Outgoing longwave radiations as pre-earthquake signals: preliminary results of 24 September 2013 (*M* 7.7) earthquake

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Outgoing longwave radiation (OLR) measurement, a satellite-based measurement can be used as a tool to identify the earthquake preparation process. OLR anomaly normally appears 1 to 30 days before the occurrence of earthquakes as revealed by analysis of previous earthquakes like the 2010 Haiti and 2011 Tohoku earthquakes. This communication presents the preliminary analysis of OLR anomaly prior to the recent 24 September 2013 (*M* 7.7) earthquake which occurred 63 km NNE of Awaran, Pakistan. The results show encouraging signs and forecasting of earthquakes is likely to be no longer 'elusive'.

Keywords: Anomaly index, earthquake forecasting, outgoing longwave radiation, thermodynamic process.

DUE to the devastating nature of earthquakes, earthquake prediction and forecasting is a challenging area of research and throughout the world several groups are working in this field. During the past several decades, there have been several attempts at earthquake prediction from different perspectives. In this communication we discuss some of ground-based, space-bound and also interdisciplinary methodologies used by scientists to decode earthquake preparation process.

The oldest precursor identified before the occurrence of devastating earthquakes is the appearance anomalous electric signals. The first paper on electric signals was published by Milne[1] in 1890. In 1976, 'streaming electro kinetic model' was proposed by Mizutani *et al.*[2], and it was later followed by several scientists[3–5]. Honkura[6] proposed 'perturbation of the electric current by a resistivity anomaly' to explain the generation of electric signals before the impending earthquakes. Later in 1985, 'single rock fracturing model' was proposed by Ogawa *et al.*[7], and the heavily debated method, 'piezo-stimulated model' was developed by Varotsos, Alexopoulos, and Nagao, famously called the VAN method. This method is based on observed empirical relationships between the occurrence and magnitude (ΔV) of a Seismo Electric Signal (SES) and the corresponding seismic activity[8,9]. Another model, called ionospheric induction model, explains that steady and oscillating ionosphere induces oscillating current; during onset process of strong earthquakes, amplitude of the oscillation increases[10]. Very low frequency (VLF) electric field perturbations could be detected during Chamoli earthquake in 1999, in the form of noise bursts 16 days prior to the occurrence of the main shock[11]. In 2002, Friedemann[12] proposed 'positive hole-pairs' model. Minerals get crystallized due to the presence of water, which introduces positive hole-pairs (PHP) in the crystal lattice. Due to micro-fracturing in the crystal lattice, PHP gains mobility and forms rapidly moving charge clouds, which is the reason for the generation of electric signals[12].

A strange ionospheric phenomenon was first reported prior to the 1964 Alaska earthquake[13]. Irregularities in electron concentration spread for few hundreds of kilometres above the earthquake preparation region, probably due to penetration of vertical ground electrical fields into the ionosphere[14]. Total electron content (TEC) has to be measured to study these irregularities; this can be measured using GPS observations. Detecting the location of impending earthquakes is possible in future, as GPS station can aid us to develop 3D ionospheric structures[15]. Using satellite image processing it is possible to detect certain earthquake-related precursors like surface deformation, ground tilting, change in surface temperature and humidity, atmospheric temperature and humidity, gas and aerosol content[16]. Co-seismic and post-seismic deformations were observed for the 1995 Neftegorsk earthquake, Russia[17]; the 2001 Bhuj earthquake, India[18]; the 2003 Bam earthquake, Iran[19] and the 2004 great Sumatra earthquake, Indonesia[20]. Appearances of short-lived thermal anomalies can be linked with the impending strong earthquakes[21–23].

Before the occurrence of devastating earthquakes, increase in stress along the fault segment changes the rock property and such changes generating different precursory signals encourage the scientists to adopt interdisciplinary studies. Van Genderen[24] used various precursory studies like rate of seismic energy accumulation, infrasonic wave, geoelectric, crustal stress, animal behaviour, magnetic storm, tide generating force resonance and satellite thermal data. He proposed to divide the globe into 29 zones; an early warning system has been set up to predict specific regions with probability of >6 magnitude earthquake occurring there within 30 days. Using a set of parameters like outgoing longwave radiation (OLR), GPS/TEC, lower Earth orbit ionospheric tomography and foF2 layer, scientists have done retrospective analysis of the 2011 Japan earthquake. This study shows that there are temporal and spatial variations observed several days before the earthquake[25].

Appearances of thermal anomalies before the impending earthquakes are observed not only at the ground surface, but they are also measured above the cloud level. OLRs are energy radiations departing from the Earth as

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infrared radiation at low energy to space. The OLR can be measured above the cloud level (16–17 km above sea level). Normally increase in radon gas emission is observed near the vicinity of the epicentre of an earthquake due to the abnormal increase in tectonic activity of a particular region, which in turn triggers the ionization of air near the ground and latent heat exchange due to variations in the humidity of air[26,27]. This phenomenon might be the probable reason for the appearence thermal anomalies before the impending earthquakes. In recent years, several studies based on the appearence of significant transient thermal anomalies before devastating earthquakes were reported[28–34]. For example, from the analysis of OLR for the 2004 Sumatra earthquake, it was found that OLR anomaly of >80 W/m^2 appeared five days before the occurrence of the event[35]. Prior to the most recent major earthquakes like Sichuan, China (*M* 7.9, 2008), L'Aquila, Italy (*M* 6.3, 2009), Samoa (*M* 7, 2009), Haiti (*M* 7.0, 2010), Chile (*M* 8.8, 2010) and Japan (*M* 9.0, 2011), transient OLR anomalies did appear[36,37]. National Oceanic and Atmospheric Administration (NOAA) satellites 15, 16 and 17 are measuring at the top of the atmosphere and data can be downloaded from the NOAA website (http://www.cdc.noaa.gov). In this communication, we have discussed the preliminary analysis of the NOAA satellite data to explore the connection between the atmospheric activities and the 24 September 2013 earthquake of magnitude 7.7 which occurred 63 km NNE of Awaran, Pakistan.

The OLR measurement is the combination of radiations from ground, lower atmosphere and clouds[38]. Using separate algorithm, OLR is calculated from the basic data, which is at 8–12 μm (ref. 39). Both the data and algorithm for examining the advanced very high resolution radiometer (AVHRR) is provided by the National Oceanic and Atmospheric Administration Climate Prediction Center (http://www.cdc.noaa.gov). The rapid development of radiation could be described as the anomalous flux of the latent heat over the area most probably due to increased tectonic activity. The appearance of anomalous radiation for short duration can be related to tectonic stress and thermodynamic processes in the atmosphere. The spatial and temporal variations in OLR flux can be reliably detected for the earthquakes of magnitude above 5.0, due to the critical energy flux needed for lithospheric–atmospheric–ionospheric coupling (LAIC).

An anomalous OLR flux can be defined as the change in energy index (d*E*_index), which signifies the statically defined maximum change in the rate of OLR for a given location and time-specific spatial locations and predefined times[40]:

$$dE\_\text{index} = \frac{(\text{Daily current field OLR} - \text{Daily base field OLR})}{\text{Standard deviation}}.$$

For this study, NOAA/AVHRR OLR daily data between 2006 and 2012 were used as a base field OLR and the OLR data was computed prior to the occurrence of 24 September 2013 earthquake. Change in energy index is calculated by finding the difference between daily current field OLR and daily base field OLR. If the value is more than '+2 sigma' confidence level of the base field OLR, then the corresponding change in energy index is considered as anomalous. The appearance of the short-lived OLR anomaly is observed before the occurrence of the above-mentioned Pakistan earthquake. The occurrence of an OLR anomaly can generally be linked to the magnitude of the earthquake. It varies from a few days to one month prior to the occurrence of the earthquake. The timeline of the appearance of these short-lived anomalies varies for each earthquake, may be due to the different nature of the tectonic settings of these places.

Short-lived anomalies appeared thrice before the occurrence of the earthquake on 24 September 2013. Before the first anomaly appeared on 8 September 2013, the OLR value was on the negative side at the epicentre, which was recorded by the NOAA satellite during its 'night' pass (Figure 1 *a*). The first anomaly was observed on 9 September 2013 with current field OLR value which was four times more than the daily base field OLR and it was recorded by NOAA satellite during its 'day' pass (Figure 1 *b*). The anomaly was short-lived and the current field OLR value was back to normal level on the same day (9 September 2013), which was recorded by NOAA satellite during 'night' pass on 9 September 2013 (Figure 1 *c*).

After the disappearance of OLR anomaly on 9 September 2013, till 14 September 2013 satellite 'night' pass, abnormality was not recorded (Figure 2 *a*). The anomaly appeared on 15 September 2013 at two locations and it was recorded during satellite 'day' pass (Figure 2 *b*). At one location (25N, 67.5E), current field OLR value was four times more than the base field OLR value. Another anomaly was concentrated at the location (25N, 62.5E) with current field OLR value three times more than the base field OLR value. Like earlier, this time also the OLR anomaly disappeared immediately, which can be inferred from the satellite data recorded during the 19 September 2013 'night' pass (Figure 2 *c*).

After the disappearance of the second anomaly in the nearby region, it was a null period in terms of OLR flux till 23 September 2013, when the satellite recorded normal current field OLR value during its 'day pass' (Figure 3 *a*). Finally, before the earthquake occurrence on 24 September 2013, for the third time, the anomaly appeared on 23 September 2013. This time also the current field OLR value was four times more than the base field OLR value at the nearby location (27.5N, 62.5E), observed by satellite 'night' pass (Figure 3 *b*). The anomaly did not disappear fully, but it was less intense and also the location of the anomaly got shifted (30N, 62.5E) from the epicentre

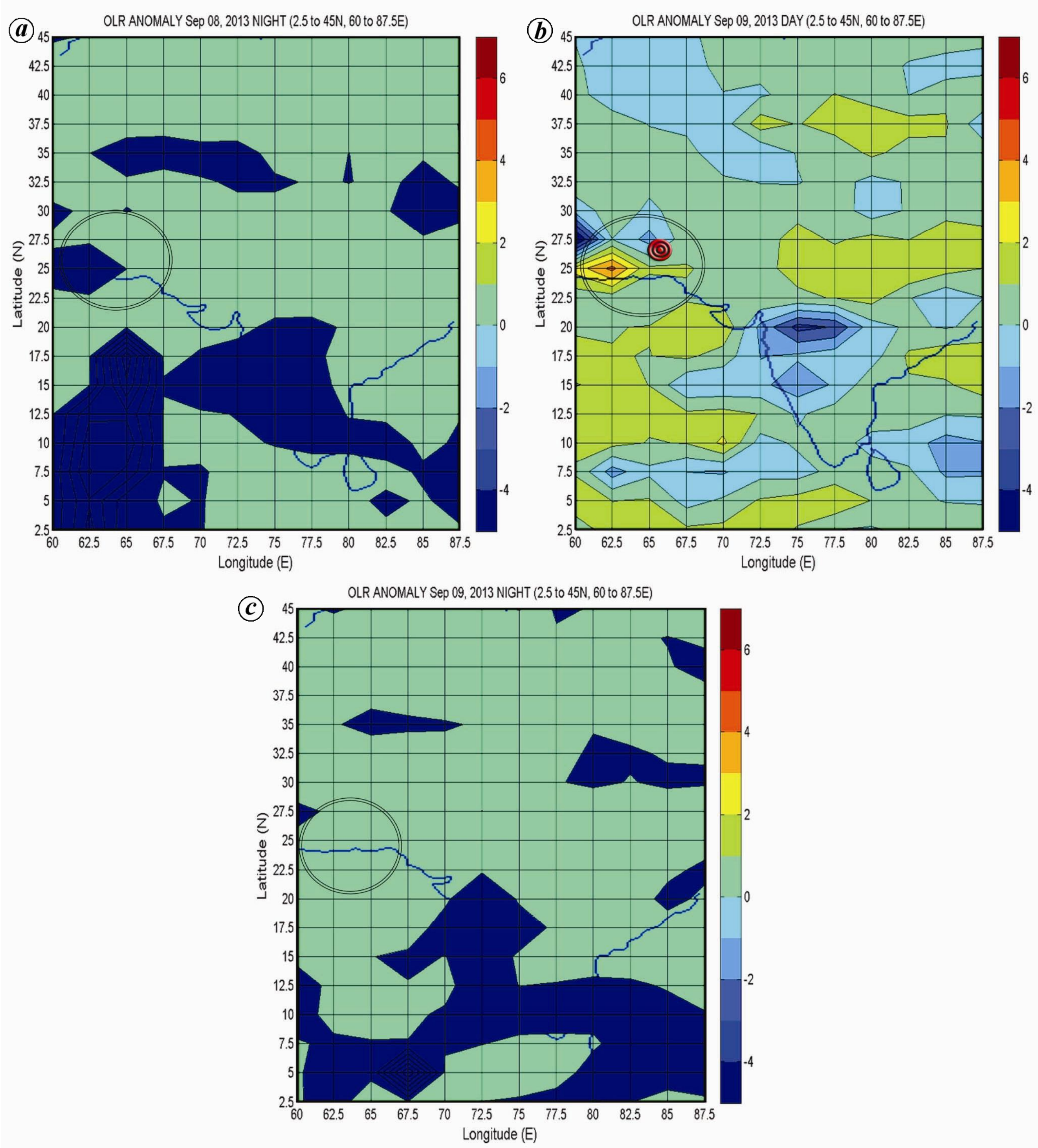

Figure 1. ***a***, Outgoing long wave radiation (OLR) picture showing no anomalous radiation in circled region recorded by NOAA satellite during 'night' pass on 8 September 2013. ***b***, OLR anomaly in the region (25N, 62.5E) close to the epicentral region (26.971N, 65.520E) marked with red coloured concentric circle as recorded by NOAA satellite during 'day' pass on 9 September 2013. ***c***, The anomaly that appeared on 9 September 2013 was a transient one and no anomaly was recorded during NOAA satellite 'night' pass on the same day.

(Figure 3 *c*). However, it completely disappeared after the occurrence of the earthquake on 24 September 2013, 16:29 (local time), as was recorded during satellite 'night' pass (Figure 3 *d*).

One of the plausible explanations for the appearance of short-lived anomaly before the devastating earthquake is the LAIC mechanism proposed by Pulinets and Boyarchuk[41]. The triggering process may be due to the

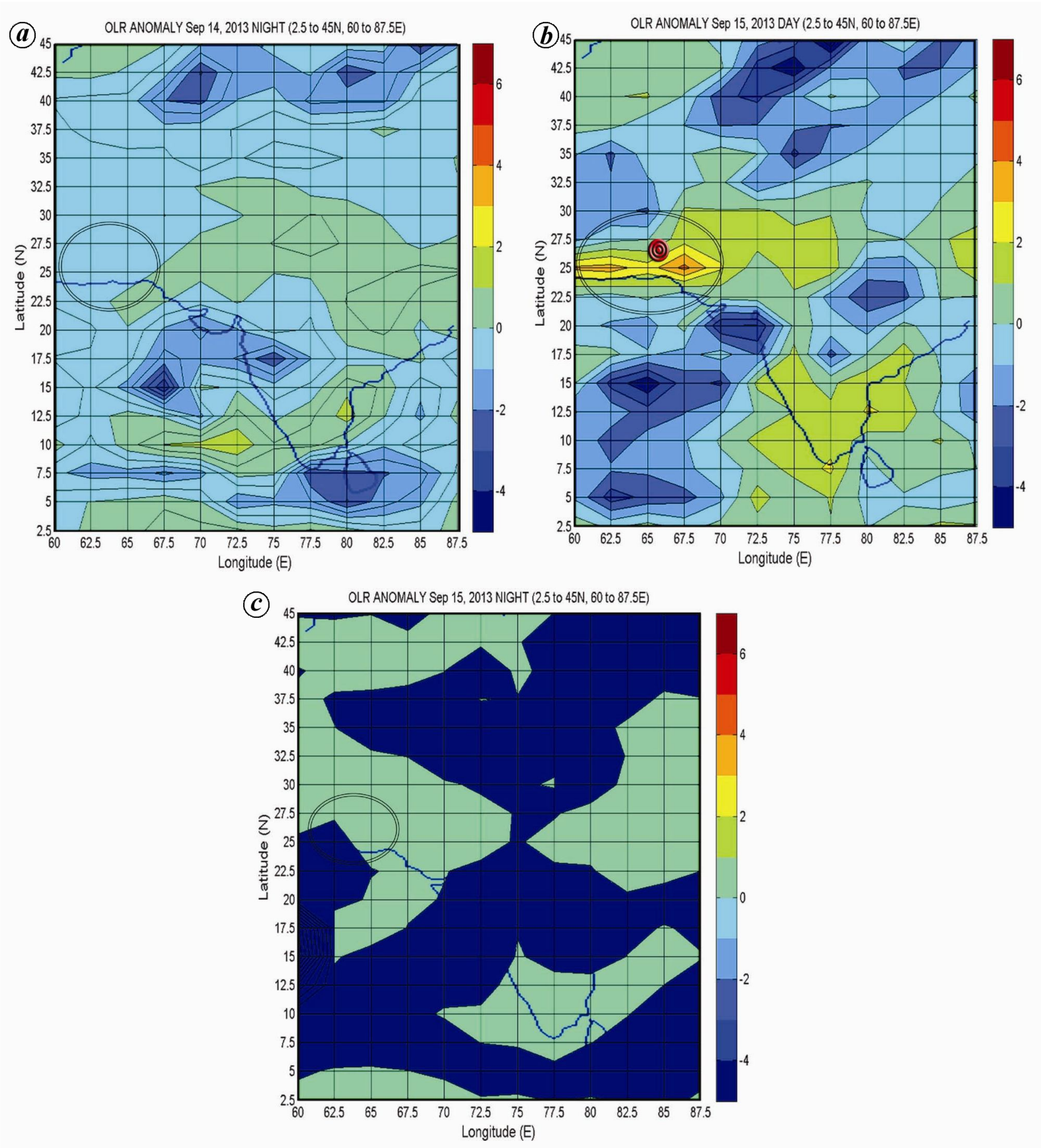

Figure 2. ***a***, OLR picture of 14 September 2013 showing no anomalous radiation recorded by NOAA satellite during its 'night' pass. ***b***, On 15 September 2013, OLR anomaly appeared near the epicentral region (25N, 62.5E) and was recorded by NOAA satellite during 'day' pass. ***c***, The anomaly was a transient one and no anomaly was recorded on 15 September 2013 during the satellite 'night' pass.

release of gases like radon from the lithosphere at the region of faulting[42–44]. This in turn increases the air ionization, leads to changes in the conductivity of air and a latent heat release due to condensation of ionized air[45–48]. The anomalous radiation lasts only for transient period since the energy flux is dynamic in the atmosphere, as proposed in the LAIC model and also appearance of anomaly may not be due to any other atmospheric phenomena, since we have compared OLR value of the year 2013 with those of previous seven years, in order to eliminate other atmospheric factors and seasonal variations. It can be inferred from our analysis that the anomaly appeared near the epicentre for a short duration during 9, 15, 23 and 24 September 2013 and it completely

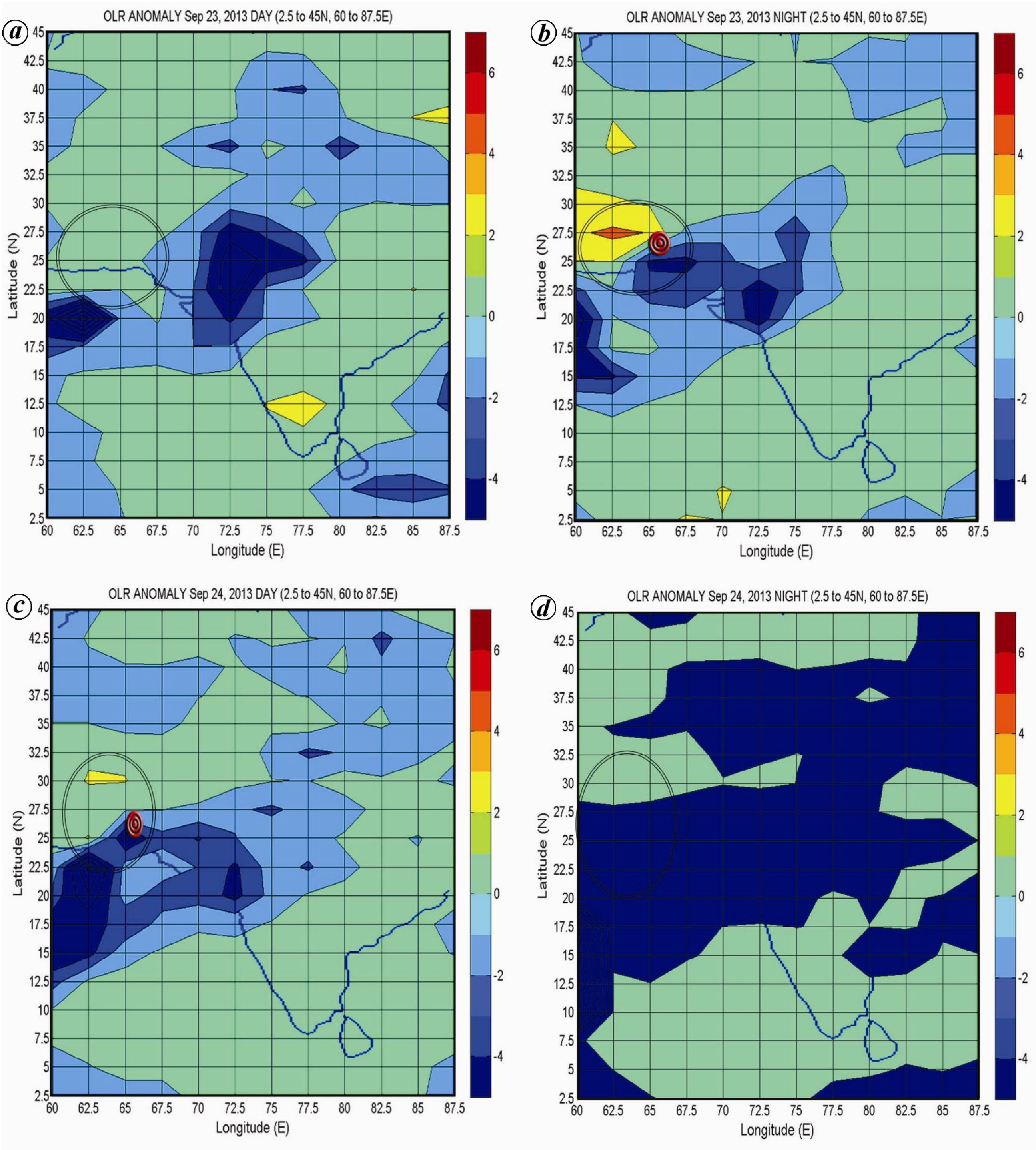

Figure 3. ***a***, OLR picture of 23 September 2013 showing no anomalous radiation recorded by NOAA satellite during ‘day’ pass. ***b***, On 23 September 2013, OLR anomaly appeared in the nearby region (25N, 62.5E) and extended close to the epicentre (26.971N, 65.520E) marked in red-coloured concentric circle, as recorded by NOAA satellite during ‘night’ pass. ***c***, OLR picture for 24 September 2013 showing less intense OLR anomaly which got shifted away from the epicentre (26.971N, 65.520E). ***d***, OLR picture showing disappearance of anomaly immediately after the earthquake on 24 September 2013, 16:27 (local time) with magnitude 7.7 at Awaran, Pakistan (26.971N, 65.520E), as recorded by satellite during ‘night’ pass on the same day.

disappeared near the epicentral region after the occurrence of the earthquake on 24 September 2013. Our analysis of data from the NOAA satellites, shows that the OLR anomaly can be used as a reliable pre-earthquake signal. The anomalous appearance of OLRs and intensity of anomaly can give us a clue about the occurrence of impending devastating earthquakes with location, magnitude and time-frame of few weeks or few days. Even though important parameters required for earthquake forecasting (i.e.) location, magnitude and time can be identified on short-term basis, depth of the earthquake cannot be found. In order to increase the accuracy of earthquake forecasting, the authors advocate for interdisciplinary studies. For example, anomalous, low-frequency acoustic gravity waves are observed before the impending earthquakes. The source of these waves can be located by beam-forming method[49] and the depth can be found from the amplitude of the low-frequency acoustic gravity waves[50]. It is possible to raise the earthquake prediction to greater level of accuracy, if we use multi-parameter and interdisciplinary precursory techniques which can be achieved by well-coordinated global networking with the help of satellite technology. Then forecasting earthquakes will no longer be considered as 'vague'.

1. Milne, J., Earthquakes in connection with electric and magnetic phenomena. *Trans. Seismol. Soc. Jpn.*, 1890, **15**, 135–162.
2. Mizutani, H., Ishido, T., Yokohura, T. and Ohnishi, S., Electrokinetic phenomena associated with earthquakes. *Geophys. Res. Lett.*, 1976, **3**(7), 365–368.
3. Corwin, R. F. and Morrison, H. F., Self-potential variations preceding earthquakes in Central California. *Geophys. Res. Lett.*, 1977, **4**, 171–174.
4. Fitterman, D., Electrikinetic and magnetic anomalies associated with dilatant regions in a layered earth. *J. Geophys. Res. B*, 1978, **83**, 5923–5928.
5. Dobrovolsky, I. R., Gershenzon, N. and Gokhberg, M., Theory of electrikinetic effects occurring at the final stage in the preparation of a tectonic earthquake. *Phys. Earth Planet. Inter.*, 1989, **57**, 144–156.
6. Honkura, Y., Perturbation of the electric current by a resistivity anomaly and its application to earthquake prediction. *J. Geomagn. Geoelectr.*, 1976, **28**, 47–57.
7. Ogawa, T., Oike, K. and Miura, T., Electromagnetic radiation from rocks. *J. Geophys. Res. D*, 1985, **90**, 6245–6249.
8. Varotsos, P. and Alexopoulos, K., Physical properties of the variations of the electric field of the earth preceding earthquakes, I. *Tectonophysics*, 1984, **110**, 73–98.
9. Varotsos, P. and Alexopoulos, K., Physical properties of the variations of the electric field of the earth preceding earthquakes, II: Determination of epicenter and magnitude. *Tectonophysics*, 1984, **110**, 99–125.
10. Meyer, K. and Teisseyre, R., Electrotelluric periodic anomalies prior to large imminent earthquakes. *Acta Geophys. Pol.*, 1988, **36**, 309–322.
11. Singh, R. P., Mishra, P. K. and Birbal Singh, Anomalous VLF electric field perturbations associated with Chamoli earthquakes of March/April 1999. *Curr. Sci.*, 2001, **80**(11), 1416–1421.
12. Friedemann, F. T., Charge generation and propagation in igneous rocks. *J. Geodyn.*, 2002, **33**, 543–570.
13. Moore, G. W., Magnetic disturbances preceding the 1964 Alaska earthquake. *Nature*, 1964, **203**, 508–512.
14. Pulinets, S. A., Khegai, V. V., Boyarchuk, K. A. and Lomonosov, A. M., Atmospheric electric field as a source of ionospheric variability. *Phys. Uspek.*, 1998, **41**, 515–522.
15. Liu, J., Chuo, Y., Shan, S., Tsai, Y., Chen, Y., Pulinets, S. and Yu, S., Pre-earthquake ionospheric anomalies registered by continuous GPS TEC measurements. *Ann. Geophys*., 2004, **22**, 1585–1593.
16. Tronin, A. A., Satellite remote sensing in seismology – a review. *Remote Sensing*, 2010, **2**(1), 124–150.
17. Tobita, M. *et al.*, Deformation of the 1995 North Sakhalin earthquake detected by JERS-1/SAR interferometry. *Earth, Planets Space*, 1998, **50**, 313–325.
18. Schmidt, D. A. and Bürgmann, R., InSAR constraints on the source parameters of the 2001 Bhuj earthquake. *Geophys. Res. Lett.*, 2006, **33**, doi: 10.1029/2005GL025109.
19. Stramondo, S., Moro, M., Tolomei, C., Cinti, F. R. and Doumaz, F., InSAR surface displacement field and fault modelling for the 2003 Bam earthquake (southeastern Iran). *J. Geodyn.*, 2005, **40**, 347–353.
20. Chini, M., Bignami, C., Stramondo, S. and Pierdicca, N., Uplift and subsidence due to the 26 December 2004 Indonesian earthquake detected by SAR data. *Int. J. Remote Sensing*, 2008, **29**, 3891–3910.
21. Tronin, A. A., Biagi, P. F., Molchanov, O. A., Khatkevich, Y. M. and Gordeeev, E. I., Temperature variations related to earthquakes from simultaneous observation at the ground stations and by satellites in Kamchatka area. *Phys. Chem. Earth*, 2004, **29**, 501–506.
22. Tronin, A. A., Molchanov, O. A. and Biagi, P. F., Thermal anomalies and well observations in Kamchatka. *Int. J. Remote Sensing*, 2004, **25**, 2649–2655.
23. Tramutoli, V., Cuomo, V., Filizzola, C., Pergola, N. and Pietrapertosa, C., Assessing the potential of thermal infrared satellite surveys for monitoring seismically active areas: the case of Kocaeli (İzmit) earthquake, 17 August 1999. *Remote Sensing Environ*., 2005, **96**, 409–426.
24. Van Genderen, J. L., An integrated global observing strategy for earthquake prediction. In IGOS International Workshop on 'Towards the Implementation of an Integrated Global Observing Strategy', 2004.
25. Ouzounov, D. *et al.*, Atmosphere–ionosphere response to the *M*9 Tohoku earthquake revealed by multi instrument space-borne and ground observations: preliminary results. *Earthquake Sci.*, 2011, **24**, 1–8.
26. Pulinets, S. A. *et al.*, Thermal, atmospheric and ionospheric anomalies around the time of Colima *M*7.8 earthquake of 21 January 2003. *Ann. Geophys.*, 2006, **24**, 835–849.
27. Pulinets, S. A., Ouzounov, D., Karelin, A., Boyarchuk, K. and Pokhmelnykh, L., The physical nature of thermal anomalies observed before strong earthquakes. *Phys. Chem. Earth*, 2006, **31**, 143–153.
28. Tronin, A., Hayakawa, M. and Molchanov, O. A., Thermal IR satellite data application for earthquake research in Japan and China, *J. Geodyn*., 2002, **33**, 519–534.
29. Saraf, A. K. and Choudhury, S., NOAA-AVHRR detects thermal anomaly associated with the 26 January, 2001 Bhuj earthquake, Gujarat, India. *Int. J. Remote Sensing*, 2005, **26**, 1065–1073.
30. Saraf, A. K. and Choudhury, S., Satellite detects surface thermal anomalies associated with the Algerian earthquakes of May 2003. *Int. J. Remote Sensing*, 2005, **26**, 2705–2713.
31. Ouzounov, D., Bryant, N., Logan, T., Pulinets, S. and Taylor, P., Satellite thermal IR phenomena associated with some of the major earthquakes in 1999–2004. *Phys. Chem. Earth*, 2006, **31**, 154–163.
32. Oyama, K. I., Shimoyama, M. and Liu, J. Y., Possible interaction between thermal electrons and vibrationally excited N2. *Ann. Geophys.*, 2011, **29**, 583–590.
33. Venkatanathan, N., Kaarthick, B. and Priyadharshini, C., OLR anomalies prior to big earthquakes ($Mw > 6.0$) – a case study on earthquakes of India's neighboring region occurred during the year 2012. *New Concepts Global Tecton.*, 2013, **1**(3), 34–44.
34. Jing, F., Shen, X. H., Kang, C. L. and Xiong, P., Variations of multi-parameter observations in atmosphere related to earthquake. *Nat. Hazards Earth Syst. Sci.*, 2013, **13**, 27–33.
35. Ouzounov, D., Liu, D., Kang, C., Cervone, G., Kafatos, M. and Taylor, P., Outgoing longwave radiation variability from IR satellite data prior to major earthquakes. *Tectonophysics*, 2007, **431**, 211–220.

36. Pulinets, S. A. and Ouzounov, D., Lithosphere–atmosphere–ionosphere coupling (LAIC) model: an unified concept for earthquake precursors validation. *J. Asian Earth Sci.*, 2011, **41**(4-5), 371–382.
37. Ouzounov, D. *et al.*, Integrated sensing, analysis and validation of atmospheric signals associated with major earthquakes. *Geophys. Res. Abstr., European Geopphys. Union General Assembly*, 2011, **13**, EGU2011-11932-1.
38. Ohring, G. and Gruber, A., Satellite radiation observations and climate theory. *Adv. Geophys.*, 1982, **25**, 237–304.
39. Gruber, A. and Krueger, A., The status of the NOAA outgoing longwave radiation dataset. *Bull. Am. Meteorol. Soc.*, 1984, **65**, 958–962.
40. Ouzounov, D., Pulinets, S. A., Romanov, A., Romanov, A., Tsybulya, K., Davidenko, D., Kafatos, M. and Taylor, P., Atmosphere–ionosphere response to the *M*9 Tohoku earthquake revealed by multi-instrument space-borne and ground observations: preliminary results. *Earthquake Sci.*, 2011, **24**(6), 557–564.
41. Pulinets, S. A. and Boyarchuk, K. A., *Ionospheric Precursors of Earthquakes*, Springer, Berlin, 2004, p. 316.
42. Toutain, J. P. and Baubron, J. C., Gas geochemistry and seismotectonics: a review. *Tectonophysics*, 1998, **304**, 1–27.
43. Omori, Y., Yasuoka, Y., Nagahama, H., Kawada, Y., Ishikawa, T., Tokonami, S. and Shinogi, M., Anomalous radon emanation linked to preseismic electromagnetic phenomena. *Nat. Hazards Earth Syst. Sci.*, 2007, **7**, 629–635.
44. Ondoh, T., Investigation of precursory phenomena in the ionosphere, atmosphere and groundwater before large earthquakes of $M > 6.5$. *Adv. Space Res.*, 2009, **43**, 214–223.
45. Prasad, B. S. N., Nagaraja, T. K., Chandrashekara, M. S., Paramesh, L. and Madhava, M. S., Diurnal and seasonal variations of radioactivity and electrical conductivity near the surface for a continental location Mysore, India. *Atmos. Res.*, 2005, **76**, 65–77.
46. Pulinets, S. A., Ouzounov, D., Karelin, A., Boyarchuk, K. and Pokhmelnykh, L., The physical nature of thermal anomalies observed before strong earthquakes. *Phys. Chem. Earth*, 2006, **31**, 143–153.
47. Pulinets, S. A., Kotsarenko, A. N., Ciraolo, L. and Pulinets, I. A., Special case of ionospheric day-to-day variability associated with earthquake preparation. *Adv. Space Res.*, 2007, **39**, 970–977.
48. Cervone, G., Maekawa, S., Singh, R. P., Hayakawa, M., Kafatos, M. and Shvets, A., Surface latent heat flux and night time LF anomalies prior to the $Mw = 8.3$ Tokachi-Oki earthquake. *Nat. Hazards Earth Syst. Sci.*, 2006, **6**, 109–114.
49. Jun, L., Yi-Chun, Y., Quan, G., Hao-Nan, F. and Peng-Xiao, T., Anomalous Infrasonic waves before a small earthquake in Beijing. *Chin. J. Geophys.*, 2012, **55**(5), 580–586.
50. ReVelle, D. O., Earthquake depth predictions using infrasonic waves. In Proceedings of 28th Seismic Research Review, 2006, pp. 936–946.

ACKNOWLEDGEMENTS. We thank the Physical Sciences Division of NOAA (http://www.cdc.noaa.gov) for providing OLR data and the anonymous reviewers for providing valuable inputs, that helped improve the manuscript. N.V. also thanks SASTRA University for encouragement to carry out the research project.

Received 30 September 2013; revised accepted 1 April 2014

Impact of assimilation of Megha-Tropiques ROSA radio occultation refractivity by observing system simulation experiment

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Numerical weather prediction models are assimilating more Global Positioning System Radio Occultation (GPSRO) observations into their operational model in recent times as a result of significant positive impact with use of GPSRO data in assimilation system. The Megha-Tropiques satellite mission is aimed to provide large number of observations over the tropical region and carries payload ROSA for providing GPSRO observations. At present, the quality of processed GPSRO retrievals from Megha-Tropiques ROSA is not satisfactory. In order to assess the impact of assimilation of good-quality ROSA observations, an observing system simulation system experiment (OSSE) was conducted using NCMRWF T574 model. The experiment was conducted for a period of 15 days during September 2012 and refractivity operator was used for assimilation. Results show significant improvement in forecast skill for forecasts beyond 72 h with OSSE data.

Keywords: Assimilation system, forecast skill, numerical models, weather prediction.

MEGHA-TROPIQUES is an Indo-French joint satellite mission for studying the water cycle and energy exchanges in the tropics. It is orbiting the Earth at low orbit (~800 km) and low inclination (20°) to provide higher satellite repetivity at lower latitudes. It carries four payloads – SAPHIR, SCRAB, Radio Occultation Sounding of Atmosphere (ROSA) and MADRAS, and can measure rainfall, water vapour and radiation. Many interactions among radiation, water vapour, clouds, precipitation and atmospheric motion determine the life cycle of convective cloud systems, and the occurrence of extreme events like tropical cyclones, monsoons, flood and droughts. Due to dynamic nature of the above parameters, the frequency of observation from low-orbiting Sun-synchronous orbits is inadequate. Only geo-stationary satellites allow continuous monitoring of the tropics, but their visible–IR sensors give limited information on the cloud surface properties or horizontal distribution of water vapour. Low-orbiting satellites with low inclinations can provide more observations at lower latitudes. An inclination at 20° provides six observations of each point on the Inter-Tropical Convergence Zone (ITCZ). The most energetic tropical systems,

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