Available online at www.sciencedirect.com
ScienceDirect
Advances in Space Research 58 (2016) 989–1001
ADVANCES IN SPACE RESEARCH
(a COSPAR publication)
www.elsevier.com/locate/asr

Thermal infrared anomalies associated with multi-year earthquakes in the Tibet region based on China's FY-2E satellite data

X. Lu [a,b], Q.Y. Meng [a,*], X.F. Gu [a], X.D. Zhang [c], T. Xie [b], F. Geng [d]

[a] Institute of Remote Sensing and Digital Earth, Chinese Academy of Sciences, Beijing 100101, China
[b] China Earthquake Networks Center, Beijing 100045, China
[c] Institute of Earthquake Science, China Earthquake Administration, Beijing 100036, China
[d] Nanjing University of Information Science & Technology, Nanjing 210044, China

Received 27 October 2015; received in revised form 17 May 2016; accepted 19 May 2016
Available online 27 May 2016

Abstract

Using the brightness temperature (TBB) and outgoing long-wave radiation (OLR) data from the FY-2E meteorological satellite, the thermal infrared anomalous change of 20 moderate–strong earthquakes in Tibet from January 12, 2010, to April 30, 2015, are studied. The study calculates the wavelet spectrum change of TBB and OLR based on the Morlet wave and discusses the regulation and characteristics of the anomalous change before and after the earthquakes. The results show that TBB anomalies appeared in 17 of the 20 $M_S \geqslant 5.0$ earthquakes. Anomalies of long-wave radiation occurred in 16 earthquakes. Moreover, their durations, locations and amplitudes are similar. The duration from appearance to disappearance of each anomaly is 30–40 days, the abnormal area is mainly distributed along the faults near the epicentre, and the anomalous maximum amplitude of TBB and OLR's relative energy spectrum are both times the average. The depths of the moderate–strong earthquakes in the study area are mainly distributed within the upper 20 km, which suggests that thermal infrared can represent the radiation characteristics of shallow earthquakes better. Finally, thermal infrared anomalies of two major earthquakes – the Yushu M_S7.1 Earthquake and the Nepal M_S8.1 Earthquake are calculated, and both show thermal infrared anomalies. There are few studies on the thermal infrared anomalies of multi-year earthquakes in the Tibet region that use the FY-2E satellite. This study discovers some characteristics of thermal infrared radiation associated with earthquakes in Tibet and looks at the relationship between thermal anomalies and faults. Studying and summarizing thermal infrared anomaly patterns associated with moderate–strong earthquakes in Tibet provide important reference values and can significantly aid earthquake research in this region.

Keywords: Tibet; Thermal infrared; Outgoing long-wave radiation; Brightness temperature; Moderate–strong earthquake

---

1. Introduction

With the increase in economic development, unexpected earthquake disasters can cause more serious economic and societal damage than ever before. However, monitoring and studying natural catastrophes, such as earthquakes, presents a severe scientific challenge. Fortunately, the all-weather, high-resolution and high dynamic range of thermal infrared remote sensing technology provides a new tool for monitoring earthquakes. The brightness temperature and longwave radiation are two parameters of thermal infrared. In the brightness temperature studies, a robust estimator was used to detect the anomalies before

---

* Corresponding author.
E-mail addresses: luxian@radi.ac.cn (X. Lu), mengqy@radi.ac.cn (Q.Y. Meng), guxingfa@radi.ac.cn (X.F. Gu), zxd@seis.ac.cn (X.D. Zhang), xtaolake@163.com (T. Xie), gengfe1@126.com (F. Geng).

http://dx.doi.org/10.1016/j.asr.2016.05.038
0273-1177/

earthquakes (Tramutoli et al., 2005, 2013a,b, 2015). And new method for anomaly recognition, seismic anomalies can be detected by the bi-angular Advanced Along-Track Scanning Radiometer (AATSR) gridded brightness temperature data based on spatial/temporal continuity analysis (Xiong et al., 2013). There are some studies about OLR with earthquake. Using the wavelet modulus maxima method, Bi et al. (2009) found that a long-wave radiation anomaly existed before an earthquake, and many other studies confirmed this significant phenomenon. The analysis of the continuous outgoing long wave radiation indicates anomalous variations prior to a number of medium to large earthquakes (Ouzounov et al., 2007). Xiong used the methods of Eddy field calculation mean and wavelet maxima to detect seismic anomalies within the outgoing longwave radiation data (Xiong et al., 2010). Extension of the GMAM method to the average GMAM (AG) method has been applied to analyze seismic anomalies within outgoing long-wave radiation (OLR) data observed by satellites from 2006 to 2013 for the two recent Wenchuan and Lushan earthquakes (Kong et al., 2015).

Besides the brightness temperature and longwave radiation, other parameter or multi-parameters (land surface temperature, total electron content, air temperature and surface latent heat flux et al.) of thermal infrared have been studied (Pulinets and Davidenko, 2014; Pulinets et al., 2006; Pulinets and Ouzounov, 2011; Dey and Singh, 2003; Wu et al., 2012; Ouzounov et al., 2012). At the same time, based on the conservation of energy in the Earth system and the migration law of surface thermal infrared radiation, Qin Kai analysed the seismic infrared thermal anomaly by selecting 6 infrared thermal parameters and put forward the infrared temporal–spatial DTS-T deviation method (deviation-time-space-thermal) to identify the thermal infrared anomaly before earthquake (Qin et al., 2013).

Many moderate–strong earthquakes are clearly preceded by thermal infrared anomalies. Did these anomalies also occur in Tibet? What are their variation patterns? The former thermal infrared research was based mainly on data from foreign satellites, such as MODIS, NOAA, and so on; however, in this paper, we carry out the temporal–spatial calculations with 2010–2015 thermal infrared data of the Tibet region from the Chinese FY-2E satellite. The FY Geostationary Meteorological Satellite can provide large-scale, continuous radiation data, and the study of long time series infrared radiation changes related to earthquakes in Tibet can answer these questions and provide a good basis for studying the reliability of seismic infrared anomalies. We calculate the relative power spectra of the long-wave radiation and the brightness temperature, and analyse the anomalous variation associated with moderate and strong earthquakes. The study area in this paper is in the range of 79°–101°E, 27°–40°N, and the data used for the discussions are the earthquake data and satellite data from January 12, 2010, to April 31, 2015.

2. General situation of tectonic structures in Tibet

The Tibet Autonomous Region covers an area of 120.04 km^2, about one eighth of the Chinese mainland, and with an average elevation of over 4000 km, it is commonly known as the roof of the world. The Tibet region is located at the junction between Gondwanaland and the Eurasia continent to the west of mainland China. It contains the key parts of collision and suturing between the main body of the eastern Tethys tectonic domain and the Eurasia continent. As a tectonically complex area that has undergone continual back-arc spreading and splitting, followed by the connecting and suturing of the Laurisia land. It is a unique natural laboratory for examining the response of the lithosphere to continental collision (Harrison et al., 1992; Hodges, 2000; Yin and Harrison, 2000; Kapp et al., 2005). Moreover, some studies believe that the strike-slip, large-scale and thrust faults lead to the significant strain in Tibet (Willett and Beaumont, 1994; Owens and Zandt, 1997; Meyer et al., 1998; Tapponnier et al., 2001; Johnson, 2002; DeCelles et al., 2002). Earthquakes occur frequently in the southern Qinghai–Tibetan plateau, which is a main dynamic source for generating earthquakes in southwest China and can lead to serious disasters. In addition, in the countries located near the southern edge of the Qinghai–Tibetan plateau, the economy is undeveloped, population is dense, house structures are vulnerable to earthquakes, earthquake monitoring network is backwards, and topography is complex, all of which can lead to serious secondary disasters. Therefore, it is of great importance to thoroughly study the seismicity of this region.

3. The earthquake situation

There are 20 $M_S \geqslant 5.0$ earthquakes that occurred in Tibet from January 12, 2010, to April 30, 2015 (Table 1), including 5 $M_S \geqslant 5.5$ earthquakes, with the largest one on August 12, 2013, the M_S6.1 Zogang County, Tibet earthquake. These earthquakes are distributed mainly along fault zones (Fig. 1). The 5 $M_S \geqslant 5.5$ events occurred on the fault zones, which are distributed in a nearly east–west direction, indicating that the seismicity in this region is dominated mainly by compressional movement. The other smaller magnitude earthquakes are distributed on fault zones trending nearly NS. This indicates that due to the subduction of the Indian plate towards the Eurasia plate that Tibet is not only under compression but also subject to faulting in the interior of the plate, resulting in the generation of earthquakes on the NS-trending fault zones. Frequency and the focal depth distribution of earthquakes in the study region are analyzed in Fig. 2.