



Ionospheric absorption variation as measured by European Digisondes, riometers and determined by the NOAA D-RAP model during intense solar flares in September, 2017

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The sudden increase of Solar X-ray and EUV emission following solar flares causes ionization and increased absorption of electromagnetic (EM) waves in the sunlit hemisphere of the Earth's ionosphere. Solar flares are also accompanied by energetic particles which can lead to additional ionization and absorption especially at the higher latitudes ($> 60^\circ$). A novel method has been developed by Buzás et al. [1] based on the amplitude data of the EM waves measured by Digisondes to calculate and investigate the relative absorption changes (compared to quiet period) occurring during solar flares. The effect of 13 intense ($>C4.8$) solar flares that occurred between 06:00 and 16:30 (UT, daytime LT = UT+2 h) from 04 to 10 September 2017 have been studied using the so-called "amplitude method". Total and partial radio fade-outs, furthermore, +20%–1400% amplitude changes (measured at 2.5 and 4 MHz) were experienced at three Digisonde stations (Juliusruh (54.63° N, 13.37° E), Průhonice (49.98° N, 14.55° E) and San Vito (40.6° N, 17.8° E)) during and after the investigated flares.

In the present study we compare the results of the amplitude method with the absorption changes measured by the Finnish Riometer Chain and determined by the NOAA D-RAP model during the same solar flare events. The X-class flares caused 1.5–2.5 dB attenuation at 30–32.5 MHz based on riometer data, while the absorption changes were between 10 and 15 dB in the 2.5–4.5 MHz frequency range (thus 10 times higher) according to the amplitude data measured by the Digisondes. The impact caused by the energetic particles after the solar flares are clearly seen in the riometer data, while it can be observed only at Juliusruh ($\sim 55^\circ$) at some certain cases among the Digisonde stations. Therefore, the absorption changes as a result of the particle precipitation is significant at high latitudes, but decreases rapidly with decreasing latitude, and is no longer detectable below the sub-auroral region. The main conclusion from the comparison of the amplitude method with the D-RAP model is that the model underestimates the values obtained from the Digisonde's measurements at both 2.5 and 4 MHz in almost every case. The differences varied between 0.2 and 15 dB at 2.5 MHz and 2.9–10 dB at 4 MHz and they did not show any systematic trend with the intensity of the flare, or with the latitude of the station.

1. Buzás, A., Kouba, D., Mielich, J., Burešová, D., Mošna, Z., Koucká Knížová, P., & Barta, V. (2023). Investigating the effect of large solar flares on the ionosphere based on novel Digisonde data comparing three different methods. *Frontiers in Astronomy and Space Sciences*, 10.