SSS31-P01 Room:Convention Hall Time:May 25 18:15-19:30

Measurements of a precise pressure in the C0002 borehole observatory using a mobile pressure gauge

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In the Nankai Trough region, several large interplate earthquakes with magnitudes of 8 have occurred repeatedly due to a subduction of the Philippine Sea Plate beneath the Eurasian Plate at a rate of 4-6 cm/year. In this area, we deployed a long-term borehole monitoring system (LTBMS) with pressure gauges (Paro-scientific Inc.8b7000-2 and 8b7000-1) into the C0002 boreholes during the IODP expedition 332 in 2010 to understand a seismogenic process of large interplate earthquakes. In the C0002 boreholes, seafloor pressure measurements are continuously conducted since the deployment. The precise pressure measurement such as the detection of long-term crustal deformation is important in order to obtain geophysical knowledge associated with the occurrence of large earthquakes. However, pressure measurements contain instrumental drifts in the sensors in addition to the pressure changes associated with a crustal deformations. Therefore a correction of the instrumental drift is necessary to estimate precise measurements of the crustal deformation. We developed a mobile pressure gauges equipped with pressure holding system for the correction. The mobile pressure gauge has a crystal water pressure meter (Paroscientific Inc. 410K) as a pressure sensor and is equipped with a pressure holding function due to a temperature control using a heater. Also, an electric valve control was adopted. These systems decrease a pressure variation throughout an observation. To estimate an accuracy of the pressure gauge, we measured a repeatability and hysteresis of the sensor. The repeatability of the sensor equipped with a pressure holding system is 1.3 hPa, while a repeatability of the sensors without a pressure holding system is 8.93. This indicates that the pressure holding system improves the accuracy of the sensors. In this March, a calibration of the C0002 pressure gauges is peformed in the KY15-05 by R/V Kaiyo (2015.3.9˜3.29). In this presentation, we show preliminary results of the cruise.

SSS31-P02 Room:Convention Hall Time:May 25 18:15-19:30

Crustal Deformation in the Southwestern Ryukyu Arc Estimated from GNSS data

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1. Introduction

The south-western Ryukyu arc is characterized by back-arc spreading and a fast plate convergence rate (12.5 cm/year). In this region, few large earthquakes are reported though a fast plate convergence rate. Well-known large earthquake in this region is the 1771 Yaeyama earthquake (M_W 8.0) with a devastating tsunami. On the other hands, slow seismic and aseismic events are often reported. For example, biannually repeating slow slip events (SSEs) are reported by Heki and Kataoka (2008), and they reported that SSEs occur on a subducted plate interface under Iriomotejima Island. Crustal deformation during several years in this region is proposed to be expressed by rigid block rotation models by Nishimura et al. (2004), Nakamura (2004), and so on. They propose that the Ryukyu region is divided to three blocks, and each block is moving independently. But boundaries are different from each other. Nishimura et al. (2004) proposed that the Yaeyama region (Iriomotejima, Ishigakijima, and some other islands) and the Miyakojima region are moving on the same block. On the other hand, Nakamura (2004) proposed that these two are on different blocks. These studies used the GEONET GNSS data operated by Geospatial Information Authority of Japan. But this region consists of remote islands, so we can't discuss detailed internal deformation.

2. GNSS data

In this study, we use 13 stations in total. 8 stations are GEONET GNSS stations located in the Yaeyama region and the Miyakojima region. And one station is located in the south of Miyakojima Island, which is operated by the Japan Coast Guard. This station has not been used for scientific analysis. And the other 4 stations are new ones we set up, which are located in Iriomotejima Island (Funauki and Oohara), Kuroshima Island, and Kohamajima Island. We estimate daily cordinates of the GNSS stations using GIPSY 6.2 with strategy of Precise Point Positioning. Next, we calculate moving average to remove errors due to the artificial offsets and the weather condition. In time-series data of 4 new stations from 2010 to 2013, we can recognize 4 deformation episodes suggesting SSE in all station's data.

3. Rigid block rotation models

We compare displacements calculated from the model of Nishimura et al. (2004) with observed one from 2010.24 to 2012.69, and we find that they have an obvious difference. The observed displacements direct counterclockwise compared with calculated one, and displacement pattern suggests displacement direction changing counterclockwise and increasing displacement rate in western stations. This may mean that a rigid block rotation in this region changed after the previous study. Therefore, we examine how good rigid block rotation can explain the observed displacement and estimate Euler vectors for the rigid block rotation. Displacement calculated from the best-fit rotation model can reproduce the observed one. The estimated Euler pole located at (128.089^{o}E, 29.095^{o}N) with angular velocity of 6.675 rad/Myr. And we examine baseline change which is independent with rigid block rotation to study internal deformation in this region.

4. Conclusion

We analyze GNSS data in the south-western Ryukyu arc. This region is characterized by a fast plate convergence rate (12.5 cm/year) and frequent slow slip events (SSEs). Because this region consists of remote islands with a few GNSS stations, we set up new 4 GNSS stations to examine detailed crustal deformation. We compare observed and calculated displacement using the proposed rigid block rotation models and find that they have an obvious difference. We also report a result for a rigid block rotation estimated from the observed displacement and a change of baseline lengths in this region to examine internal deformation.

Acknowledgements

We thank the Geospatial Information Authority of Japan and the Japan Coast Guard for providing GNSS data.

Keywords: Ryukyu trench, GNSS, Rigid block rotation

SSS31-P03 Room:Convention Hall Time:May 25 18:15-19:30

Crustal deformation around Kikaijima

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1. Introduction

Philippine Sea plate is subducting under Eurasian plate from the Ryukyu trench where is located at the east side of Ryukyu arc. On the other hand, there is back arc spreading at west side of Ryukyu arc. It was thought that the region of the back arc spreading is weak strength of crust, so, Interplate coupling is weak, too. However, I have experienced that the 2011 Tohoku-Oki Earthquake and the 2004 Sumatra-Andaman Earthquake, where are the same situation with the Ryukyu arc. It means to examine the possibility that the M9 class earthquake occurs in all subduction zones with a plate having similar tectonics background.

2. Collision with Amami plateau and high-speed uplift of Kikai-jima

Amami plateau, which is one of the world's largest scales, subducts under the Ryukyu arc from the Ryukyu trench, and Amami plateau make that Kikai-jima is high-speed uplift. Previous coastal terrace studies reveal that Kikai-jima is 2 mm/yr uplift. These evidences suggest strong interplate coupling and occurrence time of a large earthquake is about 1,000 years time scale. In addition, historical M8 class earthquake occurred around the Amami-Oshima in 1911, and seismic activity is high.

3. Tilt direction and uplift velocity at the Kikai-jima observed by leveling, and GNSS observation

A traverse line of Kikai-jima, Oshima, Amami-Oshima, Yokoate-jima can be established only more than 100km in the Ryukyu arc. A GNSS observation in Yokoate-jima (uninhabited island) was started in October 2013. Baseline change rate between Yokoate-jima and Amami-Oshima is about - 3.8×10^{-8} /yr, which is same level baseline change between Amami-Oshima and Kikai-jima (-2.5×10^{-8} /yr). However, still have a short observation period (only 8 months). On the other hand, tilting in the Kikai-jima is observed by leveling. The direction and amount of tilt are forward to the trench axis and about 10^{-7}/yr, which is in comparison with this leveling result (April, 2014) and the previous result (September, 1997). These results suggest strong plate coupling on the Ryukyu trench. However, strong plate coupling is difficult to explain both vertical and horizontal deformation components. It is may have an effect of collision of the Amami plateau.

Keywords: Leveling, Kikai Island, Interplate coupling, GNSS Observation

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SSS31-P04 Room:Convention Hall Time:May 25 18:15-19:30

Strain rate field in Kyushu district estimated from GPS velocity data

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Kyushu district is one of the areas where unique crustal deformation is detected in Japan. For major tectonic characteristics, the Philippine Sea plate subducts and repeatedly generates M7 class earthquakes with a recurrence interval of about 20-30 years at the Hyuga-nada area (Yoshioka, 2007). In the Bungo Channel, slow slip events have occurred at intervals of about 6-7 years (Ozawa et al., 2013). These differences of tectonic process may be responsible for the frictional property of the plate interface (Hirose and Maeda, 2013). Moreover, back-arc spreading at the Okinawa Trough (Nishimura and Hashimoto, 2006) also brings about complicated tectonics. Takayama and Yoshida (2007) investigated some tectonic factors using GPS velocities obtained from 1998 to 2002. Then, they suggested that there was a velocity gap of about 5 mm/yr in the EW component along N32^o where subsequent M5-6 class earthquakes occurred. However, clear active faults are not distributed there and the process of stain budget is unrevealed, indicating that the present-day crustal deformation began to develop in the recent geological age. Additionally, inelastic deformation (Noda and Matsu'ura, 2010) with high temperature is also expected, since many active volcanoes exist in this region. Therefore, it is important to estimate the influence of the inelastic behavior attributed to heterogeneity in the crust and upper mantle on the deformation field quantitatively. It is thought that the quantitative understanding of strain rates leads to the assessment of seismic potential such as locking depth of faults and estimating the future crustal deformation. In this study, we estimated the strain rate field in Kyushu district using GPS velocities.

We estimated site velocities using GEONET F3 solution, daily coordinates of continuous GNSS sites, derived from the Geospatial Information Authority of Japan (Nakagawa et al., 2009). According to a conventional method of processing for GPS time series, we removed annual and semiannual variations, and offsets caused by earthquakes and GPS antenna replacement. Next, using the method proposed by Shen et al. (1996), we calculated strain rates by forming crossover area within a 50 km diameter every one GPS observation site, assuming uniform deformation in each crossover area. Finally, we determined a rigid motion and strain rates in the whole area simultaneously by the method of least squares, and then, we obtained strain rate distribution interpolated every 20 km. We set the same period as shown in Takayama and Yoshida (2007), when few unsteady events occurred. From estimated strain rate field, following characteristics were derived.

(1) A high strain rate region with the maximum shear strain rate of about 120 nanostrain/yr was recognized along N32^o, whose width was about 50 km.

(2) The crustal shortening of about 30-210 nanostrain/yr in the northern part and the central part of Kyushu district indicated the direction of ESE-WNW on the Pacific side. On the back-arc side, the magnitude of those shortening decreased and those directions were rotating counterclockwise.

(3) The crustal shortening in the southern part of Kyushu district indicated the direction of ENE-WSW and the highest shortening rate was 130 nanostrain/yr on the back-arc side.

The result (1) suggests that the fault locking ranges from 0 to 5 km in depth, assuming the fault slip (5 mm/yr) of infinitely long fault in the EW direction under high strain rate region. As for results (2) and (3), it is necessary to consider the effects of plate subduction and back-arc spreading into the analysis. For the future, we will calculate strain or strain rate released by earthquakes (moment release) and conduct the quantification of inelastic behavior ongoing in Kyushu district by comparing strain budget.

This study was carried out under a contract with METI (Ministry of Economy, Trade and Industry) as part of its R&D supporting program for developing geological disposal technology.

Keywords: crustal deformation, strain rate, high strain rate region, inelastic deformation, Kyushu district, Philippine Sea plate

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SSS31-P05 Room:Convention Hall Time:May 25 18:15-19:30

A Method of Field Research Incorporating the Results of the Surveying by GSI and MLIT - Gravity Profiles as an Example -

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1. Introduction

To reduce the natural disasters such as earthquakes or landslides, it is essential to the studies of earth science involving field works. Thereupon, it is necessary to acquire geographic location information about these survey sites. In recent years, it has been progressing to publicize digitized geographic information from the Web site established by Geospatial Information Authority of Japan (GSI), Ministry of Land, Infrastructure, Transport and Tourism (MLIT) or many municipalities. As a result, it is possible to obtain positional data of the land (longitudes and latitudes) and elevations from the mean sea level of the reference point. These services, in many cases, can be utilized in academic research.

To make various corrections in gravity surveys, geographic information of latitude, longitude and altitude values are required on the measurement points. Therefore, in this study, the process of using those public digitized information of triangulation points and benchmarks is described to perform gravity survey.

2. Target area

Gravity measurement survey line of interest is about 5.8 Km leading from Sanjodori, Sakai-ku to Tono-cho, Kita-ku, Sakai City, Osaka. This line has been crossed in Uemachi Fault. At the center of the line, there is a growing gravity anomaly.

3. Acquisition of geographic information

Measurement of gravity was performed on the triangulation point or the benchmark. The latitude, longitude and elevation values were obtained from the numerical information provided on the above-mentioned web site is used. They can be relatively easily obtained but there is each site-specific use restrictions. The values obtained information of the point or the benchmark is used for illustration of the measurement point and correction of gravity value.

4. Result

Accuracy is good when used the results of the survey on the triangulation point or the benchmark, as compared with the case of digitizing to enter the latitude or longitude value and reading the elevation values from topographic maps (Ryoki (2011), Ryoki and Nishitani (2013), Ryoki (2014)). Then, the time, it takes for data aggregation work, can be greatly reduced. In particular, since the error of the elevation values becomes to be within the range defined by the grade of each reference point, the homogeneity of the data has been secured.

5. Conclusion

Marks of the metal, that are triangulation points or benchmarks of public survey to manage by municipalities and survey of the city district for urban regeneration by MLIT, are found relatively easily in site. It is also possible to measure gravity, etc. on that point. Thus, these usage has been found to be highly convenient in the field research. Through this study, use of triangulation point or benchmark has been shown to be effective to efficiency improvements and uniformity of accuracy in field research, such as earth science.

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Keywords: gravity structure, digital geographic information, Uemachi Fault, Mikunigaoka Subsuface Peak, high-density intrusive rock, efficiency of measurement

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SSS31-P06 Room:Convention Hall Time:May 25 18:15-19:30

The observation of the electromagnetism pulse to capture crustal movement

KUNIHIRO, Hidemitsu[1]*

[1]JYAN meeting for the study

I observe a direct wave of the FM broadcast for foretelling an earthquake and perform a study to examine crustal movement from the abnormal phenomenon of the electric wave.

The electric wave observation performed continuous observation and data analysis for a long term, but I pursued a cause and discovered that I approximately synchronized with high and low tide of the ebb and flow, and an abnormality pulse occurred in data among them because pulsing abnormality of the electromagnetism often occurred.

However, I understood that there was much abnormality before and after an earthquake when I analyzed it more because ebb and flow had abnormality not to synchronize approximately 20%.

Therefore as a result of I added earthquake statistics to 80% and the remaining async part which synchronized for ebb and flow, and having inspected a comparison, high and low tide of the ebb and flow and the plus and minus direction of the abnormality pulse synchronized, and the abnormality of the async understood that the most occurred before and after an earthquake.

Therefore, the electromagnetism pulse became the circumstantial evidence to connect ebb and flow and an earthquake.

It is this cause and mechanism, but the Inland Sea using observation data has a big ebb and flow, and, as for the differences between high tide and ebb tide, there are 2-3 meters, and the huge weight change of approximately 5 billion tons is up only in west Seto.

Furthermore, in the poking each other investigation with earthquake statistics, the high and low tide of the ebb and flow shows the thing that is very likely to be it as crustal movement and earthquake trigger because an earthquake of approximately 60% occurs in the vicinity of the ebb tide of the big tide.

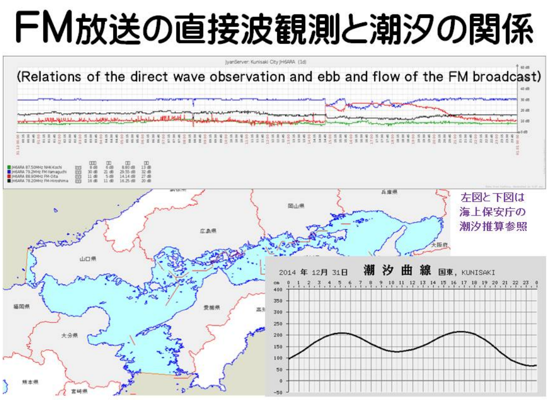
In addition, in the origin of the electromagnetism pulse, a gravity change of the ebb and flow gives impacts such as pressure or the extension in the earth crust, and an electromagnetism pulse occurs by whit destruction or friction when the earth crust becomes by compression or extension in the vicinity of boundary.

Because I form an electromagnetic field and am emitted to the air when this electromagnetism reaches by electromagnetic induction to the surface of the earth from the earth crust, a clear change appears for the synchronization of the ebb and flow like a change to an observation graph.

Therefore, if perform this electromagnetism pulse in an observation network in the long term, understand crustal movement, and provide important data foreseeing an earthquake; think that is observed.

I show each observation or data for the study.

Keywords: Foretelling an earthquake, Crustal movement, Earthquake trigger, Electromagnetism, Abnormality, earthquake



SSS31-P07 Room:Convention Hall Time:May 25 18:15-19:30

Gravity survey around the Medeshima Hills in the Sendai Plain, northeast Japan

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Our seismic and gravity survey carried out across the Sendai Plain in 2013 (Watari 2013) shows concealed active fault beneath the Sendai Plain. The concealed fault dislocates not only Pre-Tertiary basement rocks but also Miocene and Pleistocene sediments. Pre-existed bouguer gravity data suggest that the concealed active fault continue toward north via eastern foot of Medeshima Hills. However, the relationship among the concealed active fault, concealed fault of Nagamachi-Rifu active fault system, and Kagitori-Okubushi tectonic line is not so clear. To evaluate the active fault beneath alluvial plain, the length and relationship of these active faults provide essential information.

To reveal the continuity of northern extension of the concealed active fault, we executed gravity survey in the southern part of Sendai Plain, from Medeshima Hills to the right bank of Natori River. The total number of gravity stations is 232, using LaCoste & Romberg D-type gravimeter and G-type gravimeter. The interval of gravity stations is 200 m.

The result of our gravity survey shows no steep gradient of bouguer gravity associated with the concealed active fault in the northern area of Medeshima Hills, indicating that the active concealed fault is terminated in this area.

Keywords: gravity survey, concealed active fault, subsurface structure, continuity of active fault

SSS31-P08 Room:Convention Hall Time:May 25 18:15-19:30

Block Modeling of The Sunda Block Using GPS Velocities in South East Asia

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The Sunda block in Southeast Asia has its own independent block rotation. It covers most of Southeast Asia including Indo-China Peninsular, Sumatra, Borneo, Java, and the shallow waters that lies in between. The GPS network data in Southeast Asia derived by campaign and continuous observations are used in this study to simultaneously estimate the Euler rotation parameters of the Sunda block, and the elastic deformation due to the slip deficit on the block boundaries. In order to see the precise block rotation of the Sunda block, all effects contained in the data such as elastic deformations due to the inter-plate coupling in the southern boundary of the block have to be removed. We used the method devised by Meade (2009) and elastic deformation rates are computed for each fault segment assumed in a homogeneously elastic half-space using triangular dislocation elements to accurately represent complex fault system geometry. The Zone between 110^{o}E to 116.5^{o}E in the southern plate boundary of the Sunda block indicates interpolate coupling, while that between 107^{o}E to 110^{o}E shows postseismic slip after the 2006 interplate earthquake with M7.7. The optimum Euler pole parameters of the Sunda block are estimated as follows: the latitude of 24.629 $\pm$ 1.962 ^{o}N, the longitude of 117.369 $\pm$ 0.788 ^{o}E, and the angular velocity of 0.692 $\pm$ 0.066 ^{o}/Myr. This study excludes the effect of elastic deformations due to the slip deficit on the block boundaries in estimating the Euler rotation parameters, while the previous studies estimated the parameters by assuming the block rotation only.

Keywords: Sunda block, Euler rotation, GPS velocities

SSS31-P09 Room:Convention Hall Time:May 25 18:15-19:30

Abnormal strain distribution in Hokkaido, Japan, inferred from the 2003 Tokachi-oki earthquake

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To extract the abnormal strain distribution caused by heterogeneous subsurface structure in Hokkaido, Japan, we compared observed coseismic crustal deformation with theoretical crustal deformation of the 2003 Tokachi-oki earthquake (M8.0). Observed data is extracted by the difference of the daily coordinates, which is provided by GSI (F3 solutions), before and after the event. Theoretical data is calculated from dislocation model (Okada, 1992), which assumes deformation in uniform elastic half-space, using fault parameters provided by GSI. The observed coseismic displacement is explained by calculations well, except for several areas. Dilations are also roughly agreed with each other. However, several areas show deformation excess and deformation deficit with respect to theoretical model. Especially, in Hidaka region, which is high seismic velocity region (kita et al., 2012), corresponds to deformation excess area, and Kamuikotan region, which has thick sediment layer, corresponds to deformation deficit area. These results might imply the effect of the heterogeneous subsurface structure around the region.

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Modeling of the time series of the postseismic deformation in Yamagata, Japan, after the 2011 Tohoku earthquake.

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Using daily coordinate time series provided by GSI (F3 solutions), we estimate the effects of the postseismic deformation in Yamagata, Japan after the 2011 Tohoku earthquake (M9.0). We assumed that the most of postseismic signals are caused by afterslip and viscoelastic relaxation. These postseismic deformations are often modeled by logarithmic and exponential (or power-low) temporal change, respectively. We approximated observed daily postseismic deformation by these theoretical models. As a result, the logarithmic theoretical time series, which assumes afterslip, is fitted the observations well between just after the earthquake and ~100 days after the event, and exponential theoretical, which assumes viscoelastic relaxation with Maxwell body, time series explain data after ~100 days after the earthquake. Estimated time constants are ~8 days (afterslip) and ~1000 days (viscoelastic relaxation), respectively. This result is consistent with other previous studies at the eastern pacific coast in Tohoku region. Combined model consists of summation of logarithmic and exponential signals also explain the time series. Distribution of the amplitude of the viscoelastic relaxation might be reflecting heterogeneous viscoelastic structure beneath the study area.

Keywords: postseismic deformation, tohoku earthquake

Japan Geoscience Union Meeting 2015
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SSS31-P11 Room:Convention Hall Time:May 25 18:15-19:30

Revisiting Interplate Coupling Beneath the Tohoku District Based on Geodetic Observations

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Many studies have been carried out into the distribution of interplate coupling between the subducting Pacific and overriding continental plates based on observations of the surface displacement rate field using satellite geodesy. In such studies, the degree of coupling has generally been expressed in terms of the back-slip (or slip deficit) at the plate interface. In some cases, seismological rather than geodetic data have been used to investigate the spatiotemporal variation of the back-slip distribution. Although it is difficult to resolve the back-slip distribution at the plate interface off the coast of the Tohoku District along the direction normal to the trench based only on terrestrial observations, it can be constrained to some extent in the direction parallel to the trench.

Iinuma et al. (2010, 114th Meeting of the Geodetic Society of Japan) proposed a method for monitoring the spatiotemporal variation of interplate coupling based on calculating the spatial gradient of the surface displacement rate field within belt-like zones along the direction perpendicular to the trench axis. They suggested that the gradient of the horizontal component of the displacement rate depends mainly on the strength of the interplate coupling in shallow (<40 km) regions of the offshore plate interface, and that the sign of the vertical displacement rate gradient indicates the presence or absence of interplate coupling at deeper (>50 km) regions of the plate interface beneath the land. Thus, the spatiotemporal variation of interplate coupling can be monitored based on the temporal change in the trench-parallel distribution of the displacement rate gradient. Based on an analysis of small repeating earthquakes, Uchida et al. (2013, Fall Meeting of the Seismological Society of Japan) reported that there is a strong correlation between the temporal change in the displacement rate gradient and the slip rate.

Application of this monitoring method to geodetic data before the availability of satellite geodesy data may enable us to estimate the state of interplate coupling by calculating the displacement rate gradient along the direction perpendicular to the trench axis based on leveling and triangulation surveys. Therefore, in this study, leveling survey data were used to estimate the degree of interplate coupling beneath the Tohoku District for approximately the past 100 years.

The spatial gradient of the vertical displacement rate along an observation line from Ayukawa to Sendai via Rifu was calculated from leveling survey data recorded by the Geospatial Information Authority of Japan since 1900. Fifteen sets of vertical displacement rate field data were used to calculate the spatial gradient along the direction perpendicular to the Japan Trench. The results for recent decades were compared with the vertical displacement rate gradient estimated from GPS observations, and were found to be in reasonably good agreement. It can therefore be concluded that the degree of interplate coupling at deeper regions of the plate interface can be assessed even for periods before the introduction of global navigation satellite systems, based on leveling survey data alone. The results indicated that there were clear cycles in the strength of this coupling, interspersed with large interplate events such as the 1936 and 1978 Miyagi-oki earthquakes. Before these events, strong coupling existed in deeper regions, but disappeared after the main shock occurred. The results of similar investigations for observation lines from Kamaishi to Yokote via Kitakami, and Iwaki to Aizu-Wakamatsu via Koriyama will be presented at the meeting.

Keywords: Iinterplate coupling, The 2011 Tohoku-oki Earthquake, Leveling Survey, GPS

SSS31-P12 Room:Convention Hall Time:May 25 18:15-19:30

Coulomb's static stress changes induced by the 2011 Tohoku-Oki earthquake: a case of spherical earth

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Some studies indicated that seismicity around a main shock is activated where the Coulomb's static stress changes (ΔCFF) are positive (e.g. King *et al.,* 1994; Stein, 1999). ΔCFF is defined as $\Delta CFF=\Delta\tau+\mu\Delta\sigma$, where $\Delta\tau$ is the shear stress change on the fault (positive for the inferred slip direction), $\Delta\sigma$ is the normal stress change to the fault (positive for fault unclamping) and μ is the apparent friction coefficient. The failure is promoted if the ΔCFF is positive. Okada's (1992) theory on coseismic internal deformation in a homogeneous semi-infinite media has been widely used to calculate ΔCFF. Using this theory, Toda *et al.* (2011) estimated the ΔCFF induced by the 2011 Tohoku-Oki earthquake. Their results showed that the broad area over epicentral distance of several hundreds kilometers undergoes the stress changes larger than 0.1 bar. It should be considered whether Okada's (1992) theory can be directly applied to the calculation of such a broad deformation field. In other words, it is necessary to estimate the effect of the Earth's curvature and stratification on the deformation field. However, the method of theoretical calculation of coseismic internal deformation in a spherically stratified earth has not been entirely established because previous works assumed an incompressible earth (Piersanti *et al.,* 1995) or oversimplified the gravity (Pollitz, 1996). We have realized the theoretical calculation of coseismic internal deformation in a spherically stratified earth without such unrealistic approximation. We applied our method to the preliminary computation of the volumetric strains caused by the 2011 Tohoku-Oki earthquake and found that the discrepancies of the volumetric strains for the conventional half-space from those for a spherically stratified earth exceed 30 per cent at the epicentral distance of about 200 km. It is expected that there are discrepancies of the same order among the ΔCFF for the two earth models.

In this presentation, we apply our method to calculation of ΔCFF induced by the 2011 Tohoku-Oki earthquake and discuss the difference between those for a spherically stratified earth and for a half-space.

Keywords: Coulomb's static stress change, 2011 Tohoku-Oki earthquake, spherical earth, internal deformation

SSS31-P13 Room:Convention Hall Time:May 25 18:15-19:30

Travel time changes of the ACROSS signal detected by the TRIES borehole network associated with the Tohoku Earthquake

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The 2011 off the Pacific coast of Tohoku Earthquake (M9.0, March 11, 2011) caused large change of observed data, such as groundwater level, strain and stress, in Tono Research Institute of Earth Science (TRIES),which located approximately 600km away from the epicenter. In addition, significant changes in travel time of the seismic ACROSS signal transmitted from the TOKI station (JAEA Tono Geoscience Center) were detected at many Hi-net stations (Kunitomo et al.,2014a). In this study, we analyzed the ACROSS signal observed by the borehole network of TRIES distributed in the range of about 9 km from the Toki station, and discuss the seismic velocity change caused by the Tohoku Earthquake. The observation stations, SBS110, JRJ, TRIES, TGR165, TGR350, TOS, BYB, are distributed in the range about 1 - 9 km apart from the seismic ACROSS station (TOKI). Analysis period is two years, from April 2010 to March 2012. We calculated the Green's functions from the transfer functions every day by the data processing of ACROSS (Kunitomo et al.,2014b), and estimated temporal change in the travel time of S-wave by the cross spectral method. S-wave travel time showed a step-like delay at the all observation stations at the time of the 2011 off the Pacific coast of Tohoku Earthquake. The delay times which depend on the observation station, are 1 to 7 ms at SV wave and 1 to 3 ms at SH wave. Travel time delay can be divided into two types, short-term delay and long-term delay. The short-term delay recovers exponentially in about 2 to 3 weeks, on the other hand, the long-term delay remains even after one year. The short-term delay is different by observation station, and it is estimated to represent the change in the vicinity of the observation station. The delay times of SH waves are large in the stations, TRIES, TGR165, TGR350 near Mizunami Underground Research Laboratory (MIU). The long-term delay, except the stations near MIU, has generally become larger with increasing distance from the ACROSS station, and it is estimated to represent the change in broad area.

Keywords: seismic velocity change, crustal movement, seismic ACROSS, the 2011 off the Pacific coast of Tohoku Earthquake

SSS31-P14 Room:Convention Hall Time:May 25 18:15-19:30

High resolution seismic and magnetic mapping of Kucukcekmece Lagoon (Istanbul), Turkey

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To understand the submarine features of the Kucukcekmece Lagoon, a total of 42 km high resolution seismic reflection data and total field marine magnetic data were collected and processed. The results were interpreted together with bathymetric data in detail. Total magnetic intensity distribution identifies several north-northwest trending (340-350^0) magnetic lineaments (L1-L5) that are aligned with strike-slip faults mapped from offshore seismic data. Analytic signal depth estimates indicate magnetic source bodies at ~100 m depth within the Thrace Basin Cenozoic sediments. Further analysis of the magnetic field data would provide information on faults kinematics and depth. Stratigraphically, parallel reflection pattern of the lagoon indicate initial deposition under low-energy conditions. From place to place, some whiteout areas are interpreted as gas charging area. Structurally, three main fault zones, FZ1, FZ2 and FZ3 are mapped with strike-slip character in NW-SE orientation. These faults delimit the lagoon from eastern and western coast where the bathymetry decreases from 10m to 5m and is characterised by two linear NW-SE directed feature on the seafloor morphology. The direction of active faults of the lagoon are also well matching with onland NE-SW oriented ridges and lineaments toward northern part of the lagoon and southern coast area. The right lateral displacement at the coast line of the lagoon in the northern Sea of Marmara and strike-slip character of FZ1, FZ2 and FZ3 are thought that these fault zones maybe related with the North Anatolian Fault Zone (NAFZ). In terms of reducing the high seismic risk posed with increased urbanization of the densely populated Istanbul, it becomes significant to monitoring or identification of the continuities of these faults in current sediments represented at the shallow parts of the seismic sections.

Keywords: High resolution seismic data, Marine Magnetic data, Istanbul, Tectonic, Faults

Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

SSS31-P15 Room:Convention Hall Time:May 25 18:15-19:30

Focal mechanisms prove the right-turn of slab beneath Kii Peninsula

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[1]none

(Please refer to the figure. Names of the slab, topography of seabed, etc are naming only of here.)

Curve cr is the leading edge where the seismic activity disappears (1). I interpret it as the substantial edge of the slab. Mantle that heads eastward(the red arrow) in the Chugoku region pushes the edge of the slope that inclines to the northwest, of the Nankai slab. Therefore, the edge always receives the right-turn-force (2). Earthquakes occur on the surface of the slab and in it. I want to prove the right-turn by those focal mechanisms and to clarify details of the right-turn-force.

I thankfully used the monthly report(3)(4) of The Meteorological Agency for the focal mechanisms.

If fault type of the earthquake is typical, mechanics in the vicinity can be clearly understood. If it is thrust-type or normal-type, the direction of pressure or tension is understood respectively. However, judgment is required because settling-force with small material in exactly under or pushing-up-power from exactly under dresses thrust-type or normal-type respectively. On the other hand, it is necessary to judge whether the first power is pressure or tension about the lateral-type.

I grouped the earthquakes into A, B, C, D, E and F by enclosing them in the short dashed line.

The green arrow in A is average tension axis in the vicinity. I understand this area is the state of expansion because it ties and stops the Nankai slab of heading-eastward-tendency.

The gray arrows in B and C are average tension axises of normal-type in the vicinity. Tension element of the direction of gyration-radius of the red arrow might be the cause of normal-type. The southern part of B receives the power of the purple arrow (from the southwest) as the reaction that the leverage point receives.

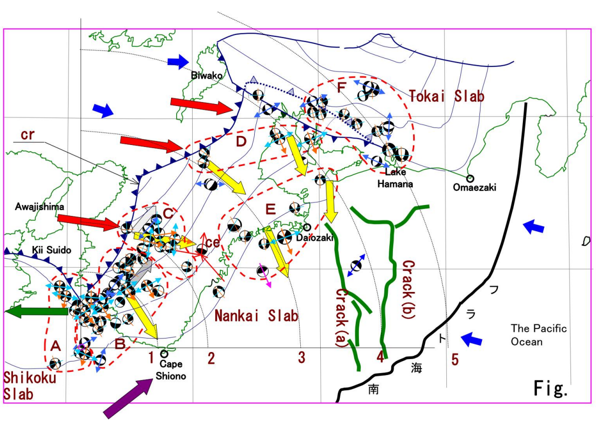
The yellow arrow in B, C, D and E is the average pressure axis in the vicinity. The yellow arrow in C seems to incline outside circular arc 2, and to have collided with E group, like the direction of the red arrow. Though the yellow arrow on circular arc 4 in D and E inclines internally than the tangent, other yellow arrows harmonize with the circular arc.

Because power to induce the overall right-turn of the Nankai slab exists widely in each place as mentioned above, it becomes grounds of the right-turn.

Though the part that rubs against the Tokai slab cannot do a smooth turn without along circular arc 5, I think that the Crack(b) reflects externals of the Nankai slab. Destruction by impossible turn occurred between, in south and north, from the Trough to Lake Hamana, in east and west, from circular arc 5 to circular arc 4. The stagnated material will form mountains.

Though there are a lot of normal-type ones in F group, the tension-axial-directions are various. I think that earthquakes that occurred because mantle pushed up(5) the Tokai slab from the under exist considerably among these.

(1)KIMURA(2001)/https://www.jstage.jst.go.jp/article/jgeography1889/110/4/110_4_581/_article/-char/ja/
(2)MASE(2014)/JpGU2014/SSS29-P10
(3)JMA/Monthly Report/January 2004/(P8)
(4)JMA/Monthly Report/October 2004/(P16)
(5)MASE(2012)/JpGU2012/SCG67-P06



/About information on earthquake referable to (3)(4)/
/About sea bottom (shape line) extracted from (6)/
/About "Nankai Slab" (shape line, contour) referable to (1)/
/About "Tokai Slab" (shape line, contour) referable to (7)/

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Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

SSS31-P16 Room:Convention Hall Time:May 25 18:15-19:30

The 2014 Bungo slow slip

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Introduction

The seismic activities off Shikoku Island are different from those off the Kyushu Island. M8 class earthquakes have occurred repeatedly off the Shikoku Island with time interval of about 150 years and M7 class earthquakes repeatedly occurred off the Kyushu Island with a recurrence interval of about 20 to 30 years. The Bungo channel area is flanked by Shikoku and Kyushu Islands and seems to be a transient area. In this Bungo channel area, slow slip events repeatedly occurred in 1997, 2003, 2009. Short-term slow slip events occurred in a low frequency area with a time interval of around half a year. Under this circumstance, the GNSS network in Japan detected a transient in 2014, which suggest occurrence of a slow slip event in a long-term slow slip area. In this study, we estimated interplate aseismic slip on the Philippine Sea plate by time dependent inversion.

Analytical Procedure

We adopted a fault patch based on the plate surface model estimated by Hirose et al (2008). We used 155 GPS sites in the Bungo slow slip area. We estimated a linear trend for the data for a period between January 2007 and January 2008 and removed the estimated linear trend from the original data. Misumi GNSS site is used as a reference point. We estimated time evolution of aseismic interplate slip using the above detrended data for the period between January 2014 and January 2014.

Results

The processed time series show a small transient for early 2014 and large transient from around July 2014. The time dependent analysis shows aseismic slip on the plate interface beneath the Bungo channel area. The estimated moment magnitude is around 6.3. Since the moment magnitude of previous long-term slow slips is around 7.2, the current event is very small. This kind of small size of slow slip event occurred in 2006. There are no clear explanations about the relationship between Mw7 class slow slip and M6 class slow slip in the long-term slow slip area.

Keywords: Bungo channel, Slow slip

Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

SSS31-P17 Room:Convention Hall Time:May 25 18:15-19:30

Rainfall correction of strainmeter data in consideration of the flow from the upper reaches (1)

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Kimura et al.(2015) showed that the flow from the upper reaches was important for the rainfall correction of the strainmeter. Therefore, Meteorological Research Institute(MRI) started the research by plural technique about the rainfall correction of the strainmeter in consideration of the flow from the upper reaches.

At first, I try the rainfall correction of the strainmeter by the introduction of the upper precipitation data of the mountain. Higashiizu-Naramoto is located in the foot of Mt. Amagi, and comes under influence that the rainfall of the mountain flows in as groundwater. The strainmeter data at Higashiizu-Naramoto was corrected only using precipitation data at Inatori(130m above sea level) Amedas(Automated Meteorological Data Acquisition System) until now. After incorporating the precipitation data of Amagisan(1,070m above sea level) AMEDAS for this, an improvement effect was provided.

In addition, MRI try the rainfall correction of the strainmeter by the observation of the river water level. Shimada-Kawane is located near the Minari River,and and comes under influence that the rainfall of the upper reaches as flow of the river. Therefore MRI install a ultrasonic type level gauge on the river.

In this announcement, I explain these summaries.

Keywords: strainmeter, rainfall correction, the flow from the upper reaches

Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

SSS31-P18 Room:Convention Hall Time:May 25 18:15-19:30

Crustal Deformation caused by the Earthquake of Northern Nagano Prefecture using InSAR analysis of ALOS-2/PALSAR-2 data

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ALOS-2, was launched on May 24, 2014, has an L-band SAR (PALSAR-2) in the same way as ALOS/PALSAR. PALSAR-2 is of help to understand of a ground surface state, and its interferometric coherence is highly effective for the crustal deformation observation.

An earthquake of M6.7 occurred near the northern Nagano prefecture on November 22, 2014. The maximum seismic intensity of this earthquake was 6-Lower. We analyzed the crustal deformation caused by this earthquake from ALOS-2/PALSAR-2 data interferograms. In this study, we used September 19, 2014 ? November 28, 2014 for ascending orbit (path:126, frame:720, right looking) and October 2, 2014 ? November 27, 2014 for descending orbit (path:25, frame:2840, left looking), and able to get a good interference result. Microwave from the satellite is irradiated from the west-southwest and west-northwest sky, incident angle in the around of the epicenter is approximately 39 and 37 degree, respectively. As the result, the eastern area from epicenter shows up to 8 fringes (=95.2 cm) crustal deformation toward the satellite in the radar-line-of-sight direction. Furthermore, Kamishiro fault has been longitudinal from north-northeast to south-southwest in the vicinity of the epicenter, and phase discontinuous line has been confirmed along the fault trace.

Some of PALSAR data were prepared by the Japan Aerospace Exploration Agency (JAXA) via the Geospatial Information Authority of Japan (GSI) as part of the project “ALOS-2 Domestic Demonstration on Disaster Management Application” of the SAR analysis of earthquake Working Group. Also, we used some of PALSAR-2 data that are shared within PALSAR Interferometry Consortium to Study our Evolving Land surface (PIXEL). PALSAR-2 data belongs to JAXA. We would like to thank Dr. Ozawa (NIED) for the use of his RINC software. In the process of the InSAR, we used Digital Ellipsoidal Height Model (DEHM) based on “the digital elevation map 10m-mesh” provided by GSI, and Generic Mapping Tools (P.Wessel and W.H.F.Smith, 1999) to prepare illustrations.

Keywords: InSAR, Crustal deformation, ALOS-2/PALSAR-2, earthquake in northern Nagano prefecture