

Sub-ionospheric VLF Science @ ICSP: Recent results

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Very Low Frequency (VLF) radio waves provide a powerful means of probing the Earth's ionosphere, particularly the D- and E-regions, which are difficult to investigate using conventional techniques such as satellites and rockets. Sub-ionospheric VLF research offers researchers a wide range of opportunities, from developing low-cost ground-based receivers to analyzing signals transmitted by high-power VLF transmitters located around the world. For more than two decades, the Indian Centre for Space Physics (ICSP) has been monitoring VLF transmissions, including those from the Indian VTX transmitter located at the southern tip of the country. Research at ICSP covers a broad range of ionospheric phenomena, including solar flares, solar eclipses, solar-cycle variability, geomagnetic storms, and seismo-ionospheric coupling. Over the years, we have developed expertise in computational modeling, VLF signal processing, and the application of ML techniques to ionospheric studies. In this presentation, we highlight some of our recent results, beginning with D-region modeling based on electron-continuity analysis and its validation through VLF signal modeling using LWPC framework during solar flares. We also present comprehensive modeling of the spatio-temporal evolution of D-region electron density, together with simultaneous multi-station VLF signal modeling, to investigate ionospheric disturbances associated with solar eclipses. In addition, we discuss detailed analyses of VLF signal variations associated with seismic activity and their possible seismo-ionospheric signatures. Participation in VLF research provides students with valuable interdisciplinary skills spanning physics, atmospheric science, mathematics, computational modeling, signal processing, and engineering. At the same time, it offers opportunities to contribute to fundamental space-weather research as well as practical applications related to radio communication and navigation.