SATELLITE THERMAL IR ASSOCIATED WITH WENCHUAN EARTHQUAKE IN CHINA USING MODIS DATA

Jianxi Huang[1], Feng Mao[1], Wensheng Zhou[1], Xianlong Zhu[1]

[1] *Architecture School, Tsinghua University, Beijing 100084, China, jxhuang@mail.tsinghua.edu.cn*

ABSTRACT :
Satellite thermal infrared (TIR) imaging data have recorded anomalies prior to major earthquakes and associations with fault systems. The purpose of this study is to verify if TIR anomalies can be found in association with known earthquakes by systematically applying remote sensing data analysis techniques to imagery recorded prior-to and immediately after large earthquakes. In this paper, MODIS satellite thermal images have been used to study the relation between thermal anomalies and seismic activity. Wenchuan earthquake was chosen as the main study area. Our research results showed that the temperature became higher 3-5 degree prior to the earthquake and the anomaly disappeared after the earthquake.

KEYWORDS: TIR, earthquakes, anomalies， association, remote sensing data analysis techniques

1. INTRODUCTION

The development and occurrence of earthquakes influenced by many factors such as seismogeological condition，terrestrial stress，groundwater etc. is a complicated process，hence，the earthquake precursor appears in complexity and irregularity. Remote sensing has been used for earthquake research from 1970s, with the first appearance of satellite images. The current situation of remote sensing applications for earthquake research indicates a few phenomena related with earthquakes: Earth's deformation, surface temperature and humidity, air humidity, gas and aerosol content. Satellite thermal infrared imaging data have recorded anomalies prior to major earthquakes and associations with fault systems. There are numerous observations of surface and near-surface temperature growth of the order of 3–5 ℃ prior to Earth's crust earthquakes. Methods of earthquake predictions have been developed using thermal IR survey. Well-known cases of gas and aerosol content change have been observed before the earthquake. Satellite methods allow us to restore the concentrations of gases in the atmosphere: O_3, CH_4, CO_2, CO, H_2S, SO_2, HCl and aerosol.
A multi-disciplinary system has been set up to monitor earthquakes and precursors so as to pro-vide a surveillance base for earthquake forecasting. The establishment of a multi-disciplinary system for monitoring earthquakes and precursors is an important base for earthquake prediction research. Since the 1960s, a multi-disciplinary monitoring system has been set up. The multi-disciplinary monitoring system consists of more than 400 seismic stations and several telemetric networks; while the precursory monitoring system includes 1,700 stations for observing crustal deformation, ground gravity, geomagnetism, groundwater chemistry, groundwater physics, etc. Also, the mobile networks for observing ground gravity, geomagnetism and crustal deformation cover a total route over 150,000km. In the 1990s, digital seismic networks, GPS networks and satellite remote sensing stations were set up with newly developed techniques.
It has been more than 30 years since the research and practice of earthquake prediction started in China after strong earthquakes (M=7.2，6.8) occurred in March 1966 in Xingtai，Hebei Province，a populated area in North China，and caused large losses to the people and to the society. Until now，some progress in research and practice has been made by Chinese scientists，especially in the following aspects: (l)a variety of earthquake cases has been accumulated，in which different kinds of so-called precursory data，observed by fixed or mobile networks of different disciplines，have been included: (2)the physical mechanism of observational means has been studied in more detail and the synthetic model of earthquake preparation has been established, based on theoretical and laboratory research as well as the data of observation. All of the progress，however，is only the

first step in earthquake prediction research, which is still in the empirical stage of development with the main feature of low rate of success in routine consultations for predicting the forthcoming earthquakes.

2. TAKE WENCHUAN EARTHQUAKE AS AN EXAMPLE

At 14:28 on May 12th in 2008, the Sichuan earthquake happened, and the epicenter located in Wenchuan county. In the area, there were many mountains, hills and basins. The earthquake brought huge crowd casualty, economic loss and so on. All government departments tried very hard to provide relief for the people. Land-use map in the study area was shown in the following figure (Fig.2.1).

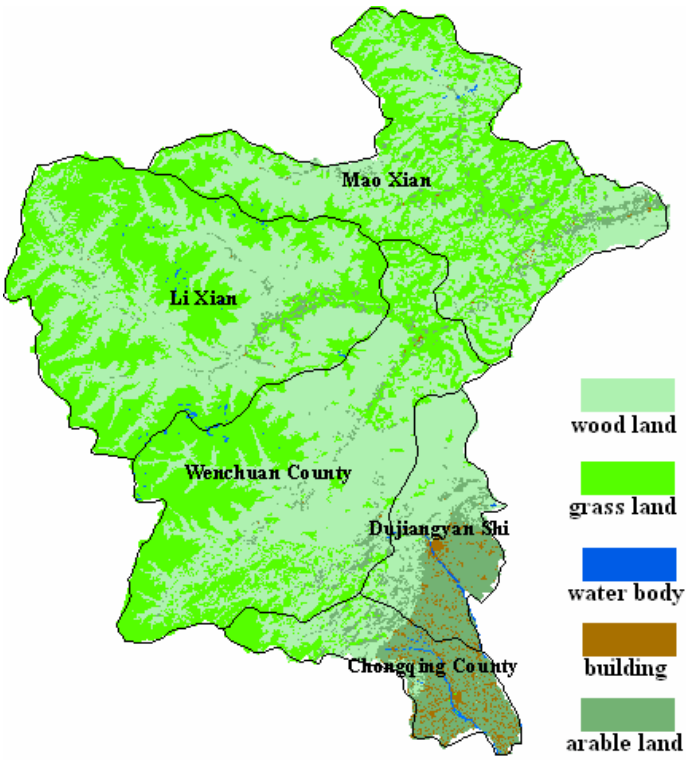

Fig. 2.1 the landuse map in study area

2.1. Research Data

In the paper, MODIS data was used to acquire surface temperature, and the remote sensing imagery owned 1km spatial resolution. It was possible to predicate earthquakes using the data. Land Surface Temperature (LST) data are calculated from MODIS. LST algorithm of NASA is precise and its error is less than 1K, while it's complex and it's not easy to use. Wenchuan earthquakes happened on May 12th, and the data include May 1st, May 2nd, May 5th, May 11th, May 12th and May 14th.

2.2. Methodology

The MODIS data are derived from NASA official network. According to the acquired data, some preprocesses have to be done. The original data contain land surface temperature (LST) imagery, but the map projection is Sinusoidal. It is necessary to convert the projection to Geographic lat/lon with datum WGS-84. In addition, the LST imagery is not the normal temperature imagery, and the pixel value is magnified 500 times. The imagery values needs to be reverted to normal temperature imagery. The band was calculated. The equation is shown in Eqn.2.1.

$$B=b1*0.02-273.15 \qquad (2.1)$$

Where B is the normal temperature value and b1 is the original imagery pixel value.

2.3 Temperature Anomalies

With preprocessing, the spatial anomaly of land surface temperature was got. The following figures shown the anomaly before the earthquake (Fig.2.2-2.5).

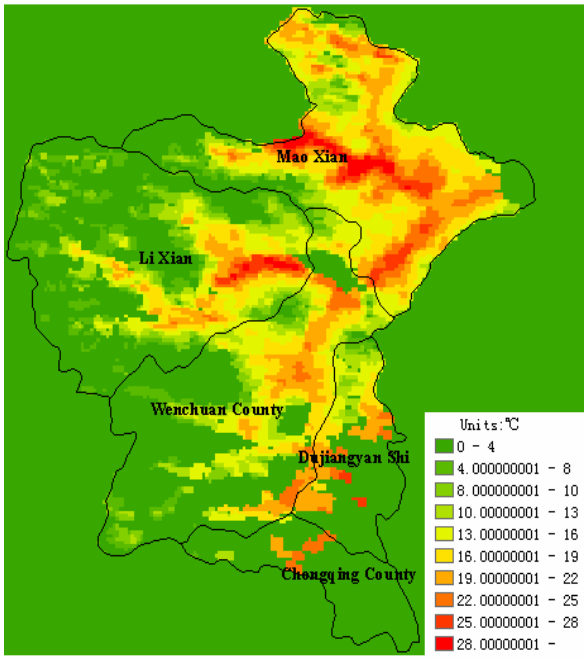

Fig.2.2 the spatial anomaly on May 1st

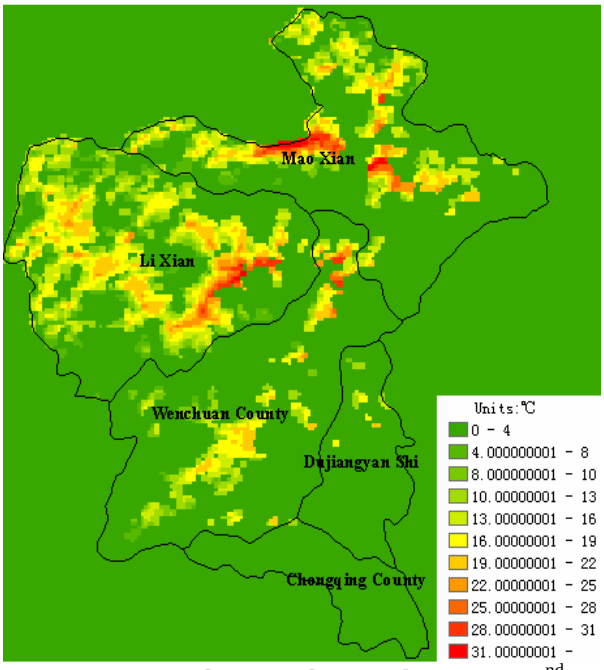

Fig.2.3 the spatial anomaly on May 2nd

According to these figures, it indicated that there was spatial anomaly of land surface temperature along a cin Wenchuan county, where the temperature was higher than circumjacent temperature. It was possible a strip to leaking energy. After the earthquake, the temperature came back usual (Fig.2.6-2.7). In Maoxian, there was high temperature area and it maybe an earthquake strip. Before and after the earthquake, the strip stilled all the time, it maybe reflected by given terrain.

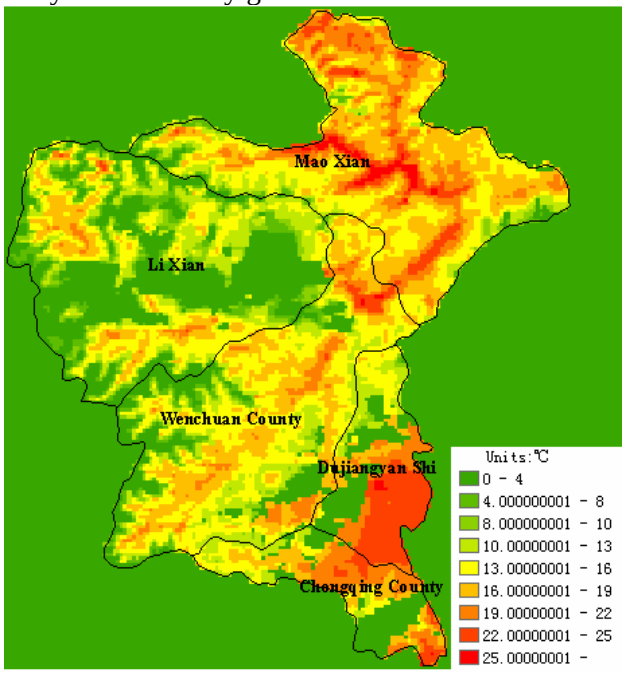

Fig.2.4 the spatial anomaly on May 5th

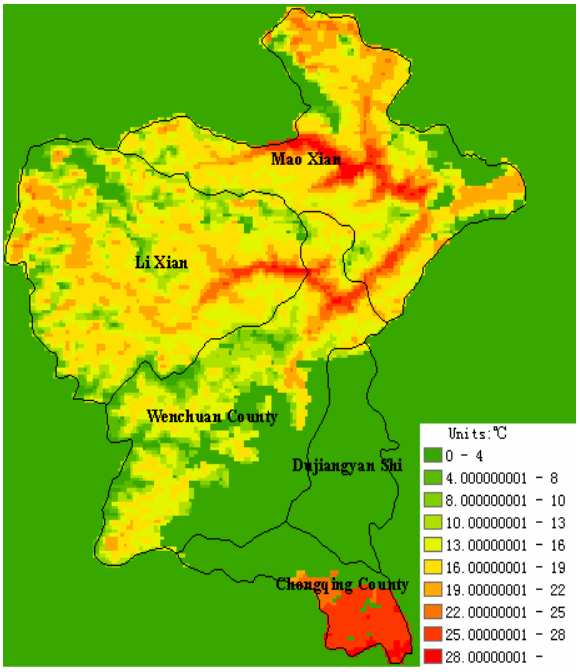

Fig.2.5 the spatial anomaly on May 11th

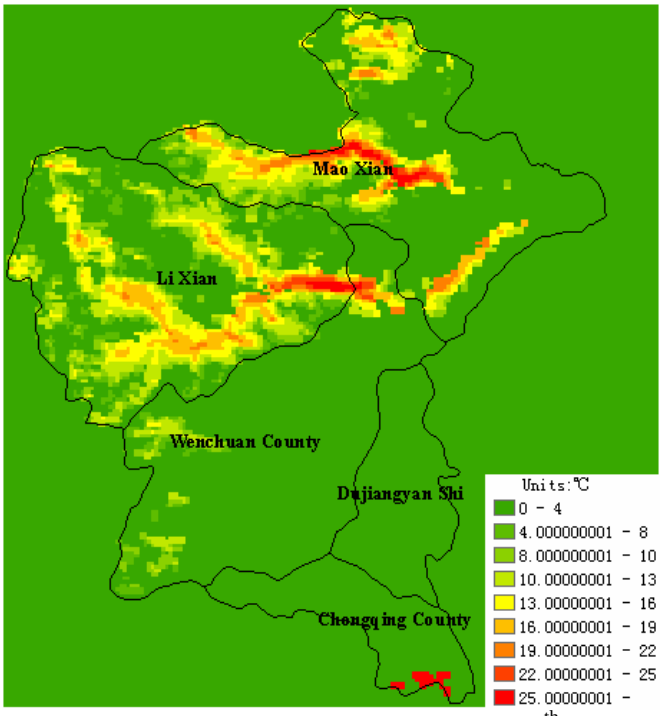

Fig.2.6 the spatial anomaly on May 12th

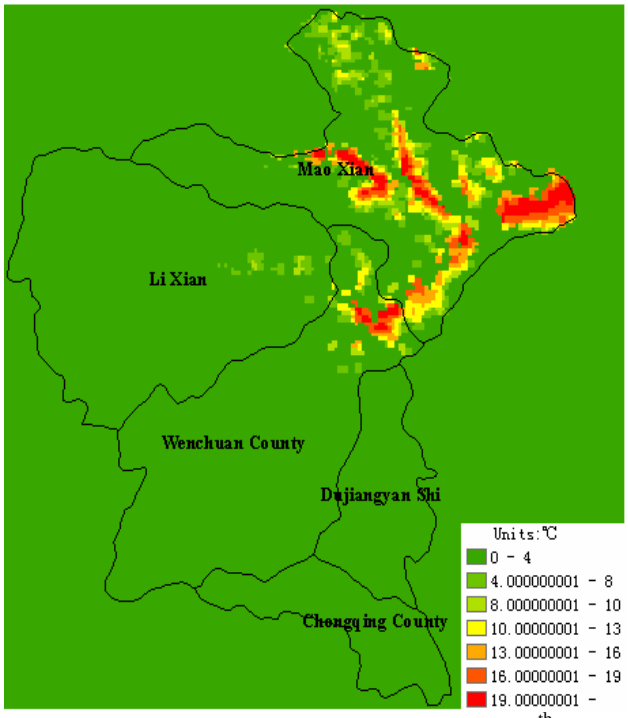

Fig.2.7 the spatial anomaly on May 14th

According to above figures, graph about the temporal anomaly in Wenchuan county could be drawn (Fig.2.8). According to the graph, it was seen that the temperature had a peak value on May 11th, which was one day before the earthquake. After the earthquake, the temperature was lower than other days. It was no doubt that the TIR anomalies were existed association with earthquakes.

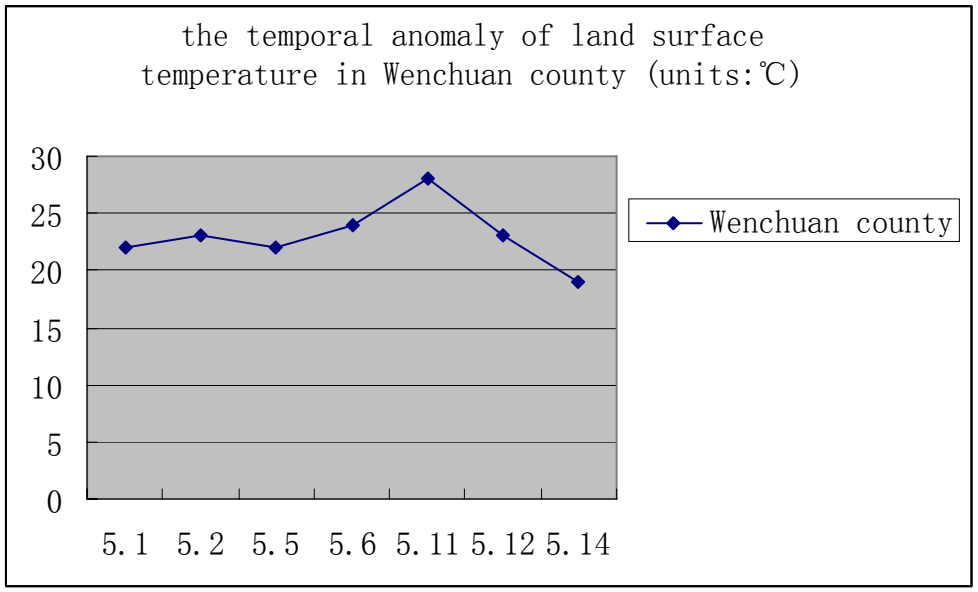

Fig.2.8 the temporal anomaly of land surface temperature in Wenchuan county

The accumulation of tectonic stress in the earth's crust caused a sudden rupture of lithosphere, going with earthquakes breaking out. Indian plate dived to Asia plat at the annual rate of 50 mm, resulting in rapid uplift of the Qinghai-Tibet Plateau. At the same time, the plateau material flowed towards east slowly, and the structure in the highland areas along the eastern edge of Longmenshan squeezed the east, which extrusion was blocked tenaciously by rigid block under the Sichuan Basin. With long-term cumulation of structural stress, the energy

was broken out in Wenchuan area suddenly, and rupture structure was extended rapidly along the fault zone of Longmenshan, causing a zone of fracture (Fig.2.9), resulting in Sichuan earthquake on 5.12.

Fig.2.9 the fault zone (the red area)

3. THE REASONS OF TEMPERATURE ANOMALIES

There is no explicit understanding how seismogenic process of earthquakes cause thermal infrared anomalies, but it is certain that the thermal infrared anomalies are combined effect under the stress experienced a complex physical, chemical process in epicenter areas. Three theories are explained.

3.1 Greenhouse Effect

It was found that greenhouse effect played important role in raising the lower atmosphere temperature before earthquakes. in seismogenic process, with the stress of constantly enhanced, new fissures emerged, associated with original fissures, and in lithosphere the gas composition such as Rn, Ne, He, H_2, CO_2, SO_2, vapor, move up along the crustal fault under high pressure, overflowing surface, known as "leaking gas phenomenon". These gases mix and change the composition of the lower atmosphere, and vapor will also absorb large number of short-wave radiation, causing the atmosphere and land surface warming. It was calculated that if concentration of CO_2 was doubled, and the temperature may increase 4.5 ℃. The water's chemical composition of gas changed significantly before earthquake observations. Before Tangshan earthquake (Ms=7.8), CO_2 concentration is four times than the normal value in three wells. Clearly, before earthquakes, the objective material conditions of greenhouse effect are existent.

3.2 Piezoelectric Effect

Earthquake preparation process is primarily a mechanical process, and hypocenter and medium continue to strengthen. When up to a certain extent, the media access to adequate atomic energy, resulting in arrangement of atom and molecule, as well as heat movement and change, which induce outer-level transition of the atomic, molecular electronics. This process will be accompanied by an electromagnetic radiation (including infrared waves). These effects can affect the magnetic radiation energy changes, and this point has been confirmed by

the experimental rock pressure.

3.3 energy conversion

In the late stages of earthquake preparation process, hypocenter areas are high stress concentration, and also high strain enhancement. When the stress reaches a certain threshold, rock damage begins. The rock rally needs a lot of energy consumption, and consumption converted large part to heat. Then, with the role of tectonic stress, the faultage start to overcome friction creeping. The movement releases energy, converting part into heat, and the temperature of fault plane is raised. As everyone knows, the shallow depth of the earthquake's epicenter is generally ten km or tens of km, and the thermal conductivity of rock is very small. It is difficult to explain calefacient lower atmosphere or land surface, a few days or tens of days. Therefore, it is very likely that the source of heat in deep underground fluid or gas for heat are the media, overflow to surface along the fissures, micro-fracture, fault, hole, such as special access, causing land surface and lower atmosphere to be warmer.

4. CONCLUSIONS

From the research, some conclusions are drawn.

1) It is feasible to predict earthquakes using thermal infrared imagery. The relation between earthquakes and temperature anomaly can be found out with satellite thermal infrared (TIR) imaging data.
2) Earthquakes prediction is a difficult task all around the world. The prediction techniques are not so perfect that scientists are bending themselves to further researches. Short-time prediction is more difficult and more exigent.
3) Earthquakes break out with the energy release in interior earth, and the research results can not be experimented at times. In this case, the researches are brought forward higher requirement.
4) There were also some limitations. The temperature anomaly may be confused by other factors, such as contamination, intricate terrain and so on.

ACKNOWLEDGEMENTS

This work has been supported by National Key Technology R&D Program (No:2006BAK30B01) and Postdoctoral Science Foundation (Research on monitoring and evaluation of thermal losses in urban building based on remote sensing).

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