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

YAMAMOTO, Masa-yuki[1*], KOMATSU, Takayasu[1], MORINAGA, Takatoshi[1], KIHARA, Daiki[1], ISHIHARA, Yoshiaki[2], HIRAMATSU, Yoshihiro[3], KANAO, Masaki[4]

[1]Kochi University of Technology, [2]National Astronomical Observatory of Japan, [3]Kanazawa University, [4]National Institute of Polar Research

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

SCG69-02 Room:102B Time:May 24 09:15-09:30

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

ENOMOTO, Yuji[1*]

[1]Toyama Industrial Technology Center

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,

$\log I = 0.5M + \log\{\mathrm{xi}\}D_c$,

where M is magnitude, $\{\mathrm{xi}\}$ 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 $f=1/\{\mathrm{Delta}\}t$: the interaction period of electrified gas flow $\{\mathrm{Delta}\}t = \{kappa\}l_c/v$, 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

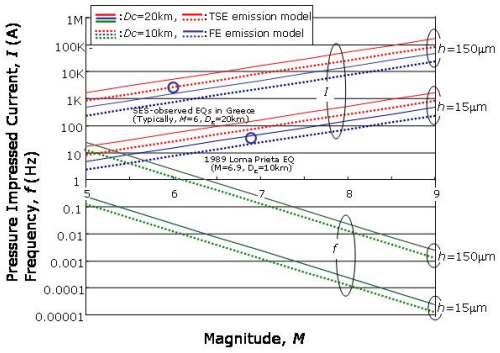


Fig.1 *I* and *f* as a function of *M*

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

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

TAKEUCHI, Akihiro[1*], NAGAO, Toshiyasu[1]

[1]Earthquake Prediction Research Center, Tokai University

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

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

HAN, Peng[1*], Katsumi Hattori[1], Febty Febriani[1], Yuki Ishiguro[1], Chie Yoshino[1]

[1]Graduate School of Science, Chiba University

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

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

HASE, Hideaki[1*], UYESHIMA, Makoto[1], KOYAMA, Takao[1], YAMAYA, Yusuke[1], OGAWA, Tsutomu[1], ICHIKI, Masahiro[2]

[1]Earthquake Research Institute, Tokyo University, [2]Graduate School of Science, Tohoku University

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

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

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

LIU, Jann-Yenq[1*], I-Te Lee[1], Koichi C.H. Chen[2], Rdrew Y. Z. Su[1], Katsumi Hattori[3], Yuh-Ing Chen[4], Ho-Fang Tsai[5]

[1]Institute of Space Science, National Central University, Chung-Li, Taiwan, [2]Department of Geophysics, Kyoto University, Kyoto, Japan, [3]Graduate School of Science, Chiba University, Japan, [4]Institute of Statistics, National Central University, Chung-Li, Taiwan, [5]GPS Science Application Research Center, National Central University, Chung-Li, Taiwan

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

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

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

FUJINAWA, Yukio[1*], NODA, Yoichi[2], Kozo Takahashi[3], Masaji Kobayashi[4], Kennichi Takamatsu[5]

[1]Fujinawa Earthquake Res. Inc., [2]Tierra Tecnica Corp., [3]Communication Res. Lab., [4]Real-time Earthquake Information Cons., [5]OKI Engineering Co. Ltd.

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 wave-form 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.

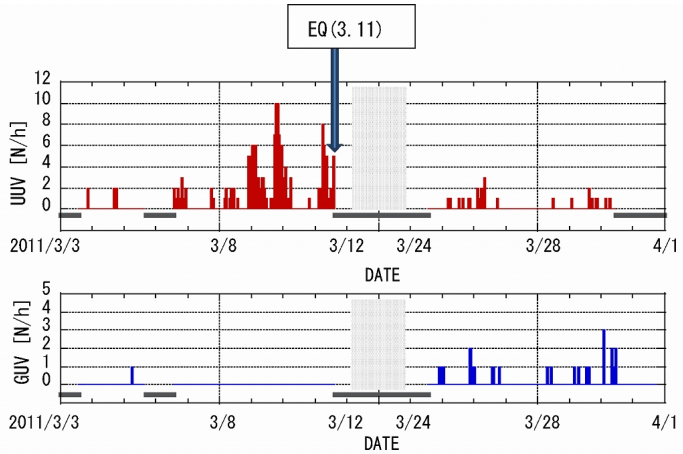
We devised a new detection system having higher dynamic ranges in the frequency and signal strength. And the field observation started on 3, March 2011 at Hasaki (now Kamisu) .We found that there are two kind of anomalous signals associated with the Earthquake; one is the very GUV and the other is the 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



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

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

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

OKUBO, Kan[1*], TAKEUCHI, Akihiro[2], TSUGAWA, Takuya[4], Taichi Murai[1], NAGAO, Toshiyasu[2], SASAI, Yoichi[2], Nobunao Takeuchi[3]

[1]Tokyo Met. Univ., [2]Tokai Univ. Earthquake prediction Res. Center, [3]Research Center for Predictions of Earthquakes and Volcanic Eruptions, Graduated School of Sciences,, [4]National Institute of Information and Communications Technology

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.

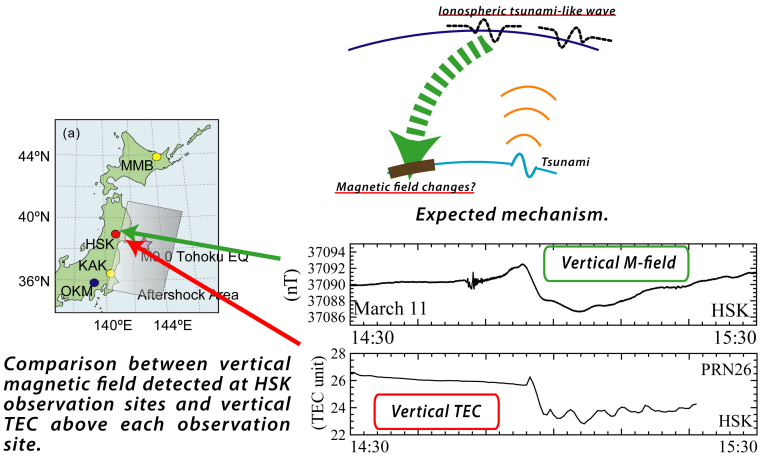
Our observation systems were established at Hosokura, Miyagi prefecture in NE Japan and at Okutama, in Tokyo. Their systems consist of a fluxgate magnetometer, GPS clock and recorder with 0.03 or 0.01 nT resolution. A vertical component accelerometer is also installed at Hosokura observatory. Since March 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.

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

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

KAKINAMI, Yoshihiro[1*], KAMOGAWA, Masashi[2], WATANABE, Shigeto[3], MOGI, Toru[1], LIU, Jann-Yenq[4]

[1]Institute of Seismology and Volcanology, Hokkaido University, [2]Department of Physics, Tokyo Gakugei University, [3]Department of Cosmoscience, Hokkaido University, [4]Institute of Space Science, National Central University

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