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Comprehensive Investigation of Ionospheric Absorption Caused by Solar Flares and Solar Proton Events in December, 2006

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The sudden increase of X-radiation and EUV emission following solar flares causes additional ionization and increased absorption of electromagnetic waves in the sunlit hemisphere in the D- and E-regions of the Earth's ionosphere. In addition, solar flares are also accompanied by energetic particles (protons and electrons) with energies from tens of keV to hundreds of MeV and attendant ionization.
The variation of two ionospheric parameters, namely the minimum frequency of echoes (fmin) and the critical frequency of the E-layer (foE) were studied to disclose the effect of the solar flares on the lower ionosphere. The lowest recorded ionosonde frequency, fmin, is a qualitative proxy for the absorption occurring in the D-layer, while the foE parameter is related to the maximum electron density of the E-layer.
Furthermore, we analysed VLF measurements from the DEMETER spacecraft to observe the attenuation of terrestrial VLF signals above/near transmitters in Europe at times of strong solar flares.
Extreme increases of the fmin values (2-5 MHz) were observed at almost every European station (Juliusruh, 53.6°N, 13.4°E; Pruhonice, 49.98°N, 14.55°; Rome, 41.9°N, 12.5°E; San Vito 40.6°N, 17.8°E) during the most intense solar flare on 05th December, 2006. This response of the fmin parameter increases with increasing latitude. During the time of the increased values of the fmin parameters the concurrent absence of the foE parameter was detected. Furthermore, total radio fade-out was observed for hours to days at the high latitude station, Tromso (69.41°N, 18.9°E) due to the Polar Cap Absorption (PCA) caused by the precipitation of high-energy protons.
The effect of the solar flare (X9) of 5th December, 2006 on the trans-ionospheric absorption is clearly seen in the Demeter data. However, the effect of the proton events can not be detected.