MONITORING AND PREDICTING STRONG EARTHQUAKES USING NOAA DATA

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ABSTRACT:

Analysis of seismicity with temperature shows that strong earthquakes are associated with thermal anomaly, and measuring temperature can be used to monitor and predict earthquakes. In general, the anomaly starts to appear in more than one month before a strong earthquake with covering area of thousands Km^2. Temperature abnormally increases 1℃ or more in one month, and 2℃ or more, even 10℃ in a half month. The epicenter locates within the anomaly area.

Analysis of thermal—IR imagery processed with NOAA data may become a more efficient approach in the use of earthquake prediction for its vast covering area, short period (2 times a day), high resolution (1×1Km), and high accuracy (1℃ or less). The approach includes 4 steps: 1. definiting relationship between seismicity and anomaly; 2. determining background of temperature in a given region; 3. atmosphere correction; and 4. monitoring and predicting.

A study case is sampled in which possibility of a strong earthquake in Linfen area was predicted with the approach. The result conformed to reality.

KEY WORDS: Thermal anomaly, strong earthquake, NOAA data, monitoring, predicting

I. INTRODUICTION

Many strong earthquakes were associated with thermal anomaly, based on analysis of seismic events with temperature data in epicenters and adjacency before the earthquakes. Monitoring the changes in temperature has been used to predict earthquakes in China.

Three ways are used to observe temperature:
1. regular measurement with meteorological instruments; 2. special measurement with high precious thermometers setting in deep wells; and 3. NOAA data processing. Owing to high cost, difficulty of data transmission or limited covering area, the former two ways are hard to meet the needs of monitoring and predicting earthquakes. The third way, however, will play important role for its low cost, vast covering scope, and other superiority. The paper introduced the feasibility of the approach and methods.

II. ACADEMIC FOUNDATION

1. Thermal anomaly pre—earthquake

In the past, a great number of thermal anomaly associated with strong earthquakes were recorded in literature in China. This aroused seismologists to consider the possibility of predicting earthquakes by monitoring the changes in temperature.

In the recent decades, analysis for seismic events with temperature data from meteorologiocal stations widespreaded indicates that thermal is an universal phenomenon, and there is a close relationship between the both. In general, the anomaly covers an area as large as thousands Km^2, and starts to appear in several months, even a half year, before a strong earthquake. Obvious anomaly appears in about a month. During this period, temperature increases in high rate. In the early stage, abourt 10—20 days. An anomaly area consists of some seperated regions each with a range of 1℃ or more. In the late stage, about 10 days, the regions migrate toward the epicenter and adjacency, forming a large district with a range of more than 2℃, even 10 ℃ in some cases. The close relation imply that continuous observation for temperature in a large area can be used to predict earthquakes (see appendix I).

2. NOAA data and thermal—IR imagery

NOAA satellites pass the same zone two times a day. Thermal — IR imagery processed with NOAA data, cover the whole surface of the earth, with resolution of 1×1 Km and accuracy of 1℃ for land surface, 0.5℃ for sea surface. Therefore, it is feasible to identify thermal anomaly caused by a strong earthquake using NOAA data, as shown on some of thermal—IR imagery got from NOAA data before the seismic events (see appendix II).

III. METHODS

1. Definiting relationship between seismicity and anomaly

The exactitude of predicting earthquakes by the approach depends largely on the level of the relationship. It is necessary to definite quantitative interrelation of time, location (epicenter), and magnitude of an earthquake to the period of anomaly lasting, covering scope, range of temperature increased, and developing tendency. Based on the relationship, one can predict earthquakes according to anomaly.

2. Determining background of temperature

Distribution and evolution pattern of temperature are controlled by geographical position, relief, geologic struicture, and thermatics in the deep. In a point view of temperature, a region may be divided into several districts arranging alterately, some with higher temperature, the others with lower temperature. While evolution pattern in each district differs from others. The background in a given region must be understand exactly so as to avoid any mistakes that a region with "normal" high temperature is treated as a region displaying anomaly related to earthquakes.

In order to understand background, it is necessary to collect temperature data from meteorological stations and other measurements for temperature. From the average values of every 10 days during 10 years or more, spacial distribution and temporal evolution pattern (increasing from spring to fall, decreasing from fall to winter) can be determined. The most practical way is to draw the contour maps of average temperature for each 10 days or less, for it is easy to contrast with the distribution and evolution pattern got from thermal—IR imagery.

3. Atmosphere correction

What is received by sensors mounted on meteorological satellites is radiance from the earth's surface. Due to obsorption, diffusion, and reflection of altmospheric layers with a thick of hundrods Km, the temperature values provided by satellite thermal—IR imagery are different from the real temperature valuies. Therefore, atmosphere correction is used to eliminate the influences of atmosphere.

Atmosphere correction is a complex duty, it needs to establish atmosphere model, radiative transfer model, and to measure atmospheric penetration, irradiation, radiative, and other parameters. Recently, a simple approach for atmosphere correction has been developed. That is, to measure temperature of main targets, especilly large water body, with a radiation thermomenter or thermal—IR radiometer, synchronously with a NOAA Satellite. Through analysis fro relativity of the temperature values from measurements and the values from NOAA data for the same targets, the real temperature can be gained directly from thermal—IR imagery.

4. Monitoring and predicting earthquakes

After the steps above, monitoring and predicting earthquakes can be performed. Monitoring is to analize regularly (every 5 days or less) spacial distribution and temporal evolution of temperature in a given region (for example, a seismic risk area) from thermal — IR imagery. When anomaly appears, based on the contrast with the background, and consideration for weather, it is needed to process and analize thermal — IR imagery every day to observe development and changes of the anomaly. According to these, the possibility of a strong earthquake occuring in the area can be predicted, including time (or period), location, and magnitude of the earthquake expected based on relationship between earthquakes and anomaly, in case of thermal anomaly being infered to be caused by a strong earthquake.

Ⅳ. TRIAL APPLICATION

In the early spring of 1991, crustal deformation anomaly appeared in Linfen Area. Some seismologists suspected that the anomaly was the precussor of a strong earthquake, and the area was in seismic risk. In order to analize the possibility, a project was approved by authority in which many approaches were used. As a trial application, monitoring the changes in temperature with NOAA data was carried out.

1. Background

Linfen city locates within a NE axial basin—Linfen Basin. Two NE seismic fault zones control the boundaries of the Basin. Three strong earthquzkes with magnitude of 7 or more occured along the zones in the 10th, 13th, and 16th century, separately. The temperature data in 7000m subground indicate that the Basin is a high heat flow region. The temperature data during 1982 — 1991 from meteorological stations show that temperature within the Basin is higher than the two sides. Temperature contours present long axial ellipses. Average temperature in May is 17—18℃ in the Southern part, and 13—14℃ in the Northern part. In June, average temperature is 21—22℃ in the Southern part, and 17—18℃ in the Northern part. Increasing rate from May to June is about 4℃ for whole area.

2. Analysis for temperature by NOAA data

Thermal—IR imagery provided by State Meteorological Center was analized for monitoring the changes in temperature in this area. The imagery during 6—21, June showed distribution of temperature in this period was similar to the background. Average temperature in 20th, and 21st was higher 3℃ than that in May. These indicated that distribution and evolution were normal.

3. Prediction of seismic risk

As mentioned above, thermal anomaly with a range of 1℃ or more starts to appear in one month, and 2℃ or more in about 10 days before a strong earthquake. No any anomaly suggests that it is not possible for a strong earthquake to occur within one month. Based on the analysis, an opinion was given to the authgority that there was no possibility of seismic risk in the area until the middle July.

4. Result

By July, no any earthquakes occured in the area, and crustal deformation anomaly disppeared graduately. The fact indicates that the approach is efficient in monitoring and predicting strong earthquakes.

V. DISCUSSION

Current study and applications of the approach is priliminary, it is needed to be completed and tested furtherly. In the practise application in future, an important problem must be payed attention: the influence of weather. In some bad weather conditions, such as raining, snowing, cloudy, it is difficult to get temperature information by NOAA data processing. In case of the situation presenting during a period of anomaly existing, possibility of a strong earthquake is analized just based on the tendency of the anomaly developing.

Morever, the cause of thermal anomaly pre — earthquake needs to understand deeply. Up date, four hypotheses are proposed: 1. transformation of dynamic enegy: motion along faults and friction between rocks generate heat in the procession of stress concentration; 2. meteorological effect: CO_2, CH_4, H_2, and other gases entering into atmosphere from the deep change air composition and generate" green house effect"; and 3. consanguinity of earthquakes with abnormal geothermics in the deep: rising of mantle induces seismicity, also increases temperature of ground surface and/or air through high hot fluid migrating upward. Deeply understanding for the cause will help to adjust the approach so as to monitor more efficiently the changes in temperature.

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Appendix I

Xingtai Earthquake (Hebei prov., China, Mar. 22, 1966, M=7.2)

Obviously thermal anomaly had appeared since 1965. The anomaly covered the Upper Northern China, separated by an EW long axial rigion with lower temperature. In the early 1966, whole Upper Northern China became a large anomaly area, containing several districts where temperature was 1.5℃ or more higher than the others. Temperature increased continuatively from Febrary to March. Accumulated amount reached 27℃, and the highest was in the epicenter.

Haicheng Earthquake (Liaoning prov., China, Feb. 4, 1975, M=7.3)

In the early January, 1975, temperature in anomaly area was 1.9℃ or more higher than the others. In the late January, temperature continuously increased. Two days before the event, temperature continuatively increased, and the range in the epicenter was 10℃.

Songpan Earthquake (Sichuan prov., China, Aug. 16, 1976, M=7.2)

Temperature had rapidly increased since the late July, and obviously in the early August. Temperature in Kangding, Markang, and Pingwu were 3.0, 2.5, and 1.5℃ higher than the background temperature, separately.

Tangshan Earthquake (Hebei prov., China, Aug. 26, 1976, M=7.8)

Anomaly area was formed in 1975, and a region with the highest temperature located in Beijing and adjacency. Since the early 1976, the region spreaded Eastward, covering the epicenter, with the range of more than 1.5℃.

Appendix II

Kazly Earthquake (Northern Tianshan, USSR, Mar. 19, 1984, M=5.3)

Thermal—IR imagery had shown especially high anomaly since Mar. 11, the anomaly covered the area of hundred thousands Km^2.

Gesongpa Earthquake (Northern Tianshan, USSR, Jun. 14, 1990, M=7.3)

Anomaly with the area of 700×1600Km had appeared on NOAA thermal—IR imagery since June 7.

Datong Earthquake (Shanxi prov., China, Mar. 19, 1990, M=6.1)

In March 12, high temperature anomaly with the area of 10000Km^2 appeared on NOAA thermal—IR imagery.