The preliminary study of the high-sampling coseismic groundwater level changes in M_L 6.4 Tainan earthquake, Feb. 6th 2016

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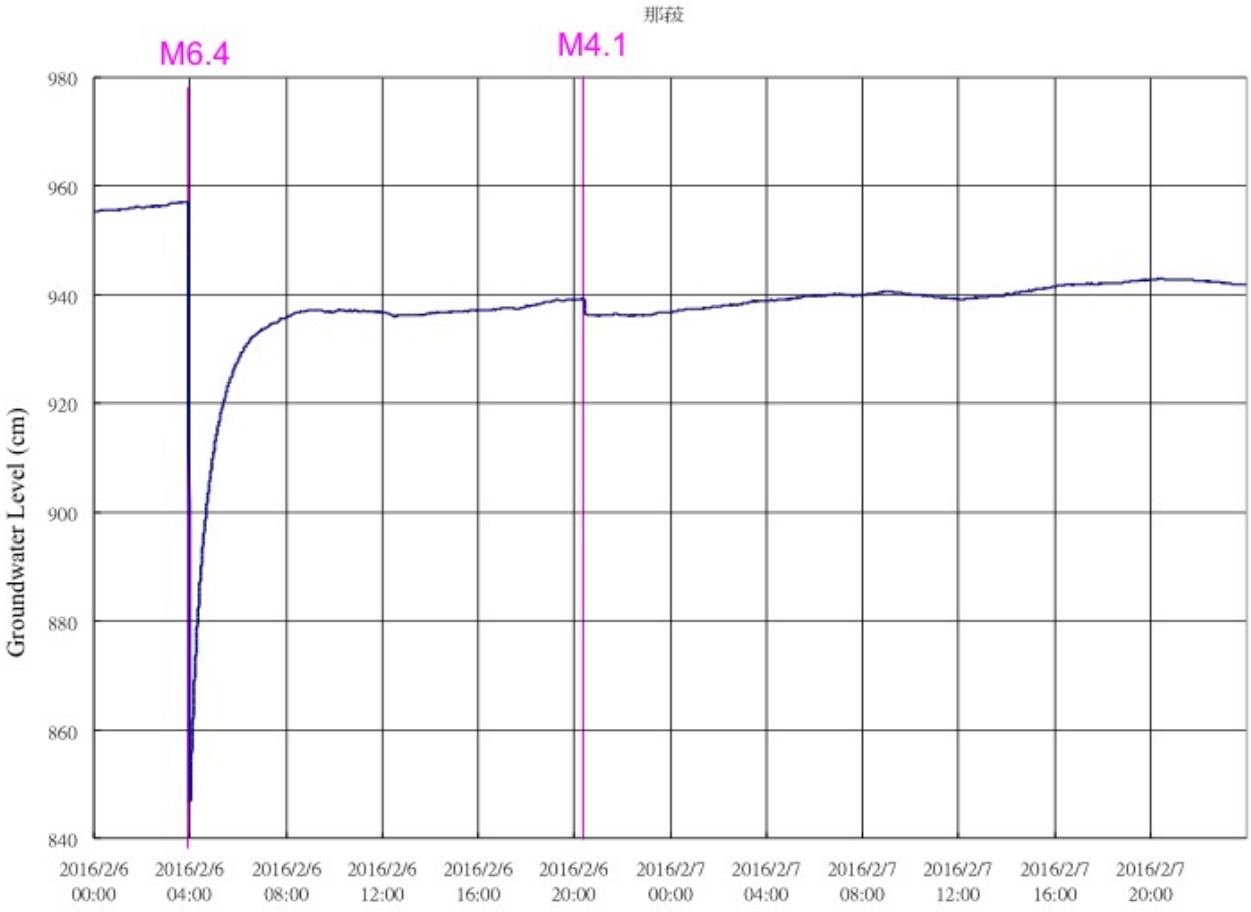
The different response by various natural stimuli and processes (tidal force, barometric loading, ground shaking and crustal strain) were used as the elements of the hydraulic information in the earthquake induced groundwater level changes. Using the natural force to act as naturally recurring stimuli to provide a sufficiently varied distribution of excitations in time and space, and represented the hydro-geological changes responses to the earthquake processes. The purposes of this study are to analyze the recently observation results of the earthquake induced pre-seismic / co-seismic variation of groundwater level ML 6.4 Tainan earthquake, Feb. 6th 2016. The analysis of the high-sampling water level responses be used to estimate the mechanical properties of the aquifer. Comparison the observation high-sampling water level changes in the each event, offers the opportunity to discussion the possible mechanism of the hydrologic response to earthquake. Some of the coseismic groundwater level changes can be explained as the poroelastic responses to the earthquake-induced volumetric strain changes inferred from the fault dislocation models. But the other changes can not be explained by the volumetric strain changes either qualitatively or quantitatively. We regarded the coseismic static volumetric strain change and the ground acceleration as the main factors to cause the coseismic groundwater level changes. The study provides some information for the pre-seismic / co-seismic mechanism but more investigations are required

Keywords: Coseismic Changes, Groundwater, Earthquake



Seismo-conductivity Anomalies: A case study of the M6.4 Meinong earthquake on Feb. 6, 2016 in Taiwan

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Anomalous phenomena of conductivity enhancements have been repeatedly observed before many earthquakes in Taiwan through orientations of the Parkinson vectors derived from 3-component magnetic data via the magnetic transfer function. Meanwhile, depths of conductivity anomalies can be roughly estimated while the skin effect is conducted into the frequency-dependent parameters of the magnetic transfer function. Locations of seismo-conductivity anomalies are determined by using anomalous orientations of the Parkinson vectors from three magnetic stations. Through the 3-year observation, locations of conductivity enhancements and hypocenters are often comparable that is obtained. The Meinong earthquake with the magnitude of 6.4 occurred in the southern part of Taiwan on Feb. 6 2016. High-conductivity anomalies associated with the M6.4 Earthquake were found in two areas. Anomalies located at the depth of 15 km were observed very close to the main shock on Jan. 31-Feb. 3, 2016. In contrast, the other anomalies at the depth of 30 km on Feb. 2-Feb. 6, 2016 are located at the northern part of the main shock in agreement with aftershocks.

Keywords: Pre-earthquake anomalous phenomena, Meinong earthquake, Seismo-conductivity anomalies

Multi parameters observations of pre-earthquake signals associated with M6.4 of Feb 06, 2016 in Taiwan. Preliminary results.

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We are conducting validation on temporal-spatial pattern of multi parameter signals with pre-earthquake origin associated with M 6.4 of Feb 02, 2016 earthquake in Taiwan.The continues analysis of outgoing long-wavelength radiation (OLR) obtained from NPOESS show rapid increase of OLR on the top of the atmosphere on Jan 1-2, 2016 (2.5 sigma significance for 25 years of analysis) and probably indicated for a large earthquake preparation process in Taiwan(map is attached). The time series variations of atmospheric chemical potential, characterizing the ionization processes inside ABL, show rapid increases during Jan 1-5 and Jan 10-15, 2016 periods. The Gamma network consisted by 4 stations registered similar anomalous pattern in increasing of the radon level during period of Jan 10-15, 2016 simultaneously on three of the stations close to the epicenter. Based on the 3-component geomagnetic data from 3 stations, high-conductivity anomalies were found in two different periods: i)Jan. 31-Feb. 3, 2016 - the anomalies were observed very close to the main shock and the ii)Feb. 2-Feb. 6, 2016 - anomalies are further North and associated with the followed aftershocks. The GIM reveals the TEC significantly enhances over Taiwan on 5 February 2016, one day before the earthquake.
Our preliminary analysis of simultaneous space and grounds measurements associated with M6.4 of Feb 06, 2016 in Taiwan suggest that pre-earthquake phase follows a general temporal-spatial evolution pattern reviled with multi instruments observations, which has been seen in other large earthquakes worldwide.

Keywords: earthqauke, precursor, forecasting, prediction

Satellite earthquake anomalous map for Taiwan region
Jan 2, 2016

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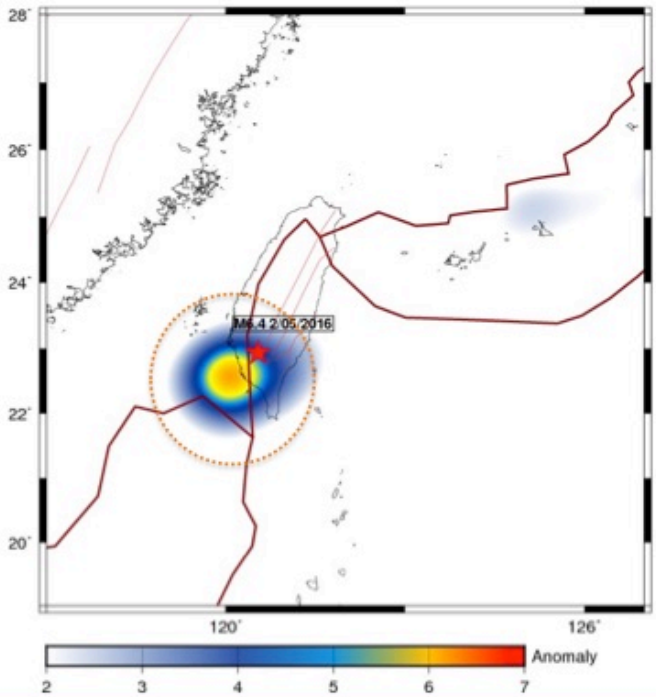

Data : NPOESS, With red star – epicenter of M6.4 of 02.06.2016. Red lines- plate boundaries , brown – faults, dash circle – estimated region for the future epicenter

Precursory gas geochemical and gamma rays anomalies prior to the 2016 M6.4 Meinong earthquake, southern Taiwan

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Taiwan is tectonically situated in a terrain resulting from the oblique collision between the Philippine Sea plate and the continental margin of the Asiatic plate, with a continuous stress causing the density of earthquakes and faults. The continuous observations of soil radon for earthquake studies have been recorded and are compared with the data from gamma rays observations. Some anomalous high radon concentrations and gamma-ray counts at certain times can be identified. A significant increase of soil radon concentrations was observed at Gukeng (GK), Chunglun (CL) and Pingtung (PT) station, and an increase in gamma-ray counts at the Chung Cheng University (CCUG) was also observed around two weeks before the Meinong Earthquake (M_L = 6.4, February 6, 2016) in southern Taiwan. The precursory changes in multi-parameters monitoring may reflect the preparation stage of a large earthquake. And, precursory signals are observed simultaneously that can conduce to expect the approximate location of the impending earthquake with high confidence. The continuous monitoring on the multiple parameters can improve our understanding of the relationship between the observed radon and gamma-ray variations and the regional crustal stress/strain in the area.

Keywords: radon, gamma rays, Meinong Earthquake

Thermal InfraRed satellite surveys over Japanese seismic area applying Robust Satellite Techniques on MTSAT observations

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Since 2001, the general change detention approach, named Robust Satellite Techniques (RST), has been applied to explore the fluctuations of Earth's thermally emitted radiation, observed by satellite sensors operating in the thermal infrared (TIR) spectral range in possible relationship with the preparation phases of major earthquakes. Used in combination with RETIRA (Robust Estimator of TIR Anomalies) index, RST data analysis approach showed good ability to discriminate anomalous TIR signals possibly associated to seismic activity, from the normal variability of TIR signal due to other causes (e.g. meteorological).
Up to now, RST has been implemented on different TIR satellite sensors on board polar (NOAA and EOS) and geostationary (like, MSG, GOES, GMS and MTSAT) platforms, to investigate the preparation phases of earthquakes of different magnitudes occurred in several seismogenic areas around the world (e.g. Italy, California, Greece, Turkey, Taiwan, etc.).
In this paper, the RST data analysis approach has been implemented on TIR satellite records collected over Japan by the geostationary satellite sensor MTSAT (Multifunctional Transport SATellites). RETIRA index was used to identify Significant Sequences of TIR Anomalies (SSTAs) on a long observation period. Significance of the correlation existing among SSTAs and earthquakes (with M≥4) occurrence was investigated in order to evaluate the possible contribute of such observations to a multi-parametric t-DASH (time-Dependent Assessment of Seismic Hazard) system for short-term seismic hazard forecasting.

Keywords: Earthquakes, TIR anomalies, RST analysis, Precursor, t-DASH

Spatiotemporal characteristics of the geomagnetic diurnal variation anomalies prior to the 2011 Tohoku earthquake (Mw9.0)

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Xu et al., 2013 and Han et al., 2015 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, temporal-spatial analyses of GDV have 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 reference station KAK and the target stations have been computed. After removing seasonal variations, 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 at both ESA and MIZ stations in the Tohoku Region. Locations of anomalies in spatial distribution show a good correlation with the epicenter of the Mw 9.0 earthquake. These spatiotemporal results are consistent with those obtained from other independent observations such as groundwater level and GPS displacements. The coupling of multiple pre-earthquake phenomena may help to understand the preparation process of a mega earthquake in the subduction zone.

Keywords: seismo-magnetic phenomena, anomalous geomagnetic diurnal variation, coupling of multiple pre-earthquake phenomena, the Tohoku earthquake

Ionospheric anomalies instantly before three large earthquakes in Chile detected with GPS observations

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In this work, the ground-based permanent GPS stations were used to study ionospheric total electron content (TEC) response to three large earthquakes in Chile: the Mw8.3 Illapel earthquake of 16 September 2015, the Mw8.2 Iquique earthquake of 01 April 2014, and the Mw8.8 Maule earthquake of 27 February 2010. The GPS arrays around the epicenters provide rare opportunities to investigate the comprehensive near-field preseismic TEC responses to three huge earthquakes in South America. Based on the GPS absolute VTEC technique and Akaike's information criterion (AIC) method, the spatial distribution of ionospheric anomalies have been analyzed for the first time, especially in the height direction. The results showed that the positive anomalies occurred at an altitude of ~200 km, while the negative anomalies occurred at an altitude of ~350 km for the large earthquakes in the south hemisphere. The negative anomalies have a lager distribution than positive anomalies. A well consistency exists between the observation and the simulation result from C.L. Kou *et al*. (2014). The distribution of both positive and negative anomalies were mainly controlled by the geomagnetic field and magnetic latitude of epicenter. Moreover, we analyzed the VTEC variations during non-seismic activity period, and compared the VTEC changes originated form strong seismic activity with the VTEC changes induced by geomagnetic storm.
Acknowledgements: This study was funded by China Scholarship Council (CSC) and partially funded by the National Natural Science Foundation of China (grant no. 41104104). We thank C. Vigny (ENS) for providing GNSS data in Chile of his group. We thank the Argentine national geographic institute (IGNA) for providing GPS data of RAMSAC network, and the Brazilian Institute for Geography and Statistics (IBGE) for providing GPS data of RBMC network. We thank IGS (www.igs.org) and UNAVCO (www.unavco.org) for making GNSS data available.

Keywords: GPS TEC, large earthquake, preseismic anomaly, spatial distribution

Modification of Ionosphere before Large Earthquakes- Report of Ionosphere Precursor Study Task Group

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The current status of ionospheric precursors associated with large earthquakes (EQs) is summarized in this paper as an outcome of a joint endeavor of the “Ionosphere Precursor Study Task Group,” which was formed with the support of the Mitsubishi Foundation in 2014–2015. The group aims to promote the study of ionosphere precursors to EQs by trying to provide new findings, to prepare for a future EQ-dedicated satellite constellation, which is essentially needed to study the global morphology of ionosphere precursors, and to determine whether short term EQ prediction is possible. The first part of the manuscript reviews the ionosphere precursors that have been reported previously. Problems and specific research subjects that have become clearer from our one-year project are described. Satellite missions that are planned or are going to be launched soon for EQ studies are briefly described in the final part of the manuscript.

Keywords: ionopshere, earthquake, wave

Theoretical Simulations of Electric Current Effects on the Ionospheric Plasma Structure

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Recent studies show ionospheric plasma density modifications due to lithosphere and atmosphere activities. One of the possible mechanisms for the ionosphere modifications might be direct current transmission effect to the ionospheric dynamo region. On the other hand, the disturbances could also affect the ionosphere by generating atmospheric disturbance waves that modify the neutral winds and thus affect the ionospheric dynamo and electron density. In this study, simulations of the direct current and disturbance wind dynamo effects are carried out using a coupled three-dimensional global ionosphere electrodynamic model. Simulations carried out by inclusion of the upward/downward transmission of direct electric current at 85 km altitude with various areas of current injections, indicate negative/positive TEC effects. The simulations for different local time sectors are also carried out showing that the effect is most prominent at dusk followed by that of at afternoon and noon periods. The simulations will also be compared with GPS-TEC observations of pre-seismic anomalies.

Keywords: Coupled Ionosphere Electrodynamic Simulation, Electric Current, Pre-seismic Ionosphere Anomalies

Co-rupture, quasi-coseismic, and post-seismic EM fields generated by the rupture process of a finite fault embedd in a porous medium

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The electrokinetic effect related with the electric double layer between rock and fluid is one of the most possible generation mechanisms of earthquake-related electromagnetic (EM) signals. Previous numerical simulation studies of earthquake-related EM signals have indicated that the electrokinetic effect is able to generate co-rupture and coseismic EM fields as well as post-seismic electric fields. However, the amplitudes of the simulated co-rupture EM signals are under the natural EM noise levels. This means they are unobservable. Thanks to the improvement in the instrument and approach applied in the field observation of EM anomalies, reports on the co-rupture electric or magnetic signals finally appeared in recent years although such reports are very rare. Quasi-coseismic EM signals which are synchronous with seismic arrival have also been recorded in field observation. According to previous simulations on the electrokinetic effect, they are thought to be the coseismic EM fields, which are local responses to the seismic arrivals in a porous medium. In this study, we carry out numerical simulations of the electrokinetically coupled seismic and EM wavefields generated by a finite fault in a layered model consisting of porous and solid materials. Results confirm that the electrokinetic effect does can generate observable co-rupture EM signals, and the observability depends on the epicentral distance, properties of the medium where the fault is located, and local EM noise levels. It is shown quasi-coseismic EM signals can be generated even if the top layer, which is above the ground water level, is assumed to be a solid layer. The quasi-coseismic EM signals at least are partially contributed by the evanescent EM waves generated at the shallow subsurface interfaces. The evanescent EM waves are sensitive to the properties of the shallow subsurface fluid. Besides the radiation EM waves of interface response, the evanescent EM waves possibly also have some potential applications associated with the shallow subsurface fluids. Our results also show that electrokinetic effect can generate post-seismic electric and magnetic fields. They are presumably induced by the low-frequency fluid diffusion after the earthquake. The post-seismic magnetic field has not been identified in previous simulations on the electrokientic effect, because its generation requires a sufficiently strong medium heterogeneity, which the uniform porous half-spaced utilized in previous simulations cannot provide. Further studies on the evanescent EM waves and the EM fields associated with the fluid diffusion caused by the stress change may provide a better understanding and interpretation of the earthquake-related EM signals.
Acknowledgements: This study is supported by the National Natural Science Foundation of China (Grant Nos. 41274054, 41274075 and 41274053).

Keywords: co-rupture EM signals, quasi-coseismic EM signals, post-seismic EM fields, electrokinetic effect, rupture process of a finite fault

National center of earthquake prediction experiment in China

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China is one of the countries which have the earliest reports on earthquake-related phenomena. There are about 50-year continuous observation data in China up to now, which provides a valuable database for earthquake-related study. China is also a pioneer country for empirical earthquake prediction. Therefore, earthquake prediction experiment in China would be interested broadly by international communities of geosciences.
Although there had been some earthquake prediction experiments in China about 20 years before, due to the great debates in earthquake prediction and the discontinuity of funding support, all these earthquake prediction experiments are not on operation at the current stage. After the 2008 Ms8.0 Wenchuan earthquake in Sichuan, China, the Chinese government evaluated the situation of earthquake prediction and hazard mitigation. As the national agency of earthquake study, China Earthquake Administration (CEA) established the national center of earthquake prediction experiment in 2015, including sub-centers in Yunnan and Sichuan. The supporting institution of national center is Institute of Earthquake Science, CEA. The national center will provide an open, cooperative, dynamic platform for earthquake prediction research. We will summarize the main goal and task of the national center of earthquake prediction experiment in Yunnan and Sichuan, China.
This study is supported by the National Natural Science Foundation of China (41574104).

Keywords: Earthquakes, prediction experiment, seismic hazard

A Summary of iSTEP (integrated Study and Test of Earthquake Precursor) projects

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After the 21 September 1999 M7.6 devastating earthquake, a program entitled the integrated Search for Taiwan Earthquake Precursor (iSTEP-1, 2002/4/1–2006/3/31), which consists of a main project and five sub-projects, was conducted to search credible precursors in seismological variations, geomagnetic and gravity fields, ground surface deformations, and ionospheric electron density anomalies, as well as to evaluate the statistical significance of observed precursors in Taiwan. Results reveal that anomalies in P-wave velocity, ground surface deformation, geomagnetic field intensity, ionospheric electron density could appear few years, months, and days before large earthquakes in Taiwan, respectively. An integrated ground-based seismo-electromagnetic observation system, including eight networks of magnetometers, electrode arrays, corona probes, FM tuners, Doppler sounding systems, ionosondes, GPS receivers, and all sky cameras, has been constructed and routinely operating to monitor earthquake precursors in the lithosphere, atmosphere, and ionosphere and to find possible lithosphere-atmosphere-ionosphere coupling in the Taiwan area. Several statistical analyses were developed to validate the observed anomalies to be credible precursors. Due to its worldwide availability, the statistical results showed that the ionospheric total electron content (TEC) derived by ground-based GPS receivers were most likely to be a credible precursor. Succeeding the iSTEP-1, the iSTEP-2 (integrated Study for Taiwan Earthquake Precursors, 2006/8–2012/7) project adding with satellite observations was conducted to have a longer time period for data collection and analysis, as well as to develop physical and statistical models. Although it was not officially funded but supported by basic ionospheric research projects, the integrated ground-based observation still has been operating uninterruptedly. Many new observations possibly related to seismo-lithospheric precursors of the earth’s surface magnetic field and the GPS surface deformation, seismo-atmospheric precursors of the infrasound signal, and seismo-ionospheric precursors (SIPs) in the electron density profile, the electron temperature, ion density, and neutral temperature probed by satellites were reported. The TEC in the global ionosphere map (GIM) routinely published (with a 2- or 4-day time delay) allows us to monitor temporal SIPs at a specific location, and to conduct spatial analysis discriminating the observed SIPs from global effects, such as solar flares, magnetic storms, etc. Statistical analyses for detecting both temporal and spatial precursors in the ionospheric TEC are developed. Meanwhile, ionospheric model simulations are also introduced to find causal mechanisms explaining the observed SIPs. The iSTEP-3 (integrated Study for Taiwan Earthquake Precursors, 2012/8–2016/7), which is proposed to focus on the SIP study, consisting of a main project and three sub-projects is formally funded. The main project continues to operate the integrated ground-based observation system, develops physical models, and compares model simulations with observed precursors, while the three sub-projects aim to develop a near real-time GIM with a 4-hour time delay for worldwide SIP monitoring, to monitor lithosphere, atmosphere, and ionosphere precursors, to find the precursor link, and to conduct earthquake hazard assessment with observed precursors, respectively.

Keywords: iSTEP, earthquake prediction, earthquake precursor, total electron content, GPS TEC

Earthquake-induced electromagnetic field due to electrokinetic effect

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Electromagnetic fields generated by earthquake events were usually reported and have drawn a lot of attentions. They can be detected before, during and after the seismic arrivals after earthquake rupture started, and are referred to as the co-rupture, coseismic and post-seismic EM signals, respectively. The co-rupture EM signal is of great importance since it arrives earlier than the seismic waves, especially the destructive shear and surface waves and has potentials in earthquake early warning and hazard reduction. The coseismic EM signal arriving simultaneously with the seismic waves are also valuable since it contains the information of the subsurface medium in the vicinity of the EM sensors. However, how these kind EM signals are generated is still controversial. Several possible mechanisms have been proposed to explain the earthquake-induced EM signals, e.g., the electrokinetic effect, the piezoelectric effect, the motional induction effect, etc.

In this study, we present the theoretical simulations of the earthquake-induced EM signals on the basis of the electrokinetic effect. This result shows that due to the electrokinetic effect the earthquake can generate co-rupture EM signal, which arrives immediately after the onset of the earthquake and much earlier than the seismic arrivals. It arrives at different EM sensors simultaneously. The earthquake can also generate coseismic EM field which arrives simultaneously with the seismic waves. Besides, our simulations indicate that when the earthquake fault rupturing stops and the seismic waves pass far away, the magnetic field vanishes while the electric field near the fault remains, decaying slowly and lasting for hundreds of seconds. The near-fault poseismic electric fields hold similar features to some field observations in literature. We apply our theoretical simulations to explain the coseismic EM data observed during the 2004 M_w6 Parkfield earthquake. By using a finite fault source model obtained via kinematic inversion, we calculate the electric and magnetic responses to the earthquake rupture are calculated. The result shows that the synthetic electric signals agree with the observed data for both amplitude and wave shape, especially for early portions of the records after the earthquake. Our simulations supports the electrokinetic effect as the reasonable mechanism for the generation of the earthquake-induced electric fields.

This work is supported by the National Natural Science Foundation of China (grants 41474038 and 41204039).

Keywords: earthquake, electromagnetic fields, electrokinetic effect

Detection of precursory anomalies using the four -component borehole strain meter (SKZ-1)

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High sensitive crustal monitoring has a long history to investigate anomalous precursory variations of earthquakes by means of several kinds of sensors as borehole volumetric sensors (Sacks and Evertson,1971), borehole extension sensor by Gladwin (1984), three component volumetric strain meter by Sakata (2004) and Ishii and Yamauchi (2007). In China the four component strain meter with high performance was developed by Su Kaichi (1977) and has been used in earthquake-prone provinces since 2006.The configuration of four sensing units at intervals of 45 degree provides a simple indicator (consistent factor) of the sensor functioning and regime of the crust assumed to be plain strain in normal state to detect candidates of anomalous variation without little ambiguities. The observation at ten sites in several provinces of China for some 10 years has proved profitable performance of the sensor: high stability and high degree of resolution to detect local and regional anomalous variations near hypocenter. In the normal stage the variations consist of steady diurnal variations due to earth tide, steady trends due to the crustal stress adjustment after construction of the borehole, and installment of the sensors. There are little urban noises with the result of the consistent factor being almost constant value of 0.99.
Here we present analyses of anomalous variations detected by use of the correlation coefficient of two independent plain strain components before two major earthquakes near the network: YiLiang M5.7earthquake and LuDian M6.5 earthquake. In the imminent sage of the Yiliang earthquake, obvious strain anomalies with periods of several days, several weeks appeared simultaneously in four components at the nearest YiLiang site of the epicenter distance15.5km. The correlation coefficients for those anomalies are well below reaching 0.2 compared with the ordinal value 1.0. At DaGuan site of larger distance 30km, there appeared no significant anomalies with the factor remaining the normal value near 0.99 or so. Analyses show that the correlation coefficient can be used to objectively detect anomalies to define the successive stage of earthquake occurrence from normal to relaxation stages.
A multiple observations using the four component strain meters, groundwater meters and electromagnetic sensor are expected to substantially contribute to investigation of the nucleation process of natural earthquakes. Present finding may contribute to efficient data analysis to detect candidate of anomalies from using big amount of continuous multiple data with higher sampling rate.

Keywords: strain meter, pre-seismic anomalies, detection method

Development of radon detector for atmosphere

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An increase of the radon in underground water at Nishinomiya City[1] and an increase of the radon in atmosphere[2] at the southern part of Hyogo Prefecture earthquake in 1995 were reported. Moreover, in the case of Tohoku Region Pacific Coast Earthquake, the data of the exhaust air monitor in the radiation facility of Fukushima Medical College (Fukushima) has been reported that the peak duration was long, and the peak decreased rapidly before the earthquake[3].
We had measured radon concentration in a pit of Kurashiki mine, and in the atmosphere in Chiba Prefecture, Chiba. We used a Radon Monitor of SUN NUCLEAR Corporation, Model 1028 in the Kurashiki, and Pylon Trace Environmental Level Radon Gas Detectors (abbreviated to TEL) in Chiba. The TEL is composed of ZnS(Ag) scintillator and a Photomultiplier. Its output spectra have continuous distribution. Then counts depend on discrimination level, and have sometimes shift of background counts. On the other hand PIN photodiode have been developed for high sensitive radon detector, and used in Super-Kamiokande[4]. This time we produced a usual detector of atmospheric radon, using PIN photodiode.
We use a Si PIN photodiode, 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, 4419 (CLEAR-PULSE) as Pulse shape amplifier, MCA-Lite (Laboratory Equipment Corporation) as 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 from Uranite. However, the Si PIN photodiode showed peak large shift. It were overcome by coating surface of white ceramic with carbon tape. We introduced atmosphere to the PIN photodiode, using air pomp, flowmeter and silica gel for dehumidification. It showed same peaks of radon daughters, and we observed daily alteration of their intensity.
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Keywords: Radon detection, atmosphere, earthquake

Observational study of atmospheric electricity parameters(atmospheric electricity field (AEF), atmospheric ion concentration (AIC), and radon concentration) at Asahi, Boso Peninsula, Japan

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The total electron content anomaly preceding the large earthquake is one of the most promising precursory phenomena in the upper atmosphere. Lithosphere-Atmosphere -Ionosphere coupling (LAI coupling) model has been proposed to explain the earthquake-related phenomena in the atmosphere and ionosphere. We evaluate the possibility of chemical channel of LAI coupling through the monitoring of atmospheric electricity parameters such as the atmospheric electricity field (AEF), atmospheric ion concentration (AIC), and radon concentration. In this paper, we will report about the property of atmospheric electricity parameters observed at Asahi station (ASA), Boso Peninsula, Japan. AIC, AEF, atmospheric radon concentration, radon exhalation quantity from the ground, and weather elements have been observed at ASA. First, we compare seasonal variation, daily variation, and response to precipitation of atmospheric electric parameter observed at ASA and those at Kiyosumi station (KYS).
Variations of AIC and AEF before precipitations are quite similar at both stations; AIC increases quickly when a precipitation starts and AEF begins to be disturbed three hours before rain starts. But the variations after stopping precipitation have individual properties. Both parameters keep high values for a few hours at ASA and it takes longer than KYS to back to the normal level. Daily variation in each season also differs in each site. In summer, AIC takes minimum value at 15:00 LT. in the daily variation at ASA. But at KYS, it takes maximum value at 15:00 LT. In winter, AEF decreases from 09:00 LT to noon and gradually increases in daily variation. In other seasons, it takes maximum value at 20:00 LT and fluctuated in relatively large range. Daily variation of AEF in winter is mostly similar to the typical daily variation at KYS for all season.
Radon exhalation quantity variation has a clear negative correlation with 3 hours delay to the air pressure variation. 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.

Keywords: Lithosphere-Atmosphere -Ionosphere coupling, atmospheric ion concentration, atmospheric electricity field, Radon exhalation quantity

Multi-parameter satellite geochemistry for validation of atmospheric pre-earthquake signals associated with major seismicity. Case study for Xinjiang, China and Baja, California

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We are presenting the development of satellite geochemistry for multi-sensor validation of short-term atmospheric phenomena preceding major earthquakes. The purpose of this study is to explore the synergetic physical link between (1) satellite thermal infrared radiation (STIR) with anomalous distribution main trace gases :(2) Carbon dioxide (TCCO2), (3) Ozone (TCO3), (4) Methane (TCCH4) and (5) carbon monoxide (TCCO), associated with major seismicity. The science rationale for multidisciplinary analysis is based on concept Lithosphere-Atmosphere-Ionosphere Coupling (LAIC) (Pulinets and Ouzounov, 2011), which is based on the gas emission from the lithosphere during the earthquake generation and explains the synergy of different processes and anomalous variations, usually named short-term pre-earthquake anomalies. We analyzed retrospectively several major earthquakes in two deferent seismo-tectonic regions: XinJiang province in China and in Baja, California including M7.2 of March 20, 2008 in China and M7.3 of April10, 2010 in Baja by systematically analyzing multi-sensor satellite atmospheric chemistry and ground temperature/ humidity observations. Meteorological satellite data include NOAA POES and AQUA/AIRS polar orbit satellites. In both cases satellite data shows (STIR, TCCO2, TCO3, TCCH4, TCCO) building atmospheric anomalies 1-20 days before the main shock. This probably is connected with enhances of the degassing rate of the lithosphere, which can provide additional source for flux emission near major faults in the area. The hourly in-situ atmospheric observation show similarly in the air temperature increases and drop in the relative humidity, probably as result of additional atmospheric ionization observed before the three earthquake events. Our initial results suggest that systematic use of multi-parameter satellite geochemistry can be used for additional physical validation of pre-seismic processes associated with the major earthquake events.

Keywords: earthquake precursor, forecasting, satelite, geochemistry, radon

A statistical investigation of z test on seismo-ionospheric anomalies in TEC associated earthquakes in Japan during 1999-2014

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Statistical analysis on seismo-ionospheric precursors (SIP) by using global ionosphere map (GIM) of the total electron content (TEC) in associated with 188 M≥6.0 earthquakes in Japan during 1999-2014. Various references days of -15, ±7, ±15, ±30 days to the earthquake are employed to find characteristics of SIP. Results show that both decrease (or negative) and increase (or positive) anomalies in the GIM TEC before the earthquakes are further examined by z test. The receiver operating characteristic curve is also applied to see whether the SIPs exist in Japan.

Keywords: earthquake, ionosphere

3D Structure of Ionospheric Disturbances Related to Large Earthquakes

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In this paper we have investigated the geomagnetic storms and Earthquake-related ionospheric disturbances. Following geomagnetic storms, the ionospheric peak electron density (Nmax) and total electron content (TEC) often increase or decrease very much from their quiet-time levels. These increase/decrease are known as positive and negative ionospheric storms. This paper deals with some extremely significant geomagnetic and Earthquake-related events in between 2000 and 2013 which involving positive and negative ionospheric variations having immense importance to space weather, with reference to TEC maps derived from a dual-frequency GPS receiver network (GEONET: GPS Earth Observation Network) built by the Geospatial Information Authority of Japan (GSI), as well as foF2 and hmF2 (maximum electron density height) derived from four ionosonde observatories in Japan and GNSS-RO data from COSMIC mission of NOAA/NSPO(USA-Taiwan joint mission). For comparison and discrimination of stormy and large Earthquake days, a 3D Structure of Ionosphere will be discussed in the presentation.

Keywords: Tomography, Ionospheric Disturbances, Geomagnetic Storms, Earthquakes, TEC

Assessment of Ionospheric TEC anomaly before large earthquake: Elimination of geomagnetic storm effects

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The detection of electromagnetic perturbations prior to large earthquakes has been proposed as a useful way to monitor the crustal activities. One of the most promising candidates is the measurement of Total Electron Content (TEC). There have been many reports on TEC anomaly associated with large earthquakes from different parts of the world. To verify the relation between TEC anomalies and seismicity around Japan, statistical studies by superposed epoch analysis have been carried out. The results have indicated that before a M>6 earthquake there are clearly higher probabilities of positive TEC anomalies in Japan. These results indicate the correlation between TEC anomalies and sizeable earthquakes. Furthermore, by making use of long-term TEC data over Japan during 2000-2013 and applying Molchan's error diagram, we can evaluate the optimal parameter for earthquake forecasting. The results show that the TEC data contain potentially useful information on earthquake forecasts.
Further research on earthquake forecasting and promoting its utilization will greatly contribute to disaster risk reduction. By using an interdisciplinary or integrated approach, which connects science with technologies related to the ongoing earthquake forecast researches such as ULF geomagnetic and GNSS methods, earthquake forecasting will be demonstratively realized.

Keywords: Ionospheric TEC anomaly, statistical studies, Molchan's error diagram

Statistical Analysis on ULF magnetic anomaly and local seismicity around Kakioka, Japan

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To clarify and verify the ultra-low frequency (ULF) seismo-magnetic phenomena, we have performed statistical studies on the geomagnetic data observed at the Kakioka (KAK) station, Japan, during 2001-2010. We investigated the energy of ULF geomagnetic signals of the frequency around 0.01Hz using wavelet transform analysis. To minimize the influences of artificial noises and global geomagnetic perturbations, we used only the geomagnetic data observed at nighttime (LT 2:30 am-4:00 am) and exclude the geomagnetic anomalies when the energy of horizontal component is large.
Statistical results of superposed epoch analysis have indicated that ULF magnetic anomalies are more likely to appear before sizeable earthquake events ($Es>10^8$) rather than after them, especially 6-10 days before the events.
Finally, we have evaluated the precursory information of ULF geomagnetic signals for local sizeable earthquakes using Molchan's error diagram. We also compared our results with previous statistical studies at KAK. The above results have indicated that the ULF seismo-magnetic phenomena at KAK clearly contain precursory information and have a possibility of improving the forecasting of large earthquakes.

Keywords: ULF seismo-magnetic phenomena, statistical study, superposed epoch analysis (SEA), Molchan's error diagram

The self-potential variation induced by groundwater flow and the self-potential tomography

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Landslide is one of the most severe natural hazards in the world and there are two types; rainfall-induced landslides and landslides triggered by an earthquake. To understand rainfall-induced landslide process by the self-potential approach, we struggle with the integrated research to clarify the coupling among hydrological, geotechnical, and electromagnetic changes. Our final goal is to develop a simple technology for landslide monitoring/forecasting using self-potential method. The previous laboratory experiments show that the self-potential variation has a relationship with the ground water condition and soil displacements. So, in this paper, we first demonstrate the numerical computations on the self-potential variation by the simulated groundwater flow, and compare the result with those observed by laboratory experiments. In the result, the simulated self-potential variation is consistent with observed one.
Then, we developed self-potential tomography to estimate the ground water condition. And we also characterize the pressure from the self-potential data, and compare the result with observed pressure head that is measured by pore-pressure gauge and found that the inverted pressure head is consistent with observed one. In addition, we apply the self-potential data observed by the flume test. The estimated pressure head from observed self-potential data shows the consistency with observed pressure head. And estimated pressure head also show the characteristic distribution before the landslide occurred. These facts are highly suggestive in effectiveness of the self-potential tomography to monitor groundwater changes associated with landslide. The details will be given in our presentation.

Keywords: Self-potential, Landslide, Tomography

A Mechanism Causing Temporal Variation in b-values Prior to a Mainshock

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Observations exhibit the temporal variation in b-values prior to a mainshock. The b-value starts to increase from the normal value at time t_1, reaches its peak one at time t_2, then begins to decrease from the peak one at t_2, and returns to the normal one at time t_3. As $t>t_3$, the b-value varies around the normal one or rightly decreases with time until the occurrence of the forthcoming mainshock at time t_4. The precursor time, $T=t_4-t_1$, of b-value anomalies prior to a forthcoming mainshock is related to the magnitude, M, of the event in a form: $\log(T)=q+rM$ (T usually in days) where q and r are two constants. In this study, the mechanism causing b-value anomalies prior to a mainshock is explored. From numerical simulations based on the 1-D dynamical spring-slider mode proposed by Burridge and Knopoff (1967), Wang (1995) found a power-law correlation between b and s, where the parameter s is the ratio of the spring constant (K) between two sliders to that (L) between a slider and the moving plate. The power-law correlation are $b\sim s^{-2/3}$ for the cumulative frequency and $b\sim s^{-1/2}$ for the discrete frequency. Since L of a source area is almost constant for a long time period, b directly relates to K. Lower K results in a higher b-value. Wang (2012) found $K=r_A v_p^2$, where r_A and v_p are, respectively, the areal density and P-wave velocity of a fault zone. Experimental results show that v_p is strongly influenced by the water saturation in rocks. The water saturation in the source area varies with time, thus leading to a temporal variation in v_p as well as K. This results in the temporal variation in b-values prior to a mainshock. The modeled result is consistent with the observed one.

Keywords: b-value, precursor time, spring-slider model, stiffmess ratio, saturation of water

Integrated earthquake forecast: combination of b-value monitoring and ionospheric precursors

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In recent years, there are many 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 years. In this study, 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 Tokachi region as a test site. We will report the results of the b-value changes in space and time for the stress field change and GIM-TEC and/or GPS-TEC changes. In this report, we will focus on the two Tokachi-oki earthquakes in 2003 and 2008. They occurred on September 11, 2003 (M8.0) and September 26, 2009 (M7.1). In addition, we will show the results for other regions, if possible.

Keywords: Earthquake, Electromagnetic, b-value, Ionosphere

Development of the quasi-real-time monitoring of volcanic lava activity using MODIS

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It is possible to quasi-realtime monitoring of volcanic lava activity could be possible if we can detect the thermal anomalies related to the exposure and lava dome of magma by satellite sensors such as MODIS. And it can be used to help for the volcano disaster prevention. In this study, we deal with seven volcanoes in Indonesia. First, we define the infrared radiation caused by the eruption and then, we use the statistical analysis for the radiation, and remove the cloud effects. Finally, we investigate the abnormal values against the background level of the temperature.
We introduce an evaluation function S to remove the spatial and temporal variation from the spatial difference of the brightness temperature data between the target point and reference point (5 km distance). When we compute the differences, we need to eliminate cloud effects adequately. To achieve this, we use the brightness temperature difference between bands of MODIS (BTD). In this study, we select the following combinations ; (1) Band34-Band35 (BTD(t)-μ < kσ, k=-2.0:), (2) Band31-Band27 (BTD(t)-μ < kσ, k=-2.6), (3) Band31-Band32 (|BTD(t)-μ| < kσ, k=-3.0), and (4) Band20-Band31 (|BTD(t)-μ| < kσ, k=-3.0). Where t, k, m, and s are the season, threshold for cloud identification, average, standard deviation for each distribution of BTD. Until the distribution satisfy the equation, we repeat the test. Then, we move to the next test. We perform this procedure up to test 4. Then we get the pixels without cloud. The result is evaluated using LIDAR data onboard CALIPSO, which has the almost same orbit and constellated with AQUA. After removing the cloud effect, we compute the deviation rate d. As results for 15 years data analysis for 7 volcanoes in Indonesia, when the deviation rate exceeds in target volcanoes 6σ, there is a tendency to have a lava volcanic activities. However, without removing the cloud effects, we find it is difficult to identify the anomaly related to the lava activities. Therefore, it is highly suggestive of the proposed method is valid for monitoring volcanoes and volcanic risk reduction.

Keywords: MODIS, Volcano, Remote Sensing

MT survey and its preliminary result at Boso Peninsula, Japan (2)

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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 topic to perform the MT survey; (1) to estimate underground resistivity structures related to the plate boundaries, seamount, asperities, and slow slip events; (2) to obtain a regional realistic resistivity structure for the numerical simulation in generation and propagation mechanisms of electromagnetic precursors, and (3) to develop a new MT technique to reduce the cultivated noises such as DC-driven 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.
The preliminary 1-D inversion results for 41 induction sites show that we can presume apparent resistivity about 1 km - 10 km depth from the surface, but relatively not clear about 100 m - 1 km and 10 km - 100 km depth from the surface. In addition, we found that the noises tend to be weaker in the southern region compared to the northern region.
To presume resistivity structure in Boso Peninsula, it is necessary to remove the artificial noises from observed MT data. The observed noises have characteristics of transient signals and processes in time domain are required such as singular spectrum analysis. Moreover, twe will analyze the observed data of 12 stations in which we used fluxgate type magnetometer to obtain lower frequency and deeper information.

Keywords: MT method, Boso Peninsula

