Feasibility study of thermal anomaly detection for earthquake: A case study from 2014 Mae Lao earthquake, Thailand

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Abstract. Earthquake is the natural disaster which causes damage to human lives and their properties, domestic animals and buildings in the areas near the epicentre. The ability to predict the earthquake can greatly reduce in catastrophic damages, but nowadays, earthquake prediction is still the unsolvable problem. However, the earthquake prediction is still an interesting topic for scientists all over the world. One of the important earthquakes precursors in earthquake preparatory phase is thermal anomaly. The thermal region data from remote sensing have been employed recently based on the concept of stress accumulation in the active plate tectonics region, which can be transformed as temperature variation prior event. Moderate Resolution Imaging Spectroradiometer (MODIS) Land Surface Temperature (LST) data have been commonly used to locate thermal anomalies prior to occurrence of earthquake event. In Thailand, 2014 Mae Lao Earthquake, the largest earthquake in the Thailand historical record with magnitude Mw 6.1, shook the area of Mae Lao District, Chiang Rai Province on 5th May 2014. To locate possibility of thermal anomalies, the daily data of MODIS MYD11A1 product for 30 days before and after the earthquake were processed and analysed. Average LST before and after earthquake events were used for removing background temperature in the area and comparative method was performed to detect the thermal anomalies. The result found that this simple technique detected the thermal anomaly occurrence during 12-23 days prior to the earthquake and 9-28 days after the earthquake. Nevertheless, in order to understand furthermore about earthquake mechanism, it is necessity of discovered thermal precursors.

Keywords: Thermal anomaly, earthquake, remote sensing, Thailand

1. Introduction

Earthquake is the natural disaster which causes extensive damage to human lives and their properties, domestic animals and buildings in the areas near the epicenter. The ability to predict the earthquake can greatly reduce in catastrophic damages. Recently, earthquake prediction research based on disastrous natural phenomenon, which is highly correlates to Earth’s deformation, surface temperature growth, gas and aerosol exhalation, and electromagnetic disturbances in the ionosphere [1]. The thermal anomaly precursor is interesting more in the earthquake prediction since it can be measured from thermal remote sensors. It indicates the significant change in both the Earth’s surface temperature and near-surface
atmosphere layers. The infra-red (IR) spectrum allows monitoring of the Earth’s thermal field with a spatial resolution of 0.5–5 km and with a temperature resolution of 0.12–0.5 °C [1]. There are many reports of land surface temperature (LST) anomalies appearing prior to the large earthquakes [2-6] as it can produce the extensive damage.

Many publications mentioned on the earthquake anomalies that related to seismic activities along geological structures (faults, cracks, fractures etc.) which have been reported in many countries such as Middle Asia, Iran, China, Turkey, Japan, Kamchatka, India, Turkey, Italy, Greece and Spain [1]. The earthquake thermal anomalies have been studied in magnitude Mw 4.5 earthquake or greater as it can produce damage to the surrounding areas.

Many previous studies found that thermal anomalies from seismic activities can be effectively detected by thermal remote sensors [3, 4, 6-11]. The some finding showed that the pattern of thermal anomalies appeared about 6-24 days before and continued for a week after an earthquake event with magnitude greater than 4.5 [1].

Thailand is assigned as a low seismicity area. There are small and moderate earthquake events which occur in northern and western parts including earthquakes from the Andaman Sea and nearby countries such as Indonesia, Myanmar, south of China, Laos and Vietnam [12]. Recently research has been focusing on moderate or large magnitude earthquake events [3, 4]. In this study, thermal anomalies from an earthquake with magnitude Mw 6.1 on 5th May 2014 was discovered and analyzed from daily MODIS LST data during pre and post event to see the feasibility of using thermal remote sensing for detecting anomalies for the earthquake.

2. Study area

One of the active fault zones in Thailand is Phayao fault zone. Phayao fault zone locates in the northern part of Thailand (figure 1). Phayao fault zone passes through three provinces including Lampang, Phayao and Chiang Rai provinces with 145 km long. Its trend is in the NNW direction.

Phayao fault zone can be separated into 2 segments with different orientation: Mae Lao segment in the northern part and Wang Nue segment in the southern part. Mae Lao segment oriented in the NE-SW direction. It length is about 65 km. Wang Nue segment oriented in the NNW-SSE direction. Its length is about 95 km. Many small and moderate earthquakes were recorded from these segments in the last ten years.

The tectonic movement of Phayao fault zone is stimulated by the collision between the Indian-Austrian plate and Eurasian plate. The movement of Indian-Austrian plate in the northern and northeastern directions causes the left-lateral strike slip movement of Phayao fault zone and alert the earthquake in this area.

3. Data and method

MODIS LST (with 1 km x 1 km resolution) data for this work were downloaded mainly from NASA (http://earthexplorer.usgs.gov). The air temperature obtained from meteorological stations nearby the earthquake epicenter were used to calibration.

This study selected the event of 2014 Mae Lao Earthquake, Chiang Rai Province, Thailand (Magnitude Mw 6.1) which occurred on 5th May 2014 at 6:08 pm local time in Thailand. The epicenter locates at 19.756 N 99.687 E and the focus or hypocenter is at the depth of 7 km. Daily MODIS LST product used in this study (5th April – 3rd June 2014) are the 1 km gridded clear-sky reprocessed MODIS Terra (MOD11A1) and Aqua (MYD11A1) LST data. Cloudy pixels were marked as the unavailable data pixels. Since the study area covers the large area. Mosaicing processing was performed. LST difference between the earthquake event year and one other year at the same pixel location as used by Ouzounov and Freund [13] was calculated.

The comparative method or background deleted method [13] was applied to detect the thermal anomalies during the pre- and post-earthquake event as formulated in equation 1.
\[
\Delta LST = LST - LST_{bg(x/y)}
\]

(1)

where:
- \(\Delta LST\) is the anomaly temperature (°C)
- \(LST\) is the average land surface temperature (°C)
- \(bg(x)\) is the average land surface temperature before earthquake event (°C)
- \(bg(y)\) is the average land surface temperature after earthquake event (°C)

Hot spot data from MODIS during the study period, locations of the hot spring and data from ground field survey were used for validating the detected thermal anomalies.

4. Results and discussion

On 5th May 2014 at 6:08 pm local time, an earthquake with magnitude Mw 6.1 occurred in Chiang Rai province which is situated in Phayao fault zone.

4.1. Land Surface Temperature (LST)

The LST was calculated from MODIS LST product. The average day time LST and night time LST during the study period (5th April – 3rd June 2014) were 29.33 °C and 21.46 °C, respectively (figure 2 and figure 3). On 5th May 2014, daytime LST ranges between 17.75–35.65 °C (figure 2) and night time LST ranges between 14.91–24.00 °C (figure 3).

![Figure 1. Map shows the study area and active faults in Phayao fault zone.](image-url)
4.2. Thermal anomalies detection
Thermal anomalies were the LST temperature after removed the background temperature from average LST of the non-earthquake period. The result showed that the first detection of thermal anomaly was on 13th April 2014 (23 days before the earthquake event) with anomaly temperature of 6.52 °C (figure 4). The thermal anomaly distribution map for the first detection of thermal anomaly shows in the figure 5. The second was on 14th April 2014 (22 days before the earthquake event) with anomaly temperature of 6.58 °C (figure 4). The thermal anomaly distribution map for the second detection of thermal anomaly shows in the figure 5. The third was on 24th April 2014 (12 days before the earthquake event) with anomaly temperature of 7.7 °C (figure 6). The thermal anomaly distribution map for the third detection shows in the figure 5.

![Figure 2. Day time LST of 6th April – 4th June 2014.](image)

![Figure 3. Nighttime LST of 5th April – 3rd June 2014.](image)

![Figure 4. Anomaly temperature of 13th – 14th April 2014.](image)
13th April 2014 14th April 2014 24th April 2014

13th April 2014

Figure 5. Distribution map of thermal anomaly before the earthquake event.

14th April 2014

Figure 6. Anomaly temperature of 24th April 2014.

24th April 2014

After the main shock, at least two events of thermal anomaly can be observed. On 14th May 2014 (9 days after the earthquake event) the anomaly temperature of 6.19 °C was detected (figure 7). The thermal anomaly distribution map for the fourth detection of thermal anomaly shows in the figure 8. The last thermal anomaly was detected on 2nd June 2014 (28 days after the earthquake event) with anomaly temperature of 6.19 °C (figure 9). The thermal anomaly distribution map for the fifth detection shows in the figure 8.

Due to the cloud cover over the MODIS imageries during the study period, the number of analysis pixels did not cover the whole study area which affected to the LST and thermal anomaly detection. However, the finding of this study was proved that MODIS LST can be observed and detected the thermal anomalies. The results can be utilized to get better disaster resilience plan on the seismic activities such as Thailand which helps local organization and people to get warning and reduce the risk.
Figure 7. Anomaly temperature of 14th May 2014.

Figure 8. Distribution map of thermal anomaly after the earthquake event.

Figure 9. Anomaly temperature of 2nd June 2014.
5. Conclusion
The earthquake event is created by the complicated uncertain mechanism. The scientists and seismologists have endeavored to discover the precursor before the earthquake event. This research used the strength of MODIS LST data to detect pattern and locations of thermal anomalies during pre- and post-earthquake event with magnitude Mw 6.1 on 5th May 2014 in Phayao fault zone, Chiang Rai province, Thailand. The comparative method was performed for removing background temperature at the same location using based year data. The hotspots, hot spring locations and ground survey data were used in validation process. The thermal anomaly investigation from MODIS LST data gave the results as: (1) the thermal anomalies showed in 12–23 days before and 9-28 days after the earthquake event, (2) the amplitude of the thermal anomaly is about 6–8 °C. From the experience of this research, because of the optical satellite data in systematic and continuous monitoring of LST and anomalies, cloud cover causes a problem which effected to the pixel data of LST and thermal anomaly detection. The finding might be useful precursory sign and be detected using continuous MODIS LST data for fault activities and pre-earthquake events observations further.

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