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

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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

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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

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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