Modeling of VLF Sub-Ionospheric Signal Variability over Multiple Propagation Path Triggered by the 2024 Total Solar Eclipse

Taraknath Bera, Sayak Chakraborty, Tamal Basak

Indian Centre for Space Physics, Kolkata

Sub-ionospheric VLF signal propagation has long been employed as an effective diagnostic tool for probing the D-region ionosphere during space weather events. In this study, we develop a detailed model to investigate the perturbations in VLF signal propagation caused by the Total Solar Eclipse (TSE-2024). The analysis incorporates transmissions from four sources - NAA (24.0 kHz), NML (25.2 kHz), WWVB (60.0 kHz), and NLK (24.8 kHz) - with recordings taken at the VRG receiving station in North America (37.44° N, 79.28° W).

The model simulates eclipse-induced VLF amplitude perturbations using the Long Wave Propagation Capability (LWPC) code, with the solar obscuration fraction (p) and solar zenith angle (χ) representing the eclipse geometry. Variations in Wait's ionospheric reflection parameters, h' and β, are assumed to scale linearly with p. To account for solar coronal radiation during the eclipse, a coronal contribution parameter (w) is introduced, modifying the impact of p on h' and β. Subsequently, the electron density profile (Ne) in the D-region is determined through Wait's semi-empirical formulation.

LWPC results provided changes in the modal attenuation coefficient (μ) and simulated differential amplitudes (ΔAsim). Comparisons with observed differential amplitudes (ΔAobs) across all paths show good agreement when w is optimized. The findings emphasize the role of coronal emissions in maintaining D-region ionization during total eclipses.