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Thermal Remote Sensing Techniques for Studying Earthquake Anomalies (Case Study in Izmit)

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ABSTRACT:

In recent years the use of satellite technologies in remote sensing takes place in pre and post events of earthquakes. Based on previous researches about pre/post-earthquake thermal anomalies, in this paper Landsat 7 images were analyzed. The aim of this study is to determine the land surface temperature (LST) pre/post-earthquake behavior in 1999 Izmit earthquake. Due to lack of data, images which are 7 days before the earthquake (10.08.1999) and only few hours after the earthquake (17.08.1999) were compared. For calculating the LST from Landsat 7 an algorithm with thermal band was used. Two comparisons were made, in the first one, part of the Marmara Sea area was compared with the surface area of the Iznik Lake. The comparison showed that there is unusual warming near the North Anatolian Fault. The results showed that in the Marmara Sea the mean warming was 1.6°C on the day of the earthquake. The second comparison showed that from 65 randomly selected point, the maximum difference in the LSTs was 3.6°C. The same warming wasn`t noticed 30 to 130 km away from the fault so it is considered that the previous anomaly was caused by the earthquake event.

KEYWORDS: Earthquakes, Remote Sensing, Land Surface Temperature (LST), Thermal Anomalies.

Introduction

For better understanding of the earthquake events, studies on relation between satellite infrared remote sensing and earthquakes have been made since 1980s (Wei, Zhang et al. 2013). The fırst application of thermal images in seismology was started in Russia in 1985 and the first result were published in 1988 by Gorny et at. After the first application similar studies were carried out in China, Greece, Japan and Spain. To develop this research further a “Satellite Prediction Research Center for Natural Disaster” was established in China. Nowadays with the Remote Sensing technology as an unbiased monitor of the Earth`s surface, and the use of thermal remote sensing has brought out new trends in earthquake research (Saraf and Choudhury 2005). In this study case, Turkey`s one of the biggest disasters has been taken as an example in the research for thermal anomalies in the specific event. for the same event other researches (Tramutoli, Cuomo et al. 2005), (Yurur 2006), (Durand, Bouchon et al. 2013) were made. A 7.4 magnitude earthquake on August 17, 1999 occurred in western Turkey also known as the Kocaeli, Turkey earthquake. It is also known as the world`s longest and best studied strike-slip (horizontal motion) faults: the east-west trending North Anatolian fault. The North Anatolian fault has produced seven large (MS >= 7.0) earthquakes in the period from 1939 through 1999. These earthquakes have ruptured the fault progressively from east to west. The time of occurrence was recorded as 00:01:39.80(UTC), 03:01:37 a.m. local time. According to USGS and Kandilli main source parameters of the earthquake are as follows: Surface Wave Magnitude: 7.8 (USGS); Moment Magnitude: 7.6 (USGS, Kandilli); Epicenter: 40.702N, 29.987E (USGS); Depth: 17 km (USGS). Rupture length of at least 125 km and right lateral offset of as large as 5 m have been reported.

Background

Similar studies show that few days before the earthquakes thermal anomalies have been noticed around the epicenter or the affected areas. A study case for the Bam earthquake of 26 December 2003 has reported the sudden temperatures increase was about 5-7°C that the usual temperature of the region. At some places the temperature was noticed to be 6-10°C higher than the usual temperature of the region in that period of the year (Choudhury, Dasgupta et al. 2006). Another study, claims that short-lived thermal anomalies typically appear 7-14 days before an earthquake, affect several thousand or tens of thousands square kilometers, displayed positive deviation of 2-4K or more and disappeared a few days after the event. The results showed that surface air temperature increased about 6.2K in the study area (Guangmeng 2008). With the ability for calculating the Land Surface Temperature with thermal remote sensing techniques, has brought out new trends in earthquake research. Not only in earthquake research but in many fields the LST is an important factor controlling most physical, chemical and biological processes of the Earth.

Tools and methods

In this paper the LST of Landsat satellite images were compared in order to check the anomalies in the earthquake of the Kocaeli, Turkey earthquake. For calculating the LST an Erdas Imagine tool was used. For retrieving the Top of Atmospheric Spectral Radians and to convert the radiance to At-sensor temperature formulas from USGS web page were used. For the other steps of the tools, formulas for calculating the emissivity (Sobrino, Jimenez-Munoz et al. 2004), and the emissivity corrected land surface temperature (Stathopoulou and Cartalis 2009) were used.

The method of this study for thermal anomalies of pre/post-earthquake events compares the previous retrieved LSTs of the Landsat data. For that cause Landsat 7 satellite images from 10.08.1999 and 17.08.1999 for the area around the epicenter were downloaded from http://earthexplorer.usgs.gov/. In this paper two different methods were used for studying the Kocaeli earthquake. For the first case, since near-air temperatures of the earthquake area were not available, and the LSTs in the urban area are not so accurate because of the data's resolution, it was decided to be looked for wide, homogeneous area for compassions/analysis.

Taking into consideration that the North Anatolian Fault is passing in the Sea of Marmara (Figure 2 – Zonal Statistics – area 1), the water area was taken to be compared with the Iznik Lake (Figure 2 – Zonal Statistics – area 2), approximately 30 km South. The map of the faults are taken from the General Directorate of Mineral Research and Exploration – Turkey (MTA) (Figure 1).

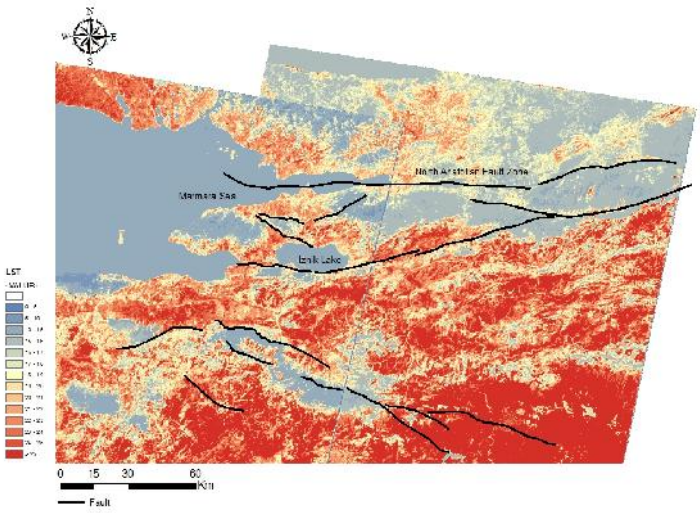

Figure 1: LST maps of the two satellite images, right side 17.08.99, left side 10.08.99, and the faults of the Anatolian plate.

For the second case, 65 randomly selected points near to the epicenter or North Anatolian Fault (Figure 2-area 1) were compared with the same number of point selected approximately 30 to 130 km south from the fault (Figure 2 - area 2).

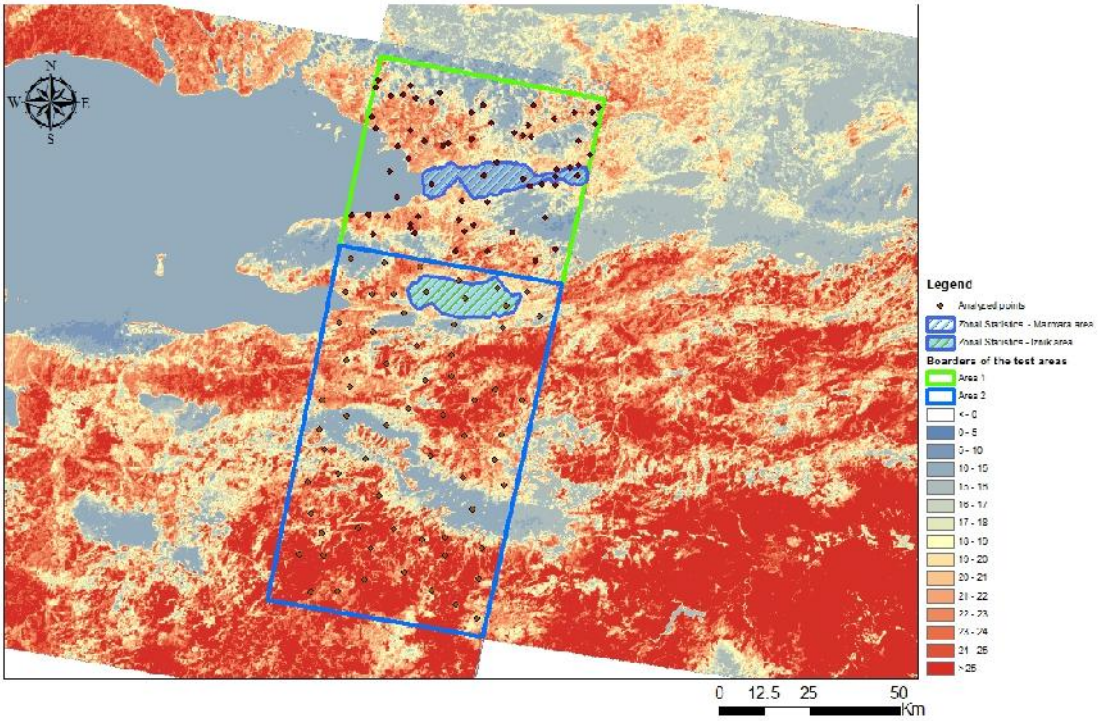

Figure 2: Mutual area from the satellite images, the randomly selected points and the boarders of the study areas and the boarders for the Zonal Statistics in Marmara Sea and Iznik Lake

Results

Figure 3 shows the LST maps from the two of satellite images downloaded from 17th and 11th of August 1999. From the made comparison it was concluded that the water from the Marmara Sea was max 3°C hotter than the water area of the Iznik Lake.

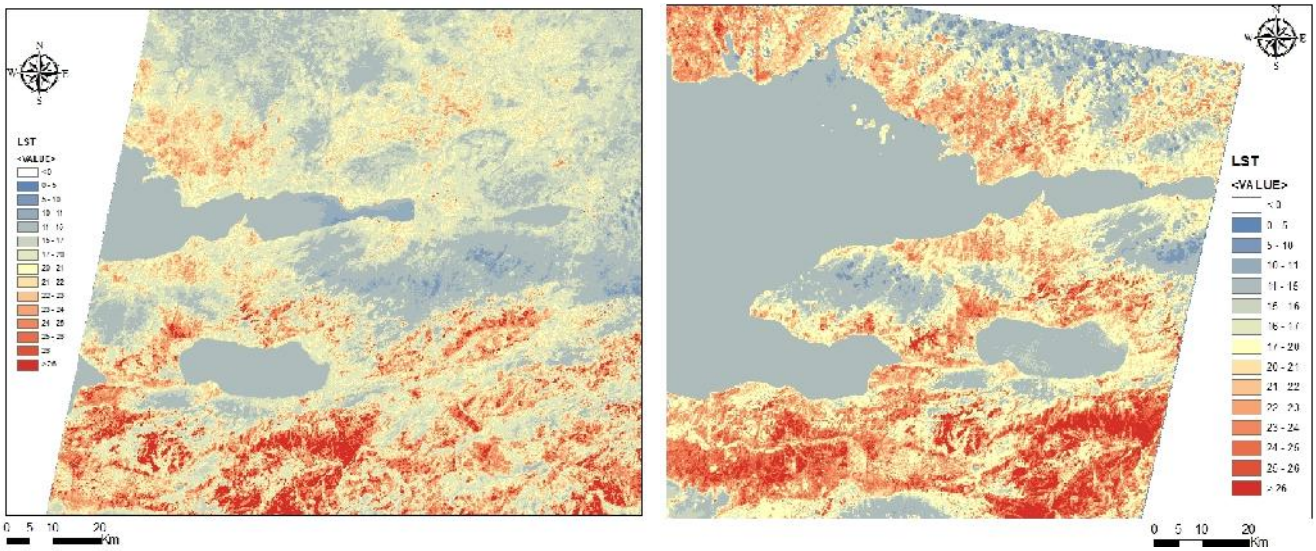

Figure 3: LST maps of the study area. Left map represents 10.08.1999 and right map represents 17.08.1999

The values of the temperatures shown at the maps in the legends were chosen detailed between 10-11°C and 15-17°C since the differences were around those temperatures.

In Table 1 below are shown the results of the Zonal Statistics made for Marmara Sea and the Iznik Lake. The important difference from the table is the mean value of the temperatures that for Marmara Sea is 1.6°C and for Iznik Lake is 0.6°C showing that the on 17.08.1999 there is unexpected warming in Marmara Sea.

Table 1: Results from the Zonal Statistics for Marmara Sea (left table) and Iznik Lake (right table)

Sea of Marmara		
°C	10.08.1999	17.08.1999
Min	9.15	10.11
Max	16.51	15.17
Mean	11.31	12.90

Iznik Lake		
°C	10.08.1999	17.08.1999
Min	12.80	13.81
Max	15.62	15.61
Mean	14.12	14.75

For excluding the possibility that the warming was caused by normal weather changes, the mutual area from the two satellite images from 10.08.1999 and 17.08.1999 was divided into two parts, the first part was with center of the North Anatolian Fault and the other part was the area that was left from the mutual area (Figure 2). Into the two parts, 65 points were randomly selected for analyzing the temperatures behavior. The results showed that in the first case, near to the North Anatolian Fault, 86% of the points has shown that there is an increase in the LSTs with maximum of 3.6°C. 2% of the results showed that there is no change in the LSTs and 12% showed that there was a decrease of the temperatures with maximum of -0.1°C. As for the second part of the study area, starting approximately 30 km south of the North Anatolian Fault, results showed that 34% of the examined points has shown that there is an increase in the LSTs with maximum difference of 1.4°C, 46% showed that there is a decrease in the temperatures with maximum difference of -3.8°C and 20% showed no difference in the Land Surface Temperatures between the two satellite images (Figure 4).

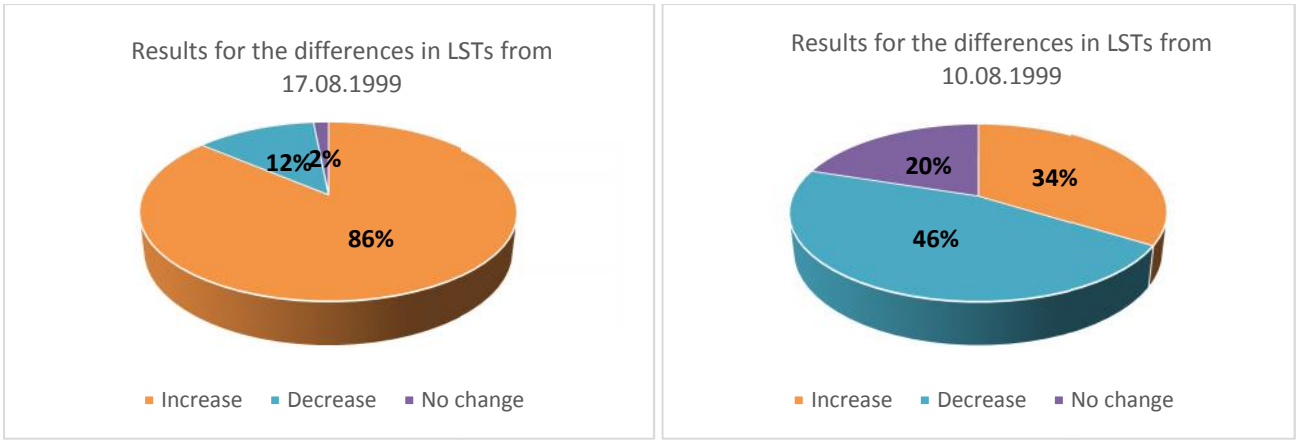

Figure 4: Results from the differences in LSTs from 17.08.1999 (on the left) and 10.08.1999 on the right.

Discussion and Conclusion

A lot of researches has shown that there are positive thermal anomalies pre/post-earthquake and they are of big assistance in helping us understand and predict the earthquake events. According to Guangmeng (2008), using the National Centers for Environmental Prediction (NCEP) satellite data such as NOAA/AVHRR and MODIS, was found that NCEP can also detect thermal anomaly before earthquake. In March and April 2007, 30 early

warnings were made and only one of them did not occur. According to Saraf and Choudhury (2005), it is clearly stated that the Izmit earthquake show an increase in temperature of the region before the earthquake. The anomaly has started from 6 August centered on the epicenter. The anomaly maps show difference of 2-6°C and a boost of temperature with an increase of 6-10°C with respect to the base period. It is also concluded that the anomaly has disappeared day after the earthquake showing similar temperatures as normal.

This study has also shown that on the day of earthquake event with comparison with one week before the event, there is unusual warming in the area around the North Anatolian Fault near to the epicenter. The same warming was not found in the other study area that was used for comparing the data from the area near to the epicenter, so it was concluded that the warming was caused by the 17 August earthquake. The analyses were made using Land Surface Temperatures maps retrieved from Landsat 7 satellite images. From the study it was concluded that the difference between the LSTs from 10.08.1999 and 17.08.1999 was maximum 3.56°C.

Taking into consideration that short-lived thermal anomalies appear 7-14 days before the earthquake events and disappear few days after the event (Guangmeng 2008), it can be assumed that anomalies were even bigger and they mid had affected bigger area.

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