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

SCG69-01 Room:102B Time:May 24 09:00-09:15

Direction finding experiments of infrasonic and audible waves by multiple-sites arrayed sensors

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Infrasound and audible sound propagation in atmosphere is one of the open fields of the atmospheric science. These waves as well as atmospheric gravity waves that can propagate vertically up to the thermosphere is important in energy transportation way among ground, ocean, troposphere, stratosphere, mesosphere, and thermosphere. These waves can possibly be a seed of observable waves in thermosphere or ionosphere as many kinds of horizontal waves observed by optically or electromagnetically at each fixed altitude, suggesting these waves might be a key of atmospheric studies in vertical interactions. Many kinds of sources in naturally and artificially on ground, ocean, or troposphere like volcanic eruptions, earthquakes, tsunamis, artificial explosions, traffic of vehicles and planes can emit audible sound and infrasonic waves, however, examples of direction finding experiments by multiple-sites arrayed infrasound sensors in mesoscale region have been limited.

In order to observe and confirm source directions and coordinates of infrasonic waves from Sakurajima volcano and two sounding rocket launches from Uchinoura Space Center (USC), JAXA, we deployed 8 infrasound sensors as two 3-sensors arrays with triangles of about 50 m separations at Miyazaki University and Kinkowan High School and 2 independent sensors at Kagoshima National College of Technology and USC/JAXA from Dec. 16, 2011 to Jan. 16, 2012. During the experiment, the Sakurajima volcano was very active and many volcanic eruptions were reported by Japan Meteorological Agency with each maximum pressure value observed at nearest volcano observatory within 5 km from the source (vent position), whereas, JAXA's sounding rocket S-310-40 was launched from USC at 23:48 on Dec. 19, 2011, and S-520-26 rocket was at 5:51 on Jan. 12, 2012, respectively. Apparent infrasonic waves by Sakurajima eruptions were recorded by Chaparral Physics Model-2 and Model-2.5 sensors with Hakusan LS-8000WD and LS-8800 data loggers as well as SAYA A/D boards with PC at each site. We developed software for the direction finding. Based on the analyzing software, these infrasonic waves were successfully confirmed as the waves from Mt. Sakurajima by comparing between the vent position of Mt. Sakurajima and the results of direction findings. In this talk we will present a summary of direction finding experiments and the next step of multiple-sites arrayed observation of infrasound in Japan and Antarctic.

Acknowledgements: The authors are grateful to Drs. Kouji Maeda and Makoto Yamauchi (Miyazaki University), Drs. Hiromasa Nozawa and Manabu Shinohara (Kagoshima National College of Technology), Dr. Takumi Abe (JAXA), and Mr. Hitoshi Hinokuchi (Kinkowan High School).

Keywords: infrasound, audible sound, direction finding, multiple-sites arrayed observation, Sakurajima volcano eruption, sounding rocket

Japan Geoscience Union Meeting 2012
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SCG69-02 Room:102B Time:May 24 09:15-09:30

Coupled interaction of earthquake nucleation with deep gases and seismo-EMs

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The source mechanisms of seismo-electromagnetic (seismo-EM) phenomena remain open questions. In order to address this problem, a new fault model taking into account a coupled interaction of earthquake nucleation with deep Earth gases is introduced based on data mining analysis of earthquake lightning (EQL): a type of seismo-EM phenomenon; i.e., coupled interaction causes a negatively electrified gas-flow as the gases pass through fractured asperities due to an exoelectron attachment reaction. The gas-pressure impressed current, which could be expressed as a function of the earthquake parameters,

log I = 0.5M + log{xi}D$_c$,

where M is magnitude, {xi} is a measure of electric-coupling intensity of asperity-cracks with deep gas flow at depth D$_c$,. The current is transient, but the electric activity repeatedly occur along successive crack paths until a network of cracks is fully developed over the asperity zone. The frequency is expressed as f=1/{Delta}t: the interaction period of electrified gas flow {Delta}t = *{kappa}*l_c/v, where *{kappa}*l_c is a measure of electrified gas displacement.

As shown in Fig.1, the current is sufficient to explain the seismic electromagnetic signal (SES) intensity observed at the ground level. A possible explanation for lithosphere-ionosphere EM coupling is as follows. The current generates a transient electric dipole at a focal zone, which induces the telluric current system having lower frequencies of less than 0.02 Hz. Changes in the telluric current within the conducting Earth' s surface; sea water, may affect ionospheric EM disturbances, which are observable as sporadic E and GPS-TEC anomalies, as often observed before strong earthquakes.

Keywords: seismo-EMs, earthquake nucleation, deep Earth gases, exo-electron, SES, GPS-TEC

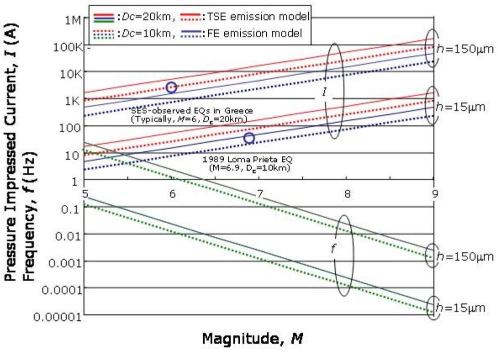

Fig.1 *I* and *f* as a function of *M*

SCG69-03 Room:102B Time:May 24 09:30-09:45

Generation of Electromotive Force and Changes of Seebeck Coefficient for Igneous Rock Blocks Subjected to Inhomogeneous

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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. However, 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 proposed that peroxy bonds, which are one of the most popular lattice defects in igneous rock-forming minerals, are deformed and become accepters. This can lead to the activation of positive holes. In the last reports, to verify "positive hole activation", we measured thermoelectromotive force of air-dried gabbro blocks under the same loading/unloading conditions and inspected the changes of its Seebeck coefficient. As a result, we confirmed that the concentration of holes increased in the loaded volume, i.e. the positive hole activation, and such a change was little in the load-free volume. In this report, we conduct the same laboratory experiments for various types of rock blocks and inspect whether or not the positive hole activation is universal in igneous rocks.

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

Japan Geoscience Union Meeting 2012
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SCG69-04 Room:102B Time:May 24 09:45-10:00

A statistical study of ULF seismo-magnetic phenomena in Kanto, Japan during 2000-2010

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Recently electromagnetic phenomena have been considered as a promising candidate for short-term earthquake prediction. And especially passive ground-based observation of ULF (ultra low frequency) geomagnetic signatures is considered to be the most promising method for seismo-magnetic phenomena study due to deeper skin depth. In order to clarify the earthquake-related ULF 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 Kanto area, 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 1:00˜4:00). And to remove influences of global magnetic perturbations, we have developed another method to obtain reliable background based on principal component analysis (PCA). 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. Especially for the case studies of the 2000 Izu Island earthquake swarm and the 2005 Boso M6.1 earthquake, significant anomalous behaviors have been detected in Z components.

Finally, we have applied superposed epoch analysis (SEA) to the above results and make a statistical study. The statistical results have indicated that before an earthquake there are clearly larger probabilities of anomalies than that after the earthquake. For Izu area, three weeks and few days before statistical value of anomalies is significant; for Boso region, around ten and few days before it is significant.

Keywords: ULF seismo-magnetic phenomena, statistical study

Japan Geoscience Union Meeting 2012
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SCG69-05 Room:102B Time:May 24 10:45-11:00

Characteristics of electromagnetic data at Marumori in Miyagi prefecture before and after Tohoku M9.0 earthquake

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Detection of electromagnetic signals associated with earthquake has been conducted in many years. Electromagnetic inductive effect, produced by electromagnetic variation in ionosphere or magnetosphere, is mainly included in observed electromagnetic data in the earth surface. The inductive effect is made by solar activity which varies widely cyclic or irregularly, and the observed electromagnetic data also vary widely. This fact sometimes leads to make mistakes identifying the signals associated with earthquakes. Therefore, when we discuss about electromagnetic signals associated with earthquakes, the signals must be distinguished from electromagnetic inductive effect.

Recently, we attempt to remove the inductive effect on time-series electromagnetic data by using MT frequency response function. This method is able to estimate inductive effect on time-series electric data from magnetic data, or magnetic data from electric data. If the inductive effect on observed electromagnetic data can be removed by the method, the signal should be clearly picked out. We will present the results of the analysis of MT time-series data in Marumori town, the southern part of Miyagi prefecture from the middle of Nov. 2010 to the end of Apr. 2011.

Keywords: The Tohoku M9.0 earthquake, electromagnetic changes, Miyagi prefecture, frequency response function

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SCG69-06 Room:102B Time:May 24 11:00-11:15

Seismo-ionospheric Anomalies of the GPS TEC Observed before the 11 March 2011 M9.0 Tohoku Earthquake

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In this paper, the total electron content (TEC) derived from ground-based GPS (global positioning system) receiving networks are used to observe the seismo-ionospheric anomalies and traveling ionospheric disturbances associated the 11 March 2011 M9.0 Tohoku earthquake. To identify the pre-earthquake anomalies, the TEC of the global ionosphere map (GIM) is examined. The Thermosphere Ionosphere Electrodynamics General Circulation Model (TIEGCM) is applied to simulate the observed anomalies. The observation shows that the TEC over the epicenter significantly enhances on 6-8 March 2011, 4-2 days before the earthquake. The spatial analysis further demonstrates that the enhancement anomaly specifically and persistently appears in the northern epicenter area. Simulation results well agree with the observations, which suggest that the electric potential around the epicenter has been distorted and significantly affect the TEC during the earthquake preparation period.

Keywords: Seismo-ionospheric Precursor, GPS TEC, 2011 M9.0 Tohoku Earthquake

SCG69-07 Room:102B Time:May 24 11:15-11:30

Detection of ultra-micro cracks associated with the great Tohoku Earthquake by means of an electromagnetic means

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We detected the pulse like ULF, ELF band electric variations associated with the great Tohoku Earthquake on March 11, 2011. The phenomena started to increase on 7^{th} March after very calm situation attained peak activity on 9^{th}, decreased on 10^{th}, recovered considerably in the morning on 11^{th} till the very moment of the huge earthquake. The signal has been very familiar to us from the observation of the ULF band vitiation at the time of small volcanic activity at the Izu-Oshima in 1992. The waveform has very peculiar form as the time evolution of the geyser. The signals have been observed in almost all volcanic eruption activities and seismic swarm as in around Mt. Hodaka in 1998, Mt. Nikko-Shirane, the Miyake Island, and Niigata earthquake. And it is confirmed that the ULF type anomalies are closely related with the crustal activity occurring in the preparatory stage of seismic swarms and volcanic activity. The waveform is similar to the time evolution of the geyser (Geyser-type ULF variation: GUV). The pre-shock, main-shock and aftershock events were rarely accompanied the signal. The phenomena have been known to be induced by the electro-kinetic effect through confined water rapid flow into the small cracks in the crust.

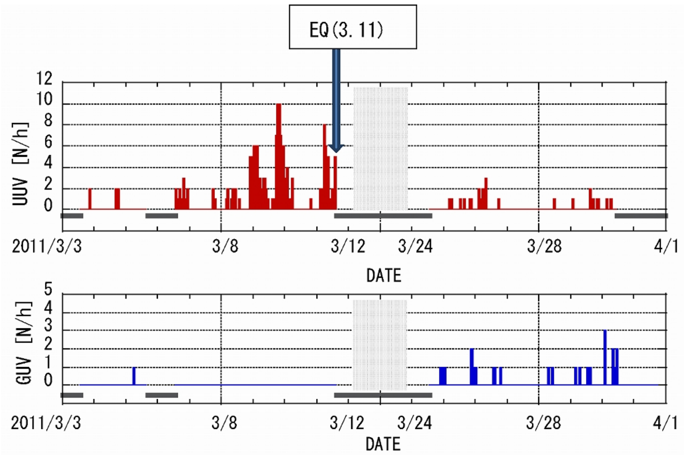
We devised a new detection system having higher dynamic ranges in the frequency and signal strength. And the field observation started on 3, March 2011 at Hasaki (now Kamisu) .We found that there are two kind of anomalous signals associated with the Earthquake; one is the very GUV and the other is the higher frequency signal so-called the Uni-corm type ULF variation (UUV). GUV has pulse width of 0.5-30minutes and strength of some 10 times of the variation induced by the earth-ocean tide effect. UUV has pulse width of 10ms and strength of one-tenth of the tidal effect. The strength of both signals maintained their magnitude in the period of the event occurrence.

The number of UUV evolved in a similar way as the pre-shocks and acoustic emissions in the preparatory stage of main fault rupture and rock fracture experiment. On the other hand, GUV has very scare activity before the event, and occurred dominantly after the event. We can infer that the UUV can be used to infer the occurrence time of the main shock before several days.

The observation site is in the corner of the south-eastern end of the huge rupture area of 500km by 200km. The GPS data and the seismic inversion data show that the rupture extended to the area near Hasaki. Based on these evidences we can infer that the ultra-micro crack has been induced even in the edge of the future rupture zone without limited to the asperity zone of off Miyagi-ken of some 45m slip. The hypothesis is far from the ordinary idea of the rupture model. It is the first finding of such phenomena of very small strength which can be detected only by means of very low noise instrument as the borehole antenna system as ours.

We dare extend our inference by suggesting that we can estimate possible magnitude from the estimation of area of the zone of the UUV occurrence by using dense network of the observation system.

Keywords: earthquake precursor, imminent prediction, electric phenomena, ULF band pulse



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SCG69-08 Room:102B Time:May 24 11:30-11:45

Analysis of geomagnetic field changes with tsunami generation in the 2011 Tohoku Earthquake

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Earth's electric and magnetic changes associated with earthquakes and tsunamis have been investigated previously. However, the apparent changes of the Earth's magnetic field signal simultaneously observed at multiple observation sites near the epicenter of the tremendously huge earthquake are rarely reported.

Our observation sites were situated at an epicentral distance of a few hundred km from the March 11, the 2011 Off the Pacific Coast of Tohoku Earthquake (Tohoku Earthquake) of Mw 9.0. In this study, we present our successful observations of Earth's magnetic field changes caused by tsunami from the 2011 earthquake that occurred off the Pacific coast of Tohoku, Japan. The key point of this report is that we successfully observed Earth's magnetic field changes caused due to the huge tsunami effects and that we make a qualitative comparison between magnetic field and GPS-TEC (total electron content) changes.

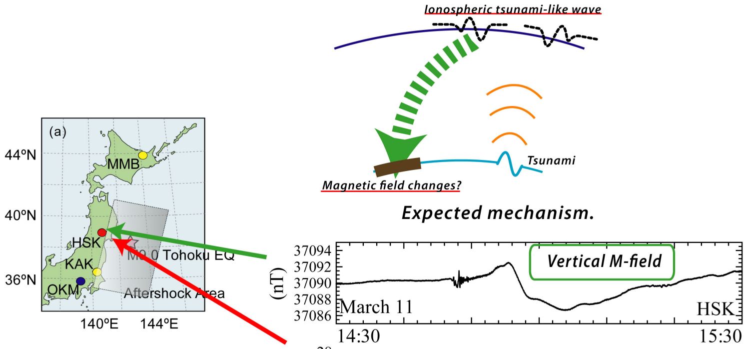
Our observation systems were established at Hosokura, Miyagi prefecture in NE Japan and at Okutama, in Tokyo. Their systems consist of a fluxgate magnetometer, GPS clock and recorder with 0.03 or 0.01 nT resolution. A vertical component accelerometer is also installed at Hosokura observatory. Since March 2004, we have observed 3 components of the geomagnetic field using a pair of fluxgate magnetometers at Hosokura mine in northeast Japan. One of them has been placed at the main gallery ?70m bellow the ground surface and another in a hole 1m bellow. The sampling interval of the lower magnetometer is 0.5 sec and the upper 1 sec. The observation clock has been synchronized by use of GPS signals. At Okutama station, we have also observed 3 components of the geomagnetic field using a fluxgate magnetometer with GPS clock at 32 Hz sampling since December 2003. The sensor is placed in a hole 1m below the ground surface near a mountain stream.

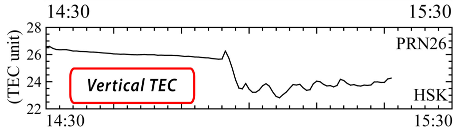
The 2011 off the Pacific coast of Tohoku Earthquake, so-called the Great East Japan Earthquake, was a mega-thrust earthquake with a magnitude 9.0 (Mw) off the coast of Japan that occurred at 14:46:18 JST on 11 March 2011. Our observation results show that the magnetic field began to change almost simultaneously with tsunami generation and propagation. These changes were detectable at multiple observation points before the arrival of tsunami waves at coastal areas.

Additionally, we compared the magnetic field with TEC changes: we found that the vertical component of the magnetic field (Hz) at HSK is very similar to TEC changes above HSK. That is, this suggests that remarkable magnetic field changes at HSK was generated by changes in the conductivity and/or current of the ionospheric layer.

These are very important and noteworthy results: Further efforts can suggest new systems for early warning of destructive tsunami using a combination of magnetic and other measurements.

Keywords: 2011 Tohoku Earthquake, geomagnetic field changes, TEC, tsunami, acoustic wave





Comparison between vertical magnetic field detected at HSK observation sites and vertical TEC above each observation site.

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SCG69-09 Room:102B Time:May 24 11:45-12:00

Variation of GPS total electron content after accident of Fukushima I nuclear power plant damaged by tsunamis

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Recently, pre-seismic ionospheric disturbances have been often reported. One of proposed speculations which produce the disturbance is that atmospheric conductivity is enhanced by pre-seismic radon emission. The speculation is based on the report that plasma density at the F2-peak was enhanced after the nuclear accident at Three Mile Inland, which radioactive materials was vented. Unfortunately, radioactive materials have been also emitted from Fukushima I nuclear power plant damaged by tsunamis generated by the M9.0 off the Pacific coast of Tohoku earthquake. The radioactive ray is stronger in the Fukushima accident than in the Three Mile Inlad accident. Therefore, the Fukushima accident is good opportunity to verify the speculation. In this paper, we investigate total electron content (TEC) before and after the Fukushima accident using a ground-based receiving network of GPS Earth Observation Network (GEONET) in Japan. Both small enhancement and disturbance of TEC were observed over the nuclear power plant after the radiation was suddenly enhanced on March 14 of 2011. However, similar signatures were not detected in the other sudden radiation enhancements. Moreover, enhancement and disturbance did not last for more than an hour over the nuclear power plant. Therefore, the results indicate difficulty that radioactive materials disturb the ionosphere even when such circumstance exits.

Keywords: seismo-electromagnetics, ionospheric disturbance, accident of Fukushima I nulclear power plant, Tohoku earthquake, total electron content

SCG69-P01 Room:Convention Hall Time:May 24 17:15-18:30

IONOSPHERE-ATMOSPHERE-OCEAN-CRYOSPHERE-GEOSPHERE INTERACTION FROM MICROSEISMS AND MICROBAROMS IN ANTARCTICA

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Several characteristic waves detected by seismographs in Antarctica are originated from physical interaction between solid-earth and atmosphere - ocean - cryosphere, involving environmental changes. An infrasound sensor was planted at Syowa Station (SYO; 39E, 69S), Antarctica at the International Polar Year. Continuous data in 2008-2009 include background signals (microbaroms) with peak with few seconds of its intrinsic period. Signals with same period are recorded in broadband seismograph at SYO (microseisms). Continuous signals are identified as Double-Frequency Microseism-baroms (DFM) with peaks between 4 and 10 s in whole season. The peak amplitudes of DFM reflect the influence of winter cyclonic storms in Southern Ocean. The DFM has relatively lower amplitudes during winters, caused by sea-ice extent around the coast with decreasing oceanic loading effects. In contrast, Single-Frequency Microseism-baroms (SFM, between 12 and 30 s) are observable under storm conditions particularly in winter. On infrasound data, stationary signals are identified with harmonic over tones at a few Hz to lower most human audible band, which appear to be local effects, such as sea-ice cracking vibration. Microseism-baroms are useful proxy for characterizing ocean wave climate, and continuous monitoring by seismograph and infrasound contribute to FDSN and CTBT in southern high latitude.

Keywords: Antarctica, Microseismic Noise, Infrasound Microbaroms, ocean wave climate, earth system, physical interaction

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SCG69-P02 Room:Convention Hall Time:May 24 17:15-18:30

Radio wave emission from 1 MHz to 18 GHz due to rock fracture and the estimation of the emitted energy

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1. Introduction

Formerly, the microwave emission due to rock fracture was reported from 300 MHz to 22 GHz [1]. We started experiments adding the 1 MHz receiving system in order to gather more data and to study the relation with lower frequencies [2].

This paper describes the measurement results of the radio wave emission from 1 MHz to 18 GHz. The estimation of the emitted energy that may be difficult to understand will be carefully explained. Then, the estimated result is presented.

Lastly, it is shown that this research work may be effective as disaster measures through the detection of earthquakes and volcanic activities.

2. Measuring system

At 1 MHz, a loop antenna and a receiver of direct reception are adopted. The relation between the input power and the indication on an oscilloscope for the antenna and receiver was calibrated using the radio wave of a broadcasting station at 954 kHz (wavelength of 314 m). The distance R is 37.2 km. Therefore, the power density of the radiated radio wave from the station is obtained by geometrical calculation.

On the other hand, in a laboratory experiment, the distance between a rock sample and an antenna is only 1 m, which is much shorter than a wavelength. As a result, the emission from a destroyed rock is expressed as a near field rather than a far filed. We convert the near field value to the far field value, then verify the energy relation.

3. Received waveforms

Figure 1 show an example of the received waveforms. In the coarse time axis in the figure (a), the waveform looks like pulses. Most pulses occurred at the same time as the pulses in the other frequency bands. The expanded waveform at 1 MHz in the figure (b) includes sinusoidal change at the frequency of 1 MHz, and its envelope attenuates exponentially.

4. Estimation of the emitted energy

The procedure is as follows:

(1) With an input power to a receiver, calibrate the voltage value on an oscilloscope.
(2) In the rock destruction experiment, read the voltage of a signal on the oscilloscope.
(3) Assuming the received signal to be a continuous wave, obtain the equivalent received power.
(4) Using the values of free space loss and the receiving antenna gain, calculate the equivalent power of the emitted radio wave.
(5) Using the signal duration or a pulse width, convert the equivalent power of the emitted radio wave to the emitted energy.

In the lecture, the concrete procedure and results of the estimation will be given.

5. Applicability of the experimental results to earthquake detection

The earthquake prediction has been officially stated impossible. On the other hand, many technologies and knowledge appear in the surroundings of seismology. The radio wave emission phenomenon due to rock fracture is one of them.

By receiving the emitted radio wave due to rock fracture and friction, we can detect an earthquake or volcanic activities. If the rock is destroyed before the ground quake, the radio wave indicates real prediction. Even if the rock destruction and the ground quake occur simultaneously, we can give an effective alarm against disaster because of a large delay time difference between the radio wave and seismic wave.

The relation between rock fracture and the ground quake is hardly clarified, and is rendered to seismologists and geologists for a future research. Seismology and seismo-electromagnetics should cooperate in this field.

6. References

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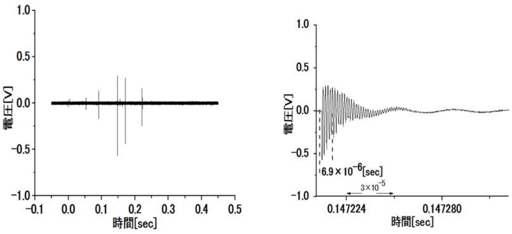
Keywords: radio wave emission, rock fracture, emitted energy, estimation, pulse waveform, earthquake detection

SCG69-P02 Room:Convention Hall Time:May 24 17:15-18:30



(a) Packed waveform (b) Expanded waveform

Fig. 1 Waveforms from quartzite at 1 MHz-band.

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SCG69-P03 Room:Convention Hall Time:May 24 17:15-18:30

ULF geomagnetic changes possibility associated with large earthquake.

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There are many reports on earthquake-related electromagnetic phenomena. Anomalous ULF geomagnetic field changes associated with earthquake is one of the most convincing and promising phenomena due to deeper skin depth. Since ULF signals associated with large earthquakes are weak, effective signal discrimination methods should be required. Several methods for the signal discrimination have been developed so far. In this study, we investigate ULF geomagnetic changes possibly associated with large earthquake during the 2001 and the 2008 in Boso Peninsula based on spectrum density ratio analysis, fractal analysis (Detrended Fluctuation analysis : DFA) and direction finding analysis. Geomagnetic data observed at Kiyosumi, Uchiura and Kakioka have been analyzed. Kiyosumi and Uchiura stations are set up within 5 km, so similar tendency results is expected to record at Kiyosumi, and Uchiura stations.

At 16:34(LT) on the Jul. 23, 2005, a large earthquake occurred in Boso Peninsula. The epicentral distance from Kiyosumi station is about 47 km. On the day, the variations of spectrum density ratio at Kiyosumi and Uchiura stations exhibit apparent changes from the average ones. On the same day, scaling index of vertical component decrease at the Kiyosumi and Uchiura stations based on DFA. On the contrary, there are no corresponding significant changes at a remote station of Kakioka. We only use the midnight time data (LT 01:30~03:30), so that signatures appear before the earthquake. And results of direction finding on that day indicate an increase of direction of arrive from the epicenter. These facts suggest the anomalous changes at the Kiyosumi, Uchiura station are a possible candidate ofearthquake-related ULF geomagnetic signals.

SCG69-P04 Room:Convention Hall Time:May 24 17:15-18:30

interferometric detection of invisible VHF radio propagation possibly associated with earthquake

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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. Temporal correlation between earthquake and anomalous propagation has gradually understood. However, spatial correlation hasn't been understood yet. Then, in this study, we develop a VHF band interferometer system and we have installed the system at Chiba and Numata to identify disturbed area related to earthquake. Accuracy of the develop system has an error of about a few degrees from direction of arrival, if received signal has enough intensity and there signal source locates within 40 degrees from the path.

In practical observation, FM Sendai [77.1MHz] has been selected as the target transmitter. The system is locked in direction of FM Sendai with the elevation of 15 degrees. Additionally, we tune the frequency which is not used for broadcast because of comparison with the natural emission.

We investigate propagation condition associated with (1) upper air profile and (2) earthquake. When a radioduct, which is an inversion layer of the refractive index of the atmosphere which arises by rapid changes of an atmospheric temperature or humidity, is generated, VHF wave is propagated to a distant place by ducted propagation. We found that intensity of a received signal increase and directional arrive of the VHF waves is tuned to be from Pacific coastline where the radioduct appear easily in summer.

As for the analysis on earthquakes, we found that the probability of direction of wave arrived from future focus seems to increase about the shallow earthquake (a maximum of M:5.7) which occurred near the Inawashiro Lake in September 29 and 30,2010.

The above results suggest that effectiveness of the usage two or more VHF interferometers to estimate the earthquake-related scattered source of the VHF wave.

SCG69-P05　　Room:Convention Hall　　Time:May 24 17:15-18:30

Bostick 1-D Inversion of Magnetotelluric Sounding at Cimandiri Fault, Pelabuhan Ratu, West Java, Indonesia

FEBRIANI, Febty[1*], HATTORI, Katsumi[1], HAN, Peng[1]

[1]Chiba University

To verify the mechanism of earth currents as sources of Ultra Low Frequency (ULF) electromagnetic emissions associated with large earthquakes occurred close to Cimandiri fault, Pelabuhan Ratu, West Java, Indonesia, the subsurface structure near Cimandiri fault has been investigated by forty eight magnetotelluric (MT) sites. The MT exploration was carried out during two weeks, from July 27, 2009 to August 8, 2009. The data were distributed along 13.2 km x 9.4 km profile. One-dimensional modelling using 1-D Bostick inversion has been applied in this research. The data analysis is going on now and details will be given in our presentation.

Keywords: ULF electromagnetic anomalous change, 1-D Bostick inversion, magnetotelluric

Japan Geoscience Union Meeting 2012
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SCG69-P06 Room:Convention Hall Time:May 24 17:15-18:30

Coseismic ionospheric disturbances and preseismic TEC anomalies of 2005 Nias and 2007 Bengkulu earthquakes from GPS-TEC

Mokhamad Nur Cahyadi[1*], HEKI, Kosuke[1]

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Ionospheric Total Electron Content (TEC) is easily derived from the phase differences of the two L band carrier waves of the Global Positioning System (GPS) satellites. Past GPS-TEC studies revealed various kinds of ionospheric disturbances originating from phenomena in the solid earth, e.g. volcanic eruption [Heki,2006], launches of ballistic missiles [Ozeki and Heki, 2010], mineblasts [Calais et al., 1998]. The 2005 Niasearthquake (Mw 8.7)[Briggs et al., 2006]and the 2007 Bengkulu earthquake (Mw 8.6)[Gusman et al., 2010] occurred as mega-thrust earthquakes in the Sunda arc, Sumatra, as aftershocks of the 2004 great Sumatra-Andaman earthquake(Mw 9.2) [Banerjee et al., 2005].

In this study, we investigate the coseismic ionospheric disturbances (CID) and pre-seismic TEC anomalies of these two earthquakes, the largest earthquakes whose ionospheric disturbances have never been studied in spite of available GPS data.Continuous GPS data in Sumatra and nearby islands are taken by the SUGAR (Sumatra GPS Array) network,which is designed by members of the Tectonics Observatory at Caltech and the Indonesian Institute of Sciences (LIPI).The sampling rate of the network is 2 minutes, sparser than 30 second sampling usually employed in other GPS networks.

CIDs have relatively short time scales, and we model temporal changes in TEC with polynomials of time and subtract them to isolate short-term changes in TEC. To investigate spatial characteristics of CID,e.g. propagation speed of such disturbances, we calculated sub-ionospheric points (SPP), ground projections of theionospheric piercing point of line-of-sights assuming a thin layer of ionosphere at altitudes ˜300 km. CIDs are detected clearly in signals of three satellites 25, 27 and 28 in the Bengkulu earthquake. Satellite 25 and 27 was located in the western sky during this time interval and moving from north to south. Because of relatively high elevation, their SIPs are close to the GPS sites. Disturbance signals moved north-westward from the epicentre gradually changing their shapes. The signals showed that the disturbance started with a positive pulse (i.e. TEC increase), being consistent with the earthquake mechanism [Astafyeva and Heki, 2009]. Apparent velocity of CID was calculated from their arrival times at different point. They were estimated as 0.74, 0.77, and 0.82 km/s with satellites 25, 27 and 28, respectively, and the propagation started from the centre of uplift about 15 minutes after earthquake.These velocities are consistent with one another within their uncertainties, and suggest that they were acoustic waves excited near the epicentre and propagating in the ionospheric F layer (i.e. not by the Rayleigh surface wave).

CID of the largest aftershock (Mw7.9) of the 2007 Bengkulu earthquake was also studied. By analysing the phase dataofthe satellite 21, we found thatacoustic-wave-origin CID with amplitude of 0.04-0.35 TECU propagatedas fast as about 0.60 km/s.

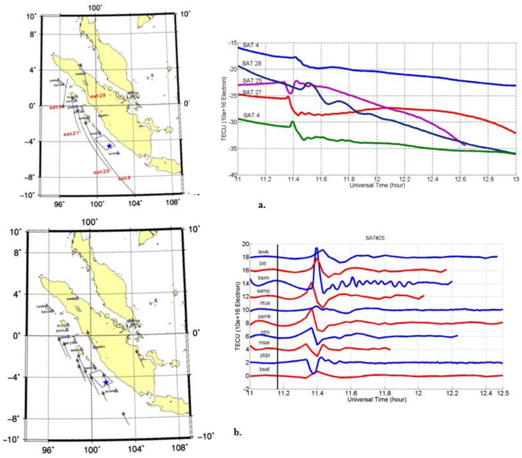
Next we investigated if there are preseismic TEC anomalies similar to the 2011 Tohoku-oki earthquake [Heki, 2011] before the 2007 Bengkulu earthquake. The disturbances are sought by three satellites (25,27 and 28) following the procedure of Ozeki and Heki [2010] (modelling vertical TEC by cubic polynomials of time).We found that clear pre-seismic TEC enhancement occurred about 60 minutes before the earthquake just like other M9 class earthquakes reported by Heki [2011].

The Nias earthquake occurred to the west of the Sumatra Island at 16:09:36 UTC, 28 March, 2005. We found that the TEC time series over a few hours period before and after the earthquake have been disrupted by severe plasma density luctuation known as plasma bubbles. This event is commonly seen in low latitude regions after sunsets [Li et al, 2009; Chu, 2005].

Figure a. (Left) SIP trajectories of the satellites and its error time series after the Bengkulu earthquake (right). B. (left) TEC disturbances by satellite 25 and its SIP trajectories (right)

Keywords: GPS, TEC, Ionosphere, Coseismic, Preseismic

SCG69-P06 Room:Convention Hall Time:May 24 17:15-18:30



Japan Geoscience Union Meeting 2012
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SCG69-P07 Room:Convention Hall Time:May 24 17:15-18:30

Key parameters for definite detections of earth-origin electromagnetic pulses

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In order to find electromagnetic (EM) pulses which might be generated by strong stress impacts to the earth crust when the earthquakes occurred, we have been conducting following observation methods for the sake of surefire detections of EM pluses in the earth. They are as follows:

1. Frequency spectra in a range up to 6.4 kHz are continuously obtained every 2.6 minute from signals of EM fields detected by sensors installed in a borehole and are displayed for monitoring electromagnetic environment in the earth [1].

2. We developed an analysis method of obtaining real-time frequency-time (f-t) diagram of EM pulses detected in the earth for obtaining information on the pulse behavior in detail, because dynamical energy collapse generally starts with impulsive movement and would be followed by radiations of heat, sound and electromagnetic waves including light. Using the information, we have developed a basic analysis method for obtaining horizontally arrival directions of detected EM pulses [2].

3. We have clarified propagating properties of EM pulses simultaneously detected on the ground and at the bottom of bore-hole, and have classified their propagation modes and their possible sources from analysis of their amplitudes and phases, their three dimensional polarization loci at the different detecting points, and local time dependences of their detections [3].

4. We have found observation sites in electromagnetically quiet environment for identifying source locations of EM pulses in the earth. Furthermore, we have developed a new EM sensor system which make it possible to detect tri-axial electric and magnetic field components sensitively in boreholes. We have also developed an analysis method for calculating strict Poynting vector of the EM pulse using the data of tri-axial (six) field components and for obtaining accurate arrival directions of an EM pulse at one point in the earth [4].

Since we have never confirmed earth-origin EM pulses yet, we have to employ key measure to detect them whose intensity would be extremely weaker than the environmental noise level. Now we are improving the system for the sake of detecting the weak earth-origin EM pulses in the earth.

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Keywords: earth-origin electromagnetic pulses, detection in boreholes, accurate measurements of 3-D arrival direction, identification of source locations in the earth, relation with earthquakes

Japan Geoscience Union Meeting 2012
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SCG69-P08 Room:Convention Hall Time:May 24 17:15-18:30

VHF radio wave transmission anomaly associated with 2011 off Urakawa EQ (Mw6.2) observed at multiple sites

MOGI, Toru[1*], MORIYA, Takeo[1], KAKINAMI, Yoshihiro[1], TSUKADA, Mariko[1]

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We have observed VHF band radio-wave propagation anomaly beyond the line of sight prior to earthquakes (EQ echo) since September 2003 at Erimo area in Hokkaido, northern Japan. EQ echoes have documented more than 40 times at the Erimo Observatory (ERM) prior to earthquakes that occurred in the Hidaka mountains since then. To confirm a region where the EQ-echo simultaneously observed for each earthquake, we have installed four observation sites with approximately 8 km spacing in the Erimo area since September 2011. Four way antennas were installed at every 90 degrees to detect an arrival direction of EQ echoes at RSK (8km away from ERM in NW) and TYO (8km away from ERM in SE) site and six way antennas (every 60 degrees) were installed at FYS (16km away from ERM in NW). We also installed the electric field mill to monitor a static electric field of atmosphere at FYS and TYO.

The EQ-echoes have been observed simultaneously in these sites associated with off Urakawa EQ (Mw 6.2) that occurred at 19:25, 24 Nov. 2011. Larger EQ echoes were documented on 21 and 22 November, which were 2 or 3 days before the earthquake, at FYS, ERM and TYO in every direction. Although some of EQ echoes were observed in same time at these sites, but some of them were appeared with time rag of duration in each EQ echo among these sites. We discussed what these time rags mean by considering possibilities of generation and moving of scattering objects.

Keywords: Radio wave transmission, earthquake forcasting, seismo-electromagnetics

SCG69-P09 Room:Convention Hall Time:May 24 17:15-18:30

Preseismic TEC changes for Tohoku-Oki earthquake in comparisons between simulations and observations

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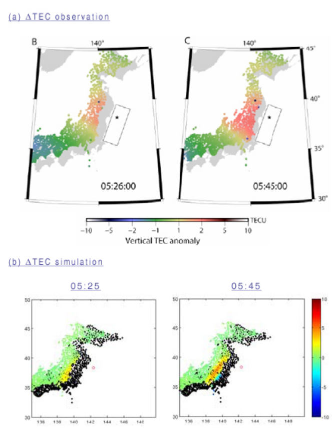
Earthquake precursors can be used for earthquake prediction to reduce the loss of resources and human lives. Pre-earthquake ionospheric signatures have been reported by many scientists. Among those, Zhao et al., [2008] and Liu et al., [2009] reported that the total electron content (TEC) may anomalously decrease or increase up to 5 - 20% several days before 2008 Wenchuan earthquake (Mw7.9). Recently, Heki [2011] found that, ˜40 minutes before the Tohoku-Oki earthquake (Mw9.0), the Japanese GPS dense network detected clear precursory positive anomaly of TEC. Similar preseismic TEC anomalies were also observed in the 2010 Chile earthquake (Mw 8.8), 2004 Sumatra-Andaman (Mw 9.2) and the 1994 hokkaido-Toho-Oki (Mw 8.3) [Heki, 2011]. The finding of TEC variations near epicenter lacks the physical mechanism to explain those pre-earthquake ionospheric signatures.

In this presentation, we propose a mechanism to couple the pre-earthquake activity with the TEC anomalies. Before the break of rocks in the main shock of earthquake, rocks are continuously subjected to stress. The stressed rocks can activate positive holes as charge carriers and generate electric currents along the stress-gradient direction with current density [Freund, 2010]. The outflow of positive charge carriers from the stressed rock sets up a potential difference, which causes the unstressed rock to become positively charged relative to the stressed rock. The mobile positive charge carriers inside the unstressed rock repel each other electrostatically and will be pushed toward the surface. The positive charges carriers are accumulated over Earth surface, and associated electric field can drive current upwardly through atmosphere into ionosphere. We formulate an electrical coupling model for the stressed rock-Earth surface charges-atmosphere-ionosphere system [Kuo et al., 2011]. A three-dimensional atmospheric current system and a NRL ionosphere simulation code [Huba, 2008] are used to study the ionospheric dynamics based on the atmospheric electric fields and currents.

For the simulations of Tohoku-Oki earthquake, we assume that the stressed associated current started ˜ 40 minutes before the earthquake, linearly increased, and reached its maximum magnitude at the time of rocks breaks in the main shock of earthquake. Provided by geolocations of GPS stations in Japanese dense network and corresponding flight tracks of GPS satellites, TEC variations calculation uses the ray tracing method for our ionospheric simulations. The simulation results are compared to the observed TEC anomalies for available nearby GPS satellites. We will demonstrate simulations with different sizes of fault region and stressed current density over Earth surface. One of simulations is shown in figure. The panel (a) show the dTEC observation [Heki, 2011], while panel (b) for our simulations. The similarity and differences between TEC observations and simulations will be discussed in this presentation.

Keywords: Tohoku-Oki earthquake, Pre-earthquake ionospheric signatures, anomaly of TEC



SCG69-P10 Room:Convention Hall Time:May 24 17:15-18:30

Geoelectric potential difference measurements at the Nii-jima and Kozu-shima Islands

NAGAO, Toshiyasu[1*], TAKEUCHI, Akihiro[1], ORIHARA, Yoshiaki[1], KAMOGAWA, Masashi[2], UYEDA, Seiya[3]

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We re-started geoelectric potential difference measurements at the Kozu-shima and the Nii-jima Islands since February 2010 under the research program of ”Observation and Research Program for Prediction of Earthquakes and Volcanic Eruptions”. During our previous observations of the geoelectric potential difference at the Kozu-shima Island in Japan under the RIKEN research program (International Earthquake Frontier Research program). 19 anomalous changes (ACs) were detected. Their possible relations with nearby earthquakes were statistically significant.

In the presentation, we would like to introduce our current observation systems and characteristic records before and after the M9 Tohoku EQ. At this moment, any earthquake with $M>3.0$ did not occur near the islands except induced seismic activities which occurred just after the M9 Tohoku EQ. We have never detected any clear AC as of January 2012.

Keywords: Geoelectric Potential, Kozu Island

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SCG69-P11 Room:Convention Hall Time:May 24 17:15-18:30

Precursor observed by MF Band 2 Freq Simultaneous Measurement prior to The 2011 off the Pacific coast of Tohoku EQ

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1. Abstract

This paper is to report detail about anomalous phenomena on the MF Band Electric Magnetic(EM herein after) wave dual frequency simultaneous measuring method observed at Kyoto EM observation post about 700km from the epicenter prior to the 2011 off the Pacific coast of Tohoku Earthquake(EQ herein after).

The EM anomaly has been detected since about 2 month and half before the EQ and continued till about 1 month after the EQ.

We tryed this measuring method from a paper of Teruaki YOSHIDA, June Heisei 17.

2. Observation System

This system contains a BOOSTER with Antenna, an EM WAVE SENSOR and a DATA PROCESSOR and observes EM as EQ precursor at MF band 2 frequency 505 kHz and 525 kHz simultaneously. Those 2 frequencies are out of band from MF broadcasting band and vacant frequency are chosen. Received and detected MF EM is transferred to observation center automatically through Internet.

Received MF EM is amplified at the BOOSTER located out door and cabled in door EM WAVE SENSOR in which EM is changed into DC logarithm potential in order to be displayed in dBm scale. This potential is sampled once in 20mSec (50 times/Sec.) picked up maximum and average value in 20 second at the DATA PROCESSOR then output in CSV format to PC. Sensitivity of the system is -110dBm in band width +-1kHz/3dB.

The reason why maximum value is observed is to be intended to measure impulsive noise, however, thunder noise may not be cached as it seems to be shorter than 20 mSec.

If only one of two frequencies receives some signal, this will not be regarded as seismic, and if signal strength goes up at both channel simultaneously, this will be judged as seismic, as seismic EM has wide frequency.

3. What's observed

This observation is performed at calm residential area with little EM interference in Kyoto since January 2010. Attached figure shows 2 input signal strength variation from 2010/9/1 to 2011/5/31 and daily average graph of maximum and average value sampled in 20m sec.

Calm status has been continued since January 2010 of observation start up to middle of December 2010, after that, receiving signal strength at both channel raise up gradually and reached at peak in the middle of February 2011. Then anomalous condition continued till early April and returned to calm condition after middle of April.

On 2011/03/11 14:46:18 prior to the 2011 off the Pacific coast of Tohoku Earthquake M9.0 D=24km occurred. As the signal strength has raised up by more than 10dB comparing with calm period at Kyoto observation post, and anomaly timing was just before the Earthquake almost co-seismic in some meaning, this EM in MF band could be regarded as precursor of the huge EQ.

4. Conclusions

In usual observation, row data is only displayed in daily, weekly, and monthly graph, we could know that another world is shown by making long span graph in different way. It may be possible if we develop another analysis data processing way in real time.

If MF band EM is observed at many places, exact place of epicenter may be pointed out and be lead magnitude by calculating distance between epicenter and each observation post and signal strength. Proceeding period of EQ occurring of bigger magnitude of 7 may be 1 to 2 months from our experience of this time, and smaller scale EQ may occur within 1 week from our past experience.

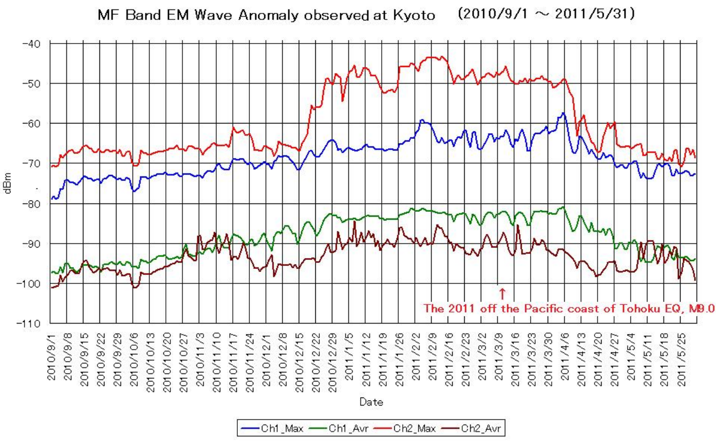
Our aim by using this method is not academic EQ prediction, our aim and purpose is practical EQ prediction as disaster prevention information. Important thing as practical disaster prevention information is to predict huge (M>6, brings human damage), middle (M5 Class, brings people big surprise) or small scale (M4 Class, brings small surprise) EQ occurrence.

Reference;

"Observation of VHF Band EQ EM measured by dual frequancy measurement method" in paper-C of Institute of Electrical Engineers of Japan issued on June Heisei 17 year by Teruaki YOSHIDA, Hiroshima City University.

Keywords: earthquake, precursor, MF Band, EM, electro magnetic wave, EM wave

SCG69-P11 Room:Convention Hall Time:May 24 17:15-18:30



SCG69-P12 Room:Convention Hall Time:May 24 17:15-18:30

3-D structure analysis of ionospheric anomalies associated with the 2011 Off the Pacific Coast of Tohoku Earthquake

HIROOKA, Shinji[1*], Katsumi Hattori[1], Takashi Ichikawa[1], Susumu Saito[2], Tatsuoki Takeda[3]

[1]Graduate School of Sci. Chiba Univ., [2]Electronic Navigation Research Institute, [3]Univ. of Electro-Communications

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, monitoring of three-dimensional distributions of ionospheric electron density is considered to be effective.

In this study, to investigate the three-dimensional structure of ionospheric electron density associated with the 2011 Off the Pacific Coast of Tohoku Earthquake (Mw9.0), the Neural Network based tomographic approach is adopted to GEONET and ionosonde data.

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). To detect the anomalous TEC change, the normalized GIM-TEC, which is computed based on 15 days backward running mean of GIM-TEC, have been investigated. Then, in order to investigate the structure of electron density in ionosphere, tomographic method is performed.

As for the 2011 Off the Pacific Coast of Tohoku earthquake, the significant enhancements are found in GIM-TEC investigation, 3 days prior to the earthquake. As a result, the reconstructed distribution of electron density was enhanced around F-layer and lower ionosphere. In our presentation, not only the electron density distribution of before the earthquake but also those on the other periods will be shown.

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Hypocenter Depth Evaluations of Earthquakes Using Geomagnetic Data in Taiwan

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When earthquakes with similar magnitudes occur at different depths, severe seismic hazards are generally in response to shallow ones. Although many studies report that timing, location and magnitude of forthcoming earthquakes could be forecasted, estimation of hypocenter depth should also be taken into account to achieve complete perception against seismic hazards. In this study, the Parkinson vectors, which tend to orient along materials with relatively-high conductivity, are computed by using 3-component geomagnetic data recorded in central Taiwan via the magnetic transfer function. The "skin effect" is further incorporated into the analytical process to understand associated depths of the Parkinson vectors when they are computed by data filtering at distinct frequency bands. Orientations and magnitudes of the Parkinson vectors are compared with epicenter azimuths and hypocenter depths of 16 earthquakes ($M >= 5.5$) between 2002 and 2005, respectively. When effects of sea water and tectonic structure are removed, the results show that the azimuth distribution of the Parkinson vectors is mainly concentrated at directions of epicenter azimuths 15 days before earthquakes. Projection depths, which are determined by using the depth with the largest difference between the magnitude distribution of the Parkinson vectors 10 days before earthquakes and within an entire study period, generally yield a difference $<$ 30 km with hypocenter depths. This would be used to roughly evaluate hypocenter depths of forthcoming earthquakes.

Keywords: Hypocenter depth, Magnetic transform function, Skin effect, Parkinson vectors

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The electromagnetism change just before the earthquake and the cause

KUNIHIRO, Hidemitsu[1*]

[1]JYAN meeting fore the study

The electromagnetism change just before the earthquake and the cause (the recommendation of the earthquake forecast experiment)

1, A change of electromagnetism environment affecting an earthquake

(1) The outbreak of the noise to disturb the sound of the radio

By Great Hanshin Earthquake that was an inland earthquake, a lot of obstacles of a radio and TV were reported, and there were many obstacle of wireless communication and the cell-phone and reports such as the eyewink light. A noise disorder of the radio is reported by the aftershock of the East Japan great earthquake disaster again (collection of testimony 1519). Therefore I work for abnormally electromagnetic grasp while always recording a broadband electromagnetic wave.

(2) Seismic center electromagnetic gravitation and harbinger phenomenon

The observation study of the FM electric wave is conducted till now in Hokkaido in the vicinity of observation and 60Mhz of the ionosphere reflection using FM broadcast. Therefore our meeting for the study receives 64 FM broadcast by 16 observation station in West Japan area around Kyushu Oita and I cross an observation net with a the BIC graph on the Internet at the same time and observe it. A harbinger (electromagnetic wave strength rises, and rolling begins) appears by the earthquake of seismic intensity three classes by the past observation, and a main shock occurs after an end in 6-3 days. The attention point seems to draw the electromagnetic wave which I should pass out of a prospect by some kind of gravitation from the usually reverse phenomenon "that an electromagnetic wave comes to resist" by a harbinger on the ground of the seismic center. I decided to call this electromagnetic gravitation "seismic center electromagnetic gravitation" as one of the earthquake harbinger phenomena. In addition, because I understand abnormal direction and strength by this observation network, I become able to estimate a position and the size of the seismic center and think that I can make three elements of the foretelling an earthquake clear more because an observation network is filled up.

(3) Underground propagation of ULF

The underground propagation of the electromagnetic wave was impossible by the insulators such as rocks, and the opinion which said that it was not possible for the spread to the ground even if an electromagnetism signal occurred at the epicenter was common till now. However, because the ULF obi in the electromagnetic wave is unique propagation, a certain study group challenges the communication that used a ground, and there is the report that succeeded in communication of approximately 3km. In addition, the result that a signal from the underground was largely stronger in than sky wave appeared when I received an electric wave signal of 50Kw in 60Khz of Saga in the approximately 150km west. I push forward a study whether I cannot catch an electromagnetic signal rising from this phenomenon at the epicenter of the earthquake as a harbinger signal of the earthquakes.

2, The need of the earthquake information generalization

I occasionally affect normal duties, and the earthquake information can cause the panic. Therefore, it is a common view to say that the handling of the earthquake information is careful, and the foresight information is kept in each place after Great Hanshin Earthquake, and there is not the announcement of the thing named the earthquake forecast.

Keywords: The outbreak of the noise to disturb the sound of the radio, Seismic center electromagnetic gravitation and harbinger phe, Underground propagation of ULF, The need of the earthquake information generalization

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Ionospheric Variations Associated with the Great East Japan Earthquake Disaster

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[1]Graduate School of Science, Chiba University, [2]Institute of Space Science, National Central University, Taiwan, [3]Solar-Terrestrial Environment Laboratory, Nagoya University

Recently, there are many reports on earthquake-related electromagnetic phenomena. Anomalous TEC (Total Electron Content) changes preceding large earthquakes are one of the most promising phenomena among of them. In this study, we investigate TEC anomalous variations in time and space for the 2011 off the Pacific coast of Tohoku Earthquake and after the accident at Fukushima Daiichi Nuclear Power Station.

In this study, TECs are computed with using the GEONET and 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 Pacific coast of Tohoku Earthquake, GPS-TEC$*$ anomalies exceeding +2 sigma appear 4 and 5 days before the earthquake. Their total durations are 13 and 14 hours, respectively. GIM-TEC$*$ anomalies exceeding +2 sigma appear 4 days before the earthquake. The duration is more than 20 hours. In space, the region of GIM-TEC$*$ anomalies 4 days before the earthquake appears over northern Japan and remains more than 24 hours.

These results are consistent with the previous statistical analysis around Japan. The detailes will be given in the presentation.