Statistical Features of Nighttime Enhancements in the Electron Concentration in the F2 Layer Maximum of the Midlatitude Ionosphere in the 23 and 24th cycles of solar activity

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Abstract. On the basis of the vertical sounding of the ionosphere in Alma-Ata (76 55'E, 43 15'N) during 2000-2014, the analysis of the occurrence probability of the nighttime electron concentration enhancements in the maximum of the F2-layer (NmF2) was performed. A comparison of parameters of very large enhancements observed in Irkutsk and Alma-Ata simultaneously was conducted. During the period considered overall 2272 observation sessions were carried out, and in 1430 sessions enhancements of NmF2 were observed. There is a distinct seasonal dependence of the occurrence probability of enhancement appearance. The same features of the distributions for the high and low solar activity are the high occurrence probability near to 90% in January, February and November, December. In addition, a rapid decrease in the probability occurs from February to March, and a gradual increase from September to December. An evident maximum of the occurrence probability in the summer months takes place for high solar activity, while for the low activity the summer months are characterized by the minimum occurrence.

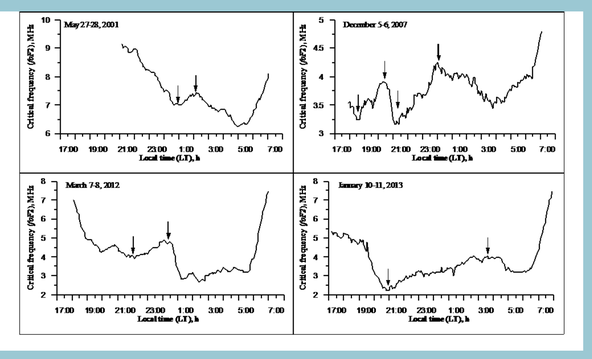

Figure 1. The main types of nighttime enhancements occurring in the foF2 records

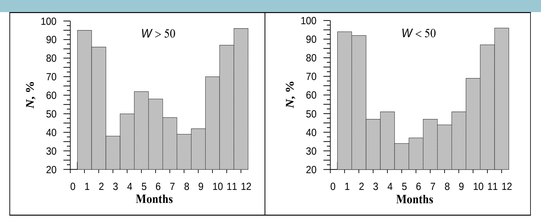

Figure 2. Distribution of monthly probability of events of the NmF2 nighttime enhancements, expressed as a percentage, for W> 50 and W <50.

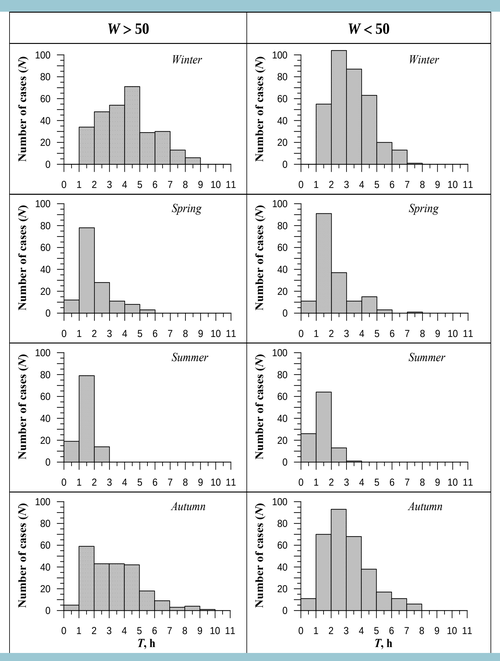

Figure 3. Distribution of the enhancement durations (T) plotted for different seasons and levels of solar activity (W> 50 and W <50). The vertical axis is the number of enhancements (N).

1 Introduction.

If do not take into account the processes of ionospheric plasma transfer, nighttime electron concentration of the midlatitude F2-layer of the ionosphere should gradually decrease, when solar source of photoionization is turned off. However, nighttime enhancements in the electron concentration in the maximum of the layer (NmF2) often occurs. The morphology of the phenomenon, including dependence of nighttime enhancements parameters on seasons, phases of the solar cycle, geomagnetic activity, and geographical location is described in [1, 2]. The paper [3] refers to the difference between the mechanisms of enhancement formation in summer and winter, as well as in different phases of the solar activity, so the study of frequency of formation (the probability of events) and other parameters on season and solar activity is of great importance to identify these mechanisms. The aim of the present study was a statistical analysis of the parameters of nighttime enhancements, including the probability of events and distributions of enhancement durations, according to Alma-Ata's (76 55 'E, 43 15' N) ionosonde data for 2000-2014.

2 Description of equipments and observation results

The vertical ionospheric sounding was conducted in the Institute of the Ionosphere (Alma-Ata) using the "Parus" digital ionosonde. The information needed for calculations of various parameters of the F2 layer was read from the ionograms using the semiautomatic method with the participation of an experienced operator.

Statistical analysis of the nighttime enhancements was carried out for the period 2000-2014, which included two maximum and minimum of solar activity. A total of 2272 sessions of observation were conducted, and nighttime enhancements were observed in 1430 sessions. Figure 1 shows the basic types of nighttime enhancements encountered in recordings. The arrows indicate the points of the beginning enhancements and their maximums. The distance between the arrows determines the duration of the development phase of enhancements. In addition to assessing the probability of events distributions of the enhancement durations were constructed. As a rule, we took into account the duration of the most powerful enhancement (for example, 7-8 March 2012).

In the case of approximate equality of the amplitudes both enhancements were included in statistics (for example, December 5-6, 2007). To characterize the duration of an enhancement we have chosen the duration of the phase of enhancement development, rather than just the enhancement duration, as it seems, mainly characterizes the duration of the action of a mechanism which responsible for the enhancement. This is due to the fact that the duration of the recovery phase (the time counted from the maximum NmF2 to its background value) is mainly determined by the speed of lowering the layer at heights with heavy losses of the electron concentration [4].

The entire data set (2000-2014) has been split into two subarrays. The first (2000-2003 and 2011-2014) corresponded to high solar activity, when the annual average Wolf numbers exceeded 50 (W> 50). The second (2004-2010) corresponded to low solar activity, when the annual average Wolf numbers were less than 50 (W <50). Figure 2 shows the distribution of the probability of events, expressed as a percentage, to W> 50 W <50. There is a pronounced seasonal dependence of the probability of events. The same characteristics of the distributions for W> 50 W <50 is a high probability event, reaching 90% in January, February and November, December. In addition, the same is a rapid decrease in the probability of February to March, and a smooth increase from September to December.

At high solar activity a distinct maximum of the probability of events in the summer months is formed, while under the low activity one can see the minimum of the probability of events. Figure 3 shows the distribution of the enhancement duration built for different seasons and levels of solar activity. It can be seen that regardless of the level of activity distributions have the same features. In the winter and fall duration distributed over a wide range, with most of durations lying in the range of 1-5 hours. In the spring and summer, the bulk of durations lies in the range of 1-2 hours.

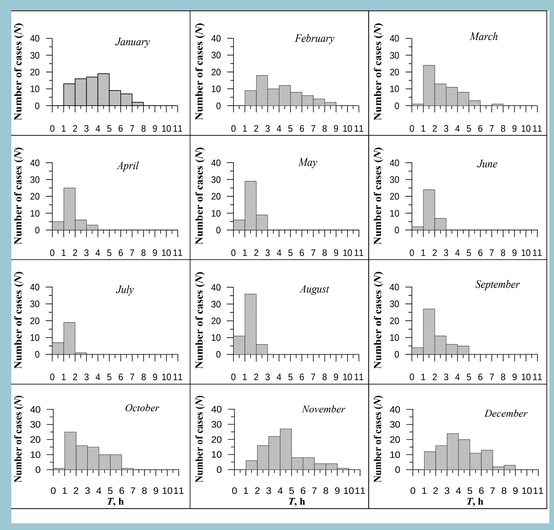

Figure 4. Distribution of the enhancement durations (T) constructed for each month and high solar activity (W> 50). The vertical axis is the number of enhancements (N).

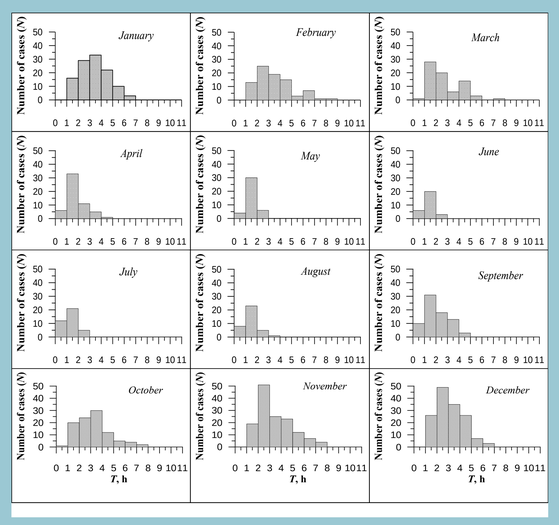

Figure 5. Distribution of the enhancement durations (T) constructed for each month and low solar activity (W <50). The vertical axis is the number enhancements (N).

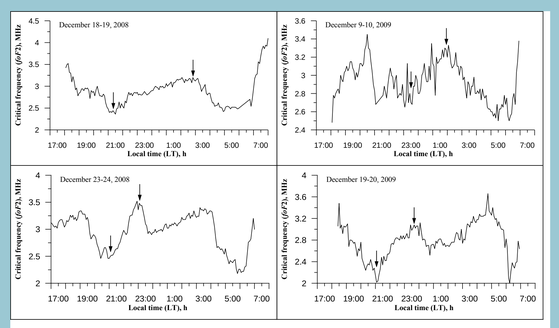

Figure 6. Behavior foF2 during very large enhancements in the electron concentration.

For a detailed review of seasonal adjustment distribution of duration of nighttime enhancements, they are presented for each month (Fig. 4, 5). For the spring and summer months (April-August) the duration of the main part of the enhancements is in the range of 1-2 hours. In March and September, there is an alteration of distribution form.

In the paper [2] the probability of events in which the enhancement takes place in the same day at different stations (Alma-Atat, Kiev, Moscow), separated by a considerable distance, is studied. The probability reached values of ~ 50 - 70% depending on the season and solar activity. We have compared the amplitudes of very strong enhancements, observed in Almaty and Irkutsk, using the date of the event, given in [5]. Under the amplitude, we knew the ratio of the electron density in the the enhancement maximum to value in the previous minimum. Estimates gave values of the amplitudes for the cases (Fig. 6), equal to 1.6, 2.75, 1.96 and 1.99 for the night of 18-19 December 2008, 9-10 December 2009, 23-24 December 2008 and 19-20 December 2009, respectively.

The fact of the simultaneous formation of enhancements at significantly spaced stations have not yet said about their single source, because of the high probability of events during the winter. However, the fact that their amplitudes are equally high, apparently favors the single source of enhancements with high spatial dimensions. Note that all dates with large enhancements occurred in a period of low solar activity. An explanation of relationship between the enhancements amplitude and solar activity is done in [3] on the basis of comparing changes with the cycle of activity of the plasma flow rate from the protonosphere and recombination rate. Since the loss rate with increasing activity increases faster than doubled as compared to the growth rate of the plasma stream, the maximum of enhancement amplitude takes place in a minimum of solar activity.

3 Summary

Analysis of the probability of events of the NmF2 nighttime enhancements showed the following:

1. There is a pronounced seasonal dependence of the probability of events of the enhancements. The same feature of distributions for the high and low solar activity is high probability of events in January, February and November, December. In addition, the same is a rapid decrease in the probability of February to March, and its gradual rise from September to December. There is a distinct maximum of the probability of events in the summer months for high solar activity, while during the low activity there is the minimum of the probability.

2. It is shown that the distribution of the enhancement duration regardless of the level of solar activity have the same features. In winter and fall duration distributed over a wide range, with most of the durations lying in the range of 1-5 hours. For spring and summer months (April-August) the duration of the main part of the enhancement duration is in the range of 1-2 hours. Comparison of the enhancement amplitudes derived in Alma-Ata and Irkutsk for the same day proved a high probability that the sources of enhancements have significant spatial dimensions.

References

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