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NARROW IONIZATION TROUGHS IN THE F REGION: MEASUREMENTS FROM THE KOSMOS-900 SATELLITE AND COMPARISON WITH GROUNDBASED IONOSPHERIC OBSERVATIONS

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We present the results of measuring the parameters of narrow troughs in the ionization of the F region of the ionosphere on board Kosmos-900. We have discovered that when narrow ionization troughs are recorded, they are always accompanied by an abrupt enhancement in the electron temperature in the same narrow latitude regions. Simultaneous measurements from the ground and from the satellite are available during orbits when the satellite passes near the meridian containing the Yakutsk chain of stations. These show that at times when the satellite records narrow ionization troughs, additional reflection tracks from the F region show up in the ionograms from the groundbased ionospheric stations. These additional tracks are interpreted in terms of the formation of a narrow ionization trough in the F region which is detected from the data of the groundbased ionospheric measurements.

The authors of [1] and [2] have reported cases where satellites have recorded narrow ionization troughs at heights in the F region which are spatially coincident with a zone of rapid westward drift of ions. Reports have also appeared [3, 4] in which narrow jets of rapid westward ion drift have been recorded in measurements from other satellites. Simultaneous measurements from satellites and from groundbased ionospheric radio-sonde stations have been discussed in [5] and [6]. From these, it has been discovered that at times when the satellites record narrow jets of rapid westward ion drift, there are characteristic changes in the structure of the high-latitude ionosphere ($F3_s$-reflections). The narrow jets are due to the development of strong poleward electric fields (up to ~300 mV/m) near the zenith of the observing station. And the structures in the $F3_s$-reflections indicate the formation of narrow (~100-200 km) and deep ($\sim 2\text{-}5 \cdot 10^4$ elec/cm^3) troughs in the latitudinal distribution of electron density N_e at heights in the F region. The authors of [5] and [6] ascribed the formation of these narrow ionization troughs to changes in the rates of certain photochemical reactions, leading to accelerated recombination processes at these heights if strong electric fields are present, and to removal of ionization from the F region on the dayside. We should point out that up to the present time, there have as yet been no comparisons between the narrow troughs in N_e recorded by satellites at heights in the F region and the results of groundbased ionospheric radio-sondes.

In this paper, we will consider certain cases where Kosmos-900 recorded narrow ionization troughs, and we will compare them with data from ionospheric radio-sondes (both vertical, VR, and return-oblique, ROR) obtained at the Yakutsk meridional chain of stations. In our study, the groundbased ionospheric observations are analyzed at times when the satellite records narrow troughs in the latitudinal distribution of electron density near the meridian along which the groundbased stations are located for ionospheric radio-sondes. We assume that if the narrow troughs in N_e recorded by Kosmos-900 are due to the formation of rapid westward ion drifts (i.e., due to the development of locally strong poleward electric fields near the ionospheric projection of the plasmapause), then additional reflection tracks from the F region should show up in the ionograms from the groundbased ionospheric station over which the satellite is passing at that point in time. (These tracks will be assumed to be due to the formation of narrow ionization troughs above the observing station [5, 6].)

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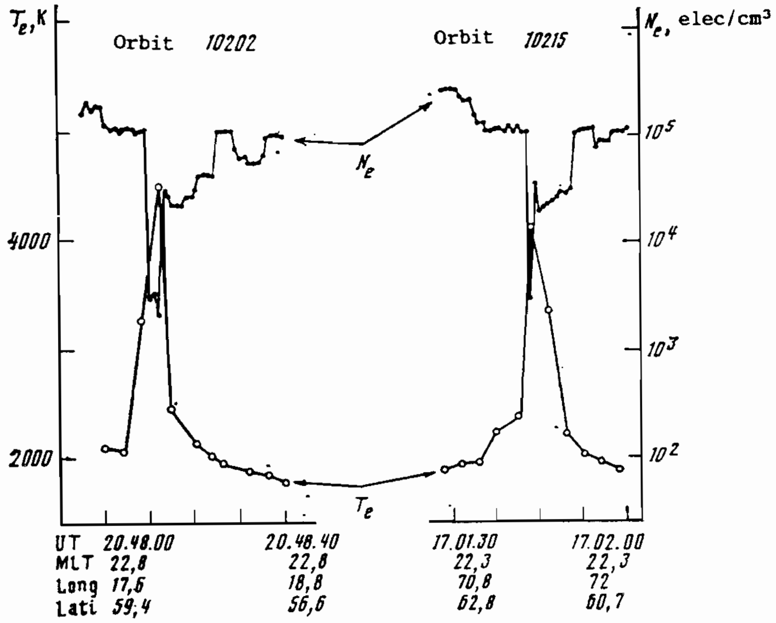

Fig. 1

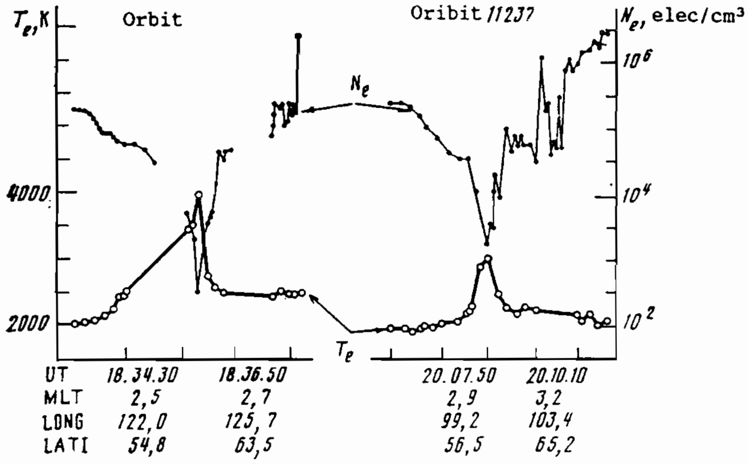

Fig. 2

Moreover, the N_e observations in this experiment were supplemented substantially by measurements of the electron temperature T_e on board the satellite. As a result, we have discovered that the electron temperature has a very sharp maximum during the times when narrow troughs are observed if we select the narrow ionization troughs according to the following criteria: the width of the trough is 1-2°, and the electron density falls off by half an order of magnitude or more.

Kosmos-900 was launched on March 20, 1977 into a nearly circular orbit at heights around $h \simeq 500$ km, and with an inclindation of 83°. The period of revolution of the satellite was ~95 min. The electron densities were measured on board the satellite by ion traps [7], and the electron temperature was measured by means of a high-frequency probe which is a modified Langmuir probe [8].

In Fig. 1 we present typical examples where we detected narrow ionization troughs in the F region accompanied by sharp peaks in the electron temperature. The data refer to orbit No. 10202 (January 25, 1979) and orbit No. 10215 (January 26, 1979). The values of N_e are denoted by filled circles, T_e by open circles. In the lower part of the figure, we indicate the times of measurements in UT and local time, as well as the coordinates of the satellite in a geographic system. It is obvious from Fig. 1 that in both cases, we observe troughs in the lati-

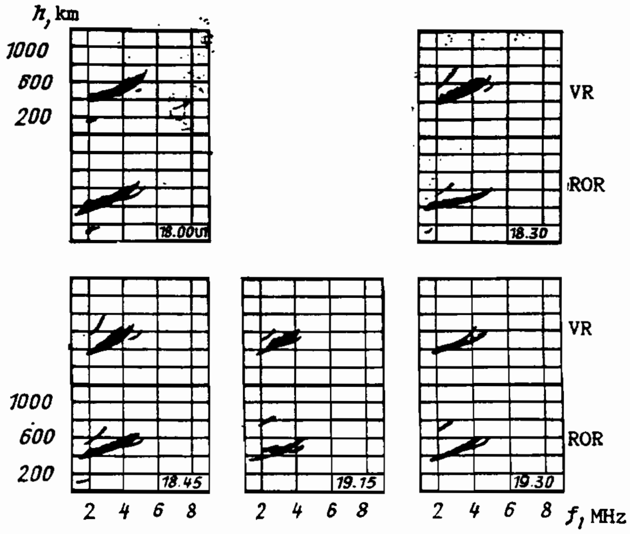

Fig. 3

tudinal behavior of ionization in the F region which have very small widths (about 30 km) and are very deep (the jump from the background electron density to the minimum value in the narrow trough is about 1.5 orders of magnitude). We note that on orbit No. 10215, the narrow trough is recorded near the clearly defined polar wall of the main ionospheric trough (MIT). Corresponding to the narrow ionization troughs, there are sharp peaks in electron temperature which coincide precisely in space with them. The difference between background and maximum T_e is about 2000 K. We should mention in this regard that the cases which we have studied among the Kosmos-900 measurements of narrow troughs in N_e and sharp maxima in T_e show the following behavior: the deeper the narrow ionization trough is, the larger the jump in T_e is.

In Fig. 2 we present Kosmos-900 measurements of N_e and T_e for April 2, 1979. It is obvious from Fig. 2 that the satellite has recorded a sharp narrow (about 100 km) ionization trough near the polar wall of the main trough. This is especially easy to see in orbit No. 11237. In orbit No. 11236, we see the usual smooth rise of T_e in the main trough region, but a jump in T_e of about 800 K is recorded in the region of the narrow ionization trough.

Let us now consider the results of simultaneous groundbased ionospheric measurements at Yakutsk station when the satellite passed over some 4° to the west of the observing station meridian, and recorded a narrow ionization trough. In Fig. 3 we present data from the ionospheric station for five observing periods. The data are presented in the form of VR and ROR ionograms. The antenna which was used was of the horizontal rhombus type: this allows information to be obtained on structure in the reflecting region in the northward direction. It is obvious from Fig. 3 that additional reflecting structure ($F3_s$-reflections, in the terminology of [5] and [6]), indicating the development of a narrow ionization trough, shows up at 18.30 UT, i.e., near the time when the satellite passed over. However, this track was not recorded during the previous observation at 18.15 UT. $F3_s$-reflections are observed up to 19.15 UT, gradually diminishing in height and merging with the regular F2-layer.

At the same time, ROR shows multiple reflection from the F2-layer, which is usually characterized by a doubling of the range of the F2-reflection. At 19.30 UT, the only features remaining are the regular and the multiple F2-reflections. Consequently, based on the results in [5] and [6] we may hypothesize that the narrow ionization troughs recorded by Kosmos-900 are also due to the development of a "polarization jet."

Mikkelsen et al. [9] have reported on simultaneous measurements from rockets and from an installation in Chatanika for incoherent scattering of radio waves. These showed that when electric fields are strong (>60 mV/m), there is an increase in the height of the level where atmospheric constituents make the transition from molecular to atomic (at about 50 km), and there is a sharp increase in the rate of the reaction $N_2 + O^+ \rightarrow NO^+ + N$. The growth in NO^+ density facilitates a rapid reduction in N_e as a result of dissociative recombination. Evans et al. [10] have reported on incoherent radar scattering experiments at Millstown-Hill which yielded measurements of the temperatures of electrons and ions, as well as densities and drift velocities of the ionization. These results showed that regions of rapid westward ion drift, enhancements in electron and ion temperatures, and large depressions in N_e are spatially coincident. In order to explain the formation of narrow troughs in the post-midnight sector, Eva et al. [10] rely on the mechanism described above. Observations with the European incoherent scattering radar are discussed by Schlegel [11]: he has also discovered that the regions of reduction in N_e and enhancement in T_e are spatially coincident. Schlegel [11] explains this by the fact that, when the energy supplied at the height of the F-region is constant (in conditions where there are no precipitating particles), an increase in T_e entails a reduction in N_e. Based on data from the same radar, the conclusion is drawn [12] that an increase in T_e without a growth in N_e may be caused by intense electrostatic waves generated by a nonlinear interaction between fast auroral electrons and plasma in the F-region.

We may therefore assume that spatial and temporal coincidences between narrow troughs in N_e and sharp peaks in the value of T_e can be explained by rather complicated physical phenomena in the upper ionosphere, and further investigations are necessary if we are to understand them.

In summary, the results of this work lead us to the following conclusions:

1. Measurements on Kosmos-900 indicate that narrow troughs (about 100 km) in the latitudinal distribution of electron density are spatially coincident with sharp enhancements in electron temperature. The magnitude of the jump in electron temperature depends on the difference between the values of electron density in the narrow trough in the background: usual it amounts to 500-3000 K.

2. We have compared satellite measurements of narrow ionization troughs with groundbase ionospheric measurements. These comparisons have shown that characteristic tracks show up on VR and ROR ionograms, indicating that narrow jets of rapid westward ion drift appear above the observing station. Consequently, based on the results of [5] and [6], we may assume that the narrow troughs in N_e observed by Kosmos-900 are also due to this mechanism.

3. Sharp increases in T_e in regions of narrow ionization troughs are apparently associated with the effects of strong electric fields acting on plasma in the F-region. In order to understand the complicated physical mechanisms which cause such sharp and localized jumps in electron temperature, further investigations of these processes are necessary.

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