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Spatial Detect Technology Applied on Earthquake's Impending Forecast

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Abstract: Impending forecast of strong earthquake is still an unsolvable scientific question in the world. Based on our analysis of the disadvantages of present earthquake forecasting, this article discussed the probability to use the Spatial Detect Technology in earthquake's forecasting, moreover summarized the status, extent and some unanswered questions of those new spatial detect techniques and methods. We can surely believe that successive, dynamic, systematic and multi-parameter stereoscopic observation will be a development tendency of earthquake's impending forecasting in future. Using those spatial detect techniques, we can capture the real time dynamic information before earthquakes. Low price, covering more area, faster, more information, more strong direct perception and continual observing are characteristics of application of remote sensing technology, which compensate the inadequate of earthquake stations on the ground and improve present system of earthquake's monitoring and forecasting. There is fairly reason to trust that the predicting precise degree of earthquake information must be improved.

1. Preface

Earthquake forecast, especially the impending earthquake forecast, is one of scientific baffling problems that has not been solved for one hundred years. Now, this problem does not still be solved. Though there are some successful examples in the past decades, the majority is failure. It is not clear yet whether the abnormal precursor relates to the earthquake determinately and quantitatively or not. This situation illuminates that there exists some limited, unilateral, and even completely wrong understanding for the earthquake. Since the reasonability and the density of ground observation distribution have some problems, the relevant information from earthquake area has great random, the limitation of this kind of situation is hard to avoid.

Earthquake is a dynamic process. It usually causes the earth's crust deformation and the physical and chemical fields change in the epicenter or more large area. Therefore, the earthquake is neither a single matter nor a close system. Where there is the broken proceeding, there is the transfer of the energy between the source and the outside media. Those kinds of exchanges can produce various physical and chemical effects on the earth's surface before earthquake or during earthquake, and this makes it possible to predict earthquake by using space remote sensing technology. In the past years, the earthquake forecast researchers have pursued the goal that by means of certain methods, some unusual phenomena related to a strong earthquake be shown and be monitored with the development of the earthquake forming, the earthquake will be determined. The development of remote sensing technology has laid solid foundation for the realization of this goal. Now, it is already possible to monitor and forecast the continent strong earthquake by the spatial detect techniques and earth observation system. These techniques will play an important role in earthquake calamity forecasting. The large-scale surface information, multi-signals and multi-platforms information from the space technology can be added to the existing earthquake ground station information, which enables us to improve the existing earthquake forecast level and forecast strong earthquakes efficiently.

2 Spatial detect techniques

Material energy exchange before earthquake mainly influence the following aspects: 1) crust displacement field (by rock's elasticity, plasticity and viscidity); 2) heat flow field (by rock's thermal conductance, heat capacity); 3) geo-electric field (by rock's resistance rate) and geo-magnetic field (by rock's magnetic conductance). Presently, the sensors on space-borne platforms are capable to take over and catch the precursory information during the course of the earthquake. Furthermore, with the development of remote sensing technology, its measuring precision and application scope will be enhanced continuously.

2.1 Crust displacement field

Remote sensing techniques to survey the crust displacement field go as follows: Very Long Base Line Interferometer (VLBI), Satellite Laser Range finding (SLR), Global Position System (GPS) and Interferometric Synthetic Aperture Radar (INSAR) etc. Presently, GPS with VLBI and SLR can be used in the measure of the earth crust relative movement speed, usually combined with the gravimeter and the leveling to improve the reliability of GPS observation network. This space geodesy using GPS has shown great advantages in monitoring large-scale earth curst displacement. It can determine both the relative displacement of plates and large-scale deformation in the plate. Especially, it can make a short-term forecast of several points covered in large-scale area with high precision and offer control network of a multi-point earthquake zone. In virtue of the control network, we can couple the result surveyed from the ground to make an overall analysis.. Scientists in America applied the GPS signals recorded from 1986 and the VLBI network on analyzing and researching the crust and rupture displacement field of the South California strong earthquake in 1992, and then established the strong earthquake calamity model. In the beginning of the 1990's, Japan gathered nearly one hundred GPS observation stations to co-survey many volcano earthquakes nationally and successfully. Chinese scientists have set up hundreds of GPS observation stations in main seismic zones since 1980's and formed the preliminary monitoring network by combined ground control survey and crust motion monitoring network. This network can supply some important basic data to establish China Crust motion model, earth's dynamics model and earthquake-forecast model. Those mentioned above just prove that it is very effective to monitor earth crust deformation by GPS. Due to the limitation of observation-point, the technique is only effective to the earthquake area but not for the unknown area.

INSAR technology has developed in the 1990's. It is based on the base line information and phase interferometer, and has many advantages in crust vertical displacement measure. Compared with InSAR technique, the newly developed Radar Differential Interferometer technique has more advantages. For example, the high sensitivity to dynamic change, high space resolution and wide covering area. Using several correlated SAR images of dynamic changes, we can generate its differential interferogram. Its precision often reaches centimeter. We can survey the earthquake's residual displacement by differential interferometer technology and the accuracy is very good. In 1993, Massonnet [1] utilizes SAR Differential Interferometer technique to survey Landers earthquake of California, first proving the ability of this technique to survey the earthquake's co-seismic displacement field. Zebker [2] got the more accurate result of this research area by another technology of differential interferometry. The precision of the generated interferogram is very fine after he eliminates the topographic phase from the earthquake interferogram. Compared with the data obtained from GPS, the correlation coefficient is 0.96 and the normal deviation is 18.9 cm. It can be found that some earth's surface broken into anomalous tiny surfaces from the radar image. During the whole process of the earthquake deformation, the property of those surfaces is invariable but their fringe pattern varies with the environment. Their research has aroused the geophysicists' interests widely. Thereafter, geophysicists research other earthquakes with this technique, such as Northridge earthquake [3], Eureka

Valley earthquake and so on. May 17, 1993, an earthquake occurred in Eureka Valley. Peltzer and Rosen [4], Massonnet and Feigl [5] respectively research the earthquake with the differential interferometry technique. Though there is some definite difference, both results are fairly consistent in the allowed error range.

Generally speaking, as for the co-seismic deformation field, because of its big displacement, short time span and good correlation of data, the precis ion is very high by differential interferometry technology. Contrarily, for the post-seismic displacement, because of the long time span, the not ideal correlation, the application of Radar Differential Interferometry technique in this aspect is not satisfactory. But for some earthquakes such as Landers earthquake, the Radar signals are still highly correlative for a long time after the earthquake. We can generate some interferogram patterns in virtue of the differential interferometry technique. From those interferograms, we can research the post-seismic displacement, fault slip and then can supply bases to earthquake forecast consequently. Through the research, scientists not only further prove the ability of Radar Differential Interferometry technique to examine the vertical displacement after the earthquake, but also discover it is possible to monitor the crust's slow deformation during the period of earthquakes under certain conditions.

Now, JERS-1, ERS-2, and RADARSAT satellites offer large numbers of original data for differential interferometry research. Meanwhile, the development of the research in this aspect and new data process algorithms has laid solid foundation for this technique. What's more, Radar differential interferometry technique can be used not only in the research of the earthquake, but also for the other geophysical phenomena such as flowing speed of ice sheets, the slow deformation of volcano. Now, scientists are planning to apply this technique to monitor certain long-term geophysical phenomena, for example, strong earthquake forecast. These kinds of research need better original data, better process algorithms and so on. Along with the continuous launch of new interferometric radar satellites such as ENVISAT, SRIM, we believe that in the future, it is promising to monitor the various geophysical phenomena that have longer time span.

2.2 Ground thermal IR abnormity

At present, some satellites can obtain the radiation of the long-wave infrared emitted from natural projects on the ground, and can monitor the precursory information of the change of the thermal IR before earthquake. Gorny et al (1988) [7] first used the remote sense data (NOAA/AVHRR) to indicator seismic activity, moreover preliminarily explored the idea and the method to predict earthquake. Aiming at understanding the earth's surface infrared abnormal phenomena reflected in remote sense image before the earthquake, some scholars further research the mechanism. Qiang Zuji (1990)[8] considered that those gases such as CO_2, CH_4, H_2 .etc went up from the deep earth and the cranny of the rock and then enhanced the greenhouse effect in the atmosphere through the radiation of the sun and electromagnetic field action. The temperature of the shallow-stratum is rising. Tronin(2000)[9] deems that the temperature increase of the earth surface before earthquake maybe hydro-geological factors or the greenhouse effect play a main role in the forming of anomalies.

In fact, the temperature of the earth's surface is a result that certain factors of the earth's surface thermal balance system affect each other. Therefore, there is much uncertainty when we capture the pre-earthquake temperature abnormal information by means of satellite thermal infrared sensor. There also are many reasons to cause thermal information to be abnormal. Therefore, the first question is to determine the thermal IR abnormal factor that is related to the earthquake forming process. Because of the effect of the crust stress change, firstly the soil structure changes the soil thermal property. When you pick thermal information up with infrared remote sense images, you cannot simplify the factors that affect thermal temperature, but should consider the effect among the earth's surface thermal balance factors. We cannot simply use the abnormality in remote sense images to determine the relationship between the thermal abnormality and the forming of earthquakes. It is impractical to utilize the thermal infrared channels of satellite data to directly monitor the temperature abnormality of the earth's surface. We can only gain the pre-earthquake precursory abnormality indirectly. Now, there are many troubles to solve in order to directly apply the technique to earthquake forecast. So far, we have not resolved them satisfactorily. In the other hand, the calibration of thermal IR information, and the process and influence of non-earthquake factors still puzzle us. This technique cannot be applied practically until the troubles are resolved.

2.3 Electronic and magnetic field

The low frequency or very low frequency electronic and magnetic abnormal signals before earthquake is also an information source that can be captured with spatial detect technique. Plenty of different large-scale long-term observation results [10] and experiments in laboratory [11] have already shown this. A number of field observations also prove that some displacements appear in earth's surface before earthquake, and the biggest velocity of the displacements appears from hours to days before earthquake. Because of the underground geological material is not symmetrical, when the stress changes, the material must cause the local break, and then formed tiny breakage and local friction. The electronic and magnetic wave radiation occurs along with those processes. Both experimental and theoretical research has shown that the source of the earth can cause disturb of the natural electromagnetic field. Under the strain condition of earth crust, the large-scale motion of electric current source only be in the status of pulse; Secondly, the characteristic frequency that arouses is 10 Hz~100KHz, and the level of the charge electric field will depend on the relative position of the epicenter on the ground. There are two possibilities that the produced electric field penetrate the ionosphere layer. The first kind of possibility relates to unstable electric field's degradation with the atmosphere height increase. The experiment has shown that among 0.1~1KHz frequency section, due to the increase of the path of the electronic particle, the value of penetration decreases exponentially with atmosphere altitude increase, the neutral gas arouse and the additional ionization cannot occur in 30~80 kilometer altitude. The additional ionosphere under unstable ionosphere also can be sub-broadband electronic and magnetic source. The second possibility relates to the arousal of local resonance between earth and ionosphere layer system. It can cause cross-change electric current of ionosphere to splash, and may arouse additional heating and ionization, hydronium cyclotron and hydronium-sound vortex extension because of the local decrease of the heating of the lower ionosphere and its density. It is possible to further enlarge the Rayleigh –Taylor non-stability and form a sparse bubble area in the ionosphere. These process urge to form a new disturb area in the upper ionosphere. Vortex area becomes the source of electromagnetic radiation and makes the radiation strong scatter. In addition, the local change of electric current system of the ionosphere caused by conductance's variability that spurs the scattering of the high-energy particle in the radiation area. The direct reflection of the ionosphere of property before the earthquake provides the physical foundation for the application of the spatial detecting technique.

Scientists have found that the very low frequency radiation apparently becomes enhanced in the epicenter area of Ms 5 or higher earthquake [12]. The former Soviet Union AE-C and ISIS-2 satellite captured the local density decreasing of the hydronium and very low frequency radiation in several hours before the earthquake. French researchers utilized GEOS-1and GEOS-2 satellite to measure 6 branches of electronic-magnetic field, 3 electronic branches and 3 magnetic branches, and found that among 296 magnitude 5 or more earthquakes near the longitude where the satellite is, the electromagnetic noise of 51 percent earthquakes in the 0.3~10KHz frequency scope increases obviously. Japanese and American scientists also use the similar satellite data to analyze some strong earthquakes. The Japanese universe development group (NASDA) implemented the earthquake plan of remote sensing in 1996. One of the most important projects is to use VLF/LF method of electromagnetism wave and aimed at capturing the electromagnetic wave of different frequencies by ? navigating satellite. The validity of this method was proved by survey some earthquakes. The identification of critical status is the vibration of sympathetic response of atmospheric gravity wave (its period is 5 or 10 days). Shallow earthquake in critical status will affect the bottom ionization and cause the low ionosphere to lower. This kind of atmospheric vibration is mainly because of the wind, but maybe also related to the earthquake. Furthermore, there exist some close relationship among the earth crust, the atmospheric layer and ionosphere. Now, this plan aims at developing the recognizing system of sky wave and ionization reflection wave, and the system of the disturbing area of the ionosphere.

3 Application prospect

Because of the limitation of the present observation means and earthquake forecast, presently it is said that the collected precursory information is not definitely related to the earthquake according to some research. Earthquake forecast should be based on multifaceted information. Future earthquake forecast will be based on the successive, dynamic, systematic, and multi-parameter stereoscopic observation. Whether the earthquake can be forecasted and it is accurate will mainly depend on the knowledge of the impending earthquake and some relevant information about earthquakes. The earthquake information acquired by space remote sensing technology has the following advantages: low price, broad cover area, full information, and dynamic observation. This can overcome the disadvantage of the ground stations and improve the system of the present earthquake observation and forecast. Remote sensing technology not only makes the acquired earthquake information more complete but also provides a new means for earthquake forecast. This shows that the remote sensing technology can play an important role in the field of earthquake forecast.

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