OLR anomalies prior to big earthquakes (Mw > 6.0) – a case study on earthquakes of India's neighboring region occurred during the year 2012

Venkatanathan N
SASTRA University

OLR ANOMALIES PRIOR TO BIG EARTHQUAKES (M_W > 6.0) – A CASE STUDY ON EARTHQUAKES OF INDIA'S NEIGHBORING REGION OCCURRED DURING THE YEAR 2012

Natarajan VENKATANATHAN*, Balasubramanian KAARTHICK and Chandrasegaran PRIYADHARSINI*****

***** (Corresponding author) Faculty of Physics, SASTRA University, Thirumalaisamudram, Thanjavur – 613 401, India. Tel. +919444807900; physics16972@yahoo.com
****** and ******* SASTRA University, Thirumalaisamudram, Thanjavur – 613 401, India.

ABSTRACT: In present scenario, satellite remote sensing technology is used to identify earthquake related phenomena like surface temperature, air temperature, humidity, gas and aerosol content. Anomalous long wave radiations normally appeared 5 to 30 days before the occurrence of moderate and big earthquakes, which can be measured at the top of the cloud level. This study aims to confirm that the Outgoing Longwave Radiation (OLR) is one of the most promising space bound precursory techniques to forecast the occurrence of moderate and large earthquakes. From the analysis, the OLR anomaly was observed for the all ten earthquakes occurred in the neighbouring regions of India during the year 2012.

***KEYWORDS**: outgoing longwave radiation, anomaly index, thermodynamic process*

INTRODUCTION

An early report on thermal anomaly, reported by Gornyy et al. (1988) were used satellite thermal infrared (TIR) data to identify anomalous phenomena appeared in Central Asian earthquake zones. Several studies (Tronin et al., 2002; Pulinets et al, 2006a; Ouzounov et al, 2011) indicated that significant short-lived anomalies appeared before devastating earthquakes. One of the best examples of appearance of OLR anomalies can be related with the mega earthquake in Sumatra on December 26, 2004. Ouzounov et al (2007) reported that, five days before (December 22, 2004) the mega thrust earthquake occurred, anomalous value of +80 W/m^2 appeared over the epicenter region. These short-lived anomalies have been identified normally 5 – 30 days before an earthquake and that covers several thousand square km.

The OLR in to space varies due to the cloud and surface temperature of the Earth (http://rammb.cira.colostate.edu) and it is the movement of thermal energy, it can be measured from the top of the atmosphere (16 to 17 km above sea level). The appearance of OLR anomalies may be due to the ionization of air near the ground and latent heat change due to variations in air humidity and temperature. It is hypothesized that it could be due to the link between stress along the fault regions, electrochemical and thermodynamic processes in the atmosphere and increasing mid IR (infrared) instability (Ouzounov et al., 2007). National Oceanic and Atmospheric Administration (NOAA) satellites "NOAA 18" is measuring at the top of the atmosphere and the data can be downloaded from http://www.cdc.noaa.gov. In this paper, we have analysed the NOAA 18 satellite data to explore the relationship between the short-lived atmospheric phenomena and the earthquakes occurred with magnitude greater than 6.0, in the neighbouring regions of India during the year 2012 given in the chronological order in **Table 1**.

Table 1: The list of earthquakes (M > 6.0) occurred in the Indian and neighbouring regions during the year 2012. *Data Source: USGS (http://earthquake.usgs.gov/).*

S. No	Date	Latitude	Longitude	Magnitude	Region
1	10/01/2012	2.43 N	93.21 E	7.2	Northern Sumatra, Indonesia
2	11/04/2012	2.33 N	93.06 E	8.6	Northern Sumatra, Indonesia
3	11/04/2012	1.25 N	91.74 E	6.0	Northern Sumatra, Indonesia
4	11/04/2012	0.80 N	92.46 E	8.2	Northern Sumatra, Indonesia
5	15/04/2012	2.58 N	90.27 E	6.2	Northern Sumatra, Indonesia
6	23/06/2012	3.01 N	97.90 E	6.1	Northern Sumatra, Indonesia
7	25/07/2012	2.71 N	96.04 E	6.4	Northern Sumatra, Indonesia
8	12/08/2012	35.66 N	82.52 E	6.2	Xizang, China
9	14/09/2012	3.32 S	100.59 E	6.2	Southern Sumatra, Indonesia
10	11/11/2012	23.00 N	95.89 E	6.8	Myanmar

MATERIALS AND METHODS

As mentioned earlier, the Outgoing Longwave Radiation (OLR) is measured at the top of the atmosphere therefore it is the measurement of combination of radiations from ground, lower atmosphere and clouds (Ohring and Gruber, 1982). Using separate algorithm the OLR is calculated from the basic data, which is at 8 to 12 µm (Gruber and Krueger, 1984). Both the data and algorithm for examining the advanced very high resolution radiometer (AVHRR) is provided by National Oceanic and Atmospheric Administration Climate Prediction Center (http://www.cdc.noaa.gov). The appearance of anomalous radiation for short duration may be related to tectonic stress and thermodynamic processes in the atmosphere.

An anomalous eddy of OLR can be defined as ΔE_index (OLR anomaly index), which signifies the statically defined maximum change in the rate of OLR for given spatial locations and predefined times (Ouzounov et al., 2011):

$$\Delta E\_Index\ (Anomalous\ Index) = \frac{(Current\ OLR\ daily\ value - Average\ OLR\ daily\ value\ of\ Past\ 5\ years)}{Standard\ Deviation}$$

For this study, NOAA/AVHRR OLR data taken between 2007 and 2011 were used as an OLR base field. The OLR base field was computed for prior to the occurrence of each earthquake given in **Table 1**. To identify the anomaly the current OLR field is compared to the "+2 sigma" confidence level of the OLR base field, calculated for the period of 2007 - 2011. If the OLR anomaly index value is greater than 2 sigma level, then it is considered as anomalous phenomena of the particular location. The appearance of the short lived OLR anomaly is observed every time before the occurrence of the above tabled earthquakes. The rapid development of radiation could be described that the anomalous flux of the latent heat over the area most probably due to increased tectonic activity. The time line of the appearance of these short-lived anomalies varies for each earthquake, maybe due to the different nature of the tectonic settings of these places. Similar anomaly was detected within a few days prior to the devastating earthquakes like Sumatra 2004 (Ouzounov et al., 2007), Haiti 2010 and Japan 2011 (Ouzounov et al., 2011).

RESULTS AND DISCUSSIONS

The results of OLR analysis for the all ten earthquakes given **Table 1** shows there is significant anomaly appeared prior to the occurrence of the events, which confirms there is some relation between the appearance of anomaly and devastating earthquakes. Even though exact triggering mechanism of the earthquakes is not exactly known, the analysis of ten earthquakes given **Table 1** shows encouraging sign that the OLR anomaly can be used as effective tool to identify the impending earthquakes in a particular region.

a) Northern Sumatra, Indonesia (January 10, 2012; M 7.2)

On January 10, 2012 an earthquake with magnitude of 7.2 occurred at off the west coast of northern

Sumatra, Indonesia as a result of strike-slip faulting (USGS). The epicenter of the event (Latitude - 2.43 N & Longitude - 93.21 E) is approximately 300 km from the epicenter of the mega earthquake occurred 2004 with the magnitude of 9.1. The earthquake is due to left lateral strike – slip faulting. The OLR anomaly appeared 7 days before the event occurred (i.e.) on January 02, 2012 and also on January 03, 2012 (**Figs. 1& 2**). On January 02, 2012 the anomalous index value was just above the 2 sigma level of the OLR base field and it appeared at two nearby regions, one at the location with latitude of 5 N and longitude of 95 E and the second seems to be smaller one, appeared at latitude 0N and 87.5 E longitude.

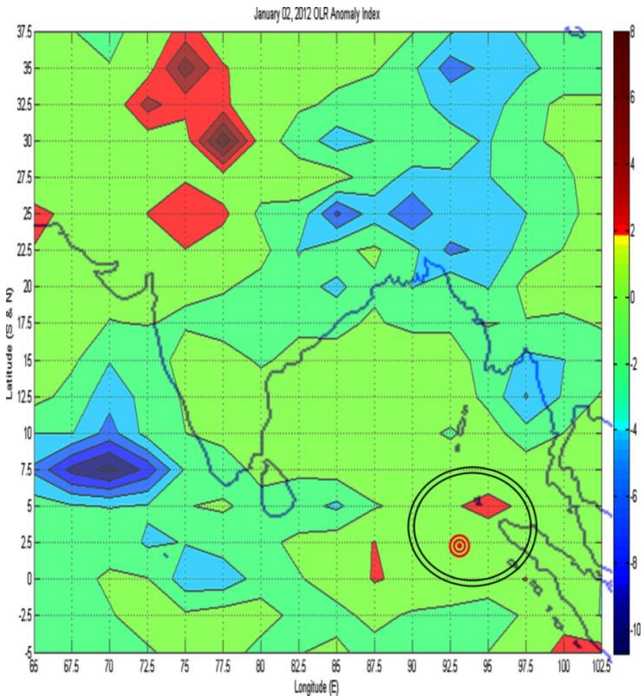

Fig. 1. OLR anomaly appeared in the region (black double circle) on January 02, 2012, 8 days before the earthquake occurred at the Northern Sumatra region with latitude 2.43 N and longitude 93.21 E (marked as concentric circles) on January 10, 2012 with the magnitude of 7.2.

The anomaly appeared on January 03, 2012, but at the different location with latitude of 2.5 N and longitude of 97.5 E, 8 times more than the +2 sigma value of OLR base field. It also appeared at the latitude of 0 N. The largest intensity of 269.6 W/m^2 was observed on January 03, 2012 at the location 2.5 N and 97.5 E.

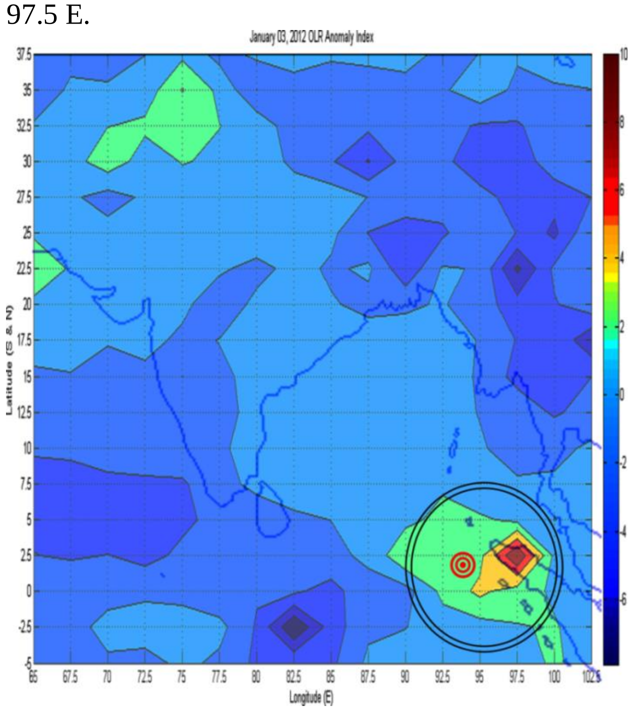

Fig. 2. The second OLR anomaly appeared 7 days before the Northern Sumatra region earthquake (2.43 N, 93.21 E).

b) Northern Sumatra, Indonesia (April 11, 2012 & April 15, 2012; M 8.6, 6.0, 8.2, 6.2)

On April 11, 2012, off the west coast of northern Sumatra, Indonesia with the magnitudes M8.6, M6.0 and M8.2 occurred as a result of strike-slip faulting within the oceanic lithosphere of the Indo-Australia plate (USGS). One more after shock was recorded with the magnitude of 6.2 on April 15, 2012. The quakes were located respectively 100 km and 200 km to the southwest of trench. At least 2 people were killed and 31 cm tsunami was recorded at Meulaboh, Indonesia (USGS).

Anomalous index with value more than two times the +2 sigma level of OLR base field was observed; first time it was on March 22, 2013 in the region at 2.5N latitude and 95 – 100 E longitude (**Fig. 3**). The second one appeared on April 04, 2012 in the nearby region (2.5N, 90E) prior to the April 11, 2013 earthquake (**Fig. 4**). Another anomaly appeared on April 11, 2012 (i.e.) four days prior to the earthquake in adjacent region (5N, 90E) on April 15, 2013. This time the anomalous index was just above the +2 sigma level of the OLR base field (**Fig. 5**). The April 11, 2012 anomaly was a precursor for the April 15, 2012 earthquake.

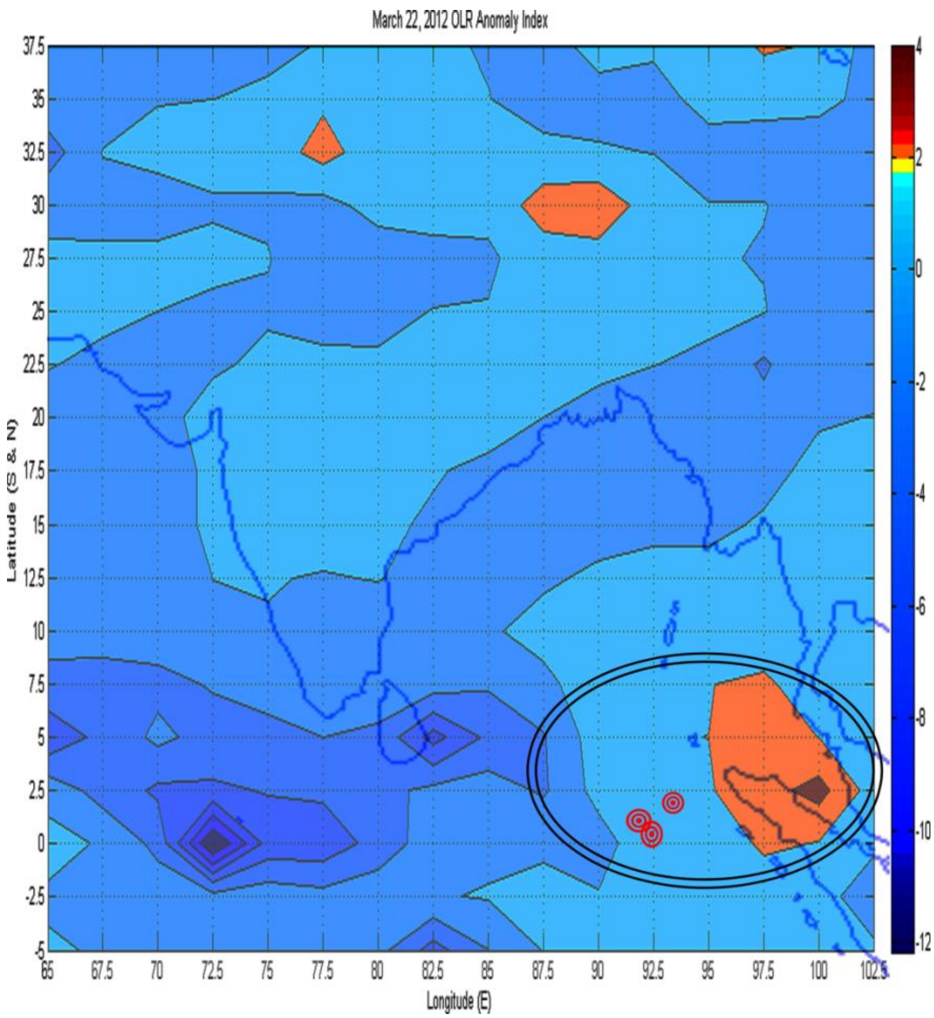

Fig. 3. First transient anomaly appeared in the vicinity of the epicentral region marked by a double black circle in the region of 2.5N and 90E. It appeared 20 days before the year’s biggest earthquake (2.33N, 93.06E) on April 11, 2012. This earthquake was followed by two more shocks to the SW with magnitude M6.0 (1.25N, 91.74E) and M8.2 (0.80N, 92.46E)

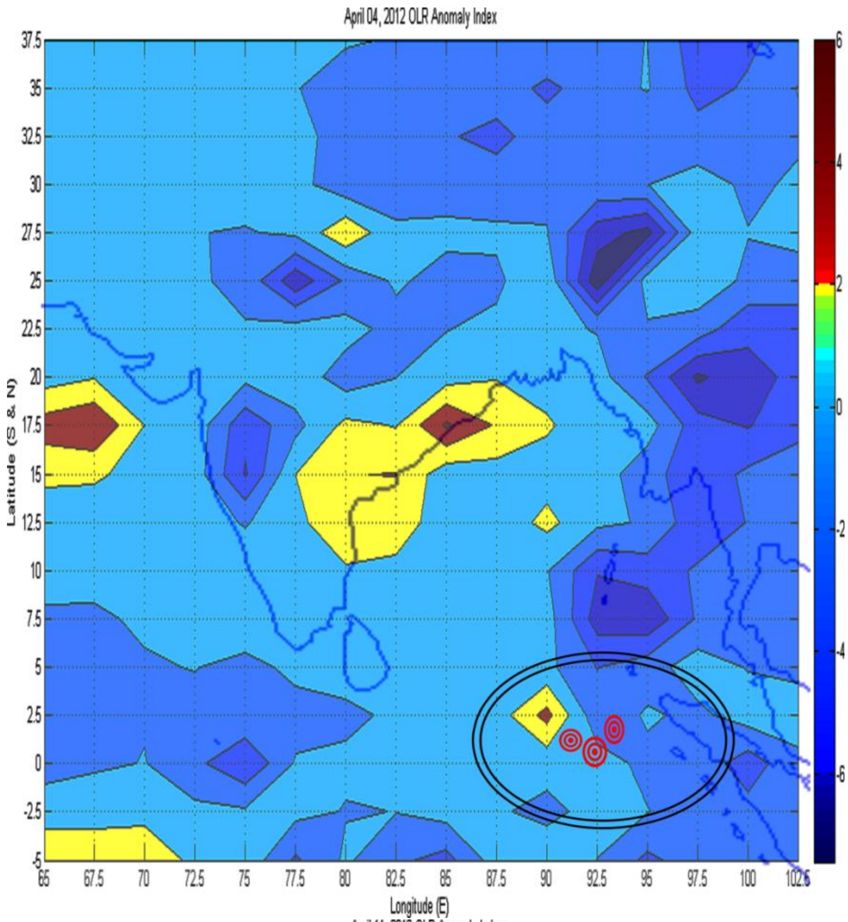

Fig. 4. OLR anomaly appeared in the region of 5N and 90E for the second time on April 04, 2012 before the mainshock and two aftershocks occurred on April 11, 2012.

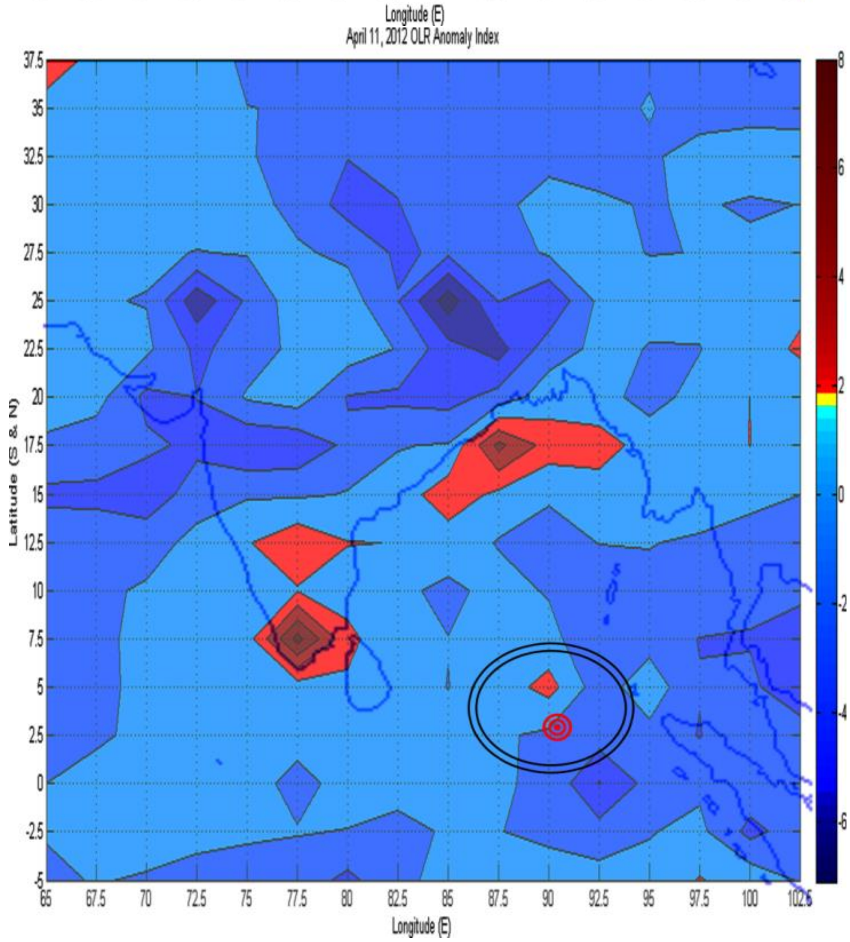

Fig. 5. For the April 15, 2013 aftershock the OLR anomaly surfaced near the epicentral region just four days before.

c) Northern Sumatra, Indonesia (June 23, 2012; M 6.1).

The earthquake with magnitude M_w - 6.1 occurred in the Northern Sumatra region on June 23, 2012 at 04:34 UTC. The exact location is 109 km South West of Medan city (Latitude - 3.01 N & Longitude - 97.90 E) with the population of 1,750,971 (USGS). From the analysis of the OLR data it was found that two anomalies appeared on two different days. The first anomaly appeared on June 04, 2012 (i.e.), 19 days prior to the earthquake (**Fig. 6**) and the second on June 18, 2012, five days before the occurrence of earthquake (**Fig. 7**).

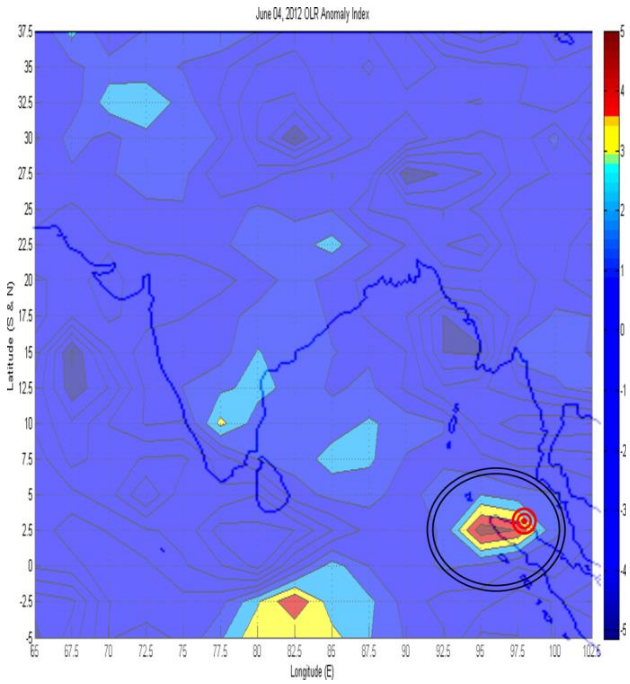

Fig. 6. The first notable big OLR anomaly inside the double black circle appeared 19 days prior to the earthquake with a magnitude of 6.1 in the Northern Sumatra region (3.01N, 97.90E).

The first anomaly appeared on June 04, 2012 was three times higher than the +2 sigma level of the OLR base field. It appeared very close to the epicenter of the June 23, 2012 earthquake. The second anomaly, which appeared five days before the earthquake, was less intense (just above +2 sigma level of base field) than the first one that appeared on June 04, 2012.

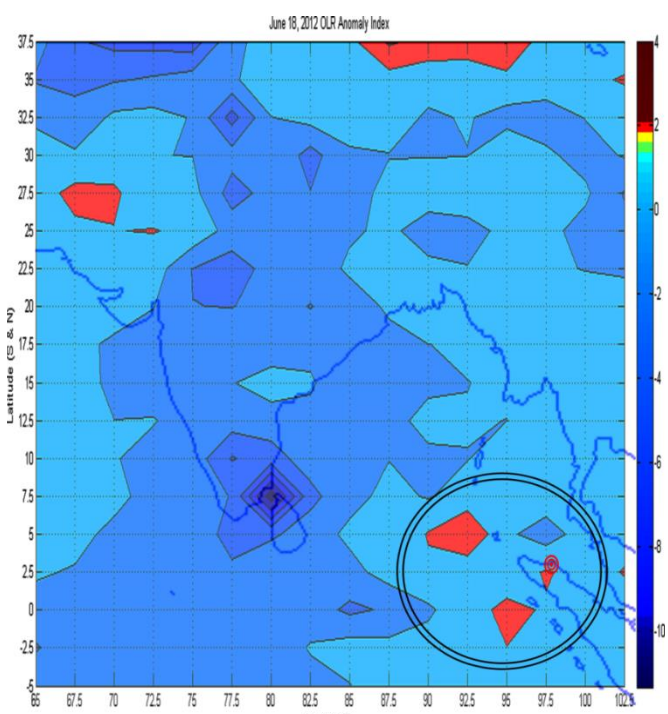

Fig. 7. Another OLR anomaly appeared nearby (5N, 97.5E) 5 days before the event at the location (2.71N, 96.04E) with an M6.4.

d) Northern Sumatra, Indonesia (July 25, 2012; M 6.4)

This event is the seventh (M>6.0) earthquake occurred in 2012 in the Northern Sumatra region. The earthquake occurred due to reverse faulting and the epicenter (2.71N, 96.04E) 330 km away from the event which occurred earlier this year with magnitude of 8.6.

The OLR anomaly appeared at Latitude – 5N and Longitude – 97.5E, with OLR anomalous index 10 times more than that of +2 sigma level of base field. The anomaly appeared three days before the main event (**Fig. 8**).

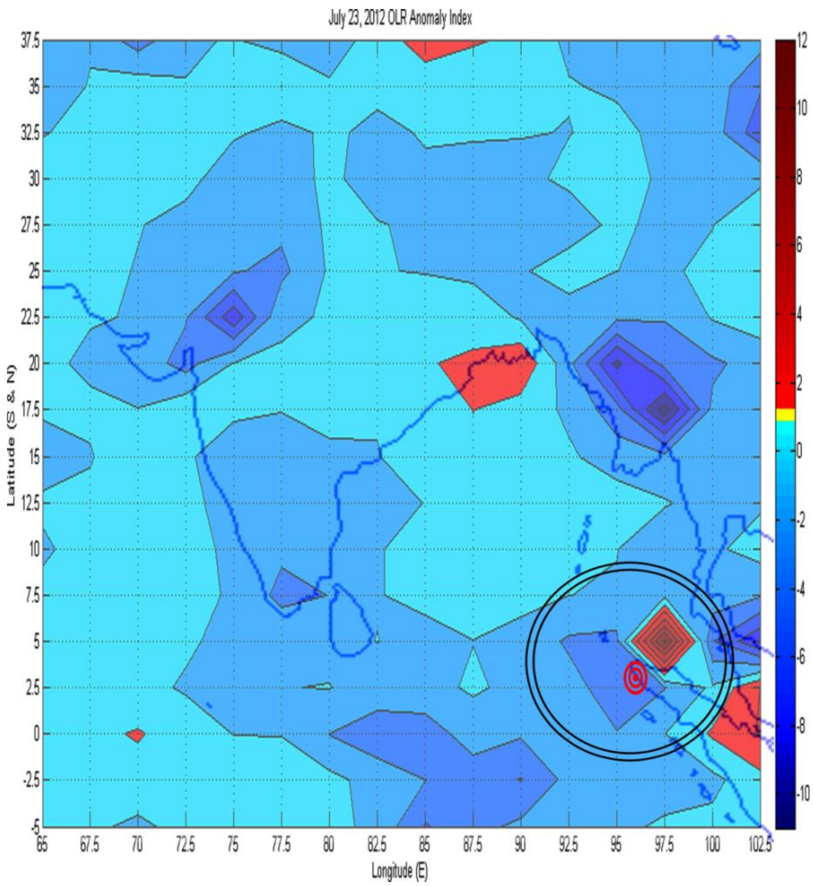

Fig. 8. In this case the OLR anomaly appeared 2 days prior to the earthquake in the Northern Sumatra region (2.71 N, 96.04 E) with the magnitude of 6.4.

e) Xizang, China (August 12, 2012; M6.2)

This earthquake occurred at the Xinjiang-Xizang border region (Latitude 35.66N & Longitude 82.52E) with M6.2 on August 12, 2012. The depth of the earthquake is very shallow.

The OLR anomaly appeared twice; the first one at 35N latitude and 80E longitude on July 29, 2013, and the second near the first location (37.5N, 85E) on August 05, 2013, with an OLR anomalous index 18 times higher than the +2 sigma level of the OLR base field value (**Fig. 10**). This value is comparatively higher than OLR anomaly values recorded for the other notable earthquakes discussed in this paper. The anomaly appeared three days prior to the earthquake.

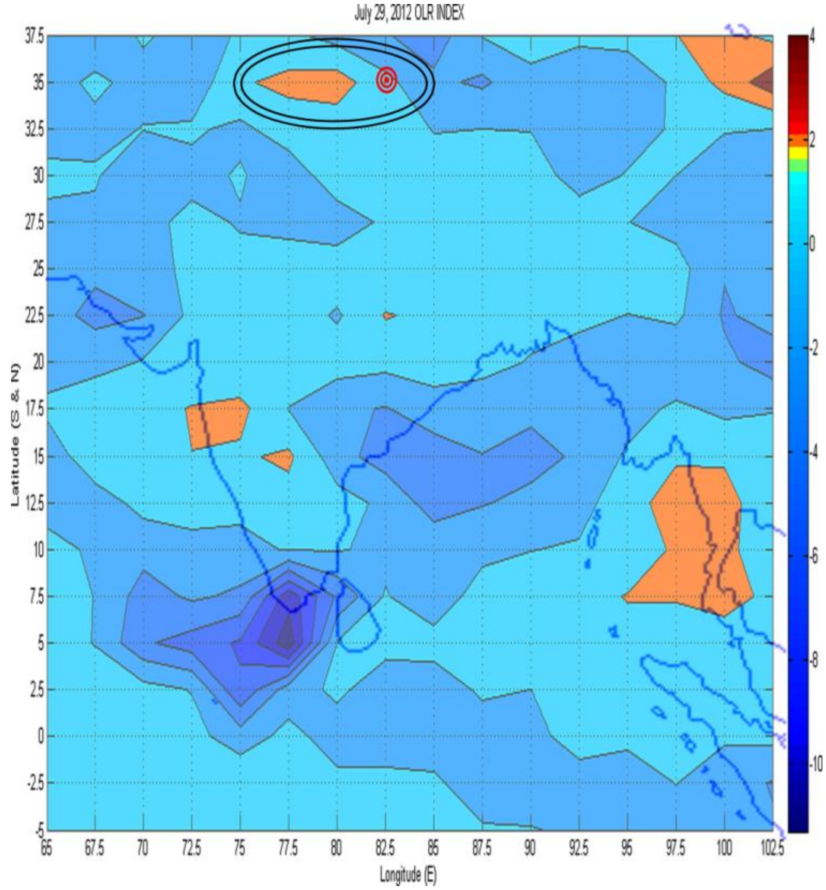

Fig. 9. This event occurred at Xizang, China, for which the first OLR anomaly appeared in the nearby region fifteen days before the event at the location (35.66 N, 82.52 E) with M6.2.

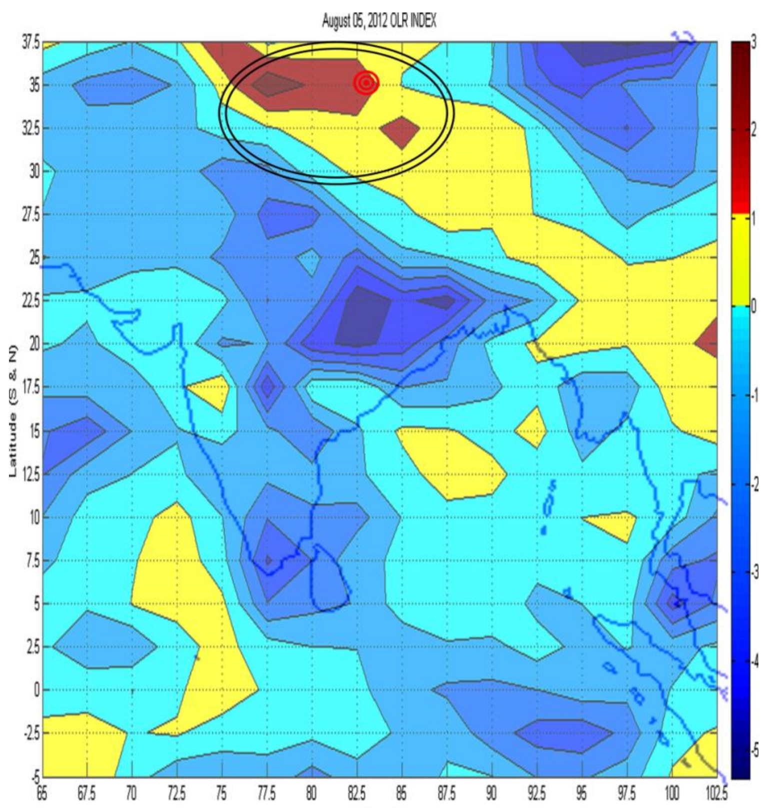

Fig. 10. Higher anomalous phenomena for the wider region appeared for the second time near the epicentral region (35.66 N, 82.52 E) 7 days prior to the earthquake occurred Xizang, China at with a magnitude of 6.2.

f) Southern Sumatra (September 14, 2012; M6.2)

An earthquake occurred in the Southern Sumatra region (3.32S, 100.59E) with magnitude of 6.2 on September 14, 2012. This event approximately 158 km away from the mega event occurred on September 12, 2007 with magnitude of 8.5. Most of the earthquakes in this region occurred as a result of thrust faulting (USGS).

Anomalous index of just above the +2 sigma level of OLR base field was observed on September 08, 2012 in the nearby region (2.5S, 97.5E) (**Fig. 11**) before the occurrence of the event in this region.

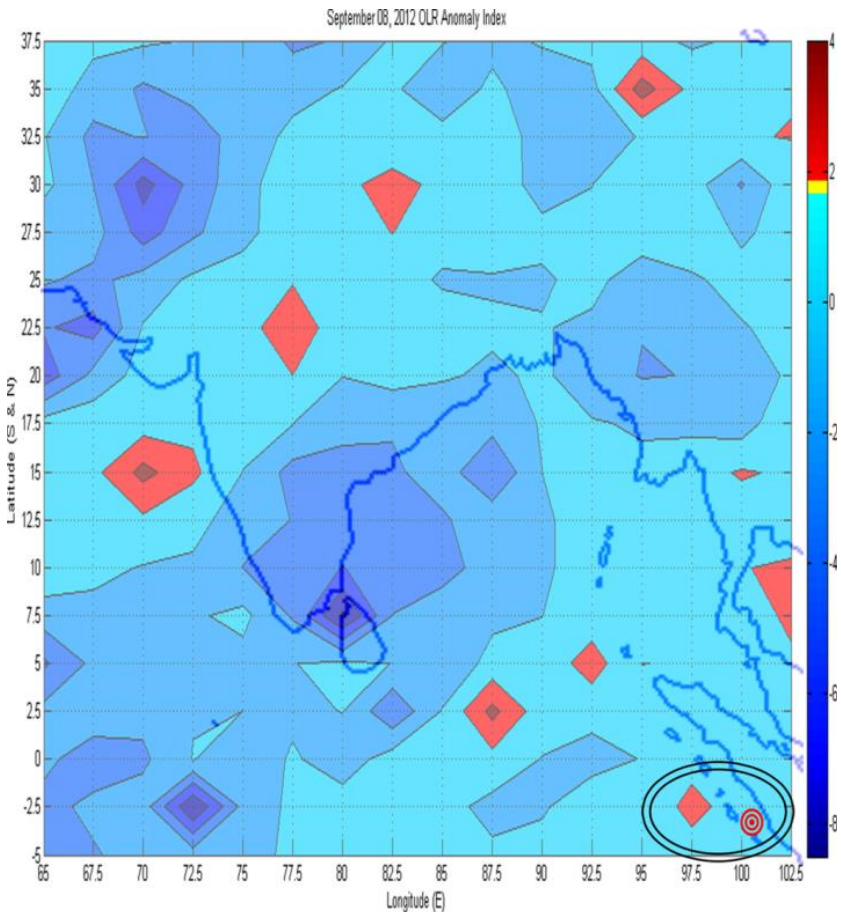

Fig. 11. The OLR anomaly appeared for a short period of time, just 6 days prior to the earthquake in Southern Sumatra (3.32 S, 100.59 E) with a magnitude of 6.2.

g) Myanmar (November 11, 2012; M6.8)

This earthquake is due to the right lateral faulting with the depth of 9.9 km. The earthquake occurred at the Myanmar region (23N, 95.89E) on November 11, 2012 with M6.8.

OLR anomaly appeared on two different days, prior to the occurrence on November 11, 2012 earthquake. First, the anomaly was not limited to the epicentral area, but it spread for several thousands of kilometers. The first anomaly appeared 20 days before the main event (**Fig. 12**). In the first anomaly the anomalous index was just above the +2 sigma level of base field at the epicenter, but it was two times greater than the +2 sigma level of OLR base field at two locations, which are 5 degrees away from the epicenter of the impending earthquake. The second anomaly appeared on November 11, 2012 (**Fig. 13**), at latitude – 25N and longitude – 92.5E. The anomaly index was just above the +2 sigma level of OLR base field.

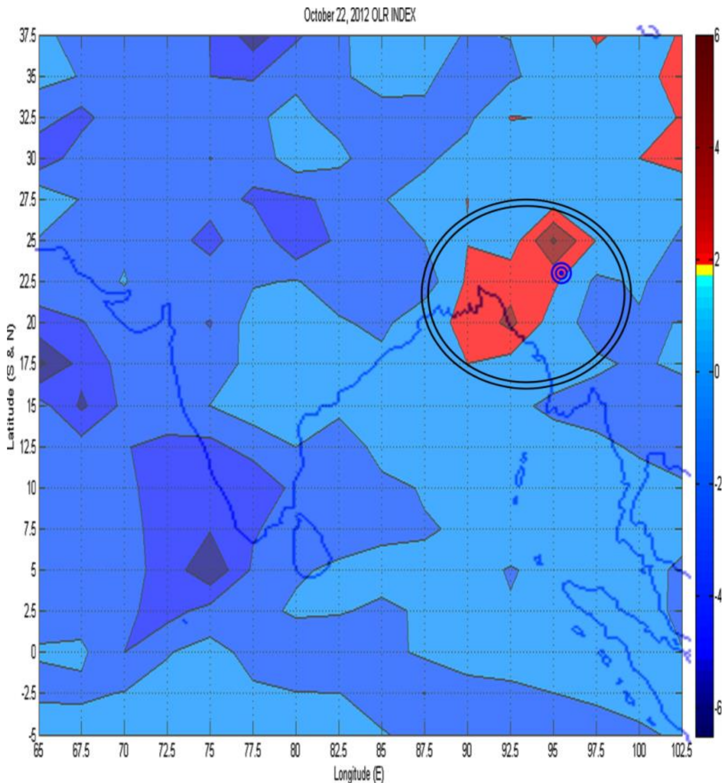

Fig. 12. Among the two anomalies appeared before the Myanmar region (23.00N, 95.89E) with the magnitude 6.8, the first one appeared for a short period of time, 19 days prior to the earthquake.

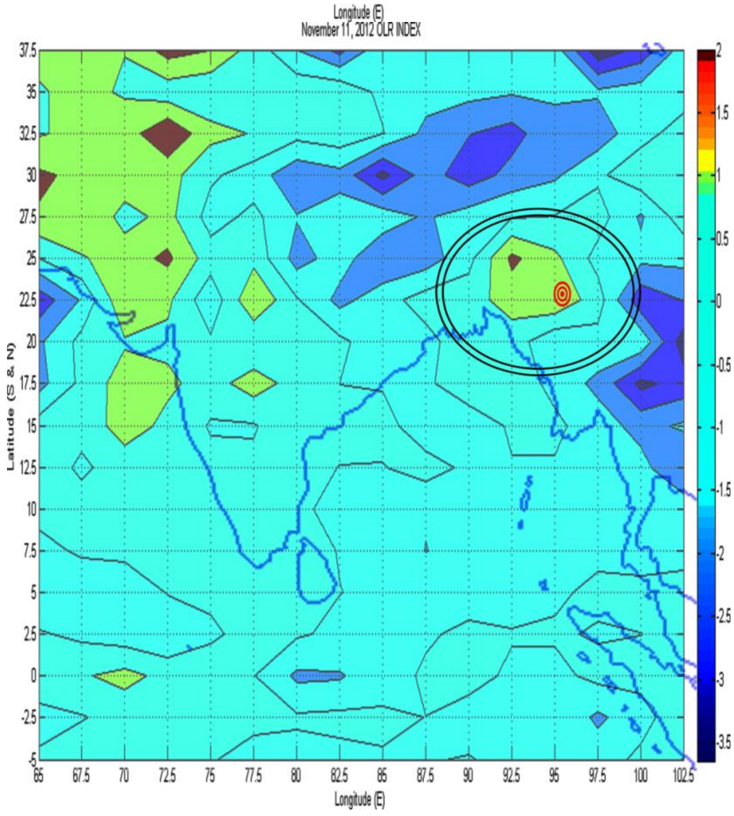

Fig. 13. The second transient anomaly appeared on the same day when the event occurs in the Myanmar region.

DISCUSSIONS

The reason behind the appearance of OLR anomaly is not known exactly, but it may be hypothesized that it may be due to the air ionization produced by the increased emanation from the increased tectonic activity in the region. Air ionization leads to changes in the relative humidity, surface temperature and air temperature, which intensify the outgoing infrared radiation (Pulinets et al., 2006a & b).

Even though the occurrence of OLR anomaly can be related to several other parameters, it can be used as an effective earthquake precursor, especially to identify the magnitude of the earthquake, and also if we correlate the results with various precursory studies, then it is possible to elevate the earthquake prediction to the unprecedented level of accuracy for this it is important to establish a well-coordinated global networks (Venkatanathan, 2012).

CONCLUSION

The OLR data derived from the NOAA satellites shows that there is reliable occurrence of OLR anomaly before the occurrence of impending earthquakes. The time frame of strong outgoing radiation over the epicentral areas was found to be 5 to 30 days before the occurrence of the event. Athough exact triggering mechanism is still unknown, it may be because of lithosphere– atmosphere–ionosphere coupling, proposed by Pulinets and Boyarchuk (2004). Problem still remains as the OLR varies due to other atmospheric phenomena. However, it is possible to predict earthquake with high degree of accuracy, if we cross correlate with other ground-based and space-based precursory studies.

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