Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

SSS24-01 Room:315 Time:May 1 15:15-15:30

Structural analysis of seismogenic fault of the 2013 Mw 5.8 Awaji Island earthquake, NW Japan

LIN, Aiming[1*] ; KATAYAMA, Shouichi[1] ; RAO, Gang[2] ; KUBOTA, Yasu'uchi[3]

[1]Department of Geophysics,Graduate School of Science, Kyoto University, [2]Department of Earth Sciences, Zhejiang University, China, [3]OYO Cooperation

The 2013 Mw 5.8 (Mj 6.3) Awaji Island earthquake occurred in the southwest Awaji Island, at 5:33, 13 April, 2013, ca.25 km southwest of the epicenter of the 1995 Mw 6.8 (Mj 7.2) Kobe earthquake, southwest Japan. Pre-existing geologic data and focal mechanism show that this earthquake was triggered by an unknown active fault with a thrusting-dominated mechanism at high-dip angle of >70 degree. Interpretations of aerial photographs and 3D perspective images, field investigations and structural analysis of fault rocks, reveal that: i) a new fault, called Yamada Fault here, striking NNW and dipping WSW at a high-angle of 86 degree was found along a topographic lineament developed along the geological boundary between the Mesozoic granitic rocks and the Late-Tertiary-Quaternary Osaka Group composed of interbeded sandstone and mudstone; ii) a main shear zone of the Yamada Fault consists of a fault core that includes a narrow fault gouge zone of <10 cm in width (generally 1~5 cm), a fault breccia zone of <100 cm in width, and a damage zone of 10~50 m in width that is composed of cataclastic rocks and fractures; iii) the foliations characterized by S-C fabrics developed in the shear zone indicate a dominantly thrusting sense, consistent with that revealed by the focal mechanism; and iv) co-seismic surface ruptures occurred locally along the Yamada Fault, which are composed of numerous short fissures ranging from centimeters to several meters in length and concentrated in a zone <5 m. Our findings show that the newly found Yamada Fault is a active fault that probably triggered the 2013 Mw 5.8 (Mj 6.3) Awaji Island earthquake. Therefore, it is necessary to reconstruct the fault model for studying the tectonic activity and paleoseismicity and to reassess the seismic hazard of the active faults for densely populated Awaji Island, northwest Japan.

Keywords: 2013 M 6.3 Awaji Island earthquake, seismogenic fault, active fault, Yamada Fault, S-C fabrics of fault rocks, fault damage zone

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SSS24-02 Room:315 Time:May 1 15:30-15:45

Quasi-cylindrical seismic waveform modeling considering surface topography

TOYOKUNI, Genti[1*] ; TAKENAKA, Hiroshi[2] ; OKAMOTO, Taro[3] ; ZHAO, Dapeng[1]

[1]RCPEVE, Tohoku Univ., [2]Okayama Univ., [3]Tokyo Tech

An accurate and efficient modeling of regional seismic wave propagation can be achieved by the axisymmetric modeling using the cylindrical coordinates. It assumes the structural model as rotationally symmetric along the vertical axis including a seismic source, and then solves the 3-D wave equation in cylindrical coordinates only on a 2-D structural cross section (i.e., 2.5-D modeling). Therefore, this method can correctly model 3-D geometrical spreading effects and the pulse shape, with computation time and memory comparable to 2-D modeling.

On the other hand, application of the conventional purely axisymmetric approximation is difficult in practice because the structure along the measurement line of the seismic survey is rarely symmetric with respect to the source location. To overcome this difficulty, Takenaka et al. (2003) proposed a "quasi-cylindrical approach". They developed a numerical scheme for seismic exploration using the finite-difference method (FDM). The FDM scheme had then been improved to include an arbitrary moment-tensor point source and the anelastic attenuation for further realistic modeling (Toyokuni et al., 2013, AGU Fall meeting).

In this work, we extended the scheme to treat land and ocean-bottom topographies. We adopted the cell-based staggered-grid FDM, which places the normal-stress components at the center of a unit cell, and applies the 2nd-order FD approximation around the free surface or fluid-solid boundary (Okamoto & Takenaka, 2005; Takenaka et al., 2009; Nakamura et al., 2012). In the presentation, we will show an application of the scheme to the waveform modeling for the volcanic areas in Japan.

Keywords: seismic waveform, finite-difference method, topography, fluid-solid boundary

SSS24-03 Room:315 Time:May 1 16:15-16:30

Spatial distribution of aftershock decay property beneath Japan Trench

IKUTA, Ryoya[1*] ; KUWAHARA, Masanori[2] ; MURAKAMI, Hiroki[3]

[1]Graduate School of Science, Shizuoka University, [2]Center of Integrated Research and Education of Natural Hazards, Shizuoka University, [3]Faculty of Science, Shizuoka University

We analyzed the aftershock sequences for individual M6-9 class inter-plate earthquakes and intra-plate earthquakes in Japan Trench for the period between October 1997 and March 2013 using JMA hypocenter catalog (final solution). The purpose is to examine a spatial relationship between the slip zone by the M9 earthquake and activity of aftershock series before the M9 and to understand the mechanism of aftershock. We approximated time variation of the number of aftershock sequences for each earthquake by the modified Omori ' s Law. Each aftershock sequence was identified from its spatial and temporal distribution. K and P parameters of Omori ' s Law were obtained by fitting the logarithmic Time-Frequency graphs of the aftershock sequence by linear function. We analyzed aftershock sequences for 44 events and adopted 17 whose K values are larger than 10 as available results because the results with smaller K values than 10 had large uncertainties due to lack of data. The results showed negative correlation between P values and Mj of the mainshocks. Before and after the M9 earthquake, there was no significant change in the aftershock parameters. However, we found a depth-dependent spatial distribution of aftershock decay properly. In the plate boundary, the aftershock sequence lasts for longtime without significant decay in the deeper portion, in contrast that the aftershock decays quickly at the shallower portion. It is known that the deeper part of plate boundary tends to slip aseismically without earthquakes. Taking this slow slipping property into account, our result suggests that the inter-plate frictional property should be responsible to the delay and decay property of the aftershocks.

Keywords: Aftershocks, Modified Ohmori's Law, Tohoku-Oki earthquake, Seismicity

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SSS24-04 Room:315 Time:May 1 16:30-16:45

Location of early aftershocks of the 2011 Tohoku-oki Earthquake using seismogram envelopes as templates

KOSUGA, Masahiro[1*] ; SAKAI, Yuuka[2]

[1]Graduate School of Sci. & Tech., Hirosaki Univ., [2]Fac. Sci. & Tech., Hirosaki Univ.

The location of early aftershocks is very important to estimate the initial size of mainshock fault, because the aftershock zone generally extends with time. However, the location of early aftershocks is often difficult due to the long-lasting coda wave of mainshock and successive occurrence of aftershocks. To overcome this situation, we developed a location method using seismogram envelopes as templates. During the process of location, we firstly calculate the cross-correlation coefficients between a continuous (target) and template envelopes, and obtain time series of station-averaged cross-correlations for all templates. We then search for templates (initial location) in the descending order of cross-correlations in a time window excluding the dead times around the previously detected events. The third process is the relative event location that accounts for the lag times between actual and template envelopes. We applied the method to the early aftershock sequence of the 2011 Off the Pacific Coast of Tohoku Earthquake (Mw = 9.0). In a time window of 30-minutes just after the mainshock, we could locate 22 events in 8 Hz band by using 96 templates recorded at 33 Hi-net stations. The number of located events by the JMA is 13. Though we should carefully examine the location of detected events, we conclude that the proposed detection method works adequately even just after the mainshock of large earthquake.
Acknowledgement: We thank the NIED for providing waveform data of Hi-net. This work was supported by JSPS KAKENHI Grant Number 23540487.

Keywords: early aftershocks, template, envelope, Off the Pacific Coast of Tohoku Earthquake

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SSS24-05 Room:315 Time:May 1 16:45-17:00

Aftershock distribution in the northern source region of the 2011 Tohoku earthquake by long-term OBSs

SHINOHARA, Masanao[1*] ; YAMADA, Tomoaki[1] ; NAKAHIGASHI, Kazuo[2] ; MOCHIZUKI, Kimihiro[1] ; MACHIDA, Yuya[1] ; SHINBO, Takashi[3] ; MURAI, Yoshio[4] ; HINO, Ryota[5] ; ITO, Yoshihiro[6] ; SATO, Toshinori[7] ; UEHIRA, Kenji[3] ; YAKIWARA, Hiroshi[8] ; SHIOBARA, Hajime[1]

[1]ERI, Univ. of Tokyo, [2]Kobe Univ., [3]NIED, [4]Hokkaido Univ., [5]Tohoku Univ., [6]DPRI, [7]Chiba Univ., [8]Kagoshima Univ.

The 2011 Tohoku earthquake occurred at the plate boundary and many aftershocks followed. To obtain a precise aftershock distribution is important for understanding of mechanism of the earthquake generation. In order to study the aftershock activity, we carried out extensive sea floor aftershock observation using more than 100 ocean bottom seismometers just after the mainshock. Deployment and recovery of the OBS were repeated, and we obtained the data from OBSs just after the mainshock to the middle of September, 2011. A precise aftershock distribution for approximately three months in the whole source area, with an emphasis on depths of events, was obtained from the OBS data. In the southern source region, an aftershock distribution until September, 2011 was also estimated. Totally urgent OBS observations located 1210 aftershocks (Shinohara et al., 2011, 2012). After the urgent aftershock observation using short-term OBSs, we continued the observation using long-term OBSs to monitor seismic activities in the source area. We deployed 40 LT-OBSs in the whole source region in September 2011 and have completed recovery of the LT-OBSs until November, 2012. In this presentation, we concentrate seismic activities in the northern source region using the data from the urgent aftershock observation and long-term seafloor observation.

We selected events whose epicenter is located below the OBS network form the JMA earthquake catalog, and P and S-wave arrival times were picked from the OBS data. Hypocenters were estimated by a maximum-likelihood estimation technique with one dimensional velocity structures. Thickness of sedimentary layer changes at each OBS site was evaluated and the estimated travel times by the location program were adjusted. We will report precise seismic activities in the northern source region with spatial and temporal variation. From preliminary analysis, seismic activity in off-Miyagi region was still low until the end of the long-term observation.

SSS24-06 Room:315 Time:May 1 17:00-17:15

A boundary of stress-field orientation in northwestern area of the Kanto plain

YANO, Tomoko elizabeth[1*] ; TAKEDA, Tetsuya[1] ; SHIOMI, Katsuhiko[1]

[1]NIED

Kanto-Tokai area is particularly important in terms of seismic hazard and mitigating disaster since this area is having high potential to economic and social impacts. Despite the fact, the Kanto region is one of the most seismic active areas due to its complicated tectonics and has an active fault zone, containing Fukaya fault, in northwestern area of the Kanto plain, which has potential to the M8 class earthquake. Many studies and research projects have attempted to understand the seismic activity and stress field. However, reliable and high-resolution catalog is required for the detailed discussion.

We have launched Japan Unified High-resolution Relocated Catalog for Earthquakes (JUICE) project since 2013. Events were relocated using the Double-Difference method for high-resolution hypocenter location to estimate seismogenic layer thickness, to evaluate active faults, and to understand the tectonic processes in Japan. We have completed for the first version of Catalog in the region of Kanto-Tokai area for the shallow (>40 km) earthquakes between M0 and M6.5 from 2001 to 2012. Here, in this presentation, we introduce the result from JUICE focusing on the northwestern area of the Kanto plain that contains a sharp boundary in which pressure and tension axis dramatically change by 90 degrees.

The JUICE catalog clearly shows a band of seismicity from Izu peninsula to the north. This seismic band has a nearly constant width of about 50 km. The focal mechanisms show that strike and thrust type dominate throughout this seismic band continuously, though there exists a area where pressure and tension axis dramatically change within this seismic band. While this " area " has been already recognized (e.g. Suzuki, 1989), JUICE helps to draw a precise " line " as a stress-field orientation boundary where happened to be close to Fukaya fault.

Bouguer gravity anomaly and seismic exploration data imply structural changes at the stress-field orientation boundary. According to the Bouguer gravity anomaly (Komazawa, 2004), the boundary appears to be associated with the gravity-low zone. The gravity anomalies show a lineation that trends NW-SE, the same direction of the boundary. Seismic profile (Sato et al., 2003) displays changes in basement character showing the pattern of depression beneath Fukaya fault. The shape of depression corresponds to the pattern of seismicity beneath this area, and also the boundary sites beneath the lowest point of the depression.

It appears to split into different regimes at the stress-field orientation boundary. We conclude that it is possible to have major tectonic boundary underneath this northwestern area of the Kanto plain. Moreover, we suggest that Median tectonic line (MTL) is a major candidate underneath this area. MTL runs parallel to the island arc through southwest Japan and divides different geological structures into outer (the forearc side) and inner arc (the backarc side). The trace of MTL disappears on the eastern side of Itoigawa-Shizuoka tectonic line, but Takagi et al. (2006) found an evidence of inner arc materials in the core sample obtained around this area. Therefore we assume that MTL is buried underneath the boundary. This finding may eventually impact on the research relates to hazard of Kanto area.

Keywords: Seismicity and tectonics

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SSS24-07 Room:315 Time:May 1 17:15-17:30

Estimating earthquake swarms in volcanic regions

KUMAZAWA, Takao[1*] ; OGATA, Yosihiko[1] ; KIMURA, Kazuhiro[2] ; MAEDA, Kenji[2] ; KOBAYASHI, Akio[2]

[1]The Institute of Statistical Mathematics, [2]Meteorological Research Institute

In the eastern Izu region, earthquake swarms have occurred repeatedly since 1978. These events are known to be triggered by magma intrusions, and the amount of magma intrusion is correlated with volumetric strain of the crust. We show the background seismicity rate is highly correlated with the volumetric strain in this region, with a short time delay. We then discuss the possibility to forecast the seismicity in volcanic regions.

To calculate the background seismicity rate, we used the epidemic-type aftershock sequence (ETAS) model extended for application to nonstationary seismic activity, introduced by Kumazawa & Ogata (2013). The time-dependent rates of both background seismicity and aftershock productivity in the ETAS model are optimally estimated from hypocenter data by Bayesian smoothing method. These rates can provide quantitative evidence for abrupt or gradual changes in shear stress and/or fault strength due to aseismic transient causes such as triggering by remote earthquakes, slow slips, or fluid intrusions within the region.

Keywords: ETAS model, Bayesian smoothing, earthquake swarm, volcanic region, Izu

SSS24-08 Room:315 Time:May 1 17:30-17:45

Source Characteristics and Coulomb Stress Change of the 19 May 2011 Mw 6.0 Simav-Kutahya Earthquake, Turkey

GORGUN, Ethem[1*]

[1]Department of Geophysical Engineering, Istanbul University

Abstract
On 2011 May 19, Simav district of Kutahya province in northwest Anatolia was hit by a moderate size (Mw=6.0) earthquake. Centroid moment tensors for 41 events with moment magnitudes (Mw) between 3.5 and 6.0 are computed by applying a waveform inversion method on data from the Kandilli Observatory and Earthquake Research Institute broadband seismic network. The time span of data covers the period between 2011 May 19 and 2011 August 22. The mainshock is a shallow focus normal event at a depth of 10 km. Focal depths of aftershocks range from 5 to 20 km. The seismic moment (Mo) of the mainshock is calculated $1.15x10^{18}$ Nm. The estimated rupture duration of the Simav mainshock is 30 s. The focal mechanisms of the aftershocks are mainly normal faulting with a variable strike-slip component. The geometry of focal mechanisms reveals a normal faulting regime with NE-SW trending direction of T-axis in the entire activated region. A stress tensor inversion of focal mechanism data is performed to acquire a more accurate picture of the Simav earthquake stress field. The stress tensor inversion results indicate a predominant normal stress regime with a NW-SE oriented maximum principal compressive stress. According to variance of the stress tensor inversion, to first order, the Simav earthquake area is characterized by a homogeneous intraplate stress field. Eventually, Coulomb stress analysis is performed to calculate the stress transfer and correlate it with the activated region. Positive lobes with stress more than 3 bars are obtained, indicating that these values are large enough to increase the Coulomb stress failure towards NW-SE direction.

Keywords: Aftershock, Coulomb Stress Analysis, Focal Mechanism, Simav earthquake, Stress tensor inversion, Western Anatolia

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SSS24-09 Room:315 Time:May 1 17:45-18:00

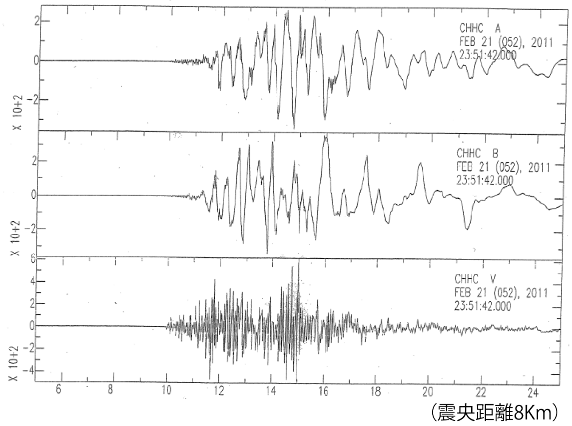
The Great Kanto Earthquake (of 1923) and YOKOHAMA (1)

NISHIZAWA, Masaru[1]*

[1]none

1. The reinforced cocrete buildings has been complated the leadership factions after The Great Kanto Earthquake (of 1923).
2. The YOKOHAMA Civilization Colour Print was important mediums of the YOKOHAMA exoticim and cultures.

Keywords: The Great Kanto Earthquake (of 1923), Yokohama, Open a port, YOKOHAMA civilization color print, The reinforced concrete building



東西、南北の波の位相は逆転していることは
他と同じで、水平方向に建物に対して
回転力（又はねじれ）が生じることが判る。

主要動以後の波形は波うっていることは
他と同様。
しかし、上下動も多少は波うってはいるが、
東西、南北に比べると小さい。

SSS24-P01 Room:Poster Time:May 1 18:15-19:30

Seismic activity in eastern Japan and the source region after the 2011 off the Pacific coast of Tohoku earthquake

UOOCHI, Akiko[1] ; KUGE, Keiko[1*]

[1]Dept. Geophysics, Kyoto University

Changes of seismic activity in eastern Japan and the source region were shortly reported after the 2011 off the Pacific coast of Tohoku earthquake (Toda et al., 2011; Kato and Igarashi, 2012). To clarify subsequent changes, we investigated seismic activity in the wide region for two and a half years since the 2011 Tohoku earthquake.

We examined a region in a range of 33.4-42N and 136-145E. The region was divided into small squares with a size of 0.2 degree, and in each square, we computed seismicity rates. First, as the background seismicity, we computed the average number of earthquakes per a year, based on seismic activity for nine years before the 2011 earthquake. Then, to obtain seismicity rates after the 2011 earthquake, we counted the number of earthquake during two periods, respectively, and computed the ratios against the background seismicity. The two periods are 0-1 and 1.5-2.5 years after the 2011 earthquake. We used hypocenters determined by JMA. In regions where large inland earthquakes occurred before 2011, the background seismicity was computed from a period excluding aftershocks. Finally, by plotting the resultant seismicity rates in maps, we searched regions where seismic activity significantly changed. By the same method, we also examined seismicity rates of interplate earthquakes in the source region of the 2011 Tohoku earthquake, based on data selected from the F-net CMT catalog.

Our results show that when two and a half years passed since the 2011 earthquake, seismicity of interplate earthquakes had been lower than the background, throughout the source region of the 2011 Tohoku earthquake except for a region off Iwata. High seismic activities for a year since the 2011 earthquake were found in Iwaki, the middle and northern parts of Akita, the southern part of the Kanto region, and also in regions near active volcanos (Bandai, Nikko-Shirane, Kusatsu-Shirane, Naeba, and Fuji mountains). When two and a half years passed, seismicity in many regions of eastern Japan had been lower than the background, including the activities near Bandai, Naeba, and Fuji mountains. However, activities in Iwaki, the middle and northern parts of Akita, the southern part of the Kanto region, and near Nikko-Shirane and Kusatsu-Shirane mountains continued to be high.

Furthermore, we carefully examined seismic activity in the regions where we detected significant changes of seismic activity. In many regions of eastern Japan, we found that locations of earthquakes and focal mechanisms were changed before and after the 2011 Tohoku earthquake.

Using JMA hypocenters, we also attempted to apply the modified Omori's law for seismic activity after the 2011 earthquake in the regions with significant changes of seismic activity. The modified Omori's law could roughly model the changes of seismic activity in many regions, even when a region is inland, away from the source region. The Omori's regression parameter, p, was estimated in a range from 0.2 to 1.1. The values ranged between 0.2 and 1.1 in the regions where seismic activity has been high for 2.5 years, whereas they were between 0.8 and 1.1 where high seismic activity for the first 1 year decreased in 2.5 years since the 2011 earthquake. In the southern part of the Kanto region, the value of p (0.2) was extremely low, compared to the other regions, which implies that the seismic activity decays very slowly. In the regions near active volcanos, the values of p tended to be high. In the source region of the 2011 Tohoku earthquake, we estimated the values of p in three regions; a whole source region, an afterslip region, and a region excluding the afterslip region. The values ranged from 1.0 to 1.1, and there was no significant difference in the three regions.

SSS24-P02 Room:Poster Time:May 1 18:15-19:30

A statistical feature of anomalous seismic activity prior to large inland earthquakes in Japan

KAWAMURA, Masashi[1*] ; WU, Yi-hsuan[2] ; KUDO, Takeshi[3] ; CHEN, Chien-chih[2]

[1]Department of Geosciences, National Taiwan University, [2]Grad. Inst. of Geophysics, National Central University, Taiwan, [3]General Education Division, College of Engineering, Chubu University

To reveal the preparatory processes of large inland earthquakes, we systematically applied the pattern informatics (PI) method to earthquake data of Japan. We focused on 12 large earthquakes with magnitudes greater than M6.4 (based on the magnitude scale of the Japan Meteorological Agency) that occurred at depths shallower than 30 km between 2000 and 2010. We examined the relationship between the spatiotemporal locations of these large shallow earthquakes and the locations of PI hotspots, which correspond to grid cells of anomalous seismic activity during a designated time span. Based on a statistical test conducted using Molchan's error diagram, we investigated whether precursory anomalous seismic activity occurred in association with these large earthquakes and, if so, studied the characteristic time spans of such activity. Our results indicate that Japanese inland earthquakes with M $\geqq$ 6.4 are typically preceded by anomalous seismic activity in timescales of 8-10 years.

Keywords: pattern informatics, seismic quiescence, seismic activation, Molchan's error diagram, stress accumulation, inland earthquake

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Coulomb stress change inverted from the seismicity rate change in southern 2011 Tohoku earthquake's source region

TAKAHASHI, Go[1*] ; TSUMURA, Noriko[1]

[1]Graduate School of Science, Chiba University

By using the analysis of seismicity rate change, we estimated spatio-temporal evolution of Coulomb stress around the upper boundary of the Pacific plate (PAC) and Philippine Sea plate (PHS) in and around the southern edge of the rupture zone of the 2011 Pacific coast of Tohoku earthquake (Mw=9.0). We used hypocenter catalog of the Japan Meteorological Agency (JMA) for the period between 1998/1/1 and 2013/3/31. Estimated stress change became large just after the 2011 Tohoku earthquake in most of rupture zone. The large stress change estimated from the seismicity reached the southern outside of the contact zone of the PHS and the PAC, while this area is located at outside of the source fault of the 2011 Tohoku earthquake. Moreover, in the October 2011 Boso slow slip event (SSE) initiation area, stress change remained large value after the 2011 Tohoku earthquake.

To estimate the effect of the mainshock and largest aftershock in our inversion result, we calculated Coulomb stress change by simulating the mainshock, afterslip and Mw7.9 aftershock for the 2011 Tohoku earthquake in an elastic half space. From similarity between the result from seismicity rate change and result of forward modeling, most of the stress change pattern in and around mainshock rupture zone after the 2011 Tohoku earthquake might be explained by the effect of the 2011 Tohoku earthquake mainshock, afterslip and the largest aftershock. On the other hand, since the result from seismicity rate change didn't correspond to the result of forward modeling in the October 2011 SSE area, this region was possibly affected by other event or closeness to break strength.

Keywords: stress change, 2011 Tohoku earthquake, aftershock, slow slip

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SSS24-P04 Room:Poster Time:May 1 18:15-19:30

Spatial distribution of earthquakes off the coast of Ibaraki and the Boso Peninsula after the 2011 Tohoku Earthquake

NAKAHIGASHI, Kazuo[1*] ; MACHIDA, Yuya[2] ; SHINBO, Takashi[7] ; YAMADA, Tomoaki[2] ; MOCHIZUKI, Kimihiro[2] ; SHIOBARA, Hajime[2] ; SHINOHARA, Masanao[2] ; MURAI, Yoshio[3] ; HINO, Ryota[4] ; AZUMA, Ryosuke[4] ; SUZUKI, Kensuke[8] ; KUBOTA, Tatsuya[4] ; HASEGAWA, Kazuya[4] ; SATO, Toshinori[5] ; TAKATA, Hiroyoshi[5] ; UEHIRA, Kenji[7] ; YAKIWARA, Hiroshi[6]

[1]Kobe Univ., [2]Earthquake Research Inst., [3]Hokkaido Univ., [4]Tohoku Univ., [5]Chiba Univ., [6]Kagoshima Univ., [7]National Research Institute for Earth Science and Disaster Prevention, [8]JAMSTEC

The 2011 off the Pacific coast of Tohoku Earthquake occurred on March 11, 2011, off shore of the northeast Japan region. Many aftershocks occurred following the mainshock. To obtain a precise aftershock activity is important for understanding the mechanism of earthquake generation, and the recovery of plate coupling at a ruptured plate boundary. In order to study the aftershock activity, we had deployed 66 long-term ocean bottom seismometers(LTOBS) off the coast of Ibaraki and the Boso Peninsula from October 2011 to November 2012.

For hypocenter determination, we selected 1606 events whose epicenter catalog which the Japan Meteorogical Agency for hypocenter determination.P- and S- wave arrival times were manually picked using the WIN system (Urave and Tsukada, 1991).Hypocenters were determined by the maximum-likelihood estimation technique (Hirata and Matsu'ura, 1987). The hypocenter location program used in this study is based one-dimensional structure with constant Vp/Vs ratio of 1.73. Because a sedimentary layer below the sea floor generally has a large Vp/Vs value, an adjustment of the station corrections is needed. To obtain the station correction, we used the following method. First, we located the hypocenter using the P- and S-wave arrival times with the assumed station correction values for the velocity structure used. The averaged differences between observed travel time and estimated travel times (O-C times) for each station were then calculated. The averaged O-C times were added to the previous station correction values, and the hypocenters were relocated. We repeated this procedure eleven times. After this procedure, the averaged O-C times were less than 0.1 s for both the P-wave and S-wavesWe estimated 458 hypocenter locations with an error of less than 5 km in the horizontal direction and less than 3 km in depth by using LTOBS data.

Most of the hypocenter locations have a depth shallower than 40km. The earthquakes form a plane dipping landward in the study area. Comparing the hypocenter locations with crustal structures obtained by active seismic studies (e.g. Miura et al., 2003). Many events occurred along the plate boundary. We also compared the hypocenter locations with aftershock distribution of the seismic observation conducted immediately after 2011 Tohoku Earthquake (Shinohara et al., 2012). Shinohara et al., (2012) reported that the low seismicity region has seen at the shallow part of the plate interface in the off-Fukushima. On the other hand, our results showed the seismicity is not low at the same region. This difference may reflect the change of stress fields at a ruptured plate boundary.

SSS24-P05 Room:Poster Time:May 1 18:15-19:30

Spatial distribution of earthquakes off the coast of Fukushima deduced from a one-year OBS observation in 2013

YAMADA, Tomoaki[1*] ; NAKAHIGASHI, Kazuo[2] ; SHINOHARA, Masanao[1] ; MOCHIZUKI, Kimihiro[1] ; SHIOBARA, Hajime[1]

[1]Earthquake Research Institute, Univ. of Tokyo, [2]Kobe Univ.

The 2011 Tohoku earthquake (M9.0) vastly changes stress field around the rupture zone, and many aftershocks and other related geophysical phenomenon such as geodetic movements have been observed. The seismicity not only keeps still high rate compared with that before the 2011 earthquake but is important to figure out the time-spacious distribution during the relaxation process for understanding the giant earthquake cycle. Many studies using ocean bottom seismometers (OBSs) [e.g. Shinohara et al,, 2011, Nakahigashi et al., this meeting] have been doing since soon after the 2011 Tohoku earthquake in order to obtain aftershock activity precisely. Here we show one of the studies at off the coast of Fukushima which is located on the southern edge of the rupture zone of the 2011 Tohoku earthquake. 12 short-period type [Lennartz 3Dlite] OBSs (SOBS) and 4 broadband type [Guralp CMG 3T] OBSs (BBOBSs) in Auguest 2012 were installed. 20 SOBSs and 4 BBOBSs attached with absolute pressure gauge [Paroscientific Model 8B] were added in November 2012. After one year continuous recording, 36 OBSs were recovered in November 2013. We selected characteristic 1,000 events in the vicinity of the OBS network based on a hypocenter catalog publish by the Japan Meteorological Agency, and extracted the events' data from all available OBS data after time corrections caused by each internal clock. Each P and S wave arrival times, P wave polarity and maximum amplitude were picked manually on a computer display using the WIN system [Urabe and Tsukuda, 1991]. We assumed one dimensional velocity structure that is modification of the result from an active source experiment close to our network, and applied time corrections every station which were estimated from differences from theoretical and observational travel times for removing ambiguity of the assumed structure. Then we adopted the maximum-likelihood estimation technique [Hirata and Matsu'ura, 1987] and calculated the hypocenters. Preliminary results show that intensive activity near the Japan trench can be seen while there was a quiet seismic zone between the trench zone and landward high activity zone.

Keywords: off Fukushima, Aftershock activity, Long-term OBS

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SSS24-P06 Room:Poster Time:May 1 18:15-19:30

Relation between Seismicity and Stress Change Associated with Interplate Slips off Boso Peninsula: Part 2

HIROSE, Fuyuki[1*] ; MAEDA, Kenji[1]

[1]Meteorological Research Institute

Hirose & Maeda (2012, 2013, JpGU; 2013, SSJ) investigated a relation between temporal variation of seismicity rate or b-value of the G-R law (Gutenberg and Richter, 1944, BSSA) and stress change associated with slow slip events (SSEs) around Boso peninsula. For example, there are three characteristic stages about seismicity: (S-1) activation during SSE, (S-2) quiescence before 2002 and 2007 SSE, and (S-3) seismicity rate increases after 2007 SSE. On the other hand, b-value repeats a cycle as follows: (b-1) small during and just after SSE, (b-2) gradually increases up to the next SSE.

By considering the correlation of seismicity rate with stress increase and inverse correlation of b-value with stress obtained in laboratory experiments (Dieterich, 1994, JGR; Scholz, 1968, BSSA), they interpreted their result as follows: for (S-1, b-1) during SSE, the slip rate at the edge of SSE on the plate boundary where is seismically active becomes higher (We can confirm it from the distribution of slip deficit and SSE estimated by GNSS data). Then because a strain accumulation rate increases, the stressing rate increases. Thus, seismicity rate increases, and b-value decreases at the same time. On the other hand, for (S-2, b-2) in SSE interval, because the slip rate on the plate boundary becomes lower than that during SSE, the seismicity rate decreases, and b-value increases at the same time. For (S-3) seismicity rate increases after 2007 SSE, the distribution of slip deficit after 2007 SSE is not much different from that before SSE. When we consider a frame of Dieterich (1994), only steady slip rate should become higher without changing of slip deficit rate so that seismicity rate changes under this situation because slip deficit on the plate boundary is independent of the value of steady slip rate (Savage, 1983, JGR). That means the drop of the coupling rate on plate boundary (slip deficit rate / steady slip rate). Therefore, the temporal change of the seismicity and b-value is comprehensively consistent with the perturbation of the slip rate on the plate boundary.

By the way, Boso SSEs had occurred every 4-7 years, but the latest interval of occurrence has a shorter period because those occurred in the end of 2011 and early in 2014. It is considered that the shortening of interval is mainly caused by the influence of the 2011 off the Pacific Coast of Tohoku Earthquake (Mw9.0, hereinafter Tohoku earthquake). We extended data period and investigated whether the same characteristics as before are also seen for the 2014 SSE. As a result, it showed such the same characteristics that (S-1) activation during SSE, (S-3) seismicity rate increases after 2007 SSE, (b-1) small during and after SSE, and (b-2) gradually increase up to the next SSE. On the other hand, (S-2) quiescence before SSE was not recognized because the perturbation of stress caused by the Tohoku earthquake may affect the seismicity.

Keywords: Boso peninsula, slow slip event, b value, stress, temporal change

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Microseismicity around the Nankai trough south off the Kii Peninsula

YAMAZAKI, Akira[1*]

[1]Meteorological Research Institute

The seismicity around the Nankai trough axis and its southern area, south off the Kii Peninsula, was not well understood, because most previous ocean bottom seismograph observations had been performed at landward from the trough axis. In order to investigate the seismicity around the region, Meteorological Research Institute conducted ocean bottom seismograph observations at around the Nankai trough axis and its southern area from 2005 to 2008, cooperated with Seismology and Volcanology Department, Japan Meteorological Agency (JMA). We conducted four observations, which period was approximately three months, using about ten pop-up type ocean bottom seismographs. As a result, we could detect a microseismic activity, which were not listed in the earthquake catalogue by JMA, around the trough axis.

The features of the microseismic activity are as follows. The depth of the hypocenters distributes around 10km to 25km. Since the depth of hypocenters determined by JMA at the region distributes around 30km to 40km, the true depth of the earthquakes is considered about 20km shallower than that of the JMA. There is a clear lower limit plane of hypocenters, and little earthquakes occur deeper than 25km. As a general tendency, the microseismic distribution has south incline at seaward from the trough axis, north incline at landward. The distribution of the hypocenters is not uniform, and we can detect some seismic clusters, liner arrangements and several seismic gaps of the 20km to 30km in diameter. It seems that seismic segment structures are formed within the Philippine Sea plate.

In general, seismic activity around a trough axis is causes by bending of oceanic plate. Moreover, the activity is affected by somewhat change of interplate coupling status at subduction zone. For instance, it is pointed out that the focal mechanism at outer rise region changes from compressional to tensional tectonic field by occurrence of large interplate earthquakes at subduction zone. We propose a possibility that the temporal change of the microseismic activity around the Nankai trough axis reflects a temporal change of the plate motion or a somewhat change of plate coupling conditions.

Keywords: ocean bottom seismograph, Tonankai earthquake, Nankai earthquake, Nankai trough, microseismicity, Philippine Sea plate

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Repeating earthquake activity along the Izu-Bonin and Ryukyu trenches

HIBINO, Kota[1*] ; UCHIDA, Naoki[1] ; MATSUSHIMA, Takeshi[2] ; NAKAMURA, Wataru[1] ; MATSUZAWA, Toru[1]

[1]Graduate School of Science Tohoku University, [2]Faculty of Sciences,Kyushu University

There are several subduction systems near the Japanese islands. The 2011 Mw9.0 Tohoku-oki megathrust earthquake occurred at the northeastern Japan subduction zone and revealed a complementary relation between the slip areas for huge earthquakes and small repeating earthquakes (REs). Investigations of REs in other subduction zones and their comparison with Tohoku area are important for revealing generation mechanism of megathrust earthquakes.

We use seismograms from the High Sensitivity Seismograph Network (Hi-net) and Japan Meteorological Agency (JMA)'s permanent seismograph stations from 8 May 2003 to 31 December 2012. We detect RE along the Izu-Bonin and Ryukyu trenches, using similarity of seismogram pairs.

Although, Igarashi (2010) and Yamashita et al. (2012) have already examined RE activity in this region, we mainly follow the method of Uchida et al. (2010) to compare with the REs at Tohoku area. In the method, pair with coherence larger than 0.95 at multiple stations is considered to belong to a repeating earthquake group. We apply this method to the earthquakes along the Ryukyu trench. Along the Izu-Bonin trench, however, the signal-to-noise (S/N) ratios of the waveforms are not so good because of the limited seismic stations at sparsely distributed islands. Therefore, we adopt a coherence threshold of 0.8 and even if S/N ratios of the waveform are good at only one station, earthquake pairs that satisfy the threshold in multiple components are considered as candidates of REs along the Izu-Bonin trench.

Along the Ryukyu trench, we find RE distribution shows two dense bands parallel to the trench axis. This feature is similar to the northeastern Japan subduction zone. We consider the regions between the two bands of REs may have strong interplate locking as suggested at Tohoku.

Along the Izu-Bonin trench, in spite of the non-strict coherence threshold, we find much fewer REs than that in northeastern Japan. Our result suggests that REs are relatively rare along the Izu-Bonin trench and they mainly occur at the shallow part where the Pacific plate contacts with the crust of the Philippine Sea plate.

These varieties in the RE occurrences suggest different interplate locking patterns along these subduction systems.

Keywords: subdection zone, repeating earthquake, Izu-Bonin, Ryukyu, interplate locking

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Ocean bottom seismic observation in the Hikurangi subduction zone offshore the North Island of New Zealand

HAIJIMA, Daisuke[1*] ; MOCHIZUKI, Kimihiro[1] ; SHIOBARA, Hajime[1] ; YAMADA, Tomoaki[1] ; SHINOHARA, Masanao[1] ; HENRYS, Stuart[2] ; FRY, Bill[2] ; BANNISTER, Stephen[2]

[1]Earthquake Reserch Institute, University of Tokyo, [2]GNS Science

The Hikurangi Plateau which has ~12 km thick crust subducts under the Australian plate
in the Hikurangi subduction zone offshore North Island, New Zealand. The plate interface is relatively shallow so that geometry of the plate interface has been revealed in detail by high quality seismic reflection data collected along dense profiles along the margin [Bell et al. 2010]. Distribution of interseismic plate-coupling has been estimated and series of slow slip events (SSEs) have been detected at around the lower limit of the coupling region due to recent installation of dense GPS network over the North Island. In the northern part, along-strike coupling region is narrow and the upper limit extends to near the trench axis and the lower limit is shallow at ~15 km depth. Most of the region of strong interplate coupling is under the sea. We need to conduct seismic observation using ocean bottom seismometers (OBSs) to understand seismicity and hypocentral distribution in detail. SSEs occur at much shallower depth than other subduction zones.

We conducted a passive seismic observation using OBSs for the first time offshore Gisborne to reveal seismisity and low-frequency events accompanying SSEs. We deployed four OBSs in April 2012 and recovered all instruments after 11 months of observation. The northern two instruments were a broadband type and the other southern two were equipped with 1Hz seismometers. Although the recorder of one of the broadband type OBSs recorded only intermittently, good data were obtained from the others. An earthquake swarm occurred to the north of the array in September to November 2012. A large SSE occurred around the Hawke's Bay to the south of the array from mid-February 2013. At first we apply STA/LTA algorithm to this data to detect seismicity. The result shows seismicity was activated accompanying both the earthquake swarm and the SSE. We tried to determine the hypocenters of these events using 4 OBSs and some GeoNet onshore seismometers. We could detect more offshore events than are listed in the GeoNet catalogue owing to higher Signal-to-Noise ratios of the OBS data while most events occurred beneath the seafloor.

Keywords: seismicity, Hikurangi, OBS

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Greenland Ice Sheet Dynamics and Glacial Earthquake Activities

KANAO, Masaki[1*] ; TSUBOI, Seiji[2] ; TOYOKUNI, Genti[3] ; HIMEMO, Tetsuto[4] ; TONO, Yoko[2]

[1]National Institute of Polar Research, [2]Japan Agency for Marine-Earth Science and Technology, [3]Tohoku University, [4]Seikei University

The Greenland ice sheet and its response to climate change have potentially a great impact upon mankind, both through sea-level rise and modulation of fresh water input to the oceans. Monitoring a dynamic response of the Greenland ice sheet to climate change is a fundamental component of long-term observations in global science. Glacial earthquakes have been observed along the edges of Greenland with strong seasonality and increasing frequency in this 21st century by the data from Global Seismographic Network (GSN). During the period of 1993-2006, more than 200 glacial earthquakes were detected, but more than 95% have occurred on Greenland, with the remaining events in Antarctica. Greenland glacial earthquakes are considered to be closely associated with major outlet glaciers at the margins of the continental ice sheet. Temporal patterns of these earthquakes indicate a clear seasonal change and a significant increase in frequency after 2002. These patterns are positively correlated with seasonal hydrologic variations, significantly increased flow speeds, calving-front retreat, and thinning at many outlet glaciers. These long-period surface waves generated by glacial earthquakes are incompatible with standard earthquake models for tectonic stress release, but the amplitude and phase of the radiated waves can be explained by a landslide source model. The seismicity around Greenland including tectonic/volcanic events was investigated by applying a statistical model to the globally accumulated data. Calculated b values, the Magnitude-frequency-dependence parameter, indicated a slight increase from 0.7 to 0.8 in 1968-2007, implying that the seismicity including glacial events around Greenland become slightly higher during the last four decades. The detection, enumeration, and characterization of smaller glacial earthquakes were limited by the propagation distance to globally distributed stations of the GSN. Glacial earthquakes have been observed at stations within Greenland, but the coverage has been very sparse. In order to define the fine structure and detailed mechanisms of glacial earthquakes, a broadband, real-time network needs to be established throughout the ice sheet and perimeter. The International Polar Year (IPY 2007-2008) was a good opportunity to initiate the program with international collaboration. Then, the Greenland Ice Sheet Monitoring Network (GLISN) was initiated for the purpose of identifying the dynamic response of the Greenland ice sheet to climate change.

Keywords: Greenland, global warming, glacial earthquakes, broadband seismometer, monitoring