Thermal Anomalies Detection Using Comparative Method for Small Earthquake

Pisanu Wongpornchai[1] and *Chanida* Suwanprasit [2]

[1]Department of Geological Sciences, Faculty of Science, Chiang Mai University, 50200 Thailand
[2]Department of Geography, Faculty of Social Science, Chiang Mai University, 50200 Thailand

Abstract. Thermal anomaly is one of the earthquake precursor in the earthquake preparatory phase. Remote sensing in thermal region has been employed based on the concept of stress accumulation in the active plate tectonics region, which may be transformed as temperature variation prior to earthquake. MODIS Land Surface Temperature has been commonly used to locate the thermal anomalies before the earthquake. Recently researches have been focusing on moderate or large magnitude earthquake events. In Thailand, small earthquake can severely damage the unprepared area. This study, the daily day- and night-time data of MODIS MOD11A1 product for 30 days before and 15 days after the earthquake on April 22, 2007, in Wiang Pa Pao District, Chiang Rai Province, Thailand, were processed and analysed to locate possibility of thermal anomalies. Thermal anomalies before and after the earthquakes were detected using the comparative method. The result found that the thermal anomaly temperature could be high up to 4.1 - 10.9 $^{\circ}$C which occurred in 21 - 22 days prior to the earthquake. Therefore, it may conclude that small earthquake can also release energy as the detectable thermal anomaly. However, more study about the relationship between thermal precursor and earthquake is needed to continue.

1 Introduction

Recently, earthquake prediction studies which are based on disastrous natural phenomenon correlated to the Earth's deformation, surface temperature growth, gas and aerosol exhalation, and electromagnetic disturbances in the ionosphere are more attended [1]. Thermal anomaly precursor has been attracted more in the earthquake prediction as it can be observed from the thermal remote sensors. Many reports depicted the appearence of the land surface temperature (LST) anomalies prior to strong earthquakes [2-7].

In many areas such as Middle Asia, Iran, China, Turkey, Japan, Kamchatka, India, Turkey, Italy, Greece, Spain and Thailand, the earthquake thermal anomalies have been studied on the earthquake with magnitude greater than 4.5 [1, 7]. However, the earthquake thermal anomalies associated with small magnitude earthquake was also interesting [8]. Many studies have found that the thermal remote sensors can detect the thermal anomalies from seismic activities [3, 4, 6-13].

Thailand is considered as a low seismicity area because its location is far from a plate boundary. However, the intraplate active faults and fractures are reported most in the northern and western parts of the country. Therefore, the small and moderate earthquakes which frequently occurred in the northern and western parts of Thailand were recorded.

Recently, many researches have been focusing on the moderate or strong magnitude earthquake events which can leading to severe unexpected damage on the natural environment, community, and life of peoples and animals. In Thailand, even though most earthquakes are small, the result from the earthquake can effect on the unprepared area. In this study, the surface thermal anomalies from a small earthquake with M4.5 on April 22, 2007 was analyzed from daily day- and night-time MODIS LST data during pre- and post-earthquake events to study the feasibility of using thermal remote sensing for detecting surface thermal anomalies.

2 Study area

In Thailand, active faults and fault zones are found in the northern, western and southern parts of the country. The study area is situated in an active major fault zone, called the Phayao Fault Zone (PFZ), northern part of Thailand. The PFZ is one of the 14 active major fault zones in Thailand. It passes through three provinces including Chiang Rai, Phayao and Lampang with 90 km long. It is trending in the NE to NW direction. On April 22, 2007, a magnitude 4.5 earthquake was detected and marked the epicenter at the PFZ at 19.40 °N latitude and 99.36 °E longitude, Wiang Pa Pao District, Chiang Rai Province, northern part of Thailand (Figure 1).

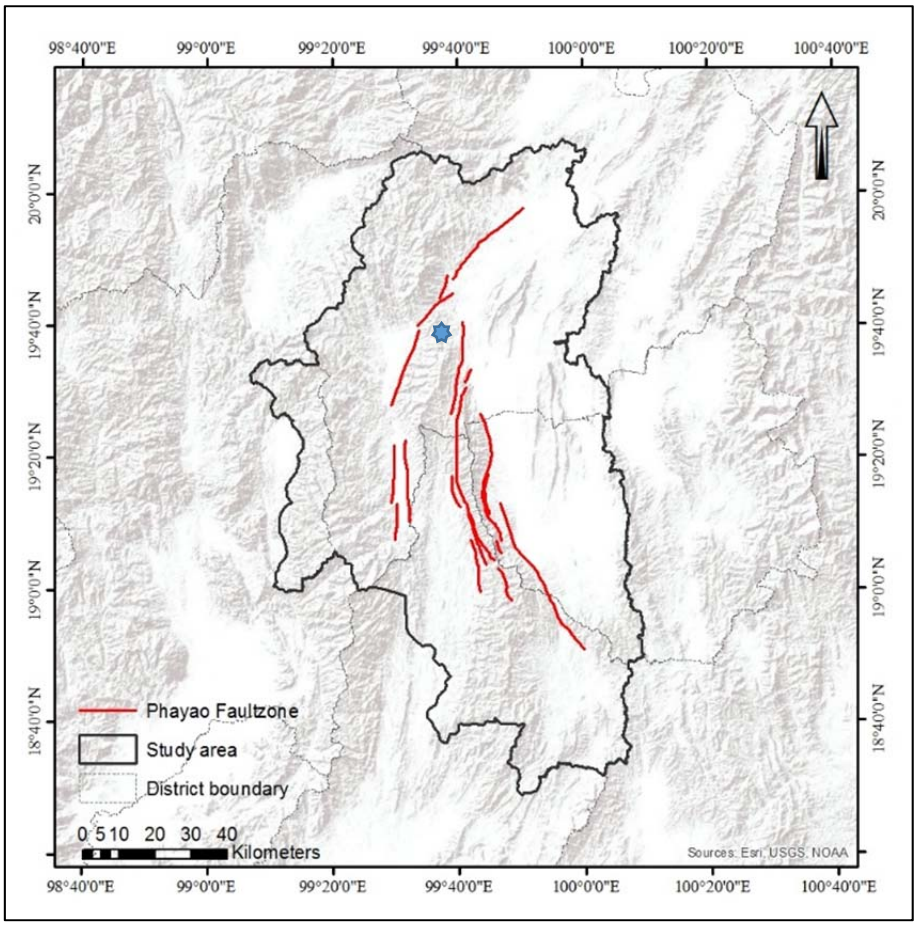

Fig. 1. The location map of the study area. The epicenter is represented by star.

3 Materials and methods

The data which were used in this study comprise of the land surface temperature (LST) satellite images. The daily LST satellite images (day- and night-time) over the study area from the thermal sensor with 1 km x 1 km resolution from Moderate Resolution Imaging Spectroradiometer (MODIS) on board Terra (MOD11A1) /Aqua (MYD11A1) Satellites were downloaded from the NASA's website. Since the earthquake was recorded on April 22, 2007, the image data set over a time period between March 23 – May 10, 2007 was used to analyze. The image data set over a time period between March 23 – May 10, 2008 was also downloaded as the reference background data set, since the earthquake was not detected for this year.

There were several steps of satellite image data processing. First, type of satellite remote sensing image was selected. Since the satellite images can be retrieved from many satellite systems, the factors those were considered for choosing the satellite images were the image resolution, data wavelength and satellite revisit time. This research concentrates on the large feature such as fault zone and the large area, so the suitable resolution at about 1 km was fine enough to use. Since the thermal anomaly appears in a very shot time, one revisit per day was considered. Second, preprocessing for satellite images was performed. This step was reselecting the suitable satellite images for doing processing since some images were covered by cloud and some image data were lost, so they could not be used. Third, the image mosaic and projection processes were performed since many satellite images were needed to mosaic for covering the huge study area and the difference in coordinate system of the satellite images was required to reproject.

Starting analysis process, the satellite images were converted into the surface temperature. The LST difference between the data in the earthquake year (2007) and the reference year (2008) at the same pixel location was calculated using the method which were purposed by Ouzounov and Freund [14]. Then, the comparative method was applied to detect the thermal anomalies during the pre- and post-earthquake as shown in the Equation (1).

$$\Delta LST = LST - LST_{bg(x/y)}, \quad (1)$$

where
ΔLST is the thermal anomaly (°C),
LST is the average LST (°C),
$LST_{bg(x)}$ is the average LST before earthquake (°C),
$LST_{bg(y)}$ is the average LST after earthquake (°C).

Finally, the natural hot spot data from MODIS during the study period, hot spring locations, man-made hot

spots and ground check survey were used for validate the surface thermal anomalies.

The surface thermal anomalies which were located at the same locations of natural hot spots, hot springs and man-made hot spots were eliminated from the surface thermal anomaly maps.

The ground check survey was the process in the field for searching for the evidences of relationship between surface thermal anomalies and faults. The surface thermal anomalies which were not related to the faults or fractures were also removed from the surface thermal anomaly maps.

4 Results

In the tropical country like Thailand, weather condition can affect the quality of the satellite images. During the time period between April 6 - April 20, 2007, the surface thermal anomaly was unable to analyze because most satellite images were covered by the clouds. Fortunately, some satellite images which were recorded before the earthquake event were still useful for the study.

On April 22, 2007, a small earthquake with magnitude of 4.5 was recorded at Wiang Pa Pao District, Chiang Rai Province, northern part of Thailand which is located in the Phayao Fault Zone.

The surface thermal anomaly from satellite images were divided into three groups as the pre-earthquake period (Mar 23 - April 21, 2007), earthquake event (April 22, 2007), and post-earthquake period (April 23 - April 30, 2007). The surface thermal anomalies of the day-time data from satellite images clearly show the surface thermal anomalies during the time period between April 1 - April 2, 2007 (20 - 21 days before the earthquake) with the maximum anomaly temperature of 10.9 °C on April 2, 2017, and during the time period between April 23 - April 24, 2007 (1 - 2 days after the earthquake) with the maximum anomaly temperature of 6.9 °C on April 24, 2007. (Figure 2).

The surface thermal anomalies of the night-time data from satellite images clearly show the surface thermal anomalies during the time period between March 31 - April 1, 2007 (21 - 22 days before the earthquake) with the maximum anomaly temperature of 4.2 °C on April 1, 2017, and on April 22, 2007 (the day of earthquake event) with the maximum anomaly temperature of 4.1 °C (Figure 3).

The main distribution of the surface thermal anomalies was found surrounding the epicenter. Most of the surface thermal anomalies appeared in the northeastern and central parts of the study area and mainly along the fault zone indicating the relationship between the surface thermal anomalies and the fault zone. However, some surface thermal anomalies can be found far from the main major fault zone, but they are related to the small faults and fractures.

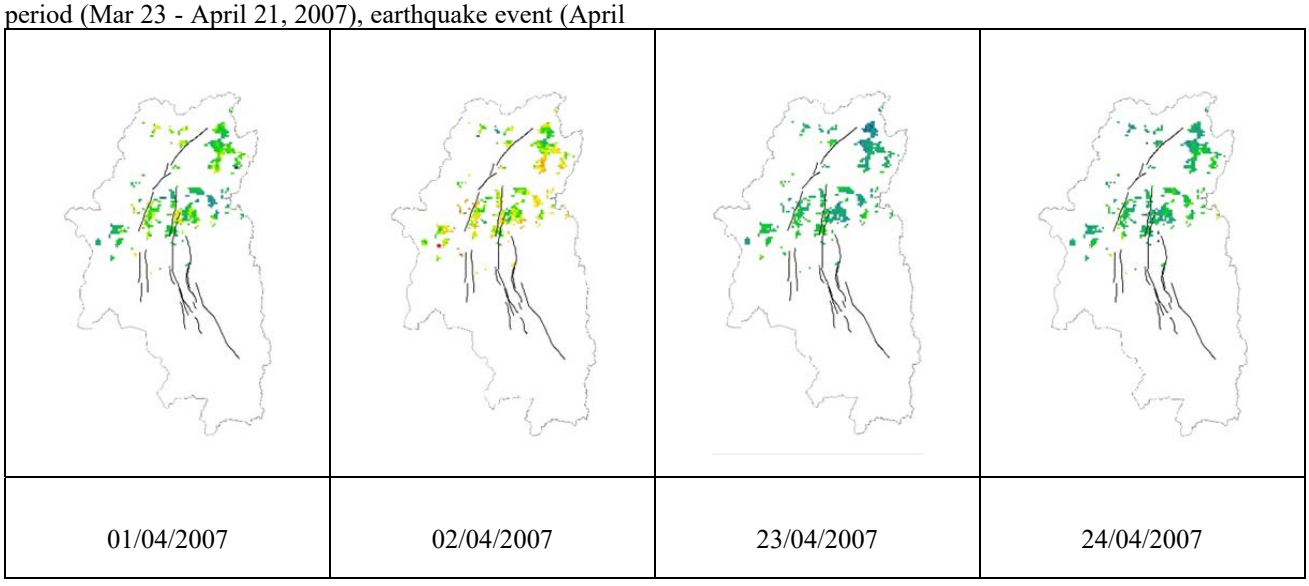

Fig. 2. The distribution of the surface thermal anomalies from the day-time data. The color scale is showm in Figure 3.

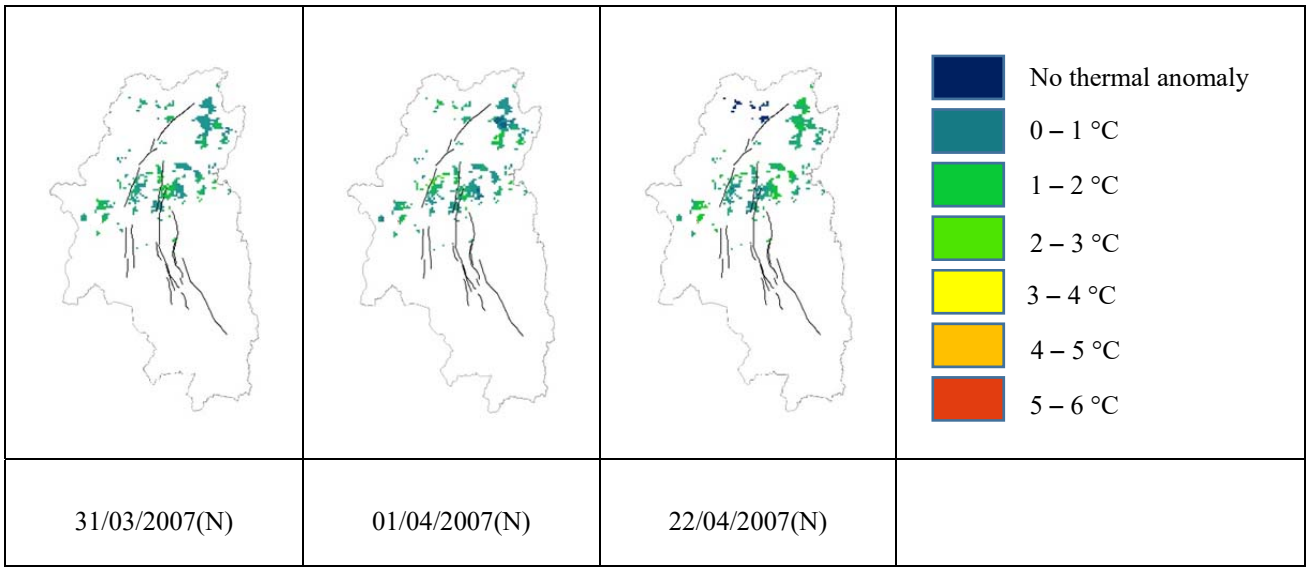

Fig. 3. The distribution of the surface thermal anomalies from the night-time data.

5 Conclusion

The earthquake is a complex geohazard event which several researchers have tried to discover the precursor before earthquake. Mostly, the study of precursor was in the moderate and strong earthquake events. This research used the advantage of the MODIS LST daily day- and night-time data to detect the pattern of surface thermal anomalies during pre- and post- small earthquake with M4.5 on April 22, 2007, in Wiang Pa Pao District, Chiang Rai province, northern part of Thailand.

Comparative method was applied for removing the background temperature using based year data. The validation process was done using natural and man-made hotspots, hot spring locations and ground survey data.

The results of thermal anomaly investigation from MODIS LST indicate: (1) the surface thermal anomalies appeared in 21-22 days before, about 1-2 days after and on the day of the earthquake event (2) the amplitude of the surface thermal anomaly is about 4.1 -10.9 °C. and (3) the surface thermal anomalies mainly appeared surrounding the epicentre and along the fault zone or local faults and fractures showing the relationship among the surface thermal anomalies, earthquake, and fault zone.

Since the optical satellite data in systematic and continuous monitoring of LST and surface thermal anomalies, cloud cover may act as a problem which effected to size of LST and thermal anomaly detection. Application on the other types of satellite image which will not be effected by the weather conditions should be developed for earthquake precursor investigation.

The small earthquake events in other cases should be tested to confirm this finding. This finding might be useful precursory sign for the observing fault activities and pre-earthquake events.

The local governments and Department of Dissaster Prevention and Mitigation will be benefit from this research.

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