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Observation of Earthquake Precursors - A Study on OLR Scenario Prior to the Earthquakes of Indian and Neighboring Region Occurred in 2016

N VENKATANATHAN, V HAREESH AND W S VENKATESH
Department of Physics, SASTRA University, Thirumalaisamudram, Thanjavur, Tamil Nadu, India; Pin–613401
Email: *venkatanathan@eee.sastra.edu*

Abstract: The scientists from across the world are studying the appearance of various precursors using ground and satellite based techniques. Continuous observation of anomalous thermal precursors like Outgoing long wave Radiation (OLR) is possible using satellite technology. These anomalous variations in the atmospheric parameters were observed several days before the occurrence of great earthquakes. In this paper the authors have analyzed OLR scenario prior to the earthquakes of Indian and neighbouring region earthquakes occurred recently in 2016. This is to identify the possible link between earthquake preparation zones and the anomalous variations in OLR scenario. From the results inference can be made that the anomalous OLR variations can effectively be used to identify the earthquake preparation zones.

Keywords: *Outgoing Longwave radiation (OLR), Anomalous Signal Index, short term prediction, LAIC and thermodynamic process*

1. Introduction

Several studies were done by many researchers on the appearance of pre-earthquake thermal anomalies in the regions like India, Japan, China, Sumatra, Italy, Iran and Haiti (Tronin et al. 2002; Qiang et al. 1999; Tramutoli et al. 2005; Filizolla et al. 2004; Genzano et al. 2007; Ouzounov and Freund 2004; Ouzounov et al. 2006; Saraf et al. 2008; Choudhury et al. 2006; Singh et al., 2010; Dey and Singh, 2003; Dey et al., 2004). Results of these studies have shown that these anomalies can be used as a reliable tool to predict the occurrence of big devastating earthquakes. Hong-Chun Wu and Ivan N. Tikhonov have analysed 56 earthquakes having magnitude above 6.0, which occurred between 2006 and 2010. They found that the jet stream groups maintain their position for several hours in the vicinity of epicenters of strong earthquakes. The behaviour of Jetstream phenomena can potentially be utilized as a tangible short-term earthquake prediction tool (Wu and Tikhonov, 2014). Vineeta Rawat et al., (2011) observed that the flux values of OLR recorded were 30–45 W/m2 higher than normal values prior to the earthquakes of India and Italy regions. Thermal anomalies can be observed at different altitudes by using remote sensing techniques, at the surface level it is in the form of surface temperature and surface air temperature (Panda et al., 2007), at the atmospheric level it is observed as surface latent heat flux (Singh et al., 2007), outgoing longwave radiation (Ouzounov et al. 2007, Liu et al., 1999) and air temperature (Jing et al. 2013, Cervone et al. 2006 & Tronin et al., 2004). Recently, scientists have been involved in the measurement of anomalous changes in 'total electron concentration' (TEC) in the F2 layer of the ionosphere (Pulinets 2012 & Liu et al. 2004) prior to the earthquake. Prior to the earthquakes several earthquakes occurred in China, analysis of wavelet maxima curves has shown prominent OLR singularities (Xiong et al., 2009). For the earthquakes occurred in Iran, on 26 December 2003 and 21 February 2005, it was found that around 5 to 10˚C rise temperature near the epicenter of the earthquakes (Choudhury et al., 2006). These thermal anomalies may be attributed to the increased tectonic activity of the earthquake preparation zones. As the stress increases the fault interface the rocks get compressed, lead to the reduction in the volume of voids present in it. The hot radon gases released from the voids of the rocks move towards the earth's surface and transfer the heat to the atmosphere (Zi Qi et al, 2004). Gases like radon ionize the air and the ionization of the air influences the air conductivity and hence the latent heat gets released in the atmosphere (Pulinets and Ouzounov, 2011; Toutain et al., 1998; Omori et al., 2007; Ondoh, 2009). In this paper the authors have analyzed the OLR scenario prior to the Indian and neighbouring region earthquakes of magnitude greater than 6.0. To analyze earthquakes discussed in this paper, the authors have been using satellite data provided by the Physical Sciences Division, Earth System Research Laboratory, NOAA, Boulder, Colorado (http://www.esrl.noaa.gov).

Table 1*: Earthquakes occurred in Indian and neighbouring region (Source: http://earthquake.usgs.gov/earthquakes)*

Date	Latitude	Longitude	Depth	Magnitude	Place
2016/01/03	24.8036	93.6505	55	6.7	30km W of Imphal, India

2016/04/13	23.1329	94.8995	134.76	6.9	74km SE of Mawlaik, Burma

Outgoing Long wave Radiations (OLR) are radiated back to the atmosphere from the Earth's surface in the form of infrared radiations and it is measured as energy radiated per unit area. It can be measured by using satellites above the cloud level (i.e.) 12 to 14 km from the ground surface. Clouds and surface temperatures can influence outgoing IR radiations and it is a major driving factor in Earth's climatic system. Prior to the occurrence of recent big devastating earthquakes, anomalous positive deviation above 2σ level did appear in the transient period of time. For example, anomalous OLR have been registered before the occurrence of great earthquakes of Japan (M9.0, 2011) (Ouzounov et al., 2011), Sumatra (M8.2, 2012) (Venkatanathan & Kaarthick, 2013) & Pakistan (M7.7, 2013) (Venkatanathan & Natyaganov, 2014). Variations in time of appearance, these anomalies may be contributed by the heterogeneous nature of the tectonics (Venkatanathan & Natyaganov, 2014). From the analysis of OLR scenario, signal level variation, recurrence frequency and spatial distribution, their respective anomaly can be studied to identify the location of earthquake preparation zones, probable magnitude and time occurrence. These extreme anomalous spikes in OLR are may be due to the strong connection between the physical phenomenon that took place in the lithosphere, atmosphere and ionosphere, explained by LAIC model (Pulinets & Ouzounov, 2011).

2. Methodology - Outgoing Longwave Radiation

Outgoing Long wave Radiations are low frequency electromagnetic radiations reflected from the earth surface and clouds, can be measured above the cloud level. The basic data obtained from the satellite is processed by using an algorithm to obtain the OLR data ranging between 10 and 13 μm (Gruber & Krueger, 1984).

For this study, the authors have downloaded the OLR data from the Physical Sciences Division, Earth System Research Laboratory, NOAA, Boulder, Colorado to calculate daily mean OLR flux. The daily mean flux of the year 2015 is considered as 'current OLR flux' (COF) and 'Mean OLR FLUX' (MOF) is calculated from the average of the daily OLR flux from the year 2006 to 2015. Using the formula given below the 'Anomalous Signal Index' (AS_index) can be found and if the AS_index is greater than the value of 1.96, then the signal corresponding to the location and time is considered as anomaly, since the COF exceeds the '+2σ' level of MOF. For the two earthquakes of Japan region, the analysis of OLR scenario was done for six months period prior to the earthquakes.

$$AS_{index} = \left\{ \frac{[OLR_{ij} - \overline{OLR_{ij}}]}{\sigma_{ij}} \right\}_t$$

Where,

OLR_{ij} – Current OLR flux of year 2016
$\overline{OLR_{ij}}$ - Mean OLR flux computed from previous year's observation (2006 – 2015)
σ_{ij} – Standard deviation
t – For a given time, calculated prior to the earthquake

Fluctuations in OLR flux may be due to the other factors like atmospheric conditions and seasonal variations. These noises present in OLR signals can be removed from the current year's OLR flux by computing it against the multiple years of MOF level as mentioned in the above formula. The disappearance of OLR anomalies after the occurrence of earthquakes clearly indicates that these anomalies are due to the intense seismic activity along the fault interface. Variations in the signal level, recurrence frequency and spatial distribution could also be used as an indicator of the magnitude of the earthquake.

3. Results

3.1. January 03, 2016, M6.7, 30km W of Imphal, India

The earthquake occurred near the Capital of Manipur (Imphal) on January 3, 2016 with the magnitude 6.7 is due to strike slip faulting, which is located in the complex plate boundary region between India and the Eurasia plate in southeast Asia (Fig. 1). From the focal mechanism it can be inferred that the event was either due to a right-lateral fault with plane dipping moderately to the east-northeast, or on a left-lateral fault with plane dipping abruptly to the south-southeast (www.neic.usgs).

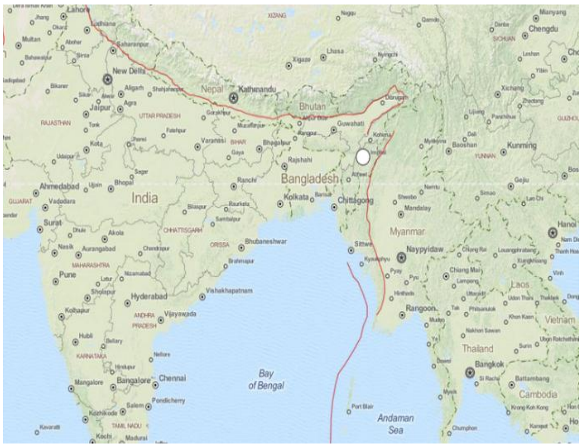

Figure 1: *Map showing epicenter of earthquake occurred near Imphal, India. Map not to scale.*

On Dec 27, 2015, 7 days prior to the occurrence of the earthquake anomalous OLR flux was observed by the geo-stationery satellite (Fig. 2).

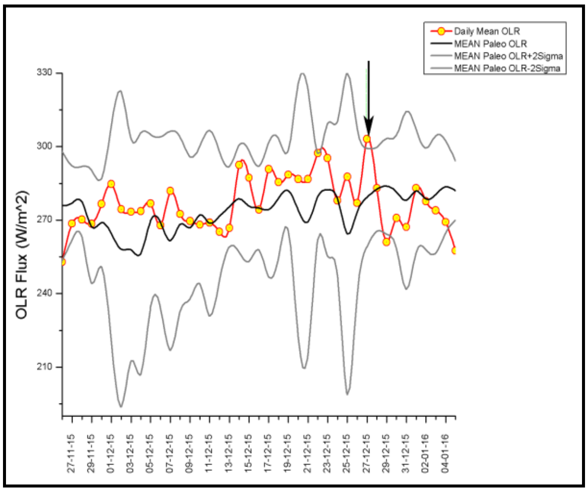

Figure 2: Graph showing anomalous OLR flux recorded (indicated with black down arrow) on Dec 27, 2016, 7 days prior to the occurrence of earthquake near Imphal.

Current OLR flux (COF) of 303.17 W/m^2 was recorded against Mean OLR flux (MOF) of 279.3236 W/m^2 and AS_index of 2.3374 was calculated for that day (Fig. 3).

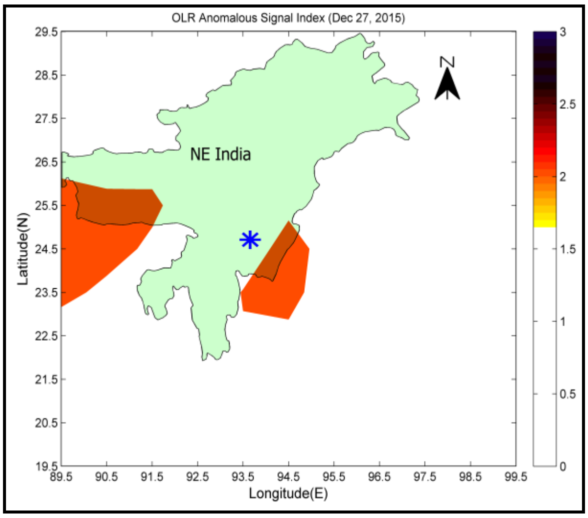

Figure 3: Map showing anomalous OLR flux appeared near the epicenter marked in blue coloured asterisk on Dec 27, 2015.

3.2. April 13, 2016, M6.9, 74km SE of Mawlaik, Burma

The earthquake occurred at southeast of Mawlaik, Burma on April 13, 2016 with the magnitude M 6.9 is due to the result of oblique reverse faulting at the depth of approximately 140 km western Burma (Fig 4). The epicenter of the earthquake is located at the latitude of 24.8036N and longitude of 93.6505E, which is around 500 km to the northeast of the Sunda Trench, where lithosphere of the India plate starts to subduct beneath Sunda and Eurasian plates. The focal mechanism indicates the rupture occurred on a strike slip fault.

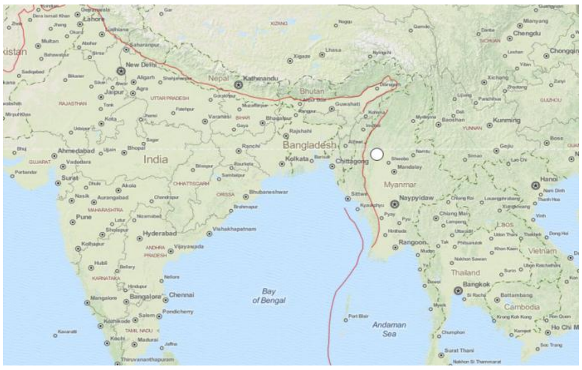

Figure 4: Map showing epicenter of earthquake occurred on April 13, 2016 at the India's neighbourhood region.

For this earthquake, the OLR anomaly was observed earlier compared to Jan 3, 2016 earthquake. The anomaly was observed on Mar 27, 2016, which is 17 days prior to the earthquake (Fig. 5).

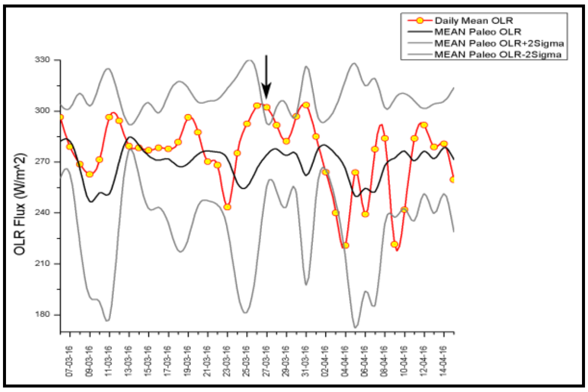

Figure 5: Graph showing OLR flux analysis compared to mean OLR flux of previous years. The anomalous spike was indicated with black down arrow

On March 27, 2016 the COF of 302.2149 W/m^2 was observed, which is 2.982092 times greater than MOF (Fig. 6).

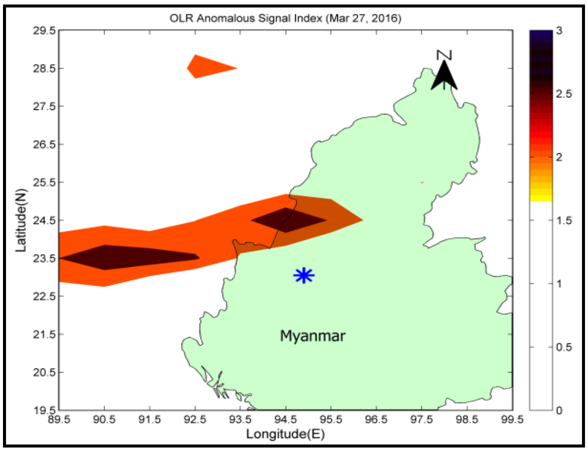

Figure 6: Map indicating the appearance of anomalous OLR flux for the larger region near the epicenter marked in blue coloured asterisk on Mar 27, 2016.

4. Discussion

The anomaly can be used as a tool to identify some of the important parameters of the impending earthquakes. The authors have chosen the above two earthquakes for analysis since both earthquakes are located in the closer vicinity and hence belongs to the same tectonic plate. This will leads to a better understanding of various parameters of earthquake with the help of OLR anomaly.

The recent study on Sea of Okhotsk earthquake occurred on May 24, 2013 suggests deep earthquakes are likely more efficient in dissipating stress than are shallow ones. This could be reason for more emanation of Radon gas and appearance of OLR anomaly for more spatial region for April 13, 2016 earthquake (depth – 134.76 km) compared to the January 3, 2016 earthquake (depth – 55 km). Also from the correlation of the above two earthquakes we can infer that more positive deviation of OLR flux values above the $+2\sigma$ value, higher magnitude of the impending earthquake. For the Jan 03, 2016 earthquake the current OLR flux value was 3.850674 W/m^2 more than that of the mean OLR flux value and the magnitude of the earthquake is 6.7, but for the April 13, 2016 earthquake the current OLR flux value was 9.52696 W/m^2 higher than that of the mean OLR flux value, which has recorded the magnitude as 6.9 on Richter scale.

5. Conclusion

The present paper state that the appearance of OLR anomaly holds good for earthquakes with magnitude greater than 6.0 and hence can be used to predict earthquakes of magnitude above 6.0. The appearance of OLR anomaly can be used in stages to identify the important parameters like location, magnitude and time occurrence in term of days, which are required for the short term prediction of earthquakes. The appearance of OLR anomaly can be used to interpret the location of the impending earthquakes and variations in OLR flux in terms space and time can be used as a reliable clue to identify the possible magnitude and time frame within which the earthquake may occur. Also the authors suggest the use of OLR scenario of a particular region obtained from geostationary satellites instead of polar orbiting satellites and using OLR anomaly in conjunction with other anomaly studies, like TEC, infrasound anomaly and other long term prediction algorithms, we can fine tune prediction of the earthquake research by identifying the important parameters of earthquake prediction (i.e.) location in term of latitude and longitude, time and magnitude of earthquakes. Then, predicting earthquake will no longer be a ‘COMPLEX’ phenomenon.

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