motion pulses from the Tohoku earthquake, a source model including nine subevents with relatively small size (on the order of several kilometers) was developed (Nozu et al., 2012). The model is called the 'SPGA model'. On the other hand, several 'SMGA models' have been proposed for the same earthquake, in which larger subevents (on the order of several tens of kirometers) are considered. In this study, the errors between the synthetic and the observed ground motions are evaluated for each of these source models. The result clearly indicates that the SMGA model cannot reproduce strong ground motions in the frequency range from 0.2 to 1 Hz, which is characterized by strong-motion pulses. In this frequency range, the performance of the SPGA model is significantly better than the SMGA models. The SPGA model also reproduces the seismic intensity proposed by Sakai et al. (2002), which is in good agreement with the building damage. Based on such results, the author concludes that the SPGA model should be used to calculate strong ground motions for a future mega earthquake as long as the strong motion prediction is aimed at structural safety.

Keywords: mega earthquake, the Tohoku earthquake, source model, strong ground motion, SPGA model, SMGA model

Observed (black) and synthetic (red) velocity waveforms (0.2 -1 Hz)
MYGH12, surface, NS

SSS23-05   Room:211   Time:May 1 10:00-10:15

A pseudo point-source model for off Miyagi intraslab earthquake on May 26, 2003

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In a recent research, a pseudo point-source model, which is a simplified version of the conventional characterized source model, was proposed and it was verified that the source model can be applied to the 2011 Tohoku earthquake, Japan. In the source model, the spatio-temporal distribution of slip within each subevent is not modeled. Instead, the source spectrum associated with the rupture of each subevent is modeled. For the future application of the source model, it is important to investigate its applicability to other destructive earthquakes.

In this study, the off Miyagi intraslab earthquake on May 26, 2003 is taken as an example, and the applicability of the pseudo point-source model is investigated. It was revealed that the source model can reproduce the waveforms and the Fourier spectra at least as well as the conventional characterized source model.

Keywords: pseudo point-source model, intraslab earthquake, strong ground motion, the 2003 off Miyagi earthquake

Strong ground motion simulation for the July 23, 2005 northwestern Chiba earthquake by pseudo point-source model

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We propose a pseudo point-source model (Nozu, 2012) of the July 23, 2005 northwestern Chiba earthquake. The model is developed for the benchmark test (Hisada *et al*., 2013) in which various strong ground motion generation methods are compared.

In the pseudo point-source model, detailed spatiotemporal slip distributions within a subevent are not considered. Instead, the source spectrum associated with the rupture of each subevent is specified and it is assumed to follow the omega square model. This model has been applied for some earthquakes and shows good agreement with observations.

With this simplificationi, each subevent involves only six parameters, namely, longitude, altitude, depth, seismic moment, corner frequency and rupture time. In addition to these parameters, strike, dip and rake angles of the subevent are considered in this study in order to investigate the effect of radiation pattern while average value has been used in the previous studies. In this study, it is assumed that the theoretical radiation pattern becomes less evident with the increase of the hypocentral distance divided by the wavelength. This means that when the hypocentral distance is large of the wavelength is short, the radiation pattern is close to the average value rather than the theoretical value and vice versa. A new parameter Q_R is introduced to express this effect that determines how slowly the radiation pattern converges to the average.

The parameters for this particular earthquake are determined as follows. The hypocenter and the mechanism are from Koketsu and Miyake (2005). The seismic moment (=9.11×10^{17}Nm), the density (=3.2g/cm^3) and the S wave velocity (=4.46km/s) in the source region are from the F-net. The corner frequency (=0.75Hz) and Q_R(=10π) are determined so that the synthetic velocity waveforms and the Fourier spectra become consistent with the observations.

The site amplification factor for the K=net or KiK-net sites is from Nozu and Nagao (2005). For other sites (Building Research Institute and UR sites), the site amplification factors are newly determined by using the spectral ratio of the observed records between the target site and neighboring K=net or KiK-net stations. In terms of the Fourier phase information, we pick up 3 earthquakes before the main shock and chose the best one for each site.

As an example of the result, the synthetic Fourier spectra at 3 sites are compared with the observations (see the Figure).

Keywords: pseudo point-source model, benchmark test, the 2005 northwestern Chiba earthquake, radiation pattern, site amplification factor
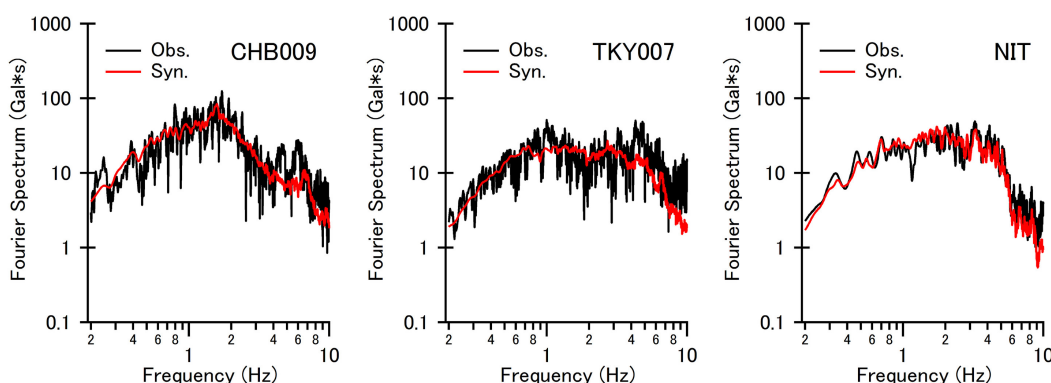
Comparison of acceleration fourier spectrum
(CHB009 and TKY007: K-NET station, NIT: BRI station)

SSS23-07   Room:211   Time:May 1 10:30-10:45

Three-dimensional grid modeling based on analysis of borehole data

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The article presents a 3D geologic modeling method and applies it to build a subsurface 3D geologic model in the northern Tokyo and southern Nakagawa lowlands and the adjacent upland area. The modeling method, using borehole data for ground survey consists of (1) the surface modeling of the base of the Chuseki-so (the latest Pleistocene to Holocene incised-valley fill) , which has been improved by interpolating borehole data and (2) the 3D grid modeling of lithofacies and N-values constrained by the above surface model. The 3D grid model is very useful for not only geologic expression, but also the ground model of seismic response characteristics, because this can be converted to be S-wave velocity and density models.

Keywords: 3D model, ground, grid model, basal surface of the Chuseki-so, Tokyo lowland, borehole data

SSS23-08   Room:211   Time:May 1 11:00-11:15

Three-dimensional structure model for modeling strong motion around the Ryukyu arc

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The Ryukyu Islands have frequently been damaged by large earthquakes and tsunamis since ancient times. For instance, in 1771, gigantic tsunamis are occurred from an earthquake and more than 12000 people died in Yaeyamya Islands. From the point of view of disaster prevention, it is also important to improve the precision of strong ground motion prediction. Here we build a 3D numerical structure model for modeling of strong ground motion, which includes land and ocean-bottom topographies and a seawater layer as well as subsurface structures of the arc side and the PHS slab, partially based on the J-SHIS model for near-surface structure (NIED) and a slab-top depth model of the PHS (Headquarters for Earthquake Research Promotion, Japan). We then try to improve the near-surface structure model in the islands using our original microtremor surveys. We also conduct numerical simulations of seismic motions for three sub-oceanic earthquakes occurring near the Amami Islands, Okinawa Island and Miyako Island to confirm the applicability of the constructed structure model and to check the improvement of the near-surface model.

Keywords: Ryukyu arc, strong motion, simulation

SSS23-09 Room:211 Time:May 1 11:15-11:30

3-D sedimentary layers model and simulation of seismic motions around the Tachikawa fault zone

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Tachikawa fault is one of the most activity faults in the western part of the Tokyo metropolitan area. Strong motion estimation is necessary to know the possible damage due to rupture of the fault considering effects of geological structure. However, a three-dimensional subsurface structural model is not well tuned in the vicinity of the fault.

In this study, we estimated a three-dimensional structure of deep sedimentary layers around the Tachikawa fault zone using Rayleigh wave phase velocity and horizontal-to-vertical spectrum obtained from microtremor explorations and receiver functions from the obtained records of the K-NET, KiK-net and SK-net. And we simulated seismic ground motions around the Tachikawa fault zone using the three-dimensional finite difference method to validate of a three-dimensional structure of deep sedimentary layers.

To accomplish it, we first conducted the array observations of microtremors at 12 sites around the Tachikawa fault. Rayleigh-wave phase velocity at periods from 0.5 to 5.0 seconds was estimated from a frequency-wave number spectral analysis of the microtremors. We next conducted the observations of microtremors at 268 sites on nine lines across the Tachikawa fault zone. Predominant periods of the H/V spectrum clearly indicated differences of subsurface structure across the Tachikawa fault.

Then, we conducted the joint inversion of the phase velocity and the receiver function to a P and S-wave velocity profile based on the simulated annealing method. P-wave velocities, S-wave velocities and thickness of individual layers are inverted very well, and the S-wave velocities of the inverted profile are 0.5, 0.9, 1.5, 2.4 and 3.2km/s. We constructed a three-dimensional structures of the deep sedimentary layers in this area from integrating the 1-D S-wave velocity profiles at all the stations. The basement depth at hanging-wall side of the Tachikawa fault is larger than that at foot-wall side with a difference of about 1.7km in the 3-D model.

Finally, we simulated seismic ground motions around the Tachikawa fault zone using the three-dimensional finite difference method considering three-dimensional velocity structure down to 50km. The results indicate that the maximum accelerations in simulated waveforms were similar to the observed one.

Keywords: Tachikawa fault zone, array microtremor exploration, Rayleigh wave phase velocity, 3-D sedimentary layers model, 3-Dfinite difference method

DETERMINATION OF S-WAVE VELOCITY STRUCTURE BY MICROTREMOR ARRAY OBSERVATION IN TEKIRDAG AND ZEYTINBURNU (TURKEY)

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The use of environmental vibration recordings (microtremors) is cost effective and easily collected data for site characterization that is a component of microzonation mapping and has become very popular around the world in the last years.

Local site conditions have a major effect on the level of ground shaking. For this reason we carried out microtremor measurements by using circular small array configuration at twenty one locations in Tekirdag, four locations in Zeytinburnu and one location in Yesilkoy. In addition to eight large array measurements for estimating S-wave velocity structures of shallow deeper soil formations for site effect analysis. These sites were selected by considering the different geological units (i.e. recent landfill, clay stone, silt stone, alluvium, lime stone, sand) in the cities. We also collected data on five buildings in Tekirdag in order to understand dynamics properties of buildings.

We estimated the phase velocities of Rayleigh waves at each site from the vertical components of recorded microtremor data by using Spatial Autocorrelation (SPAC) method. Obtained phase velocity dispersion curves are varied from area to area. The obtained phase velocities range from 100 m/s to 750 m/s along the coastline in Tekirdag while, they range from 200 m/s to 500 m/s for Zeytinburnu area.

Genetic Simulated Annealing Algorithm technique was applied for inversion of phase velocities to estimate 1-D S-wave velocity structures beneath the sites. The inverted Vs profiles are not uniformed. The preliminarily results show that similar phase velocity changes have been seen at the low and the high periods on the different geological units along the parallel direction of the coastline. When we check the velocity changes from coastline toward the inland, we can see the different phase velocities on the different geological units.

Keywords: Microtremor, Spac, S-wave velocity, Tekirdag, Zeytinburnu, Turkey

SSS23-11   Room:211   Time:May 1 11:45-12:00

Characteristics of long-period strong ground motion in the Keihin-area during the 2011 Tohoku earthquake

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The velocity response spectra of 5% damping calculated from the observed data in the Keihin area during the 2011 Tohoku Earthquake had no significant peak at period of around 8 s and had peak over 100cm/s at period of around 3 s. The acceleration seismograms had spindle-shaped envelope and peak accelerations were recorded about 120 s after S-wave on-set. The maximum velocity response at period of around 3 s was recorded in the first half part of waveforms. It is important to realize the difference of wave propagation characteristics between in the first half part and the later part of the waveforms. In this article, the propagation characteristics of long-period strong ground motions during the 2011 Tohoku Earthquake were studied by semblance analysis using the data observed in the Keihin area.

Sixteen strong motion observatories in the Keihin area were used for array analysis. The major axis of the array area is about 18 km and minor axis is about 9km. Distance between adjacent observation points is from 0.6km to 5km. We performed semblance analysis using narrow-band pass filtered waveforms and evaluated the phase velocity for each time sections from the peak point of semblance in slowness plane. The center periods of the filters were 1, 2, 2.5, 3, 4, 5, 6, 7, 8, 9, 10, 12, 15 and 20 s. The length of time window for analysis was 20 s and the time windows were opened every 10 s in wave traces.

The peak semblance values were high for longer period waveforms and were lower value for short period waveforms. The value at period of 1 and 2s were lower than 0.5. The values calculated from large array data were lower than those from small array data. The semblance values in first part of waveform were high but the values in the later part show lower value. The phase velocities in first half part are over 3 km/s for all case. The phase velocities in later part were 1 to 2 km/s and showed the dispersion characteristics. The back azimuths of wave propagation in the first part indicated the epicenter direction but those in later part did not indicate constant direction especially in short period range.

To examine the relation between this dispersion characteristics and underground structure, we calculated phase velocities of surface waves using the underground structure model. The phase velocities evaluated in the first part were faster than phase velocity of the fundamental mode. The phase velocities evaluated for several last time windows in the later part coincided with the phase velocity of the fundamental mode. These characteristics are similar to the results from the data observed the Tokyo lowland area [Uetake (2013)].

Judging from the property of the acceleration waveform and a result of the semblance analysis, the waves caused large response in a period of 2-3 s were more likely to be a body wave not a surface wave of the fundamental mode.

Keywords: Long-period strong ground motion, the 2011 Tohoku earthquake, Semblance analysis, Phase velocity, Keihin area

SSS23-12 Room:211 Time:May 1 12:00-12:15

Characteristics of Long-period Ground Motion in the Osaka Sedimentary Basin due to the 2011 Great Tohoku Earthquake

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The 2011 great Tohoku earthquake (Mw 9.0) occurred on March 11, 2011, and the largest aftershock (Mw 7.7) occurred in the Ibaraki-oki region, adjacent to south boundary of the mainshock's source region. Long-period ground motions (2?10s) of large amplitude were observed in the Osaka sedimentary basin about 550-800km away from the source regions during both events. We collected the strong motion records in and around the Osaka basin and analyzed the long-period ground motions. The amplitude of horizontal components of the ground motion at the site-specific period is amplified at each sedimentary station and its duration is prolonged. The predominant period is around 7s in the bayside area inside the Osaka basin where the largest pSv among the stations inside the Osaka basin were observed. The pSvs at the bedrock sites surrounding the Osaka basin also have their peak values around 7s.

Then, we focus on the propagation characteristics from the source region to the Osaka basin. We compared the pSvs of 7s at the sedimentary stations in the Osaka basin with those in the Kanto basin. The maximum pSv among the Osaka basin is comparable to the maximum pSv among the Kanto basin whose fault distance is about 500km nearer than the Osaka basin. Moreover, the amplitude of observed pSvs is systematically larger than prediction from the empirical attenuation relationship by Kataoka et al. (2008) at non-sedimentary stations in the region between the Nobi and Osaka basins. The large long-period ground motions in the Osaka basin might be generated by the combination of propagation-path and basin effects.

Thus, we simulate ground motions due to the largest aftershock using the three-dimensional Finite Difference Method (GMS; Aoi and Fujiwara, 1999). The reason we use the largest aftershock is that this event has a relatively small rupture area and simple rupture process compared to the mainshock. The size of the model space is 730km (EW) x 330km (NS) x 100km (Vertical) including the source region and the Osaka basin. A three-dimensional velocity structure model based on the Japan Integrated Velocity Structure Model (Koketsu et al., 2008, 2012) is assumed. The minimum S-wave velocity is 350m/s and the grid spacing in the sedimentary layers is 200m for horizontal direction and 100m for vertical direction, respectively. The minimum effective period in this computation is 3s. We estimated a point source using the long-period ground motions (4-10s) at a station close to the source region (KiK-net CHBH14) and used it for our simulation.

We compared the synthetic and observed waveforms in the periods of 4-10s. As well as the observed ones, the amplitude of synthetic waveforms was amplified and the durations were prolonged at the sedimentary stations in the Kanto basin, the Nobi basin and the Osaka basin. The feature of the attenuation relations in the region between the Nobi basin and the Osaka basin was qualitatively reproduced. At the period of 7s, the amplitudes of synthetic waveforms were little underestimated in the Osaka basin.

Finally, we simulate the ground motion during the mainshock. The model space is 730km (EW) x 400km (NS) x 100km (Vertical). The grid interval and velocity structure model are same as those for the largest aftershock. We assume two point sources based on the two southern SMGAs of the four SMGAs estimated by Asano and Iwata (2012). As a result of the simulation, the synthetic waveforms reproduced the observed ones qualitatively. Therefore, we conclude that the large long-period ground motions in the Osaka basin during both events mainly resulted from the combination of those two SMGAs, propagation-path and basin effects.

Long-period ground motion evaluation for the Nankai Trough megathrust earthquakes

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We evaluate long-period ground motions associated with the Nankai Trough earthquakes (M8~9) in southwest Japan. Large interplate earthquakes occurring around the Nankai Trough have caused serious damages due to strong ground motions and tsunami. Such large interplate earthquake potentially causes damages to high-rise and large-scale structures due to long-period ground motions. The long-period ground motions are amplified particularly on sedimentary basins, where big cities have been established. Therefore it is important to evaluate long-period ground motions as well as strong motions and tsunami for the anticipated Nankai Trough earthquakes.

The long-period ground motions are evaluated by the finite difference method (FDM) using " characterized source models " and the 3-D underground structure model. The parameters of the characterized source model are determined based on a " recipe " for predicting strong ground motion [Earthquake Research Committee (ERC), 2009]. We construct various source models (more than 300 scenarios) assuming various possible source parameters, including rupture area, asperity configuration, and hypocenter location. Each source region is determined by " the long-term evaluation of earthquakes in the Nankai Trough " published by ERC. The asperity configuration and hypocenter location control the rupture directivity effects. These parameters are important because our preliminary simulations are strongly affected by the rupture directivity (Maeda et al., 2013). We apply the system called GMS (Ground Motion Simulator) for simulating the seismic wave propagation based on 3-D FDM scheme using discontinuous grids (Aoi and Fujiwara, 1999) to our study. The 3-D underground structure model used in the FD simulation is the Japan integrated velocity structure model (ERC, 2012).

We evaluate the long-period ground motions using the peak ground velocity (PGV) and velocity response spectra (Sv). The simulation shows a large variation of PGV and Sv at a site. The large variation is important to understand the seismic hazard. The variation at the Kanto region, an eastern extension of the source area, seems larger than those at the Nobi and Osaka regions. The scenarios with wider source area have larger PGV and Sv than those with smaller source area. The large number of simulations of this study allows us to select scenarios that correspond to representative (e.g. average and maximum) response spectra at each site.

Keywords: Nankai Trough, long-period ground motion, megathrust earthquake, hazard assessment, GMS

SSS23-14   Room:211   Time:May 1 12:30-12:45

Long-period ground motion evaluation for the Sagami Trough megathrust earthquakes

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[1]National Research Institute for Earth Science and Disaster Prevention, [2]Mizuho Information & Research Institute, Inc.

It is important to assess seismic hazard in consideration of uncertainty and occurrence frequency in order to mitigate disasters from future earthquake. Iwaki et al. (2013) examined the influence of the long-period ground motion on uncertainty of asperity (strong motion generation area) or hypocenter location, and the heterogeneity of rupture velocity or slip direction for megathrust earthquakes occurring at the Sagami Trough region. They showed that the asperity or hypocenter location largely affects to the amplitude and predominant period of simulated long-period ground motions. Based on their results, we simulate long-period ground motions by a large number of source models considering the uncertainty of asperity or hypocenter location, and we try to assess long-period ground motion due to megathrust earthquakes occurring at Sagami Trough by evaluating the simulation results statistically.

We set ten source regions containing Taisho and Genroku earthquakes by changing those from Iwaki et al. (2013) referring the model by Central Disaster Council (2013). The range of moment magnitude (Mw) is 7.9 to 8.6 and total number of source model is more than 150. We use a "characteristic source model" and source parameters are evaluated by following the method in "Recipe" by Headquarters of Earthquake Research Promotion of Japan. We use a velocity structure model by Earthquake Research Committee (2012) but we revise the topography of the Philippine Sea plate based on recent researches. The long-period ground motions are simulated using a 3D finite difference method with discontinuous grid coded by Aoi and Fujiwara (1999). As long-period-ground motion hazard assessment, we first calculate average and slightly large (i.e. +1 sigma; sigma is the standard deviation) amplitude of peak velocity and velocity response spectrum whose natural period is 5, 7 and 10 seconds respectively on engineering bedrock for every ten source region. And then we integrate them by assuming the "weight" which corresponds to occurrence frequency of each source region.

Although a large number of source models are set up in this study, the uncertainty on the megathrust earthquake occurring at Sagami Trough cannot be covered completely. So it should be required to examine much source models. On the other hand, the source region of magnitude 8-class earthquake at Sagami Trough extends to beneath the metropolitan area. In addition, it is said that the occurrence of the magnitude 7-class earthquake, which does not take in this study, is imminent in southern Kanto region. It is necessary to advance broadband ground motion hazard assessment also including a short-period ground motion.

Keywords: long-period ground motion, seismic hazard assessment, Sagami Trough, megathrust earthquake, GMS

SSS23-15　　　　　　　Room:211　　　　　　　Time:May 1 14:15-14:30

Emplical ground motion model for long period motions and for long distance -Distance dependent geometrical spreading ter

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The GMPEs have been proposed by Sato et al.(2012), Kataoka et al.(2008), and Yuzawa and Kudo(2011). For predictions of long period ground motions on Kanto Plain for the Nankai Trough mega earthquake, the proposed GMPEs cannot be adopted because of the deficiency of applicable distance ranges. In order to establish an adoptable GMPE for long distance, we investigate the distance dependent geometrical spreading term.

We used records for magnitude equal to or greater than 5.0 and distance less than 1000 km. The dataset used in this study is provided by F-net, because of high sensitivity for long period motions and continuous recordings. Since the F-net stations can be regarded as hard rock sites, the site term was not taken into account in the regression.

First, we use a constant geometrical spreading and anelastic attenuation for distance. The regression curve at the 20sec of period decays more slowly than the average of records in the short distance less than 100km, and decays more steeply than records in the longer distance. It implies that the GMPE with a constant geometrical spreading term may underestimate near the source region and in the longer distance.

In the long period range, the dominance of seismic wave changes from the body wave to the surface wave according to the travelling distance, and the slope of the geometrical spreading depends on distance. We will evaluate the geometrical spreading term in the separated distance range to reveal how the geometrical spreading changes.

Keywords: long period motions, long distance, geometrical spreading

SSS23-16 Room:211 Time:May 1 14:30-14:45

Long-Period Ground Motion Prediction Equations and Their Application to the Magnitude Estimation of Large Earthquakes

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[1]Earthq. Res. Inst., Univ. Tokyo

We developed long-period ground motion prediction equations (GMPEs) for peak ground velocities (PGVs) and peak ground displacements (PGDs) in a period range of 5-30 s. We only used strong motion data of KiK-net downhole stations located in layers of shear-wave velocities equal to or greater than 2000 m/s. We confirmed that the site effects due to surface geology for long-period PGVs and PGDs can be ignored at these observation stations. The dataset consists of 20 earthquakes of $6 \leq M_w \leq$ 9.1 occurred in and around Japan. Two-stage regression analyses were carried out to derive the GMPEs. We fit the data with bilinear regression lines bending at M_w 7.5. Additional factors of focal depth and earthquake type were found to enhance the fitting with the observed data. Our developed long-period GMPEs predict the PGVs and PGDs of crustal earthquakes are larger than those of inter-plate and intra-plate earthquakes. The attenuation coefficients presented in the current study indicate that the long-period PGVs and PGDs increase by increasing depth.

We used the long-period GMPEs developed in this study to estimate the moment magnitude by fitting observed PGVs and PGDs at period range of 5-30 s with GMPEs. We estimated the magnitudes of the same 20 earthquakes and the 2013 Awaji Island earthquake (M_w 5.8) recorded by downhole accelerometers of KiK-net. The results are consistent with the moment magnitudes from the Global CMT project. The method is useful to estimate the magnitude of giant earthquakes such as the 2011 Tohoku earthquake (M_w 9.1). The proposed method can estimate the moment magnitude quickly if information of source area is available.

Keywords: long-period ground motion, ground motion prediction equation, moment magnitude, PGV, PGD

SSS23-17 Room:211 Time:May 1 14:45-15:00

Evaluation of random errors of displacements and velocities from strong motion records

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Strong motion accelerographs have been deployed worldwide to monitor the ground shaking of the Earth and the recorded accelerograms have been used to recover the velocities and displacements by integration. In spite of their fundamental importance in seismology and earthquake engineering, few works address the error estimates of the derived velocities and displacements. Although accelerographs have been used to compute velocity and displacement waveforms for more than 80 years, we show that no publications on error estimates of computed velocity and displacement waveforms are correct from the statistical point of view. We show that the error estimates of the velocities and displacements obtained from accelerograms in the earthquake literature approach to zero as the sampling interval of accelerographs tends to zero; these are erroneous from the statistical point of view. As a result, we present a set of formulae to correctly estimate the errors (or variances)of the integrated velocities and displacements from accelerograms. In addition, we also derive the covariances between the velocities and displacements.

SSS23-18   Room:211   Time:May 1 15:00-15:15

Earthquake detection from strong ground motion observation network in Himalaya, India

MASUDA, Tetsu[1]* ; KOKETSU, Kazuki[1] ; TAKANO, Kiyoshi[2] ; FURUMURA, Takashi[2] ; OKI, Satoko[3] ; ITO, Takamori[3] ; CHADHA, Rajender kumar[4] ; SRINAGESH, Davuluri[4] ; SRINIVAS, Dakuri[4]

[1]Earthquake Research Institute, [2]University of Tokyo, [3]Keio University, [4]National Geophysical Research Institute

It is an important subject to establish the technical issues and environment of data acquisition and analysis of natural hazards for the disaster mitigation, the first aid and recovery planning. The Indo-Japanese collaborative project on 'Information Network for Natural Disaster Mitigation and Recovery' of 'Science and Technology Research Partnership Sustainable Development International Collaborative Research Program' supported by JST and JICA, Japan initiated strong ground motion observation, crustal movement measurement, and building vibration measurement in Indo-Gangetic plain and foot hills of Himalaya, India.

We started the strong ground motion observation network with deployment of broadband velocimeters and digital equipments at 26 sites near the seismic active region in Himalaya, India by October 2012. The continuous time history of ground motion is digitally recorded with high resolution. Because of the broadband response of the sensor and the high resolution of the recorder, it is expected that the long- period motions or weak ground motions from small local earthquakes and distant earthquakes will be recorded as well as the short-period strong ground motions. It is a necessary task for the seismic data analysis to detect earthquakes using continuous records from the network. In this paper, we present a method developed for fast and precise earthquake detection from continuous records of the network.

The stations of the network are located in the compounds of local schools. The ambient noise is not always low but it changes as well as contains abrupt increases. We developed a detection method with simple algorithm adequate for the noisy circumstances. We compared our detections with the earthquakes reported in the NEIC catalogue. Our results show that the network detected all earthquakes of magnitude 7 or more, more than 90% of magnitude 6.5 through 6.9, more than 50% of magnitude 6.0 through 6.4 regardless of epicentral distances, and more than 80% of magnitude 6 or more from epicentral distances less than 100 degrees.

Several local earthquakes with short S-P times which were not reported in the NEIC catalogue were also detected by the network. Local seismicity is an index of the stress status, and detection of local earthquakes is important to understand the stress distribution in a small region. The preliminary results show that the network will provide data from local and global earthquakes to study the local seismic activity in the Himalayan region, the propagation path effects from the source to the stations, amplification effects at sites, the physical process of the seismic source, and subsurface velocity structure.

Keywords: strong ground motion, observation, network, earthquake detection

SSS23-19   Room:211   Time:May 1 15:15-15:30

Liquefaction damage expansion caused by the generation of surface waves from base end section

NAKAI, Kentaro[1]* ; NODA, Toshihiro[1] ; MURASE, Kotaro[1] ; ASAOKA, Akira[2] ; SAWADA, Yoshihiro[2]

[1]School of Engineering, Nagoya University, [2]Association for the development of earthquake prediction

The 2011 off the Pacific coast of Tohoku Earthquake caused liquefaction to occur in reclaimed lands in Urayasu City and in other wide areas of reclaimed land along Tokyo Bay. One of the important characteristic of the observed liquefaction damage is that the level of liquefaction damage was nonuniform spatially, and the variation in the damage levels was large. The difference in damage levels in various parts has often been explained by the presence/absence of past ground improvement and by the difference in the dates of reclamation work. From the boring survey at Urayasu, thin layer of soft alluvial clay is located directly under the liquefiable layer on the inland side where liquefaction damage was small. However, the basement layer is inclining towards coast side and alluvial clay layer is increasing in thickness as approaching to the coast where liquefaction damage was severe. This paper examines the cause of extensive and nonuniform liquefaction damage observed in Urayasu City by focusing attention on the stratum inclination at the deeper part of the liquefiable layer with the use of 2D elasto-plastic seismic response analysis of the multi-layer ground. The analysis code employed in this report was the soil-water coupled finite deformation analysis code GEOASIA (Noda et al. 2008), which incorporates an elasto-plastic constitutive model (SYS Cam-clay model; Asaoka et al. 2002) that allows description of the behavior of soils ranging from sand through intermediate soils to clay under the same theoretical framework.
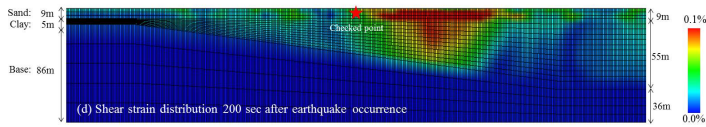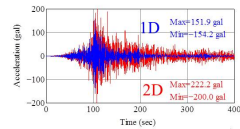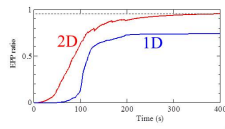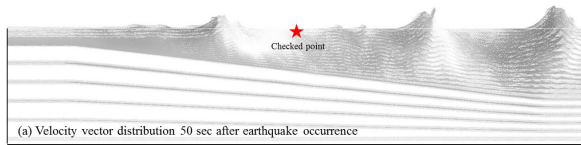
Fig.1 (a) illustrates the velocity vector distribution 50 sec after earthquake occurrence. Only the area around the sloped part is shown in this figure, and the scale in the vertical direction has been magnified by 2 times. Surface waves generate at the base end section of the inclination which shows orbit in a counterclockwise direction with ongoing wave propagation to the right-hand side. Excess pore water pressure ratio at the liquefiable layer is shown, superimposing the result of 1D analysis with same stratigraphic composition at the point. 2D analysis result shows liquefaction (excess pore water pressure ratio is greater than 0.95), even 1D analysis did not liquefy (Fig.1 (b)). In the case of 2D analysis, in addition to the magnitude, duration time of the oscillation increases in subsurface layer accompanied by the generation of surface waves (Fig.1 (c)). Excess pore water pressure ratio of 2D analysis continues to increase for a long period even after the primary earthquake motion. Fig.1 (d) illustrates the shear strain distribution 200 sec after earthquake occurrence. Although shear strains are small in the non-inclined horizontal strata, large strains are produced in the subsurface liquefiable layer. Furthermore, this strain distribution is nonuniform and localized even assuming homogeneous initial conditions for subsurface layer. The nonuniform, localized shear strain are due to the existence of the sloped boundary. In other words, in addition to the vertical component of seismic movement being generated by the stratum slope, multi-dimensional propagation is also exhibited because of complex reflection behavior in the diluvial layer. Moreover, in sloped layers such, the danger of liquefaction is increased compared with the one-dimensional model. The actual liquefaction damage observed in Urayasu City was heavy in the sloped stratum locations where midterm reclamation work had been executed. This behavior resembles the results of the analysis carried out here. The current analysis shows that even in the case of homogeneous geomaterials, stratigraphic nonhomogeneity results in large variations in ground deformation behavior and that such deformation becomes particularly large in sloped strata locations. These things cannot be taken into consideration in one-dimensional analysis and highlight the necessity of performing multi-dimensional effective stress analysis.

Keywords: liquefaction, stratum inclination, surface wave, effective stress analysis

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(a) Velocity vector distribution 50 sec after earthquake occurrence

(b) Excess pore water change at checked point ★

(c) Acceleration response at checked point ★

(d) Shear strain distribution 200 sec after earthquake occurrence

SSS23-20 Room:211 Time:May 1 15:30-15:45

Relationship between liquefaction occurrence ratio and strong ground motion duration for the 2011 off the Pacific coast

SENNA, Shigeki[1]* ; WAKAMATSU, Kazue[2] ; MATSUOKA, Masashi[3]

[1]NIED, [2]Kanto Gakuin University, [3]Tokyo Inst. Tech

In this study, We first reorganized the points of liquefaction in the 2011 off the Pacific coast of Tohoku Earthquake and plotted the number of liquefaction points in 250m mesh units, because many areas had not been investigated or were insufficiently investigated, as revealed in the information on liquefaction points disclosed and summarized by December 2011.

Next, using the reorganized liquefaction data, the seismic intensity were calculated and the 'real-time seismic intensity' noted by Kunugi et al.(2008) based on the waveforms recorded by seismographs of K-NET, KiK-net, the Meteorological Agency, and the municipalities and examined the effects of earthquake duration on liquefaction using the data on liquefaction points and the method of Matsuoka et al.(2011) to calculate the liquefaction occurrence, so that the liquefaction occurrence can be examined with consideration of the effect of the duration of seismic motion in the March 11 earthquake.

Keywords: Occurrence of liquefaction, Continuation time of strong ground, Geomorphologic classification, Fragility curve, Regional peculiarity

The Wave Features Theory and Soliton

NISHIZAWA, Masaru[1]*

[1]none

1. The eye of Writers under the title " The Great Kanto Earthquake (of 1923) " correctly spotted, the demolished style difference between the large and small structure.

2. Fourier Spectrum of Earthquake Motion near the observatory forms The Normal Distribution (Gaussian Distribution). And The further near the observatory. And The Sharp shape of Normal distribution mean densely the frequency.

Keywords: Wave Features Theory, Soliton, KDV Equation, Nonlinear waves
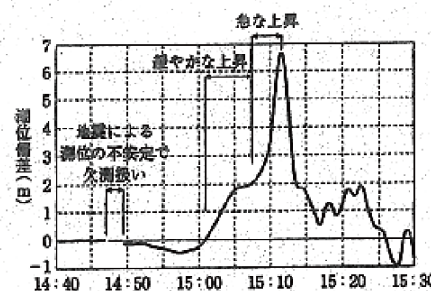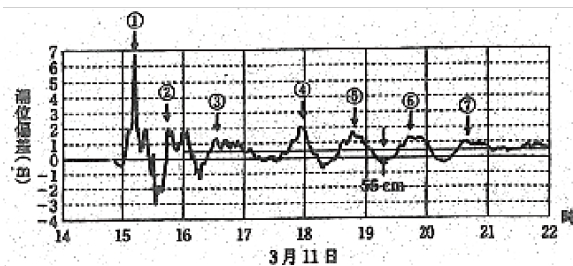
岩手県南部沖のＧＰＳ波浪形の記録（左）と最初の部分の拡大図（右）
国土交通省のデータをもとに作成

Kazuo OIKE
「Massive earthquake in Japan archipelago 」
(Iwanami Library of Science 185，P10)
①：Soliton
②～⑦：Break down of Solitary wave Solitons
Reference：Mikio HINO 「流体力学」
(Asakura Publishing Co., Ltd. (1992))

SSS23-22   Room:211   Time:May 1 16:15-16:30

Seismic hazard karte : A Tool for distribution of seismic hazard information with Multi-index

AZUMA, Hiroki[1*] ; FUJIWARA, Hiroyuki[1]

[1]National Research Institute for Earth Science and Disaster Prevention

1. Overview of seismic hazard karte

NIED distributed the "seismic hazard karte(chart)" in July, 2013. An "seismic hazard karte" is what summarized the earthquake hazard information for every point, arbitrary places can be searched and the diagnosis of the earthquake hazard about the place can be drawn up. A result displays many indices, such as various foundation information, hazard curves, etc. about the danger of an earthquake, like the notice of a medical examination by the view format summarized to A41 sheet using many charts and graphs.

2. Purpose of Development

It was thought possible to spread the recognition to seismic hazard by using for the user itself the form of diagnosing a certain point with the connection as a starting point, from the investigation by HERP, the argument in a comprehensive sectional meeting, etc. Although the seismic hazard karte was dispatch fundamentally turned to the whole average citizen like other seismic hazard information, when it decomposed into use-cases, it assumed roughly dividing and being used in the following domains. For insurance and real estate, as customer-oriented service data. As the teaching materials which teach the tool for advancing a measure at a workshop or a home to the local resident engaged in disaster prevention educational persons concerned and disaster prevention, and the view of the seismic hazard information on the area. It developed by being that it is easy to carry out use, respectively conscious as a sample of the way of expressing a response using J-SHIS Web API which is open API, and designing to IT persons concerned and developers.

3. Distributed Result

There are many echoes from the exhibited beginning and it is thought that effect fixed as one of the how to show the seismic hazard information evaluated across the board by the country was achieved. Nothing new as contents have in the information offered as seismic hazard karte this time, and it is already J-SHIS seismic hazard station offered, was only visualized in a different form. However, receiving a karte "it may be very intelligible. From the thing of having also let the family know who lives in the distance"as a positive thing, many reactions "worth of the possessions affair of our company will be influenced and it will be troubled by it if such a thing comes out" were seen by the negative thing, like when the hazard information is released newly.

4.References.

Seismic hazard karte |http://www.j-shis.bosai.go.jp/labs/karte/ (Japanese only)
Manual |http://www.j-shis.bosai.go.jp/karte-manual (Japanese only)
Description |http://www.yullege.jp/?p=282 (Japanese only)
J-SHIS Web API |http://www.j-shis.bosai.go.jp/api-list (Japanese only)
Hiroki Azuma, Shinichi Kawai and Hiroyuki Fujiwara, 2013, Development of J-SHIS and Applications Using API, Journal of Disaster Research, Vol.8 No.5, 869-877.

Keywords: Seismic hazard, information tool
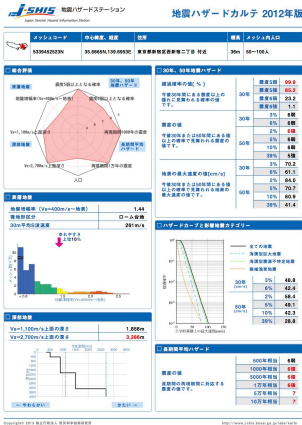
JMA intensity distribution of the 1943 Tottori earthquake derived from immediately conducted questionnaire survey

NAKAMURA, Mariko[1] ; KAGAWA, Takao[2]* ; NOGUCHI, Tatsuya[2] ; NISHIDA, Ryohei[2]

[1]Okayama City Office, [2]Tottori University

Questionnaire surveys were conducted by university of Tokyo immediately after five disastrous earthquakes in 1940s to evaluate modified Mercalli (MM) intensity scale. The raw data of the surveys had been stored long time without following analyses. We have studied explanation of each item in the Questionnaire sheet and developed the relational expressions between MM and JMA intensity scales. Finally, we derived JMA intensities at 1935 sites in southwest Japan, and estimated JMA intensity distributions with almost same resolution as modern intensity observation network. The distribution map suggests radiation pattern of strike slip fault and effect of surface geology. The result is worth of basic information for earthquake disaster prevention.

Keywords: the 1943 Tottori earthquake, questionnaire survey, JMA intensity scale, modified Mercalli scale

Mortality in the East Japan Great Earthquake (4) Infants and elderlies should always suffer heavy rate of deaths?

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[1]TRIES, ADEP, [2]Engr. Fac. Kyoto Univ.

With the aim of clarifying age dependency of mortality in earthquakes we have been conducting a series of studies, just employing a simple division of number of deaths over population in age intervals of 5 or 10 years from area to area in devastated region. What we have found up to now is that there are 2 dominant types approximated by the capital U and J letters in English on the 2 dimensional coordinates of X axis as increasing ages and Y axis as mortality. In case of the 2011 East Japan earthquake, the age dependency in terms of J letter type dominates in most of devastated areas, which suggests that the mortality gets heavier with increasing ages but for infants it stays milder. Such result on age-dependency looks to be apart from our general recognition as infants are very much vulnerable in mortality at many disasters. The discrepancy requests further in-depth studies. In order to settle this issue we attempted two different approaches, that is, 1) comparing natural deaths of certain population with number of accidental deaths by an earthquake (Ozaki. 2012) and 2) introducing a way of evaluating the loss of life expectancy as an weighting factor inversely changing with increasing ages.

Consequently, we succeeded to make clear that infants are still very vulnerable in the meaning of bringing heavy rate of deaths.
Reference
Ozaki; kousei no shihyou, 59, 2012 (in Japanese)

Keywords: East Japan Earthquake, Mortality, Age-dependency, Life Expectqancy

SSS23-P01   Room:Poster   Time:May 1 18:15-19:30

Disaster research in the Toyama Earthquake(1718)

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[1]Iida city Museum

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.

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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[1]Faculty of Engineering, Iwate University, [2]GraduateSchool of Engineeing, Iwate University

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

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

SSS23-P04   Room:Poster   Time:May 1 18:15-19:30

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

SSS23-P05   Room:Poster   Time:May 1 18:15-19:30

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

SSS23-P06   Room:Poster   Time:May 1 18:15-19:30

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

SSS23-P07   Room:Poster   Time:May 1 18:15-19:30

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).

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

SSS23-P09   Room:Poster   Time:May 1 18:15-19:30

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

SSS23-P10 Room:Poster Time:May 1 18:15-19:30

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 region (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

SSS23-P12 　　　　　 Room:Poster 　　　　　 Time:May 1 18:15-19:30

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

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

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.

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

SSS23-P15　　　　　　　　　Room:Poster　　　　　　　　　Time:May 1 18:15-19:30

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×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

SSS23-P16　　　　　　　　Room:Poster　　　　　　　　Time:May 1 18:15-19:30

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^oN are different from ones at the arrays south of 39^oN. 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.

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

SSS23-P18 Room:Poster Time:May 1 18:15-19:30

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

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 × 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

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

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[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