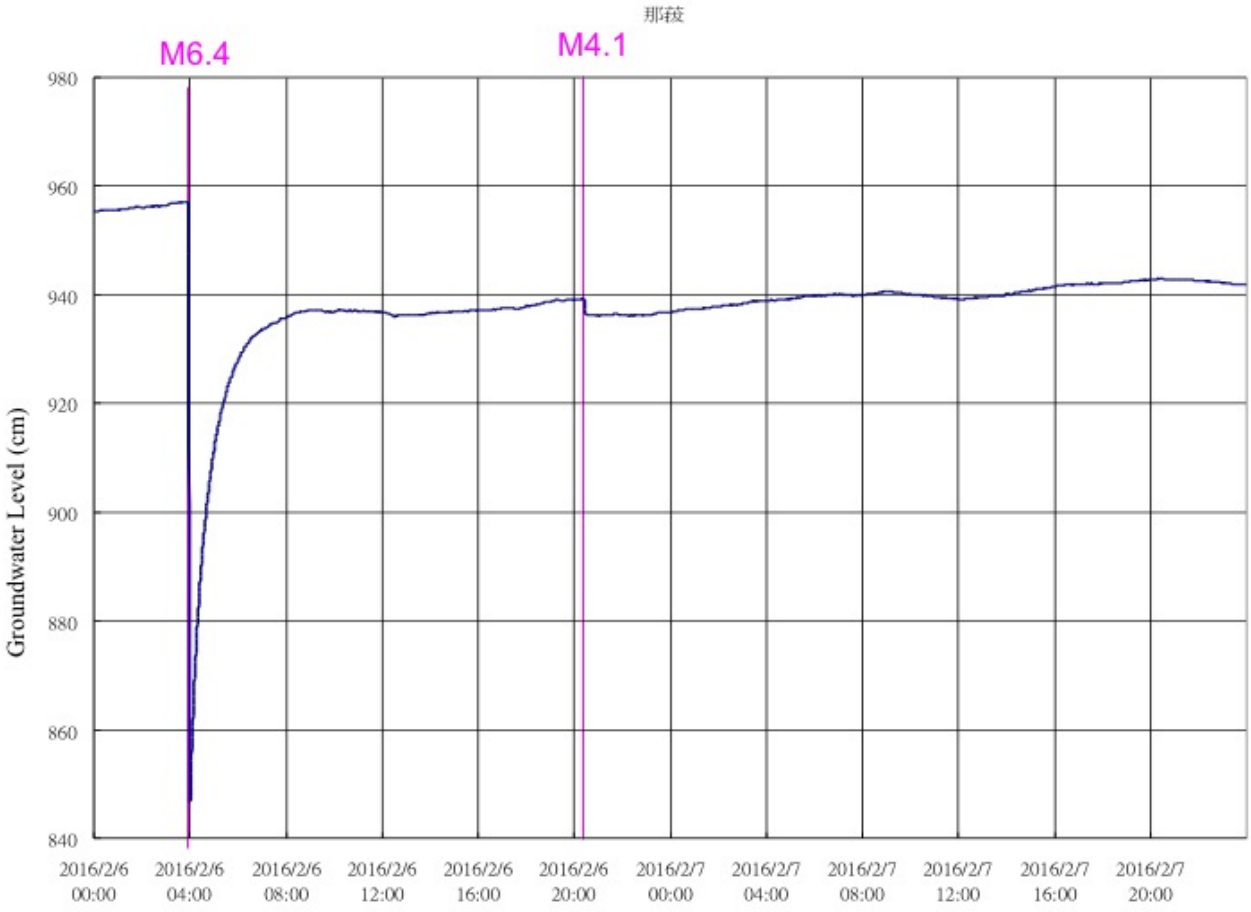
The preliminary study of the high-sampling coseismic groundwater level changes in M_L 6.4 Tainan earthquake, Feb. 6th 2016

*WENCHI LAI[1], ShihJung Wang[2], KuoChin Hsu[3], Naoji Koizumi[4]

1.Disaster Prevention Research Center, National Chengkung University, Taiwan, 2.Geotechnical Engineering Research Center Sinotech Engineering Consultants, INC., Taiwan, 3.Department of Resources Engineering, National Chengkung University, Taiwan, 4.Department of Ecosystem Studies, School of Environmental Science, The University of Shiga Prefecture

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

*Chieh-Hung Chen[1], Cheng-Horng Lin[2], Chun-Rong Chen[3]

1.Department of Earth and Environmental Sciences, National Chung Cheng University, Taiwan, 2.Institute of Earth Sciences, Academia Sinica, Taipei, Taiwan, 3.Department of Earth Sciences, National Central University, Chung-Li, Taiwan

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.

*Dimitar Ouzounov[1], Lou C. Lee[2], J.Y. Liu[3], C.H Chen[3], Sergey Pulinets[4], Menas Kafatos[1]

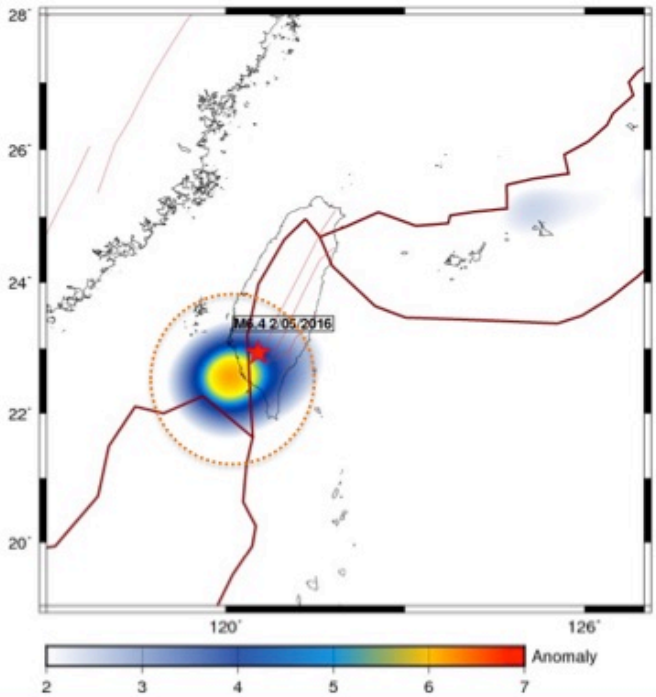
1.Center of Excellence in Earth Systems Modeling & Observations (CEESMO) , Schmid College of Science & Technology Chapman University, Orange, California, USA, 2.Institute of Earth Sciences, Academia Sinica, Taiwan, 3.Institute of Space Science, National Central University, Taiwan, 4.Space Research Institute, Russian Academy of Sciences, Moscow, Russia

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

Dim.Ouzounov@gmail.com



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

*Ching Chou Fu[1,2], Lou Chuang Lee[1], Tsanyao Frank Yang[2], Peng Kang Wang[1], Tsung Kwei Liu[2], Vivek Walia[3], Cheng Hong Chen[2], Cheng Horng Lin[1], Tzu Hua Lai[4], Gioacchino Giuliani[5], Dimitar Ouzounov[6]

1.Institute of Earth Sciences Academia Sinica, 2.Department of Geosciences, National Taiwan University, 3.National Center for Research on Earthquake Engineering, NARL, 4.Central Geological Survey, MOEA, 5.Permanent Foundation G. Giuliani, L'Aquila, 6.Chapman University, One University Drive, Orange

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

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

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)

*Peng Han[1,3], Katsumi Hattori[1], Qinghua Huang[2]

1.Department of Earth Sciences, Graduate School of Science, Chiba University, 2.Department of Geophysics, School of Earth and Space Sciences, Peking University, Beijing, China, 3.Institute of Statistical Mathematics, Tokyo, Japan

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

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

1.Institute for Geo-informatics & Digital Mine Research, College of Resources and Civil Engineering, Northeastern Univ., China, 2.Department of Earth and Planetary Sciences, Hokkaido Univ., Japan

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

*Koichiro Oyama[1,2], R Ryu[4], C.H. Chen[5], L Bankov[8], D Minakshi[3], H Liu[2,7], J.Y. Liu[6], T Kodama[9]

1.Plasma and Space Science Center,National Cheng Kung University, 2.International Center for Space Weather Study and Education, Kyushu University, 3.Physics department, Gauhati University, Assam, India , 4.Satellite Technology Research Center, Korea Advanced Institute of Science and Technology, Daejon, Republic of Korea, 5. Department of Earth Science, National Cheng Kung University, Tainan, Taiwan, 6.Institute of Space Science, National Central University, Chung-Li, Taiwan, 7.Department of Earth and Planetary Sciences, Kyushu University, Fukuoka, Japan, 8. Bulgarian Academy of Sciences, Sofia, Bulgaria, 9.Japan Aerospace Exploration Agency, Tsukuba, Japan

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

*Charles Lin[1], Jann-Yenq Liu[2], Chuan-Ping Lein[1], Chia-Hung Chen[1]

1.Department of Earth Science, National Cheng Kung University, 2.Institute of Space Science, National Central University, Chung-Li, Taiwan

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

*Hengxin Ren[1], Qinghua Huang[2], Xiaofei Chen[1]

1.Sch. Earth Space Sci., Uinv. Sci. Tech. China, Hefei 230026, China, 2.Dept. Geophysics, Peking Univ., Beijing 100871, China

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

*Qinghua Huang[1], Xiaodong Zhang[2]

1.Peking University, 2.Institute of Earthquake Science, CEA

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

*Jann-Yenq Liu[1], Yi-Ben Tsai[2], Chieh-Hung Chen[3], Yuh-Ing Chen[4]

1.Institute of Space Science, National Central University, Taiwan, 2.Department of Earth Sciences, National Central University,Taiwan, 3.Department of Earth and Environmental Sciences, National Chung Cheng University, Taiwan, 4.Institute of Statistics, National Central University, Taiwan

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

