

Detection of Pre-Seismic Ionospheric Perturbations over the Indian Plate in November 2025 Using VLF Signals

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Detection of pre-seismic ionospheric perturbations is an important step toward understanding lithosphere–atmosphere–ionosphere coupling associated with earthquakes. In this study, we report the detection of D-region ionospheric perturbations over the Indian Plate associated with a sequence of earthquakes that occurred near Narsingdi, Bangladesh, on 21, 22, and 27 November 2025, with magnitudes (M) of 5.4, 4.3, and 4.1, respectively using the Indian Centre for Space Physics (ICSP)-VLF network. VLF signal data transmitted from JJI/22.2 kHz and VTX/18.2 kHz and received at the ‘ICSP’ and ‘Ionospheric and Earthquake Research Centre & Optical Observatory (IERCOO)’ stations during 16 November–1 December 2025 were analyzed. Two widely adopted VLF diagnostic methods were employed for the detection of pre-seismic D-region ionospheric perturbations. The first method is based on the detection of anomalous time shifts in the sunrise (δt_{SR}) and sunset (δt_{SS}) terminator signatures of VLF signal amplitudes, while the second detects anomalous nighttime signal fluctuations through the standard deviation of the signal amplitude (σ_A). Both methods detected significant anomalies several days before the occurrence of the earthquakes, indicating the presence of pre-seismic ionospheric perturbations. The successful detection of consistent anomalies using two independent diagnostic techniques demonstrates the capability of VLF observations for detecting pre-seismic D-region ionospheric perturbations over the Indian Plate. This study presents the first VLF-based detection of pre-seismic D-region ionospheric perturbations associated with earthquakes in this region and highlights the potential of continuous VLF monitoring for earthquake precursor investigations.