Mechanisms of Nighttime Enhancements in the Electron Concentration in the F2-Layer of the Midlatitude Ionosphere

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Abstract. Using the data of vertical sounding of the ionosphere in Almaty (76 55' E, 43 15' N) the reaction of parameters of the ionospheric F2-layer to various types of nighttime enhancements in the electron concentration in the layer maximum (Nmf2) was studied. Examples of recordings of a combination of the enhancements caused by different mechanisms are presented. The similarity of the reaction of the F2-layer parameters to the nighttime enhancements caused by the rise of the layer and plasma flux from the protonosphere and passage of large-scale travelling ionospheric disturbances was found. Difficulties in identifying these two events in the case of their equal duration are explained by the difference in the reaction of the F2-layer parameters to the enhancements caused by the rise of the layer and plasma fluxes from the protonosphere and occurrence of the summer midlatitude ionospheric anomaly is shown.

1 Introduction. Various types of the nighttime enhancements in the electron concentration in the F2-layer maximum (Nmf2) of the midlatitude ionosphere differing by mechanisms of their formation are known. In the majority of the papers the nighttime enhancements in Nmf2 in the midlatitude ionosphere are related to an increase in the velocity of the downward plasma flux from the protonosphere and by the rise of the height (hmF2) of the layer maximum caused by the equatorward thermospheric wind to heights where the recombination rate is small. The probability of the formation of nighttime enhancements in Nmf2 is very high. It should be noted that the nighttime variations in Nmf2 can also be caused by large-scale travelling ionospheric disturbances (LS TIDs). The probability of the observation of the LS TIDs is very high as well. That is why the goal of this paper is to reveal signs in the behavior of the nighttime F2-layer, making it possible to identify the events of enhancements in Nmf2 and LS TIDs according to the ionospheric vertical sounding data.

2 The equipment and processing method. The vertical ionospheric sounding was conducted using the “Parus” digital ionosonde. The ionospheric sounding was conducted every 5 minutes. Data processing included a calculation of vertical distributions of the electron concentration (N(h) profiles) by the POLAN method [1] and deriving time variation of several parameters of the F2-layer (electron concentration at fixed heights (Nmf)), the concentration in the layer maximum (Nmf2), and the actual heights of the maximum (hmF2) and bottom (hmF) of the layer and of its semithickness (Ab F = hmF2 − hmF).

3 Observation results and discussion. Fig. 1a shows the time variation in the electron concentration at several fixed altitudes. Fig. 1b shows the behavior of hmf, hmf, b, and f0 principal points of which could be described in the following way. The equatorward thermospheric wind lifts the layer from height hmf = 315 km at t ≈ 2100 LT to height hmf = 425 km at t ≈ 0200 LT. The decrease in the layer semithickness manifests a decrease in the electron temperature. That is how a self-supporting, avalanche-like process in the background of the mechanism of the formation of electron concentration nighttime enhancements described by Mikhailov et al. [2] is formed. The process slows down when the height of the layer maximum begins to decrease, returning it into the region of a high recombination rate. According to the considered mechanism, the peak in Nmf is formed later than the peak in hmf.

4 The first, well-pronounced enhancement with a peak in Nmf observed at t ≈ 1905 LT shows the same behavior of the parameters as in Fig. 1, although the enhancement occurs in the premidnight hours. The enhancement, which began at t ≈ 2120 LT and continued for almost the entire rest of the night, shows the same behavior of the parameters.

Liu et al. [3] mentioned the premidnight event of the midlatitude nighttime anomaly of the F2-layer as one of the possible causes of premidnight enhancement in Nmf2. As a result of measurements and simulation, Karpachev et al. [4] showed that the summer anomaly is formed as a combination of the effects of the neutral wind in the available configuration of the geomagnetic field, photoionization, and thermal compression of the ionosphere at the sunset. The maximum amplitudes of the anomaly are observed at longitudes corresponding to the maximum distance between the geomagnetic and geocentric equator. For the northern hemisphere, these longitudes are located near 135 E (anomaly of northeastern Asia with a maximum amplitude at the longitudes of Japan and the Okhotk Sea [3]).

5 Figure 5 shows the behavior of the layer parameters, which could be interpreted as a sequence of a nightime enhancement in the electron concentration and LS TID. The night of October 25−26, 2005 was characterized by moderate magnetic activity, at which the Dst index at 2000, 2200, 2400, 0200, and 0400 LT took values of −22, −24, −25, −35, and −28 nT, respectively. The electron concentration increase, which began at t ≈ 2225 LT and lasted longer than moderate magnetic increase, at which its maximum was reached at t ≈ 0245 LT. At the same time, the behavior of all parameters of the layer corresponds to the mechanism considered on the example of the enhancement presented in Fig. 1. It should be noted that such a character of the electron concentration enhancement—long, lasting several hours, with an increase and rapid decrease forming the Nmf peak—presents the most commonly seen form of enhancement [5].

If one compares the phase relations between the variations in the electron concentration at adjacent fixed heights for two considered events (Fig. 5a), one can find their visual similarity in spite of the difference in the mechanisms in their background. In the LS TID, the delay in the wave phase at a lower height relative to a higher altitude is caused by the slope of the phase front typical for AGW. In the case of electron concentration enhancements, such a height phase delay is caused by the velocity direction of the plasma flux from the protonosphere. In spite of the similarity in the reaction of the F2-layer parameters to the considered events, their identification in the given case presents a rather simple task, because the duration of the Nmf, which is ≈ 5 h, substantially exceeds the LS TID period, which is ≈ 2 h. A different situation could occur at comparable durations of both events. In that case, apparently, the problem of identification would be hardened substantially. According to statistical studies, the duration of both events can be comparable; however, most of the events of nightime enhancements in Nmf have a duration exceeding the maximum value of the LS TID periods.

6 Fig. 5 shows the behavior of the layer parameters, which one can interpret as a sequence of premidnight and postmidnight enhancements in the electron concentration, with an overlapping of LS TID on the second increase in Nmf. The night of January 22−23, 2005 was characterized by a rapid growth of magnetic activity, at which the Dst index at 2000, 2200, 2400, 0200, and 0400 LT took values of −5, −6, −47, −58, and −67 nT, respectively. The behavior of all of the parameters of the layer of the premidnight enhancement in the electron concentration with a Nmf peak at t ≈ 2120 LT corresponds to the mechanism considered using the example of the enhancement shown in Fig. 1. Periodic LS TIDs caused by processes in the polar regions related to the magnetic activity increase are overlapped on the second, postmidnight, long-lasting enhancement, with an Nmf peak at t ≈ 0330 LT. In this case, the LS TID is a wave process, which is manifested by quasi-periodic oscillations of all of the parameters of the F2-layer. The oscillation period is ≈ 5 h, and at least four oscillations fit into the interval of the electron concentration Nmf increase, so in this case it is fairly simple to perform separation of the events.

6 The premidnight and postmidnight enhancements in the electron concentration with LS TID overlapped on the latter enhancement

Summary. Various types of enhancements caused by different mechanisms are presented. It was found that the similarity in the reaction of the F2-layer parameters to nighttime enhancements caused by the rise of the layer and plasma flux from the protonosphere, and passages of large-scale ionospheric disturbances, is presented. Difficulties in the identification of these two events when they are of similar behavior are noted. The difference between the reaction of the F2-layer parameters to the enhancements caused by the rise of the layer and plasma flux from the protonosphere and the summer midlatitude anomaly in the ionosphere is shown.

References