Study on the Earth's Surface Brightness Temperature by Using Satellite Thermal Infrared Data in China Earthquake Monitoring Area

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***Abstract*—Satellite thermal infrared remote sensing is a promising observation technique to monitor fracture activity and earthquake precursors because it has many advantages such as large field of vision, high accuracy, and short cycle, as well as good reflection of certain infrared anomalies of strong earthquakes. The surface brightness temperature of the Earth is an integrated quantitative form of thermal infrared radiation of surface matter, and it is also the result of surface heat balance. This paper uses the key earthquake monitoring areas in China (the 2008 China Earthquake Key Monitoring Area divided by the China Earthquake Administration) as the research area, the data used is FY-2C satellite data, the brightness temperature data of 9 key earthquake monitoring areas in China from 2007-9-18 to 2008-8-19 were studied. The following conclusions are drawn: The trend of brightness temperature changes greatly due to the influence of clouds; The trend of brightness temperature changes greatly owing to the climate impact over the same period; The annual changes in brightness temperature show different characteristics by reason of different latitudes in different regions; The annual variation in brightness temperature presents different characteristics that are influenced by the terrain. On this basis, this study uses a geostationary satellite data processing system designed and developed by ourselves to generate synthetic image products of brightness temperature that have been remove noise and cloud in the mainland region every 5 days and analyzes the laws of brightness temperature. The conclusions are as follows: The annual variation curve of brightness temperature is relatively smooth, and the fluctuation of brightness temperature is much smaller than the curve of daily brightness temperature; Annual changes in brightness temperature can better reflect the brightness temperature trend in the region; The annual changes in brightness temperature eliminate the effects of short-term climate change and the effects of cloud disturbances to some extent; The distribution of brightness temperature is controlled by elevation and latitude, showing some regularity.**

***Index Terms*—brightness temperature, thermal infrared remote sensing, seismic monitoring area**

I. Introduction

Large area temperature anomalies often occur before earthquake, the range and extent of brightness temperature anomalies can be determined by using satellite thermal infrared remote sensing technology. This scientific idea was discovered in the late 1980s by scientists of the former Soviet Union ГОРНЫЙ ВИ[1] during the analysis of the aerospace thermal infrared satellite. Tronin et al.[2] used NOAA satellite thermal infrared images to study the seismic activity belt in Central Asia and obtained the statistical correlation between thermal infrared anomalies and the seismic activity belt in Central Asia. The application of thermal infrared remote sensing in China began in the 1990s. Through the study of thermal infrared remote sensing images, it is expected that earthquake precursors can be predicted. Kong Lingchang et al.[3] discussed the theoretical basis of thermal infrared warming and its relationship with other anomalies and they also explored the universality of satellite thermal infrared warming before the earthquake. Guo Weiying, Shan Xinjian[4], extracted thermal infrared anomalies in the Mani earthquake with magnitude 7.5, and Chen Shunyun et al.[5] studied the earthquake of magnitude 7.8 in Pakistan on October 8, 2005. Qu Chunyan et al.[6-8] conducted a falsification study on the precursor of the M5.9 earthquake between eastern and western Ujumqin Banner and eastern Inner Mongolia on March 24, 2004, and studied two earthquakes above grade 6 in 2003 in Dayao, Yunnan. The above scholars' studies have made useful attempts to apply thermal infrared remote sensing in seismology. This paper uses the key earthquake monitoring areas in China (the 2008 China Earthquake Key Monitoring Area divided by the China Earthquake Administration) as the research area, the data used is FY-2C satellite data, the brightness temperature data of 9 key earthquake monitoring areas in China from 2007-9-18 to 2008-8-19 were studied. By studying the law of surface brightness temperature, we can obtain the surface brightness temperature at different stages of the earthquake and get its regularity. It is of great significance to study the seismic process and the abnormal surface brightness temperature change process affected by the earthquake.

II. Materials and Methods

A. Source of data

The statistics data of the changes in brightness temperature are derived from data warehouses generated by satellite receiving and data processing systems. In addition to the FY-2C's own raw disk data, the data warehouse contains synthesizing Chinese regional data every 5 days and every 10 days after satellite data processing system removes cloud and noise, includes full channel data and individual brightness temperature distribution data with a resolution of 5 km/pixel (table 1) Considering that the main research object is the geothermal anomaly caused by tectonic activities, we chose to process about 4 to 7 data per day from 0:00 to 3:00 (Beijing time) at night time. The rationale for the selection is that this period mostly reflects the lowest temperature in a day, and the Earth's surface temperature is relatively less affected by sunlight.

TABLE I.
BRIGHTNESS TEMPERATURE DATA SOURCE

Year	Data Type	Number of Data Sets (numbers)	Data Size (Mb)	Data Format
2006.01~2008.08	FY-2C disc data	22754	3027485	HDF
2006.01~2008.08	FY-2C Daily Night Disc Data	3272	1368558	HDF
2006.01~2008.08	FY-2C China Region Data	22427	256600	HDF
2006.01~2008.08	FY-2C compiles Chinese region data every 5 days	179	1679	HDF
2007.09~2008.08	FY-2C compiles Chinese regional data every 10 days	33	528	HDF
Total		48665	4654850	

B. Analytical area data sampling

The area under study is from the 2008 China Earthquake Key Monitoring Area divided by China Earthquake Administration, including: 1. Longling-Yongsheng, Yunnan; 2. Xundian, Yunnan-Mabian, Sichuan; 3. Gansu, Sunan-Gulang; 4. Xinjiang Baicheng - and quiet; 5. Xinjiang Wuqia-Tashkorgan; 6. Gansu Qinghai Sichuan Junction Area. Including the Yutian earthquake, the Geize earthquake and the Wenchuan earthquake, there are 9 regions. Among them: 7 is the Yutian earthquake area, 8 is the Geize earthquake area, and 9 is the Wenchuan earthquake area.

Its geographical distribution is shown in Figure 1:

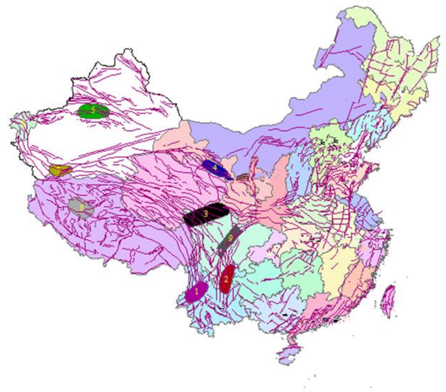

Figure 1. 9 seismic monitoring areas distribution map

Take the data sample set from 2008-3-1 to 2008-3-5 as an example. The main parameters are shown in Table 2.

TABLE II.
MAIN PARAMETERS OF SINGLE-DATA SAMPLE SET FOR 2008-3-1

Original data source time: 2008-3-1 03:01:00; Data processing time: 2008-8-2 06:41:15; Original data name: FY2C.20080229_1901.HDF				
Monitoring area number	$\bar{T}$	n	T_{max}	T_{min}
1	277.829	1590	283.48	270.9
2	274.049	1559	279.51	263.77
3	239.654	3386	264.21	225.3
4	257.469	1331	266.85	247.22
5	262.923	2022	271.46	251.6
6	250.177	2526	269.93	230.92
7	252.156	1107	269.65	239.32
8	255.503	1948	261.55	249.88
9	262.682	1769	275.47	237.1
Original data source time: 2008-3-1 ~ 2008-3-5; Data processing time: 2008-8-2 08:07:11; Generated data Product name: FY2C@080301-080305_SN.HDF				
Monitoring area number	$\bar{T}$	n	T_{max}	T_{min}
1	281.862	1590	285.06	270.78
2	276.697	1559	284.51	265.36
3	261.341	3386	264.78	245.42
4	261.899	1331	266.36	253.96
5	266.881	2022	270.1	253.31
6	266.905	2526	272.55	252.65
7	257.502	1107	267.64	247.52
8	258.691	1948	263.61	251.65
9	271.610	1769	276.71	257.75

C. Valid sample criteria

Data sampling began on September 13, 2007 and ended on August 10, 2008. The sampling parameters include the average brightness temperature, maximum and minimum brightness temperature value, number of samples, and number of valid samples in each sampling area. Three times the error criterion was applied during the sampling process. The number of valid samples is the number of samples minus the number of non-data samples and invalid data samples. Considering the relatively limited range of each monitored area, the differences in terrain, geology and other factors within the area are limited. Set the average brightness temperature sample:

$$\overline{T} = \frac{1}{n}\sum_{i=1}^{n} T_i \tag{1}$$

Where n is the number of samples. The valid sample criterion is

$$\left|T - \overline{T}\right| < 3\sigma_n(T) \tag{2}$$

$$\sigma_n(T) = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(T - \overline{T})^2} \tag{3}$$

III. RESULTS AND ANALYSIS

A. The distribution pattern of daily brightness temperature samples in the region

Daily brightness temperature monitoring was performed on the above 9 monitoring areas to extract the average brightness temperature value of each FY-2C satellite data for storage in the area. The brightness temperature distribution of 9 monitoring areas was analyzed using the database of brightness temperatures from 2007-9-18 to 2008-8-19, and a line graph of brightness temperature changes over time was generated.

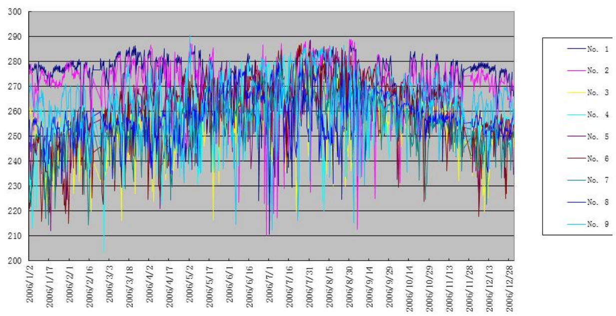

Figure 2. Daily brightness temperature changes in 9 monitoring areas

From the trend of the brightness temperature monitoring curve in the above nine districts, we can see that:

The trend of brightness temperature changes greatly due to the influence of clouds: Because the cloud layer is composed of a large amount of ice crystals, the value of the brightness temperature below the freezing point is displayed after the cloud top radiation value displayed on the satellite sensor is converted to brightness temperature. In a cloud-covered area, the brightness temperature will decrease, and after the cloud is eliminated, the brightness temperature will gradually rise again. This period is about 2-5 days. The drop-down line on the line chart is a typical feature affected by cloud cover. In the absence of cloud cover, the change in brightness temperature tends to be flat, as in the period of twenty days from November 25, 2006 to December 18, 2006, the brightness of area 1 changes horizontally and linearly.

The trend of brightness temperature changes greatly owing to the climate impact over the same period: From the change curves of 1-9 regions in 2007 (not listed here), it can be seen that the brightness temperature values in December are all higher than those in November and January, and the changes are more severe, which is mainly due to the climate impact of the same period, the monthly mean temperatures in Sichuan, Hainan, Guangdong, and Yunnan were the second highest in the same period in history since 1951. Compared with the same period of the year, temperatures in most parts of the country were higher than the same period. The northeastern and central parts of Inner Mongolia, northern Shanxi, most of Zhejiang, most of Fujian, southern Guangdong, Hainan, eastern Yunnan, central and western Tibet, and southern Qinghai were significantly higher than the same period by 2 to 4°C.

Annual changes in brightness temperature show different characteristics by reason of different latitudes in different regions: For the north and west high-latitude regions such as the 3-8 region, the annual variation of brightness temperature is very similar to the seasonal variation. The brightness temperature gradually decreases from autumn to winter and reaches the minimum in about the middle of January; The brightness gradually rose in spring and autumn and reached its highest value in late July. For the low latitudes in the south, such as Zone 1 and Zone 2, the brightness temperature fluctuates near the central value, showing the feature that the annual brightness temperature difference is small and the daily brightness temperature difference is large. For the low latitudes in southern China, a large amount of summer rainfall and frequent cloud activity are the main reasons for the low brightness temperature in summer.

The annual variation in brightness temperature presents different characteristics that are influenced by the terrain: For District 9, which is Wenchuan earthquake area, this area located in the basin. The annual change of brightness temperature is similar with that of the southern low latitude area. The annual variation of brightness temperature is small. However, the summer brightness temperature value is slightly higher than the winter brightness temperature value, unlike the 1~2 area, which is lower than the winter brightness temperature value.

B. The distribution pattern of daily regional synthesized brightness temperature samples in the region

In this study, a self-designed geostationary satellite data processing system was used to process the disc data of 2007-2008. First, a continental brightness temperature synthetic image product with cloud and noise removal every 5 days is generated. Next, the brightness temperature monitoring database was extracted and generated for each of the 9 monitoring areas, the year-variable line charts are drawn, as well as the 9 areas year-change curves.

It can be seen from the synthetic brightness temperature annual variation chart that the synthetic brightness temperature annual variation and the daily brightness temperature-year variation show different rules. Because the synthesizing brightness temperature effectively eliminates the interference of the cloud layer, its average brightness temperature also smooths the influence of the climate to a certain extent, so the annual change chart is much smoother than the daily brightness temperature (Figure 3).

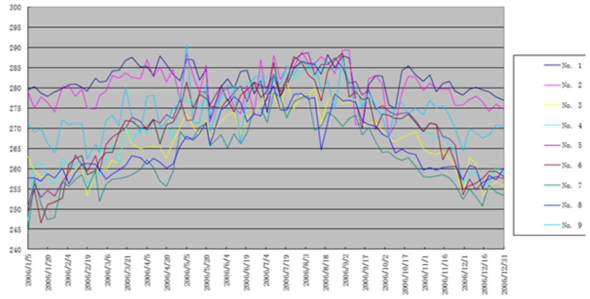

Figure 3. Comparison chart of brightness temperature changes of synthesized data for every 5 days in 9 monitoring areas

The rules of the annual variation are as follows:

The annual variation curve of brightness temperature is relatively smooth, and the fluctuation of brightness temperature is much smaller than the curve of daily brightness temperature;

Annual changes in brightness temperature can better reflect the brightness temperature trend in the region: For example, the brightness temperature year-on-year oscillation of zone 1 around 279.09K, and the amplitude is in the range of 18K. The change of brightness temperature is obviously more stable, which is consistent with the characteristics of "four seasons such as spring" in Yunnan;

The annual changes in brightness temperature eliminated the effects of short-term climate change and the effects of cloud disturbances to some extent: For the changes in the brightness temperature of the monitoring area, there are no obvious drop-down vertical line like daily brightness temperature. For the low latitude areas in the south such as District 1 to 2, in the summer rainy period, the combined brightness temperature of the 5 days did not show the characteristics that low value of daily brightness temperature, to a certain extent, the impact of the short-term climate is smoothed;

The distribution of brightness temperature is controlled by elevation and latitude, showing some regularity: During the winter of mid-January, the high latitude and altitude areas (Xinjiang, Tibet, such as the 5,6,7 monitoring areas) have the lowest value of brightness temperature, which is mainly controlled by latitude. With the change of latitude, the brightness temperature value shows the characteristics that the higher the latitude is, the lower the brightness temperature is. In August, the brightness temperature was mainly controlled by altitude, and the Qinghai-Tibet Plateau had the lowest brightness temperature, The Sichuan and Yunnan regions (1 and 2 monitoring areas) also experienced low values of brightness temperature at this time, which was mainly due to the excessive rainfall at that time, which had a greater impact on the thermal infrared brightness temperature.

IV. CONCLUSION

As an important indicator of the release of heat within the earth's crust, the surface brightness temperature has a close relationship with seismic activity, and there are many factors that affect the surface brightness temperature. This paper uses the key earthquake monitoring areas in China (the 2008 China Earthquake Key Monitoring Area divided by the China Earthquake Administration) as the research area, the data used is FY-2C satellite data, the brightness temperature data of 9 key earthquake monitoring areas in China from 2007-9-18 to 2008-8-19 were studied. Draw the following conclusion:

The distribution pattern of daily brightness temperature samples in the region: The trend of brightness temperature changes greatly due to the influence of clouds; The trend of brightness temperature changes greatly owing to the climate impact over the same period; The annual changes in brightness temperature show different characteristics by reason of different latitudes in different regions; The annual variation in brightness temperature presents different characteristics that are influenced by the terrain.

The distribution pattern of daily regional synthesized brightness temperature samples in the region: The annual variation curve of brightness temperature is relatively smooth, and the fluctuation of brightness temperature is much smaller than the curve of daily brightness temperature; Annual changes in brightness temperature can better reflect the brightness temperature trend in the region; The annual changes in brightness temperature eliminated the effects of short-term climate change and the effects of cloud disturbances to some extent; The distribution of brightness temperature is controlled by elevation and latitude, showing some regularity.

In this paper, by studying the law of surface brightness temperature, we obtain the regularity of the Earth's surface brightness temperature at different stages, it is use to have a guiding role in the study of the earthquake process and the abnormal change of the surface brightness temperature.

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