Japan Geoscience Union Meeting 2011
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SSS031-P01 Room:Convention Hall Time:May 23 14:00-16:30

The Metropolitan Seismic Network for Detecting Mega-thrust and Intra-slab Earthquakes beneath the Tokyo Metropolitan Are

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We have started the special project for earthquake disaster mitigation in the Tokyo Metropolitan area (Fiscal 2007-2011) and have been constructing the MeSO-net (Metropolitan Seismic Observation network) as a part of the project. The MeSO-net consists of about 300 stations at the project termination. The project started in 2007 and so far 249 stations have been deployed at mainly elementary and junior high schools. To achieve stable seismic observation with reducing surface ground noise, sensors were installed in boreholes at depth of 20m. The sensors have a wide dynamic range (135dB) and a wide frequency band (DC to 80Hz). Data are digitized with 200Hz sampling and telemetered to the Earthquake Research Institute. The result shows that the MeSO-net can detect and locate most earthquakes with magnitudes (M) more than 3 in the metropolitan area. This is the last fiscal year of the project so that we will provide an accurate estimation of the plate boundaries of the Philippine Sea (PSP) and the Pacific plates beneath the metropolitan area, allowing us to possibly discuss clear understanding of the relation between the PSP deformation and M7+ intra-slab earthquake generation. Our project currently drives toward its ultimate goal to contribute directly to the next assessment of the seismic hazard in the Tokyo metropolitan area.

Keywords: Seismic instruments and networks, Subduction zones, Earthquake source observation, Tomography, Earthquake ground motion and engineering seismology

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Heterogeneous distribution of seismic intensity in the Metropolitan area by MeSO-net

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The Special Project for Earthquake Disaster Mitigation in the Tokyo Metropolitan Area has been ongoing (2007-2012). Under this project, the Metropolitan Seismic Observation network (MeSO-net), which consists of about 400 observation sites, has been constructed. This network consists of five dense linearly arrayed stations and evenly spaced stations. This five liner arrays focus on observing highly active seismicity, many repeating earthquakes, slow slip area, and historical large earthquakes. The correlations of waveform from local and teleseismic events are high because observation points are deployed at about 2 or 3-km intervals. In addition, identification of any stations of the later phase is easy even if artificial noise is very intense. These widely developed stations have been used effectively for the seismic tomography method. These dense intervals of MeSO-net will induce a more highly resolved structure than previous studies. MeSO-net has observed earthquakes of more than M2.0. Low-frequency waveforms of less than 0.1 Hz have been observed by MeSO-net. The distribution of amplitudes observed at each station show heterogeneous amplification of shaking motions.

The present study is supported by Special Project for Earthquake Disaster Mitigation in Tokyo Metropolitan Area from the Ministry of Education, Culture, Sports, Science, and Technology of Japan.

Keywords: MeSO-net, ultra-dense seismic network, intensity, seismicity, plate structure

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How do waves attenuate under urban areas?: Insight from the Tokyo Metropolitan Seismic Observation network (MeSO-net).

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The Tokyo Metroploitan area is instituted inside the 4 km deep Kanto sedimentary basin and is under-plated by both the Philippine and the Pacific sea plates. 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. 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 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 intensity scale are selected. A grid search method is applied to determine the $t*$ values by matching the observed and theoretical spectra. The apparent corner frequency of the signal at each station is constrained before fitting for the $t*$. The $t*$ data where then inverted to estimate a 3D Qp structure under the Tokyo Metropolitan area, using a layered initial Q model. Two different model where tested, one model with a homogeneous Q 600 structure and one model with the top layer at 0 km representing the Kanto Basin set to 100, with all the grids below that layer to 600. The poor station/event distribution has as result a Q structure greatly depended on the initial model and ray paths. For the homogeneous initial model the Q below the kanto basin is estimated to an average 340, and failed to resolve to probable low Q values inside the basin. For the layered Q model it is estimated approximately at 500 below the Kanto basin. In addition, a notable amplification of the spectrum in the 6 ? 18 hz range can also be observed in the data of several MeSO-net stations, which suggests that is not a minor local effect but a possible characteristic of the Kanto basin.

Keywords: attenuation, tomography, MeSO-net

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Seismic structure of the northeastern Tokyo Metropolitan area by dense seismic array observations

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In central Japan, the Philippine Sea Plate (PHP) subducts beneath the Tokyo Metropolitan area, Kanto region. The bottom of the PHP is in contact with the upper surface of the Pacific Plate (PAP) beneath eastern Kanto. Detailed structure of the PHP-PAP contact zone is important to constrain the process of earthquake occurrence beneath the Tokyo Metropolitan area. Active and passive seismic experiments were conducted to obtain a structural image beneath northeastern Kanto (Sato et al., 2010). The geometry of upper surface of the PHP has been revealed by seismic reflection profiling (Sato et al., 2010). Natural earthquake data set is useful to obtain a deep structural image. Two passive seismic array observations were conducted to obtain a detailed structure image of the PHP-PAP contact zone beneath northeastern Kanto. One was carried out along a 50-km-long seismic line between Kujukuri and Kasumigaura. (K-K line) and the other was carried out along a 65-km-long seismic line between Tsukuba and Mito (T-M line). Sixty-five 3-component portable seismographs were deployed on K-K line with 500 to 700 m interval and waveforms were continuously recorded during a four-month period from June, 2010. Forty-five 3-component portable seismographs were deployed on T-M line with about 1-2 km spacing and waveforms were continuously recorded during the seven-month period from June, 2010. The continuously recorded data were divided into event files, starting from an origin time determined by the Japan Meteorological Agency (JMA). In order to obtain a high-resolution velocity model, a well-controlled hypocenter is essential. Due to this, we combined the seismic array data with permanent seismic station data. We used 95 telemetered seismic stations in the present study. During the seismic array observation, the JMA located 581 earthquakes ($Mj>1.0$) in a latitude range of 35.8-36.5 N and a longitude range of 140.0-140.6 E. We selected 135 earthquakes, all of which occurred near the survey lines. The arrival times for the first P- and S- waves obtained from 135 local earthquakes were used in a joint inversion for earthquake locations and three-dimensional velocity structure, using the iterative damped least-squares algorithm, simul2000 (Thurber and Eberhart-Phillips, 1999). The depth section of Vp/Vs structure along the T-M line shows the lateral variation of the Vp/Vs values along the top of the PAP. Clustered earthquakes are located in and around the high Vp/Vs zone.

Acknowledgement: We are very grateful to ERI technicians for data acquisition. We also wish to thank the National Research Institute for Earth Science and Disaster Prevention: the Japan Meteorological Agency: and the Earthquake Research Institute, the University of Tokyo, for allowing us to use their waveform data.

Keywords: dense seismic array observation, Philippine Sea Plate, Pacific Plate, seismic tomography

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Distribution of anisotropic intensity beneath Izu collision zone estimated from S-wave splitting.

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We used velocity seismograms observed around Tanzawa and Hakone regions. At the stations, waveforms are recorded at a sampling rate of 120 Hz. To obtain the splitting parameters, we selected waveforms by following criteria: (a) incident angle less than 40 degreeto avoid disturbance of particle motion associated with phase convergence at the surface. (b) focal depth less than 8 km. We apply cross correlation method (e.g., Shih and Meyer, 1990) in order to obtain S-wave splitting parameters. Seismograms are band-pass filtered in 2-8 Hz. The combination of two horizontal (NS and EW) component seismograms are rotated clock wise from north (0 degree) to east (90 degree) by step of 2 degree. For each step, the cross correlation coefficient is calculated between the rotated waveforms. We discard the data whose maximum cross-correlation coefficient is less than 0.8 because of not suitable for our analysis. The errors of splitting parameters are estimated with t-test (Kuo et al., 1994). Data with the 95 % confidence region wider than 0.3 sec in Dt and 30 degree in LSPD are also discarded.

We obtained anisotropic intensities having various range in and around Hakone volcano. At shallow part of Hakone volcano, anisotropic intensity is 2 ˜ 5%. These values seem to have temporal variations through large earthquake swarms.

Keywords: anisotropic intensity, Izu collision zone, Hakone

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Subduction structure of the Izu-Bonin arc and its implications for the seismic activity

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Collision and subduction structure in the Izu collision zone has been revealed by recent seismic experiments of Special Project for Earthquake Disaster Mitigation in Urban Areas, including a wedge-like structure of the Tanzawa block and its delamination from the subducted Philippine Sea plate in the eastern part (Sato et al., 2005; Arai et al., 2009), and multiple collision structure of the Misaka and Tanzawa blocks in the western part (Sato et al., 2006; Arai et al., 2011). However, the physical property of the subducted crust of the Izu-Bonin arc and its relation to seismicity, especially in the lower crustal level, remains to be solved.

In order to reveal the subduction structure of the Izu block in the southern part of the collision zone, we performed seismic tomography analyses incorporating active and passive source seismic data. The analyses were undertaken in two directions along the eastern (2003 Odawara-Kiryu) and western (2005 Odawara-Yamanashi) profiles. Hypocenters and velocity structure were simultaneously determined based on the double-difference method (Zhang and Thurber, 2003).

The obtained P and S wave velocity models showed large lateral velocity variations associated with the collision/subduction processes of the Izu-Bonin arc. The northward dipping low velocity layer along the Kozu-Matsuda Faults was imaged between the Tanzawa and Izu blocks. The middle/lower crust of the Izu block with P wave velocity of 6.5-7.0 km/s is subducted beneath the Tanzawa, within which intensive seismicity occurs. These events form 10-km-thick seismicity zone dipping northward in the depth of 15-30 km. From this distribution, this seismicity must be related to the subduction process of the Izu block. Vp/Vs ratio in this seismogenic zone shows the intermediate value, which agrees well with hornblende gabbro measured in dry condition (Nishimoto et al., 2008). Not only Vp/Vs ratio but also other geophysical evidence such as b value and resistivity structure (Aizawa et al., 2004) suggest low water content and poor dehydration in the subducted Izu-Bonin arc crust. Furthermore, the low water content is also consistent with the seismic evidence obtained from active source data (Arai et al., 2011). Thus, it is concluded that the role of dehydrated fluid is not significant for this activity. We propose two hypotheses for physical causes of the remarkable seismicity beneath the Tanzawa; a fracture zone associated with the progress of the crustal delamination and high crack density in the middle/lower crust of the Izu-Bonin arc. These two factors may contribute to generate microseismicity in the collision zone.

Keywords: Izu collision zone, Seismic wave velocity structure, Physical property, B value, Seismicity, Seismic tomography

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Primary estimation of deep subsurface structures in the Tokyo metropolitan Area, by the inversion of H/V spectral ratios

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We estimated deep subsurface structures in the Tokyo metropolitan Area, using dominant periods of H/V spectral ratios of coda waves observed by MeSO-net (Metropolitan Seismic Observation network). At first, we obtained dominant periods of H/V of coda waves averaged by several different earthquakes and the dominant periods are quite stable with a small variability (Tsuno et al., 2010). The dominant periods of H/V obtained by MeSO-net are generally in good agreement with the depths of the seismic bedrock in the Tokyo metropolitan Area (Yamanaka and Yamada, 2006). Also, we compared the observed dominant periods of H/V with peak periods of ellipticities calculated by the theory of fundamental mode of Rayleigh waves using Yamanaka and Yamada's model. The dominant periods of H/V matched well for sites where the shallow basin structures are located; however, dominant periods of H/V didn't match well for sites where the deep basin structures are located. In Yamanaka and Yamada's model, which is based on phase velocities of Rayleigh waves obtained by array microtremors observations, there are still uncertainties in the data obtained from deep basin structures when phase velocities for long periods were not obtained by array microtremors observation data. Therefore, we improved the S-wave velocity structural model in the Tokyo metropolitan Area, especially for bedrock and/or a deep boundary between layers, using the inversion method of H/V of coda waves observed by MeSO-net.

We applied the Genetic Algorithm (Yamanaka and Ishida, 1996) for the inversion of H/V spectral ratio of coda waves. Deep S-wave velocity structures were inverted from H/V spectral ratio on and around the dominant periods. As the estimated structures, we adopted the best fit between observations and calculations over 3 trials of changing random numbers in the inversion. S-wave velocities of all the layers and a depth of the top surface layer from Yamanaka and Yamada's model were constrained; and therefore, the thicknesses of the second layer (Vs 1.0 km/s) and the third layer (Vs 1.5 km/s) were estimated by this inversion procedure. Peak periods from ellipticities of fundamental mode of Rayleigh waves by the estimated structures matched well with the observed dominant periods of H/V. The estimated structures are deeper than the previous model proposed by Yamanaka and Yamada (2006) for the area of the west coast of the Tokyo Bay, where the calculated dominant periods of H/V were underestimated. At some sites in this area, the interface of the seismic bedrock was estimated at a depth of about 3.5 km (In Yamanaka and Yamada's model, the depth of the interface was about 2.5 km.).

Preliminarily, we estimated the deep subsurface structures in the Tokyo metropolitan Area, using H/V spectral ratios of coda waves on and around the dominant periods. However, the amplitudes of H/V spectral ratio, which are defined by the division of the geometric mean between horizontal components by a vertical component, are composed of Rayleigh waves and Love waves; and therefore, we would need to include the amplitude of Love waves for the inversion of H/V. As a next step, we will examine the contribution of Love waves for the horizontal amplitude of H/V in the inversion process.

Keywords: Deep underground structures, Tokyo metropolitan Area, H/V spectral ratio, Coda waves, MeSO-net, Inversion

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Estimation of S-wave velocity structure in Ookayama, Tokyo, using array microtremors and earthquake observations

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To quantitatively evaluate the site effect, we need to understand a subsurface velocity structure, especially for the S-wave velocity. To predict earthquake ground motions in the large and/or deep basins, such as the Kanto Plain and the Osaka Basin, it is necessary to understand deep subsurface velocity structures. Though phase velocities of surface waves to long periods are required for estimating the deep velocity structures, the power of microtremors is generally small. On the other hand, we can obtain earthquake ground motions for long periods by recording data of large earthquakes. Therefore, we performed the array microtremors observations in and around the Ookayama Campus of Tokyo Institute of Technology where the array earthquake observations have been already carried out. Phase velocities of Rayleigh waves up to a period of 2.5 seconds were obtained by applying the SPAC method for array microtremors data. Also, phase velocities of Rayleigh waves from a period of 3 seconds to 5 seconds were obtained by applying the Semblance analysis for recording data of earthquakes larger than a Magnitude of 5. Moreover, we verified the relationship between directions of wave propagation and phase velocities.

Acknowledgements: This study was supported by GCOE (Global COE Program: International Urban Earthquake Engineering Center for Mitigating Seismic Mega Risk).

Keywords: Array microtremors observation, the SPAC method, the F-K analysis, the Semblance analysis, S-wave velocity, the Kanto Plain

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Validation of subsurface structure in Kanto basin by surface wave tomography using seismic interferometory

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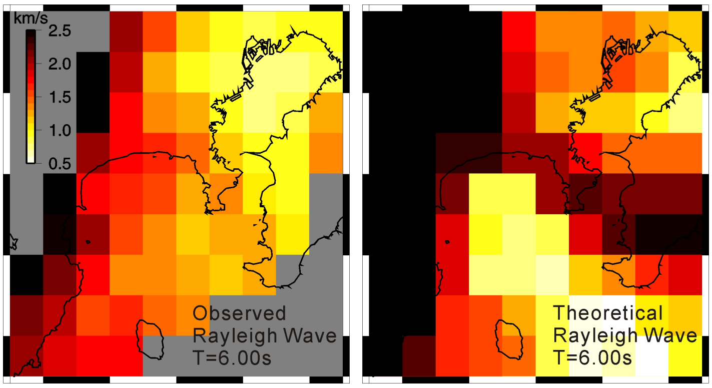
It is important to estimate appropriately the effect of sediment layers for strong motion prediction in a large basin, such as Kanto basin. Accordingly some S-wave velocity structure models have been proposed (e.g. Koketsu, 2009). Although they carried out validation of the model by simulating observed ground motion during small events, it is still a difficult task because of uncertainty of source and subsurface structure out of the basin. Seismic interferometory is used for estimation of surface wave Greens function (e.g. Shapiro and Campillo, 2004). Seismic interferometory is useful to estimate subsurface structure between two stations. Dense observation sites is enable to conduct tomographic inversion using seismic interferometory (e.g. Shapiro, 2005).

We started long time continuous microtremor observation at 16 sits around Tokyo and Sagami bay. Then we applied seismic interferometory to estimate group velocities of fundamental Rayleigh and Love waves (Yamanaka et al., 2010). The comparison between the observed and calculated group velocities suggests that the model is appropriate in general. However, there is discrepancy between observed and theoretical ones in the Region of Izu Peninsula and Sagami bay. It may attribute the theoretical model of those areas because of difficulty to conduct geophysical explorations in such area.

Surface wave tomographic analysis for the group velocity of the surface waves was conducted to validate the model regionally. We divided the area into 0.125 degree meshes large, the size which can be covered well by the ray paths. We assumed a straight path for the analysis and estimated surface wave group velocities at periods of 2-6s at each cell. We used Simultaneous Iterative Reconstruction Technique for tomographic analysis and iterative calculation was conducted to estimate cell slowness until the residuals of traveltimes become the minimum. The result was compared with the calculated one from theoretical model (Yamanaka and Yamada, 2006). Although the observed velocity of the surface waves are slow overall, both two maps explain the difference of topographic character well. However, we found a discrepancy in Izu peninsula and Sagami bay area. It suggests a necessity of the modification of the model in those areas.



Keywords: seismic interferometory, tomography, microtremor, Kanto basin, group velocity

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Reviews vergion 1 of the earthquake type and the recurrence interval for the Kanto Earthquakes

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The recurrence interval differs by how to classify the earthquake type. The type is summarized approximate four types, A.1923-type, B.1703-type, C.1923-1703 combination-type and D. 1923-1703 addition-type, from pre-existing studies. The difference of C.and D. is addressed. C.1923-1703-conbination-type is hereafter. The 1923 earthquake has the source in north region along Sagami Trough and the 1703 earthquake has the source in south region, respectively, from the different deformation patterns (Fig. 1a and 1c). The 1923-type and 1703-type of earthquakes occur by a complementary relation each other [Matsuda et al. (1974, 1978)] or trigger each other [Nakata et al. (1980)]. D. 1923-1703 addition-type (Sagami trough-type) is that same subduction zone off the Miura peninsula is ruptured nearly similar in both 1923 and 1703 earthquakes from the crustal deformation pattern on Miura. There are no discrimination between the 1923-type and the 1703-type in source region off Miura Peninsula, and the same type of earthquake is repeated off Miura Peninsula [Ishibashi (1977), Shishikura (2003)]. The recurrence interval is not distinguished between 1923 and 1703 earthquakes as follows.

A.1923-type; poorly known

B.1703-type; 950 to 2,500 years [Seno (1977)], 2,000 to 2,700 years [Shishikura (2003)].

C.1923-1703 combination-type; 800 to 1500 years [Matsuda et al. (1974, 1978)], 1,450 to 2,600 years [Nakata et al. (1980)].

D.1923-1703 addition-type; 260 to 320 years [Kanamori (1973)], 200 to 300 years [Ishibashi (1977)], 180 to 400 years [Seno (1977)], 470 to 1,143 years [Matsuda (1985)], 300 years [Kumaki (1982)], two patterns of ~600 years and ~900 years [Kumaki (1988)], 380 to 400 years [Shishikura (2003)].

Keywords: Kanto earthquake, earhquake type, recurrence interval, occurrence time, earhquake cycle, long period prediction

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Correlation between Coulomb Stress Changes Imparted by Large Historical Earthquakes and Current Seismicity in Japan

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We investigated the correlation between current seismicity in Japan and the static changes in the Coulomb Failure Function (dCFF) due to eight large historical earthquakes (since 1923, magnitude (M) 6.5 or above) with a strike-slip fault mechanism in two ways. The one is a previously-used method that the dCFF calculated on the mainshock receiver fault mechanism is compared with the epicentral distribution of recent seismicity. The other calculates the dCFF on two nodal planes of focal mechanism solutions and investigates the probability distribution. We found that recent seismicity for the mainshock receiver fault is concentrated in the positive dCFF regions of four earthquakes (i.e. the 1927 Tango, 1943 Tottori, 1948 Fukui, and 2000 Tottori-Ken Seibu earthquakes), while no such correlations are recognized for the other four earthquakes (i.e. the 1931 Nishi-Saitama, 1963 Wakasa Bay, 1969 Gifu-Ken Chubu, and 1984 Nagano-Ken Seibu earthquakes). However, the probability distribution of the dCFF calculated on nodal planes of the focal mechanism solutions clearly indicates that recent earthquakes concentrate on positive dCFF regions. That is to say, current seismicity is possibly correlated with the positive dCFF due to large historical earthquakes. Furthermore, it is revealed that specified receiver fault mechanisms sometimes accompany large uncertainty and fail to obtain fair conclusion.

Though seismicity rate changes (aftershocks) can continue for a long period, few studies have investigated the correlation between the dCFF due to large historical earthquakes and recent seismicity. Many studies have focused on earthquake triggering and seismicity rate changes due to changes in the dCFF resulting from large earthquakes (e.g. Harris and Simpson, 1992; Stein et al., 1992; Toda et al., 1998). Based on the dCFF, Mueller et al. (2004) investigated focal regions and focal mechanisms of four earthquakes (M~7) that occurred from 1811 to 1812 in New Madrid, MO, USA. If recent seismicity represents aftershocks of these earthquakes, aftershock activity has continued for 200 years. Furthermore, Utsu et al. (1995) reported that the number of felt earthquakes in Gifu, central Japan, have obeyed the Omori formula for a century after the 1891 Nobi earthquake.

In this study, we investigated the correlation between the dCFF due to eight large historical earthquakes with a strike-slip fault mechanism and current seismicity using the unified Japan Meteorological Agency (JMA) catalog from October 1997 to May 2010. We also calculated the dCFF on two nodal planes of the F-net focal mechanism solutions by the National Research Institute for Earth Science and Disaster Prevention (NIED). The dCFF assuming specified receiver fault mechanisms may generate large errors under a complex stress field in which various types of earthquakes occur, and this uncertainty can be substantially reduced by using focal mechanisms as receiver faults (e.g. Toda, 2008).

The results strongly suggest that the background seismicity rate estimated from earthquake catalogs is possibly affected by large historical earthquakes that occurred prior to the start of the catalog. The proposed correlation between the dCFF and recent seismicity may be affected by multiple factors controlling aftershock activity or decay time.

Acknowledgments
We used the unified JMA catalog and F-net focal mechanism solutions determined by NIED. We also used the program by Okada (1992) for calculating dCFF. We thank all of these organizations and individuals. This study is supported by the Special Project for Earthquake Disaster Mitigation in the Tokyo Metropolitan Area from the Ministry of Education, Culture, Sports, Science, and Technology of Japan.

Keywords: Coulomb stress change, Seismicity, Focal mechanism

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Earthquake forecast testing experiment: Kanto as a testing region

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We present a summary of the earthquake forecast testing experiment in Japan and demonstrate the first results obtained by using Kanto, one of the testing regions of the experiment. The experiment has been formally initiated within the Japanese Testing Center of the Collaboratory for the Study of Earthquake Predictability (CSEP) in Nov. 2009. This activity aims to quantitatively forecast time, place, and magnitude of future earthquakes in and around Japan based on seismicity data. To launch this experiment, the Earthquake Research Institute (ERI) has installed and set up the Testing Center for rigorous evaluation of earthquake forecast models and testing in cooperation with SCEC and ETH. The Center completely follows the design proposed by the CSEP. The researchers submitted their earthquake forecast models to the Testing Center before the start of the experiment and the Center evaluates the models' performance by the official suits of CSEP tests (N-, L-, M-, S-, and R-tests) after the end of a forecast period. The Japan Meteorological Agency (JMA) unified catalog was decided to use for observation of the tests. The JMA catalog is routinely modified during a certain time period and we decided, as a rule, to use fixed authorized data for evaluation. We have to wait until the modification is completed. Currently, a time delay for real-time is six-months. 91 earthquake forecast models were registered into 12 categories consisting of 4 testing classes (1-day, 3-months, 1-year, and 3-years) and 3 testing regions that cover Japan, the Japan's mainland and Kanto. For the "Kanto" region, the respective testing classes include 4, 7, 8, and 8 models. The main feature of tests using the Kanto region is to focus on seismicity under the complex tectonic condition: the triple junction of the three plates. In the presentation, we show the results obtained from the "Kanto" region applied to all testing classes. We discuss future direction of research to look for good collaboration with the Special Project of the Earthquake Disaster Mitigation in the Tokyo Metropolitan Area.

Keywords: Earthquake, Global collaboration, Prediction and forecasting, Seismicity and tectonics, Japan, Statistical seismology