Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

SCG011-01 Room:304 Time:May 25 08:30-08:45

ULF seismo-magnetic phenomena in Izu and Boso Peninsula, Japan during 2000-2010

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Earthquakes are one of the most destructive of natural hazards, and it has been long a dream of scientists to achieve effective prediction. Recently electromagnetic phenomena have been considered as a promising candidate for short-term earthquake prediction. In order to clarify the earthquake-related ULF (ultra low frequency) magnetic phenomena, a sensitive geomagnetic network has been installed in Japan and plenty of data associated with moderate-large earthquakes have been accumulated. In this study, we have analyzed geomagnetic data observed during the past decade in Izu and Boso Peninsula, Japan.

First, the ULF magnetic signals at the frequency 0.01Hz have been investigated. We have applied wavelet transform analysis to the 1Hz sampling data observed at three magnetic observatories in Boso Peninsula (Kiyosumi, Uchiura, and Fudago) and Izu Peninsula (Seikoshi, Mochikoshi, and Kamo) , respectively. The signature at the 0.01Hz frequency band has been revealed and daily average energy has been computed. In order to minimum artificial noise, we only use the midnight time data (LT 0:00˜3:00). And to remove influences of global magnetic perturbations, three standard geomagnetic stations (Memambetsu, Kakioka, and Kanoya) operated by the Japan Meteorological Agency have been selected as reference stations and PCA method has been applied to the yearly energy variation of the 0.01Hz signals at the three stations. The first principal component which contains more than 95% energy is considered to be global background.

After comparing the results at the stations in Boso and Izu Peninsula with global background, it is found that there are several local energy enhancements which only appear in Boso or Izu area. Statistical investigation has also been carried out and detailed results will be presented in our presentation.

Second, we have investigated the geomagnetic diurnal variation observed at each station in both Boso and Izu Peninsula from 2000 to 2010. Usually for a region that is not large, diurnal variation in magnetic stations should be stable and quite similar to each other. However, the situation could be changed if there were some strong local underground activities such as earthquakes and volcanoes which may cause electromagnetic emissions and/or underground resistivity changes. In this study, we have applied PCA method to the diurnal variation hoping to extract information about local underground resistivity and electromagnetic anomalies.

It is found that the contribution of the second principal components, which may relate with the local underground conductivity structure and/or the local electromagnetic disturbance, has some significant anomalous behaviors during the past ten years. Especially before the 2005 M6.1 and M6.0 earthquake, very clear anomalies have appeared.

Keywords: ULF seismo-magnetic phenomena, Wavelet transform, Principal component analysis (PCA)

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SCG011-02 Room:304 Time:May 25 08:45-09:00

Examinations of seismo-magnetic signals using the Morlet wavelet method

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Ratios of geomagnetic daily variation ranges between two stations in Taiwan are approximately equal to 1, due to that magnetic latitude difference is less than 4^o. When one station is located nearby epicenters, the ratios depart and recover the original constant few days before and after earthquakes, respectively. Although the anomalous changes of the ratios have been considered to be seismo-magnetic anomalies, a frequency band of them is still not fully understood. We apply the wavelet coherence as a numerical index to compare amplitude distributions in this study. When data recorded by two stations both away from epicenters are used, the wavelet coherence often approaches 1 suggesting that geomagnetic fields are dominated by changes in the ionosphere and/or magnetosphere. If one station located near epicenters is added into the analytical process, the small wavelet coherence (about 0.2) can be observed at the period of approximately 0.5 day during earthquakes. Analytical results and seismo-magnetic ratio changes yield a good agreement either in the time or frequency domain. Notably, the results also shed light on locating epicenters before earthquakes occur.

Keywords: Geomagnetic field, Earthquake prediction, Wavelet transfrom

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Electromagnetic pre-seismic anomalies induced by intermediate depth earthquakes (Vrancea zone-Romania)

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Recent studies show that before the earthquake initiation, the high stress level reached within the seismogenic volume may generate dehydration of rocks and fluids migration along surrounding faulting systems and could be reflected by electrical conductivity changes. In this paper we investigate these changes of conductivity using ULF electromagnetic and geomagnetic data recorded at both Geodynamic Observatory Provita de Sus, located on the Carpathian electrical conductivity anomaly (CECA), at about 100km distance of Vrancea epicentral zone, and Geophysical Observatory Surlari taken as reference station. Using ground-based monitoring system (GMS 06 and MAG03 DAM electromagnetic and geomagnetic equipments, respectively), possible anomalous variations of the electromagnetic normalized function (EMNF) have been surveyed, on the ULF range ($f < 0.0166$ Hz), in correlation with earthquakes with $Mw > 4.0$ triggered at the intermediate depth interval 70-160km, in seismic active Vrancea zone Subsequently, a methodology based on the correlation of the EMNF values (Bzn = Bz/Bperp and Ron = Ropar/Roz) selected according to temporal invariability criteria for a 2D geoelectric structure, in terms of non-seismicity, taking into consideration just their deviations from the electromagnetic pattern initially calculated, was elaborated. To have a comprehensive view on the applied methodology, the daily mean distribution of the Bzn and Ron parameters in correlation with the Vrancea deep seismic events taken from the seismic bulletin of the National Institute for Earth Physics, occurred simultaneously, in 2010 year, are revealed. Finally, we have to conclude that with 7-10 days before an EQ with M>4.0 occurred, the daily mean variation of the EMNF had anomalous behavior marked by a significant increase versus its standard deviation (EMNF>2.5 STDEV), and the results illuminate triggering mechanism and may represent an important step toward earthquakes forecasting.

Keywords: EM pre-seismic anomaly, Intermediate depth eartquakes

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ULTRA LOW FREQUENCY (ULF) ELECTROMAGNETIC ANOMALOUS VARATIONS RELATED TO EARTHQUAKES IN JAVA ISLANDS, INDONESIA

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The tectonic setting of Indonesia is very complex, because it is a meeting point of several tectonic plates: the Eurasian Plate, the Australian Plate, the Indian Plate, and the Pacific Plate. Such condition makes Indonesia become one of the most seismically active regions in the world. Therefore, to minimize such disasters, the research on the short-term earthquake (EQ) prediction is an important issue. One of the most promising approaches is the study of ultra low-frequency (ULF) electromagnetic anomalies preceding large earthquakes. ULF is the frequency range of electromagnetic wave less than 100 Hz. Because of deeper skin depth, ULF electromagnetic waves can penetrate through the Earth crust. In this paper, we focus on the frequency of 0.01 Hz band and would like to evaluate whether there is ULF geomagnetic anomalies preceding large earthquakes happened in Indonesia or not. Our group has installed the three components fluxgate magnetometer at Pelabuhan Ratu, West Java, Indonesia since September 2007. I have analyzed data from September 1, 2008 to October 31, 2010. There are twelve moderate-large earthquakes (M?5) during the analyzed period. The largest earthquake occurred during the analyzed period is M7.5 EQ (depth=57 km, epicenter distance =135 km, Sept. 2, 2009) according to Indonesian Meteorological, Climatological and Geophysical Agency (BMKG) earthquakes catalog. To clarify the ULF geomagnetic variations preceding all the earthquakes, spectral density based on Fast Fourier Transform (FFT) and wavelet transform (WT) as well as the analysis of spectral density ratio have been performed. The results of spectral density ratio analysis unveil clear enhancements before the largest EQ which occurred on Sept. 2, 2009 (M=7.5). These facts suggest that the spectral density analysis would be useful for seismo-electromagnetic study.

Keywords: ULF electromagnetic variation, Spectral density ratio analysis, Java Island earthquakes

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ULF geomagnetic anomaly possibly associated with earthquake

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The southern part of Kanto District, Central Japan is one of the seismically active regions in Japan because of three plates (Pacific, Philippine Sea, and Eurasia). In order to investigate the electromagnetic phenomena associated crustal activity, the precise ULF electromagnetic measurement network has been established for these 10 years. At each station, three magnetic components and two horizontal electric components are observed in general. There are two arrays with interstation distance of 5 km in Izu and Boso Peninsulas and 10 years data have been we accumulated. During this periods, we had the 2000 Izu islands earthquake swarm, the 2002 and 2007 Boso slow slip events and so on. Signal associated with crustal activity are very weak in comparison with other noise such as geomagnetic pulsations and artificial noise, therefore advanced signal processing is required. In my presentation, I would like to show some methodologies and related results. In this paper, some case studies and statistical study on ULF electromagnetic changes possibly associated with crustal activities will be presented.

Keywords: ULF geomagnetic anomaly, earthquake, crustal activity

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SCG011-06 Room:304 Time:May 25 09:45-10:00

Observations for confirming earth-origin electromagnetic pulses

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I introduce the transition of observations for confirming earth-origin electromagnetic (EM) pulses.

Some people and radio scientists reported that they detected EM noise by radio receivers during their own works just when the Hanshinn-Awaji earthquake had occurred in 1995. The noise was more intense compared to their usual observed level.

In order to confirm whether the noise was surely generated in the earth or not, we began to observe them by constructing borehole of 100 m in depth in the campus of Kyoto Sangyo University and by inserting a vertical electric dipole antenna in it in 1999 [1]. Furthermore, for determining arrival directions of EM pulses detected in the borehole, we accomplished a new sensor system composed of horizontally and orthogonally arranged two magnetic search coils and a vertical electric dipole antenna [2]. At 14:49:50 on 6 January 2004, the system detected an intense EM pulse just when an earthquake occurred, and displayed arrival azimuths of the pulse on the computer display in real-time. We determined the source location of the EM pulse at a point along the obtained arrival azimuth by applying the travel distance estimated from the propagation theory [3], and identify it in the epicenter region of the earthquake [4].

Based on the successful observation of the earth-origin EM pulse, we had tried to detect earth-origin EM pulses at two or three observation points and to identify their source locations on the horizontal plane by the triangular measurement on real-time basis. We set up the same observation equipments at an Earthquake observatory (34.48N, 136.30E) of Nagoya University, where is about 82 km south-east of Kyoto Sangyo University. However, the obtained locations were not the real source points but spurious ones, because the spuriousness was caused due to interferences of EM pulses radiated from local power lines [5].

On the other hand, we had been constructing another observation site in electromagnetic quiet environment at 33.69N, 135.34E on the campus grounds of Seto Marine Biological Laboratory of Kyoto University located on a narrow peninsular (about 300 m wide) in Shirahama town, Wakayama-prefecture, and drilled a borehole of 100 m in depth and accomplished it in July 2008. At this site, we examined differences of amplitudes and phases of magnetic fields measured by horizontal magnetic search coils installed at 95 m-depth in a borehole and on the ground. We clearly confirmed that amplitudes of vertically incident EM pluses (lightning generated ones) and their phases at the bottom of the borehole were strongly depressed and largely delayed, respectively. So we estimated electrical parameter of the medium in the sedimentary layer, such as the electrical conductivity, the skin depth for a VLF signal, and its propagation velocity in the medium.

We detected another kind of EM pulses (different from lightning generated ones) with small amplitude of magnetic field and with one- or two-cycle oscillations. We tried to determine their propagation directions up- or down-ward from phase differences of waveforms of horizontal magnetic fields simultaneously detected at the 95 m-depth in the borehole and on the ground. Some of results indicated clear phase differences suggesting down- or up-ward propagations. However, others could not be distinguished their up- or down-directions because their waveforms did not show conformity with each other. We found the reason from results of their polarizations. Almost of all magnetic field vectors at the 95 m-depth indicated ellipsoidal polarizations on a vertical plane whereas those on the ground were linear polarizations. These EM pulses were artificial ones. Therefore we have been developing a method for obtaining three-dimensional arrival directions of EM pulses in the earth, by means of strict Poynting vector of detected pulses. Now we are going to observe them by this method.

Keywords: earth-origin electromagnetic pulses, developement of EM sensors, EM detections and their soruce locations, Relation between erath-origin EM pulses and earthquakes

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Natural time analysis for seismicity in Japan

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The VAN method has been the only working short term earthquake prediction system for more than two decades. The indeterminacy of a few weeks for the occurrence time of main shocks has been a drawback.

If earthquake is a critical phenomenon as defined in statistical physics, prediction is synonym for indentifying the approach to criticality. Varotsos and colleagues proposed that by analyzing the seismicity in a newly introduced time frame called "natural time", the approach to criticality can be clearly identified. In natural time, based on the premise that a system has its own clock, the time is assumed to proceed only when an event takes place. It was found empirically that if the analysis is started at the time of SES (Seismic Electric Signals in the VAN method) appearance, the main shock occurs a few days after the criticality has been recognized. This means, seismic catalogs can play an amazing role in short term prediction to reduce the prediction lead time when combined with SES data.

We made a statistical analysis on seismicity in both natural and conventional times and confirmed that natural time is more efficient and the order and magnitude of earthquakes do play an important role in recognizing criticality. We also tried the natural analysis on major M>7 earthquakes in Japan, including 1995 M7.3 South Hyogo Pref. (Kobe), 2000 M7.3 Western Tottori Pref., 2003 M8.0 Tokachi Oki, 2004 M7.1 Off Kii Peninsula, 2005 M7.0 West-off Fukuoka Pref., 2008 M7.2 Iwate-Miyagi Nanbu earthquakes for which no SES data exists and 2000 earthquake swarm in Izu island region. Some positive results were obtained except for Tokachi and Iwate-Miyagi cases.

Keywords: Natural Time, Seismicity, Critical phenomena

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A study for the quantitative and statistical evaluation of geoelectric potential changes associated with earthquakes

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We would like to present the pre-seismic telluric current anomalies in Japan and their statistical significance. By the author's knowledge, it is only Greek-VAN group who has been successfully predicting earthquakes for more than a couple of decades. However, the reproducibility of their method has so far been barely verified elsewhere.

In Japan, VAN-like telluric current measurements were intensively conducted after the devastating 1995 Kobe earthquake. At the Kozu-shima volcanic island, we observed 19 anomalies for 23 M>3 earthquakes which occurred within 20 km of the station from May 14, 1997 to June 25, 2000. It has also been demonstrated that the correlation between the observed anomalous changes and the subsequent earthquakes is statistically very high. Our observations also indicate the existence of extremely high degree of heterogeneity in the subterranean electrical structure of the volcanic islands. Therefore, the high heterogeneity under Kozu-shima Island has been studied, though only for the shallow depth, by a VLF-MT survey. The apparent resistivity was found to range in three orders of magnitude. Current injection into the ground was also conducted for the resistivity survey. It was verified that various features of the observed anomalous changes were different from those of changes caused by artificial sources and induction of geomagnetic disturbances.

The author considers that this thesis presents the first convincing demonstration of the existence and statistical significance of VAN-type pre-seismic telluric current anomalies in Japan (or outside Greece).

Keywords: precursor, VAN method, telluric current

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SCG011-09 Room:304 Time:May 25 10:45-11:00

Relationship between the precursory mechanical properties and electromagnetic properties

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There are a number of reports on the seismic quiescence phenomena before large earthquakes. We proposed new RTM algorithm. RTM algorithm is a kind of weighted coefficient methods in the time, distance and size of an earthquake. We test it by applying to three large earthquakes in Japan, namely the Hyogo-ken Nanbu Earthquake in 1995, the Noto Hanto Earthquake in 2007 and the Iwate-Miyagi Nairiku Earthquake in 2008. The results show that the RTM algorithm is more sensitive to the seismic quiescence phenomena than the cureent RTL algorithm. At this moment, whole surveyed parameters (R, T, M and so on) are empirically selected. We have to consider the physical meaning of the ”best fit” parameter e.g., the relation of delta CFS, etc. Furthermore, the most important issue is the relationship between electromagnetic precursory phenomena and seismicity changes. We would like to solve this problem in the future.

Keywords: Quiescence, EM phenomena

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SCG011-10 Room:304 Time:May 25 11:00-11:15

Experiment Method of Microwave Detection in Association with Rock Fracture and Energy Consideration of the Obtained Data

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Formerly, microwave emission was found when a rock was compressed to be broken. At first, it was assumed secondary phenomena of piezoelectricity. However, experiments of several kinds of rocks revealed that the emitted power is not proportional to the content of quartz.

This paper first describes the detection and measurement method of microwave emitted in association with rock fracture. Then, experimental data is investigated from the viewpoint of generated energy.

Several kinds of rocks were pressed with a compressor to destruction. The samples are quartzite, granite, gabbro, and basalt. In the receiving system, the signal is amplified by a low noise amplifier first, sampled by a sufficiently high sampling frequency. Then the digitized data are stored. Observation frequency was 22GHz, 2GHz, 300MHz, and 1MHz.

Difficult points of the measurement are as follows:

1. Quite high frequencies should be treated. The ever-tried frequencies are 300 MHz, 2 GHz, and 22 GHz, which are much higher than the frequencies treated in usual geophysics.

2. In microwave measurement, impedance matching is inevitable. This is one of most difficult items in electrical measurements.

3. The phenomena are instantaneous, and lasts typically less than one msec. This fact is more serious than usual microwave measurements. We have to record the signal with an accurate triggering device.

4. The obtained signals suggest quite wide frequency band, which exceeds technological capability for only one wide-band receiver to cover the whole band. Therefore, we have to divide the total frequency band to several sub-bands, and use heterodyne receiving technology if necessary.

5. As the high frequencies are enclosed in the envelopes, we have to investigate carefully the original signal waveform and power.

6. In order to calibrate the emitted power, special knowledge of waveform of band-limited signal is needed.

In the receiving system, special care is required for microwave detection. The signal is first amplified by a low noise amplifier, digitized in a sampling frequency high enough for the observed frequency, and then stored as data. The observed frequency is 22GHz, 2GHz, 300MHz and 1MHz. If the data storage capacity is too small to keep the data for a required observation time, namely at 22GHz and 2GHz, the signal is converted to a lower frequency by a heterodyne receiver and then processed to data.

The observed microwave is intermittent pulse in every case. The width of each pulse is quite narrow, 2 nsec at the highest frequency of 22 GHz. For most kinds of rocks, 22 GHz was not detected, but the other frequencies were all observed. The pulse group just after the rock fracture and the pulse group later generated sporadically are different each other in terms of time interval between the emissions and emitted energy.

As the waveforms thus obtained are almost sinusoidal in shape, we can calibrate the power through the receiving system. From the results, we calculate the radiated power per a unit frequency for each frequency band. As for the pulse group just after the rock fracture, quartz has the maximum emission at 2GHz-band in all frequencies while gabbro has the maximum at 300MHz-band. As for the averaged value over the observation time, quartz has the shifted maximum at 300MHz-band while gabbro has the maximum at 300MHz-band unchanged.

This discovery is the world first so that we have to clarify the characteristics such as dependency on several parameters.

Keywords: Rock fracture, Microwave emission, Pulse, Detection experiment, Receiver, Energy consideration

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SCG011-11 Room:304 Time:May 25 11:15-11:30

The correlation between lower ionospheric perturbations as seen by VLF/LF propagation and EQs

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The subionospheric VLF/LF propagation is extensively used to investigate the lower ionospheric perturbation in possible association with earthquakes. An extensive period of data over 7 yr from January 2001 to December 2007 and a combination of different propagation paths in and around Japan are used to examine the statistical correlation between the VLF/LF propagation anomaly (average nighttime amplitude, dispersion, and nighttime fluctuation) and earthquakes with magnitude $>$6.0. It is then found that the propagation anomaly exceeding the 2s (standard deviation) criterion indicating the presence of ionospheric perturbation is significantly correlated with earthquakes with shallow depth ($<$40 km). Finally, the mechanism of seismoionospheric perturbations is discussed.

Keywords: Earthquakes, VLF/LF propagation, correlation study

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SCG011-12 Room:304 Time:May 25 11:30-11:45

Tomographic Analysis of Ionospheric Anomaly Preceding the 2007 Southern Sumatra Earthqauke (M8.5)

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The ionospheric anomalies possibly associated with large earthquakes have been reported by many researchers. However, a physical mechanism of pre-earthquake ionospheric anomalies has not been clarified. To understand the mechanism, it is believed that monitoring of three-dimensional ionospheric electron density distributions is effective. In this study, to investigate the three-dimensional structure of ionospheric electron density prior to the earthquake, the Residual Minimization Training Neural Network (RMTNN) tomographic approach (Ma et al., 2005) is adopted for data of GPS ground receivers and ionosonde. The advantage of this method is model-independence and flexibility in reconstruction. At first, we investigate the Total Electron Content (TEC) anomaly associated with the earthquake using the Global Ionosphere Maps (GIM) published by the Center for Orbit Determination in Europe (CODE). Then, in order to investigate the structure of electron density in ionosphere, RMTNN method is performed. As for the 2007 Southern Sumatra earthquake (M8.5), the significant decreases are found in GIM-TEC investigation and results on tomographic approach show that they take place in the heights of 250-400 km, especially at 330 km height. But the height which gives the maximum electron density is not changed. Global tendency of the decreases area is expand to the east with an altitude and it is concentrated in the southern hemisphere of over the epicenter. Such results are consistent with the observation of FORMOSAT-3/COSMIC and GPS-TEC. In our presentation, not only the case of the 2007 Southern Sumatra earthquake but also other earthquakes will be also shown.

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Present status and results: Satellite observation of seismo-electromagnetics

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Recent results and future plan of satellite observation of seismo-electromagnetics will be reported.

Keywords: seismo-electromagnetics, ionosphere, electron density, electron temperature, satellite, International Space Station

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Localized changes in the geomagnetic total intensity values prior to or associated with major earthquakes

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Changes in total geomagnetic field intensity, of 2?3 nT, were reported to be observed prior to the 1995 Hyogo-ken Nanbu (Kobe) earthquake at the Amagase (AMG), located approximately 70 km from the epicenter. We examined whether the observed variations are local signals arising from the Earth's crust, or global variations that are unlikely to originate from the crust. To remove global-scale variations in total geomagnetic intensity data, we employed a regional geomagnetic field model. Using data recorded at five reference sites in Japan, we estimated global-scale variations in total geomagnetic intensity, and removed them from the observed total geomagnetic intensity at the AMG site. The reminder still showed variations during the period prior to the Kobe earthquake. In addition, these pre-seismic variations include two of the largest shifts recorded during the entire observation period at the AMG site, raising the possibility that these variations were indeed related to the earthquake (Yamazaki and Sakanaka, 2011, J. Geodyn.).

These variations cannot be interpreted as signals arising from the area close to the seismic source because of the large distance between the epicenter and the site. Therefore, our results raise the possibility that the physical state of the Earth's crust shows marked changes over a wide region in the lead-up to a seismic event. However, we cannot exclude the possibility that large noises were recorded at this time by chance. These uncertainties are inevitable given the reliance on data collected at only one site. To overcome this difficulty, we apply the similar approach to data obtained at difference sites in Japan during 1997?2010, which are recorded by the Geographical Survey Institute of Japan and the Japan Meteorological Agency. The results will be presented at the conference.

Keywords: geomagnetic total intensity value, earthquake, locality