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

SCG069-01 Room:304 Time:May 24 16:30-16:45

Ionospheric anomalies possibly associated with large earthquakes

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Many anomalous electromagnetic phenomena possibly associated with large earthquakes have been reported. TEC (Total Electron Contents) anomaly is one of the most promising phenomena preceding large earthquakes. Recently, some statistical studies have revealed that negative TEC anomalies significantly appear a few days before large earthquakes occurred in Indonesia, Taiwan, and China. However, those regions are located in geomagnetic low latitude and affected by the Equatorial ionization anomaly (EIA).

In this paper, we examine pre-earthquake ionospheric anomalies in time series and perform a statistical test by using TEC derived from global ionosphere maps (GIM) around the Japan area for the first time. The normalized GIM-TEC (GIM-TEC$*$), which is computed based on 15 days backward running mean of GIM-TEC, have been investigated for minimizing possible confounding effects of consecutive earthquakes and identify the abnormal signals. Superposed epoch analysis have been performed for the statistical analysis of TEC anomalies associated with M>=6.0 earthquakes during the 12-year period of May 1998 - May 2010. The statistical result indicates the significance of the positive TEC anomalies 1 - 5 days before earthquakes within 1000 km from the epicenter around Japan. Furthermore, those anomalies depend on the epicentral distance and magnitude of earthquakes.

Keywords: Total Electron Content, Ionosphere, earthquake, earthquake precursor, Global Ionosphere Maps, Superposed Epoch Analysis

Japan Geoscience Union Meeting 2011
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SCG069-02 Room:304 Time:May 24 16:45-17:00

Direction finding of ULF geomagnetic data at Tarumizu station, Kagoshima Prefecture

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Anomalous ULF geomagnetic field changes associated with the 1997 Kagoshima-ken Hokuseibu Earthquake has been reported by Hattori et al.,2002. In order to evaluate the significance the ULF geomagnetic field variation, the long term analysis has been performed. Then, the result show significant increase 18 days before the earthquake have been confirmed.

In this paper, we investigate Source azimuth, and check whether source azimuth locate a region of future EQ. The source regions of the anomalous signals have been investigated using direction finding analysis. We analyze the data from January 1, 1995 to December 31, 2006. We use only nighttime data (LT00:00˜04:00) for elimination of artificial noise. In this paper, for direction finding analysis, goniometer or lissajous method have been adopted. The direction of arrival is given by the following formation. S=arctan(Bx/By)+90deg. These methods have an ambiguity of 180deg.

Results of direction finding indicate an increase of direction of arrive from the epicenter 18 days before the earthquake. But we can’t show its significance. Additional analysis such as future analysis may be required to show further evidence.

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SCG069-03 Room:304 Time:May 24 17:00-17:15

Natural time analysis for sandplie model

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Seismicity as a critical phenomenon has been actively discussed by many authors (e.g., Bak and Tang., 1989; Turcotte, 1997; Sornette, 2000; Rundle et al., 2003; Keilis-Borok and Soloviev, 2003). It has been shown that seismic electric signals (SES) and EQs reveal dynamic evolution characteristic to critical stage when their time series is analyzed in the framework of natural time, which was introduced by the Varotsos' group (e. g., Varotsos, 2005; Varotsos et al., 2002). The possible usefulness of natural time analysis in predicting catastrophic events has been demonstrated not only for the subjects of our immediate concern, but also for other critical phenomena, including sudden cardiac death (Varotsos et al., 2004; Varotsos et al., 2005). Here we investigate sandfile experiment by using natural time analysis.

Keywords: Natural Time, Seismicity, Critical phenomena

Japan Geoscience Union Meeting 2011
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SCG069-04 Room:304 Time:May 24 17:15-17:30

Three dimensional arrival directions of electromagnetic pulses in the earth

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In order to confirm electromagnetic (EM) pulses which might be generated by strong stress impacts to the earth crust when the earthquakes occurred, we have been observing them by a sensor system inserted into a borehole of 100 m in depth in the campus of Kyoto Sangyo University. Although we also have been trying to detect earth-origin EM pulses and to identify their source locations on real-time basis by an observation network with two or three sites, we could not find them yet.

At one of observation sites, we installed two magnetic sensor systems at 95 m-depth in a borehole and on the ground. We detected EM pulses and examined differences of amplitude and phase between their waveforms. We clearly confirmed that amplitude of vertically incident EM pluses were strongly depressed, and that their phases at the bottom of the borehole were largely delayed. 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.

On the other hand, we detected EM pulses with small amplitude of magnetic field and with one or two cycles which were different from lightning generated ones. We tried to determine their propagation directions, up- or down-ward, from phase differences between waveforms of a horizontal magnetic field component of EM pulse simultaneously detected at the 95 m-depth in the borehole and on the ground. Some of their waveforms indicated clear differences between their phases, suggesting down- or up-ward propagations. However, others could not be distinguish their propagation directions, because their waveforms did not show conformity with each other. We found a reason from behaviors magnetic field vectors at the vertically different two detecting points. Almost all of EM pulses detected in the earth indicated ellipsoidal polarizations whereas most EM pulses detected on the ground indicated linear polarizations. We have recognized that we have to use Poynting vectors of EM pulses detected in the earth and have to determine their arrival directions. For this purpose, it was needed to develop a new sensor system composed of tri-axial electric and magnetic sensors.

Manufacturing a tri-axial electric dipole antenna system was another hard subject, because we cannot secure wide space for the deployment of horizontal dipole elements in the narrow borehole. For solving this problem, we have been developing horizontal antenna having enough gain equivalent to that of usual long horizontal antenna. At the present stage, we can not introduce the details of the tri-axial electric dipole antenna, because we are applying for a patent for this new sensor system, we would be able to show it at the symposium.

Keywords: electromagnetic pulses, propagation in the earth, detection of arrival direction, development of detection system

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SCG069-05 Room:304 Time:May 24 17:30-17:45

Signal Discrimination of ULF Electromagnetic Data with Using Singular Spectrum Analysis and Principal Component Analysis

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Various electromagnetic phenomena associated with the crustal activity have been reported in a wide frequency range (DC-HF). In particular, ULF electromagnetic phenomena are the most promising among them because of the deeper skin depth. But sometimes ULF electromagnetic data contain spontaneous or impulsive variations caused by interactions between the geomagnetic field and the solar wind, leak current originated from a DC-driven train (train noise), and precipitation. In generally, intensity of electromagnetic signals associated with the crustal activity is smaller than above variations. Therefore, it is important that how to identify the other intense and spontaneous changes. In this paper, we have developed algorithms to detect or remove the above changes using Singular Spectrum Analysis and Principal Component Analysis. As a result, we can detect geomagnetic storms generally, and mostly remove such variations. In terms of variation from train noise and precipitation, we can not remove such changes. But it is found that we can detect such changes mostly. The train noise detection enables to analyze the daytime data although we did not use them for investigation on earthquake-related ULF electromagnetic phenomena so far.

Keywords: ULF, electromagnetic field, Singular Spectrum Analysis, Principal Component Analysis, train noise, detection

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SCG069-06 Room:304 Time:May 24 17:45-18:00

Generation of Electromotive Force and Changes of Seebeck Coefficient on Igneous Rocks under Non-uniform Stress

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To study mechanisms of electromagnetic phenomena related to earthquakes, we have conducted laboratory experiments using rock samples. According to our previous experiments, when a terminal of an air-dried igneous rock block is uniaxially loaded, there appears the electromotive force making electric currents flow from the stressed volume to the unstressed volume. There is a positive correlation between the degree of stress/strain and the electromotive force. Because quartz-free gabbro tends to generate the stronger electromotive force than quartz-rich granite, it is inconsistent to consider piezo-electric effect as the main factor of this electromotive force. To explain this force, we have focused on peroxy bonds: one of the most popular lattice defects in igneous rock-forming minerals, e.g., O_3Si-OO-SiO_3 in quartz. When this bond is deformed by mechanical force, an antibonding energy level of this bond shifts down into the Valence band and an electron can jump in this level from a neighbor oxygen site. As a result, a positive hole is activated in this neighbor site and an electron is trapped in the deformed peroxy bond. Once positive holes are activated, they can spread away through the Valence band. Though we have expected that the positive holes flowing from the stressed volume to the unstressed volume be the source of the electromotive force induced by non-uniform stress, the activation/spread of positive holes is not yet proved. In this study, we measured thermoelectromotive force of air-dried gabbro blocks whose one terminal was uniaxially loaded/unloaded. We verified the activation/spread of positive holes from the increase/decrease of the Seebeck coefficient during loading/unloading. The results indicated that the Seebeck coefficient of the gabbro without loading was about 0.8-1.2mV/K, meaning the majority of charge carriers are hole. On the other hand, the Seebeck coefficient of the volume under 60MPa of stress decreased to about 0.5-0.7mV/K, and that of the volume under stress free did not remarkably change, i.e., about 0.8-1.2mV/K. This meant that the concentration of holes increased in the stressed volume and such a change was little in the unstressed volume. In conclusion, it was clarified that holes were activated in the stressed volume and the distribution of the holes spreading reached only near around the stressed volume. Provably, only a little part of the holes reached the unstressed edge. The small slant in the distribution between these holes and the electrons trapped at the deformed peroxy bonds, i.e., the electric polarization in the stressed volume, is the source of the electromotive force induced by non-uniform loading. An increase of the stress/strain degree causes an increase of the positive hole concentration, leading increases of the electric polarization and the electromotive force. In the Earth's crust, a change of stress/strain in and around a fault before/during faulting will cause the activation/spread of positive holes, leading a change of polarization and a formation of an abnormal electric field in and around the fault.

Keywords: Seismo-electromagnetics, Igneous rock, Electromotive force, Lattice defect, Positive hole

Japan Geoscience Union Meeting 2011
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SCG069-07 Room:304 Time:May 24 18:00-18:15

Time and space correlations of EQ-echo with epicenter of earthquake, emitting and observing stations

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To confirm the relationship between anomalous transmission of VHF-band radio waves and impending earthquakes, we designed a new data-collection system and have documented the anomalous VHF-band radio-wave propagation beyond the line of sight prior to earthquakes (EQ-echo) since December 2002 in Hokkaido, northern Japan. We show here relationships between path of EQ-echo and epicenter, and appearance time of EQ-echo and occurrence time of earthquake. From empirical lows between total duration time of EQ-echo and M or maximum intensity of earthquake, and paths of EQ echo from broadcasting stations to observing stations and epicentral region, to forecast large earthquake (M>5) is not difficult.

Keywords: VHF scattering wave, earthquake precursor, earthquake forcasting, hokkaido

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SCG069-08 Room:304 Time:May 24 18:15-18:30

Measurement of pre-seismic atmospheric anomalies in Okayama, Japan

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Fujiwara et al. (Geophys. Res. Lett., 2004) verified the appearance of anomalies in the atmosphere before earthquakes through observation of anomalous transmission of VHF electromagnetic (EM) waves beyond line-of-sight. The cross-correlation between the earthquake occurrences and the anomalies shows that the appearance of anomalies was significantly enhanced within 5 days before earthquakes. In order to verify the spatial correlation, thus, we developed VHF interferometric system to find the coming direction of scatted electromagnetic waves (Yamamoto et al., Proc. Jpn. Acad., 2009). Since we have installed this system in Okayama, Japan, we would like to show the preliminary results in this presentation.

Keywords: Earthquake, Ionospheric Anomaly, Atmospheric Anomaly, EM Wave Propagation, Interferometric Measurement

Japan Geoscience Union Meeting 2011
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SCG069-P01 Room:Convention Hall Time:May 25 14:00-16:30

Simultaneous observation of VHF radio wave transmission anomaly propagated beyond line of site prior to earthquakes in m

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The VHF radio wave transmission anomalies propagated beyond line of site prior to earthquakes (hereafter termed EQ-echo) have been observed more than 20 times from 2004 at the Erimo observatory (ERM) in Hokkaido, Northern Japan. A statistical relationship between magnitude of preceding earthquake (M) and total duration time of the EQ-echo (Te) has been proposed in this area (Moriya et al.2009). To confirm a region where the EQ-echo observed for each earthquake, we installed another 3 observatories with approximately 5 km spacing in the surroundings of ERM ; Fuyushima (FYS), Rusaki (RSK) and Tohyoh (TYO).

In consequence, the EQ-echoes have been observed at least one observatories prior to 7 earthquakes (totally 9 earthquakes M>3.9 occurred) between 2009 and Oct. 2010. The logarithm relationship between M and Te for these 7 earthquakes showed similar relationship proposed by Moriya et al. (2009).

In addition, EQ-echoes were simultaneously observed at three observatories, ERM,RSK and FYS, before earthquake in Hidaka Mountains at 10 Mar. 2009 (M=4.1). Although the wave forms of the EQ-echoes were similar in each record, the initial time and duration time of each EQ-echo were different in some minutes each other. To detect arrival direction of the EQ-echo, six-ways antennas were installed at every 60 degree in FYS since 2009. By using this multi-way antennas, we estimated the arrival direction of EQ-echo before the earthquake that occurred at 14 Oct. 2010 (M=5.5). Although this method seemed capture changes of arrival direction of EQ-echoes in duration time (from 120 to 170 degrees from the north), this estimated directions were different from the direction of epicenter (about 0 degree) and the Hiroo broadcasting station (about 80 degree). These time lags of EQ-echoes and change of arrival direction may suggest the expanding or moving of scattering object which affects appearance of an EQ-echo.

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SCG069-P02 Room:Convention Hall Time:May 25 14:00-16:30

Dual frequency interferometer system to detect for earthquake-related anomalous VHF radio propagation

Yuka Tone[1*], Nozomi Ohno[1], Katsumi Hattori[1], Isao Yamamoto[2]

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Recently, earthquake-related electromagnetic phenomena have been reported in various frequency bands. In the VHF band, it is known that anomalous propagation (invisible propagation) precedes larger earthquakes. It is considered to be caused by reflection and scattering of VHF radio waves due to atmospheric disturbances generated in the preparation process of larger earthquakes. Temporal correlation between earthquake and anomalous propagation has gradually been reported. However, a spatial correlation hasn't understood yet. Therefore, in this study, we develop a VHF band interferometer system and we conduct experimental test to evaluate characteristic of the system to identify disturbed area related to earthquake. The system is composed of two Yagi antennas, crystal filters, amplifiers, Phase Delay Controllers, FM digital tuners, a signal generator, and a Phase Difference analyzer.

Now, we perform observation for invisible propagation at Chiba Univ. with the developed system. The target transmitter is FM Sendai [77.1MHz]. The system is locked in direction for FM Sendai [N13^{o}E] with elevation of 20^o. Then, we observe 84.1 MHz which is not used for broadcast as a reference, because a comparison with behavior of dual frequencies helps to identify the source of invisible propagation, that is a natural source or a broadcasting source).

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SCG069-P03 Room:Convention Hall Time:May 25 14:00-16:30

VHF interferometry system for anomalous propagation of FM radio broadcasting wave and its preliminary result

Nozomi Ohno[1*], Yuka Tone[1], Katsumi Hattori[1], Toshiaki Takano[2], Isao Yamamoto[3]

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Earthquake-related electromagnetic phenomena have been reported in various frequency ranges in a few decades. There are a lot of observation methods of the earthquake-related phenomena. Active sounding using VLF and VHF radio transmitter is one of the popular methods. Anomalous propagation is registered prior to the large earthquakes. The over-horizontal propagation is considered to be generated by disturbances of the atmosphere above the epicenter or along the propagation path. A recent study shows that the appearance of anomalies was significantly enhanced within 5 days before earthquakes with M more than 4.8. However, there is no information on the scattered place.

In this study, a simple interferometer system for VHF radio wave to identify the source position between space-time of earthquake-related atmospheric disturbances has been developed and installed at Chiba University (Nishi-Chiba campus). The target FM radio station is located in Sendai and the broadcasting frequency is 77.1 MHz with horizontally polarization (5 kW). The distance between the receiver and the transmitter is approximately 300 km that is over-horizontal range.

In this presentation, evaluation of this system and a characteristic of the VHF radio wave propagation will be report.

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SCG069-P04 Room:Convention Hall Time:May 25 14:00-16:30

VHF anomalous transmission associated with lightning activity

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VHF electromagnetic (EM) waves cannot usually propagate long distance because they penetrate through the ionosphere. They can reach far away receivers beyond the line-of-sight only when reflection and scattering due to ionospheric or atmospheric disturbances happen. According to Fujiwara et al. (Geophys. Res. Lett., 2004), appearance of anomalies in the atmosphere before earthquakes (EQs) has been verified through observation of anomalous transmission of VHF EM waves beyond line-of-sight. The cross-correlation between the EQ occurrences and the anomalies shows that the appearance of anomalies was significantly enhanced within 5 days before EQs. Preliminary one-month observation has been done in Hualien, Taiwan, for observation of VHF anomalous transmission possibly associated with EQs. Taiwan is one of best place for the statistical study of EQ-related phenomena due to active seismicity. Suitable place for FM transmission observation is restricted due to FM radio station jam. In eastern Taiwan, less artificial noise may be expected because of only small city existence. Different allocation of FM radio in Taiwan and Japan contributes to less radio wave interference. In our observation, anomalous VHF propagation beyond line-of-sight during heavy thunderstorm activities was measured. Besides non-transient (the order of minutes to hours) anomalous VHF propagation caused by Es-layer reflection and radio duct, anomalous propagation lasting for a few hours during a heavy thunderstorm was found. A calculation of ray tracing did not support this refraction due to thunderstorm-scale duct. Our further investigation implies that this reflection may be caused by scattering of VHF radio wave inside the thundercloud.

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SCG069-P05 Room:Convention Hall Time:May 25 14:00-16:30

The summary of the research of seismo-electromagnetic phenomena observed by the observation network of Chubu University

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Earth Watch Safety Net Research Center of Chubu University has established electromagnetic observation network in order to study seismo-electromagnetics. We have observed ULF/ELF electromagnetic waves in order to catch the emissions from the focal region of earthquakes. And we have observed VLF electromagnetic waves at Kasugai in order to measure the change of the propagation characteristic in the ionosphere and atmosphere disturbed by the energy from the epicentral region.

In this study, we talk about the result of the observation by this network. Anomalous ULF emissions and excitations of Schumann resonances were observed at Nakatsugawa station in the case of the 2004 Mid-Niigata Prefecture and 2007 Noto Hantou earthquake. And we found some ULF emissions propagated from the direction of the epicentral area of 2007 Noto Hantou earthquake. However, in the case of the 2008 Iwate-Miyagi Nairiku earthquake and 2009 Suruga-Bay earthquake, we could not found anomalous ULF/ELF signals, and could not find ULF electromagnetic waves possibly propagated from the epicentral areas. But we found some changes of the propagation characteristic of VLF electromagnetic waves before these earthquakes.

The observed ULF/ELF/VLF anomalies possibly associated with earthquakes were not so convincing enough to forecast the earthquakes at this stage. These anomalies observed by ULF/ELF/VLF ranges would be only a little hint of the mechanism and scenario of the generation of the seismo-electromagnetic phenomena. And so we need more event studies, further observation and interdisciplinary research.

This multi-point observation network is now supported by Academic Frontier Project for Private Universities: matching fund subsidy from MEXT, 2006-2010.

Keywords: seismo-electromagnetics, ULF/ELF/VLF observation, Schumann resonance

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SCG069-P06 Room:Convention Hall Time:May 25 14:00-16:30

Study of the Lithosphere-Atmosphere-Ionosphere Coupling (Chemical cannel)

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Recently, Ionospheric anomalies possibly associated with large earthquakes have been reported by many researchers. These reports suggest the existence of ”Lithosphere- Atmosphere-Ionosphere Coupling (LAI coupling)”. For the LAI coupling, 3 cannels have been proposed; they are ”acoustic”, ”chemical”, and ”electromagnetic” channel. In this study, the chemical cannel is considered to be dominant and in order to understand basic characteristics of it, we observe ion content concentration, atmospheric electric fields, and meteorological parameters in the southern part of Boso Peninsula. We have installed COM-3700, produced by Com System Inc., to observe ion content concentration at Akishima (Tokyo), Kiyosumi (the southern part of Boso Peninsula) and Uchiura (the southern part of Boso Peninsula). Atmospheric electric field and weather conditions (temperature, humidity, air-pressure and window conditions) have also been observed simultaneously at Kiyosumi station. We are now collecting fundamental data to understand variations. In our presentation, we will show you observed data and their possible relationship.

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SCG069-P07 Room:Convention Hall Time:May 25 14:00-16:30

Possible ionospheric anomalies associated with large earthquakes in japan: Case study with GEONET

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Recently, there are many reports on earthquake-related electromagnetic phenomena. Anomalous TEC (Total Electron Content) changes preceding large earthquakes are one of the most among of them. In this study, TEC anomaly variations in time and space have been investigated for the 2007 Noto-Hanto earthquake (M6.9) and the 2007 Chuetsu-Oki earthquake (M6.8). In this study, TECs from ground based receivers GPS have been computed with using the GEONET, which provide a higher resolution than those from GIM (Global Ionosphere Maps). In order to remove a daily variation of TEC, 15 days backward running average TECmean(t) and its standard deviation sigma(t) at a specific time are taken for the normalization. The normalized TEC$*$(t) is defined as follows: TEC$*$(t) = (TEC(t)-TECmean(t))/sigma(t).

For the 2007 Noto-Hanto earthquake, TEC$*$ decreases excess -3sigma criterion 5 and 13 days before the earthquake near the epicenter. The duration of the above negative anomalies lasts more than a few hours. In space, the region of the negative anomalies is concentrated in a small area. On the other hand, positive anomalies beyond +3sigma are detected 12 ,17 and 18 days before the earthquake. In space, the region of the positive anomalies with +3sigma 12days before the earthquake is found to be extent all over Japan.

For the 2007 Chuetsu-Oki earthquake, there are positive anomalies beyond +3sigma. They are detected 5, 12 and 17 days before the Chuetsu-oki earthquake near the epicenter. The duration of positive anomalies is more than a few hours. In space, the region of the positive anomalies with +3sigma 5 days before the earthquake is found to be extent all over Japan. But there are no negative anomalies beyond -3sigma a few days before the earthquake.

These results are correlated with the GIM based TEC anomalies for both earthquakes.