OUTGOING LONGWAVE RADIATION ANOMALY PRIOR TO THE BIG EARTHQUAKES: A STUDY ON THE SEPTEMBER 2015 CHILE EARTHQUAKE

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Abstract: Several scientists are involved in satellite based technology to understand the complex earthquake preparation process. Outgoing Longwave Radiation (OLR) is one of the important tools to identify the earthquake preparation process. Anomalous variations in OLR are usually observed 3 to 30 days prior to the big earthquakes near the epicentral region, and are measured above the cloud level. In this paper the authors have analyzed the OLR data derived from satellites for detail analysis of Chile earthquakes occurred at the location 32.5S latitude and 70W longitude on September 16, 2015. The anomalous variations in OLR were observed on 31 August 2015, 16 days prior to the occurrence of the earthquake. From the analysis, the author has found that variations in OLR flux can be utilized as efficient tools to identify the impending big earthquakes.

Keywords: *OLR anomaly, Anomaly Index, thermodynamic process, short term earthquake prediction*

Introduction

Scientists of various countries are involved in earthquake precursory studies in order to identify the earthquake preparation zones. In recent years scientists are using satellite technology to identify precursors and they prefer satellite technology over other ground based observations since continuous monitoring at relatively low cost is possible. Outgoing Longwave radiations (OLR) can be observed above the cloud level and it can be recorded by satellite IR sensors. Anomalous positive deviations in OLR are normally observed prior to the occurrence of the big earthquakes. The OLR is being measured by polar orbiting satellites around the world twice a day i.e. during the day pass and the night pass (Venkatanathan and Natyaganov, 2014). Out of these two, the night pass data is most preferred by many scientists for analysis because it does not have the solar radiation noise component in it. The possible reason for the variations in OLR is due to the coupling between lithosphere, atmosphere and ionosphere due to the increased tectonic activity. The increased tectonic activity releases the radon gas from the voids of rocks, but this radon gas does not propagate on its own to the surface. The greenhouse gases like methane, carbon dioxide and other gases acts as the carrier of radon gas. At the surface the air molecules gets ionized by this radon and releases the latent heat, which is observed as the change in temperature, which in turn is measured as OLR above the cloud level. The OLR data analysis has many advantageous: a) Wideband data can be obtained for signal processing, b) as it has been divided into global grids with local time span it is easy to understand, and c) even the minimal deviation in OLR can be recorded with high sensitivity.

So, in this paper the authors are considering intensive OLR data analysis using several methods in order to give a reliable solution to the ever demanding field of pre-earthquake analysis. The authors discuss here the OLR scenario prior to the occurrence of the recent Chile earthquake occurred on September 16, 2015 with the magnitude of 8.3 (**Fig. 1**). The earthquake was located at 31.570°S latitude and 71.654°W longitude with the depth of 25 km (http://earthquake.usgs.gov).

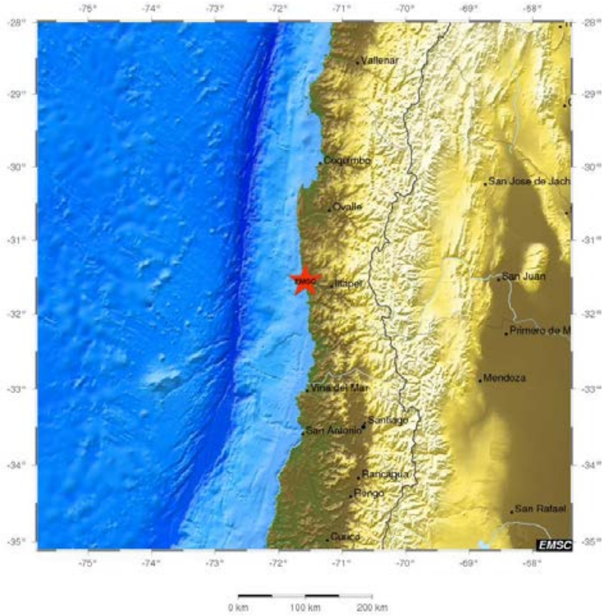

Fig. 1: Map showing location of the Illapel, Chile earthquake (M8.3) occurred on September 16, 2015. Courtesy: http://www.emsc-csem.org/Earthquake/earthquake.php?id=459672.
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Methodology

OLRs are energy radiation that are reflected back to the atmosphere by the Earth's surface. These IR radiations are measured above the cloud level and the OLR is controlled by the temperature of the Earth and atmosphere. These radiations can be recorded using satellites like NOAA 15 and NOAA 18 with IR sensors ranging from 8 to 12 µm providing 2.5º x 2.5º gridded data set (Gruber and Krueger, 1984). These data can be downloaded from NOAA website http://www.cdc.noaa.gov. The appearance of OLR anomaly for short period of time may be due to increase in stress along active fault regions. Anomaly can be identified by comparing "Current OLR flux" (COF) against "Mean OLR flux" (MOF) (mean value obtained from the average of past years from 2008 to 2014). If the value of COF is more than +2σ confidence level of MOF, then the OLR value of particular day can be considered as an anomaly. Also, The OLR anomaly can be identified by finding variation in the energy level ratio (δE), which indicates the maximum change in the level of OLR for a given location and time (Ouzounov et al., 2011):

$$\delta E = \frac{\left(y^*\left(a_{i,j}, b_{i,j},\ t\right) - \bar{y}^*\left(a_{i,j}, b_{i,j},\ t\right)\right)}{\sigma_{i,j}}$$

Where,

$\delta E - Maximum\ static\ change\ in\ energy\ in\ the\ form\ of\ OLR$

$y^* = Current\ OLR\ flux\ for\ predefined\ time\ (t0)\ and\ spatial\ location$
$\quad with\ latitude\ \left(a_{i,j}\right) and\ longitude\ \left(b_{ij}\right)$

$\bar{y}^* = Paleo\ OLR\ flux\ for\ predefined\ time\ (t)\ and\ spatial\ location$
$\quad with\ latitude\ \left(a_{i,j}\right) and\ longitude\ \left(b_{ij}\right)$

$\sigma_{i,j} - standard\ deviation\ \ calculated\ from\ paleo\ OLR\ value$

From the analysis of earthquakes occurred in the China region (**Table 1**) the authors found that a short-lived OLR anomaly preceded the occurrence of all three earthquakes.

Table 1. Earthquakes occurred in China in 2014, and OLR anomalies observed prior to them are given in last column of the table.

Date	Latitude	Longitude	Magnitude	Place	OLR anomaly observed in number of days prior to the earthquake
2014-02-12	35.905°N	82.586°E	6.9	Hotan, China	12 days
2014-08-03	27.189°N	103.409°E	6.2	Wenping, China	30 days
2014-10-07	23.386°N	100.487°E	6.0	Weiyuan, China	25 days

Results and Discussion

The earthquake with the magnitude of M8.3 occurred on September 16, 2015 in the west of Illapel, Chile. OLR anomaly was observed on August 31, 2015. This was recorded during both day and night pass of the

NOAA 15 and NOAA 18 satellites. First the anomaly was recorded during the day pass of the “NOAA 15” satellite on August 31, 2015 (**Fig. 2**). The anomaly started disappearing on the same day, but less intense OLR anomaly was recorded during the night pass of the “NOAA 18” satellite on August 31, 2015 (**Fig. 3**).

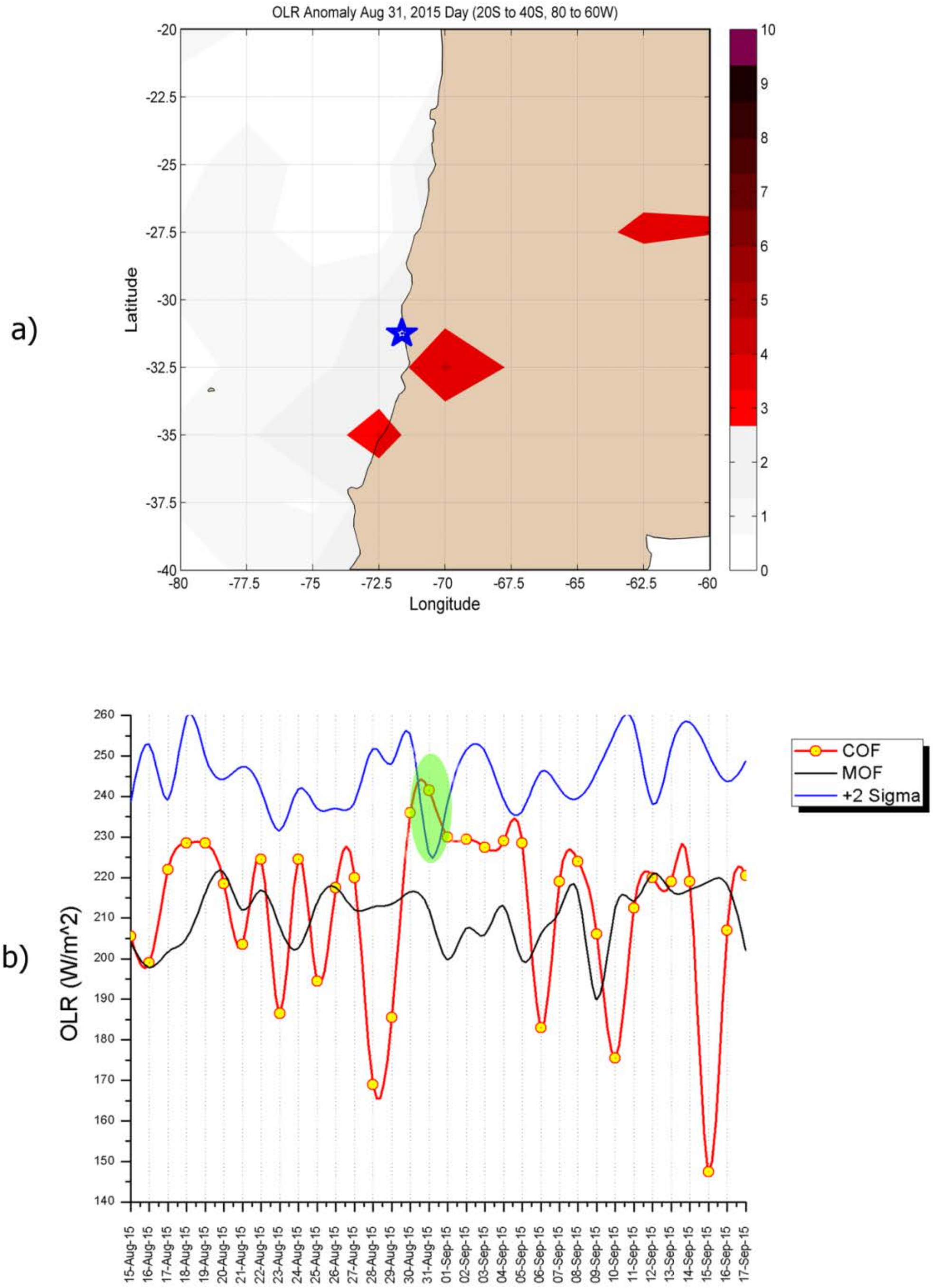

Fig. 2a (top). Showing OLR anomaly recorded by the “NOAA 15 satellite during its day pass on August 31, 2015 at the location 32.5S latitude and 70W longitude.
Fig 2b (bottom): Graph showing OLR scenario at the location 32.5S latitude and 70W longitude between August 15, 2015 and Sep 17, 2015.

On August 31, 2015, during the day pass of the “NOAA 15” satellite, the anomalously high OLR flux was recorded at the location 32.5S latitude and 70W longitude. The COF value was 241.5 W/m^2 and it is 29.5 W/m^2 more than that of MOF value recorded for between 2008 and 2014. On the same day the night “NOAA 18” satellite recorded again an anomalous OLR at the same location (32.5S latitude and 70W longitude). This time the COF value was 24 W/m^2 more than that of MOF value.

a)

b)

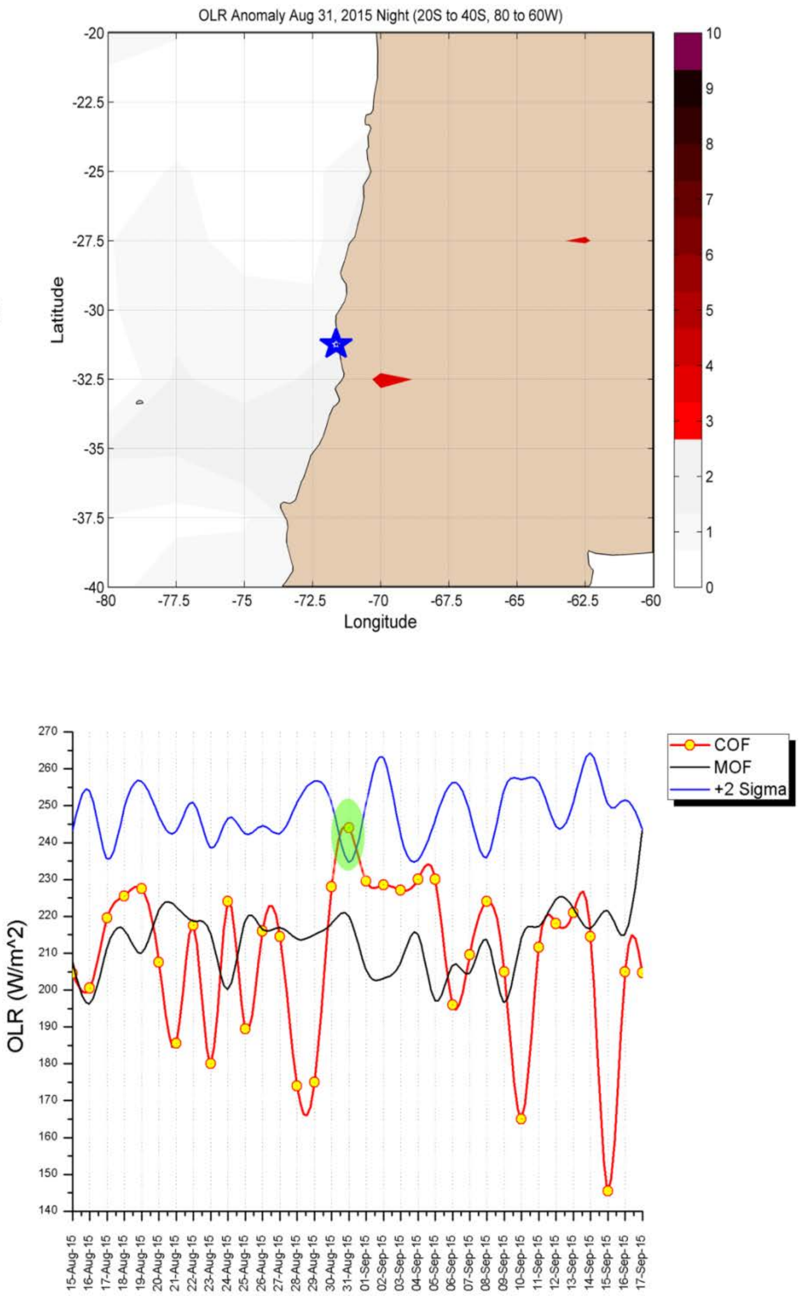

Fig. 3a (top): Showing OLR anomaly recorded by the "NOAA 18 satellite during its night pass on August 31, 2015 at the location 32.5S latitude and 70W longitude.
Fig 3b (bottom): Graph showing OLR scenario at the location 32.5S latitude and 70W longitude between August 15, 2015 and Sep 17, 2015.

Conclusion

This paper presents the OLR scenario prior to the occurrence of big earthquakes. The increased tectonic activity is the reason for the appearance of anomalous thermal variations. The probable reason for the unusual behaviour of OLR flux may be due to the escalation of stress along the fault interface, which leads to the radon gas emanation towards the surface of the Earth. Discharge of radon intensifies the air ionization, which in turn alters the air conductivity and latent heat release. This is the physical rationale behind the OLR precursory studies. The analysis of OLR establishes that appreciable positive deviation was observed prior to the occurrence of the big earthquakes. Thus OLR study in combination with the other surface and atmospheric parameters can be used as an effective tool to identify the earthquake preparation zones in order to facilitate the disaster mitigation process.

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References

Gruber, A. and Krueger, A., 1984. The status of the NOAA outgoing long wave radiation dataset. *Bulletin of American Meteorological Society*, v. 65, p. 958–962.

Ouzounov, D., Pulinets, S.A., Romanov, A., Romanov, A., Tsybulya, K., Davidenko, D., Kafatos, M. and Taylor, P., 2011. Atmosphere–ionosphere response to the M9 Tohoku earthquake revealed by multi-instrument space-borne and ground observations: preliminary results. *Earthquake Sci.*, v, 24, no. 6, p. 557–564.

Venkatanathan, N. and Natyaganov, V., 2014. Outgoing Longwave Radiations as pre-earthquake signals: Preliminary results of September 24, 2013 (M7.7) earthquake. *Current Science*, v. 106, no. 9, p. 1291 – 1297.

Websites:

http://earthquake.usgs.gov

http://www.cdc.noaa.gov

http://www.emsc-csem.org/Earthquake