Thunderstorm – lower ionosphere relationship as shown by ionograms recorded at Pruhonice in two summer campaigns of 2013

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Thunderstorm – ionosphere coupling have been studied by ionograms obtained from the Digisonde DPS4D at Pruhonice, Czech Republic and using a five-point continuous Doppler sounding system operating at 3.59 MHz during two campaigns in summer, 2013. Thunderstorms passed through the Czech Republic on 29th of May (09:50 - 15:25) and on 20th of June (18:00 - 24:00). The corresponding lightning activity was recorded by the LINET and BlitzOrtung lightning detection networks. In the second case, numerous sprites were captured above the thunderstorm in the region of the ionosonde from Sopron, Hungary. During that period, ionograms were recorded in every minute. Peaks of ionospheric f_{min} values occurred much more frequently and with higher amplitudes characteristically in the period of sprites occurrences. Moreover the lack of the sporadic E layer has been found in those hours.

1. Introduction

Thunderstorms generated in the troposphere can affect the ionosphere through electrodynamic and mechanical processes.

Lightning discharges may deposit electromagnetic energy in the middle atmosphere and lower ionosphere through quasi-electrostatic and electromagnetic fields. These fields above thunderstorms can accelerate electrons which produce additional energetic charged particles and Transient Luminous Events (TLEs, i.e. sprites, blue jets, etc.). Intense lightning discharges and TLEs (especially sprites and elves) may also cause heating and extreme long-lasting changes in ionization in the upper D and lower E-region ionosphere [1], [2]. Theoretical simulations predicted that impulsive lightning electric field changes reduce the electron density at 75-85 km owing to electron attachment to O_2 and increase the electron density at 85-95 km owing to ionization of N_2 and O_2 [3]. Shao et al. [4] found that electron density in the lower ionosphere is decreased in response to lightning activity and they suggest that the enhanced electron attachment is responsible for the reduction.

Mechanical coupling can be produced through upward propagating waves in the neutral atmosphere generated by the thunderstorm [5]. These waves may be of different types including infrasonic waves [6], planetary waves and internal atmospheric gravity waves (AGWs). Using the continuous HF Doppler sounder the wave activity in the ionosphere during tropospheric convective storms in Central Europe was studied [7]. Infrasonic waves with the period of 2-5 min were found in the case of exceptionally intense meteorological activity in the troposphere [7].

The f_{min} values obtained from ionosonde were studied, which depends, apart from other factors, on the absorption from D-region ionosphere and therefore is a fairly good indicator of the changes in the electron density in D-region. The absorption level varies with period between 8 and 12 days, which could be related planetary waves [8].

Davis and Johnson [9] showed a statistically significant increase in the critical frequency of the sporadic E layer (*foEs*) 6 hours after the time of a thunderstorm. Barta et. al [10] have found a statistically significant decrease in the *foEs* after the time of lightning flashes, indicating a decrease in the electron density associated with lightning in the vicinity of Rome.

2. Data analysis

In this study, an analysis concerning the parameters of the lower ionosphere (f_{min}, *foEs*, *fbEs*), Doppler sounder data and thunderstorm activity observations (lightning, sprites) in the vicinity of Pruhonice, Czech Republic is performed to disclose troposphere - lower ionosphere coupling mechanisms. LINET as well as, BlitzOrtung lightning data, sprite events observed by a Watec 902H2 Ultimate camera from Sopron, Hungary, data of a five-point continuous Doppler sounding system operating at 3.59 MHz developed at the Institute of Atmospheric Physics AS CR, and manually evaluated ionograms obtained from the Digisonde

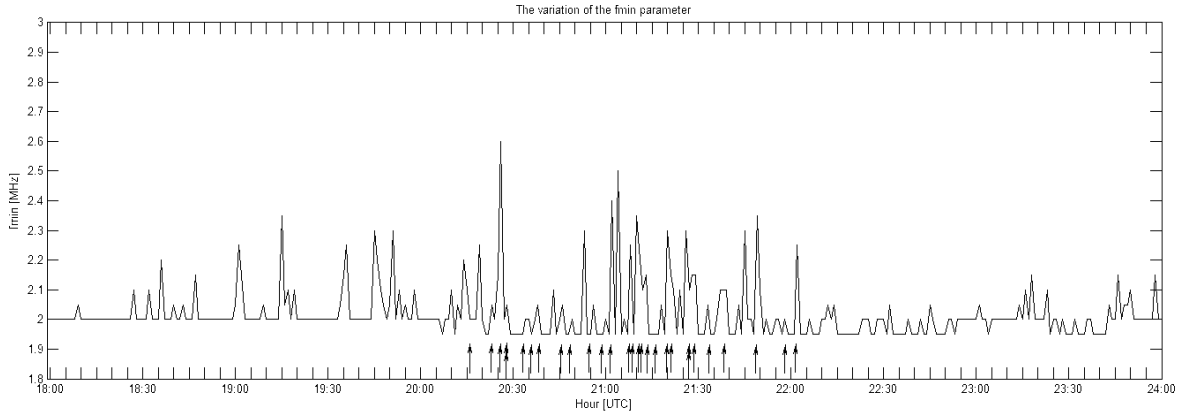

Figure 1. The variation of the f_{min} parameter during the campaign and the time of the sprites on 20th of June. The arrows show the time of the observed sprites.

DPS-4D at Pruhonice are used in this work. Ionograms were recorded in every minute during the two campaigns: 29th of May (09:50 - 15:25) and 20th of June (18:00 - 24:00).

3. Results

30 sprite events were observed from Sopron over the region of Czech Republic during the campaign period on 20th of June. Peaks in ionospheric f_{min} values occurred much more frequently and with higher amplitudes only in that time window which the sprite events grouped in (Figure 1.). The sprite observation started at around 20:15 and continued during the whole campaign period. After the time of the last observed sprite (at 22:02), the peaks in the f_{min} variations became smaller and less frequent. The changes in the f_{min} values indicate variations in the electron density of D region which are likely related to energetic lightning strokes and sprite activity below the region probed by the Digisonde DPS-4D. The sporadic E layer disappeared in the period, when the sprites as well as the higher and more frequent peaks of the f_{min} were observed (~ from 20:15 to 22:00).

The character of Doppler shift record on 20 June, 2013 - short period GW and probably also infrasound observation in some cases - suggests that the source could be relatively local. The time interval 20:30-22:00 was selected for the analysis, because clear traces could be seen in Doppler shift spectrograms. The analysis showed that the AGWs propagated to the North-East (azimuth ~45°). This might support that the source was the thunderstorm which was coming from the South - West and passed through the western part of the Czech Republic.

There are some peaks in the variation of the f_{min} parameter during the campaign on 29th of May too but these peaks are smaller than in the other case.

According to the HF Doppler shift records on 29 May 2013 at the afternoon and evening, the GWs propagated roughly to the North-West (typical azimuths from ~290° to ~345°), consequently the source could be located in South from Czech Republic. In this case, the thunderstorm was in the centre and northern part of the country so it cannot be related with these GWs.

The thunderstorm characteristics and lightning parameters (location, type, polarity, peak current) during the two campaigns has also been considered.

Acknowledgement to the grant P209-12-2440 of the GA of the Czech Republic, LINET and BlitzOrtung lightning detection networks, furthermore TAMOP-4.2.2.C–11/1/KONV-2012-0015 (Earth-system) project sponsored by the EU and European Social Foundation.

4. References

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