International Workshop on

Earthquake Preparation Process 2017

- Observation, Validation, Modeling, Forecasting -

Program & Abstracts

IWEP2017

May 26-27, 2017

Chiba University, Chiba, Japan

International Workshop on Earthquake Preparation Process 2017

- Observation, Validation, Modeling, Forecasting - (IWEP4)

Sponsor

Chiba University, Japan

Co-sponsor

The Earthquake Prediction Society of Japan

integrated Study and Test for Earthquake Precursors (iSTEP-4), Taiwan

Supported by

National Central University, Taiwan

Chapman University, US

Tokai University, Japan

Date: May 26-27, 2017

Venue: Conference Hall, the 1st floor of Sciences and Technology Building No.1, Nishi-Chiba Campus, Chiba University, Chiba, Japan

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P8: **Nico Genzano** et al., A retrospective long-term (2005-2015) correlation analysis of Significant Sequences of Thermal Anomalies and Earthquakes (M>5) occurrence over Japan

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Notes:

Oral presentation: 30 or 20 minutes including 5 minutes question-and-answer time.
Using PC and projector are available.

Poster presentation: Poster board size: 90(W) x 180(H) cm; all the posters will be shown in the conference room between May 26 morning and May 27 afternoon.

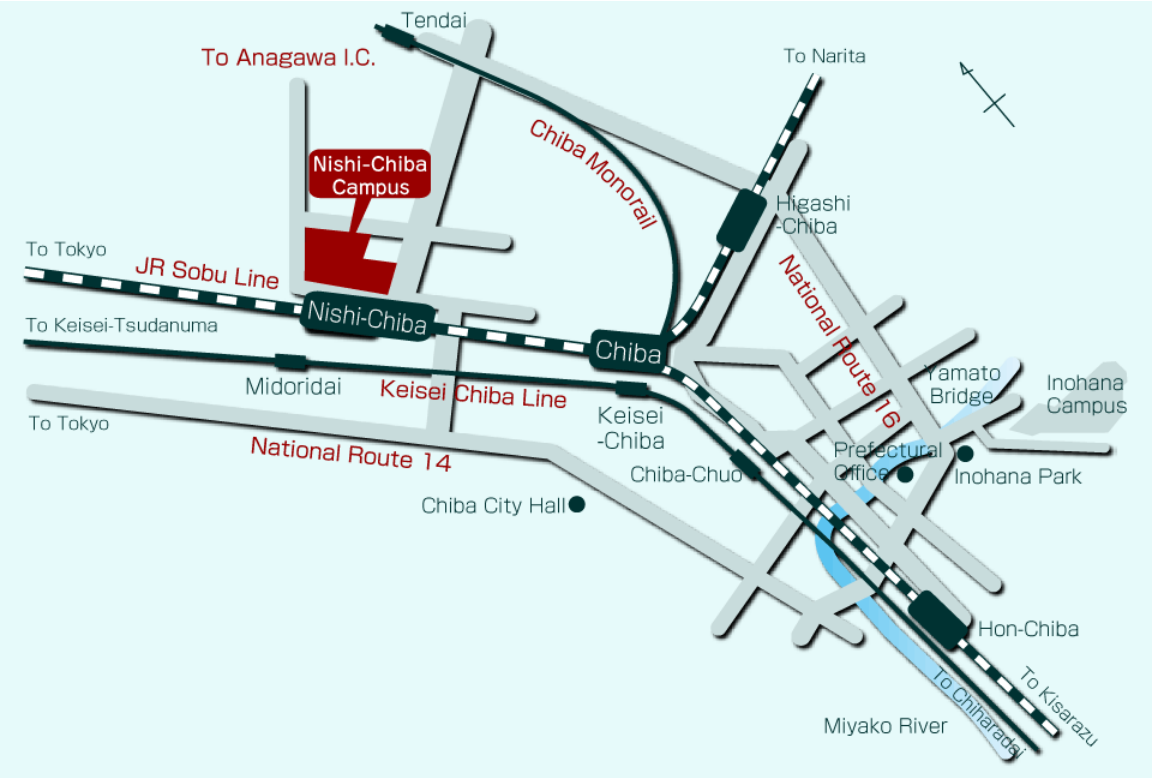
Welcome Party: If you wish to attend the welcome party on May 27 evening, please inform us by email as soon as possible. The price will be around 6,000JPY per person (3,000JPY for students).

Access:

http://www.chiba-u.ac.jp/e/about/campus/access/index.html

http://www.chiba-u.ac.jp/e/about/campus/nishichiba/index.html

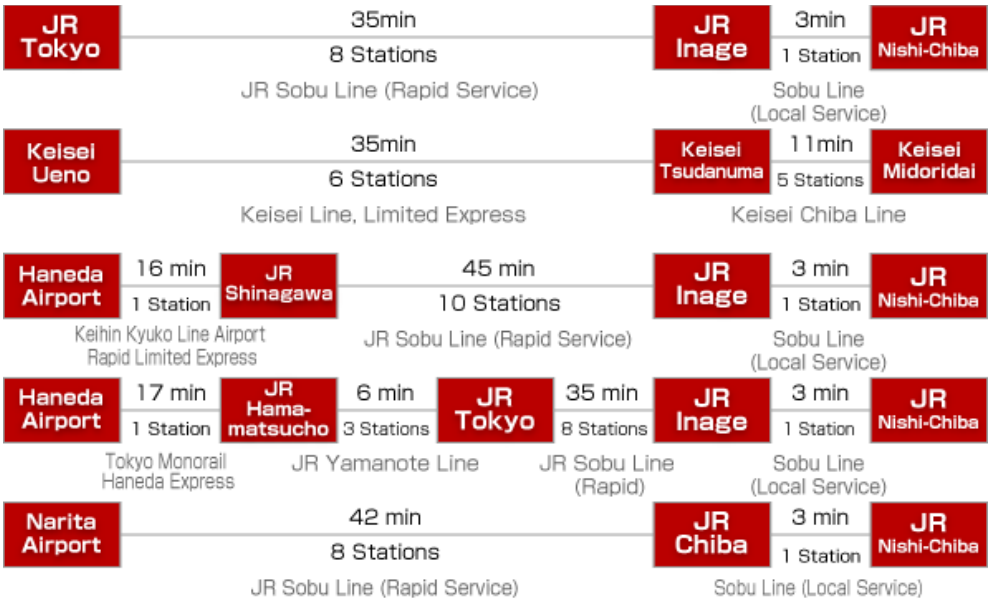
Access to Nishi-Chiba Campus, Chiba University



2-min walk from JR Nishi-Chiba Station to the South Gate of Nishi-Chiba Campus

7-min walk from Keisei Midoridai Station to the Center Gate of Nishi-Chiba Campus

10-min walk from Chiba Monorail Tendai Station to the North Gate



Access to the Conference Hall

Abstracts of oral presentations

Radon activity - the hidden driver behind the atmospheric pre-earthquake anomalies

D. Ouzounov[1], S.Pulinets[2], K.Hattori[3]

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[2]Space Research Inst., Russian Academy of Sciences, Moscow, Russia
[3]Department of Earth Sciences, Chiba University, Chiba, Japan

We are presenting experimental measurements and theoretical estimates showing that radon measurements recorded before large earthquake are correlated with release of the heat flux in atmosphere during ionization of the atmospheric boundary layer .The recorded anomalous heat (observed by the remote sounding -infrared radiometers installed on satellites) are followed also by ionospheric anomalies (observed by GPS/TEC, ionosond or satellite instruments). As ground poof we are use radon measurements installed and coordinated in five different seismic active regions California, Taiwan, Italy, Greece and Japan. Radon measurements are performed indirectly by means of gamma ray spectrometry of its radioactive progenies ^{214}Pb and ^{214}Bi (emitted at 351 keV and 609 keV, respectively) and also by Alfa detectors.

We use a Sensor web of observations of five physical parameters- radon, seismicity, temperature of the atmosphere boundary layer, outgoing earth infrared radiation and GPS/TEC and their temporal and spatial variations several days before the onset of some of major (M>6) events in those regions. Our preliminary analyses suggest that pre-earthquake phase follows a general temporal-spatial evolution pattern in which radon plays a critical role in understanding the LAI coupling. This pattern could be reviled only with multi instruments observations and been seen and in other large earthquakes worldwide.

This work is part of international projects to study the complex chain of interactions lithosphere – atmosphere -ionosphere (LAI) in presence of ionization in atmosphere loaded by radon and other gases and is supported by International Space Science Institute (ISSI) in Bern and Beijing.

Exploring the relationship between soil degassing and seismic activity by continuous radon monitoring in the Longitudinal Valley of eastern Taiwan

Ching-Chou Fu[1], Tsanyao Frank Yang[2], Min-Chien Tsai[3], Lou-Chuang Lee[1], Tsung-Kwei Liu[2], Vivek Walia[4], Cheng-Hong Chen[2], Wen-Yen Chang[5], Tzu-Hua Lai[6]

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2. Department of Geosciences, National Taiwan University, Taiwan

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5. College of Environmental Studies, National Dong Hwa University, Taiwan

6. Central Geological Survey, MOEA, Taiwan

Key words: *radon, carbon dioxide, Longitudinal Valley, Rueisuei earthquake, Fanglin earthquake*

Donghua (DH) continuous soil gas monitoring station is located on the suture zone in eastern Taiwan. The variations in radon concentration are synchronized to variations in carbon dioxide (CO_2), which is considered as the companion gas for radon (Rn). Results reveal that semi-diurnal variation of soil-gas, probably generated by the solar tide effect, achieve values of ~ 500 Bq/m^3 for Rn and 0.4% for CO_2. The variations exceeding the threshold by statistical analysis can be used to identify events associated with geodynamic processes such as earthquakes. A significant increase in soil-gas concentrations was recorded 2 months before the Rueisuei earthquake (M_L = 6.4, October 31, 2013) and recurrent anomalies were observed 3 weeks before the Fanglin earthquake (M_L = 5.9, May 21, 2014). Both earthquakes occurred in the Longitudinal Valley area of eastern Taiwan. This study suggests that longer periods of soil gas anomalies are positively correlated with impending earthquake of larger magnitude. From the high precision GPS data showed an appreciable decrease in extension rate was also observed approximately 4 months before the Rueisuei earthquake. It is worthy to have a continuous monitoring on multiple parameters (soil radon, carbon dioxide, atmospheric pressure, humidity, temperature and precipitation) at DH station.

Changes in Ground water level and Linkage with the Meteorological/Atmospheric Parameters Associated with Earthquakes

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Numerous parameters are measured in boreholes, on ground, and also through satellites to find a reliable precursory signal. Earthquakes occur at any location on the solid earth and beneath the ocean. Characteristics of the earthquakes vary from one location to other location due to changes in the geological settings and geophysical environment. Numerous parameters show co-seismic changes and also anomalous variations prior to earthquakes. Changes in ground water level associated with earthquakes in China and Nepal and US (Mineral Virginia and La Habra) have shown co-seismic changes. If the water level is shallow, the changes in water level show complimentary changes in meteorological parameters. In contrast, if the water level is deep, ground, atmosphere and meteorological parameters do not show any appreciable changes. Also, variability in the hydrological regime controls the damage pattern of the buildings, formation of cracks and oozing of the gases and liquefaction. Gound water level measured in boreholes in China associated with Wenchuan, Lushan and Gorkha Nepal earthquake in China and water levels measured near the epicentral region of earthquake occurred in Mineral, Virginia, USA will be discussed. Changes in water levels and corresponding enhancement in thermal temperature, relative humidity and CO concentrations show changes in few cases prior to the earthquakes when the water level is shallow.

Multi geophysical field precursors before strong earthquakes and their relationship

Xuemin Zhang[1], Jing Liu[1], Yanqiang Wu[1], Hui Li[2]

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[2] Institute of Seismology, CEA

The mechanism of earthquake preparation is still in debate. As the prominent precursors, multi geophysical fields have been detected and applied in earthquake research. With the development of satellite monitoring technology, the detection accuracy and spatial-temporal resolution in surface deformation field, gravity field and electromagnetic field have been improved a lot since last century, which makes the general analysis on multi fields possible before strong earthquakes. Taking 2008 M7.9 Wenchuan and 2010 M7.1 Yushu earthquake in China as examples, the multi geophysical field analysis has been carried out, and the relationship among them has been discussed. The geophysical field includes deformation field from GPS, gravity field, infrared, and electromagnetic field at ground and onboard satellite. The results show that, about 2.5 years before, deformation and gravity field began to present their anomalies, while around 1.5-0.5 year, infrared and ULF exhibited their disturbances, at last, electromagnetic field at ground and satellite gave perturbations just a few days or a few hours before the earthquakes. Accompanying the different progress stages of the earthquakes, anomaly concentrations occurred in different parameters, which are typically correlated with the variations of stress accumulation rate in different stages. It illustrates the necessarity of multi geophysical field monitoring in earthquake research. But there still exist some problems that need to be investigated and verified in future as following, 1) the disunity in time and spatial distribution of different fields; 2) no record on same signals from ground to ionosphere detected; 3) the complexity on trigger and coupling mechanism among different geophysical fields.

Cluster-cluster aggregation in fracture networks and earthquake precursor generation

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Preseismic changes are appearing with lead time up to 20 - 30 days when both regional seismic activity and coseismic changes are growing after exceeding some intensity threshold. The increase of the coseismic and preseismic changes is definitely correlating with the decrease of hypocenter depths. It probably indicates a mechanism of upward migration of earthquake (EQ) hypocenters that was observed in the very beginning of the Millennium and it supports the idea on the episodic upward migration of fluid sizable amounts which play an active role in EQ triggering [1]. Fifteen years ago this had led to the creation of a percolation model of EQ triggering due to the upward migration of gas-fluid transparency zones [1 - 4]. This model is based on the idea that a large family of the EQ peculiarities is closely related to degassing process of the Earth, which is a real challenge to the traditional models. For a long time the surface gas exposure was regarded as one of the most important EQ precursors and it was recognized only recently that gas could play a fundamental role in the EQ preparation process due to percolation instability. In the framework of this percolation strategy [5] we propose a new model of an EQ source formation considered as the result of cluster-cluster interaction between two (or more) transparency zones. The model assumes two stages of the EQ source formation. At the preliminary stage, two or more transparency zones appear successively in the seismoactive region as transparency cluster in fracture network. The time of development of such structures makes time intervals from several months up to years. The start of the main stage of an EQ corresponds to the occurrence of the fluid conducting channel between the mature transparency zones. The fluid current pulse between the adjacent ends of the structures at this stage is obtained over a time much shorter than the duration of the preliminary stage. Two model situations are considered. The first is the one when two (or more) finite clusters merge together. In the second case, clusters merge together with the original ground fissuring area. In the frame of the model discussed, the lithosphere emission sources are represented by heterogeneous and non-stationary current systems, which are caused by sporadic fluid transport in fracture networks. The asymmetry between the maximum stresses of compression and extension are taken into account to explain preseismic changes of upward migration.

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Temperature dependence of stress-induced current in gabbro

Chihiro YAMANAKA, Daiki MAEZONO

Department of Earth and Space Science, Osaka University

Despite of a lot of criticism which point out a lack of causal relationship with seismic activity, seismo-electromagnetic phenomena have been studied for years. Recent discovery of preceding TEC (Total electron content) anomalies in ionosphere above epicenter before large earthquake (> M8), has attracted the attention[1)2)].

If such TEC-anomalies were not caused by space or solar activity, the reason should be attributed to terrestrial. Mainly, magnetic storms by solar activity appear as the global effects and can be distinguished from local effect. In addition, if such anomalies are remarkable at just before the large earthquakes, the cause should be due to the physical effects in lithosphere around hypo-central region.

Charge separation at seismic zone is an interpretable model of TEC anomalies before large earthquakes. Electromagnetic fields caused by charges along the seismic zone may interact with the electrons in ionosphere[3)].

Stress induced current in rock is caused by various mechanism, such as piezoelectric, stream potentials, and active-hole conduction[4)]. In this research, we aimed the experiment of stress induced current for gabbro at temperatures as high as actual seismic zone. Because of the nature of the adopted rock and experimental conditions, effects of piezoelectric and stream potentials are negligible.

We prepared a closed electric circuit which sandwiched the rock of 3×6×10 cm by cupper electrodes, then increased the pressure and temperature up to 5 MPa and 200℃, respectively. As a result, induced current showed the positive correlation with temperature and the behavior was an exponential increase from pico-ampere to 600 pA. The result indicates the thermal excitation of charges in rock just like the case in semiconductors.

References

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Proceeding of the 3rd Earthquake Prediction Society of Japan (2016) (in Japanese).

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The Current Status of the 1st CSES Satellite Mission

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Scientific objectives of Mission

To obtain world-wide data of space environment of the electromagnetic field, ionospheric plasma and charged particles.

To monitor and research environment in real-time while the satellite pass over the China and concerned territory.

To monitor and study the ionospheric perturbations which may possibly associated with earthquake activity, especially with those destructive ones.

To analyze the features of seismo-ionospheric perturbations, in order to test the possibility for short-term earthquake forecasting.

To support the research on geophysics, space sciences as well as electric wave sciences and so on.

To provide the data sharing service for international cooperation and scientific community.

CSES-1 Working Schedule before the End of 2017

Data Policy will be published in about the end of June

FDR of Sat. and Rockets in the end of June

Onboard test and inter-calibration plan will be fixed in the end of June

Sat. will be launched in Middle Aug.

Onboard test will be done from Aug to the end of 2017

International inter-calibration will be done twice in Nov and Dec.

First collection of CSES data will be released in the end of 2017 together with 3rd CSES workshop.

Preseismic ionospheric anomalies: Current overview & perspective

Kosuke Heki[1], Liming He[1,2]

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An increasing number of GNSS receivers continuously operating worldwide, makes it possible to observe changes in the ionospheric TEC associated with large earthquakes, e.g. coseismic ionospheric disturbances ~10 minutes after earthquakes by acoustic disturbances (Cahyadi & Heki, 2015 GJI). Heki (2011 GRL) also found TEC enhancement starting ~40 min before the 2011 M_w9.0 Tohoku-oki earthquake. He also confirmed similar TEC enhancements occurred before all the earthquakes in this century with M_w 8.5 or more (Cahyadi & Heki, 2013JGR; Heki & Enomoto, 2015 JGR). Several critical papers have been published during 2013-2015, claiming that (1) the preseismic increase is an artifact popped up by defining the reference curves using the data after earthquakes, and (2) the anomalies originate from geomagnetic activities rather than earthquakes. In our rebuttals papers (Heki & Enomoto, 2013; 2014; 2015 JGR), we demonstrated statistical significance of the preseismic increases of vertical TEC rates. We also counted the occurrences of similar changes in TEC caused by space weather during times of no earthquakes and demonstrated it statistically unrealistic to attribute all the observed preseismic anomalies to space weather.

Recently, He and Heki (2016 GRL) analyzed the spatial distribution of preseismic ionospheric anomalies of 3 large earthquakes in Chile, i.e. the 2010 Maule, the 2014 Iquique, and the 2015 Illapel earthquakes. There, both positive and negative anomalies started simultaneously at altitudes of ~200 km and ~400 km, respectively, with 3-D structure similar to Kuo et al. (2014 JGR) predicted as the upward vertical electric current from the ground. We found three different kinds of M_w dependence of the anomalies so far. At first, Heki and Enomoto (2015) found that the amount of the preseismic VTEC rate changes depend on M_w and background VTEC, i.e. larger precursors occur before larger earthquakes under similar background VTEC. Secondly, Heki and Enomoto (2015) found that earthquakes with larger M_w have longer precursor times (i.e. start earlier). Third, He and Heki (2016) showed that the anomalies of larger earthquakes have larger spatial dimensions. Recently, He and Heki (submitted) studied 32 earthquakes with M_w7.0-8.0 in this century, and found that 8 earthquakes showed possible preseismic changes starting 20-10 minutes before earthquakes. We could observe them before M_w7.0-8.0 earthquakes when background VTEC are very large. We found that the TEC anomalies started also ~40 minutes before the 2011 Tohoku-oki earthquake above northern Australia, geomagnetic conjugate point of the earthquake. This supports that the anomaly is due to electric fields in the ionosphere.

Enhancement and Equator ward motion of midlatitude trough – Case of March 11 2011 EQ

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Keywords: Earthquake, Ionosphere, Mid-latitude trough

Influence of the quake which occurred on 11 March 2011 off the west coast of Tohoku is found over the huge area of ionosphere, showing various features in ground and satellite observations. These are two days oscillation of electron density observed by ionosonde stations in high and mid-latitude regions (Beijing, Kokubunji, Khabarovsk) , enhancement of atomic oxygen ion density and formation of mid latitude trough recognized in atomic oxygen ion density measure by DMSP15 satellite and in Global Ionosphere Model[Rodger et al., 1992]. The paper focuses formation of mid-latitude trough, equatorward motion, and enhancement of plasma density at the equatorward edge of mid-latitude trough. The formation of the mid-latitude trough is consistently explained as due to the enhanced night time westward dynamo electric field, which is reversed to eastward during daytime. We propose one mechanism that the electric field is enhanced by the modification of neutral wind at the heights of ≈ 100 Km. The wind system is modified as a result of nonlinear interaction between planetary scale wave and the internal gravity wave of extremely small amplitude [Karpov and Besarab, 2008]. Several side evidences which support the idea are presented such as behavior of received VLF signal [Klimenko et al., 2011; Rozhnoi et al., 2007; Sun eta al., 2011].

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2D and 3D Characteristics of Ionospheric anomalies preceding the large earthquake

Katsumi Hattori[1,2], Peng Han[1,3], Shinji Hirooka[1], Mustafa Yagmur[1],
Chie Yoshino[1], Takaaki Kobari[1], Ayano Honma[1], Jann-Yenq Liu[4]

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Many papers on ionospheric anomalies possibly associated with large earthquakes have been reported. As for the Ionospheric approach, it is important to reduce the effect of geomagnetic storms. 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 in magnitude and 4 types in the onset time (local time). A bootstrap method is used to calculate the average variation of the TEC for each type of storm. Then, we could find the accurate period affected by each type of storm. Next we performed statistical analysis of the TEC anomalies possibly associated with large earthquakes in Japan area during 1998-2013. There are statistical significance of positive TEC anomalies 1-5 days before and 16-20 days after M>=6.0 earthquakes. The significance of 16-20 days after earthquakes may be due to aftershock effects of the Tohoku earthquake. Then, we used the Molchan's error diagram to evaluate the efficiency of TEC anomalies for short-term earthquake forecasts. The result indicates that the predictions based on TEC anomalies are better than random guess, which suggests that the TEC anomalies contain certain precursory information of earthquakes. As for the tomographic approach, we investigate the spatial and temporal distribution of ionospheric electron density prior to the 2011 Tohoku earthquake (Mw9.0) and additional large earthquakes in Japan. We found the common TEC increase on 1-5 days prior to the earthquakes was remarkable and the electron density was decreased around the east-region of reconstructed area above the epicenter around 250 km altitude and increased the wide area around 3-400 km, respectively. We also analyzed several cases for ionospheric storms using the tomography. The detailed results will be presented in my talk.

Ionospheric disturbances at different altitudes observed with HF Doppler

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Many studies have reported that ionospheric disturbances observed after large earthquakes. One of the main causes for these disturbances is acoustic wave excited by Rayleigh wave propagated on the ground from the epicenter. The acoustic wave disturbs ionospheric electron density in propagating through the ionosphere. Using HF Doppler sounding system (HFD) which observes radio waves at different frequencies, ionospheric disturbances at the different altitude can be observed simultaneously. In the present study, the system by which radio waves at four different frequencies are observed is utilized, implying that the ionospheric perturbations at up to four different altitudes are observed by this system. In examining earthquakes occurred around Japan since 2003, we have found 3 events in which the ionospheric perturbations were observed with the multiple frequencies. From their waveforms, the higher components of the perturbations decay, as the altitude is higher. In conjunction with the seismometer data observed below the reflection point of the HFD radio waves, the amplification ratio of the atmospheric wave from ground to the ionosphere have calculated in 3 bands (10.0-25.6, 25.6-45.5, and 45.5-76.9 mHz). Theoretical amplification ratios were also calculated based on energy conservation law, considering absorption by viscosity, thermal conductivity, and relaxation losses of atmosphere (Chum et al., 2012). In comparison of the theoretical estimation, amplification ratio determined by HFD is rather smaller. However, their height profiles are qualitatively consistent each other; higher frequency components are more greatly damped in at high altitude. There might be the reasons for this difference; attenuations of wave energy that is not considered, differences between model parameters and real values, and lesser conversion efficiency when ground motions excite infrasound waves.

IWEP2017

" Antenna Pattern Matching Technique and Its Applications to Finding Anomalies on the Earth's Surface"

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A remote sensing satellite often uses multi-frequency measurements of microwave energy (brightness temperature) emitted by the Earth's surface. The field of view (FOV) at each frequency differs in size because of its hardware design.

The correlation coefficient C_{ij} is defined by,

$$C_{ij} = \iint_{\Delta_i \Delta_j} P_i(x,y)\, P_j(x,y)\, dxdy$$

where $P_i(x,y)$and $P_j(x,y)$ are the antenna footprints at i- and j-frequencies, respectively. If two footprints are different in size, their correlation coefficient does not clearly reflects the extent of phenomena which are sensitive to frequency : e.g. the distribution of cumulonimbus cloud. Or, it is not sure whether the extent of the correlation coefficient reflects the size difference of the foot prints or the actual distribution difference at two frequencies.

For the retrieval of more accurate geophysical parameters from multi-frequency brightness temperatures, the brightness temperatures should be modified to be the same as measured in the same FOV. The Backus–Gilbert (BG) method is one of the antenna pattern matching techniques used for this modification. We applied the BG method to remote sensing data to define a new data set of modified brightness temperatures, a level 1R (L1R) product that is freely and widely available. We optimized the implementation of the BG method to obtain the L1R product, with smoothing factors dynamically determined for all modified brightness temperatures.

The modification is dependent on the sensor hardware so that most users of the remote sensing data cannot convert the raw data to the ones with the identical antenna foot prints. Instead, if the L1R product is given after the modification, many users can participate in the collaborative data analysis.

This paper describes first the principle of the antenna pattern matching technique, and its implementation method, including the criterion to determine the smoothing factors. Then, the availability is shown in the case of the Global Change Observation Mission 1st-Water (GCOM-W1) satellite, which carries an Advanced Microwave Scanning Radiometer-2 (AMSR2) and was launched in 2012.

Investigation of ionospheric TEC anomalies before large earthquakes over Pakistan

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Abstract Pre-earthquake ionospheric Total Electron Content (TEC) anomalies before strong earthquakes of magnitudes ≥ 5 were observed over Pakistan in 2015-2016. The strongest earthquakes of magnitudes 7.8 and 7.3 were occurred in Nepal in 2015. Another three earthquakes of magnitudes ≥5 were occurred in Pakistan in 2015-2016. We produced TEC time series to detect the pre-earthquake signals by using the data of dual frequency GPS receivers. These receivers are installed at Islamabad, Multan and Quetta stations in Pakistan. The solar and geomagnetic conditions were quiet during the occurrence of selected earthquakes. In general the pre-earthquake ionospheric anomalies were appeared 2-5 days prior to M7.8 and M7.3 earthquakes. Similarly, in case of local earthquakes the TEC anomalies were observed 7 to 8 days earlier before the occurrence of earthquakes in Pakistan. The present results suggest that ionospheric TEC is useful to register pre-earthquake ionospheric anomalies before large earthquakes.

The 3-stage earthquake preparation process observed at the 2011 Tohoku-Oki earthquake

Yoshiki SUE (-)

1. Introduction

At the 2011 Tohoku-Oki earthquake (M=9.0), anomalous ground motion affected availability of the F-net broadband seismograph network in Japan. Degradation occurred twice in the period from mid-December, 2010 to early March, 2011. Then the main shock occurred on March 11. These phenomena are further studied with such other results as GNSS and seismic activities, and the following results are obtained.

2. Results of Analysis

The period of 3 months before the earthquake was consisted of 3 stages.

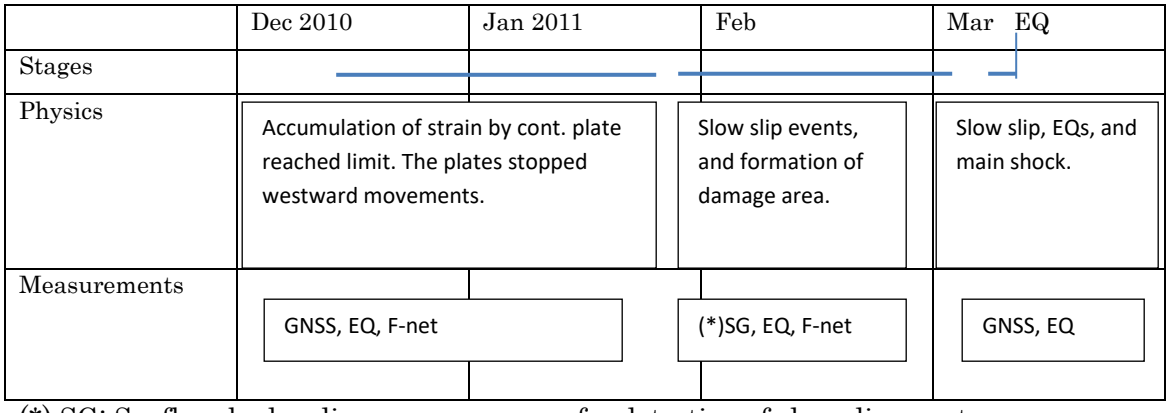
[First stage, From mid-December, 2010 to around January 28, 2011] Accumulation of strain by the continental plate reached limit in the Tohoku region. The continental and oceanic plates stopped westward movements. The wide area in Japan showed anomalous vibration or slip. The epicenter of the imminent earthquake was not formed.

[Second stage, From around January 29 to around March 2] The continental plate started to react to the oceanic plate. Slow slip events occurred at the plate boundary and medium earthquakes occurred near the epicenter of the imminent earthquake.

[Third stage, From around March 8 to March 11] Large slip of the continental plate started on March 8, which was recorded by GNSS. Then the foreshock of M=7.3 and smaller earthquakes followed. On March 11, the main shock occurred.

3. Conclusion

Ground motions, which could be observed by several means, showed preparation process of the earthquake. Such data will give useful information for EQ forecasting.



(*) SG; Seafloor hydraulic pressure gauges for detection of slow slip events

Characteristics of atmospheric parameter changes in Atmospheric Electric Field (AEF), Atmospheric Ion Concentration (AIC), Atmospheric Radon Concentration (ARC), Radon Exhalation Quantity (REQ) at Asahi, Boso Peninsula, Japan

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The Ionospheric anomaly is one of the most promising precursory phenomena for large earthquakes. Lithosphere-Atmosphere-Ionosphere Coupling (LAIC) model has been proposed to explain these phenomena. To examine the possibility of chemical channel of LAIC through the monitoring of atmospheric electricity parameters, we have installed sensors for the atmospheric electric field (AEF), atmospheric ion concentration (AIC), radon concentration, radon exhalation quantity (REQ), and weather elements. We will report the properties of variation in atmospheric electricity parameters observed at Asahi station (ASA), Japan to identify earthquake-related signals in these parameters. We found that the variation of radon exhalation quantity shows a clear negative correlation with 3 hours delay to the air pressure variation in clear days. Each season differs in daily pattern. AIC and AEF variations show lag correlation with radon exhalation quantity variation. To extract anomalous radon variation related to earthquakes, we should set a network of Radon monitoring and establish a model of radon variation for the future detailed analysis. We also observed cases that AEF has showed a spike-like increase at the same time as the time when AIC has largely increased. It must be going to be checked whether AEF data was taken in fair-weather period, however, it is suggested that change in local charge distribution may have influenced AEF.

Seismo Electromagnetics and Related Phenomena: Review

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Abstract

This paper is mainly based on Chapter 5 (Conclusions and recommendations for future research) in a book by Molchanov, O. A., and M. Hayakawa (Terrapub, 2008) entitled "Seismo-Electromagnetics and Related Phanomena: History and latest results". The contents are not old, but still valid now.

A pillar of the EQ short-term forecast is precursor statistics and the appropriate system should include the following:

a) Selection and classification of the reliable precursors.
b) Development of theoretical basis of precursory activity.
c) Organization of precursory station network (in addition to seismic network), development of special interstation communications, inter-system relations (i.e. with meteorology system) etc.

The estimation of occurrence rate (or alarm rate) is a rather speculative parameter here, though we selected the most reliable precursors as it was explained in previous chapters. The point is that in the absence of recording station network almost all the results are dependent on individual properties of registration and it is rather difficult to obtain the estimation on reasonable statistics. In other words, almost all the data are either a case study or a result of one site registration. Nevertheless we can stress, at least, three significant results of precursor selection procedure in the study of Seismo-Electromagnetics and Related Phenomena (SERP):

1) We demonstrate that only several registarion parameters provide more or less reliable information on EQ preparation: ULF magnetic field and electric field variations, seismic and acoustic recordings, hydrology/geochemistry data, VLF/LF sounding of the upper atmosphere, HF scattering in the troposphere, etc. Satellite methods, both onboard registration of plasma-wave turbulence intensity together with VLF signals and remote sensing, are also valuable for estimation of the regional seismic situation and as a support of the ground measurements. For comparison we remind that in a study frame of previously-used precursors more than one hundred precursors were suggested to analyse (Rikitake, 1982; Scholz, 1990).
2) Unlike the traditional research in our SERP study an essential attention is paid to the effects in the "atmosphere and ionosphere". We have tried to show that a combination of geophysics and radiophysics leads to enrichment of the research by new methods, ideas and data processing techniques.
3) Evident two-stage development has been found in the precursors of ground origin: Seismic foreshocks, seismo-acoustic emission, ULF electromagnetic emission and even in hydrology/geochemistry phenomena, which appear with short-term scale from several weeks to several days (we call this "short-term precursors") but especially intensify on the last day before the main shock (we call this "imminent precursor"). That is why we introduce a distinction between short-term and near-seismic (imminent) precursors.

There is a special terminology in order to estimate the precursor efficiency (Console, 2001). These are, (1) success rate, (2) false alarm rate, (3) alarm rate, (4) failure rate, (5) probability gain. We will show the most important probability gain for nearly all the seismogenic phenomena discovered so far.

Finally we show a procedure of alarm rate and probability gain estimation, with taking an example of ULF/ELF atmospheric precursor (ELF impulsive radiation) observed actually for several years at Kamchatka, Russia.

Ref. Molchanov, O. A., and M. Hayakawa, Seismo-Electromagnetics and Related Phenomena: History and latest results, TERRAPUB, Tokyo, 189p, 2008.

Probability tomography and wavelet analysis of self-potential data

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Self-potential method is a kind of near-surface geophysical technique, which has been adopted in exploration of metal ore, monitoring of contaminants and natural hazards. This study focuses on the self-potential data processing. The source element occurrence probability tomography can give the probability of the source location and the charge property. In order to improve the limited resolution of the probability tomography for the multiple sources, we combine the charge occurrence probability tomography with the complex wavelet transform method in self-potential data processing. We apply the complex wavelet analysis the synthetic self-potential data obtained from the forward modeling of some given models. We also apply the combined probability tomography and the continuous complex wavelet analysis to the synthetic self-potential data. As an example, we apply the above combined method to the data from sandbox experiments and test the possible time-lapse tomography. This study is aiming at providing an effective continuous monitoring method of ground water flow.

On the motional-induction effect and its induced electromagnetic fields during an earthquake

Yongxin Gao, Xiaofei Chen, Hengshan Hu

When seismic waves propagate in the conducting crust, they make the crust material move and cut the ambient geomagnetic field, and hence product electromotive force and induction electric currents, which give rise to variations of electromagnetic (EM) field. The coupling between the seismic waves and EM disturbances is called motional induction effect and it is a possible mechanism for the anomaly EM disturbances that were observed during earthquake events. In this work, we study the properties of the EM field generated by an earthquake due to such a mechanism. By solving the governing equations that couple the elastodynamic equations with Maxwell equations, we derive the seismoelectromagnetic wavefields excited by a single point force and a double couple source in a full space. Two types of EM disturbances can be generated, i.e., the coseismic EM field accompanying the seismic wave and the independently propagating EM wave which arrives much earlier than the seismic wave. Simulation of an M_w 6 earthquake shows that at a receiving location where the seismic acceleration is on the order of 0.01 m/s^2, the coseismic electric and magnetic fields are on the orders of 1 μV/m and 0.1nT, respectively, agreeing with the EM data observed in the real earthquake, and indicating that the motional induction effect is effective enough to generate observable EM signal. The motional induction effect is compared with the electrokinetic effect, showing the overall conclusion that the former dominates the mechanoelectric conversion under low-frequency and high-conductivity conditions while the latter dominates under high-frequency and low-conductivity conditions.

This work is supported by the National Natural Science Foundation of China (grants 41474038 and 41204039).
Keywords: earthquake, electromagnetic fields, electrokinetic effect

Testing Pre-earthquake Atmospheric Signals for Alerting Large Earthquakes: Case Studies for Japan and Taiwan

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In this study we are exploring retrospectively/prospectively the potential of atmospheric and ionospheric signals to alert for large earthquakes. To achieve this, we start computing Molchan Error Diagram (MED) retrospectively and prospectively for anomalous ionospheric /atmospheric signals. The Multi Sensor Networking Analysis (MSNA) is our method for validation and is based on a joint analysis of several physical and environmental parameters (Satellite transient infrared radiation anomalies (STIR), Seismo-ionospheric anomalies (SEA) based in electron concentration in the ionosphere (GPS/TEC), radon/ion activities, air temperature and seismicity patterns) that were found to be associated with earthquakes. The MSNA is based on multi disciplinary approach, because it is widely recognized that our understanding of geophysical processes is improved by integration of studies from seismology, geochemistry, geomagnetism, atmospheric science and geology. The science rationale for multidisciplinary analysis is based on the Lithosphere-Atmosphere-Ionosphere Coupling (LAIC) concept (Pulinets and Ouzounov, 20121), which explains the synergy of different geospace processes and anomalous variations, usually named short-term pre-earthquake anomalies. Our validation processes consist in two steps: (1) A continuous retrospective analysis preformed over two different regions with high seismicity- Taiwan and Japan for 2003-2011 (2) Prospective testing of with potential for M6+ events Japan for 2014-2015 period for STIR. Our results suggest that: (1) Pre-earthquake signals follow a general temporal-spatial evolution pattern (with 1-30 days time-lag), which has been seen in other large earthquakes worldwide; (2) MED test results indicates that pre-earthquake atmospheric anomalies could provide short-term predictive information of major earthquakes in the tested regions; and (3) Testing of pre-earthquake signals shell continue with an extended multi-parameter analysis.

Smart Disaster Mitigation Based on Novel Materials and Structures

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The authors have been establishing the concept “Disaster Mitigation and Sustainable Engineering” which intends to enable sustainability as well as disaster mitigation, effectively and economically. It will be successfully realized by novel structures and materials such as “Smart Structures and Materials.” Their conventional applications have been explored in aerospace fields, etc., but after the Japanese earthquake and tsunami disasters on March 11, 2011, the authors have been exploring a new direction. Serious disasters may occur today, or may not occur for a long period of time. Structures and devices for disaster mitigation consume lots of money. So, they are better to be used daily and/or produce something useful such as energy for their monitoring, maintenance, corrosion suppression, self-repair, and so on. Compact and deployable structures are also very useful.

Several structures have been considered by the authors based on the above mentioned concept, that is, Smart River Banks, Multifunctional Artificial Forests, Smart Inflatable Tsunami Airbags, in conjunction with “Applications of Electroactive Polymers in Electrical Power Generation Using Ocean Waves” presented at the SPIE SS/NDE 2015 in San Diego as an invited presentation, and also, Smart Shelters, Smart Furniture, and so on. Some of them will be introduced in this presentation.

In addition, other related challenges in the world will be introduced such as the flap-gate type prod ucts (no energy, no operation Rising Seawall “neo RiSe” etc.) developed by Hitachi Zosen Corporatio n (Hitz) in Japan, the Project MOSES in Italy, the LAYFIELD Aqua Dam in the USA, some deployable structures in Thailand, and so on. Especially, the flap-gate type products have been developed in a smart way and will be introduced in detail. Asanuma, Nakayasu et al. have been discussing how to enhance their smartness.

As for the general basic problems such as selection of materials, bonding of materials, long term durability, maintenance, repeatability, the authors have been trying in various ways. For example, in order to realize the deployable structures, lightweight materials such as aluminum alloys and carbon fiber reinforced plastics are better to be used instead of steels. To do this, relatively thick aluminum oxide layer was found to increase bonding strength and fracture toughness as well as to enhance corrosion resistance and prevent galvanic corrosion.

There exist other difficulties such as mutual understanding among mechanical engineers, civil engineers and many other people. The authors are trying to develop a research team covering variety of fields to work together by taking advantage/disadvantage of the location of Chiba University as a “Disaster Front.” Asanuma et al. have also developed System of Systems for Disaster Mitigation and Sustainability-Technical Section as a part of JSME (The Japan Society of Mechanical Engineers) M&P (Materials and Processing) Division to enhance Disaster Mitigation and Sustainable Engineering.

integrated Study and Test for Earthquake Precursors (iSTEP-4)

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The iSTEP-4 (integrated Study and Test for Earthquake Precursors) project goal is to search characteristics of seismo-ionospheric precursors in the total electron content (TEC) and develop lithosphere-atmosphere-ionosphere (LAI) coupling models finding possible causal mechanisms for the large earthquake prediction and forecast of the globe. The project is granted by Ministry of Science and Technology to National Central University, which will be carried out in a 4-year period from 1 August 2016 to 31 July 2020. The project consists of a main project and three sub-projects. The Main project operates the integrated ground-based seismo-electromagnetic observation system in Taiwan and develops physical models to find possible mechanisms. The observation system is used to monitor earthquake precursors in the lithosphere, the atmosphere, and the ionosphere, and to find the LAI coupling in Taiwan. Sub-project I employs the near real time global ionosphere map (GIM) of the TEC to monitor temporal and spatial SIPs (seismo-ionospheric precursors) of the world. It also utilizes the electron temperature, ion temperature, ion density, and ion velocity recorded by Advanced Ionospheric Probe onboard FORMOSAT-5, as well as electron density profiles and atmospheric temperature, pressure, and water vapor pressure profiles observed by FORMOSAT-3/COSMIC (F3/C) and FORMOSAT-7/COSMIC-2 (F7/C2) to three dimensionally study and confirm SIPs and SAPs (seismo-atmospheric precursors). Sub-project II focuses on SLPs (seismo-lithospheric precursors) in the geomagnetic field, GPS surface deformation, groundwater level, etc., which will be given to the simulation model of Main project and the data assimilation model of Sub-project I to find the LAI link and to expose possible source causing SIPs. Sub-project III shall conduct a statistical analysis by applying the Receiver Operating Characteristic (ROC) curve on the GPS total electron content to search for statistical evidences and find characteristics of SIPs of the world. To sum up, the integration of multi-precursors under study in this project shall develop physical models and data assimilation models to find the SIP causal mechanism, which should enable a better chance to assess the temporal-spatial earthquake hazard in different regions.

2017 IWEP in Japan, May 27

Observations of earthquake precursors in Taiwan and comparisons between observations and model calculations

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Abstract

In the search of earthquake precursors in the Taiwan area, there have been continuous measurements of the gravity, geomagnetic perturbation, crustal deformation, ionospheric disturbance, ground water level, and leaky gas (Radon) from the crust in the past two decades. Later, the gamma-ray sensors, downhole strain-meters, telluric electric field measurements and thermal infrared ray analysis are further established. In addition, an electric coupling model for the lithosphere-atmosphere-ionosphere was developed. A three-dimensional ionosphere simulation code (SAMI3) is used to study the ionosphere dynamics. The presence of dynamo current from the crust can lead to variations of total electron content (TEC). In this talk, some important results from the integrated observations and theoretical models for pre-earthquake signals are presented and compared.

Applying QL1-NMF for Analyzing Environmental ELF Magnetic Signals

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1 Nonnegative Matrix Factorization Based on Minimizing Quasi-L1 Norm

The NMF algorithm model approximately factorizes a given nonnegative matrix under nonnegativity constraints. With this model the $n\times T$ matrix $\boldsymbol{X}$, which has only nonnegative values, is approximately factorized by NMF as $\boldsymbol{X} \approx \boldsymbol{AS}$ $(\boldsymbol{X}, \boldsymbol{A}, \boldsymbol{S} \geq 0)$ where $\boldsymbol{A}$ is an $n\times r$ mixing matrix and $\boldsymbol{S}$ is an $r\times T$ component matrix.

In order to robustly analyze data including outliers, we propose nonnegative update functions as follows:

$$A_{ij} \leftarrow (1-\beta)A_{ij} + \frac{\sum_k S_{jk}\frac{X_{ik}}{E_{ik}^2+1/\alpha}}{\sum_k S_{jk}\frac{[\boldsymbol{AS}]_{ik}}{E_{ik}^2+1/\alpha}}\beta A_{ij}, \qquad S_{jk} \leftarrow (1-\beta)S_{jk} + \frac{\sum_k A_{ij}\frac{X_{ik}}{E_{ik}^2+1/\alpha}}{\sum_k A_{ij}\frac{[\boldsymbol{AS}]_{ik}}{E_{ik}^2+1/\alpha}}\beta S_{jk}, \quad \boldsymbol{E} = \boldsymbol{X} - \boldsymbol{AS}$$

2 Applying to Environmental Magnetic Measurements

Our research group has been measuring extremely low frequency (ELF) magnetic fields across Japan [1]. Figure 1 shows our observed ELF signals (6 of 28 sites) on March 17 in 2005. Each vertical axis indicates the EM energy [pT^2/Hz], and each horizontal axis indicates the time course [hour (LT)]. They have common changes that are the effect of background signal. An anomalous signal was observed at Unzen (e) before the 2005 Fukuoka Earthquake (M 7.0, on March 20). Observation site at Unzen is 112 [km] from the epicenter.

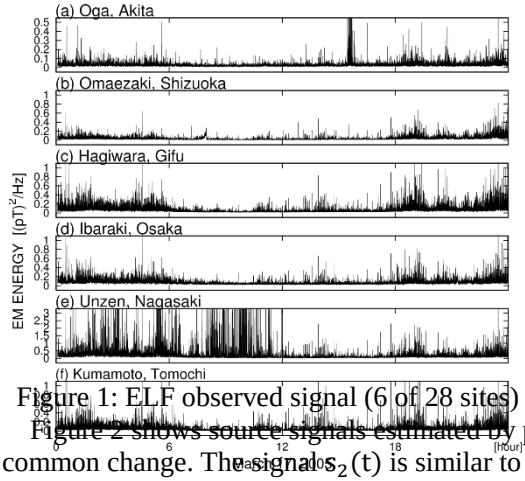

Figure 1: ELF observed signal (6 of 28 sites)

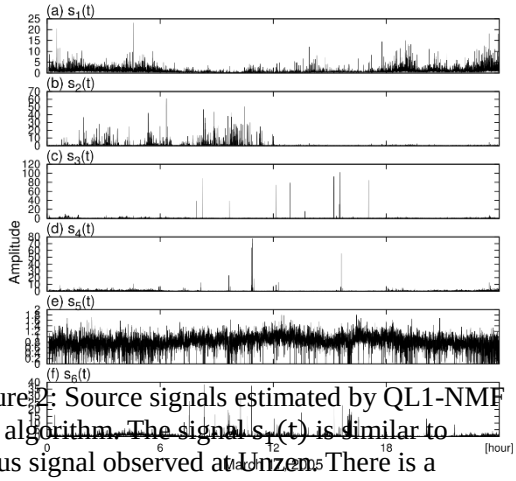

Figure 2: Source signals estimated by QL1-NMF

Figure 2 shows source signals estimated by proposed algorithm. The signal $s_1(t)$ is similar to common change. The signal $s_2(t)$ is similar to anomalous signal observed at Unzen. There is a possibility that $s_2(t)$ is earthquake-related source signal.

3 Conclusion

We proposed new QL1-NMF algorithm in this paper. Our algorithm could estimate the signal which has possibility of earthquake-relation.

Acknowledgment

This work was supported by Scientific Research (A) 26249060 from the JSPS.

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Detection of small amplitude VLF pulse arrival time by using an autoregressive (AR) model

- obtaining more precise electromagnetic wave source position –

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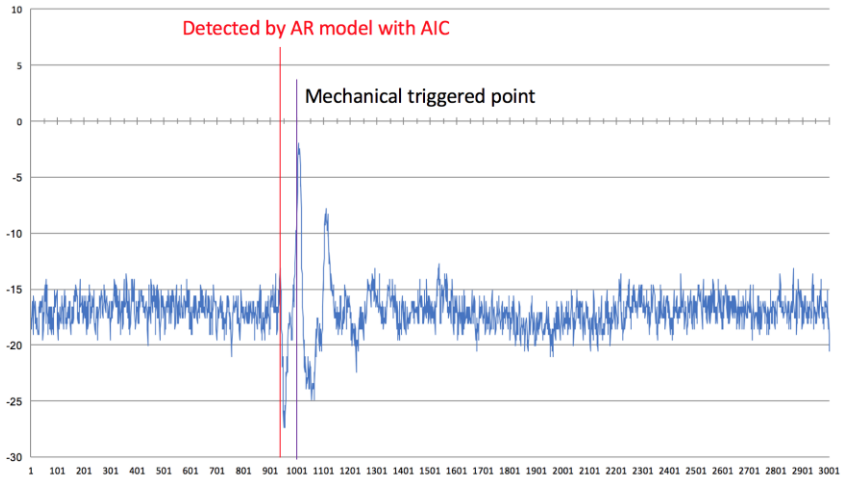
Asada et al., (EPS, **53**, 55–62, 2001) claimed that precursory pulses in VLF range frequently observed nearby inland earthquakes. They also mentioned about some features of precursory electromagnetic (EM) signals. One of the most notable feature is that the amplitude of precursory signals is very small (one order of magnitude smaller than the ordinary atmospherics).

Our newly designed measurement instrument has a very high sampling rate (10^8Hz). If we determine arrival time of EM wave precisely, we can estimate the source location by using the time of arrival (TOA) method. For strong atmospherics, we can simply use mechanical trigger time as EM wave arrival time. However, for small amplitude signals, the trigger time is not an arrival time. Therefore, we started developing a detection software of EM signal arrival time. In this field, seismology has long experiences.

We got a software from Hokkaido University (Dr. Takanami) detecting P-wave arrival time by using AR model and AIC (Akaike's Information Criterion) for criteria. We modified and adopted above software for EM waves and obtained some useful results. In the presentation, we would like to present very preliminary results.

Acknowledgements

Dr. Tetsuo Takanami kindly provided us the source file of detection of arrival time program for P-wave. This study was partly supported by the Joint Usage/ Research Center program of Earthquake Research Institute, the University of Tokyo and Ministry of Education, Culture, Sports, Science and Technology (MEXT) of Japan, under its Earthquake and Volcano Hazards Observation and Research Program.



On the lower ionospheric perturbation for the 2016 Kumamoto earthquakes on the basis of VLF propagation data observed at multiple stations and wave-hop theoretical computations

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Abstract

There have been published many papers on VLF characteristics to study seismo-ionospheric perturbations. Usually VLF records (amplitude and/or phase) are used to investigate mainly the temporal change of VLF propagation features with special attention to one particular propagation path.

The most important advantage of this paper is the simultaneous use of several propagation paths. A succession of earthquakes (EQs) happened in the Kumamoto area in Kyusyu island; an EQ with magnitude of 6.5 on 14 April and the main shock with magnitude 7.3 on 16 April. Because the EQ epicenters are not far from the VLF transmitter (with the call sign of JJI in Miyazaki prefecture), we can utilize simultaneously 8 observing stations of our network. Together with the use of theoretical computations based on wave-hop theory, we are successful in deducing both the temporal and spatial evolutions of the ionospheric perturbation associated with this succession of EQs. It is found that the ionospheric perturbation begins to appear about two weeks before the EQs, and this perturbation becomes most developed 4-6 days before the main shock, followed by a decay. When the perturbation is most disturbed, the maximum change in vertical direction is depletion in the VLF ionospheric height of the order of 10km, and its horizontal scale (or its radius) is about 1,000km. These spatio-temporal change of the seismo-ionospheric perturbbation will be investigated in details in the discussion, a comparison has made with the VLF characteristics of the 1995 Kobe with the same magnitude and of the same fault-type, and a brief discussion on the generation mechanism of seismo-ionospheric perturbation is finally made.

Searching the Existence of Seismo-Atmospheric Gravity Waves around the Altitude of the Stratosphere

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Seismo-atmospheric gravity waves (SAGWs) in the lower ionosphere few days appearing large earthquakes have been reported in previous. To find the LAI (lithosphere-atmosphere-ionosphere) link is seismo-generated SAGWs, this paper studies AGWs in the stratosphere during the earthquake preparation period. We use temperature profiles retrieved from the ERA-Interim atmospheric reanalysis dataset, and calculate the potential energy of AGWs below 60km altitude. The AGW activities with vertical wavelength ranging from 2 to 10 km and from 10 to 20 km are evaluated separately, which these two bands cover the dominant vertical scale in the stratosphere. Three major earthquakes, the 1999 Mw 7.6 Chi-Chi earthquake, the 2008 Mw 7.9 Wenchuan earthquake, and the 2011 Mw 9.0 Tohoku earthquake, are examined in 6-hour interval from 15 days before to 15 days after the earthquakes. No clear signatures of stratospheric AGWs can be found in these three cases. This suggests that the model of generating SAGWs in the ionosphere prior to earthquakes needs be reconsidered.

Recommendation for Earthquake Forecasting System and Organization

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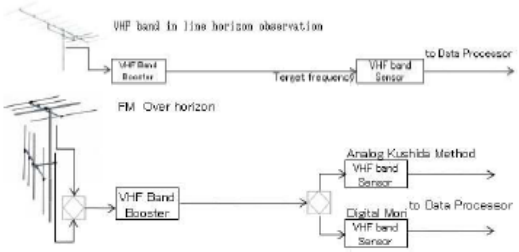
NPO Environment and Earthquake Forecast Technical Research Center

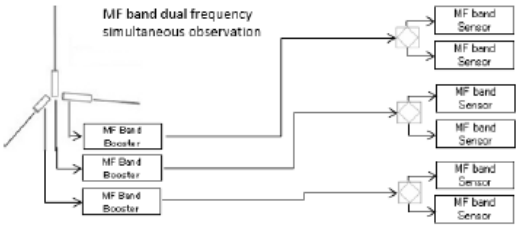
Short term earthquake prediction should be started now as practical disaster prevention information. It is the best for the country to responsibly create earthquake prediction information, however, our and your countries do never try to do so. Therefore, what you can do now is that you observe precursors of earthquake and create earthquake prediction information at your own risk based on your own data and public data such as GPS data from Geospatial Information Authority of Japan (GSI) and earthquake catalog and tidal level deviation data from Japan Meteorological Agency (JMA) in case of Japan. Multiple methods listed in this paper are recommended for your own observation as effective examples.

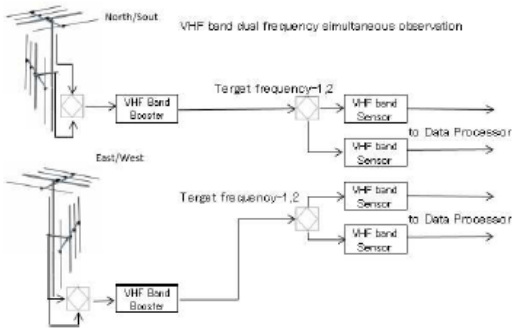
1. Recommended Observation method and system

1) Tree Bio-electric Potential observation
2) Combination observation of VHF band within and over horizon

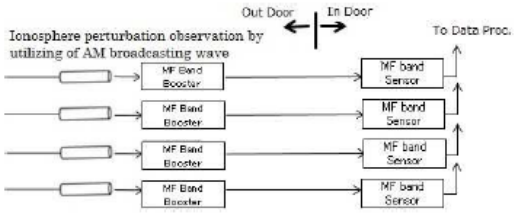


3) LF/MF/VHF/UHF band dual frequency simultaneous observation



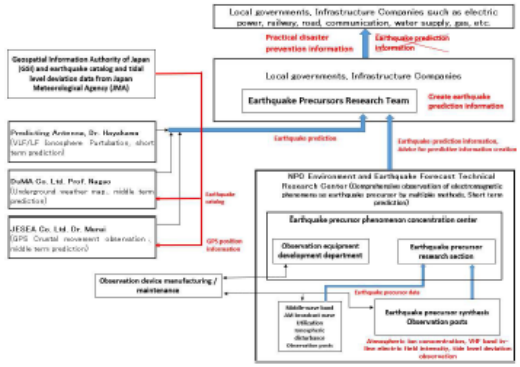


4) Ionosphere perturbation observation by utilizing of AM broadcasting wave



5) Air ion concentration observation
6) Tidal level deviation observation

2. Observation and Prediction organization chart



References;

Precursors of earthquakes in the line-of-sight propagation on VHF band, K. Motojima

Anomalous VHF radio wave transmissions as an earthquake precursor observed in the Erimo area, Hokkaido, Japan T. Moriya

VLF/LF signals method for searching of electromagnetic earthquake precursors M. Hayakawa

Statistical consideration of relationship between occurrences of earthquake and fluctuations in the radio wave propagation

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Research of the geophysical electromagnetic phenomena with seismic activity is important for hazard-resistant strategy. The purpose of our research is to find out any relation between occurrences of earthquake and anomalous line-of-sight propagation in the VHF waves.

We have been observed broadcasting radio waves from line-of-sight region for several years. Observational results of the radio wave propagation had sometimes anomalous fluctuations associated with earthquakes. Then, in order to extract the anomaly from the propagated wave fluctuation, we adopted continues wavelet transformation (CWT) to the received wave strength. Wavelet coefficients had sometime large value prior to earthquakes. For statistical consideration we used a statistical concept of probability gain PG for estimating the relationship between anomalous fluctuations and earthquakes. The most appropriate parameters, scale a of Morlet wavelet, seismic magnitude M, depth of hypocenter D, distance L between the wave path and epicenter location, were searched with respect to the PG. After the calculation of all parameters combination, the maximum PG was **9.59** for $\mathbf{a = 9.775}$, $\mathbf{M \geq 4.5}$, $\mathbf{D \leq 50km}$, $\mathbf{L \leq 100km}$ in **NHK FM Tokyo** broadcasting wave, $\mathbf{f = 82.5MHz}$. Moreover, other broadcasting waves, **NHK FM Chiba**, **NHK FM Saitama** and **FM Tokyo**, which were coming from the line-of-sight region, indicated the high probability gain PGs. The PGs indicate **8.68** for **NHK FM Saitama**, $= \mathbf{85.1MHz}$; **8.20** for **NHK FM Chiba**, $\mathbf{f = 80.7MHz}$; **3.33** for **FM Tokyo**, $\mathbf{f = 80.0MHz}$. The PGs showed the maximum value at 6~48 hours before time of earthquake occurrence. These results suggest that the anomalous fluctuations in the VHF line-of-sight propagation appear in the short-term of earthquake preparation process frequently.

However, we can't exhibit any hypothetic model which makes the anomalous propagation associated with earthquake. It is in future work.

Predict Japan strong earthquake with satellite clouds data-one year validation

Guo Guangmeng

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In the IWEP2 meeting in 2015 in Chiba， we introduced the method of predicting earthquakes with satellite clouds images. Since then we began to study Japan area, observed the satellite images everyday and make predictions when the cloud anomaly appeared. All the predictions are published in Researchgate website and notice some Japan scientists before the quake occurrence. From June 2015 to June 2016 we published six predictions on Researchgate, and USGS report five M6 strong earthquakes in Japan area (Table 1). That means nearly all our predictions are followed by strong quakes, except the M5.7 earthquake occurred on 2016-6-26 which is 0.3 smaller than M6.0. The disadvantage our method is that the epicenter location prediction is not good. If Japan scientists can provide some method to estimate the location, and combined with our method, then these predictions will be applicable in disaster reduction.

Table 1. 6 predictions in June 2015 to June 2016, and the earthquake catalogue reported by USGS

	date	Time(UTC)	Lon	Lat	Magnitude
Prediction 1:	2015-6-8	06:01	142.03	41.56	M6.1
	2015-6-10	08:33	143.32	39.68	M5.8
	2015-6-11	04:45	143.33	39.67	M5.7
	2015-6-11	04:51	143.34	39.61	M5.7
Prediction 2:	2015-11-13	20:51	128.87	31.00	M6.7
Prediction 3:	2016-1-11	17:08	141.08	44.47	M6.2
Prediction 4:	2016-1-14	03:25	142.78	41.97	M6.7
Prediction 5:	2016-4-14	12:26	130.70	32.78	M6.2
	2016-4-14	15:03	130.72	32.69	M6.0
	2016-4-15	16:25	130.75	32.79	M7.0
	2016-4-20	12:19	141.62	37.80	M5.9
Prediction 6	2016-6-26	22:57	142.22	36.99	M5.7

Evaluation Methods of Earthquake Forecasts and earthquake predictions

Jiancang Zhuang and Yosihiko Ogata

The Institute of Statistical Mathematics

Abstract

Objective evaluation of forecasting performance is an essential issue in research on earthquake predictability. Since the occurrence probabilities of large and small earthquakes are completely different, the score for a successful prediction of a large earthquake which rarely occur should be significantly different from that of small earthquakes. Similar reason applies to predictions in non-active and active seismic regions. First of all, it is necessary to build reference models for forecasting future seismicity in different regions. For probability forecasts, their significance can be evaluated by using the log likelihood ratio of the performance to the reference, or the information gain, for which the Akaike information criterion (AIC) is useful to estimate the information gain and to determine the significance of the proposed model will have against the reference models. Due to the under-development of forecasting algorithms and the lack of prediction experience, it is often the case that predictions are not given in the format of probabilities, but as earthquake warnings (binary predictions).We will explain how to use a gambling score to evaluate such binary predictions, where a reference model is also necessary and where each time the prediction succeeds or fails, the predictor is rewarded or penalized by using a fair gambling rule according to the reference model. Usually, the uniform distribution (homogeneous Poisson process) for the occurrence times and locations of earthquakes has been used as the reference model, in addition to the Gutenberg-Richter law (exponential distribution) for earthquake magnitudes. However, when a reasonable inhomogeneous Poisson process is used as the reference model, the warning-type predictions that are currently available rarely have better performance.

Statistical modeling of earthquake temporal occurrences incorporating seismo-magnetic data

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2. The Institute of Statistical Mathematics, Tokyo, Japan

This study aims to develop statistical models for earthquake temporal occurrences based on both earthquake catalogs and other geophysical observations. As an example, the seismo-magnetic signals at Kakioka (KAK) station are utilized to illustrate the modeling strategies, because previous studies suggest they might contain certain precursory information of local sizable earthquakes. Self-exciting, external-exciting, and combined models modified from Ogata's LIN-LIN algorithm have been applied to forecast the occurrences of M>4.05 earthquakes within 100 km from the KAK station. The self-exciting and external-exciting models perform significantly better than the Poisson Model, implying there are explanatory power in earthquake catalogs and magnetic anomalies, respectively. The combined model, which integrates information from catalogs and magnetic observations, is greatly superior to any of the other three models. Additional tests show that external exciting component derived from the magnetic data is not post-seismic in character, and is more likely to cooperate with large earthquakes. The combined model proposed in this study could also be useful to incorporate other non-catalog observations and may have potential value in improving short-term earthquake probability forecasts.

Keywords: Ionosphere/magnetosphere interactions; Probabilistic forecasting; Earthquake hazards; Modelling and interpretation; Japan.

Abstracts of poster presentations

Development of Radon Detector and Observation at Okayama

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2. Chiba Institute of Science, Chiba, Japan

Abstract. An increase of the radon in underground water at Nishinomiya City and an increase of the radon in atmosphere 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.

A PIN photodiode have been developed for high sensitive radon detector, and used in Super-Kamiokande. Last year we made a detector to measure atmospheric radon, using PIN photodiode. We use a Si PIN photodiode as detector, S3204-09 (Unsealed), supplied by Hamamatsu Photonics K.K. We constructed a radon detection system, using a stainless pot as air container, H4083 as charge amplifier, C4900-01 as High voltage power supply module, a pulse shape amplifier, a Multi-Channel Analyzer, and a Personal computer as data analysis. Output of the multi-channel analyzer showed clear alpha peaks of ^{218}Po and ^{214}Po of radon daughters.

This time we have measured the radon in the atmosphere by the system, for one year at Okayama University of Science, and observed daily variation.

Keywords radon, Si PIN photodiode, alpha, ^{218}Po, ^{214}Po

Geomagnetic Sq variations associated with large earthquakes

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2. Graduate School of Science, Chiba University, Chiba, Japan

3. The Institute of Statistical Mathematics, Tokyo, Japan

Han et al. (2016) have reported unusual behaviors of geomagnetic diurnal variation (GDV) in the vertical component prior to the 2011 off the Pacific coast of Tohoku earthquake (Mw 9.0). Spatiotemporal characteristics of the GDV anomalies and the possible coupling of multiple pre-earthquake phenomena have been demonstrated. To make a further understanding of the reported geomagnetic anomalies, spherical cap harmonic analysis (SCH) method is applied to separate the inner and external geomagnetic Sq variations. The inner source Sq field, which is an induced field of external one, may reflect possible conductivity structure changes related to earthquake. We calculated three-component Sq variations of inner and external respectively based on 17 geomagnetic observatories' data, then analyzed likely abnormal related to seismic. The detailed results will be shown in our presentation.

A Novel Seismic Monitoring System- AETA

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2 Computer School of Wuhan university, Hubei Wuhan 430072;
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Abstract Different earthquakes have different precursory anomalies. The abnormal phenomenon of electromagnetic disturbance and geo-sound signal have been found in many earthquakes. But these two signals haven't got much attention in the seismology research domain and have no numerous monitoring instruments. We developed a real-time monitoring system named AETA which can monitor the two signals at the same time. These signals are obtained from our carefully designed probes, then transmitted to the cloud server through the network and been processed and analyzed later. 60+ instruments have installed in China mainland supported by China Earthquake Administration. The suspected abnormal signal within 15 days before many earthquakes were recorded by the system in many seismic events. This novel monitoring system may be a good choice for the short-term and imminent earthquake prediction although a lot of experiments and verification are needed to do in the future.

Key words Earthquake monitoring; Electromagnetic Disturbance; Geo-sound; Seismic Precursor; Short-term and Imminent Earthquake Prediction

Acknowledgements This work was supported by the fundamental research project of Shenzhen Science & Technology (Grant Number: JCYJ20160428153956266).

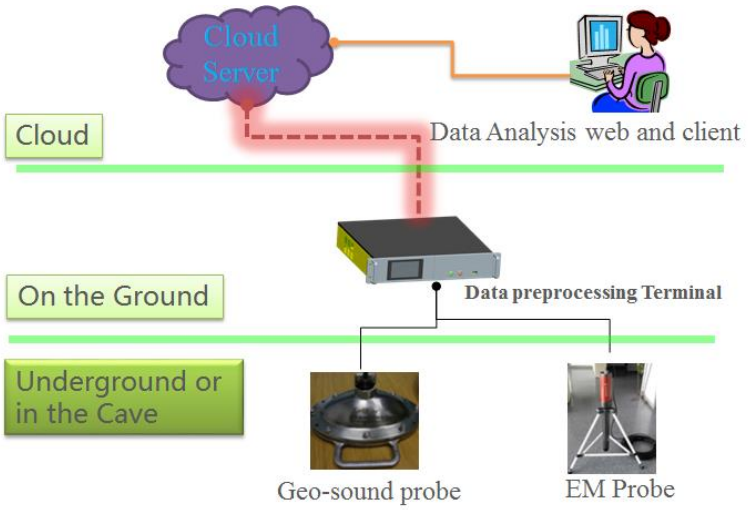

Fig1. The structure of AETA

How to properly detect pre-earthquake ionospheric anomalies by using the total electron content of global ionospheric map

Cheng-Yan Liu[1], Tiger JY Liu[1,2], and Yuh-Ing Chen[3]

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Le et al. [JGR 2011] reports a statistical analysis on the pre-earthquake ionospheric anomaly by using the total electron content (TEC) data from the global ionosphere map (GIM) published by CODE associated with total of 736 M≥6.0 earthquakes in the global area during 2002-2010. They find that the anomalous behavior of TEC within just a few days before the earthquakes is related with the forthcoming earthquakes with high probability. By contrast, Thomas et al. [JGR 2017] examine changes in the GIM TEC published by JPL with occurrences of 1279 M≥6.0 earthquakes globally for 2000–2014. They reported no statistically significant changes in GIM TEC prior to earthquakes and concluded no evidence that monitoring changes in GIM TEC might be useful for predicting earthquakes. The conclusion reached by Le et al. [JGR 2011] and Thomas et al. [JGR 2017] are completely opposite. Note that SCIENCE has to be reproducible and/or repeatable. The major differences between Le et al. [JGR 2011] and Thomas et al. [JGR 2017] are (1) CODE vs. JPL GIM TEC, (2) 736 M≥6.0 earthquakes during 2002-2010 vs. 1279 M≥6.0 earthquakes during 2000–2014, and (3) median/mean reference vs. pure mean reference. Results show that (1) the GIM TEC published by CODE and JPL are nearly identical; (2) the GIM TEC might be wrongly extracted at the latitude in the opposite hemisphere by Thomas et al. [JGR, 2017]; and (3) Thomas et al. [JGR, 2017] using the two standard deviations as the criterion for detecting anomalies is not suitable and applicable. The median base analysis is essential to analyze ionospheric data.

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Thomas, J. N., J. Huard, and F. Masci (2017), A statistical study of global ionospheric map total electron content changes prior to occurrences of M ≥ 6.0 earthquakes during 2000–2014, J. Geophys. Res. Space Physics, 122,doi:10.1002/2016JA023652.

Detection of electromagnetic earthquake precursors with low amplitude

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Purposeful observations of the low-frequency magnetic field in the frequency range $f = 10^{-3}$–10^{1} Hz in seismically active areas have been conducted since the late nineties of the last century, when sporadic electromagnetic radiation correlated with earthquakes was discovered [1]. As a rule, the lithosphere emission source is represented by a heterogeneous and non-stationary current system, which is caused by sporadic fluid transport in fracture networks. The generation mechanism of earthquake precursors is associated with the electrokinetic conversion due to fluid diffusion in the porous and fractured ground. The electrokinetic effect is originated due to the appearance of an electric double layer formed at the solid/liquid interface during the movement of the liquid. The double layer is made up of a layer of ions absorbed on the surface of the rock and of a diffuse mobile layer extended into the liquid phase. When a fluid is made to flow through a porous medium, there will be occurrence of a potential, the so-called streaming potential, across the sample, because of the relative motion between the solid and liquid. The amplitude of the electrokinetic current source in the lithosphere is defined by a joint action of Ohm's and Darcy's laws. Both of them are heavily influenced by the presence of the percolation phase transitions in the fracture network during pre-seismic activity [1, 2, 3]. This explains the non-stationary character of the electrokinetic sources in the lithosphere and its low amplitude in comparison with the Earth's natural electromagnetic sources. In the present paper we represent a recently proposed method to detect electromagnetic signals with low amplitudes [4]. In this method we take into account specific features in the spatial distribution of the Earth's natural electromagnetic noise and use the universal model of an underground magnetic field source. It is shown that the level of correlation of natural magnetic noise at spacing about one hundred kilometres is sufficiently high. When subtracting time series the correlated noise is subtracted as well. This allows us to detect the signals from a local source of weak magnetic fields with amplitudes lower than the level of natural background noise.

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Preliminary results of MT Survey at Boso Peninsula, Japan

Naoki Koizumi[1], Hao Cheng[1], Chie Yoshino[1], Katsumi Hattori[1], Peng Han[2], Mao Okuda[3], Kotaro Sugano[3], Midori Hayakawa[3], Toru Mogi[4], Shin'ya Sakanaka[5]

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2.The Institute of Statistical Mathematics, Tokyo, Japan,
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A magnetotelluric (MT) survey is one of the methods to understand the underground electric properties. In Boso area, Japan, there are three main topics 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 train system and factories. For challenges to solve them, we decided to carry out the MT survey in Boso area, Japan during 2014 - 2016. Due to sensing down to 100 km depth, we used induction and fluxgate magnetometers. We set 41 and 12 sites for induction and fluxgate type magnetometers, respectively. To remove noises from MT data, we attempted remote reference method that is conventional MT method in frequency domain. Hereupon, MT impedance at southern Boso area is improved to a certain degree. In other hand, the one at northern Boso are is not very improved. Therefore, we attempted MSSA (Multi-channel Singular Spectrum Analysis) for MT data in time domain to improve MT impedance. We performed SVD (Singular Value Decomposition) of original time series in MSSA, and reconstructed time series by using the principal components that indicate relatively high correlation in horizontal geomagnetic field between observation site and remote reference site. Then, unexpected MT impedance seen after remote reference method is tend to be restrained. It supposedly indicates that preprocessing MT data in time domain is effective and promise.

We calculated underground resistivity structure from southwest to northeast by using long period sites' data, there is low resistivity region (0.1 – 10 ohm-m) around 1 - 2 km depth. This region possibly indicates fluid in sediment layers overlying large amount of surface at Boso area. There is low resistivity region (0.1 – 10 ohm-m) under about 3 – 10 km depth at southwest site, which possibly indicates ultramafic rock or accretionary prism pushed up by subducting seamount.

The possible coupling of multiple pre-earthquake phenomena of the 2011 Tohoku earthquake (Mw9.0)

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Recent studies have reported unusual behaviors of geomagnetic diurnal variation (GDV) in the vertical component prior to the 2011 off the Pacific coast of Tohoku earthquake (Mw 9.0). To make a better understanding of this phenomenon, time-spatial analysis of GDV has been applied in this study. Geomagnetic data of long term observations at 17 stations in Japan have been analyzed using the same method in Han et al. 2015. Ratios of diurnal variation range between the target station and the reference station KAK have been computed. After removing seasonal variations revealed by wavelet transform analysis, the 15-day mean values of the ratios in the vertical component shows a clear anomaly exceeding the statistical threshold about 2 months before the mega event in both ESA and MIZ stations in the Tohoku Region. Similar results could not be found in other regions of Japan. Spatial distributions of the ratios show a good agreement between the location of the anomalies and the epicenter of Mw 9.0 earthquake. These time-spatial results seem to be consistent with independent results obtained from other observations such as radon density, seismicity, and GPS displacements, which suggest the geomagnetic data might be useful in earthquake monitoring and disaster mitigation.

A retrospective long-term (2005-2015) correlation analysis of Significant Sequences of Thermal Anomalies and Earthquakes (M>5) occurrence over Japan

Nicola Genzano[1,2], Carolina Filizzola[3], Katsumi Hattori[2,4], Mariano Lisi[1], Rossana Paciello[3], Nicola Pergola[3] and Valerio Tramutoli[1,3,4]

[1] School of Engineering, University of Basilicata, Potenza, Italy

[2] Graduate School of Science, Chiba University, Chiba, Japan

[3] Institute of Methodologies for Environmental Analysis of the National Research Council, Tito Scalo (PZ), Italy

[4] International Space Science Institute, Beijing, China

Among the proposed approaches, also the multi temporal approach Robust Satellite Techniques (RST) was used to study the space-time fluctuations of Earth's emitted Thermal InfraRed (TIR) radiation observed by satellite sensors in concomitance of large earthquake occurrences.

The RST methodology is based on a statistical definition of "TIR anomalies" and a suitable method for their identification even in very variable local (e.g. related to atmosphere and/or surface) and observational (e.g. related to time/season, but also to solar and satellite zenithal angles) conditions. In order to study the preparatory phases of earthquakes occurred in various geo-tectonic contexts of the world, it was implemented on time-series of TIR satellite records collected by sensors onboard of polar and geostationary platform, showing good ability to discern transient anomalous signals possibly associated to seismic activity from normal TIR signal fluctuations (i.e. related to the change of natural factor and/or observation conditions).

In this paper, the RST data analysis approach has been implemented on 11 years (June 2005 -December 2015) of TIR satellite records collected over Japan by the geostationary satellite sensor MTSAT (Multifunctional Transport SATellites) and RETIRA (Robust Estimator of TIR Anomalies) index was used to identify Significant Sequences of TIR Anomalies (SSTAs) in possible space-time relations with seismic events. The results obtained analyzing the whole time series of satellite TIR observations (more than 3700 images) will be discussed, also considering its enhanced potential, when applied in the framework of time-Dependent Assessment of Seismic Hazard (t-DASH) system

Variations of radon concentration in the air and radon exhalation quantity at Asahi, Boso Peninsula, Japan

Junpei Omura[1], Peng Han[2], Chie Yoshino[1], Katsumi Hattori[1], Michikuni Shimo[3], Toshiharu Konishi[4], Ryuichi Furuya[5]

1. Graduate school of Science, Chiba Uiversity, 2. The Institute of Statistical Mathematics, 3. Fujita Health University, 4. OHYO KOKEN KOGYO CO., LTD., 5. COM SYSTEM, INC.

The Ionospheric anomaly is one of the most promising precursory phenomena for large earthquakes. Lithosphere-Atmosphere-Ionosphere Coupling (LAIC) model has been proposed to explain these phenomena. To examine the possibility of chemical channel of LAIC through the monitoring of atmospheric electricity parameters, we have installed sensors for the atmospheric electric field (AEF), atmospheric ion concentration (AIC), radon concentration, radon exhalation quantity (REQ), and weather elements. In this paper, we will preliminarily report the properties of variation in radon parameters observed at Asahi station (ASA), Japan to identify earthquake-related signals in these parameters. We investigate the variations of radon concentration and exhalation recorded at ASA from June, 2014 to May 2017. And we examine the correlation between the occurrence of sizeable earthquakes and changes in radon concentration in the air and exhalation quantity. For the earthquake, we use the JMA catalog and collect earthquakes within 100 km radius. The details will be shown in our presentation.

Singular spectrum analysis of magnetotelluric data observed in Boso Peninsula

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Abstract

In Boso Peninsula, we have several stations to study seismo-electromagnetics. Among of them we had very interesting phenomena to show the fluid flows under the ground related to slow slip event. In addition, we have observed geomagnetic anomalies before sizeable earthquakes. In order to understand generation and propagation mechanisms of earthquake-related ULF electromagnetic signatures, we need the computer simulation on electromagnetic waves using FDTD or FEM. Due to this aim, we carried out the MT survey in BOSO area, Japan during 2014-2016.

The magnetotelluric (MT) method can produce the electrical resistivity images of the crust and upper mantle by measuring natural electromagnetic signals at the earth surface in a wide frequency band. Due to sensing down to 100 km depth, we used induction and fluxgate magnetometers. 2D inversion analysis based on Ogawa and Uchida (1996) have been performed. However, because of the existence of thick sedimentary layer and the artificial noises caused by DC-driven trains, factories, etc, the noise ratio is quite high. Thus, we must find an adequate noise reduction method to estimate realistic resistivity structure for entire region of the Boso Peninsula and it is the future task.

Characteristics of Ionospheric Electron Density response to Geomagnetic Storms and large Earthquakes

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Pre-seismic electron density anomalies have been a widely discussed phenomena in ionospheric studies. However, it is not well-known what causes these anomalies and what is the possible source mechanisms. These are still having not been elucidated questions and more investigations are needed to make clear that phenomena. The another question is how to distinguish ionospheric anomalies from other disturbances such as geomagnetic storms. In many cases, simultaneous geomagnetic activities make it difficult to detect an earthquake precursor effect in the ionosphere. Therefore, a characterization and classification of magnetic storm and earthquake signatures is necessary to make reliable forecasting. For this purpose, in this study, we investigated the similar and differing effects of magnetic storms and earthquakes on the ionospheric composition.

Int this study, the time period after magnetic storms and before earthquakes were mainly investigated. The selection of earthquakes was carried out between 1998 to 2013 with M>6 and depth<30 km. Following this, to detect the anomalous behaviour, we examined the temporal and spatial distribution of TEC values of those cases by using GIM-TEC data. Thus, we found that 28 earthquakes had caused anomalous changes in the ionosphere. We further examined these earthquakes with tomography method to investigate their 3D distributions. There we found that 13 of them had also shown the similar anomalous effect. Meanwhile, magnetic storm cases were chosen between 1998 to 2013 within the intense storm category in which Dst < -100 nT. And the onset time was selected in daytime hours from 6 am to 6 pm. By applying this criteria, 42 magnetic storms were extracted. Among them, we selected arbitrarily 10 different storm cases and same analysis steps was followed to determine the anomalous changes. For TEC analysis, we mainly made use of TEC data from both local receivers (GPS-TEC) and global receivers (GIM-TEC). The GPS-TEC data sets were inverted to electron density form (Ne) in the tomography process with neural networks to examine the 3D electron density distribution of the ionosphere. On the other hand, since the TEC is sometimes slower to respond to compositional changes in the ionosphere, we further employed the ionospheric foEs, NmF2 and hmF2 quantities as complementary data. There, we prepared time series figures of these parameters and compared their responses against storm and earthquake effects. Results will be presented in the presentation.

Earthquake-related Thermal Infrared Anomaly

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We investigate the possible thermal infrared (TIR) anomalies related to 3 moderate earthquakes (M>6) in the central Italy using MODIS onboard the AQUA satellite. The analyzed earthquakes are the L'Aquila EQ (M6.3) on 20090406, the Norcia EQ (6.2) on 20160824, and the Norcia EQ(M6.6) on 20161030. We perform the statistical analysis in time and space with cloud reduction using the nighttime data from 20060101to 20161231 observed by AQUA. The analyzed area is ±10° from the epicenter of L'Aquila EQ with 0.01° resolution. We use bands 20, 27, 31, 32, 34, and 35 for computation. For cloud discrimination, difference values between two bands (34-35, 31-32, 31-27, 31-20) are used and we evaluate the results using Lidar data onboard Calipso (CALIOP). We can conclude that the cloud detection is well-established. Then, we investigate the anomalous TIR change in time and space statistically. The results are highly suggestive of the existence of TIR anomaly before the moderate EQs around central Italy and have the potential to monitor crustal activity and forecast earthquakes. Further investigations on assessment of forecast ability and application to the other regions will be required.

Analysis of b-value and TEC Variations before Large Earthquakes in Japan

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In recent years, there are many reports on electromagnetic phenomenon preceding large earthquakes. Anomaly of the total electron content (TEC) is one of the most promising anomalies for the short-term earthquake forecast. On the other hand, it is reported that the b-value around the epicenter region decreases prior to the large earthquake. The b-value can compute using the Gutenberg Richter law. The lead time is around few or tens of years. We can't discriminate anomalous changes on earthquakes and solar activities easily at the moment. In this paper, we try to develop a method for the earthquake short-term forecast using the b-value and the TEC analysis. We investigate the effectiveness of the integrated analyses on the b-value for the middle-term forecast and TEC analysis for the short-term forecast.

We select the 2003, 2008 Tokachi-oki EQ (M8.0) and the 2011 Tohoku-oki EQ. As results, we found the variation of b-value has a tendency to decrease for M7class EQs in the analyzed regions and the neighbor's area. For the 2003Tokachi-oki EQ, we investigated temporal variation for the b-value with interval of 1day. We found decrease of b-value occurred 16 days and 2-3days before the main shock. On the other hand, for anomaly of the TEC in the Hokkaido-region, we found significant increase of TEC 2 days before the EQ(M>6.0,D<40 km) using the statistical analysis during 1998-2015. That is, the positive anomaly is dominant, In the case of the 2003 Tokachi-oki EQ, TEC anomaly occurred 2 days before main shock. However, immediately after this TEC anomaly , solar activity becomes active, and after that, positive anomaly may be masked from solar activity. From these results, in the 2003 Tokachi-oki EQ,we found that anomaly of b-value occurred 16 days before main shock after that, TEC anomaly occurred. The results for the 2011Tohoku-oki EQ show the similar tendency in b-value and TEC variations. From above results, we can conclude that simultaneous use of the b-value and the TEC analysis is suggestive of the effectiveness in short-term earthquake forecast for the M7 or higher earthquakes Details will be given in the presentation.

Multi-sensor monitoring network for earthquake precursors and preparation process near subduction zone at Boso, Japan, 2017

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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, TIR, and OLR will be incorporated to help to understand the preparation process and evaluate the applicability of various pre-earthquake signals towards short term earthquake forecasting. We call this idea “sensor WEB”. We will show the state of the art in our poster presentation. This study is supported by Grand-in-Aids for Scientific Research of Japan Society for Promotion of Science (26249060).

Transfer function analysis of ULF geomagnetic changes related to earthquake activity around Kakioka, Japan, during 1997-2015

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Recently, ultra low frequency (ULF, less than 1 Hz) has been considered one of the most prospective bands to detect earthquake precursory signatures because of its larger skin depth. Han et,al., 2014 have performed statistical studies at Kakioka(KAK) station, it is proved that ULF geomagnetic changes preceding earthquake at KAK station has statistical significances. However, we can use only the remote station as a reference which shows a high correlation with KAK station. Therefore, to study use any remote station for investigation the ULF geomagnetic changes related to earthquake, we have performed statistical studies using the geomagnetic transfer function approach using the KAK station, Japan, during 1997-2015. We investigated the energy of ULF geomagnetic signals of the frequency around 0.01 Hz using wavelet transform analysis. To minimize the influences of artificial noisesand to remove global geomagnetic perturbations, we used only the geomagnetic data observed at nighttime (LT01:30 A.M. to 04:30 A.M.) and utilized observations from a remote station, Memambetsu, as a reference. We have computed geomagnetic Z component at KAK station using transfer function, and defined P value (the ratio observed Z component and computed). We have determined threshold for geomagnetic anomaly from P value. Earthquake as Es>10^8 at KAK station have chosen for this study. Statistical results of superposed epoch analysis have indicated that significant correlation between ULF geomagnetic changes and earthquake 21-25 days before the events. Further, we have evaluated the precursory information of ULF geomagnetic changes related to earthquake using Molchan's error diagram. The probability Gain(PG) is around 1.3 against a Poisson model. The above results have indicated that it is possible to use any remote station using transfer function. Details will be given in the presentation.

Characteristics of atmospheric parameter changes in Atmospheric Electric Field (AEF), Atmospheric Ion Concentration (AIC), Atmospheric Radon Concentration (ARC), Radon Exhalation Quantity (REQ) at Asahi, Boso Peninsula, Japan

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The Ionospheric anomaly is one of the most promising precursory phenomena for large earthquakes. Lithosphere-Atmosphere-Ionosphere Coupling (LAIC) model has been proposed to explain these phenomena. To examine the possibility of chemical channel of LAIC through the monitoring of atmospheric electricity parameters, we have installed sensors for the atmospheric electric field (AEF), atmospheric ion concentration (AIC), radon concentration, radon exhalation quantity (REQ), and weather elements. We will report the properties of variation in atmospheric electricity parameters observed at Asahi station (ASA), Japan to identify earthquake-related signals in these parameters. We found that the variation of radon exhalation quantity shows a clear negative correlation with 3 hours delay to the air pressure variation in clear days. Each season differs in daily pattern. AIC and AEF variations show lag correlation with radon exhalation quantity variation. To extract anomalous radon variation related to earthquakes, we should set a network of Radon monitoring and establish a model of radon variation for the future detailed analysis. We also observed cases that AEF has showed a spike-like increase at the same time as the time when AIC has largely increased. It must be going to be checked whether AEF data was taken in fair-weather period, however, it is suggested that change in local charge distribution may have influenced AEF.