Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

MIS30-01 Room:301B Time:May 21 14:15-14:30

Examination of statistical significance of earthquake-related precursory phenomena -Izu Islands Kozu case, as an example

Toshiyasu Nagao[1*], Yoshiaki Orihara[1], Masashi Kamogawa[2]

[1]Earthquake Prediction Research Center, Tokai University, [2]Tokyo Gakugei University

We published the paper entitled ”Preseismic anomalous telluric current signals observed in Kozu-shima Island, Japan, Proceedings of National Academy of Sciences of the United States of America (PNAS), Vol. 109, no. 47, 19125-19128, doi: 10.1073/pnas.1215669109, 2012, by Yoshiaki Orihara, Masashi Kamogawa, Toshiyasu Nagao and Seiya Uyeda”. The authors believe that this paper is the first example of the proof of the existence of precursory electric signals by using the well-considered statistical approach in the ground observation. For the next step, to persuade suspicious general scientists, we have to present the effectiveness of this kind of precursory phenomena. Because some seismologists claim that the ETAS model performs very good prediction in comparison with random prediction with probability gain of 100. The most important issue is to introduce the concept of ”probability gain”. Actually, this argument is somehow nonessential. However we have to overcome this kind of argument. In the presentation, we would like to propose the minimum step of necessary statistical evaluation items.

Keywords: precursor, statistics

Japan Geoscience Union Meeting 2013
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MIS30-02 Room:301B Time:May 21 14:30-14:45

An estimation of electromagnetic field variations due to the thermoelectric effect accompanying a point heat source gene

Tsutomu Ogawa[1*], Akihiro Takeuchi[2]

[1]ERI, Univ. Tokyo, [2]Earthquake Prediction Research Center, Institute of Oceanic Research and Development, Tokai Univ.

Thermoelectric effect which couples both the temperature gradient and the electric field to both the heat flow and the electric current density can cause, in principle, coseismic electromagnetic field variations due to fault motions with frictions. The present study attempts to estimate the field variations.

Assuming a point heat source with spherical symmetry which is regarded to be generated by a point dislocation with friction in a homogeneous whole space, the equation of the temperature is separated. The magnetic field variation is not excited.

Expanding the self-consistent system of the equations with spherical symmetry, the temperature satisfies a non-linear diffusion equation, for the coupling between the heat flow and the electric field depends on the temperature.

By a kinematic approach which considers the contribution of the temperature gradient to the electric current density and neglects the contribution of the electric field to the heat flow, the resultant electric field and the temperature variations with respect to time both show increase, maximum and decay. However, order estimations with realistic quantities of physical properties suggest that the arrival time of the maximum amplitude at kilometers away from the heat source amounts to years. The maximum amplitude of the electric field does not exceed the observable level in realistic situations.

Japan Geoscience Union Meeting 2013
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MIS30-03 Room:301B Time:May 21 14:45-15:00

Numerical simulation of co-seismic electromagnetic signals in porous media

Qinghua Huang[1*], Dan Zhang[1], Hengxin Ren[2]

[1]Department of Geophysics, Peking University, [2]School of Earth and Space Sciences, University of Science and Technology of China

Field observations indicated the existence of the electromagnetic signals accompanying with natural earthquakes. Such co-seismic electromagnetic signals may provide some useful information of earthquake process. So it is becoming an interesting topic in geophysical community. Unfortunately, the generation mechanisms of co-seismic electromagnetic signals are not well understood at the current stage. In this study, we simulate numerically the co-seismic electromagnetic signals in layered porous media by using the generalized reflection and transmission coefficients method. We focus on the characteristics of electromagnetic signals generated by a double couple point source or a finite fault source in different models. The effects of source time function type and center frequency have been investigated. The numerical results show that the co-seismic electromagnetic signals depend on the model structures and the rupture sources. The simulation results also indicate that seismic waves and electromagnetic signals have good correlations in both the waveform and the dominant frequency.

This study is supported by the China-Korea-Japan (CKJ) Joint Research Collaboration Program by the Ministry of Science and Technology of China (2010DFA21570).

Keywords: Seismo-electromagnetic signals, Finite fault, Source time function

Japan Geoscience Union Meeting 2013
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MIS30-04 Room:301B Time:May 21 15:00-15:15

Locating earthquakes using magnetic data via the magnetic transfer function in Taiwan

Chieh-Hung Chen[1*], Han-Lun Hsu[2], Strong Wen[3], Chung-Ho Wang[1]

[1]Institute of Earth Sciences, Academia Sinica, Taipei 115, Taiwan, [2]Institute of Geophysics, National Central University, Jhongli 320, Taiwan, [3]National Center for Research on Earthquake Engineering, Taipei 106, Taiwan

Magnetic data have been widely utilized to survey direction of high-conductivity materials via the magnetic transfer function. Many studies have reported that conductivity of rocks close to epicenters is increased before earthquakes due to stress accumulation. Here, magnetic data are utilized to investigate location in which conductivity is enhanced during earthquakes in Taiwan. Analytical results show that anomaly increased conductivity appears about 30 days prior to M5 earthquakes in Taiwan. Directions determined through the anomalous increased conductivity via the magnetic transfer function well agree with earthquake azimuths to one magnetic station when effects of tectonic structure and sea water on magnetic data are mitigated. Earthquake epicenters can be further determined by using an intersection of anomalous directions determined by two or more magnetic stations. Meanwhile, depths of forthcoming earthquakes can be roughly estimated when the skin effect is conducted into the magnetic transfer function.

Keywords: Seismo-electromagnetic anomaly, Magnetic transfer function

Japan Geoscience Union Meeting 2013
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MIS30-05 Room:301B Time:May 21 15:15-15:30

Study for earthquake prediction by detections of electromagnetic pulses in the earth

Minoru Tsutsui[1*]

[1]Kyoto Sangyo University

So far we could not find electromagnetic (EM) pulses generated by earthquakes. However, we have found that high frequency (a few kHz) components of EM waves would decay due to high electrical conductivity during their propagations in the earth medium, and that EM waves in the extremely low frequency range (0-25HHz) could be detect.

In the observation at Kyoto Sangyo University, during the period of 13 months from December 20, 2011 to January 25, 2013, we found EM pulses clearly for ten earthquakes among thirteen ones with magnitude of >M2 occurred within a circle region of radius of 40 km centered at the EM observation site. In this case, EM pulse detection is affected by the electrical conductivity of the land.

On the other hand, we found, from the data of EM pulses related earthquakes, that we detected these EM pulses which might be excited by the wave front of the propagating seismic wave in the crust near the EM observation site. Therefore, a waveform of detected EM pulse might include multi-EM waves radiated from various place along the propagation path of the seismic wave.

For earthquake prediction, we need to clarify the mechanism of the waveform formation of the detect EM pulses. For this purpose, we need to observer EM pulses in deeper earth (at about 1 km depth).

Keywords: electromagnetic pulses in the earth, detections in boreholes, relation with earthquakes, earthquake prediction

Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

MIS30-06 Room:301B Time:May 21 15:30-15:45

Comparative study of ULF depression and ELF radiation associated with seismic activity

Yasuhide Hobara[1*], T. Yasue[1], Alexander Schekotov[2], Masashi Hayakawa[1]

[1]Research Station on Seismo-Electromagnetics, UEC Tokyo, Japan, [2]Schmidt Institute of Physics of the earth, Russian Academy of Sciences, Moscow, Russia

Magnetic anomalies in the ULF and ELF ranges in association with major seismic activities are investigated. Previously depression of the magnetic intensity in the ULF range and the radiation in the ELF range were separately studied for different seismic events. In this paper we report first time the comparison of the results between the ULF and ELF anomalies based on the several common seismic events occurred in the vicinity of Japan. The ULF magnetic depressions are observed by two fluxgate magnetometers in Hokkaido and Kyushu while ELF radiations are identified by two induction type magnetometers in Hokkaido and central Japan. Initial result indicates that both ELF and ULF anomalies are observed nearly simultaneously with local seismic events.

Japan Geoscience Union Meeting 2013
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MIS30-07 Room:301B Time:May 21 16:15-16:30

INTEGRATED STUDIES OF EARTHQUAKE PRECURSORS IN INDONESIA

Boko Nurdiyanto[1*], Drajat Ngadmanto[1], Hastuadi Harsa[1], Muhaimin[1], Beny Hendrawanto[1], Sulastri[1], Suliyanti Pakpahan[1], Arafah[1], Thomas Hardy[1], Katsumi Hattori[2], Febty Febriani[1], Pupung Susilanto[1], Noor Efendi[1], Retno Yogi[1]

[1]Indonesia Meteorological Climatological and Geophysical Agency (BMKG), [2]Graduate School of Science, Chiba University

Integrated studies of earthquake precursors have been done by the research and development center of BMKG since 2010. Studies of earthquake precursors carried out in stages and sustainable that is focused on geophysical, geo-atmospheric and geochemical parameter. This studies are to develop test methods that have been developed with field data in Pelabuhan Ratu, West Java. The target for third year is to studies of vp/vs ratio, magnetic, impedance of EM wave, temperature, humidity and radon consentration as well as verify the predictability of earthquake precursors based on information that has been done.

Research focused on identifying the physical parameters of the character as an earthquake anomaly precursor in the Pelabuhan Ratu, West Java, Indonesia along 2012. The analysis of vp/vs ratio using earthquake catalog and phase report sheet from BMKG. Electromagnetic parameter data used is the magnetotelluric data that observed at geophysical observatories of Pelabuhan Ratu which was collaboration with Chiba University (Japan). Observation data of the radon gas concentration, air temperature and humidity in the soil obtained from RAD7 that installed with sensor of soil gas probe is planted in the ground as deep as 1.2 meters. And surface temperature data is the maximum temperature (Tmax) and minimum temperature (Tmin) were recorded using a mercury thermometer.

Based on the analysis of vp/vs ratio, the accumulation of stress in rocks began to be detected around 1-3 months before the earthquake occurred. Results of electromagnetic parameters analysis using polarization of magnetic data and impedance of EM wave obtained precursor anomaly approximately 14-56 days before the earthquake occurred, so these parameters are included in short-term precursors are likely due to the electrokinetic and microcrack before the accumulation of energy released as earthquakes. Parameters of temperature and humidity as well as radon gas precursor patterns detected about 9-30 days before the earthquake happened so that the parameters are included in short-term precursors. Radon gas and temperature anomalies associated with the deformation in the region of observation before the earthquake occurred.

Keywords: EARTHQUAKE PRECURSORS, INTEGRATED STUDIES, INDONESIA

Japan Geoscience Union Meeting 2013
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MIS30-08 Room:301B Time:May 21 16:30-16:45

Investigation of ULF seismo-magnetic phenomena in Kanto, Japan during 2000-2010

Peng Han[1*], Katsumi Hattori[1], Febty Febriani[1], Hiroki Yamaguchi[1], Chie Yoshino[1]

[1]Graduate School of Science, Chiba University

In this study we have conducted an investigation of ULF seismo-magnetic phenomena in Izu and Boso Peninsulas, Japan, based on the data observed from 2000-2010.

First, case studies of major events have been applied. Energy of ULF geomagnetic signals at the frequency around 0.01 Hz has been investigated by wavelet transform analysis. In order to minimize the influences of artificial noises, only the midnight time data (LT 1:00 ~ 4:00) have been utilized. To indentify anomalous changes from ionospheric disturbances, the standard station Memabutsu has been chosen as a reference station. (1) Case studies of the 2000 Izu Islands earthquake swarm have indicated that there are unusual geomagnetic energy enhancements in vertical component before and during the earthquake swarm. (2) Case studies of the 2005 Boso M 6.1 earthquake have also shown clear geomagnetic energy enhancements in vertical component before the earthquake. (3) Case studies of the 2002 and 2007 slow slip events have demonstrated that there are geomagnetic energy enhancements in both vertical and horizontal components during the slip events.

Then, to verify and clarify the relation between ULF geomagnetic anomalies and seismicity, statistical studies by superposed epoch analysis (SEA) have been carried out. The results have indicated that before a sizeable earthquake there are clearly higher probabilities of ULF anomalies than after the earthquake: for Seikoshi (SKS) station in Izu, about 20~30 days before, one week and few days before, and one day after the event statistical results of daily counts are significant; for Kiyosumi (KYS) station in Boso around two weeks before, few days before, and one day after the event.

Finally, to find out the detailed waveform of anomalous magnetic signals, waveform analysis has been performed. The results show that there are mainly two kinds of seismo-magnetic signature. (1) Noise-like signals: Compared with the background, the signals exhibit small increases of amplitudes at a wide frequency range. (2) Transient/quasi-rectangular signals: the signals have transient/quasi-rectangular waveforms with amplitudes of several nT (~ nT). The noise-like signals usually persist for several days or even a few weeks, and are mainly associated with large earthquakes; the transient/quasi-rectangular signals have durations of few seconds to few ten seconds, and are registered mainly during slow slip events.

Based on the results obtained above, we conclude that: (1) there is a correlation between ULF geomagnetic anomalies and local sizeable earthquakes in Izu and Boso Peninsulas, Japan, and the common period of significant results is few days before and one day after a sizeable earthquake; (2) there are mainly two kinds of seismo-magnetic signature registered in Izu and Boso Peninsulas: noise-like signals and transient/quasi-rectangular signals. The mechanisms of the anomalous geomagnetic signals are still unclear and need further studies.

Keywords: ULF seismo-magnetic phenomena, earthquake, wavelet transform analysis, statistical study, geomagnetic field, superposed epoch analysis (SEA)

Japan Geoscience Union Meeting 2013
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MIS30-09 Room:301B Time:May 21 16:45-17:00

Is an ionospheric electron enhancement preceding the earthquakes a precursor?

Yoshihiro Kakinami[1*], Masashi Kamogawa[2]

[1]Kochi University of Technology, [2]Tokyo Gakugei University

Heki [2011] reported that the TEC gradually enhanced from 40 minutes before the 2011 M9.0 off the Pacific coast of Tohoku earthquake (Tohoku EQ) to the time when the co-seismic acoustic wave reached the ionosphere and the TEC immediately recovered at the normal state. This paper shows an alternative interpretation of total electron content (TEC) variation in the ionosphere associated with the Tohoku EQ. Our interpretation is that a tsunamigenic ionospheric hole, a wide depletion of the TEC, occurred after the co-seismic acoustic wave reached the ionosphere and gradually recovered at the normal state with several tens of minutes [Kakinami et al., 2012]. The difference between Heki [2011] and Kakinami et al. [2012] is attributed to the reference curves of the TEC to extract the ionospheric variations. The former is given by the least-squares fitting curve of the EQ day data excluding an expected precursor period, while the latter is given by the data of the similar orbit of global positioning system (GPS) satellite on another day. The results strongly suggest that variation of slant TEC is explained by the depletion of TEC due to tsunami rather than the precursory enhancement.

Keywords: Seismo Electromagnetics, precursor, ionospheric disturbance, total electron content, Tohoku earthauake

Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

MIS30-10 Room:301B Time:May 21 17:00-17:15

Seismo-ionospheric precursors of the total electron content associated with M?6.0 earthquakes in Japan

Jann-Yenq Liu[1*], Koichi Chen[2], Ho-Fang Tsai[3], Katsumi Hattori[4]

[1]Institute of Space Science, National Central University, TAIWAN, [2]Department of Earth Science, National Cheng Kung University, TAIWAN, [3]GPS Science and Application Research Center, National Central University, TAIWAN, [4]Department of Earth Sciences, Graduate School of Science, Chiba University, JAPAN

This paper reports statistical results of seismo-ionospheric precursors (SIPs) of the total electron content (TEC) in the global ionosphere map (GIM) associated with 132 earthquakes with magnitude 6 and/or greater in Japan during 1 May 1998 ? 10 March 2011. To detect SIP, a quartile-based (i.e. median-based) process is performed. The earthquakes without being led by magnetic storms are further isolated and investigated to confirm the SIP existence. Results show that the SIP mainly is the TEC significantly increase in the afternoon period 1-5 days before the earthquakes in Japan. Finally, the SIP of the GPS TEC associated with the 11 March 2011 M9.0 Tohoku earthquake is presented and discussed.

Keywords: seismo-ionospheric precursors, GPS, total electron content, M9.0 Tohoku earthquake

Japan Geoscience Union Meeting 2013
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MIS30-11 Room:301B Time:May 21 17:15-17:30

Three-dimensional structure analysis of ionospheric anomalies associated with large earthquake

Shinji Hirooka[1*], Katsumi Hattori[1], Takashi Ichikawa[1]

[1]Graduate School of Sci., Chiba Univ.

The ionospheric anomalies possibly associated with large earthquakes have been reported by many researchers. However, a physical mechanism of pre-seismic 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 prior to large earthquake, the Neural Network based tomographic approach is adapted to GEONET and ionosonde data.

In the case of the 2011 Off the Pacific Coast of Tohoku Earthquake (Mw9.0), the significant enhancements are found in Total Electron Content (TEC) investigation, 1, 3-4 days prior to the earthquake. Especially, TEC increase of 3 days prior to the earthquake was remarkable. As a result of tomographic analysis, the reconstructed distribution of electron density was enhanced in sub-ionosphere to over F-region in comparison with 15 days backward median distribution. Moreover the enhanced area was seems to be developed to upper ionosphere from sub-ionosphere with time. The rise velocity along magnetic field line was approximately 70 m/s. The tomographic results suggest the existence of some energy influx from the surface associated with seismic activity. Then, in order to understand the relationship of detected phenomenon and earthquake, we performed the tomographic analysis for other earthquakes occurred in Japan. Details will be shown in the presentation.

Keywords: Pre-seismic ionospheric anomaly, Ionospheric tomography, GPS

Japan Geoscience Union Meeting 2013
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MIS30-12 Room:301B Time:May 21 17:30-17:45

Multi-parameter observations of pre-earthquake atmospheric signals and their validation. The LAIC concept.

Dimitar Ouzounov[1*], Sergey Pulinets[2]

[1]Chapman University, One University Drive, Orange, CA 92866, USA, [2]Space Research Institute, Russian Academy of Sciences, 117997, Moscow, Russia

We are carrying out a scientific framework involving multi-sensor observations in our investigation of phenomena preceding major earthquakes. The recent catastrophic earthquake in Japan in March 2011 has provided a renewed interest in the important question of the existence of precursory signals preceding strong earthquakes and their physical validation. We describe a possible physical link between atmospheric observations with earthquake precursors using the latest Lithosphere-Atmosphere-Ionosphere Coupling model, the physical concept that we are validating. LAIC model explains the synergy of different ground surface, atmosphere and ionosphere processes and anomalous variations, which are usually named as short-term earthquake precursors.

We demonstrate our approach based on integration and analysis of several atmospheric and environmental parameters that were found associated with earthquakes. The newly developed approach named as Interdisciplinary Space ? Terrestrial Framework (ISTF) permits to identify the precursory phenomena in seismically active areas. The observations included in ISTF are: thermal infrared radiation, radon/ ion activities; air temperature and humidity and a concentration of electrons in the ionosphere. We present our findings of the retrospective thermal radiation precursory detection for more then 100 earthquakes (M>6) occurring in 2004-2011 over Taiwan and Japan including the latest M9.0 great Tohoku earthquakes of March 11, 2011. The cause-effect relationship between different types of precursors united by physical basis of the LAIC model is the main advantage of the presented ISTF approach

Keywords: LAIC, earthquake, earthquake precursor, thermal anomaly, GPS/TEC

Japan Geoscience Union Meeting 2013
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MIS30-13 Room:301B Time:May 21 17:45-18:00

Proposal for the coordination program of next ”earthquake prediction research” based on the electromagnetic methods

Toshiyasu Nagao[1*], Toru Mogi[2]

[1]Earthquake Prediction Research Center, Tokai University, [2]Graduate School of Science, School of Science, Hokkaido University

FY 2013 is the final year of the current five years program called the University’s earthquake prediction research study. During the current program, devastating Tohoku earthquake occurred in 2011. Therefore extensive revision is requested by the evaluation committee. Unfortunately, the short-term prediction research is not on the map among the current program. We believe that the most important issue in the prediction is the short-term prediction. Therefore, for the next five years’ program (if it’s exist), we have to propose unified project based on the electromagnetic methods. This really needs close coordination of the SEMS community. In the presentation, we would like to present the outline of impending research plan and tactics.

Keywords: Earthquake prediction, Electromagnetics

Japan Geoscience Union Meeting 2013
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MIS30-P01 Room:Convention Hall Time:May 21 18:15-19:30

Statistical Changes in the 3-component Geomagnetic Fields at Okutama site in Central Japan before and after the 2011 off

Akihiro Takeuchi[1*], Toshiyasu Nagao[1]

[1]Earthq. Predict. Res. Cent., Inst. Oceanic Res. Dev., Tokai Univ.

We have observed the 3-component geomagnetic fields with a fluxgate magnetometer at the Okutama site in Central Japan, at 1 Hz sampling since December 2003 and at 32 Hz sampling in and after May 2008. This site is located just outside the area where the seismic activity increased after the 2011 off the Pacific coast of Tohoku Earthquake. In this study, we checked whether or not there are statistical changes in the observed data before and after the earthquake. However, the daytime data included noises mainly from trains driven by DC electric power. Therefore, we used only the nighttime data from 2:30:00 to 3:04:08 JST. The power spectrum densities, especially of the period range from 1/16 s to 45 s, had seasonal variations. The annual median, 1st quartile, and 3rd quartile were calculated for the differences between the power spectrum densities and their seasonal variations. As a result, we found (1) the variations of the annual interquartile range, especially for short period spectrum ranges, were in harmony with those of geomagnetic indices and the solar activity and (2) the annular medians for all period spectrum ranges decreased after the earthquake though the declined levels were within the annual interquartile ranges just before the earthquake. One of the possible reasons of the decreases may be the change of the local groundwater condition after the earthquake though we could not ignore the effect of saving electricity due to a power shortage in Japan after the earthquake.

Keywords: geomagnetic field, Tohoku earthquake

Japan Geoscience Union Meeting 2013
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MIS30-P02 Room:Convention Hall Time:May 21 18:15-19:30

Fundamental measurements of Radon concentration in a cave and the atmosphere for earthquake prediction II

Kiyotaka Ninagawa[1*], Tomoaki Nishiyama[1], Isao Yamamoto[2], Shigenori Kawano[3], Tohru Okabayashi[4]

[1]Department of Applied Physics, Okayama University of Science, [2]Department of Information and Computer Engineering, Okayama University of Science, [3]The Shimane Nature Museum of Mt. Sanbe, [4]Department of Medical Risk and Crisis Management, Chiba Institute of Science

An increase of the radon in underground water at Nishinomiya City[1] and an increase of the radon in atmosphere[2] at the southern part of Hyogo Prefecture earthquake in 1995 were reported. Moreover, in the case of Tohoku Region Pacific Coast Earthquake, the data of the exhaust air monitor in the radiation facility of Fukushima Medical College (Fukushima) has been reported that the peak duration was long, and the peak decreased rapidly before the earthquake[3].

We had started to measure radon concentration in a pit of Kurashiki mine, Okayama from the beginning of November, 2009, and started to measure radon concentration in the atmosphere from the end of May, 2011 at Chiba Institute of Science in Choshi, Chiba. We used a Radon Monitor of SUN NUCLEAR Corporation, Model 1028 in the Kurashiki, and a Pylon Trace Environmental Level Radon Gas Detector in Choshi.

In relation to the Southern Hyogo Prefecture Earthquake, seasonal variation in the radon concentration of the air was removed by using the exponential smoothing method[4, 5]. This time we also try to analyze radon concentration variations at the above 2 area using the exponential smoothing method.

In the variation of radon concentration in the pit of the Kurashiki mine, there were twice cases which were over 3 residual error. The 1st case was that earthquake of magnitude 3.3 had happened at eastern Shimane after three weeks. The 2nd case was that no earthquake had happened for four weeks. Then we could not get clear correlation between increase of residual error and the earthquake.

The exponential smoothing method was applied to variation of radon concentration, although the observation period at the Chiba Institute of Science has not passed for two years. However,we could get no date which exceeded 3 residual error. In earthquakes at Choshi, Chiba, their epicenters were almost in the sea.

Since the data of Kobe Pharmaceutical University and Fukushima Medical U niversity are a prolonged measurement over ten years, it is necessary to continue radon concentration observation for a long period at Kurashiki and Choshi.

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Keywords: radon, cave, atmosphere, earthquake, prediction

Japan Geoscience Union Meeting 2013
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MIS30-P03 Room:Convention Hall Time:May 21 18:15-19:30

Observation and detection of ULF geomagnetic changes before earthquake in Kanto

Yamaguchi Hiroki[1*], Peng Han[1], Katsumi Hattori[1]

[1]Graduate School of Science, Chiba University

1. Research Purpose / Background

Many electromagnetic phenomena relevant to an earthquake have been reported in recent years.

Since it precedes with an earthquake and, it is thought that these electromagnetic phenomena are very important for earthquake prediction.

In observation of an earthquake electromagnetism phenomenon

1-1. The technique of observing directly the electromagnetic waves emitted from the focus on the ground

1-2. The technique of detecting the ionospheric perturbation relevant to an earthquake using the terrestrial existing electric wave

1-3. The technique of detection of ionospheric perturbation using a satellite, etc.

Its attention was paid to ULF magnetic field change considered to precede with an earthquake and to generate also in this research.

In ULF, a frequency band of 10 Hz or less is put, and it is a detectable range.

From the epicenter to observation station show that

Magnitude 6 -> radius 60 km

Magnitude 7 -> radius 100 km

It is experientially calculated from the past observations.

That is, it is shown that it is very effective in pinpointing a position in advance to a big earthquake.

It aims at contributing to future seismic activity prediction in building a ULF network of observation and analyzing observational data.

2.The special feature of this research

Now, prepare for the earthquake in the metropolitan area.

2-1. The south Kanto network of a ULF magnetic field observation exists, and it is storing the data for about ten years.

2-2. The result which suggests significance statistical about an earthquake and the abnormalities in ULF has been obtained.

2-3. It is necessary to reinforce the present network.

2-4. We are anxious about the earthquake of magnitude 8 classes off Boso, and it is necessary to collect the basic data immediately after the earthquake on March 11, 2011.

Furthermore, I would like to tie to generating mechanism pursuit of an earthquake electromagnetism phenomenon by also doing many researches of other techniques (change of the radon concentration in the atmosphere, etc.), and conducting synthetic analysis in combination with ULF.

3. Research Program and Method

After 3.11, the ULF observation station which targeted the offing of Choshi distortion is not released completely offshore. And we are anxious about the occurrence of a big earthquake, so observation station was newly established in Asahi-city, Chiba, and observation was started.

Next, synthetic analysis is conducted by combining acquisition data with the ULF data of other observation pstation, and the other technique observational data (radon concentration observation in the atmosphere, etc.).

4. Result Expected

It was difficult to catch ULF magnetic field change preceded with the earthquake off shore from Choshi in the once network of observation.

Since there are comparatively many occurrences of an earthquake also before that the distortion after 3.11 remains, and 3.11 in this area, a possibility that ULF electromagnetic radiation is caught in advance and can be detected by establishing an observation station in this area newly becomes very high as stated previously.

A possibility that a big earthquake will occur can greatly contribute to the elucidation of the generating mechanism of a precursor in the detection accuracy of an earthquake ULF signal analyzing increase and its data by observing in high area.

Furthermore, an earthquake precursor is detected, and the research to solve is useful for future disaster reduction, and is a field also with great expectation from society.

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Japan Geoscience Union Meeting 2013
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MIS30-P04 Room:Convention Hall Time:May 21 18:15-19:30

Focal Mechanism Dependence of Coseismic Ionospheric Disturbance Waveforms Revisited:Strik Slip,Normal,and Reverse Fault

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

[1]Department of Natural History Sciences, Faculty of Science, Hokkaido University

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 including those by large earthquakes. Here we study coseismic ionospheric disturbances (CID) of earthquakes with three different kinds of focal mechanisms, i.e. reverse, strike-slip, and normal faulting. The first category earthquakes include the 2004 Sumatra-Andaman (Mw 9.2) and the 2007 Bengkulu (Mw 8.5) earthquakes. Their CIDs have already been reported in past studies [Heki et al., 2006; Cahyadi and Heki, 2013], but here we present some new data from GPS points in Malaysia. The second category includes the 2012 April northern Sumatra earthquake (Mw 8.6), one of the largest strike-slip earthquakes ever observed. Normal fault earthquakes large enough to disturb the ionosphere are rare. Astafyeva and Heki [2009], by analyzing the 2007 January outer rise earthquake off the central Kuril Islands, suggested that coseismic crustal subsidence in normal-fault earthquakes excite atmospheric waves led by a rarefaction pulse, and hence will cause CID starting with the negative polarity. However, theoretical considerations predict that such waves may not be stable enough to reach the F layer. In December 2012, we experienced a normal fault earthquake in the outer rise region of the Japan Trench (Mw 7.3), which would offer the second opportunity to study the CID waveform of normal-fault earthquakes.

We use GPS data from SUGAR (Sumatra GPS Array), the Malaysian GPS network, and GEONET (GPS earth observation network) in Japan. CIDs are detected clearly in signals of two satellites 13, and 20 in the 2004 Sumatra Andaman earthquake (Fig.1b). Satellite 32 and 20 in the 2012 April Sumatra earthquake detected clear CID in the western sky (Fig.1c). These CID started with only positive changes, possibly originating from the uplift region of the sea floor. Clear CIDs were also detected by satellite 8 in the 2012 NE Japan earthquake. An interesting result from the 2012 normal fault earthquake in Japan is that its CID signals initiated with positive pulses (Fig.1e). After all, we could not find any correlation of the CID signal waveforms with the focal mechanisms of earthquakes

In addition to the initial change polarities, we study various aspects of the CIDs including propagation speeds, atmospheric resonances, directivity, etc. To investigate spatial characteristics of CID, e.g. propagation speed of such disturbances, we calculated sub-ionospheric points (SPP), ground projections of the ionospheric piercing point of line-of-sights assuming a thin layer of ionosphere at altitudes ˜300 km. We also briefly mention pre-seismic TEC anomalies of the 2012 north Sumatra earthquake because its moment magnitude suggests the existence of small preseismic TEC anomalies as found before M9 class earthquakes [Heki, 2011; Cayadi and Heki, 2013].

(Figure caption) Figure 1. (a). SIP (sub-ionospheric point) trajectories by four satellites before/after the three earthquakes in Sumatra (left), i.e. the 2004 Sumatra-Andaman (black), the 2007 Bengkulu earthquake (light grey), the 2012 North Sumatra earthquake (dashed line), and the 2012 outer rise earthquake in NE Japan (right). On the trajectories small black stars are SIP at the time when earthquakes occurred, and beach balls indicate mechanisms of earthquake. (b), (c), (d) and (e) show time series of slant TEC changes in these earthquakes. The black vertical lines in the time series (b, c,d,e) indicate the earthquake occurrence times (for the 2012 event, the largest aftershock ˜2 hours after the mainshock also generated CID).

Keywords: reverse fault, normal fault, strike-slip, GPS-TEC, earthquake

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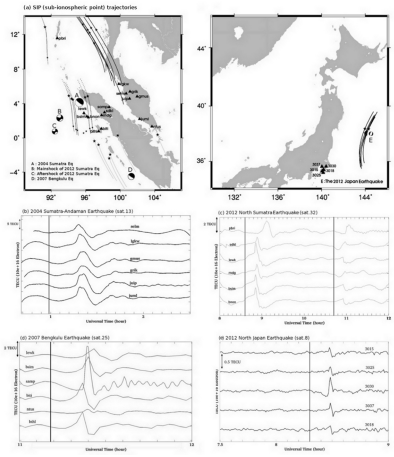

Japan Geoscience Union Meeting 2013
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Ionospheric Anomalies Associated with Large Earthquakes during 1998-2011

Takashi Ichikawa[1*], Katsumi Hattori[1], Shinji Hirooka[1], Jann-Yenq Liu[2], Yuichi Otsuka[3]

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

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 case and statistical studies have revealed that negative TEC anomalies significantly appear a few days before large earthquakes occurred in low geomagnetic latitude areas such as Indonesia, Taiwan, and China. On the contrary, in middle geomagnetic latitude areas such as Japan, Mexico, and Chile, positive TEC anomalies significantly appear a few days before large earthquakes. In this study, we investigate TEC anomalies before large earthquakes whether there is a geomagnetic dependence.

TEC values are computed by 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, GPS-TEC$*$, (t) is defined as follows: TEC$*$ (t) = (TEC(t)-TECmean(t))/sigma(t).

We investigate TEC anomalous variations in time and space for the 2011 off the Pacific coast of Tohoku Earthquake. GIM-TEC$*$ anomalies exceeding +2 sigma appear 3-4 days before the earthquake. The duration is more than 20 hours. This result is consistent with the previous statistical results that positive anomalies significantly appear 1-5 days before M>=6.0 earthquakes in Japan area.

SEA (Superposed Epoch Analysis) have been performed for the statistical analysis of TEC anomalies associated with M>=6.0 earthquakes occurred in low geomagnetic latitude(+15 to -15 degree) and middle geomagnetic latitude(+40 to +25 degree,-25 to -40 degree). For the low-latitude area, negative anomalies significantly appear 6-10 days before the earthquakes. For the mid-latitude area, positive anomalies significantly appear 1-5 days before the earthquakes. Furthermore, those anomalies depend on the magnitude of earthquakes. These results suggest that TEC anomalies before large earthquakes have geomagnetic dependences.

Keywords: Ionosphere, Earthquake

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Statistical analysis on relation between ULF geomagnetic anomaly at Kakioka and local seismicity

Maiko Hirokawa[1*], Katsumi Hattori[1], Peng Han[1]

[1]Chiba University

There are many reports on earthquake-related ULF geomagnetic anomalies but there are active debates on the reliability about the anomalies and on the generation mechanism. Therefore, we investigated relation between local seismic activity and magnetic activity statistically in this study. The vertical intensities of the geomagnetic fields at 1 Hz sampling are examined at Kakioka and Kanoya (as a reference station) from 2000 to 2010. The wavelet filter is performed and the data around 0.01 Hz are focused. Nighttime data from 2:30 to 4:00 are used in the analysis to reduce contamination of artificial effects. The daily energy over the nighttime period analyzed is computed and correlation between Kakioka and Kanoya is investigated. It is found that the correlation between them is high (0.94). This is highly suggestive of the relative similarity of the underground electrical structures between Kakioka and Kanoya and enables to model computation using the Kanoya (reference station) data. The ratio between the original data at Kakioka and the idealized data at Kakioka derived from those at Kanoya is computed. An invalid assumption on the electrical structures beneath both stations gives a constant value of the ratio and it is possible to remove global changes such as magnetic storms due to upper atmospheric sources. An anomalous change in the ratio expects a local change of the underground structure or additional noise. We investigate the relationship between the anomalous changes and local seismicity. We define the criterion on the anomaly of the ratio as median+1.5IQR (IQR: inter-quantile range). Earthquakes which satisfy Es>10^8 are selected within 100 km of epicentral distance from Kakioka and within 60 km depth from earth surface. Then we perform Superposed Epoch Analysis. The results show that 5-15 days before the earthquake, geomagnetic anomaly appears significantly and there is the Es dependence. These epidemiological results show the relation between local seismicity and geomagnetic anomaly.

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Volcanic and lava activity detecting using MODIS data

Rika Tsutsumi[1*]

[1]Graduate School of Science, Chiba University

There are a lot of active volcanoes in the world. But it is difficult to monitor all volcanoes because of costs. However, we can monitor efficiently a lot of volcanoes using satellite remote sensing technologies, because a volcanic activity will cause the increase in surface temperature and satellite (whose sensor can observe the surface temperature) remote sensing can cover a large area on surface. Therefore, our purpose of this study is to create an adequate algorithm detecting thermal anomalies related to volcanic activities (especially lava activity witch causes serious damages involve human lives) using satellite data. The developed algorithm investigates the difference temperature behavior between a target point and reference points. Therefore, removing cloud is essential in our algorithm.

The developed algorithm has been applied to Mt. Merapi (Indonesia), Mt. Shinmoe-dake (Japan) and so on and we found the effectiveness of it and reduction of faint changes due to clouds.

In addition, we examined the cloud removal method that we used in this study by comparing with continuous observation lidar data conducted by Institute for Environmental Studies at Tsukuba.

The details will be shown in our presentation.

Keywords: volcanic activity, satellite data, MODIS, Shinmoe-dake, lidar

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Present Status of the ELMOS Small Satellite Constellation

Tetsuya Kodama[1*]

[1]Japan Aerospace Exploration Agency

Present status of the ELMOS small satellite constellation will be presented.

Keywords: ELMOS, Small satellite constellation, GPS occultation, Electron density, Electron temperature, Lithosphere-Atmosphere-Ionosphere Coupling

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Seismo-electromagnetic data observed by Chubu University before and after 2011 Tohoku Earthquake

Jun Izutsu[1*], OHTA, Kenji[1], Masashi Hayakawa[2]

[1]College of Engineering, Chubu University, [2]Advanced Wireless Communications Research Center, The University of Electro-Communications

Chubu University has established electromagnetic observation network in order to study seismo-electromagnetics.

We have observed ULF/ELF electromagnetic waves at three observation stations (Nakatsugawa, Shinojima and Minami Izu) in order to catch the emissions from the focal region of earthquakes. And also we have observed VLF electromagnetic waves at Kasugai in order to measure the change of the propagation characteristic in the ionosphere and atmosphere disturbed by the energy from the epicentral region.

In this study, we talk about the result of the observation before and after the 2011 Tohoku Earthquake.

In our past studies, we had observed anomalous excitations of Schumann resonances before the 2004 Mid-Niigata Prefecture earthquake and the 2007 Noto Hantou earthquake at Nakatsugawa. However, we cannot found any anomalous Schumann resonances before the 2011 Tohoku Earthquake.

We found strong ULF emissions possibly propagated from the direction of the focal region of the 2011 Tohoku Earthquake on March 2, 2011, 9 day before the earthquake. And also we found propagation anomalies of VLF electromagnetic waves several days before and after the 2011 Tohoku Earthquake. But there was large foreshock on March 9. So we cannot point out that these anomalies were precursors of the 2011 Tohoku Earthquake, and even cannot point out that they were precursors of earthquakes in this stage.

The observed ULF/ELF/VLF anomalies possibly associated with earthquakes were not so convincing enough to predict the earthquakes. And so we need more case studies, further research, and trying to make a probabilistic forecast.

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

Keywords: Seismo-electromagnetics, 2011 Tohoku Earthquake, ULF/ELF/VLF

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Geomagnetic anomalies possibly associated with the 2011 off the Pacific coast of Tohoku earthquake (Mw9.0)

Peng Han[1*], Katsumi Hattori[1], Hiroki Yamaguchi[1], Febty Febriani[1], Chie Yoshino[1]

[1]Graduate School of Science, Chiba University

In this paper we have reported unusual changes of geomagnetic fields observed in the vicinity of the epicenter of the 2011 Tohoku earthquake (Mw9.0).

Firstly, we have investigated geomagnetic diurnal variations observed at ESA and KAK. Usually, the diurnal variations at the two stations are quite similar, because the inter station distance is not so large. In this study, the ratios of diurnal variation ranges of KAK to ESA have been monitored. The results indicate that about two month before the Mw9.0 earthquake, the ratio of Z component has increased significantly. This unique change was derived from more than one year data. After checking the original data, it is confirmed that the diurnal variations at ESA station in early January, 2011 have clearly unusual behaviors compared with other reference stations which are far from the epicenter.

And then, we have monitored underground apparent resistivity at ESA station. The mega Mw9.0 earthquake is located in the seismically active area. Actually, this place is also magnetic anomaly region. The short term variations of vertical geomagnetic fields at stations to the north and south of this region exhibit opposite phases. Preliminary results show that the energy of geomagnetic fields at short periods of ESA station is much smaller than that of KAK station, which suggests that the underground conductivity in ESA area may be different from other place. Analyzing MT data observed at ESA is now on-going.

Keywords: ULF seismo-magnetic phenomena, earthquake, geomagnetic field