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Impact of the Most Intense Solar Events of Solar Cycle 23 on the Lower Ionosphere

Veronika Barta (1), Dávid Koronczay (2,1), Kitti A. Berényi (2,1), Árpád Kis (1), and Gabriella Sátori (1)

(1) Research Centre for Astronomy and Earth Sciences, Hungarian Academy of Sciences, Sopron, Hungary (veronika.barta@gmail.com), (2) Eötvös University, Budapest

The sudden increase of X-radiation and EUV emission following solar flares causes additional ionization 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.

The time series of the fmin and foE parameters recorded at meridionally-distributed ionosonde stations in Europe were analyzed during the most intense solar events (July 14, 2000; Sep 2001, Oct/Nov2003, Dec 2006) of the Solar Cycle 23. Extreme increases of the fmin values (2-7 MHz) were observed at almost every European station (Juliusruh, 53.6°N, 13.4°E; Chilton, 51.5°N, 359.4°E; Rome, 41.9°N, 12.5°E; SanVito 40.6°N, 17.8°E) during the most intense solar flares of the selected events. This response increases with decreasing solar zenith angle. During the time of the increased values of the fmin parameters the concurrent absence of the foE parameter was detected. This total radio fade-out was observed for hours to days in almost every event at high latitude stations (Loparskaya, 63.35N; St. Petersburg, 56.18N, Sodankyla, 67.4N, Tromso, 69.4N) due to the Polar Cap Absorption (PCA) caused by the precipitation of high-energy protons.

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 which occurred on 5th and 6th of December, 2006. A quantifyable change in transionospheric VLF absorption associated with the flare events was observed. However, the effect of the proton events following the flares can not be detected in the DEMETER data.