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Seismic Influence On The Ionosphere As Determined From Ground Based Multi-experimental Approach

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The ionosphere is a complex system. It is under solar control from above. However, there are many sources which influence it from below such as electric and electromagnetic and various types of upward propagating waves in the neutral atmosphere like planetary waves, tidal waves, gravity waves and infrasonic waves etc. Recently, it has been found that the seismic events on the ground also affect the structure and dynamics of the ionosphere through fields and waves generated from epicentral locations. In the present paper, we report the results of ground and ionospheric observations conducted through multiple experimental set up at Agra (Geograph. Lat. 27.2°N, Geograph. Long. 78°E) corresponding to some large magnitude (M>6.5) earthquakes occurred in the Indian subcontinent around India. Our experiments include measurements of GPS-TEC, phase and amplitude of ground based VLF transmitter signals, measurement of vertical electric field emissions using a borehole antenna, and ultra-low frequency (ULF) magnetic field emissions using search coil magnetometers.

Nighttime fluctuation (NF) method is employed to analyse VLF amplitude data of NWC (f = 19.8 kHz) and NPM (f = 21.4 kHz) signals corresponding to four earthquakes occurred on 18 September, 2011 at Nepal-India border (M = 6.9), 11 April, 2012 at northern Sumatra (M = 8.5), 16 April, 2013 (M = 7.8) at Pakistan-Iran border, and 24 September, 2013 (M = 7.4) in Pakistan. Four parameters like trend, dispersion, fluctuation and atmospheric gravity wave modulation index (AGWM) are determined for $\pm$ 15 days from the earthquake day. We find that precursory criteria are satisfied in the data 11-15 days prior to the occurrence of earthquakes. The diurnal variation of GPS-TEC, studied in the two cases of earthquakes (M = 7.8 and M = 7.4) also show anomalous enhancements on these days. The enhancements in the AGWM parameter on these days support the effect of atmospheric gravity waves in these anomalies.

We have also monitored VLF electric field emissions at f = 3.012 kHz using a borehole antenna at our Mathura station (Geograph. Lat. 27.49°N, Long. 77.67°E) about 70 Km north of Agra corresponding to two earthquakes occurred in Nepal 25 April and 12 May, 2015 (M = 7.8 and 7.3 respectively). We find unusual enhancements in VLF amplitudes about 14 and 7 days before the main shocks. The variation of GPS-TEC data obtained for nearby IGS station Lucknow also indicate enhanced TEC values 11 and 5 days before the main shocks. The ULF data are under analysis and the results will be incorporated after the analysis process is completed.

The above results obtained from ground and ionospheric observations clearly show that earthquakes influence the ionosphere from D/E region to F region and the atmospheric gravity waves are principally involved in the perturbation process.