Preface to the special issue on seismo-electromagnetics: Earthquake-related phenomena, laboratory evidences and their mechanism*

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The earthquake prediction is commonly recognized as one of the most difficult problems in natural science with globalization of the world and also one of the most important social issues concerning the human survival and social securities due to the possible paroxysmal and huge disasters from strong earthquakes. Its difficulties in science, have caused long term of disputations in the world, about whether or not it is worth making the researches on it in the present stage; and its importance in society development, however, has made the governments in many countries to adopt the countermeasures not only for mitigating, in maximum possibilities, the losses in peoples live and properties, but also for, supporting scientific researches on earthquake prediction. China is the one of these countries, specially with well organized earthquake monitoring and researches on earthquake prediction in the past more than 40 years, due to the severe fact that China is one of the countries prone to strong earthquakes in the world, with urgent demands from people and the society.

To this end, Chineses government adopted the policy of the multi-approach explorations for earthquake prediction, from various kinds disciplines in Earth science, such as geophysics, geodesy, geochemistry, hydrology and so on, The seismo-electromagnetic methodology is one of them, which is characteristic of observations of electric and/or magnetic quantities physically. The countermeasures for the explorations have been the following: setting up networks in the main seismic belts in Chinese mainland, developing the specific techniques in terms of various electromagnetic observational methodologies, monitoring the temporal-spatial variations of different kind of quantities in terms of the special techniques in the fixed stations or field spots of the networks, identifying and getting rid of the non-earthquake

effects or even the manmade interferences from the observations, and finally exacting the anomalous information from the variations possibly associated with earthquakes in the surrounding areas, on the bases of the mechanism studies of the variations, routing procedures served for earthquake predictions was constructed. In the previous stage all the observation system were set in the ground or in the shallow depth of the Earth, being called ground-bases observations. In the latest stage, however, the observation and monitoring could be extended to the space due to the fast development of new tech of observations from space in the recently years, as so called space-based observations in contrast to the previous ones.

The seismo-electromagnetic methodology, refers to four subjects in China: geo-electricity, geo-magnetism, low-frequency electromagnetic disturbances and remote sensing, which have covered very wide electromagnetic frequency bands, from lowest one such as to the frequency less than 0.01 to the highest one such as to the frequency in inferred radiation of 10^{13} Hz, and consisted of either electromagnetic field measurements and electrical properties detections of Earth media.

The researches on earthquake prediction in China began after a strong earthquake, $M_{6.8}$ Xingtai earthquake occurred in March 8 in Heibei province, a populated area in North China and caused more than eight thousands people died and near 40 thousands wounded. This was also the start point of the monitoring and researches by seismo-electromagnetic methodology.

Since then till now, the following tasks have been done in China. The first, a lot of earthquake cases have been accumulated, especially those strong earthquakes with magnitude $M_S \geq 7$ occurring inside the observation networks which would provide the opportunities

to realize the features of earthquake-related phenomena, to test and develop the methodology of electromagnetic observations including the improvement of extracting techniques for the anomalous information, although most strong earthquakes were not predicted. The second, the mechanism of the variations for observed electromagnetic phenomena have been investigated through laboratory experiments or mathematical modeling, the variations are distinguished into two categories: one might be caused by the factors related to the seismogenic process, and the other would be due to the non-earthquake effects such as seasonal changes, or even manmade electromagnetic interferences due to the fact that with the development of the economy the electromagnetic environments had been greatly deteriorated. The third, the observational techniques have been greatly developed, partly coming from the case inspections during the long term monitoring practice, and partly resulting from the high tech being applied to the observation systems continuously, so that the electromagnetic monitoring systems have been developed into the stage of digital, intelligent and networked control (Qian and Lin, 1995; Qian, 2010).

In general, The practice in earthquake monitoring and researches in China has indicated that the researches on earthquake prediction is still in the empirical stage although it has experienced for more than 40 years. And the main tasks for the stage would be the following: (1) accumulating earthquake cases specially the cases of strong earthquake as more as possible; (2) studying the physical mechanism for the variations observed in the monitoring process based on the theoretical studies and laboratory experiment; (3) improving the observation techniques continuously according to the demands of earthquake monitoring and researches (Qian, 1999).

Thirteen papers collected in the special issue are to reflect the progresses and latest development in the seismo-electromagnetic studies presented by the scientists from different countries: Japan, Russia and United States and China, the topics have touched the different fields in seismo-electromagnetic, including methodology or technology studies for electromagnetic field measurements or property detections both in the ground-based monitoring and observations from space, case studies for earthquake-related phenomena, and discussion on the mechanism of the variations in the earthquake monitoring in the theoretical studies, the laboratory tests and mathematical modeling.

Zhao et al. introduced the researches on the geoelectrical resistivity observation system with the char-

acteristics of digital, intelligent and networked technologies which have played very important role in the earthquake monitoring for the variations in Earth electrical property associated with strong earthquakes. The paper has sufficiently exhibited the special demands for monitoring temporal variations of electrical properties of the Earth media, and the requirements keeping in the system functions of high accuracy and stability as well as good ability of interference rejection for long term observation in the earthquake monitoring and researches, and how much efforts the authors have been made for the demands and requirements.

Two papers in the special issue dealt with earthquake-related satellite observations which have been one of new orientations in the earthquake monitoring and prediction researches in the world. The one is from Parrot who was the principal investigator of the French project of DEMETER. DEMETER was a micro satellite launched on June 29, 2004, and was successfully operated for six and half years and specially designed mainly for seismo-electromagnetic observations in ionosphere. This paper presented the results concerning the statistics of the ion density in ionosphere in relation to the seismic activities in the world-wide scale. It is necessary in his studies to have statistics for the observed information from satellite due to the fact that the ionosphere is highly variable, and it is also characteristic of the comparison of the statistics with random analysis to give more convincing conclusions for the anomalous signatures. It would be lucky that DEMETER had operated just in the period of the lower activity stage of this solar cycle and of many huge earthquakes occurred in the world, so that not only the statistics could be done in a relative clear way but also the case studies could be sufficiently accumulated to give great contributions to the researches of seismo-electromagnetic in the scientific sense, no matter whether the anomalous information being existing in each case or not, which could be positive experiences or negative lessons for the further studies. And the another paper written by Shen et al. dealt with the project of China seismo-electromagnetic satellite (CSES) on the bases of studies of the DEMETER data by Chinese seismologists. The satellite in the project will be launched before the end of 2014 and the project would be a special one jointly operated with the existing observations in ground-based electromagnetic monitoring networks in China, and its main objectives would be to improve the capacity of capturing more earthquake-related information to serve for the earthquake monitoring and prediction researches in this

country.

Hayakawa et al. contributed two papers with one of review in big volume, showing the effective researches on the electromagnetic emissions and good statistical results in the ULF-VLF-LF bands associated with earthquakes either in Japan and its adjacent regions or in the globe scale such as for Sumatra earthquake, Haiti earthquake and so on. His works are creative in this field and gradually populated in the other countries or regions in the world, as a promised method applied in short term forecast of earthquakes. The results from his team seem to be a little optimistic although it might cause some debates from the scientists with different view of points for earthquake prediction. However, as he said in his articles, “in order to mitigate the earthquake disasters it would be immediately useful to forecast the approach of a large earthquake on the timescale of hours, days, and weeks”, in spite of that, “it has been far from realization”, they all have an active but realistic attitude for the earthquake prediction researches.

Three papers dealt with the studies of earthquake cases especially those very strong earthquakes with huge devastations in recently years, such as $M_S8.0$ Wenchuan earthquake in China and $M9.0$ Tohoku earthquake in Japan.

Ouzounov et al. presented the combinational studies for the signals from four kinds observations: outgoing long wave radiations (OLR), GPS/TEC, lower Earth orbit ionospheric tomography and critical frequency foF2 with anomalous behaviors jointly appearing in the time period of March 3 to 11, shortly prior to the $M9.0$ Tohoku earthquake, recorded either from Japanese ground-based monitoring stations or from space-based satellite observations near the epicentral area. He et al. showed the anomalous spatial-temporal distributions of electron density observed from DEMETER several days before $M_S8.0$ Wenchuan earthquake and over the regions not far from the epicentral area on the bases of careful analysis of background variations and removing the influences from the solar activities. The similar processing of anomalous information extractions so called two step method applied by Ma et al. in the satellite microwave data AMSR-E to analyze the micro radiation anomaly in order to eliminate the factors from the stable impact of geography, terrain, coversphere and seasons, as well as the random influences from variations in the weather condition in the case study of $M_S8.0$ Wenchuan earthquake.

Other contributions were mainly associated with the methodology and mechanism studies including the-

oretic aspect, physical and numerical modeling aspects in the seismo-electromagnetic studies.

Pulinets discussed the mechanism of the geo-electromagnetic being called as a LAIC (lithosphere, atmosphere and ionosphere coupling) model, from the theoretical aspect, and dealt with the system of the Earth shells of lithosphere, atmosphere and ionosphere as an open complex nonlinear one with dissipation and the earthquakes being taken as a self-organization process close to the critical state of the system. The radon emission produced possibly in the earthquake preparation in the lithosphere would be the start point of his model, and it is the radon emission that might cause the intensive ionization of boundary layer of atmosphere so as to the perturbations in the ionosphere and finally constitute a synergy chain for the explanations of anomalous behaviors not only in the variations of various parameters in ionosphere, but also that in the atmosphere and ground observations such as the latent heat flux, Earth surface temperature, which would be verified by the observations in the several case studies shown in the paper. Wang et al. pointed out that although many cases about the abnormal electromagnetic disturbance changes associated with earthquakes have been exhibited by Chinese researchers in the past years there were several problems in this observations, for example, no synchronicity of anomalous phenomena recorded in different observational points; lack of consistent and well-defined technical requirements for various instrumentation; lack of clear physical expressions of output data for some observations and lack of strict inspection and calibration procedures for observation systems, which need to be seriously dealt with, specially for putting forward the progress in the technical treatment and data application in the earthquake prediction practice. This paper also presented suggestions for solving the problems and improving the methodology with making a code and developing a set of special techniques, and finally provided the results for testing the technology in the field based on the code. Takeuchi et al. presented the laboratory experiment on the model showing the existence of the electromotive force when igneous rock samples subjected to non-uniform loading which made the current flow from the stressed volume to the unstressed part, specially stronger in the quartz-free samples than that in the quartz-bearing ones, with the explanation or mechanism of the electromotive force generation, which is different from the electro-kinematic model by the electromagnetic effect of pore water, the main one of the hypotheses for geo-electrical potential differences. Li described

some studies about the methodology of anomalous information in magnetic field observations by the comparison of ULF informations between 0.01 Hz and 0.1 Hz and its relation with their penetrations, although the paper only touched to the earthquake of medium magnitude. Wang et al. studied the constrains for the mathematic modeling applied in the seismo-electromagnetic researches, specially in dealing with the selectivity of seismic electrical signals (SES), and pointed out that the relative errors resulting from the meshing effects may not be negligible which might lead to some inadequate or unconvincing explanation of the SES selectivity.

Finally I would like to express many thanks to all the authors for their fruitful contributions and all reviewers for their responsible and careful evaluation, opinions and suggestions for modification of reviewed papers. Moreover, I should specially point out that due to some papers in the special issue touching the topic on earthquake prediction, some interesting discussion and even intense arguments appeared in the process of the questions and answers between the reviewers and

authors, and might not stop even when the issue being published, which would be normal and helpful in the researches of seismo-electromagnetic in the future, and I sincerely hope that the discussion would continue after the issue published.

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