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

SSS26-01 Room:303 Time:May 19 09:00-09:15

Pseudo Shot Records by Seismic Interferometry with VLBI (2)

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We recorded seismogram of VLBI driving at GSI Head Office in April, 2012. Ito et. al. (2012) reported properties of pseudo shot records calculated from VLBI driving, earthquakes, and traffic noise by cross-correlation in the SSJ 2012 Fall Meeting. We report properties of stacked pseudo shot records by VLBI driving, earthquakes, and traffic noise, respectively.

We categorized the pseudo shot records by seeing the original waveforms. We did not use records including obviously two or three kinds of sources. However, we have to note that each record is not free from other sources.

We can see at least a sound wave, surface wave, and other events in T-component of the stacked pseudo shot record with VLBI driving. We also can see events in R-component of the stacked pseudo shot record with VLBI but relatively much poorer than in the T-component. In the stacked pseudo shot records with earthquakes, one H-component that is T-component of the VLBI driving is much better than another H-component that is R-component of the VLBI driving. The almost same results are obtained with traffic noise. The source locations of earthquakes and traffic noise are not considered at the survey line arrangement. In other words, the improvements of these two stacked pseudo shot records are caused by the unclear waveforms with VLBI driving. Therefore, we conclude that it is effective that pseudo shot records are made with T-components seismogram of VLBI driving.

Acknowledgment: We thank the Physical Geodesy Division, Geodetic Department, GSI.

Keywords: seismic interferometry, VLBI, pseudo shot record

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

SSS26-02 Room:303 Time:May 19 09:15-09:30

Development of the cosmic-ray muons detecting system in boreholes to image the fault zone structure

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It is important to assess active fault's dips and dip directions in order to predict the seismic intensity. However, we cannot always get these data by geological surveys because the crush zone is easy to be eroded. In addition, digging has been necessary to know the width and density structure of the crush zone. However, we can easily investigate the structure if we use indirect way by the geophysical exploration. Therefore the technique using cosmic-ray muons, one of the method of the geophysical exploration, was applied to the new way exploring the fault zone structure.

In recent years, it has been shown the usefulness of this method using cosmic-ray muons by successful examples imaging active volcanoes and fault structure(e.g. Tanaka et al., 2007, 2008, 2009, 2011). Using this way, we can obtain the average density along the detecting direction and its result almost only depends on the density of the components. This unique property, which any other methods of the geophysical exploration do not have, may provide useful data unless its heterogeneity at the shallow part of the continental crust. However, traditional muon-detecting devices were set on the ground and caught muons coming only from the sky, so we have not been able to survey the underground structure. It is difficult to miniaturize the traditional muon detecting devise and put it into boreholes because traditional one has a function which detects paths of the muon.

In order to solve this problem, we developed a new technique. We gave up its function detecting their paths and introduced new one which statistically knows coming directions instead. Using this technique, we could miniaturize the muon-detecting devise. Putting it into a borehole, we are able to survey ground structure several hundred meters from the borehole inside. If we give a demonstration and can get a good estimation of the structure near a borehole, we can show it has the ability to assess fault zone structure from one borehole.

We gave a demonstration putting the detector into a well located in Hongo campus, the University of Tokyo, and investigated ground structure. The detector was installed from ground level to 60m depth and inferred the rock density near the well. The result showed good agreement with a past digging investigation data. Its spatial resolution is lower than the traditional one because of the miniaturization, but this result showed it is possible to image underground structure by using cosmic-ray muons.

It is expected as a new method to supply the knowledge of fault zone structure at the shallow part of the crust.

Keywords: muon, borehole, fault

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

SSS26-03 Room:303 Time:May 19 09:30-09:45

Strategic seismic data acquisition and processing for the delineation of subducting slab

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In recent years, the quest for increased precision and channel capacity of receiver system led to the combination of telemetry and autonomous recorders with the deployment of dense seismic array for full-azimuth 3D or 100-200km long 2D survey. Furthermore, multi-scale and multi-mode survey layout has been realized by the simultaneous data acquisition of regional refraction, low-fold wide-angle reflection and standard reflection survey for the several targets on the same seismic line.

In our study, multilateral approach beyond the conventional CMP stack is applied to the multi-scale, multi-mode seismic data for the extraction of reflection patterns related to subducting Philippine sea plate. The high-resolution velocity structure can be estimated by the hybrid profiling of wide-angle reflection and refraction data. The uncertainty of the tomography solutions is estimated using a nonlinear Monte Carlo approach with randomized initial models, and the velocity structure of upper crust is constrained by subsequent forward reflection and refraction modeling. In the last decade, many case studies have demonstrated that the Common-Reflection-Surface (CRS) stack based on paraxial ray theory produces an efficient alternative profile to conventional CMP stack with a pronounced signal-to-noise ratio. The CRS-driven velocity attribute with the short-wavelength structural heterogeneity has the potential imaging capabilities including velocity model for improved prestack depth migration.

In order to build the detailed geophysical model of subducting Philippine Sea plate, we developed a processing workflow based on the combined tomographic analysis of refraction, wide-angle reflection, and CRS-driven reflection data. Through the strategic seismic data acquisition and processing for several reflection suvey around Tokyo metropolitan region, the geometry constraints for subduction megathrust and the connectivity of the spray faults were identified. Further, steady-creep and seismogenic asperities zone related the slip deficit on the plate interface were characterized by the distribution of reflection intensities for relative-amplitude preserved CMP/CRS ensembles.

Keywords: Subducting Slab, Seismic Reflection Profiling, Multi-dip CRS Analysis

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

SSS26-04 Room:303 Time:May 19 09:45-10:00

The seismic experiment with artificial sources at the Nobi fault area (Preliminary Report)

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1) Introduction

The mechanism of the inland earthquakes is related to the concentration of the strain and accumulation of the stress. It is very important to know the relationship between the stress/strain and fault plane. The 1891 Nobi earthquake is one of the biggest inland earthquakes in Japan. We are doing geophysical observations at the area. We have done seismic studies at the Atotsugawa fault area. We obtained several data that the lower crust structure and fluid are very important factors to the cause of the inland earthquake. In the Nobi earthquake area, the seismic tomography studies figured out the existence of a low velocity structure beneath the fault. The low velocity region continues to the subducting Philippine Sea slab. It is expected that there is some close relationship between the cause of the inland earthquake and liquid in the crust. We did seismic experiment with artificial sources to declare the characteristics of the low velocity zone.

2) Content of exploration

The seismic experiment has done on November 15 and16, 2012. The profile line is located from Fukuchiyama, Kyoto to Ina, Nagano. The length of the profile line is about 280 km. The number of the seismic stations was 1793. Eight artificial sources with dynamite were used. The 500kg and 300kg dynamites are used for 6 and 2 shot points, respectively.

3) Results

We obtained fine seismic record at all of the shots. We can see clear first arrival and later phases. Those later phases seem to the reflected phases from Moho and upper boundary of the subducting Philippine Sea slab. Based on the iso-depth lines of the Philippine Sea slab, which were obtained from seismic studies, the configuration of the Philippine Sea slab is considered to be distorted in this area. The depth of the Philippine Sea slab is shallow at the eastern side. The minimum depth is located beneath the Nobi fault area. On the record section, the reflective zone can be detected at the center part of the profile line. The reflective zone is consistent with the depth of the subducting Philippine Sea slab.

In this area, the resistivity was researched. The low resistivity region was obtained along the fault. We will declare the characteristics of the low velocity region considering the relationship between the resistivity and low velocity regions.

Keywords: crustal structure, artificial source

Japan Geoscience Union Meeting 2013
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SSS26-05 Room:303 Time:May 19 10:00-10:15

Anisotropic feature inferred from receiver function and S-wave splitting analysis around the high strain rate zone

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In the high strain rate zone (HSRZ), E-W compressive stress field is observed, and large earthquakes with M>6 are frequently occurred. In this study, we try to reveal depth-dependent anisotropic feature in this region by using teleseismic receiver functions (RFs) and S-wave splitting information. As a target, we select NIED Hi-net stations N.TGWH and N.TSTH, which are located very close to the HSRZ. For RF analysis, we choose M>5.5 teleseismic events from October 2000 to September 2012. Low-pass filters with fc = 1 and 2 Hz are applied to estimate RFs. In the radial RFs, we find clear positive phase arrivals at 4 s in delay time for both stations. Since this time delay corresponds to 35 km-depth velocity discontinuity existence, these phases may be the converted phases generated at the Moho discontinuity. Seeing the back-azimuth paste-ups of the transverse RFs, we can find polarity changes of later phases at 4 s in delay time at the N.TSTH station. This polarity change occurs for direction of N0E (north), N180E (south), and N270E (west). Although we have no data in N90E (east) direction, this feature implies that anisotropic rocks may exist above the Moho. In order to check this feature, we consider 6-layered subsurface model and compare synthetic RFs with the observation. The first three layers are for thick sediments and upper crust including a dipping velocity interface. The fourth, fifth and sixth layer corresponds to the mid crust, lower crust and uppermost mantle, respectively. The best model infers that the mid- and lower-crust beneath the N.TSTH station should have strong anisotropy whose fast axis directs to the N-S, though the fast axis in the uppermost mantle seems to show E-W direction. At the N.TWAH station, we should consider that thick low-velocity mid crust whose fast axis directs to the N-S in order to explain clear negative phases arriving just before the Moho phase. To check anisotropic feature of these stations, we also apply S-wave splitting analysis to the local events. In order to avoid contaminations of scattered phases, we select seismic waveforms with incident angle less than 35 degrees. We select good S/N records and apply 2-8 Hz butter-worth type band-pass filter to the waveforms. Then, we estimate the leading S wave polarization direction (LSPD) and delay time of each event. We can select crustal earthquakes (< 30 km in depth) and the intermediate-depth earthquakes (80~120 km) which occur along the subducting Pacific slab. For deeper events, LSPD shows NW-SE. On the other hand, only for shallow events, LSPD indicates NNW-SSE. This result is consistent with the feature of RFs. We can conclude that the crustal anisotropic feature beneath these stations corresponds to the lineament on the ground surface, not to the E-W compressive stress field. The LSPD in the uppermost mantle may reflect to the lattice-preferred orientation of anisotropic minerals beneath the stations.

Keywords: High strain rate zone, Receiver function, Anisotropy, NIED Hi-net

Japan Geoscience Union Meeting 2013
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SSS26-06 Room:303 Time:May 19 10:15-10:30

Electrical conductivity structure beneath backarc side of Chubu District, Central Japan, revealed by the Network-MT

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Series of the Network-MT survey was performed in backarc side of Chubu district since 2005. The 1st campaign was performed in the vicinity of the Atotsugawa fault area (source region of the Hietsu Earthquake) from 2005 to 2008. We extended the research region to the west and the 2nd campaign was performed in the vicinity of the Noubi earthquake source region from 2011 to 2013. Since both the Philippine Sea Plate and the Pacific Plate are subducting beneath the area, and the Niigata-Kobe Tectonic Zone, where most significant strain rate accumulation was detected before the 2011 great Tohoku Earthquake by the dense GPS array (GEONET), we aimed at obtaining wide and deep resistivity structure beneath backarc side of Chubu district to investigate dehydration process on the subducting plates and generation mechanism of the Niigata-Kobe Tectonic Zone.

After showing two 2-D cross sections beneath Fuchu-Akigami and Takamatsu-Tsukechi lines obtained from the 1st campaign, 3-D image in the vicinity of the Noubi Earthquake source region obtained from the 2nd campaign will be shown. The 1st and 2nd image show clear correlation between the NKTZ (or active faults in the zone) and crustal and/or mantle wedge conductor, which indicates existence of connected fluids. The 3rd image reveals deep seated conductor beneath along the NKTZ, probably indicating existence of dehydration from the deep seated Pacific slab. Another conductor exists near the surface along the Noubi earthquake source fault, whereas mid-crust beneath the fault zone is highly resistive.

Keywords: resistivity structure, backarc side of Chubu Dstrict, Network-MT, Niigata-Kobe Tectonic Zone, crustal fluid

SSS26-07 Room:303 Time:May 19 10:30-10:45

Local Vp/Vs ratio estimation in earthquake swarm area around Mt. Ontake

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Mt. Ontake is a stratovolcano in the central Japan. After the first historic eruption occurred in 1979, two small phreatic explosions occurred in 1991 and 2007. Since 1976, earthquake swarm activities in the southeast area of Mt. Ontake have been observed continuously. Although the annual number of earthquakes of this swarm has sometimes been up to 2000, the magnitudes of those have been less than M1. In this area, the M6.8 western Nagano Prefecture earthquake occurred on 14 September 1984.

The relationship between occurrence of earthquake swarm and fluid has been discussed (e.g., Nur, 1974). In the earthquake swarm area, fluid supply from lower crust is suggested from electrical conductivity surveys (e.g., Kasaya et al., 2002) and an analysis of Li and Sr isotopic compositions in spring water (Nishio et al., 2009). We estimated local Vp/Vs ratio, which is sensitive to fluid existence, in the source region of earthquake swarm around Mt. Ontake.

We directly estimated Vp/Vs ratio in the source region of earthquake swarm by using method of Lin and Shearer (2007). If dTp and dTs are P and S wave travel time differences for a common station of a pair of nearby events, respectively, Vp/Vs ratio in a micro area can be expressed as Vp/Vs=dTs/dTp where seismic velocity is constant. Given a number of different stations and event pairs, plotted points (dTp,dTs) should be on a straight line with slope Vp/Vs. This slope is obtained using grid search for the line with the minimum perpendicular distance to each plot. Because (dTp,dTs) plots have errors in both dTp and dTs values, we iterated grid search to equalize both dTp and dTs error scales. First, we determined Vp/Vs ratio in a micro area for each seismic station. Then we eliminated stations data in which Vp/Vs ratio did not converge by iterated grid search when we estimate Vp/Vs in a micro area. We used earthquake data from 1997 to 2011 listed in the JMA catalog and we set dimension of a micro area as 0.01 degrees x 0.01 degrees x 1.5 km depth to analyze the data.

At the depth from 4 to 7 km, we obtained Vp/Vs values in micro areas in the earthquake swarm area to be from 1.6 to 1.9. Vp/Vs values were estimated to be about 1.8 for micro areas where many earthquakes occurred. In another area, Vp/Vs values were estimated to be up to 1.9. At this depth seismicity extends to the southeast region of Mt. Ontake. At the depth from 7 to 10 km, Vp/Vs values were larger than those at the depth from 4 to 7 km depth for the whole analyzed areas. Vp/Vs values were estimated to be up to 2.0 in several areas. At this depth seismicity is concentrated in the east and northeast regions from Mt. Ontake. In micro areas where earthquakes intensely occurred, higher Vp/Vs values of about 1.9 were found. At the depth from 4 to 10 km, Vp/Vs values were increased gradually. We also conducted the double-difference tomography using same data set to estimate velocity and Vp/Vs structures around Mt. Ontake. As a result, we found that high Vp/Vs values were estimated in the source region of earthquake swarm area by the both method.

Several high Vp/Vs areas at the depth from 6 to 7 km in this study correspond to the region where deep crustal origin fluid is suggested by the electrical survey and isotopic analysis. The estimated high Vp/Vs values in the shallow area suggest fluid existence.

This study is supported by Multidisciplinary research project for high strain rate zone of the MEXT, Japan.
We thank to use the JMA earthquake catalog in this study.

Keywords: Vp/Vs ratio, earthquake swarm

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

SSS26-08 Room:303 Time:May 19 11:00-11:15

3D seismic velocity structure around Philippine Sea slab subducting beneath Kii Peninsula (3)

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1. Introduction

Kii Peninsula is a part of the source area of Nankai Trough megaquakes and the region through which the strong seismic waves propagate to the big cities in Kansai. Moreover, the rupture starting point is thought to be possibly at off the peninsula. After the 2011 Tohoku Earthquake the assumed source area of the Nankai Trough earthquake was readjusted and extended to a land side deeper portion. The extended portion corresponds to 30 - 40 km depth in the plate boundary, where hydrous minerals in the oceanic crust are dehydrated. The discharged fluids will influence the frictional condition of the plate boundary. Therefore, it is important to estimate accurately seismic velocity structure at these depths.

2. Current results

We carried out linear array seismic observations in Kii Peninsula since 2004 in order to estimate the structure of the Philippine Sea slab and the surrounding area. We have performed receiver function analyses for four profile lines in the dipping direction of the slab and two lines in the perpendicular direction so far. We estimated three dimensional shapes of seismic velocity discontinuities such as the continental Moho, the upper surface of the oceanic crust and the oceanic Moho (Fukui et al., 2012). In addition, we performed seismic tomography with a velocity model embedded the discontinuities and observed travel times at stations in the linear arrays (Shibutani et al., 2012). The results show the following features of the Philippine Sea slab. At the depth of 40 km the oceanic crust shows low velocity anomaly. As we go up to shallower depths, the low velocity anomaly seems to continue to the mantle wedge and to the lower crust. It becomes a large low velocity region at the depth of 16 km under the northwestern part of the Kii Peninsula. It is known that seismic activity is very high in the upper crust above the low velocity region. These features show that hydrous minerals in the oceanic crust are broken down by dehydration at the zone of deep low frequency events, then the discharged fluids flow into the mantle wedge and the lower crust, and reduce the velocity in the regions.

3. Updating the results

In the receiver function analysis, we update the image of S wave velocity discontinuities along Kameyama - Gobo profile line by adding new receiver functions. We make up eight new profile lines by selecting permanent stations and temporary stations in the linear arrays and draw up the receiver function images. We try to estimate more detailed 3D shapes of the discontinuities by interpreting the new images together with those for the above mentioned six profile lines. In the seismic tomography, we add more travel time data. We try to utilize events in wider areas as well as deep focused events in order to improve the resolutions in depths more than 40 km.

We used waveform data from permanent stations of NIED; JMA; ERI, Univ. of Tokyo; Nagoya Univ. and DPRI, Kyoto Univ.

Keywords: tomography, receiver function, Philippine Sea slab, Kii Peninsula, Nankai Trough megaquake

Japan Geoscience Union Meeting 2013
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SSS26-09 Room:303 Time:May 19 11:15-11:30

The estimation of S wave reflector in the northern Kinki region

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In order to forecast earthquakes, it is necessary to estimate more accurately the structures of the crust, such as the shape of reflectors and active faults. In the northern part of the Kinki region, dense seismic observation has been conducted, and we can estimate them with improved resolution. Using the data obtained from this observation network, we did a reflection analysis in the west coast region of Lake Biwa and Tamba region. As a result of the analysis, we found a distinct S wave reflector in the Tamba region. Furthermore, we found that the extent of this reflector is consistent with that of epicentral distribution in the Tamba region.

SSS26-10 Room:303 Time:May 19 11:30-11:45

Travel time change of Toki seismic ACROSS signals observed by Hi-net in Tokai area from 2004 to 2012

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Travel time change of Toki ACROSS signals observed by Hi-net in Tokai region from 2004 to 2012 is reported on. At Toki station, the specifications of seismic signal being transmitted since Feb. 2004 are as follows: <Feb.2004 to Feb.2007> FM signal with a carrier frequency of 13.01 Hz, modulation period 50s in the frequency range 10.25-19.45Hz and ~2700N in spectrum amplitude. <Mar.2007 to ongoing> FM signal with a carrier frequency of 13.005 Hz, modulation period 50s in the frequency range 10.245-19.445Hz and ~2700N in spectrum amplitude. The signal and operational mode of rotary transmitter with the vertical rotation axis are optimized for acquiring the accurate tensor transfer function data in frequency domain and Green's function in time domain between the source and receivers located anywhere.

The major results observed at Hi-net Yaotsu (11.3km form Toki station) and Hourai (56.9km) are as follows: Travel time changes of maximum amplitude phases (including direct P wave, direct S wave and these later phases) were calculated using the cross-spectral method. Secular change of travel time is imperceptible at Yaotsu station. At Hourai station, travel time of seismic ACROSS signals are decreasing at the rate of about 0.5ms per year in S wave, about 0.3ms per year in P wave for several years now. This result may indicate stress accumulation in crust.

Acknowledgement: Hi-net data are provided by National Research Institute for Earth Science and Disaster Prevention, Japan (NIED). Toki ACROSS transmitting station is managed by Japan Atomic Energy Agency (JAEA).

Keywords: seismic ACROSS, cross-spectrum, seismic velocity change, secular change, The 2011 off the Pacific coast of Tohoku Earthquake

SSS26-11 Room:303 Time:May 19 11:45-12:00

Seismic Structure under the Kanto Plain Derived from Receiver Function Analysis by using Improved Deep Subsurface Model

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The S-wavevector receiver function (SWV-RF) is useful for deep borehole records to image the seismic structures below the stations (Takenaka and Murakoshi, 2010). The SWV-RF is derived by deconvoluting the upgoing S-wave component with the upgoing P-wave component of the records (Reading et al., 2003). The most significant difference between the SWV-RF from deep borehole records and standard receiver function from the ground surface ones is relatively robust to the structure model in the SWV-RF. The SWV-RF can eliminate the free surface response and the first P-pulse entirely and give the complete representation of the converted waveform in principle. Murakoshi and Takenaka (2011) and Murakoshi and Takenaka (2012) applied the SWV-RF from the deep borehole records of the Hi-net (NIED) to obtain the seismic structures under the Kanto Plain, Japan. This method needs the structure model from the surface to the sensor location. In this study, we applied the SWV-RF analyis by using improved deep subsurface model for seismic structure under the Kanto plain.

Keywords: receiver function, Kanto Plain, crustal structure, plate structure, deep borehole

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

SSS26-12 Room:303 Time:May 19 12:00-12:15

Attenuation structure beneath the Tokyo Metropolitan area

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The material properties of the complex subduction zone beneath the Tokyo Metropolitan can be estimated by the seismic attenuation Q of seismic waves observed at local seismic stations. Previous studies have provided us only with the large scale attenuation structure for all Japan (Jin & Aki, 2005; Nakamura et al., 2006; Edwards & Rietbrock, 2009) or only for the shallow part inside the Kanto basin (Kinoshita, 1994; Yoshimoto & Okada, 2009). In this study we aim to derive a detailed picture of the attenuation structure in the crust and upper mantle beneath the Kanto basin. The waveform data used in this study are recorded at the dense seismic array of the Metropolitan Seismic Observation network (MeSO-net). The station network is distributed on five lines with an average spacing of 3 km and in an area with a spacing of 5 km in the central part of Kanto plane. The 296 MeSO-net stations are equipped with a three-component accelerometer at a bottom of a 20-m-deep borehole, signals from which are digitized at a sampling rate of 200 Hz with a dynamic range of 135 dB. The attenuation of seismic waves along their path is represented by the $t*$ attenuation operator that can be obtained by fitting the observed P wave amplitude spectrum to a theoretical spectrum using an omega square source model. In order to accurately fit the spectral decay of the signal, only earthquakes that are recorded with intensity greater than 1 in the Japan Meteorological Agency (JMA) intensity scale are selected.

The waveforms of 452 earthquakes were selected from the JMA unified earthquake list from January 1st 2010 to May 31st 2011. A grid search method is applied to determine the $t*$ values by matching the observed and theoretical spectra. The $t*$ data where then inverted to estimate a 3D Qp structure under the Tokyo Metropolitan area, using a layered initial Q model. Grid points were set at 15 km spacing in the horizontal direction and with 10 km spacing at depth. We implemented the 3D velocity model estimated by Nakagawa et al., 2012 and in addition we set the initial Q values at 116 for the 0 km grids and to 400 for all the grids below them.

The obtained model suggests average Q values of 50˜100 inside the Kanto basin. Furthermore, a low Qp zone is observed in the area where the Philippine Sea plate meets the upper part of the Pacific sea plate. This are is located at approximately 40 km depth, beneath the north-east Tokyo and west Chiba prefecture areas and is represented by Qp values of 300. Earthquakes occurring on the Pacific plate pass through this low Q area inside the Philippine sea plate and are attenuated significantly. This kind of anomalous wave attenuation must be taken in account when estimating the hypocenter of historical earthquakes. Combined with the detailed velocity structure beneath the Kanto basin, our results help us to understand the material properties of the subducting plates. The implementation of our findings in strong motion simulation studies could help towards a better understanding of the damage area of future earthquakes and mitigate the disaster of the effected areas.

Keywords: Attenuation, Tomography, MeSO-net