Japan Geoscience Union Meeting 2012
(May 20-25 2012 at Makuhari, Chiba, Japan)

SCG63-01 Room:303 Time:May 20 09:00-09:15

Episodic slow slip events in the Japan subduction zone before the 2011 Tohoku-Oki earthquake

ITO, Yoshihiro[1*], HINO, Ryota[1], KIDO, Motoyuki[1], FUJIMOTO, Hiromi[1], OSADA, Yukihito[1], INAZU, Daisuke[1], MIURA, Satoshi[2], OHTA, Yusaku[1], UCHIDA, Naoki[1], TSUJI, Takeshi[3], ASHI, Juichiro[4], MISHINA, Masaaki[1]

[1]Graduate School of Science, Tohoku University, [2]Earthquake Research Institute, The University of Tokyo, [3]Department of Civil and Earth Resources Engineering, Kyoto University, [4]Atmosphere and Ocean Research Institute, The University of Tokyo

We describe two transient slow-slip events that occurred before the 2011 Tohoku-Oki earthquake that occurred near the high coseismic slip region near the Japan Trench. A transient crustal deformation, which occurred over 7 days in November 2008, was measured using ocean-bottom pressure gauges and an on-shore volumetric strainmeter simultaneously; this deformation has been interpreted as an Mw 6.8 slow-slip event with a slip magnitude of 0.4 m at most. The other transient crustal deformation was observed in mid-February 2011, just before the 2011 Tohoku-Oki earthquake: the source model of this deformation is probably almost the same as that of the 2008 transient slow slip. The two transient slow deformations preceded interplate earthquakes of magnitudes M 6.1 and M 5.8 in December 2008 and February 2011, respectively. The hypocenters are located at the down-dip ends of the slow-slip area. Our findings indicate that the slow-slip events induced an increase in shear stress, which in turn triggered the interplate earthquakes. The slow-slip area is also located within the large coseismic slip area of the 2011 earthquake; in particular, the slow-slip area is mainly located in the down-dip end of the high coseismic slip region near the Japan Trench. The result suggests that a fault segment where velocity strengthening occurs at low slip velocity and velocity weakening occurs at high slip velocity probably exists in the down-dip portion of the high coseismic slip area of the 2011 Tohoku-Oki earthquake.

Keywords: Slow slip event, The 2011 Tohoku-Oki earthquake, Ocean-bottom pressure observation

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SCG63-02 Room:303 Time:May 20 09:15-09:30

Depth-dependency on direction and velocity of tremor migration in Kii peninsula

OBARA, Kazushige[1*], MATSUZAWA, Takanori[2], TANAKA, Sachiko[2], MAEDA, Takuto[1]

[1]Earthquake Research Institute, The University of Tokyo, [2]National Research Institute for Earth Science and Disaster Prevention

Coupling phenomenon of non-volcanic tremor and slow slip event in southwest Japan [Obara, 2002; Obara et al., 2004] and Cascadia [Dragert et al., 2001; Rogers and Dragert, 2003] called Episodic tremor and slip (ETS) is an evidence for weak coupling of the plate interface at the downdip side of the seismogenic zone. One of the most significant features of tremor is migration. So far there exist three types of tremor migration; along-strike long-term migration at a speed of about 10 km/day [Obara, 2010], rapid tremor reversal (RTR) which is along-strike migration at a speed of order of 100 km/day propagating in the opposite direction from the long-term migration [Houston et al., 2011], and much faster slip-parallel migration at a speed of order of 1000 km/day detected in southwest Japan [Shelly et al., 2007] and Cascadia [Ghosh et al., 2010]. These three migration modes might reflect the main and sub rupture processes during the slow slip episode. Whether the tremor migration is composed of only above three modes or more is very important to construct the appropriate physical model for slow slip phenomena. In this paper, we investigate tremor migration by detecting automatically linear distribution of tremor sequence in Kii peninsula, southwest Japan.

We mainly analyzed a tremor catalog derived from the modified envelope correlation method [Maeda and Obara, 2009] considering with amplitude information applied to borehole data of the High Sensitivity Seismograph Network (Hi-net) administrated by the National Research Institute for Earth Science and Disaster Prevention (NIED) of Japan [Obara et al., 2005] from 2001 to 2010. In order to extract various migrating tremor sequences, we set four different time scales; 0.5, 1, 2 and 4 hours. For the given time window, at first, we choose a linear trend from the space-time plot. In this process, outliers with their distances from the regression line greater than two times of the standard deviation are removed. Then, the linearity of the tremor distribution in the map view and the space-time plot is checked by the principal component analysis. Total numbers of extracted migrating tremor sequences are 167, 213, 169 and 203 for time scales of 0.5, 1, 2 and 4 hours, respectively. The direction of migration is clearly different depending on the time scale. As a result, the tremor migration is characterized by prefixed direction at widely ranging speeds from a few to several 10 km/hr depending on the location. Decrease in the migration speed with increasing measurement time scale suggests that a diffusion process controls migration. The along-strike migration at the slower speed is concentrated in the updip edge of the tremor zone, on the other hand, the slip-parallel faster migration is detected in the downdip side. The long-term migration seems to be composed of and excited by the updipmost along-strike creep propagation. The updip along-strike migration might reflect existence of abundant fluid accumulated at the corner of the mantle wedge. Both of the faster slip-parallel migration and RTR might represent a projection of the along-strike fluctuation of slip pulse propagation at the slip-parallel striation.

Keywords: non-volcanic tremor, slow earthquakes, subduction zone, source migration

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SCG63-03 Room:303 Time:May 20 09:30-09:45

Triggered non-volcanic tremor in SW Japan by the Love waves from the 2011 M9.0 Tohoku earthquake and its aftershocks

ENESCU, Bogdan[1*], Kevin Chao[2], Zhigang Peng[2], OBARA, Kazushige[3], MATSUZAWA, Takanori[1], TANAKA, Sachiko[1], TAKEDA, Tetsuya[1]

[1]National Research Institute for Earth Science and Disaster Prevention, [2]Georgia Institute of Technology, [3]Earthquake Research Institute, The University of Tokyo

The March 11, 2011 M9.0 Tohoku earthquake was followed by large aftershocks and broad seismic activation both inland and offshore Japan (e.g., Hirose et al., 2011; Ogata, 2011; Toda et al., 2011). Previous studies (Enescu et al., 2011; Miyazawa, 2011; Obara and Matsuzawa, 2011) reported remotely triggered seismicity at distances up to about 1350 km from the mainshock. Deep non-volcanic tremor in south-west Japan (Obara, 2002) was also clearly activated following the Tohoku earthquake. We focus here on the detailed analysis of the triggered tremor.

We detect tremor that correlates with the passage of the mainshock surface waves at several Hi-net seismic stations in Shikoku region, at distances of about 1000 km from the Tohoku earthquake epicenter. We use an envelope cross-correlation technique to locate the tremor sources. The best tremor location is determined using a 3D grid-search that minimizes the residuals between observed and calculated travel time differences at pairs of recording stations. While the depth of the tremor source is not well constrained by our grid search, the signal originates from a deep source in the lower crust. Our location results show that the mainshock triggered tremor in two distinct areas, in western and central Shikoku, in regions where ambient (i.e., not triggered) tremor occurs (e.g., Obara et al., 2010). The triggered tremor in western Shikoku also occurs close to the tremor triggered by previous large, remote earthquakes (e.g., Miyazawa and Mori, 2006).

We have also detected triggered tremor during the passage of the incoming surface waves from the earliest aftershock (M7.4) of magnitude above 7.0, which occurred about 23 min. after the mainshock, as well as from the largest aftershock (M7.7) that occurred about 30 min from the mainshock. However, we did not find any evidence of triggered tremor by the M7.3 foreshock, occurred on March 9th, 2011.

We have estimated the peak dynamic stresses during the passage of surface waves from the mainshock and the two aftershocks, using the observed peak ground velocity at nearby F-net and KiK-net stations. The obtained values are roughly between 10 KPa and 180 KPa (the upper value corresponds to the mainshock), higher than the apparent triggering threshold found in this and other regions (Chao et al., 2011).

We have checked whether the detected tremor was triggered by the passage of the Love or Rayleigh waves from the Tohoku mainshock and its aftershocks. Our results indicate that the Love waves were the main triggering factor. The tremor triggered by the mainshock and the M7.4 aftershock, in particular, correlate well with the Love waves cycle. Our results are consistent with theoretical modeling that shows that Love wave displacement to the south-east (sea-ward) would promote up-dip shear on the plate interface in the Shikoku region (Hill, 2010). In a related study, Chao et al. (2011) report Love wave triggering in Shikoku by other remote earthquakes. While the triggering by Rayleigh waves in south-west Japan has been well documented (e.g., Miyazawa and Mori, 2008), our recent work shows for the first time clear evidence of Love wave triggering in the region.

Keywords: Non-volcanic tremor, SW Japan, triggering, Love waves, 2011 M9.0 Tohoku earthquake

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SCG63-04 Room:303 Time:May 20 09:45-10:00

Semi-Volcanic Deep Low-Frequency Earthquakes

ASO, Naofumi[1*], OHTA, Kazuaki[1], KURIHARA, Yoshiharu[1], IDE, Satoshi[1]

[1]The University of Tokyo

<**Backgrounds**>

Deep low-frequency earthquakes (LFEs) are categorized into three types based on their locations: volcanic LFEs near the Mohorovicic discontinuities beneath active volcanoes, tectonic LFEs on the plate boundaries, and isolated intraplate LFEs near the island arc Mohorovicic discontinuities far from active volcanoes. The geographical distribution of LFEs suggests that these three types of LFEs are related to great natural phenomena such as volcanic eruptions, interplate megathrust earthquakes, and large inland earthquakes, respectively. While tectonic LFEs have been revealed in many respects since their discovery in the beginning of this century, volcanic LFEs and isolated intraplate LFEs are less understood and the previous works on them tended to focus on individual activities of regional LFEs [e.g., *Hasegawa et al.*, 1991; *Ohmi and Obara*, 2002]. As a comparative study, *Aso et al.* [2011] pointed out that the isolated intraplate LFEs in Osaka Bay show similar activities to volcanic LFEs, but the universal characteristics of LFEs and the basic differences between three types of LFEs have never been revealed. In the present study, we extracted the common characteristics of isolated intraplate LFEs by analyzing the activities of isolated intraplate LFEs in multiple regions, and compared three types of LFEs based on a common method by analyzing volcanic LFEs and tectonic LFEs in the same way.

<**Data and methods**>

Based on the method developed by *Aso et al.* [2011], we analyzed and compared the seismicity of isolated intraplate LFEs in Osaka Bay and eastern Shimane, volcanic LFEs in Sakurajima, and tectonic LFEs in northern Kochi and central Ehime. Because the detected LFEs by Japan Meteorological Agency (JMA) are not sufficient for statistical analysis, in the present study, we automatically detected LFEs using waveform correlation on the Hi-net continuous records and estimated the magnitude of the detected LFEs based on the amplitude ratios. To study temporal and spatial characteristics, we quantified the sensitivity to tidal stress by taking activity spectrum and examined the detailed structure of hypocenter distribution by applying the NCC relocation method [*Ohta et al.*, 2008].

<**Result and discussions**>

The isolated intraplate LFEs and volcanic LFEs obey the Gutenberg-Richter law with a b-value of 2, while distinct upper limits were found in the frequency magnitude statistics of tectonic LFEs. The activity spectra of the isolated intraplate LFEs and volcanic LFEs show no evidence of tidal modulation, while those of tectonic LFEs have a clear peak at the M_2 period, suggesting tidal modulation. The relocated hypocenters of isolated intraplate LFEs and volcanic LFEs are distributed vertically as well as horizontally, while the distributions of tectonic LFEs are linear or planar on the nearly-horizontal plate boundary. These characteristics of three types of LFEs in five regions manifest that isolated intraplate LFEs are quite similar to volcanic LFEs, and that tectonic LFEs are different phenomena. Moreover, the discretized triggering model developed by *Kurihara et al.* [2012 (this meeting)] shows similar triggering probabilities for isolated intraplate LFEs and volcanic LFEs. In addition to the fact that most isolated intraplate LFEs occur beneath Quaternary volcanoes, these new findings about activities of LFEs suggest that isolated intraplate LFEs are generated by movements of fluids, as suggested for volcanic LFEs previously. Hence we propose that isolated intraplate LFEs should be named as "semi-volcanic" LFEs. In the future works on LFEs, semi-volcanic LFEs should be regarded as almost the same phenomena to volcanic LFEs, and their analyses may contribute to the understanding of volcanic LFEs and volcanism. Another kind of important information to identify the actual physical process is provided by focal mechanisms, which have been also estimated reliably by *Aso et al.* [2012 (this meeting)].

Keywords: Low-Frequency Earthquake, Semi-Volcanic LFE

SCG63-05 Room:303 Time:May 20 10:00-10:15

Detection of short-term slow slip events using GPS data in southwestern Japan (Part 2)

NISHIMURA, Takuya[1*], MATSUZAWA, Takanori[2], OBARA, Kazushige[3]

[1]GSI of Japan, [2]NIED, [3]ERI, Univ. of Tokyo

Nishimura and Suito (2011) reported that GPS was able to detect short-term slow slip events (SSEs) which had been observed only by tiltmeters and strainmeters on the plate interface of the Philippine Sea plate. Here, we present a method to detect the deformation associated with the SSEs in southwestern Japan and fault models of the SSEs inverted from GPS data. We also compare them with a tremor activity (Maeda and Obara, 2009; Obara et al., 2010) and the fault models of the SSEs estimated from tilt data (Sekine et al., 2010).

Daily coordinates of 565 GEONET stations in southwestern Japan were used to detect the deformation of the SSEs. We fitted a step function to the filtered daily coordinates to detect displacements in a direction of N130^{o}E which is opposite to the relative plate motion between the Philippine Sea plate and southwestern Japan. The candidate dates of the SSEs are determined if the significant displacements were detected. And three components (i.e., EW, NS, and UD) of the displacement were inverted to estimate a rectangular fault model. We finally recognized SSEs if the observed displacement were well reproduced by the fault model.

201 candidates of SSEs were found in a period from June 19, 1996 to August 14, 2011. They were categorized into 88 certain SSEs, 51 probable SSEs and 62 non-SSEs. Moment magnitude (M_w) of the 137 certain and probable SSEs ranges between 5.4 and 6.4. SSEs with M_w => 6.2 have occurred only in western and central Shikoku 7 times. No certain SSEs occurred in the Kii Channel and east of 137.5^{o}E (Lake Hamana). A couple of certain SSEs have occurred in Ise Bay where the tremor activity is weak.

Comparing the fault models from GPS with those from tilt data (Sekine et al., 2010), we found 27 SSEs included in both catalogues. There is no systematic difference of their M_w estimated from GPS and tilt. SSEs with M_w => 6.1 were included in both catalogues. However, 25 and 17 SSEs were detected solely from GPS and tilt data, respectively. Those SSEs must be real slip events because they accompany tremor activities. It, therefore, suggests that the detectability of neither GPS nor tiltmeter is perfect for small SSEs. We calculated moment released by SSEs in each segment along the Nankai Trough. The moment rate is roughly constant in western Shikoku for 15 years but it increases around 2006 in eastern Shikoku. The increase may reflect a long-term change of conditions on the plate interface because similar increase is also observed in tremor activities (Obara et al., 2010). However, we cannot rule out that the increase is artificial due to replacement of GPS antennas and additional GPS stations.

Keywords: short-term SSE, GPS, southwestern Japan

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SCG63-06 Room:303 Time:May 20 10:15-10:30

Activation of short-term slow slip events and deep non-volcanic tremors due to the Bungo-Channel slow slip event

KISHIMOTO, Tsuyoshi[1*], SUDA, Naoki[1], OZAWA, Shinzaburo[2], YARAI, Hiroshi[2]

[1]Hiroshima Univ., [2]GSI

In the Nankai subduction zone, slow earthquakes with various time constants occur in the transition region of the subducting plate interface. In particular in the Bungo Channel region, the westernmost part of the slow earthquake belt in southwest Japan, not only short-term slow slip events along with very low-frequency earthquakes and non-volcanic tremors with a recurrence interval of 2 to 3 months, but also long-term slow slip events occurred in 1997, 2003, and 2009-2010 at the shallower part of the subdudting plate interface. It has been observed that very low-frequency earthquakes are associated with these aseismic slips at the further shallower portion near the Nankai trough. These aseismic events also activate tremor occurrences at deeper part in the Bungo Channel region. These suggest that the long-term slow slip events affect the source regions of other slow earthquakes. In our previous study, we focused on activated tremor occurrences during the 2009-2010 long-term slow slip event. We calculated the coulomb stress rate in the tremor source region from the slip history of 2009-2010 long-term slow slip event, and compared it with tremor durations in the three subregions, southwest and northeast of Hiburi Island, and westernmost Shikoku. We found that observed tremor activity changes were consistent with the calculated Coulomb stress rate due to the long-term slow slip event in each subregion.

According to the steady-state seismicity rate theory based on the rate- and state-dependent (R/S) friction law, the calculated Coulomb stress rate should be proportional to the observed tremor duration, but we found that the observation did not satisfy this relation. This is because we assumed that the observed tremor activity change was a direct consequence of the long-term slow slip event. In the model of concurrent occurrence of slow earthquakes, tremors are triggered by the transient stress change due to the short-term slow slip events. In this study, on the basis of this model, we consider a two-step model for the observed activation of tremor occurrence: the long-term slow slip event first activates occurrence of short-term slow slip events, and then they activate the tremor occurrence. Using this model, we have found that the steady-state seismicity rate theory gives a better quantitative explanation to the apparent consistency between the calculated Coulomb stress rate due to the long-term slow slip event and the observed tremor activity.

Keywords: slow slip event, deep non-volcanic tremor, coulomb stress rate, Bungo Channel

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SCG63-07 Room:303 Time:May 20 10:45-11:00

Slip history for the 2011 Boso peninsula slow slip event and the accompanying earthquake swarm

HIROSE, Hitoshi[1*], KIMURA, Hisanori[2], KIMURA, Takeshi[2], MATSUZAWA, Takanori[2]

[1]Department of Earth and Planetary Sciences, Kobe University, [2]National Research Institute for Earth Science and Disaster Prevention

Around the Boso peninsula, central Japan, slow slip events (SSEs) lasting for one to two weeks that are accompanied by earthquake swarm activity recur every 5-7 years in association with the subduction of the Philippine Sea plate (Sagiya, 2004; NIED, 2003; Ozawa et al., 2003, 2007). In October 2011, the latest episode occurred after the shortest interval of four years and two months in 30 years. The crustal deformations for this episode and the previous episode in 2007 are detected with the GEONET GPS array operated by the Geospatial Information Authority of Japan and the NIED Hi-net high-sensitivity accelerometers (tiltmeters). In order to clarify the relation between these SSEs and the accompanying earthquake swarms, it is important to estimate detailed source processes of the SSEs, and to compare them with the temporal and spatial distribution of the earthquakes. In this study, we investigate the slip source processes for the 2007 and 2011 SSEs based on the Hi-net tiltmeter data and the GEONET data.

The slip histories for both episodes show the following common features in an overall view: (1) slip initiates at the eastern offshore area of Katsuura and the center of the slip migrates to the west direction gradually as the slip accelerates, and (2) the earthquake activity also migrates from the eastern area to the west, corresponding to the slip migration. These evidence strongly suggests that the earthquake swarms are triggered by the slow slip. However, the two episodes have slightly different slip histories. For the 2007 episode, slip initiates at the eastern offshore area and migrates to the northern, deeper part in the initial stage. For the 2011 episode, the northward slip migration seen in the 2007 episode is not resolved significantly, but the slip propagates slightly to the southwestern, shallower area after the slip acceleration and the active phase of the earthquake swarm. Although these differences in the slip histories might be artifacts caused by different station coverages, there is a possibility that the differences show the variation in the slip processes through the cycle of the Boso SSEs. Since the source region of the SSEs is located by the rupture area of the interplate great earthquakes along the Sagami trough, the SSEs are important indicators to study the interseismic preparation process for the megathrust earthquakes.

Acknowledgments: The GPS data were provided by Geospatial Information Authority of Japan.

Keywords: Sagami trough, subduction zone, GPS, tilt change, earthquake swarm

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SCG63-08 Room:303 Time:May 20 11:00-11:15

Atomistic origin of velocity-strengthening friction

HATANO, Takahiro[1*]

[1]ERI, Univ. Tokyo

Since the discovery of non-volcanic deep low-frequency tremor (Obara 2002), various kinds of slow earthquakes (or slow slips) have been discovered. However, the underlying physical mechanisms that yield such diversity of slow slips are still not known. Because the slow slips play an essential role in the stress accumulation processes in subduction zones through the cycle of slow slips and the moment release dynamics, various models have been proposed that address to reproduce slow slips and their cycle. In most of the models, friction laws are employed that possess positive velocity dependence. It is natural because the slow slips involve some kinds of stability, which may be represented as positive velocity dependence. However, from materials science point of view, it is not generally understood that under what conditions friction can have positive velocity dependence.

Here we report the atomistic nature of the rate- and state-dependent friction law, which is often adopted in modeling slow earthquakes. We begin with the creep constitutive law that describes the deformation process of a true contact junction and derive the rate- and state-dependent friction law. As a result, the empirical parameters (generally denoted by a, b, and L) are expressed in terms of atomistic parameters (activation energy, temperature, etc). By virtue of these expressions, one can determine the velocity dependence of friction from materials constants, and the length constant from the surface topography. We further discuss these results that are relevant to slow earthquakes: in particular, 1) crossover from negative to positive velocity-dependence. 2) role of water in velocity dependence.

Keywords: friction, rate- and state-dependent friction, creep

SCG63-09 Room:303 Time:May 20 11:15-11:30

Geological process of the slow earthquakes

KITAMURA, Yujin[1*], KIMURA, Gaku[2], KAWABATA, Kuniyo[3]

[1]IFREE, JAMSTEC, [2]Dept. Earth Planet. Sci, Univ. Tokyo, [3]Inst. Geophys., National Central Univ.

We present an attempt to unveil the geological aspects of slow earthquakes and the related plate boundary processes and to establish a model for slow earthquake formation. As we have investigated material along subduction channel from on-land outcrops and ocean drilling cores, a series of progressive deformation down to the down-dip limit of the seismogenic zone was revealed. Studied tectonic melanges in the Shimanto Belt, Japan are regarded as fossils of plate boundary fault zone in subduction zone. Detailed geological survey and structural analyses enabled us to separate superimposed deformation events during subduction. Material involved in the plate boundary deformation is mainly an alternation of sand and mud. As they have different competency and are suffered by simple shear stress field, sandstones break apart in flowing mudstones. We distinguished several stages of these deformations in sandstones and recognized progress in the intensity of deformation with increment of underthrusting. It is also known that the studied Mugi melange bears pseudotachylyte in its upper bounding fault. Our conclusion illustrates that the subduction channel around the depth of the seismogenic zone forms a thick plate boundary fault zone, where there is a clear segregation in deformation style: a fast and episodic slip at the upper boundary fault and a slow and continuous deformation within the zone. The former fast deformation corresponds to the plate boundary earthquakes and the latter to the slow earthquakes. We further examined numerically whether this plate boundary fault rock is capable of releasing seismic moment enough to fit the observed slow earthquakes. The shallow very low frequent earthquakes (VLFs) are chosen to be modeled and our estimation satisfies the natural data. These results make a strong impact on the study of seismic energy balance because we show a possibility to give an absolute value of them from geological approach, which could not have been achieved with seismology.

Keywords: Slow earthquake, Shimanto Belt, Nankai Trough, plate boundary earthquake, tectonic melange

SCG63-P01 Room:Convention Hall Time:May 20 15:30-17:00

Non-volcanic low frequency tremors at Kii channel detected by vertical seismic array network (VA-net)

TAKEDA, Naoto[1*], IMANISHI, Kazutoshi[1]

[1]Geological Survey of Japan, AIST

In 2007, Geological Survey of Japan has started an integrated borehole observation (water levels, strains, seismic waves etc.) in southwest Japan for forecasting the Tonankai and Nankai megathrust earthquakes. At present, 14 stations are in operation. Each site has three level vertical seismic array. We developed a high sensitive detection method (Vertical Seismic Array Detection: VSAD) of non-volcanic low frequency tremors (NVTs) using the three level vertical seismic array network, VA-net, and demonstrated that the method enables us to detect minor NVTs which cannot be identified by a conventional envelope cross-correlation method (Imanishi et al., 2011).

The spatial distribution of the NVTs in southwest Japan is not uniform and has some clear gap areas of activities (e.g., Obara, 2010). On the basis of the VSAD method, Takeda et al. (2011) succeeded in detecting NVTs in Ise Bay, which is one of major gap regions of NVT activities. In this study, we report the NVT activities in another major gap region, Kii Channel, that was detected by the VSAD method.

We analyzed vertical seismic array waveforms of our observatory in Anan city of Tokushima prefecture, which faces Kii Channel. The VSAD method was applied over the last three and a half years. It is noted that large activities of long duration were not recognized, while small activities lasting a few minute were frequently detected. We determined epicenters of these NVTs by using manually picked S-wave arrival times and found that these events are located to the northeast of Anan city.

References:

Imanishi, K., N. Takeda, Y. Kuwahara, and N. Koizumi (2011), Enhanced detection capability of non-volcanic tremor using a 3-level vertical seismic array network, VA-net, in southwest Japan, Geophys. Res. Lett., 38, L20305, doi:10.1029/2011GL049071.

Obara, K. (2010), Phenomenology of deep slow earthquake family in southwest Japan: Spatiotemporal characteristics and segmentation, J. Geophys. Res., 115, B00A25, doi:10.1029/2008JB006048.

Takeda, N., K. Imanishi, and N. Koizumi (2011), Non-volcanic low frequency tremors only detected by vertical seismic array network (V-net), Japan GeoScience Union Meeting 2011, SCG058-P03.

Acknowledgements: We use seismic waveform data provided by National Research Institute for Earth Science and Disaster Prevention (Hi-net), JMA and University of Tokyo.

Keywords: vertical seismic array, VA-net, Non-volcanic low frequency tremor, Kii channel

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SCG63-P02 Room:Convention Hall Time:May 20 15:30-17:00

P- and S-wave detection of the low frequency earthquakes (LFE) using 3D array (3)

SUZUKI, Sadaomi[1*], OKUBO, Makoto[1], IMANISHI, Kazutoshi[2], KITAGAWA, Yuichi[2], TAKEDA, Naoto[2]

[1]TRIES, [2]AIST

Tokai area is the eastern side of Southwest Japan subduction where great earthquakes and deep low-frequency earthquakes (LFEs) occur along the convergent plate boundary.Researching the relationship between the great interplate earthquakes and activity of LFEs, Tono Research Institute of Earthquake Science (TRIES) installed two seismic arrays at Shimoyama in Tokai area. The first was a small-aperture array (six stations in the area of 120m diameter) with short-period velocity type seismographs. The second was a middle-aperture array (four stations in the area of 4 km diameter) with high-sensitive acceleration type seismographs. Geological Survey of Japan (AIST) also installed a seismic array of three borehole-type instruments with high-sensitive seismographs at three depths of 50m, 200m, and 600m at Shimoyama.We used seismic data of those three arrays and SMYH station of Hi-net array of National Research Institute of Earth Science and Disaster Prevention (NIED) as 3D array data for investigating LFEs. Using the 3D array (total 14 stations), we observed a remarkable activity of LFEs occurring in Tokai area in November 10-30, 2010. We analyzed the 3D array data to pick out direct P and S-waves propagating from LFE origins by using the semblance method. Assuming a homogeneous half space model with Vp=4.5 km/s and Vs=2.2 km/s,we obtained a semblance distribution for each component depending on the three factors of time, back-azimuth and incident angle of seismic waves. The maximum semblance point in each component shows a direct P-wave in UD, and S-wave in NS and EW, respectively. Incident angles and back-azimuths are compared with theoretical ones calculated by using JMA hypocenter data. Using the estimated S-P time of the LFE, we recalculated the depth of its hypocenter. The LFE locates near the interface of the Philippine Sea Plate subducting under Tokai area.

Keywords: deep low-frequency earthquake, 3D array, P- and S-waves, semblance, plate boundary

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SCG63-P03 Room:Convention Hall Time:May 20 15:30-17:00

Multiple Seismic Array Observations of Non-volcanic Deep Tremor in Western Shikoku (Part2)

TAKEDA, Tetsuya[1*], MATSUZAWA, Takanori[1], SHIOMI, Katsuhiko[1], OBARA, Kazushige[2]

[1]NIED, [2]ERI, Univ. of Tokyo

Deep non-volcanic tremors become very active during episodic slow-slip events in western Japan and Cascadia. Detailed tremor activity are important to understand the mechanism of tremor and the relationship between tremor and SSEs. However it is difficult to determine the location of tremors with high accuracy because tremors show faint signals and make the identification of P/S-wave arrivals difficult. The Envelope Correlation method (Obara, 2002) and the Hybrid method (Maeda and Obara, 2009), which are focusing on energy temporal change and excluding phase information, were developed. Seismic array analysis (e.g. Ueno et al., 2010, Ghosh et al., 2010), which is focusing on phase information, is also useful to evaluate tremor activity, especially to estimate the arrival direction of seismic energy, as it can distinguish multiple tremor sources occurring simultaneously. Here, we have conducted seismic array observation and analyzed seismic data during tremor activity by applying the MUSIC method to trace tremor location and its migration in western Shikoku.

We have installed five seismic arrays in western Shikoku since January 2011. One of the arrays contains 30 stations with 3-component seismometers with a natural frequency of 2 Hz (Type-L array). The array aperture size is 2 km and the mean interval between stations is approximately 200 m. Each of the other arrays (Type-S array) contains 9 seismic stations with the same type of seismometers of the Type-L array, and is deployed surrounding the Type-L array. The small array aperture size is 800 m and its mean station interval is approximately 150 m. All array stations have recorded continuous waveform data at a sampling of 200Hz.

We have installed five seismic arrays in western Shikoku since January 2011. One of the arrays contains 30 stations with 3-component seismometers with a natural frequency of 2 Hz (Type-L array). The array aperture size is 2 km and the mean interval between stations is approximately 200 m. Each of the other arrays (Type-S array) contains 9 seismic stations with the same type of seismometers of the Type-L array, and is deployed surrounding the Type-L array. The small array aperture size is 800 m and its mean station interval is approximately 150 m. All array stations have recorded continuous waveform data at a sampling of 200Hz.

In May 2011, an episodic tremor and a short-term slip event occurred for the first time during the observation period. We could retrieve the array seismic data during the whole tremor episode. The analysis of data from the type-L array confirms concentrated seismic energy arriving from the anticipated direction of tremor which is located by the Hybrid (Maeda and Obara, 2009; Obara et al., 2010). Most of the arrays could detect the arrival direction; the Type-L array could also estimate the slowness with an adequate accuracy. We converted from slowness to location (latitude and longitude) in MUSIC spectrum by assuming tremor occurs on the plate boundary and compared with results of the Hybrid method. The MUSIC spectrum peak approximately is consistent with the epicenter of the Hybrid method. But spectrum peak concentration that the Hybrid method cannot detect is also observed. This is an advantage of the seismic array analysis that also uses phase information.

Keywords: Low frequency tremor, Multiple seismic array

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SCG63-P04 Room:Convention Hall Time:May 20 15:30-17:00

Resolving slip evolution of deep tremor in western Japan

OHTA, Kazuaki[1*], IDE, Satoshi[1]

[1]EPS, Univ. of Tokyo

Recent studies have shown that deep tectonic tremors in many subduction zones consist of numerous low-frequency earthquakes (LFEs) that occur as shear slips on the plate interface. LFE hypocenters are determined relatively accurately, and in western Japan, they are concentrated in a narrow zone around the anticipated plate interface [Ohta and Ide, 2011]. Therefore, the location of LFEs may constrain the instantaneous location of tremor sources and illustrate its migration behavior, as demonstrated by a matched filter analysis with template LFEs [Shelly et al., 2007]. Nevertheless, it is yet unclear whether tremor occurs at exactly the same location as LFEs. Since tremor behavior on the plate interface are various and spatially characteristic [Ide, 2010], there might be some tremor activity undetectable using template LFEs. Moreover, while the previous method using matched templates has achieved to draw the discrete picture of the slip behavior of potential tremor, it is not sufficient to explain the entire rupture process. To understand the underlying physics of tremor and other slow earthquakes, it is essential to highly resolve the spatial and temporal behavior of the rupture of these events.

This study determines spatiotemporal slip distribution associated with deep tremor in western Japan, without the spatial limitation of template LFEs. We first estimate the location of the plate interface based on the precise hypocenter locations of LFEs in a target region and prepare "synthetic template waveforms" by stacking the seismograms of these LFEs at every grid point arranged on this interface. These synthetic template waveforms can be used in a matched filter analysis to continuous waveforms, to grasp a crude image of tremor source. Furthermore, we use the synthetic waveforms as substitute of Green's functions, and invert continuous tremor waveforms by a non-linear slip inversion method.

We apply the method to 3600 s continuous velocity seismograms recorded at Hi-net stations in the western Shikoku, on 16 March, 2008 from 23:00-24:00, to obtain the detailed slip history of about 1200 s tremor sequence. The slip episode migrates from south to north and consists of three stages: (1) the southern part for 80 s, (2) the central part for several hundred seconds, and (3) the northern part for 60 s. Average migration velocity is between 10-50 m/s, and the first and third stages correspond to unknown VLF events, whereas the second stage includes a much longer slip episode. These differences may be associated with the heterogeneities of material properties on the plate interface.

Keywords: deep tremor, slow earthquake, subduction zone, Nankai Trough, slip distribution

SCG63-P05 Room:Convention Hall Time:May 20 15:30-17:00

Triggered low frequency tremors in Tonankai accretionary prism, by the 2011 Tohoku-Oki earthquake

TO, Akiko[1*], OBANA, Koichiro[1], TAKAHASHI, Narumi[1], FUKAO, Yoshio[1]

[1]Japan Agency for Marine-Earth Science & Technology

There have been many reports of triggered tremors and micro-earthquakes, by the 2011 Tohoku-Oki earthquake, most of which are based on land observations. Here, we report that numerous low frequency tremors are recorded by broadband ocean-bottom seismographs of DONET, a network of cabled observatory systems deployed in the Tonankai accretionary prism of the Nankai trough. Ten stations were in operation at the time of the earthquake. The tremors are observed at five of the stations, which are located on the landward slope of the Nankai trough. On the other hand, the signals are weak at stations near the coast, which are placed on the Kumano Forarc basin.

The tremors are dominant in a frequency range of 1-10Hz. Their duration ranges from tens of seconds to a few minutes. More than 20 events per hour can be detected in the first few days after the earthquake. The activity continues about one month with a decrease in the frequency of occurrence.

An intriguing feature of the observed tremors is that some of them are associated with a very low frequency (VLF) component, most clearly visible between 0.02 and 0.05 Hz. We found 74 such events within 5 days after the great earthquake. The VLF signals of the 72 events are observed at stations located above the shallowest part of the splay fault, and the remaining at a station above the up-dip toe of the main thrust. The instrument-corrected seafloor displacement corresponds to a subsidence of up to 0.04 mm with a rise time of 10-20 s. For each event, the VLF signal is detected only at one station in contrast to the high frequency signal (1-10Hz), which can be observed at more than a few stations. The disappearance of the large VLF signal at neighboring stations located only ~20km away indicates that the station which recorded this signal is well within the near field of the source.

In the presentation, we discuss the spacial and temporal variation of the triggered low frequency tremors during one month after the great earthquake.

Keywords: low frequency tremor, Ocean bottom seismometer, 2011 Tohoku-Oki earthquake

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A new detection method for very low-frequency earthquakes in southwest Japan

NIZATO, Taro[1]*, SUDA, Naoki[1]

[1]Hiroshima Univ.

Very low-frequency earthquakes (VLF) have been detected along with deep non-volcanic tremors in southwest Japan (Ito et al., 2007, 2009; Takeo et al., 2010). In these studies, it has been shown that the fault strike and dip angles of VLF events reflect the upper surface geometry of the subducting Philippine Sea plate and the slip angles are consistent with the motion of the subducting plate. These studies, however, simply applied methods of grid moment-tensor analysis for ordinary earthquakes to the VLF detection, so that a considerable number of small VLF events might be missed. In this study, we have developed a new method specialized to the detection of VLF events. In this method, VLF events are assumed to occur at grid points on the subducting Philippine Sea plate interface, having source mechanisms predetermined from the subducting plate surface geometry and the plate motion. By using this method, it is expected that we are able to detect smaller VLF events missed in the previous analyses. To evaluate availability of our method, we conducted numerical simulations in which we analyzed synthetic waveforms calculated using the observed VLF source parameters. As a result, our method was able to detect VLF events at the nearest grid points in most cases, indicating availability of our method to the VLF detection. In the presentation we will show the result of real data analysis.

Keywords: very low-frequency earthquake, slow earthquake, grid MT method, automatic detection

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Distinguish between very low frequency earthquakes and landslides signal.

TU, Yoko[1]*, ANDO, Masataka[1], LIN, Cheng-Horng[1], KUMAGAI, Hiroyuki[2]

[1]Inst.Earth Science,Academia sinica, [2]National Research Institute for Earth sc.

Almost every year, large typhoons strike Taiwan, which bring a huge rainfall sometimes up to 4000 mm in a few days. Such enormous rainfalls induces large landslides and submarine slumps in and around Taiwan. A series of landslides and submarine slumps due to the Typhoon Morako were identified and located by Lin et al. (2010) using band-pass filtered (0.02-0.05Hz) seismograms recorded at broadband stations of the BATS. This technique can be applicable to a real-time monitoring of landslides and submarine slumps. However, east of Taiwan and south of Ishigaki and Yonaguni islands near the trench axis of the Ryukyu subduction zone, a number of very low frequency earthquakes (VLFEs) occur at shallow depths (Ando et al., 2012) where 600-700 VLFEs occur every year and recorded at broadband even at the BATS stations. Although VLFEs have not been found beneath Taiwan, there is a possibility that VLFEs occur there from the point of view of tectonic situations. Nevertheless, the bandpass filtered (0.02-0.05 Hz) waveforms of the landslides and VLFEs are quite similar; both contain a spectral peak between 0.03 and 0.08 Hz. It is very hard to distinguish the two different phenomena on the seismograms alone. To distinguish landslide events from VLFEs and ordinary earthquakes, we take a method to identify landslides as follows: 1) Applying a bandpass filter (0.02 -0.05Hz) to raw broadband seismograms. 2) Picking up low frequency events from the filtered seismograms, 3) Removing ordinary earthquakes using an identification technique of P and S waves and surface waves, and hypocenter catalogues unless it is a real-time determination. 4) Locating the events with an inversion technique. 5) If the location of the event is at shallow depths beneath Taiwan or in submarine valleys, and if heavy rain-fall happened over the days, we assume the events a landslide. Our experiment with this method is still preliminary and further studies are required.

Keywords: VLFEs, landslides, broadband seismic system

SCG63-P08 Room:Convention Hall Time:May 20 15:30-17:00

Along-strike variations in relationship among slow slip events, low-frequency tremor and very low-frequency earthquakes

KIMURA, Takeshi[1*], HIROSE, Hitoshi[2], MATSUZAWA, Takanori[1], KIMURA, Hisanori[1], TANAKA, Sachiko[1], OBARA, Kazushige[3]

[1]National Research Institute for Earth Science and Disaster Prevention, [2]Graduate School of Science, Kobe University, [3]Earthquake Research Institute, The University of Tokyo

In southwest Japan the Philippine Sea Plate is subducting beneath the continental plate. Dense and high-quality observation networks such as NIED Hi-net have revealed that various types of slow earthquakes have occurred repeatedly on the plate interface. In the case of western Shikoku, simultaneous occurrences of the short-term slow slip event [SSE; Obara et al., 2004] with the magnitude of about 6.0, the nonvolcanic deep tremor [Obara, 2002] and the very low-frequency earthquake [VLFE; Ito et al., 2007] have been observed. In this study, we compare the slip process of short-term SSE with the tremor and VLFE activities which occurred from December 23, 2011 to January 10, 2012 around western Shikoku. This short-term SSE, whose magnitude is estimated to be 6.2 by a preliminary analysis assuming a rectangular fault with a uniform slip, is one of the largest events in western Shikoku. Moreover, this is the first case that an episode of tremor activity and short-term SSE occurs in a wide area from Bungo channel to central Shikoku.

In order to estimate the detailed slip process of this SSE, we apply a time-dependent inversion method [Segall & Matthews, 1997; Hirose & Obara, 2010] to a set of ground tilt data recorded by Hi-net high-sensitivity accelerometers (tiltmeters). From the hourly-resampled ground tilt data, tidal and atmospheric pressure effects are removed using the BAYTAP-G program [Tamura et al., 1991]. The plate interface configuration in the target area is modeled by placing 17 x 7 subfaults with the size of 10 x 10 km^2, referring to Shiomi et al. [2008].

The estimated cumulative slip distribution shows two separate areas with the large slip in western and mid Ehime prefecture and a gap area with the small slip between them. The location of the large slip area in western Ehime prefecture coincides with the area where the large slip occurs when the short-term SSEs occur repeatedly at approximately 6-month interval [Hirose & Obara, 2010]. After January 3, a large slip of the SSE developed beneath western Ehime prefecture and then the slip area jumped to mid Ehime prefecture while the tremor activity migrated from western Ehime to mid Ehime continuously. As a result, in two large slip areas, the slip and the tremor activity occurred simultaneously, and in the gap area, the tremor activity increases without the large slip. In the case of the VLFEs, some VLFEs occurred when slip occurred in the large slip area in western Ehime, and a VLFE occurred in the other large slip area. In the gap area, VLFEs were not detected.

In the episode of slow earthquakes from December 2011 to January 2012, we can show that the relationship among the slip of the SSE, tremor activity and very low-frequency earthquakes varies along the strike of the subducting Philippine Sea slab. In most of the tremor activities and short-term SSEs in western and central Shikoku, the migration of the source area stopped when the source area reached to the gap area. Moreover, only two and no VLFEs have been detected in the large slip area in mid Ehime prefecture and in the gap area, respectively, while many VLFEs have occurred in the other large slip area. Therefore, the along-strike variation in the relationship among three types of the slow earthquakes during the target episode would be caused by a spatial difference in the slip property on the plate interface.

Keywords: subduction zone, slow earthquake, short-term slow slip event, deep low-frequency tremor, deep very low-frequency earthquake, tilt change

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SCG63-P09 Room:Convention Hall Time:May 20 15:30-17:00

Short-term slow slip event monitoring by joint analysis of crustal strain, tilt and groundwater changes

ITABA, Satoshi[1*], MATSUMOTO, Norio[1], KITAGAWA, Yuichi[1], KOIZUMI, Naoji[1], MATSUZAWA, Takanori[2]

[1]Geological Survey of Japan, AIST, [2]NIED

National Institute of Advanced Industrial Science and Technology (AIST) and National Research Institute for Earth Science and Disaster Prevention (NIED) have been exchanging crustal strain data of AIST and crustal tilt data of NIED since 2011. We developed a joint analysis method using crustal strain and tilt, and estimated fault models of short-term Slow Slip Events (S-SSE) [Itaba et al., 2011]. We can detect S-SSEs of about Mw5.5 or more by this joint analysis within the wide range in Shikoku, Kii Peninsula and Tokai.

The space density of Aichi Prefecture and Shizuoka Prefecture is low though AIST has a strain observation network in Shikoku, Kii peninsula, and Tokai. On the other hand, Japan Meteorological Agency has many strain observatories in Tokai. Moreover, in recent years, the groundwater changes associated with S-SSEs are observed at the groundwater observation network of AIST. Consequently, we developed a new joint analysis method of crustal strain, tilt and groundwater changes.

In this presentation, we will introduce this joint analysis method, detectability of S-SSE and the example of joint analysis.

Keywords: short-term slow slip event, tremor, strain, tilt, groundwater, crustal movement

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Monitoring of small short-term SSEs in southwest Japan based on GEONET data

FUJITA, Akio[1*], SATOMURA, Mikio[2], IKUTA, Ryoya[2], SHIMADA, Seiichi[3], KATO, Teruyuki[4]

[1]Graduate School of Science, Shizuoka University, [2]Department of Geosciences, Faculty of Science, Shizuoka University, [3]National Research Institute for Earthsicence and Disaster Prevension, [4]Earthquake Prediction Research Center, Earthquake Research Institute, The University of Tokyo

In south-western part of Japan, there occur episodic tremors and slips beneath Nankai trough(Obara 2010). These short-term slow slip events(S-SSEs) especially in Tokai region are known to be very small and hard to detect by GPS. Our study is a trial for monitoring these S-SSEs around south-west part of Japan, including Tokai region, by geodetic inversion method using GPS data.

The data used inversion was F3 solution for 15 years from1996 to 2011 which were provided by Geospatial Information Authority of Japan (GSI) in south-west of japan. The procedure is followings :

1.Correction of offset in the GPS time series by earth quakes and antenna maintenance.

2.Principal component analysis(PCA) of the time series to remove the 1st principal component as common mode error between all the site.

3.Taking differences between two 10 days-averages with 1 week interval, which is done for all the data with 1 day shift.

4.Adopting Bayesian inversion method proposed by Yabuki and Matsuura [1992] ro above data.

Solving this inverse problem, we adopted a priori information which suppressed the slips on the fault surface without enough solvability. The slip axis was limited in the direction of the plate convergence of N45W but both polarities were allowed. In this study, we added two new conditions, one is that back slip rate must not exceed the convergence rate of Philippines sea plate, another that is the slip rate is zero in deeper position than 60km.

In our previous study, in which the two were not applied, we found unrealistic back and forward-slip in the deeper part where no coupling is expected because of the high temperature. We fixed the problem of the unrealistic slips by new conditions and then detectability of S-SSEs is better than that by the old method.

GPS is proofed to be a good tool to monitoring very small inter-plate slip.

Acknowledgement: In this study, we use GEONET data provided by GSI, and hypocenter data proposed by Japan Meteorological Agency.

Keywords: slow slip, deep low-frequency tremor, GPS, inversion

SCG63-P11 Room:Convention Hall Time:May 20 15:30-17:00

Long-term slow slip events around eastern Shikoku and Kii Channel

KOBAYASHI, Akio[1*], YARAI, Hiroshi[2]

[1]Meteorological Research Institute, [2]Geospatial Information Authority of Japan

Long-term slow slip events around eastern Shikoku and Kii Channel are investigated using the GEONET GPS data. We estimated the steady deformation rate at each GPS station from the daily coordinates for the period from January 2006 to December 2009. Then the steady deformation rates were subtracted from all the coordinate data. The artificial offsets of the coordinate were corrected using data set shown on the homepage of the Geospatial Information Authority of Japan. We can see south-eastern displacements of a little less than 1 cm at GPS stations in eastern Shikoku from April 2001 to April 2003. These unsteady displacements are also seen in the time series of coordinate and the baseline length. Moreover, the change of the baseline length is also seen in 1996.

We estimated slip distribution on the plate boundary, assuming the unsteady displacements were caused by the slip on the plate boundary. The estimated slip is distributed from eastern Shikoku to the Kii channel. Non-volcanic deep low-frequency tremors are distributed belt-like along the Nankai trough. However, the active tremor is not observed in the Kii channel. It may provide important information about the condition of the plate interface that the long-term SSEs are seen in the region where the active non-volcanic deep low-frequency tremor is not seen.

Keywords: long-term slow slip, GPS, crustal deformation, eastern Shikoku, Kii Channel

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Strain data obtained in a vault near the Bungo Channel, above an epicenter area of long term slow slip events

YAMAZAKI, Ken'ichi[1*], TERAISHI, Masahiro[1], KOMATSU, Shintaro[1]

[1]Disaster Prevention Research Institute, Kyoto University

We have observed changes in strain using extensometers in a vault at Sukumo site near the Bungo channel, beneath which long-term Slow Slip Events (SSE) have repeatedly occurred. Earlier reports on strain data claimed that SSE has successfully recorded SSEs beneath the Bungo channel. However, data at Sukumo are highly affected by distortions due to changes in temperature. By referring temperature data obtained near the Sukumo site, secular variations in temperature possibly explain reported anomalies in strain data. This result implies that we cannot interpret recorded anomalies in strain data directly correspond to SSEs.

Keywords: extensometer, vault, slow slip event, Bungo Channel, changes in temperature

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SCG63-P13 Room:Convention Hall Time:May 20 15:30-17:00

Modeling of the Boso slow slips and effects of the 2011 off the Pacific coast of Tohoku Earthquake on the slow slips

YAMAZAKI, Takafumi[1*], SHIBAZAKI, Bunichiro[2], SATO, Toshinori[1], HASHIMA, Akinori[1], HIROSE, Hitoshi[3]

[1]Chiba Univ, [2]BRI, [3]Graduate School of Science, Kobe University

1. Introduction

Slow slip events (SSEs) off the Boso peninsula have occurred at intervals of about 5-6 years. The Boso SSEs are characterized by occurrence at depth 10-20km on the seismogenic zone. In this study, we model the SSEs using rate- and state- dependent friction law with aging law and investigate value of parameters of friction constitutive law to simulate observed feature of the SSEs. Such a parameter study is important to identify the reason the Boso SSEs occur on the seismogenic zone and to estimate materials and states at the SSEs area. We also research effects of the 2011 off the Pacific coast of Tohoku Earthquake on the Boso SSEs.

2. Methods

In our modeling, the region of the Boso SSEs is set on the basis of an inversion analysis of Hirose et al. (2008). Since the SSEs occur spontaneously, we set velocity weakening ($a-b < 0$) in the SSEs area and velocity strengthening ($a-b > 0$) out of the area. We assume that effective normal stress (Sn) increases with depth, and is set to 5-7 MPa at the SSE area. We run simulations with various parameters of a-b, Dc only in the SSEs area. To investigate the effects of the 2011 Tohoku Earthquake, we include changes of shear and normal stresses on the plate interface due to the coseismic slip of the earthquake.

3. Results

The parameter study reveals that parameter sets which can simulate the Boso SSEs are limited. The parameter set of Sn = 5-7 MPa, a-b = -0.004, Dc = 1.0cm can simulate observed interval, duration, and Mw of the Boso SSEs. The study with the effects of the 2011 Earthquake shows shortening of intervals with about 0.5 yr. This result may explain the shortening of intervals from 58 months (2002-2007) to 50 months (2007-2011).

Keywords: slow slip, parameter study, 2011 Tohoku Earthquake