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THE F2-LAYER PARAMETER VARIATIONS DURING SPRING EQUINOX 2013, ACCORDING TO THE KHARKIV AND EISCAT INCOHERENT SCATTER RADARS DATA

The investigations of temporal variations of the electron density in the F2-layer maximum, ion and electron temperatures in the mid-and high latitudes during the 2013 year spring equinox are conducted. The features of the temporal variations of the parameters of the F2-layer in Kharkiv and Tromsø during the spring equinox are revealed. It was established that during the spring equinox changes amplitude electron and ion temperatures in the ionosphere over Tromsø less than the amplitude of temperature changes of electrons and ions in the ionosphere over Kharkiv on the entire time interval of joint observations from 07:00 to 24:00 UT.

Keywords: the spring equinox, the temporal variations of the parameters of the F2-layer in middle and high latitudes.

Statement of the problem. The incoherent scatter (IS) radar in Kharkiv and radar EISCAT Observatory's radars form the European chain of IS radars , which allows you to gain knowledge about the ionosphere structure at mid- and high latitudes, as well as to create modern ionosphere and thermosphere models. The comparative analysis of temporal variations of the electron concentration in the F2-layer maximum, ion and electron temperatures in the mid- and high latitudes for quiet period during different seasons allows improving the theory region F2 and thermosphere. The creation of reliable theoretical ionosphere region F2 model for middle and high latitudes, taking into account different heliogeophysical conditions, is of interest both for the development of the theory of ionosphere, and for solving applied tasks of radio waves.

The analysis of the literature. The F2 region research at different latitudes are conducted by IS radars and other methods. The [1] presents the results of studies of seasonal variations of maximum electron concentration of the F2-layer ($n_{em}F2$) and electron and ion temperatures in high and middle latitudes. It was noted that in equinox season in Tromsø not observed before-sunset high $n_{em}F2$, which is observed in Kharkiv, and that after sunset in Tromsø there is more rapid decrease $n_{em}F2$ compared with decrease $n_{em}F2$ after sunset in Kharkiv. In [2], the results of study temperatures of electrons and ions, as well as $n_{em}F2$ in Kharkiv and Tromsø during a strong magnetic storm on August 5 – 6, 2011 are presented. The sharp monotonous decrease $n_{em}F2$ in Kharkiv and Tromsø after beginning of the magnetic storm and unusual intermittent night ionospheric plasma in Kharkiv to daytime temperatures of electrons and ions there was observed. In [3] the variations $n_{em}F2$ with 13 stations vertical sounding located at different latitudes were investigated. It was noted that during high solar activity (index $F_{10,7}$ was

equal to 140) standard changes n_{em}F2 make up 20% at day and 33% at night. Seasonal changes n_{em}F2, especially, the increase n_{em}F2 during the equinox were marked. In [4], the results of the study temperatures of electrons and ions for summer, winter and equinox seasons at different latitudes and at different levels of solar activity are presented. It was noted that the daily values of electron temperature exceeds its average night values in 2.8 – 4.6 times in the transition from solar activity minimum to its maximum, and day values of ion temperature – in 1.2 – 2.2 times.

The aim of the article – to reveal the specific features of temporal variations of electron concentration in the F2-layer maximum, ion and electron temperatures in the mid-and high latitudes during spring equinox at a moderate solar activity.

Heliogeophysical environment 14 and 20 March 2013. Measurements with IS radars in Kharkiv and Tromsø held March 19 – 22, 2013 (Kharkiv) and March 14, 2013 (Tromsø) in accordance with the International Geophysical Calendar.

On March 20, 2013 the index of solar activity $F_{10,7}$ mattered 108 (solar activity was moderate). Planetary the daily index of geomagnetic activity A_p for March 20 had a value of 9 and three-hour planetary K_p-index matter not exceeding 3 (basically had value equal to 2, in the period of measurements from 07:00 to 24:00 UT), i.e. this period of time was absolutely quiet.

On March 14, planetary the daily index of geomagnetic activity A_p had a value of 5, and three-hour planetary K_p-index matter not exceeding 2 (generally equal to 1), i.e. this period of time was absolutely quiet. Index of solar activity $F_{10,7}$ had a value of 123, i.e. solar activity was moderate.

Variations of electron concentration in the F2-layer maximum of March 14, 2013, according to Tromsø radar data, and March 20, 2013, according to Kharkiv radar data. The main interest in the study F2-region are temporal variations of electron concentration n_{em} in the F2-layer maximum in the mid-and high latitudes in different seasons. Fig.1 shows a comparison of the temporal variations lgn_{em}F2 on the time interval 07:00 to 24:00 UT according to Tromsø and Kharkov radar data in a quiet day 14 and 20 March 2013. As can be seen from Fig. 1 the time course of lgn_{em}F2 for Kharkiv has two distinct local maximum at 08:00 and 13:00 UT, as the time course of lgn_{em}F2 for Tromsø with a local maximum at 13:00 UT. In Tromsø electron concentration in the maximum of the F2-layer (n_{em}F2) monotonically decreases slowly after 13:00 to 17:00 UT, and after 17:00 UT is more rapid decrease of the electron concentration in the F2-layer maximum is observed. In Kharkiv n_{em}F2 also monotonically decreases after 13:00 till 18:00 UT, and after 18:00 UT more quickly decreases, and the decrease n_{em}F2 in Kharkiv slower compared to Tromsø.

The Fig. 1 shows the values of lgn_{em}F2 for Kharkiv exceed the values of lgn_{em}F2 for Tromsø almost in the whole time interval joint observations from 08:00 to 24:00 UT. The value n_{em}F2 for Kharkiv at 08:00 UT exceeds the value n_{em}F2 for Tromsø by 23%, and the value n_{em}F2 at 13:00 UT – by 3% (value n_{em}F2 in Kharkiv

and Tromsø almost the same). The value n_{em}F2 for Kharkiv at 17:00 UT exceeds the value n_{em}F2 for Tromsø by 29%, at 18:00 UT – by 91%, at 21:00 UT – by 79%, and at 24:00 UT n_{em}F2 in Kharkiv exceeds n_{em}F2 in Tromsø by 74%.

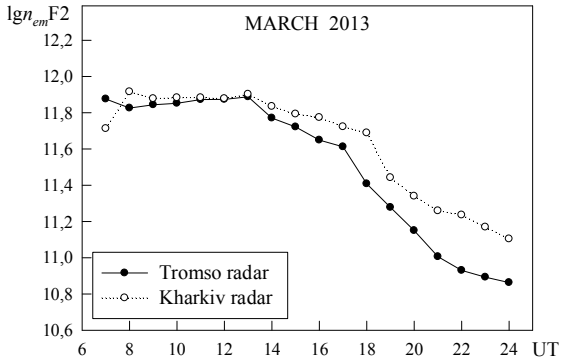

Fig. 1 – Comparison of the temporal variations of lgn_{em}F2, according to Tromsø radar data for 14.03.2013 and Kharkiv radar data for 20.03.2013

In Kharkiv until sunset at an altitude of 300 km at 17:41 UT there is slow monotonous decrease n_{em}F2, and after 18:00 UT there is faster descending n_{em}F2. In Tromsø there is slow monotonous decrease n_{em}F2 from 13:00 to 17:00 UT, and after sunset at 16:40 UT in Tromsø there is more rapid decrease n_{em}F2, moreover, this reduction faster in comparison with the reduction n_{em}F2 after sunset in Kharkiv. It should be noted that before-sunset highs n_{em}F2 in Tromsø and Kharkiv are not observed.

Thus, in the period of spring equinox n_{em}F2 in Kharkiv exceeds n_{em}F2 in Tromsø in the whole time interval joint observations from 08:00 to 24:00 UT. Before-sunset highs n_{em}F2 in Tromsø and Kharkiv are not observed. After sunset in Tromsø there is more rapid decrease n_{em}F2 compared with decrease n_{em}F2 after sunset in Kharkiv.

Electron temperature variations on March 14, 2013, according to Tromsø radar data, and March 20, 2013, according to Kharkiv radar data. Variations of electron temperature T_e on March 14, 2013 at the height of 344 km in Tromsø and at a height of 342 km on March 20, 2013 in Kharkov are shown in Fig. 2.

From Fig. 2 you can see that the electron temperature T_e in Tromsø more electron temperature in Kharkiv in the whole time interval joint observations from 07:00 to 24:00 UT. The temperature of electrons in Kharkiv, starting from 08:00 UT, gradually increases to its maximum value – 2120 K at 14:00 UT. After 14:00 UT with the sunset in magneto-conjugated with Kharkiv point (Madagascar island) at 14:59 UT electron temperature is slowly reduced, and with the sunset in

Kharkov 15:49 UT there is more rapid decrease T_e to its minimum value 827 K that it takes at 22:00 UT. The amplitude changes T_e, i.e. the difference between the maximum and minimum temperatures of electrons in Kharkiv is 1293 K.

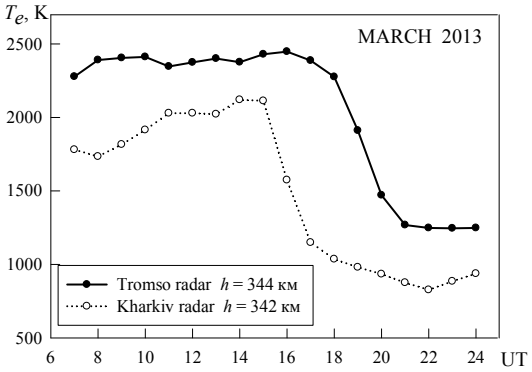

Fig. 2 – Comparison of temporal variations of T_e, according to Tromsø radar data for 14.03.2013 and Kharkiv radar data for 20.03.2013

In Tromsø electron temperature gradually increases to its first local maximum 2412 K at 10:00 UT, the second local maximum T_e – 2401 K is observed at 13:00 UT. After this, the electron temperature gradually increases to its maximum value 2448 K that it takes at 16:00 UT, and with the sunset at 16:40 UT T_e quickly reduced to its minimum 1246 K that it takes at 23:00 UT. The amplitude changes T_e in Tromsø is 1202 K, i.e. in Tromsø amplitude changes of electron temperature on the time interval 07:00 – 24:00 UT 91 K less, than in Kharkiv.

The temperature of electrons in Tromsø exceeds the temperature of electrons in Kharkov: in the interval from 07:00 to 15:00 UT – 497 – 311 K, and in the interval 16:00 – 24:00 UT – 874 – 311 K.

Thus, in the period of spring equinox electron temperature in Tromsø exceeds the temperature of electrons in Kharkiv in the whole time interval joint observations from 07:00 to 24:00 UT. The temperature of electrons in Kharkiv has a pronounced maximum at 14:00 UT, with the sunset in magneto-conjugated with Kharkiv point (Madagascar island) at 14:59 UT electron temperature is slowly reduced, and with the sunset in Kharkov at 15:49 UT there is more rapid decrease T_e to its minimum value. In Tromsø rapid decrease of the electron temperature is observed only after sunset in Tromsø at 16:40 UT. In Tromsø amplitude changes of electron temperature on the time interval 07:00 – 24:00 UT 91 K less, than in Kharkiv. This is because in Tromsø on the heights of 300 km and more 14.03.2013 the Sun never sets, and at these heights dominates the polar day.

Ion temperature variations on March 14, 2013, according to Tromsø radar data, and March 20, 2013, according to Kharkiv radar data. Variations

of ion temperature T_i on March 14, 2013 at the height of 344 km in Tromsø and at a height of 342 km on March 20, 2013 in Kharkov are shown in Fig. 3.

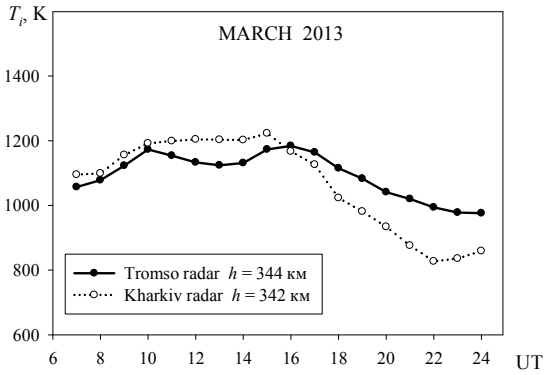

Fig. 3 – Comparison of time course T_i, according to Tromsø radar data for 14.03.2013 and Kharkov radar data for 20.03.2013

The figure shows that the temperature of ions in Kharkiv more than the temperature of ions in Tromsø on the time interval 07:00 – 15:00 UT, i.e. before sunset in Kharkiv on 15:49 UT. After sunset in Kharkiv temperature of ions in Tromsø in the time interval 16:00 – 24:00 UT was higher than the temperature of ions in Kharkiv.

The temperature of ions in Kharkiv, starting from 08:00 UT, gradually increases to its maximum value – 1223 K at 15:00 UT. After 15:00 UT with the sunset in Kharkiv temperature of ions monotonically decreases to its minimal value 827 K that it takes at 22:00 UT. The amplitude changes T_i, i.e. the difference between the maximum and minimum temperature of ions in Kharkiv is 396 K.

In Tromsø ion temperature has two local maximum at 10:00 and 16:00 UT and the local minimum at 13:00 UT. After 16:00 UT ion temperature slowly decreases until 17:00 UT, and after sunset in Tromsø at 16:40 UT ion temperature monotonically decreases to its minimal value 976 K that it takes at 24:00 UT. The amplitude changes T_i in Tromsø is 208 K, i.e. by 1.9 times less than in Kharkiv.

The temperature of ions in Kharkiv was higher than the temperature of ions in Tromsø in the interval 07:00 – 15:00 UT on 19 – 79 K, and the temperature of ions in Tromsø in the interval 16:00 – 24:00 UT higher than the temperature of ions in Kharkiv on 17 – 167 K.

Thus, in the period of the spring equinox, the temperature of ions in Kharkov higher than the temperature of ions in Tromsø on the time interval 07:00 – 15:00 UT, i.e. before sunset in Kharkov at 15:49 UT, and after sunset in Kharkiv temperature of ions in Tromsø was higher than the temperature of ions in Kharkiv.

After sunset in Kharkiv and Tromsø the temperature of ions in Kharkiv and Tromsø monotonically decreases to their minimum values, moreover, the decreasing of the temperature of ions in Kharkiv faster than descending T_i in Tromsø.

The amplitude changes T_i in Tromsø in 1.9 times less than in Kharkiv. This is because in Tromsø on the heights of 300 km and more 14.03.2013 the Sun never sets, and at these heights dominates the polar day.

The conclusions. 1. During the spring equinox n_{em}F2 in Kharkiv exceeds n_{em}F2 in Tromsø in the whole time interval joint observations from 08:00 to 24:00 UT.

2. Before-sunset highs n_{em}F2 in Tromsø and Kharkiv are not observed.

3. After sunset in Tromsø there is more rapid decrease n_{em}F2 compared with decrease n_{em}F2 after sunset in Kharkiv.

4. During the spring equinox the temperature of electrons in ionosphere over Tromsø exceeds the temperature of electrons in ionosphere over Kharkiv in the whole time interval joint observations from 07:00 to 24:00 UT.

5. During the spring equinox, the temperature of the ions in ionosphere over Kharkiv higher than the temperature of ions in ionosphere over Tromsø in the whole time interval 07:00 to 15:00 UT, i.e. before sunset in Kharkiv at 15:49 UT.

6. After sunset in Kharkiv and Tromsø the temperature of ions in ionosphere over Kharkiv and Tromsø monotonically decreases to their minimum values, moreover, the decrease of the temperature of ions in the ionosphere over Kharkiv faster than descending T_i in ionosphere over Tromsø.

7. The amplitude changes T_i in Tromsø in 1.9 times less than in Kharkiv. This is because in Tromsø on the heights of 300 km and more 14.03.2013 the Sun never sets, and at these heights dominates the polar day.

References: 1. *Zhivolup T.G.* Variations of parameters of the F2-layer in the spring equinox 2012, according to the Kharkiv and EISCAT incoherent scatter radars data // Bulletin of the National Technical University "Kharkiv Polytechnic Institute". Series: "Radiophysics and ionosphere". – 2013. – № 28 (1001). – P. 3-9. **2.** *Zhivolup T.G. , Dzyubanov D.A.* Variations of parameters of the F2-layer during the strong magnetic storm on 5 – 6 August 2011, according to the Kharkiv and EISCAT incoherent scatter radars data // Bulletin of the National Technical University "Kharkiv Polytechnic Institute". Series: "Radiophysics and ionosphere". – 2012. – № 57 (963). – P. 61-69. **3.** *Rishbeth H., Mendillo M.* Patterns of F2-layer variability // J. Atm. Sol.-Terr. Phys. – 2001. – V. 63. – P. 1661-1680. **4.** *Sharma D.K., Sharma P.K., Rai J., Garg S.C.* Effect of solar activity on ionospheric temperatures in F2 region. // Ind. J. Radio Space Phys. – 2008. – V. 37. – P.319-325.

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Проведено дослідження часових варіацій електронної концентрації в максимумі шару F2, іонної та електронної температур в середніх і високих широтах в період весняного рівнодення 2013 р. Виявлено особливості часових варіацій параметрів шару F2 в Харкові і Тромсьо в період весняного рівнодення. Встановлено, що в період весняного рівнодення амплітуди зміни температур електронів і іонів в іоносфері над Тромсьо менше, ніж амплітуди зміни температур електронів і іонів в іоносфері над Харковом на всьому часовому інтервалі спільних спостережень з 07:00 до 24:00 UT.

Ключові слова: весняне рівнодення, часові варіації параметрів шару F2 в середніх і високих широтах.

Проведены исследования временных вариаций электронной концентрации в максимуме слоя F2, ионной и электронной температур в средних и высоких широтах в период весеннего равноденствия 2013 г. Выявлены особенности временных вариаций параметров слоя F2 в Харькове и Тромсё в период весеннего равноденствия. Установлено, что в период весеннего равноденствия амплитуды изменения температур электронов и ионов в ионосфере над Тромсё меньше, чем амплитуды изменения температур электронов и ионов в ионосфере над Харьковом на всем временном интервале совместных наблюдений с 07:00 до 24:00 UT.

Ключевые слова: весеннее равноденствие, временные вариации параметров слоя F2 в средних и высоких широтах.