LITHOSPHERE-ATMOSPHERE-IONOSPHERE-MAGNETOSPHERE (LAIM): TRACKING EARTHQUAKES FROM SURFACE AND SPACE

The ever occurring earthquakes do not fail to remind us of the incessant seismic activity that the earth is forcing us to experience. It does not need to underline the fact that it creates havoc and turns life and environment in total disarray. The geotectonic processes that are perennially at work within the confines of the earth are not completely and comprehensively understood. They are being studied through different techniques and methodologies that have brought to fore some of its hidden features. These features are a sort of jigsaw puzzle that needs to be pieced together by putting in place some of the missing clues.

Some of the elusive signatures that can further help understand the complex picture that nature paints for us, can be sought from integrating the processes that operate, not just within the earthen realm, but also in the domain encompassing the atmosphere, ionosphere and the magnetosphere. In fact, Indian Institute of Geomagnetism (IIG) has taken a lead in harnessing atmosphere, ionosphere and magnetosphere (AIM) to understand the seismology of earth. This is a very novel idea which will induce scientists to think out of the box.

The cosmos is an integrated system. Events that take place billions of light years away, may not affect earth instantaneously, but they do come visiting at some point of time. Sun drives life on earth. Moon influences the tidal pattern of the vast water bodies pooled on earth. Similarly, earth processes, in a sort of reverse way, influence the processes operating in the realm of AIM. The plaything of cosmos is waves. Waves, of different hues and characteristics, are the preferred medium in which the world receives and sends its signals. This is kind of a Braille language which needs to be learned and understood to comprehend nature.

Seismology is a drama completely enacted through the language of waves. The shaking of earth is the obvious effect that we experience and suffer the brunt of. The vicious force that it unleashes, due to some breakage of material in the lithosphere, spreads out to the surface of the earth. **But does it stop at the surface? Obviously not. It perturbs the atmosphere. The surface and Rayleigh waves have the greatest ground amplitude, and the agitation caused, rises up to the height of ionosphere**, the physics of which is now well understood. The earth, atmosphere and ionosphere are seen to oscillate the seismic induced waves almost in tandem. Also, the infrasonic pressure waves travel upwards as acoustic gravity waves to juggle ionospheric electron content. The atmosphere is seen to amplify and enhance these waves at ionospheric heights. This is a blessing in disguise. The ionosphere is under constant and intense scrutiny through radio sounding techniques likes GPS and ionosonde.

Ionospheric seismology is fast gaining credence. Some of the statistical studies conducted on major earthquakes and the ionospheric data generated prior to and after the earthquake has thrown up many surprising and helpful facts. IIG carried studies after the Sumatra earthquake and found a few anomalies in the ionospheric recording prior to its occurrence.

Litho-, astheno-, iono-, magneto-sphere (LAIM), being a ‘layered yet continuous’ domain, has physical and chemical influences that may or may not be easily separated from one another. Hence, one needs to guard against these ‘cheats’. The space weather manifestations like coronal mass ejections and magnetic storms are actively engaged in banging in the charged particles that can change the normal attributes of the AIM. These can then be erroneously ascribed to unconnected causes. However, dedicated and pointed research will find ways to circumvent this problem. This obstacle can be successfully overcome by designing specific and novel experiments to understand the LAIM coupling.

The northeastern hills are as important for their eco-diversity as for their tectonic setting. The seismicity of this region is well known, which at times goes into high gear. The subsidence of Indian crustal block under the Burmese plate induces an additional stress on the northeastern region. The Himalayan ranges battling the isostatic imbalance further adds to the possibility of initiation of temblors.

The integrated approach to monitor the earthquake activity starting from surface to ionospheric heights (lithospheric-atmospheric-ionospheric; LAI) has been initiated at Shillong geophysical research center (SGRC), a regional center of IIG. Shillong and Silchar magnetic observatories have also been specially entrusted with the task of monitoring changes in ground magnetic fields with reference to tectonic activity associated with Dauki fault and subsidence in the nearby area.

The LAI coupling is shown pictorially in Figure 1. The epicenters of earthquakes are shown in Figure 2. The GPS derived ionospheric total electron content (TEC) observations were used to identify the signatures of 2012 Indian Ocean doublet earthquake at ionospheric heights (Figure 3). Two major earthquakes with magnitudes $M_w = 8.6$ and $M_w = 8.2$ occurred on 11 April 2012 and the ionosphere responded to this by producing TEC disturbances over the Indian Ocean and at stations located as far into India after ~10 minutes of the main shocks.

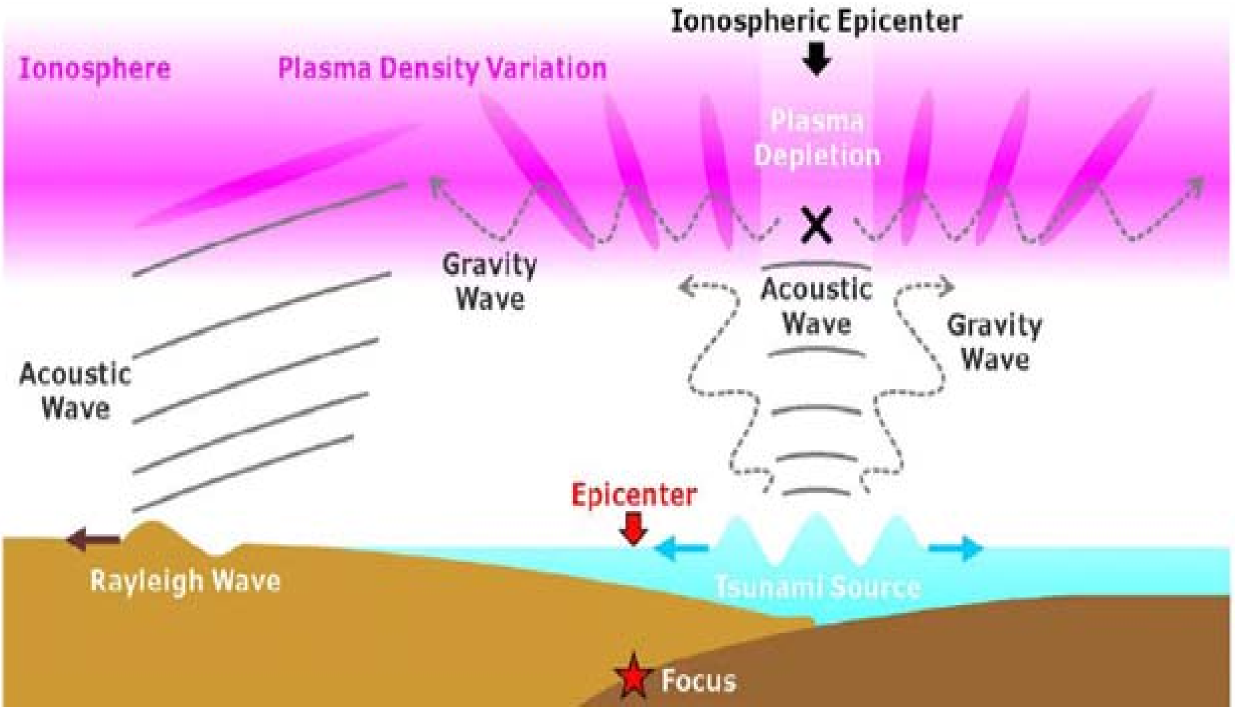

Figure 1. Pictorial representation of Lithosphere – Atmosphere – Ionosphere Coupling. © NICT

The figure shows that when vertical ground motion occurs near the epicenter, it oscillates the nearby atmosphere and thereby produces acoustic frequency waves. These waves propagate upward in the atmosphere and their amplitude enhances with height. On arrival of these waves, at the ionospheric heights, they perturb and rearrange ionospheric constituents causing plasma depletion (seen on the right).

Earthquake induced surface waves disturb the atmosphere, and then ionosphere, in similar fashion as described above (seen on the left).

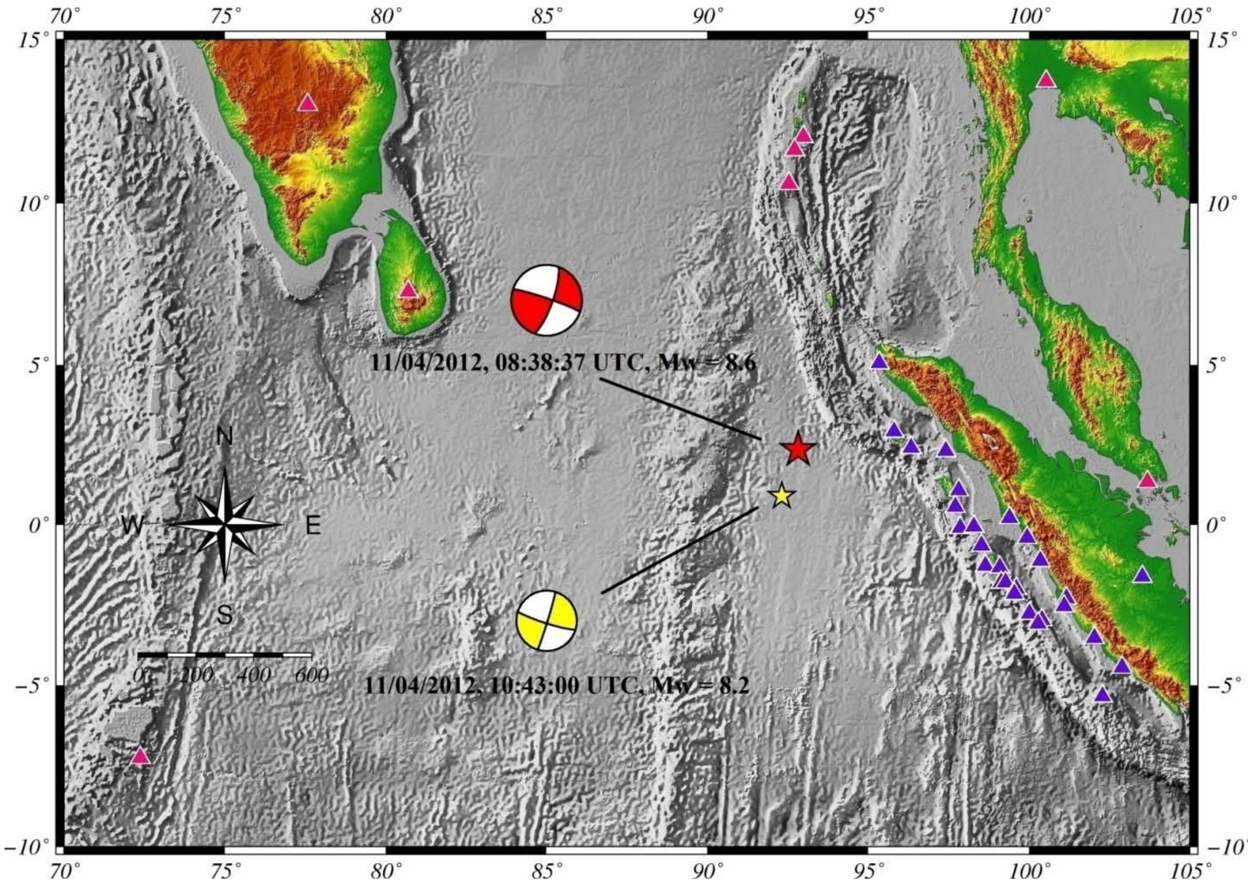

Figure 2. Locations of epicenters of April 2012 Indian Ocean earthquake. Two major earthquakes with magnitudes $M_w = 8.6$ and $M_w = 8.2$ occurred on 11 April 2012.

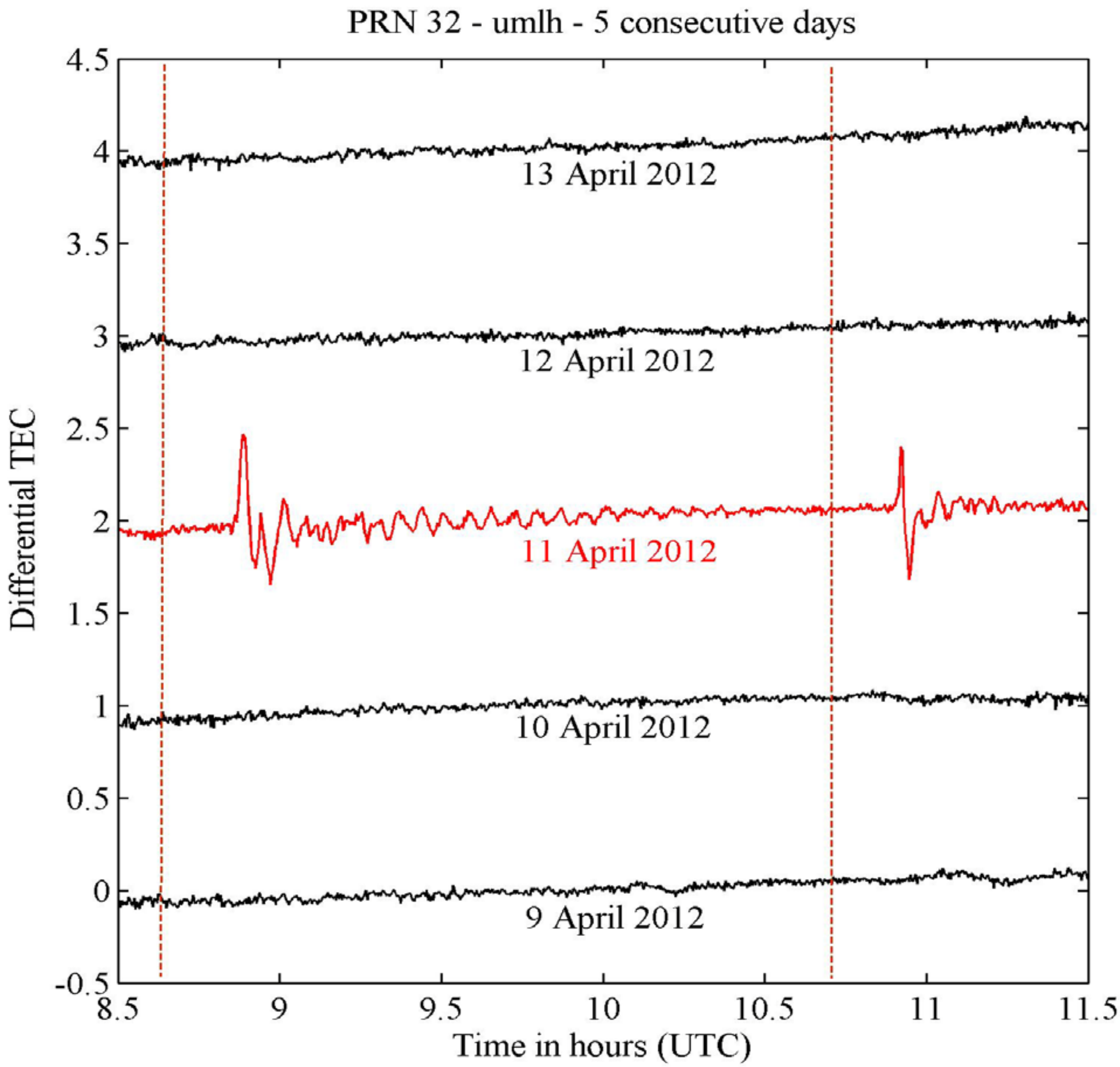

Figure 3. The actual ionospheric response to lithospheric disturbances (in red) is shown for the 11 April 2012 Indian Ocean earthquake. The total concentration of electron content derived from GPS was used to identify the signatures of 2012 Indian Ocean doublet earthquake at ionospheric heights. The ionosphere responded to this by producing TEC disturbances over the Indian Ocean and at stations located far into India, after ~10 minutes of the main shocks.

This popular science article is compiled by Praveen B. Gawali with additional inputs from Dr. Mala Bagiya based on the following original research article:

A. S. Sunil, Mala S Bagiya, C. D. Reddy, Manish Kumar and Durbha Sai Ramesh. 2015. Post-seismic ionospheric response to the 11 April 2012 East Indian Ocean doublet earthquake, Earth, Planets and Space, 67:37, DOI 10.1186/s40623-015-0200-8.