

Earthquake Prediction with Satellite Cloud Image

GUO, Guang meng^{1*} ; YANG, Jie¹

¹Nanyang Normal University,China

Russian scientists has found some linear clouds in tectonic active area in 1980s, while few papers about this topic were published in the following 30 years except Russian scientists. One of the reason may be that clouds are difficult to be described with numbers or formulas, it is qualitative, and qualitative researches are difficult to be published. After years observation, we found that clouds related with seismic activity have three features, first their shape are linear, second they are often over fault systems, third they often stay over fault systems for hours and do not move with winds. Such clouds are found in Japan, Italy, Bulgaria and New Zealand. With the help of satellite, we have made several successful predictions about these countries earthquakes. We think that clouds are reliable earthquake precursors, while if you want to make an accurate prediction, satellite clouds images are not enough, and it is better to combine other geophysical data to get an accurate result.

Keywords: Earthquake Prediction, Clouds, Satellite

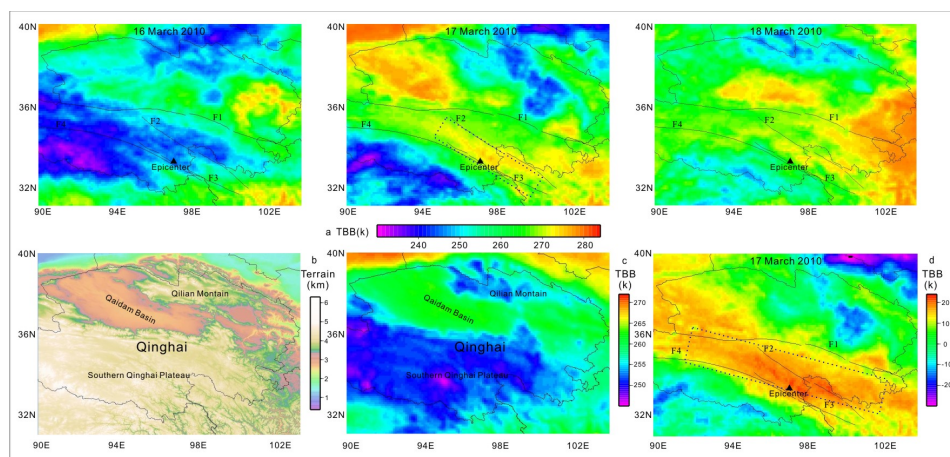
Discriminating satellite IR anomalies associated with the Ms 7.1 Yushu earthquake in China

KAI, Qin^{1*} ; LIXIN, Wu¹

¹China University of Mining and Technology

In the process of exploring pre-earthquake thermal anomalies using satellite data, Blackett et al. (2011) found that the reported anomalies before the 2001 Mw 7.7 Gujarat earthquake, in India, were related to positive biases caused by data gaps. They supposed that such effects could also be responsible for other cases. We noted a strip-shaped TIR anomaly on 17 March 2010, 28 days before the Ms 7.1 Yushu earthquake (below figure). Here we again investigate multi-year infrared satellite data in different bands to discriminate whether the anomaly is associated with the earthquake, or is only normal bias caused by the data gaps. From the water vapor images, we find lots of clouds that have TIR anomalies. However, on the cloudiness background, there is an obvious strip-shaped gap matching the tectonic faults almost perfectly. In particular, the animation loops of hourly water vapor images show that the cloud kept moving from west to east, while they never covered the strip-shaped gap. We consider that the cloud with this special spatial pattern should have implied the abnormal signals associated with the seismogenic process. Based on current physical models, the satellite IR anomalies both on TIR and water vapor bands can be explained using synthetic mechanisms.

Keywords: earthquake, satellite, anomaly, thermal, remote sensing



Onsite earthquake early warning techniques and its applications at schools in Taiwan

HSU, Ting-yu^{1*} ; WU, Shyu-yu¹ ; HUANG, Shieh kung¹ ; CHIANG, Hung-wei¹ ; LIN, Pei-yang¹ ;
LU, Kung-chun¹

¹NCREE

Regional earthquake early warning (EEW) system is not suitable for Taiwan due to most of the destructive seismic hazard comes from in-land earthquakes, thus makes the lead-time before destructive earthquake wave arrives provided by the regional EEW system can be null. On the other hand, on-site EEW system can provide more lead-time at the region close to an epicenter since only the seismic information on the target site is required. Instead of leveraging the information of several stations, the on-site system extracts some P-wave features from the first few seconds of vertical ground acceleration of a single station and performs the prediction of the coming earthquake intensity at the same station according to these features. Recently, a new method of estimating seismic intensity using the support vector regression (SVR) has been developed. However, till now, most popular on-site algorithms are TauC-Pd-Attenuation (TPA) method and Pd-Threshold method (PdT). The objective of this study is to evaluate the performance of these three methods using earthquake data of the Taiwan Strong Motion Instrumentation Program and the earthquake data of EEW stations of National Center for Research on Earthquake Engineering in Taiwan. The results show that SVR method can provide more reliable and accurate EEW among these three methods.

Keywords: earthquake early warning, on site, single station

Earth observation using the GAIA-1 and GAIA-2 satellite platforms

SRI SUMANTYO, Josaphat tetuko¹ ; BAHARUDDIN, Zafri^{1*}

¹Chiba University

Earth observation from space provides a vantage point unlike any other. Global Navigation Satellite System (GNSS) and GPS satellites orbiting the planet are all emitting microwave signals. These signals can be exploited using the radio occultation (RO) technique which can be used to sense minute changes in the atmosphere. By studying these changes it is hoped that natural phenomenon such as earthquakes can be predicted before they occur. With that in mind we have a long term plan to launch a satellite with a GNSS-RO sensor called GAIA-1 to seek out the possibility of this potential prediction. Lessons learnt from GAIA-1 will be applied to it's next generation GAIA-2, where the primary payload will be a synthetic aperture radar (SAR) system. This presentation will introduce both satellites and their respective payloads, mission plan, and system architecture.

Keywords: radio occultation, GPS, GNSS, synthetic aperture radar, satellite

Statistical study on short-term earthquake forecast using TEC anomalies over Japan area

HONMA, Ayano^{1*} ; HAN, Peng² ; HATTORI, Katsumi² ; LIU, Jann-yenq³

¹Faculty of Science, Chiba University, ²Graduate School of Science, Chiba University, ³National Central University, Taiwan

To reduce the effect of strong geomagnetic activities such as geomagnetic storms, the TEC data of 2 days after Dst index exceed -60 nT were excluded in previous statistical studies of earthquake related TEC anomalies. Actually, the influences of a magnetic storm on TEC variations depend on the intensity and onset time of the storm. In this study, to clarify such dependences, we applied classification analysis method to the storm data (Dst) and discussed the response of TEC variation to each type of storm.

We picked out all the 294 geomagnetic storms during 1998-2013, and classified them into 3 types according to its magnitude and 4 types according to the onset time (local time). We checked the TEC data from 2 days before till 5 days after the onset of each geomagnetic storm. A bootstrap method (10000 times extraction) is used to calculate the average variation of the TEC for each type of storm. The average variation can be regarded as an average response of TEC to the related type of storm. If the average value of TEC exceeds the $\text{mean} \pm 2\sigma$ threshold, we consider it being affected by the storm. By this mean, we could find the accurate period affected by each type of storm.

We employed the results obtained above to remove the TEC data associated with geomagnetic storms. Next we performed statistical analysis of the TEC anomalies possibly associated with large earthquakes in Japan area during 1998/05-2013/12. There are statistical significance of TEC anomalies 1-5 days before and 16-20 days after $M \geq 6.0$ earthquakes. The significance of pre-earthquake anomalies is consistent with the results reported by Kon et al., 2011. The significance of 16-20 days after earthquakes may be due to aftershock effects of the Tohoku earthquake. To remove the influences of any pre- and after- shock effects, we proposed a new method which considers 'isolate EQs' only. 'Isolate EQs' are earthquakes which is unique in a 61 days window centered by the day of the EQ. The result shows there are clear high possibilities of TEC anomalies 1-5 days prior to $M \geq 6$ earthquakes.

Finally, we used the Molchan's error diagram to evaluate the efficiency of TEC anomalies for short-term earthquake forecasts. The results indicates that the predictions based on TEC anomalies are better than random guess (Poisson model), which suggests that the TEC anomalies contain certain precursory information of $M \geq 6.0$ earthquakes.

Keywords: statistical analysis, geomagnetic storm, TEC anomalies, earthquake, SEA, Molchan's Error Diagram

Seismo-ionospheric precursors of the 11 March 2011 M9.0 Tohoku Earthquake

LIU, Jann-yenq^{2*} ; LEE, I. T.³ ; CHEN, C. H.⁴ ; HATTORI, K.⁵ ; CHEN, Y. I.⁶ ; HUANG, C. S.¹ ;
SU, Y. Z.¹

¹Institute of Space Science, National Central University, Chung-Li, Taiwan, ²National Space Organization, Hsinchu, Taiwan,
³Center Weather Bureau, Taipei, Taiwan, ⁴Department of Earth Sciences, National Cheng-Kung University, Tainan, Taiwan,
⁵Graduate School of Science, Chiba University, Chiba, Japan, ⁶Institute of Statistics, National Central University, Chung-Li, Taiwan

In this paper, the total electron content (TEC) of the global ionosphere map (GIM) is used to observe seismo-ionospheric anomalies associated the 11 March 2011 M9.0 Tohoku earthquake, while the Thermosphere Ionosphere Electrodynamics General Circulation Model (TIEGCM) is applied to simulate and understand the observed anomalies. The GIM TEC associated with $M \geq 6.0$ earthquakes in Japan are statistically examined during 1998-2011. It is found that the GIM TEC significantly enhance day 3 before the earthquakes. On the other hand, the TEC over the epicenter also significantly and continuously enhances on 6-8 March 2011, 4-2 days before the Tohoku earthquake. The agreement between the statistical result and the event anomaly implies that seismo-ionospheric precursor related to the Tohoku earthquake might be observed. The spatial analysis further is further conducted to find 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 affects the TEC during the earthquake preparation period.

Keywords: Seismo-ionospheric precursors, Tohoku Earthquake

Validation of pre-earthquake atmospheric signals and their connection with major seismicity

OUZOUNOV, Dimitar^{1*} ; HATTORI, Katsumi² ; PULINETS, Sergey³ ; MOGI, Toru⁴

¹CEESMO/Chapman University, Orange, CA, USA, ²Department of Earth Sciences, Chiba University, Chiba, Japan, ³Space Research Institute, Russian Academy of Sciences, Moscow, Russia, ⁴Institute of Seismology and Volcanology, Hokkaido University, Sapporo, Japan

We are presenting a new approach of utilizing multi-parameters space and ground observations to study pre-earthquake processes related to major earthquakes. In this study we are exploring the potential of atmospheric and ionospheric signals to alert for large earthquakes. To achieve this, we start validating retrospectively and prospectively anomalous ionospheric /atmospheric signals. Our method for validation is based on a joint analysis of several physical and environmental parameters (Satellite thermal infrared radiation (STIR), electron concentration in the ionosphere (GPS/TEC), VHF-bands radio waves, radon/ion activities, air temperature and seismicity patterns) that were found to be associated with earthquakes. The science rationale for this methodology is based on the concept of Lithosphere-Atmosphere-Ionosphere Coupling (LAIC) [Pulinets and Ouzounov, 2011], which explains the synergy of different physical processes, usually named short-term pre-earthquake anomalies.

Our validation include continuous retrospective analysis performed over two different regions with high seismicity- Taiwan and Japan for 2003-2011 .The retrospective tests show STIR and GPS/TEC anomalous behavior in advance for most of these events with false positives less than 25%. The prospective tests for Honshu and Hokkaido (Japan) started in 2014. Our initial test results suggest systematic appearance of STIR anomalies, one to several days in advance to major events, including the two largest earthquakes for that period - M7 of July 12, 2014 and M6.9 of Feb17, 2015 in Eastern Honshu. The proposed is multi-parameters approach and new observations could be further integrated into and the synergy of these parameters implying their connection with the earthquake preparation processes.

Keywords: earthquake forecasting, pre-earthquake signals, Thermal anomaly, GPS/TEC, radon, LAIC

Statistical Analysis of ULF Seismo-Magnetic Phenomena in Kanto, Japan

HAN, Peng^{1*}; HATTORI, Katsumi¹; ZHUANG, Jiancang²

¹Graduate School of Science, Chiba University, Chiba, Japan, ²Institute of Statistical Mathematics, Tokyo, Japan

In order to clarify and verify the ultra-low frequency (ULF) seismo-magnetic phenomena, we have performed statistical studies on the geomagnetic data observed at several stations, in Japan, during 2001-2010. They are Kiyosumi (KYS), Uchiura (UCU), Fudago (FDG), Seikoshi (SKS), Mochikoshi (MCK), Kamo (KAM), and Kakioka (KAK). KAK is a standard geomagnetic station operated by JMA (Japan Meteorological Agency) and the others are operated by us. We investigated the energy of ULF geomagnetic signals of the frequency around 0.01Hz using wavelet transform analysis. To minimize the influences of artificial noises and global geomagnetic perturbations, we used only the geomagnetic data observed at nighttime (LT 2:30am-4:00 am). In this abstract, we describe the results of KAK as an example. As for KAK data, we utilized observations from a remote station, Kanoya (KNY), as a reference. Statistical results of superposed epoch analysis have indicated that ULF magnetic anomalies are more likely to appear before sizeable earthquake events rather than after them, especially 6-15 days before the events. Further statistical investigations show clearly that the ULF geomagnetic anomalies at KAK are more sensitive to larger and closer events. Finally, we have evaluated the precursory information of ULF geomagnetic signals for local sizeable earthquakes using Molchan error diagram. The probability gain is around 1.6 against a Poisson model. The above results have indicated that the ULF seismo-magnetic phenomena at KAK clearly contain precursory information and have a possibility of improving the forecasting of large earthquakes. The statistical results for the other stations also show similar tendency. These facts suggest that ULF magnetic anomalies have a significant correlation and precursory information on a sizable earthquake.

Keywords: ULF seismo-magnetic phenomena, statistical test, short-term earthquake forecast

Detectability of seismic network: an approach of the probability-based magnitude of completeness method

HUANG, Qinghua^{1*} ; LI, Zhichao²

¹Peking University, ²China Earthquake Networks Center

The magnitude of completeness is a key quantitative index to assess the detectability of regional seismic network. This paper deals with the detectability of the Capital-circle Seismic Network in China by adopting the probability-based magnitude of completeness (PMC) method which can reveal the detailed spatio-temporal characteristics of regional seismic network detectability. The earthquake data (2002-2009) and station information are from China Earthquake Administration (CEA). We estimated the network detectability and discussed the possibility of improving the network detectability according to the spatio-temporal distribution of completeness magnitudes and the simulation results. The results show that the detectability of the Capital-circle Seismic Network is high in most regions, although the detectability in a few regions needs to be enhanced. Simulation results suggest that increasing stations may further enhance the detectability of the seismic network. This study may be helpful for the optimization of the regional seismic network.

This study is supported partially by the National Natural Science Foundation of China (41025014).

Keywords: Probability-based magnitude of completeness (PMC), seismic network, detectability

Earthquake Monitoring and case study by using Multi-parameters Remote Sensing information in China

XUHUI, Shen^{1*} ; WANG, Lanwei¹ ; YUAN, Shigeng² ; ZHANG, Xuemin¹

¹Workinggroup of Earthquake-related satellite mission, China Earthquake Administration, ²China DFH Sat. Co.Ltd

In the last ten years, a few national research plans and scientific projects on remote sensing application in Earthquake monitoring research are implemented in China and some progress were achieved on EQ-related ionospheric and RS precursors extracting and distinguishing by statistical research, case study and real-time monitoring experiments on historical or recent earthquakes. The LAI coupling models were computed and checked also, which laid the foundation for gradually promoting the practical use.

Focusing to advance earthquake monitoring capability and to search for the way of earthquake prediction, the prototype data processing and application platform of satellite-based EQ monitoring system, which integrate mainly GNSS, electromagnetism, infrared RS and D-InSAR technologies were developed systematically. and integrated earthquake remote sensing application system has been designed comprehensively.

On the basis of these works, the first space-based platform in earthquake stereoscope observation system in China, which named as China Seismo-Electromagnetic Satellite (CSES) now is on his phase of electrical model and qualifying model. According to the schedule, the 1st CSES will be launched before the end of 2016 and 2nd CSES will come into review soon.

Keywords: Earthquake monitoring, China Seismo-Electromagnetic Satellite, LAI coupling, remote sensing application

Multiple seismo-anomalies associated with three major earthquakes in China, Japan and Taiwan

CHEN, Chieh-hung^{1*} ; ZENG, Xiaoping² ; HATTORI, Katsumi³ ; LIU, Jann-yenq⁴

¹Department of Earth and Environmental Sciences, National Chung Cheng University, Chiayi 621, Taiw, ²Institute of Geophysics, China Earthquake Administration, Beijing 100081, China, ³Graduate School of Science, Chiba University, Inage, Chiba 263-8522, Japan, ⁴Institute of Space Science, National Central University, Jhongli 320, Taiwan

Seismo-crustal deformation, groundwater (containing levels, temperature and radon), geomagnetic and ionospheric anomalies are integrated together to investigate pre-earthquake anomalous phenomena associated with the M6.1 Ludian earthquake, China, the M9.0 Tohoku-Oki earthquake, Japan and the M7.6 Chi-Chi earthquake, Taiwan. Seismo-crustal deformation and groundwater anomalies generally lead the other promising parameters because stress accumulation in crust is one of the major driving forces of earthquakes. Uplift and depression groundwater levels are exactly related with compression and tension stress loading in the crust, respectively. Decreases of groundwater temperature and radon concentration are resulted from uplift groundwater levels. Meanwhile, groundwater would infuse into fracture zones of faults once cracks are developed before earthquakes that can enhance conductivity near hypocenters and/or faults affecting electromagnetic fields and electron total electron contents in the ionosphere. Those aforementioned relationships can be utilized to eliminate anomalies which are unrelated with earthquakes to further increase of the accuracy and understand causal mechanisms of pre-earthquake anomalous phenomena in seismogenic processes.

Keywords: Groundwater, Electromagnetic field, Total electron content, Crustal deformation, Earthquake forecast

Space-borne observations of pre-earthquake atmospheric signals associated with major seismicity in Xinjiang, China

OUZOUNOV, Dimitar^{1*} ; PULINETS, Sergey² ; SHEN, Xuhui³ ; SUN, Ke³ ; KAFATOS, Menas¹

¹CEESMO/Chapman University, Orange, CA, USA, ²Space Research Institute, Russian Academy of Sciences, Moscow, Russia,
³Institute of Earthquake Science, China Earthquake Administration, Beijing, China

We are presenting the latest development in multi-sensor observations of short-term phenomena preceding major earthquakes. The purpose of this study is to verify if satellite thermal infrared radiation (STIR) anomalous can be found retrospectively in association with three major earthquakes in XinJiang province China (M6.9 of 02.12.14; M6.2 of 08.12.2012; M7.2 of 03.20.08) by systematically analyzing multi-sensor satellite and ground temperature/ humidity observations for the period of 2008-2014. Meteorological satellite data include NOAA polar orbit POES and Chinese geostationary satellite FY2D. In the case of M6.9 of 02.12.14, NOAA STIR data for January ?February shows building an atmospheric anomaly 10-20 days before the main shock. FY2D STIR data show similar trend by revealing anomalous value with persistency of more then 9 hours on Jan 31, 2014. The 2012 (M 6.2) and 2008 (M7.2) event shows similar STIR anomalies over the major Altyn Tagh fault lines within 10-15 days before the seismic event. This probably is connected with the geochemistry gas increase, which can provide additional source for flux emission near major faults in the area. The hourly in-situ atmospheric observation show similarly in the air temperature increases and drop in the relative humidity, probably as result of additional atmospheric ionization observed before the three earthquake events. Our initial results suggest that systematic use of multi-parameter observations can be used for additional physical validation of pre-seismic processes associated with the major earthquake events.

Keywords: short-term earthquake forecasting, pre-earthquake signals, Thermal amomaly, GPS/TEC, radon, LAIC

Multi-sensor monitoring network for earthquake precursors and preparation process near subduction zone at Boso, Japan

HATTORI, Katsumi^{1*} ; HAN, Peng¹ ; MOGI, Toru² ; GOTO, Tada-nori³ ; TAKANO, Tadashi⁴ ; IZUTSU, Jun⁵ ; KAMOGAWA, Masashi⁶ ; YAMANAKA, Chihiro⁷ ; TAJUMI, Ichi⁸ ; YASUKAWA, Hiroshi⁹ ; ANDO, Yoshiaki¹⁰ ; SONODA, Jun¹¹ ; SAKAI, Hideo¹²

¹Graduate School of Science, Chiba University, ²Hokkaido University, ³Kyoto University, ⁴Nihon University, ⁵Chubu University, ⁶Tokyo Gakugei University, ⁷Osaka University, ⁸Nagoya Institute of Technology, ⁹Aichi Prefectural University, ¹⁰The University of Electro-Communications, ¹¹Sendai National College of Technology, ¹²Toyama University

New observations from ground and space have provided multiple evidences of pre-earthquake signals and the latest studies show their statistical significance, repeatability, and universality. In this project, to understand the preparation process of large earthquakes and slow-slip events in subduction zone, especially to clarify the nucleation stage of the earthquake cycle, we plan to establish a dense observation network in Boso, Japan, where large subduction earthquakes are expected soon.

Since the subsurface fluid flow may play an important role in the preparation process of subduction activities, we intend to employ electromagnetic approaches including oceanic and continental MT survey to monitor the underground resistivity structure which is sensitive to the dynamics of fluid. Other geophysical monitoring such as ULF geomagnetic and geoelectrical observations, radon measurements, and inland GPS movements, will be incorporated to help to understand the preparation process and evaluate the applicability of various pre-earthquake signals towards short term earthquake forecasting.

Keywords: multi-sensor monitoring network, earthquake precursors, earthquake preparation process, short-term earthquake forecast

Establishment of NPO Japan Earthquake Precursor Comprehensive Observation Center and Experiment of earthquake prediction

SAITO, Yoshiharu^{1*}

¹NPO Japan Earthquake Precursor Comprehensive Observation Center (JEPCCOC)

NPO JEPCCOC has been established on January 7 2015.

NPO JEPCCOC is operated by hardware engineers who develop observation system, software engineers who develop data collection and display system and ordinary people who observe various phenomena.

Multi-method at multi-point observation is performed; first of all, we inspect correlation between actual occurred earthquake and observed anomaly.

We start from Tree Bio-electric Potential (TBP) observation and dual frequency observation at multi-frequency band and we try prediction of earthquake occurrence in the near future.

We plan to cooperate with other groups which are observing tidal level deviation, air ionization, and so on.

Frequency band of EM observation is VLF (3~30kHz, under development), LF (30~300kHz), MF (300~3MHz), VHF (30MHz~300MHz) and UHF (300MHz~3GHz, under development)

TBP and dual frequency EM are being observed at 9 posts in Japan at this moment.

Plants are found to have instinct to catch precursor from huge earthquake as well as animals. It is known that animal's anomalous action before huge earthquake i.e. alignment to one direction of earthworm before Taiwan Chi-Chi EQ and rapid escape action of elephants at Sumatra EQ.

In the other hand, plants show anomalous action sometimes, for example, Mimosa Pudica reacts when it is touched by hand, vent down before typhoon and anomalous action before EQ. Those anomalous actions were reported to plant physiologist Toriyama since middle of 1970 age.

Toriyama started to observe Tree Bio-electric Potential (TBP) since 1977 as tree is much easier than grass to measure TBP. The way of measuring TBP is put an electrode on the surface of tree and another electrode into ground, then measure electric potential between two electrodes.

28 EQs with magnitude of about 7.0 occurred between 1977 and 1989 around Japan, obvious anomaly was observed at 17 EQ of those. 5 patterns of anomalous potential were found in this period and more one pattern was found after then.

These anomalous actions may be caused by receiving electric magnetic (EM) signal through ground via root or ion through atmosphere at leaves or some other cause. As mechanism is not solved yet, possibility to predict the 3 elements of earthquake occurrence i.e. when, where and magnitude is very low, however, we can say that possibility to know occurrence of huge earthquake soon is very high.

In order to predict EQ occurrence with high probability, it is important to combine data obtained from several methods. We are trying to observe EM signal at several frequency band with adjacent dual frequency from VLF to UHF, Aero ion concentration, Animals anomalous action and Tidal level deviation as well.

Frequency band of EM signal from EQ focus is known to be emitted from DC to SHF. We wait at various frequencies at VLF, LF, MF, VHF and UHF at adjacent dual frequency, if a signal received at only one frequency, it may not be seismic, it may be some signal which has some meaning, if two signals received at both frequencies simultaneously, and it may be seismic signal.

As it is known radon and ion is emitted before big EQ, air ionization concentration is being observed at 17 observation posts in Japan.

Daily action of fishes and snakes are observed numbers to across optical sensor, mouse action is observed by rotation motion, cat action is observed number of steps by walking counter on neck.

Tidal level deviation is measured at 187 points along coast line by Japan Meteorological Agency (JMA) and other public organization. It is able to know deviation in sigma by software processing.

It may be possible to judge huge EQ will occur soon, when anomalies are observed by some of those methods simultaneously. We will report anomaly data prior to great EQ observed by above mentioned 5 methods.

Keywords: prediction, bio potential, EM, tidal, ion, radon

MT survey and its preliminar result at Boso Peninsula, Japan

KOIZUMI, Naoki^{1*} ; HAN, Peng¹ ; YMAZAKI, Tomohiro¹ ; YOSHINO, Chie¹ ; HATTORI, Katsumi¹ ;
OKUDA, Mao² ; MOGI, Toru²

¹Graduate School of Science, Chiba University, ²Institute of Seismology and Volcanology, Faculty of Science, Hokkaido University

A magnetotelluric (MT) survey is one of the methods to understand the underground electric properties. In Boso area, Japan, there are three main topic to perform the MT survey; (1) to estimate underground resistivity structures related to the plate boundaries, seamount, asperities, and slow slip events, (2) to obtain a regional realistic resistivity structure for the numerical simulation in generation and propagation mechanisms of electromagnetic precursors, and (3) to develop a new MT technique to reduce the cultivated noises such as DC driven trains. In these aims, we decided to carry out the MT survey in Boso area, Japan during 2014-2016. Due to sensing down to 100 km depth, we use induction and fluxgate magnetometers. The first MT survey in 2014-2015 had 21 and 6 stations for induction and fluxgate type magnetometer, respectively. We checked the observed data and analyzed the local midnight time (02:00-04:00(JST)) data because of noises and performed 1D inversion.

The preliminarily results show that we can presume the resistivity structure about 80 m-2 km depth from the surface. A typical resistance down to 200 m depth was 1-10 ohm-m and below 200 m depth, a specific resistance was estimated at 0.1-1 ohm-m at many stations. This suggests that there is a geological boundary around 200 m depth. In comparison with the geologic structure interpreted by the reflection seismology data, the upper part seems to be the Shimousa Group, and the lower, the Kazusa Group (Earthquake Research Committee, 2005).

To presume resistivity structure at the deeper depth, it is necessary to remove the artificial noises from observed MT data. These observed noises have characteristics of transient signals and processes in time domain are required such as singular spectrum analysis and neural network analysis. Further preprocessing will be essential.

Keywords: MT method, Boso Peninsula

investigations of geomagnetic diurnal variations associated with the 2011 off the Pacific coast of Tohoku earthquake

YAMAGUCHI, Takuto^{1*} ; HAN, Peng² ; YOSHINO, Chie² ; HATTORI, Katsumi²

¹Faculty of Science, Chiba University, ²Graduate School of Science, Chiba University

As one of the most promising candidates for short-time earthquake forecasting, the seismo-electromagnetic phenomena have been intensively studied for several decades. Recently, Xu et al. (2013) have reported unusual behaviors of geomagnetic diurnal variations in the vertical component prior to the 2011 off the Pacific coast of Tohoku earthquake (Mw9.0). In this study, we carry out further studies by investigating the spatial distribution of the anomalous geomagnetic diurnal variations associated with the Tohoku earthquake.

Ratios of Z component diurnal variations between the target station and the remote reference station Kakioka have been computed. After removing seasonal variations revealed by wavelet transform analysis, the 15days running mean of the ratio shows a clear anomaly exceeding the statistical threshold about 2 month before the mega event in Esashi and Mutsu stations, which are close to the Mw9.0 earthquake epicenter. These results indicate that the location of the anomalies is consistent with the epicenter. Moreover, other independent geophysical parameter such as seismicity and crustal deformation also show clear unusual changes simultaneously, which suggests these anomalies might be related with the mega event.

Visualization of Groundwater Motion Using Self-Potential Tomography for Indoor Rainfall-Induced Landslide Experiment

HATTORI, Katsumi¹ ; YMAZAKI, Tomohiro^{1*} ; TERAJIMA, Tomomi²

¹Graduate School of Science, Chiba University, ²DPRI, Kyoto University

As it increases in the frequency of the local heavy rain in recent years, the occurrence number of the landslide also increases. It's an important problem to elucidate the process of the landslide caused by rainfall and monitor the slope and forecast the occurrence time to reduce damages. To achieve this, we need to monitor groundwater movement. In this study, we try to develop the early warning system with SP method to predict/monitor rainfall-induced landslide.

The relationship between the SP fluctuation, the movement of water, and the displacement of soil is confirmed by the former interior flume experiments. We adopt the PRESS-aided Philips-Tikhonov regularization to develop the SP tomography and sand-box experiments to apply the tomography successfully show the water levels and flows. To expand the SP tomography approach to the flume tests, we perform the numerical simulation to visualize the underground water condition. The size of the slope is depth 9.0 m, height 4.8 m and width 1.0 m. And the height of the soil stratum is 0.7 m. We assume a rectangular reconstruction area and we divide the area into a 0.2 m x 0.1 m pixel, and compute the value of electric charge every pixel. In addition we assume the electric charge outside of the slope area is 0 and the permittivity in the analyzed area is uniform. Checkerboard-like positive and negative electric charges are generated and the number of electrodes was changed with 16-85. An error of 10% of the observation value has been added to data observed at electrodes.

We found the following results; (1) it's possible to reconstruct the structure of charge distribution with scale of 1.2 times greater than the inter-electrode distance. (2) the objective selectivity of the optimal reconstructed image with minimum PRESS criterion fails in the case of sparse electrodes.

Keywords: Self-Potential Tomography, PRESS-aided Philips-Tikhonov regularization, visualize underground water condition

Multiple geophysical observations for earthquake monitoring in Kanto, Japan

YOSHINO, Chie^{1*} ; HATTORI, Katsumi¹ ; YAMAGUCHI, Hiroki² ; HAN, Peng¹ ; TASHIRO, Ryosuke² ;
SHIMO, Michikuni³ ; KONISHI, Toshiharu⁴

¹Graduate School of Science, Chiba University, Chiba, Japan, ²Fuji Security Systems Co., LTD., ³Fujita Health University,
⁴Ohyo Koken Kogyo Co., LTD.

In order to understand the preparation process of large earthquakes and clarify the mechanisms of Lithosphere-Atmosphere-Ionosphere (LAI) coupling, an observation network are established in Kanto, Japan. Multiple geophysical parameters such as geomagnetic field, geoelectric field, radon concentration, ion concentration, and atmospheric electric field are monitored. The meteorological data at each station are also recorded. These data may provide some new knowledge of earthquake process. We will demonstrate the observation system and some recent data in our poster.

Keywords: multiple geophysical observations, earthquake monitoring, preparation process of large earthquakes, mechanisms of Lithosphere-Atmosphere-Ionosphere coupling