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Disturbances of the Topside Ionosphere Caused by Typhoons

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Abstract—The measurements on board the Cosmos-1809 satellite of various parameters of the topside ionosphere plasma during more than ten typhoons in various regions are analyzed. It is shown that specific zones of increased pressure of the electron gas, electric field, and intense ion oscillations are formed during the intensification stage. In some cases the "typhoon eye" is formed over the tropical depression zone in the ionosphere, that is, the region with sharply decreased plasma density and pressure is observed a day and more prior to the moment when it happens in the atmosphere.

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1. INTRODUCTION

Tropical hurricanes are powerful natural process on the Earth. In the scope of the World Meteorological Organization (WMO), there are functioning 8 centers which control dynamics of regional tropical cyclones. At the sites of the centers, vast information on tropical hurricanes is presented and the corresponding bibliography is given. However, in the meteorology, as a rule, atmospheric parameters are studied at altitudes not exceeding the stratospheric ones. As far as the total energy release in the hurricane structures reaches 10^{25} J, their influence should extend up to the magnetosphere.

In the 1980s–1990s in IZMIRAN under the guidance of Academician V. V. Migulin, influence of lithospheric processes and powerful anthropogenic sources on the ionosphere began to be studied [Migulin et al., 1998]. N. V. Isaev was an active participant of these works. His most known publications are: [Isaev et al., 1987] and [Chmyrev et al., 1989].

One of important factors of influence on the ionosphere are powerful natural processes in the atmosphere: cyclones, atmospheric weather fronts, typhoons, etc. The most cited publications in this field were: [*Meteorological*..., 1987; Baryshnikova et al., 1989; Holzworth et al., 1985; Kelley et al., 1985; Mikhailova et al., 2000; Raghavarao et al., 1987]. At the same time, problems of interrelation between the atmosphere and ionosphere began to be studied in the laboratory headed by N.V. Isaev [Isaev et al., 2000, 2002; Sorokin et al., 2005]. The other group of IZMIRAN scientists fruitfully working in this region showed based on VLF measurements that the zone of typhoon impact on the topside ionosphere is much broader than the region covered by the cyclone [Mikhailova et al., 2002; Mikhailov et al., 2005]. In the last paper by N.V. Isaev [Isaev et al., 2008], to clarify physics of the interrelation between typhoons and ionosphere, the data of a set of devices on board the Cosmos-1809 satellite were used and also the results of measurements conducted at the same satellite to study anthropogenic impact on the ionosphere were attracted. In the N.V. Isaev laboratory, information on flights of the Cosmos-1809 satellite over more than 70 typhoons is collected. Part of this information is processed and presented in this paper in order to reveal the interrelation between typhoons and the parameters of the topside ionosphere.

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2. EXPERIMENTAL DATA

To study ionospheric effects which could be related to typhoons, we used the results of observations on board the Cosmos-1809 satellite. It was a copy of the Intercosmos-19 satellite with equipment for studying of the topside ionosphere [*Equipment*..., 1980] and mainly solved the problems of Rosgidromet. The Cosmos-1809 satellite operated from December 18, 1986, to May 23, 1993. The apogee, perigee, inclination, and period of its orbit were 980 km, 950 km, 82.5°, and 104 min, respectively.

The following devices operated most successfully on board the Cosmos-1809 satellite:

1. Detector of electric field (DEF). DEF made it possible to measure the electric field (f = 0–3 Hz) within the ±500 mV/m range (at the measurement base of 5 m) with a resolution of 0.5 mV/m. These measurements were conducted by the double probe method with a floating potential. Two components were measured: Ey in the horizontal plane at an angle of 45° anti-clockwise to the velocity vector and Ex in

Names of the typhoons and their position during the Cosmos-1809 satellite operation

No.	Name of typhoon	Time of existence	Location of typhoon at satellite passage: latitude (degrees)	longitude (degrees)
1	Edme	Jan. 17–26, 1989	20 S	80 E
2	Firinga	Jan. 24–Feb. 1, 1989	11 S	62 E
3	Kirrily	Feb. 5–10, 1989	25 S	102 E
4	Harry	Feb. 6–22, 1989	19 S	162 E
5	Roslyn	Sept. 13–30, 1992	18 N	138 W
6	Ted	Sept. 14–24, 1992	37 N	134 E
7	Tina	Sept. 17–Oct. 11, 1992	13 N	110 W
8	Bonnie	Sept. 17–Oct. 2, 1992	37 N	52 W
9	Seymour	Sept. 17–27, 1992	24 N	122 W
10	Val	Sept. 19–27, 1992	30 N	151 E
11	TC05B	Sept. 21–25, 1992	22 N	90 E
12	Charley	Sept. 21–27, 1992	36 N	34 W
13	Daniclle	Sept. 22–26, 1992	34 N	73 W
14	Ward	Sept. 23–Oct. 7, 1992	16 N	178 E
15	Aviona	Sept. 25–Oct. 1, 1992	4 S	84 E

almost vertical plane at an angle of ≈45° clockwise to the velocity vector.

2. Analyzer of low frequencies (ALF-2ME). The electromagnetic field components within the 70 Hz–20 kHz band were measured in the regime of real-time transmission, and also in low-band channels at frequencies 140, 450, 850, 4600 Hz, and 15 kHz with $\Delta f/f = 1/8$ in the memory regime. The sensitivity to the electric and magnetic components was 5×10^{-7} W mHz$^{-0.5}$ and 10^{-5} nT Hz$^{-0.5}$, respectively. The dynamical range was 60 dB. Narrowband registrations data were used in the work.

3. Impedance probe (IP-2) for measurements of electron density and its variations. The sensor of the radio-resonance probe was a 1 m long pin included as a capacity into the HF generator contour. The generator operated at a frequency of ~5 MHz. At changes in the plasma density, the capacity of the contour changed and so changed its resonant frequency. The time constant of the device was determined by the HF filter and was ~15–20 ms. The spatial resolution of small-scale irregularities in the ZAP-4 regime was 1.5 km.

4. High-frequency probe (KM-9) for measurements of the electron temperature within the 600–5000 K range. The accuracy of measurements was up to 50 K.

Moreover, additionally the electron gas pressure was calculated using the formula $P = Ne\,k\,T$, where k is the Boltzmann constant.

The database of the Cosmos-1809 satellite was used. It was found that the information from the satellite in the memory regime with the reading rate of 2.56 s (ZAP-4) and total time of a switch on of ~17 h almost always contains a fragment of passage over the typhoon's zone. In the database considered by us, more than 70 typhoons were found. For the initial processing, 4 seances were chosen: January 23, 1989, February 10, 1989, February 11, 1989, and September 24, 1992. Table shows the data on typhoons in these periods.

3. MAIN RESULTS

The moments of the satellite passage over the Harry hurricane (forth category) in its intense development phase are the most interesting ones for the analysis. The data obtained during the nighttime flight of the satellite on February 10, 1989, were chosen and analyzed: orbit 10849 23.4° eastward, orbit 10 850 2.8°

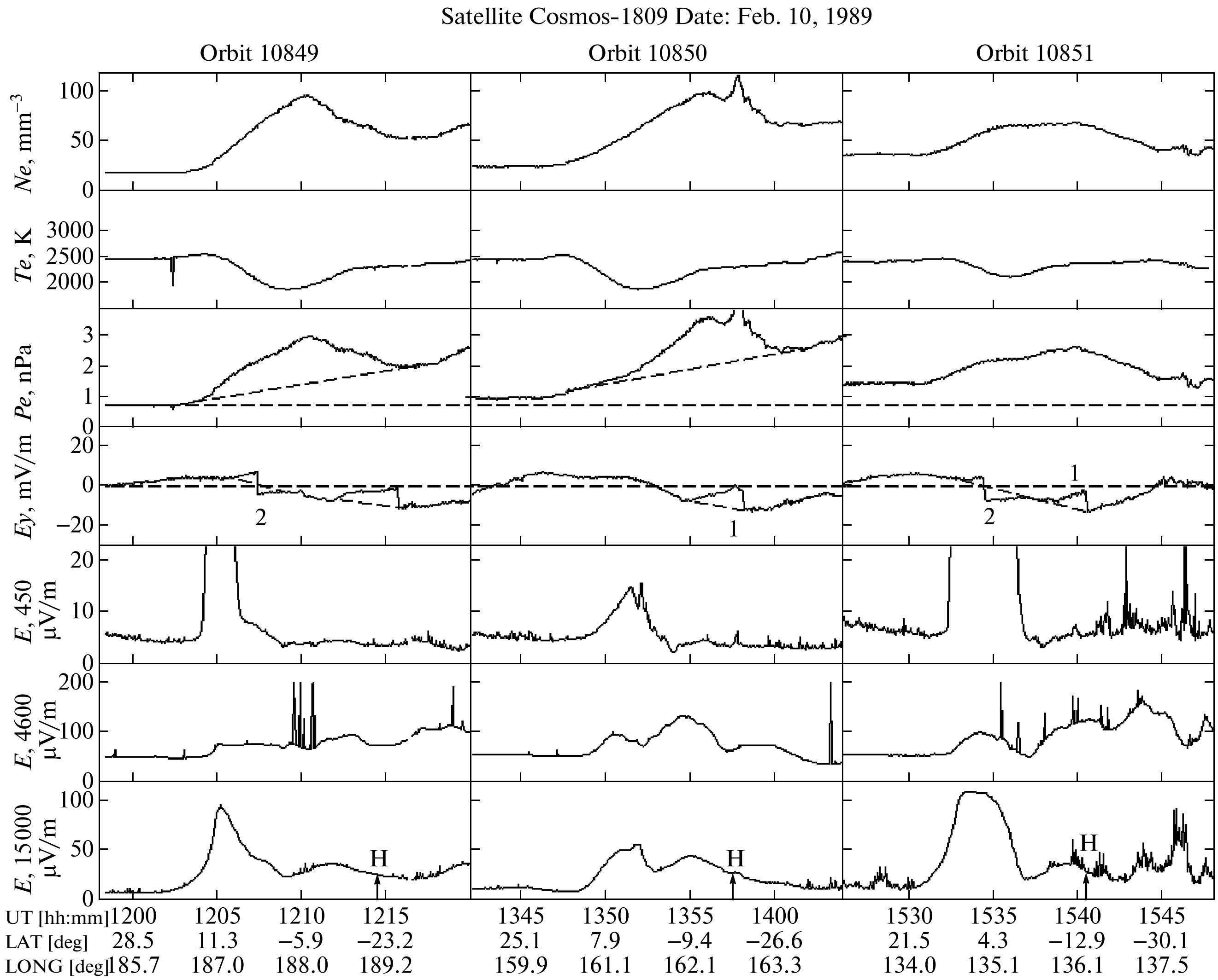

Fig. 1. Parameters of the plasma (h = 960 km) of the nighttime ionosphere (0036 LT) over the zones of the 4th-category hurricane Harry (19° S, 163° E) during its intensification and weakening hurricane Kirrily (28° S, 102° E).

westward, and orbit 10851 29° westward of the hurricane center, respectively. The local time at the equator for the chosen flights was 0036 LT. Figure 1 shows plasma parameters: the temperature and density of electrons, electron gas pressure, the *Ey* component of the quasi-constant electric field, and variations in VLF oscillations at frequencies of 450 and 4600 Hz. Besides the Harry hurricane, other hurricanes (Kirrily, Edme, and Firinga) were observed in the studied region. Arrows at the bottom panel mark the moment of passage of the hurricane latitudes and first letters of their names.

As a result of the analysis, the following peculiarities were revealed.

Over the tropical hurricane zone, an anomalous electric field (shown in the *Ey* panel by numeral 1) is formed which causes the upward drift of the plasma. Since a nighttime flight was chosen, the field does not penetrate into the magneto-conjugated region of the other hemisphere [Gdalevich et al., 1973]. Only in these regions of the anomalous electric field, strong (up to 8% at the 10 850 orbit) oscillations of the plasma density $\Delta N/Ne$ are observed [Isaev et al., 2002]. The total quasi-constant field (the *Ex* and *Ey* components) indicates to the eastward drift of the plasma in the equatorial region. The jump in *Ey* marked by numeral 2 corresponds to the moment of satellite passage over the geomagnetic equator and the induced potential difference changes sign.

Over the "eye" of a powerful typhoon at the satellite height, an upwelling plasma jet is observed to which the peak in the plasma density *Ne* in orbit 10 850 corresponds. Other peculiarities in changes of integral characteristics of the plasma are seen in the panel of

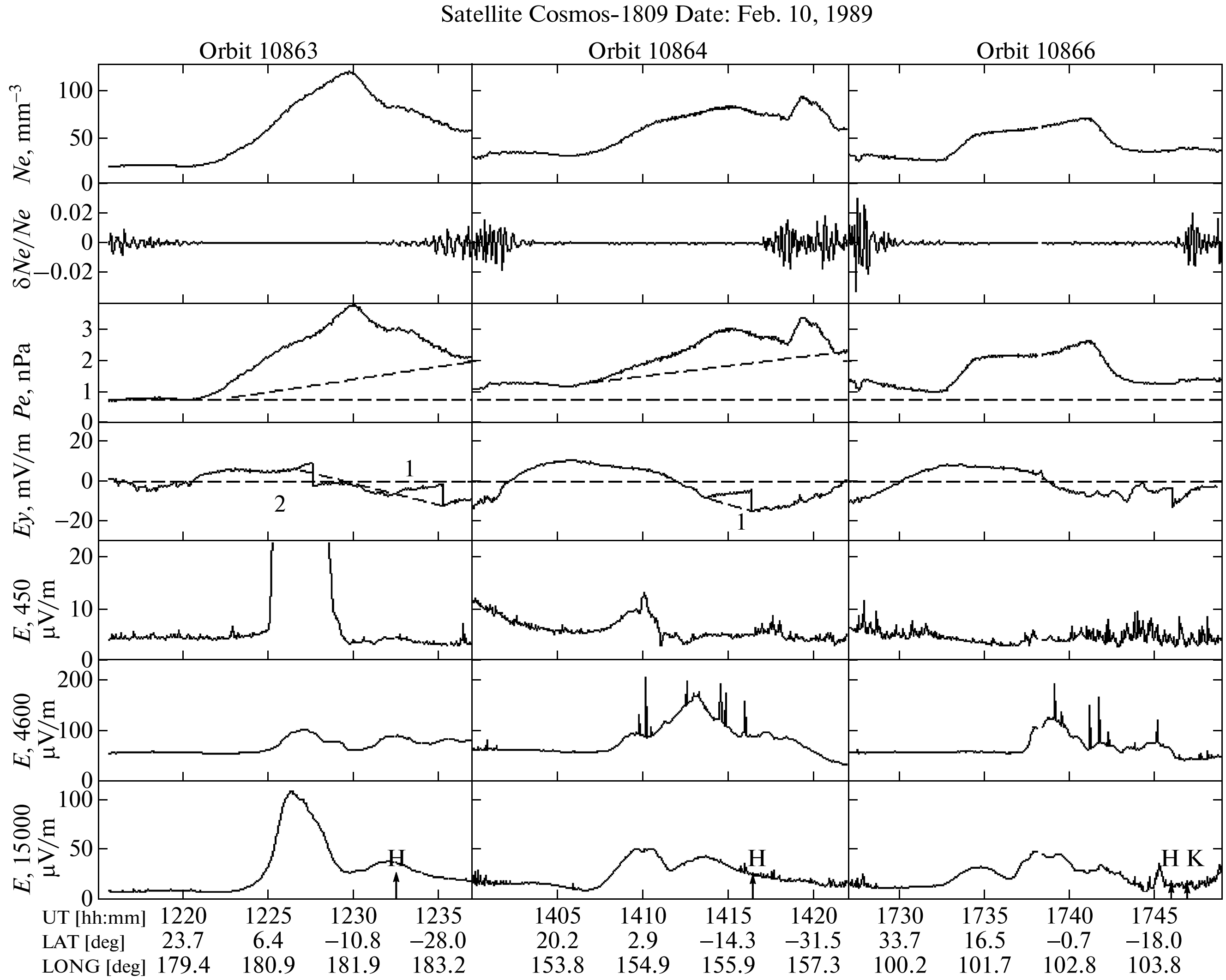

Fig. 2. Parameters of the plasma ($h = 960$ km) of the nighttime ionosphere (0027 LT) over the zones of the 4th-category hurricane Harry (20° S, 162° E) during its intensification and the transformed into storm Kirrily hurricane (28° S, 102° E).

the electron gas pressure. The zone of anomalous pressure is shifted relative to the geomagnetic equator, the latter fact making it possible to state the existence of the plasma pressure gradient (dashed oblique line in orbits 10 849 and 10 850 relative to line in orbit 10851). This indicates to the presence of an extra source of plasma disturbance in the Southern Hemisphere. The electron pressure increase in orbit 10 851 is apparently related to the impact of the Kirrily tropical cyclone.

In the panels of the VLF-oscillation variations, the following features are observed. A strong enhancement of propagation of non-canalized whistlers at a frequency of 450 Hz due to intense thunderstorm activity in the Southern Hemisphere leading to anomalous increase in oscillations at the cyclotron frequency of hydrogen in the magneto-conjugated region of the other hemisphere (the 450 Hz channel). The same cause leads to a sharp change in the intensity of potential oscillations near the lower hybrid resonance (is registered in the 4600 Hz channel).

On the next day, the Harry hurricane conserved the maximum intensity and was shifted by 2° south—westward, whereas the intensity of the Kirrily tropical cyclone began to decrease. The satellite flied over the hurricane zone 4° westward and 6 min earlier by local time relative to the previous day. Figure 2 shows the results of measurements in two orbits 10 863 and 10864 nearest to the Harry hurricane and in orbit 10866 passing the Kirrily hurricane zone (28° S; 102° E).

In the nighttime sector (0030 LT) in the vicinity of the Harry hurricane, the picture similar to that in Fig. 1 is observed. The extra plasma which came as a result of the vertical drift caused by the anomalous

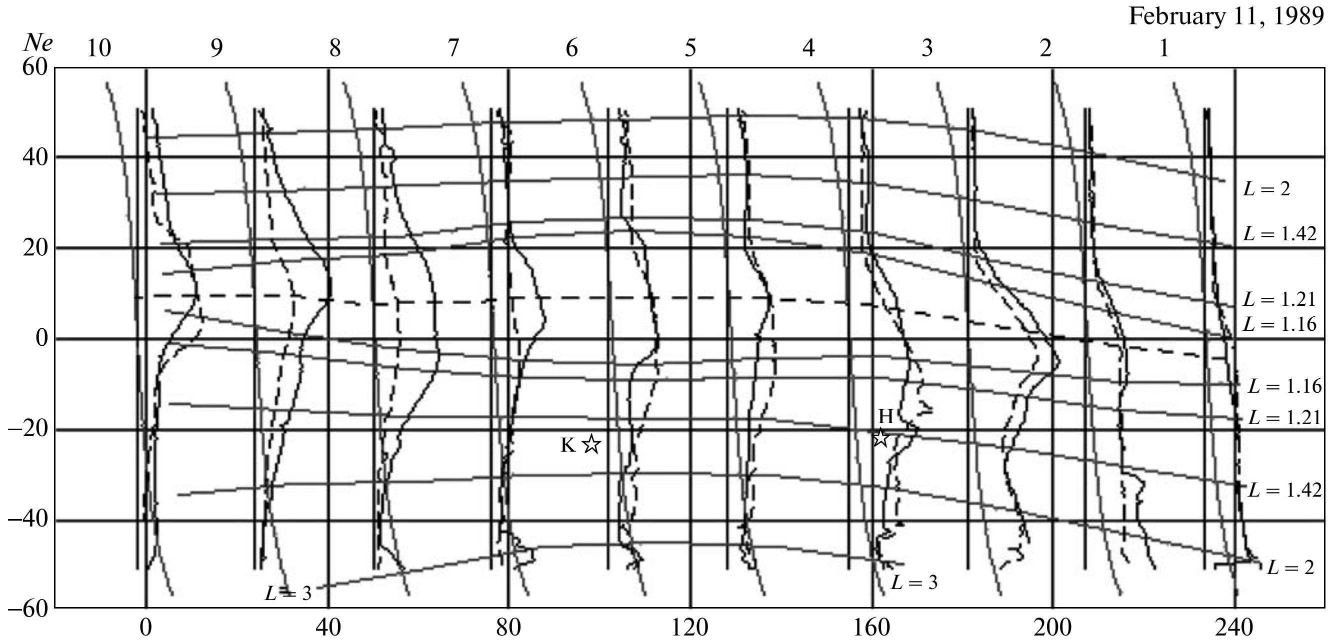

Fig. 3. Chart of the nighttime plasma density along the satellite trajectory on February 11, 1989 (thick curves) and February 10, 1989 (dashed curves; shifted westwards by 6°). Positions of the Harry and Kirrily hurricanes are marked by asterisks.

electric field over the tropical cyclone zone (panel *Ey* in Fig. 1) is shifted eastwards (panel *Ne* in Fig. 2). The 10863 orbit passed by 5° closer to the center of Harry than orbit 10 849. At that, the minimum distance was 18.9° and the observed maximum of the electron density was by 40% higher than in orbit 10 849. Orbit 10864 passed 6.4° eastward of the center of the Harry tropical cyclone, where still upwelling plasma flows are observed, but their intensity is by a factor of 2 weaker. It should be noted that the structured flow which was observed in orbit 10 850 over the hurricane center ($L = 1.41$) in orbit 10 864 is seen at a latitude of 28.5° ($L = 1.78$) where the hurricane was shifted to a few days later.

Over the zone of the decaying tropical cyclone Kirrily (orbit 10 866) in the topside ionosphere, a redistribution of the extra plasma almost symmetrically to the geomagnetic equator occurs in the ±15° region.

The second horizontal panel in Fig. 2 shows the electron density fluctuations. The facts attracts attention that the entire field tube over the anomalous electric field zone and upwelling jet is disturbed, and the disturbances are observed also in the magneto-conjugated region. It is evident that the maximum disturbances are related to the jet. Earlier (on February 10, 1989) such disturbances were detected only in the Southern Hemisphere.

The temperature profiles of electrons along the trajectory did not change. Colder (by 500 K) electrons are observed at inner *L* shells relative to the zone of irregularities ($L < 1.23$) in the same way as in Fig. 1 and so are not presented here.

The quasi-constant electric field in orbit 10866 over the Harry hurricane impact zone has a complicated interference picture.

Figure 3 presents the electron gas density during the nighttime flights of the satellite in ten consequent orbits on February 10, 1988 (orbits 10847–10856) and February 11, 1988 (orbits 10861–10870) shown by dashed and thick curves, respectively. The scale of the density graph at each flight coincides with the scale in Figs. 1 and 2 relative to the vertical line passing though the point of crossing of the equator by the satellite trajectory. In order to reveal the changes having occurred during the day, the electron gas density graphs (dashed curves) in orbits 10847–10856 were shifted by 6.5° westward of their true position. Figure 3 shows also some of the *L* shells at the satellite height and the geomagnetic equator (dashed curve). Stars and letters show the position of the Harry and Kirrily typhoon centers.

The increase in the electron gas density within the radius of approximately 1000 km over the typhoons which was noted describing Figs. 1 and 2 here is pronounced more distinctly. In addition, Fig. 3 indicates that during this day a substantial increase in the plasma density in the 25°–78° E zone occurred symmetrically relative to the geomagnetic equator. The data at the orbits marked by No. 1 show that if the geomagnetic equator is located southwards from the geographic one, in February in the Southern Hemisphere at night

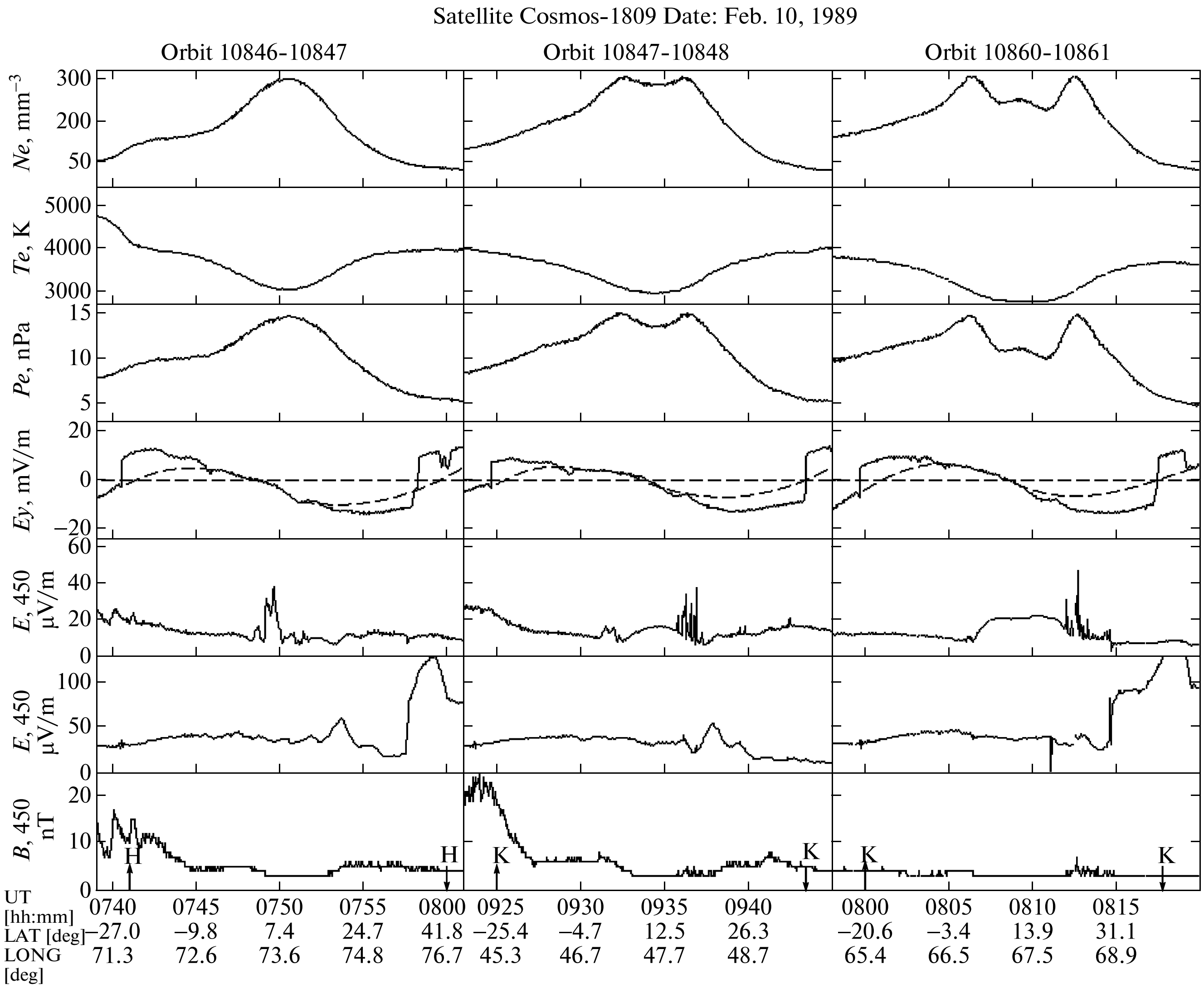

Fig. 4. Parameters of the plasma ($h = 960$ km) of the daytime ionosphere (1240 LT) over the zones of the Kirrily hurricane (28° S, 102° E) on February 10 and 11, 1989.

in comparison with the Northern Hemisphere there is observed an excess in the density and, respectively, pressure of the electron gas with a linear increase along the trajectory in the considered region.

More complicated picture is observed in the daytime ionosphere. At the daytime flights of the satellite, energetic photoelectrons appear, the typhoon intensity decreases, and the influence of various man-made factors (for example, operation of powerful radio transmitters) increases. On February 10 and 11, 1988, the satellite equipment was switched on during 16 h, and the daytime flights passed westwards from the 90° E meridian, near the zone of the Kirrily typhoon development. Figure 4 shows the results of measurements at the orbits closest to the Kirrily typhoon. In the bottom panel, the upward arrow and letter "*K*" correspond to the moment of the satellite flight over the typhoon latitude, whereas the downward arrow corresponds to the flight across the magneto-conjugated L shell. The distribution of density and temperature of the daytime equatorial ionosphere (1242 LT) at a height of 960 km is typical for the considered region. The extremes in *Ne* and *Te*, as they should be, are observed at the geomagnetic equator, whereas no substantial features related to the typhoon are seen. Only the jump $Ey = 10$ mV/m at the latitude of the Kirrily typhoon at 25° S ($L = 1.67$) indicates to an extra source of the electric field which is directed equatorward along the meridian. The disturbed field is extended down to the magnetic shell $L = 1.19$ which rests on the E layer over the Kirrily typhoon. This L shell is slightly lower in the nighttime ionosphere (Fig. 2), this fact corresponding to a decrease in the E-layer height by 5–10 km. The magnetic shells in the

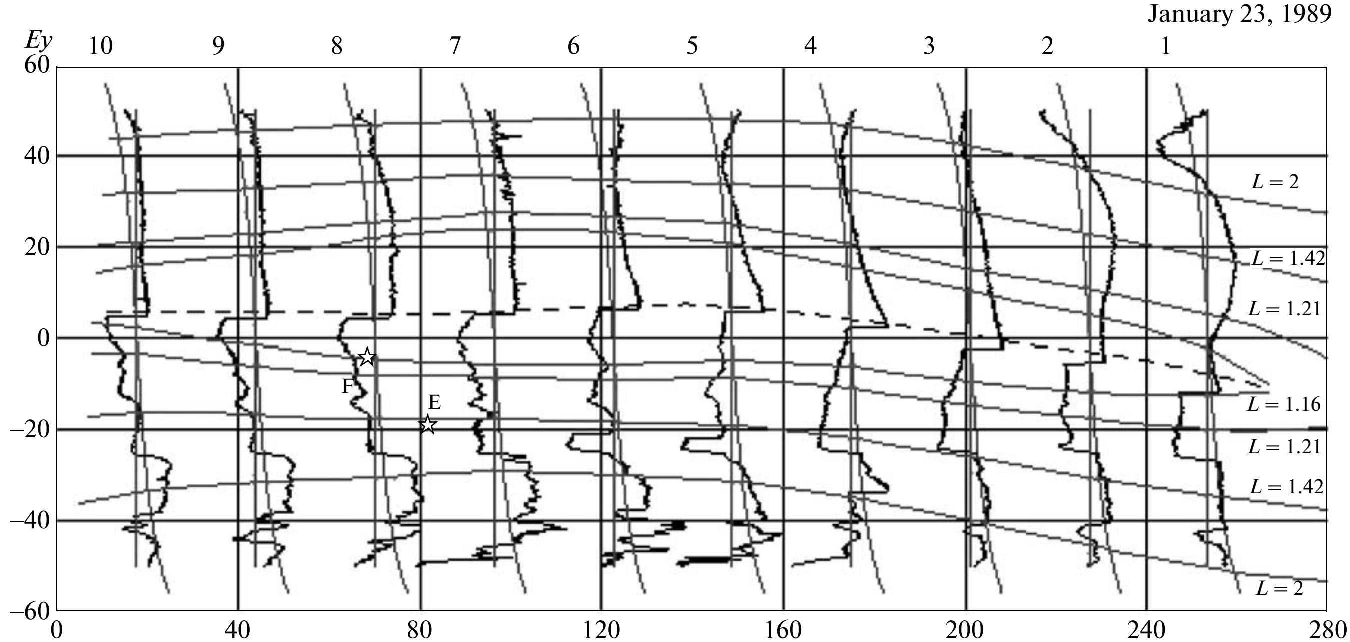

Fig. 5. Electric field in the nighttime ionosphere (0246 LT) in projection onto the horizontal axis under an angle of 45° to the satellite velocity vector. Positions of the Edme and Firinga hurricanes are marked by stars.

daytime ionosphere become quasi-potential and in the magneto-conjugated region a mirror field is observed also directed equatorward along the meridian. The distortion of the field picture at the midlatitude boundary is apparently related to the entrance of the satellite into the zone of the influence of the Novosibirsk radio transmitter.

In the low-frequency measurements presented in the bottom panels in Fig. 4, over the developed typhoon a peculiarity only in the magnetic channel at a frequency of 450 Hz is seen. Oscillations at the cyclotron frequency of hydrogen come to this channel. The sharp jump in the *E* 4600 Hz channel is often related to the acoustic impact on the ionosphere (see, e.g., [Kostin and Murashev, 2002]). The electrostatic turbulence at frequencies of the *E* 450 Hz channel within the 15°–20° N latitude region over Aden is most probably related to one of nonlinear mechanisms, e.g., discussed by Gurevich [2007].

The next four pictures show the reaction of the ionosphere on January 23, 1989, in different local time at the development of typhoons Edme and Firinga in the same region of the southern Indian Ocean. The Edme typhoon got the force of a hurricane 6 days ago, whereas the second tropical storm was transferred into the hurricane stage in the morning of the next day. The quasi-constant electric field provides a general idea on dynamical processes in the ionospheric plasma. Figure 5 shows the values of the horizontal component of the electric field *Ey* in ten consequent orbits (10599–10608) in the nighttime ionosphere at the equator (0246 LT). The measured value of the field is presented relative to the vertical line passing through the crossing point of the satellite trajectory with the equatorial plane in the same scale as in the previous figures. Stars mark the position of tropical cyclone centers.

One can see in Fig. 5 that in the equatorial and midlatitude ionosphere of the Northern Hemisphere, there are no disturbances of the field. Southwards from the geomagnetic equator (dashed curve) where the sharp change in the sign of *Ey* occurs, disturbances in the electric field are observed. The small shift of the field strength jump (a few degrees) relative to the geomagnetic equator in five–ten orbits is apparently related to the pitching angle of the satellite.

The jump in the electric field strength at a latitude of 25° S common for all orbits is related to the satellite exit from the Earth's shadow. Southwards from 34°–35° S, the satellite begins to cross the magnetic field tubes resting on the sunlit ionospheric *E* layer, and the strong changes in *Ey* are related to the plasma dynamics near the terminator.

The *Ey* trend along the trajectory between the jumps of the field strength of opposite signs at orbits 1–4 is related to the fact that in this region the magnetic field declination is eastward. The satellite crosses the magnetic tubes resting on the ionosphere less sunlit than at orbits 7–10 where the magnetic field declination is westward.

The character of the electric field behavior in orbits 5 and 6 shows that at the latitude of the Edme typhoon, apparently, an eastward plasma drift takes

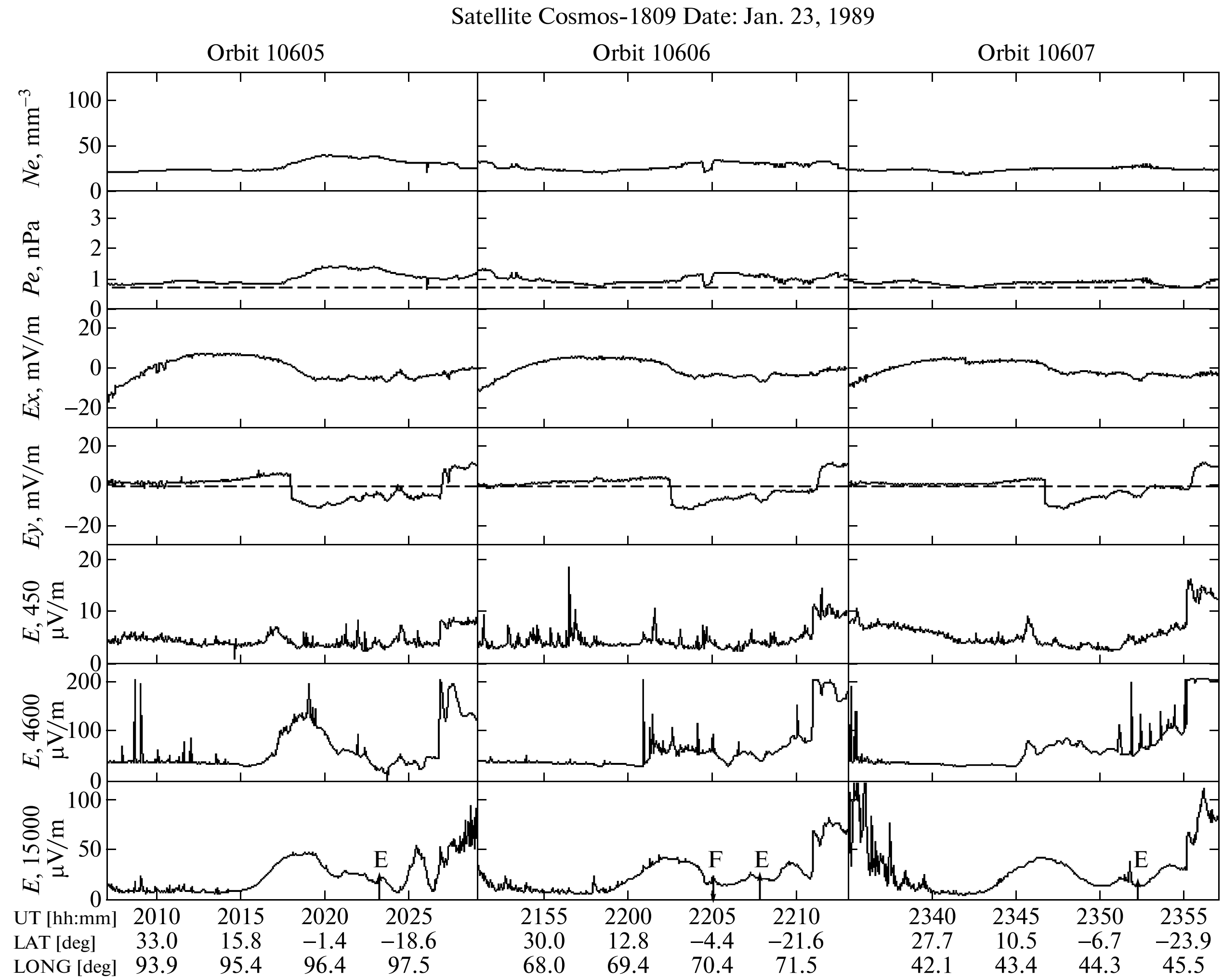

Fig. 6. Parameters of the plasma of the nighttime ionosphere (0246 LT) over the zones of the Edme (20° S, 80° E) and originating Firinga (11° S, 62° E) hurricanes.

place. One could conclude on a partial reversal in the *Ey* behavior. At the latitude of the originating typhoon Firinga, substantial disturbances in the electric field are also observed.

A detailed picture of the behavior of various ionospheric parameters in the vicinity of these typhoons is shown in Fig. 6. At the 10605 orbit passing by 18° eastward of the Edme typhoon, an extra peak in the electron density and pressure is seen shown by an arrow. The broad maximum in the electron density with an increase in the value by a factor of 2 extends southwards from the geomagnetic equator till the satellite exit out of the Earth's shadow. At the 10606 orbit passing through the originating typhoon Firinga in the zone with a dimension of about 200 km, a depletion of the density and pressure by 40% is observed (marked by an arrow and a letter *F*). In orbit 10 607, a small relative increase in *Ne* up to 50% is shifted to 20° S up to the zone of depletion of the pressure *Pe* related to cooling of the electrons prior to the morning terminator.

Note that the broad maximum in *Ne* with relative increase in the value by more than a factor of 2 was detected also in orbits 10599–10604 eastwards from the hurricane zone and coincided with the characteristic decrease in *Ey* (Fig. 5). At that, at these orbits from the geomagnetic equator to latitudes of ~40° S, a linear growth of the pressure *Pe* is observed. Orbits 10599 and 10602 where such increase begins substantially northwards (from latitudes of ~20° N, as in orbits shown in Figs. 1 and 2) present an exception.

The analysis of two components of the electric field *Ex* and *Ey* (Fig. 6) makes it possible to state that outside equatorial latitudes ($L \geq 1.6$) and at those latitudes the westward and eastward plasma drifts, respectively, are observed. The data of low-frequency measurements presented below show that in the zone of the originating typhoon in orbit 10606 the number of

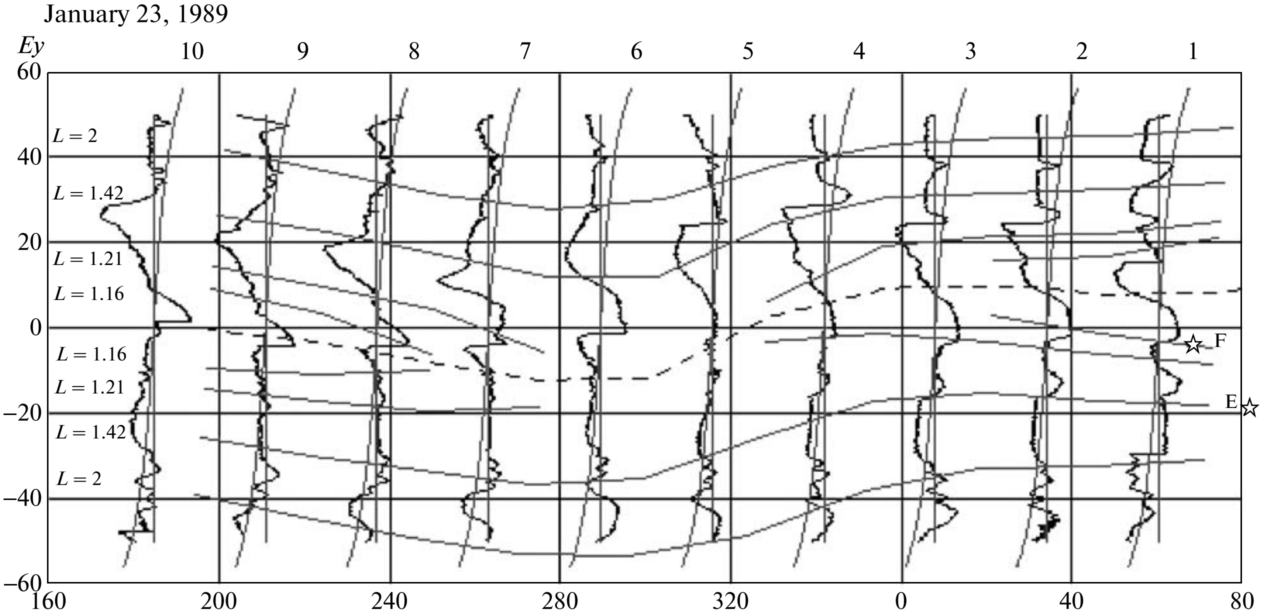

Fig. 7. Electric field in the daytime ionosphere (1446 LT) in projection onto the horizontal axis under an angle of 45° to the satellite velocity vector. Positions of the Edme and Firinga hurricanes are marked by stars.

intense thunderstorm charges penetrating into the topside ionosphere is larger than in the zone of the developed typhoon Edme (orbit 10605).

Figure 7 shows the *Ey* component of the electric field measured on January 23, 1989, in ten consequent orbits (10599–10609) in the daytime sector at the equator (1446 LT). The *Ey* component is shown relative to the vertical axis passing through the point of crossing of the satellite trajectory with the equatorial plane in the same scale as in the previous figures. Dashed curve shows the geomagnetic equator at the satellite height. One can see that several types of large-scale drift motions were occurring in the ionosphere. Some of them were at the typhoon latitude and in the magneto-conjugated region within a band ~80° wide westward from the region of typhoons. Their position is marked by stars. Other motions occur near the equator and have a global character, their intensification occurring at the 200–300° E meridians.

The detailed behavior of the plasma parameters in three orbits (10 599–10 602) is presented in Fig. 8. The number of a rising orbit changes at crossing the equator. Over the region of the originating Firinga typhoon at 1045 UT, a depression in the plasma density is detected which 12 h later was sharply structured and identified with the typhoon "eye" (Fig. 6).

The joint analysis of two components of the electric field indicates to a formation over the Edme typhoon zone of the westward horizontal electric field marked in Fig. 8 by an upward arrow. The field is transferred into the magnetically conjugate region of the Northern Hemisphere (shown in the panel by downward arrow). There is a vertical component in this region directed Earthwards along the magnetic field (panel *Ex*). In the geomagnetic equator region, the electric field changes its sign and has a meridional direction which corresponds to the eastward transport of the plasma.

The VLF-complex data presented in the bottom panels of Fig. 8 have the following features. The sharp jump of the *E* 4600 Hz component within the 20° S–30° N zone is related to the passage of IGW. Similar signals have been numerously registered on board the Cosmos-1809 satellite after the entering into the ionosphere of acoustic wave from underground nuclear explosions [Kostin and Murashev, 2002]. At the boundaries of these structures, an intense propagation of whistlers is observed. The intensification of cyclotron oscillations of hydrogen ions (channel *E* 450 Hz) coincides with the equatorial plasma motion. This effect is observed also at the absence of typhoons. The anomalous emissions at a latitude of 15° N near the 45° E meridian are related to the constant ground-based man-made source (Fig. 2).

Observation of other events confirms the results presented above. The measurements data obtained from the Cosmos-1809 satellite on September 24, 1992, were considered. On this day, 10 typhoons were registered on the Earth which are shown in table. The typhoon season in the Northern Hemisphere ends in September and typhoons begin to develop in the Southern Hemisphere. At the rising and descending orbits on September 24, 1992, the satellite crossed the equator at 0938 LT (the dawn sector) and 2138 LT (the

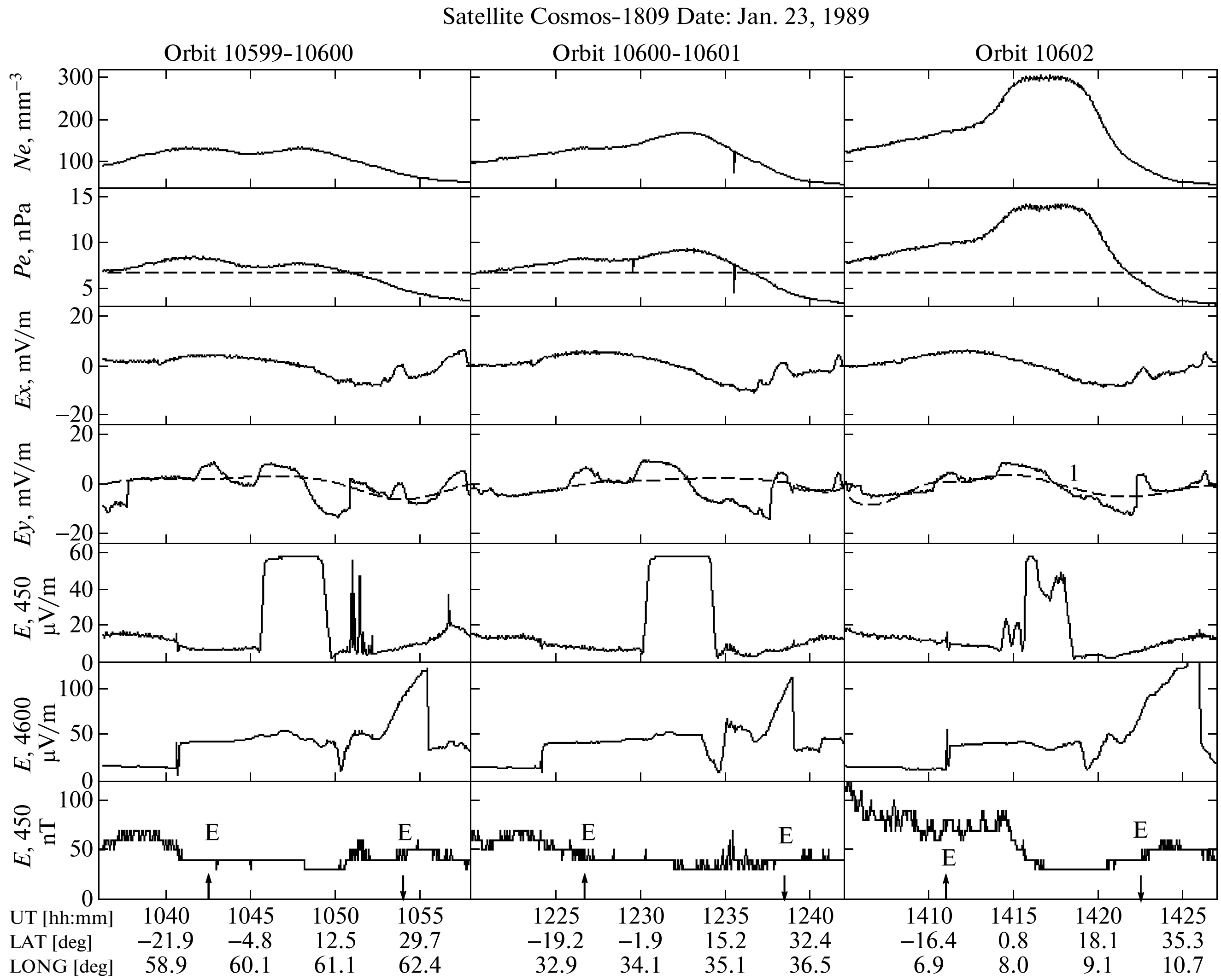

Fig. 8. Parameters of the plasma of the daytime ionosphere (1446 LT) over the zones of the Edme (20° S, 80° E) and originating Firinga (11° S, 62° E) hurricanes.

dusk sector), respectively. In the dawn sector, the satellite was sunlit, whereas in the dusk sector it stayed in the Earth's shadow, the shadow height changing from 1400 to 5000 km.

Figure 9 shows the measurements in three orbits over the Indian Ocean in the dawn sector. The orbits in the region of formation of the Aviona typhoon were selected. A day prior to its registration, according to the ground-based observations over the tropical depression zone in the ionosphere a strongly structured depletion of *Ne* with strong fluctuations Δ*Ne* (middle panel) is observed. The broad maximum in *Ne* in the first panel, most probably, is related to the impact of the Ted and TC05B typhoons. According to the VLF measurements, a strong thunderstorm activity is detected in the Northern Hemisphere.

The analysis of the chain of six typhoons in Northern Atlantic and in the eastern Pacific Ocean needs a special consideration, because in North America there are many man-made sources influencing the ionosphere.

Figure 10 shows changes in the plasma parameters in the topside ionosphere on September 24, 1992, in three orbits after passing the evening terminator. According to the VLF data, in orbit 29 120 which passed over the strong Ted typhoon (37° N, 134° E) in the zone from 20° N to 30° S, a jump-like increase in the *E* 4600 Hz channel and decrease in the *E* 450 Hz channel are observed. This effect could be related to the uplifting of oxygen ions and displacement of hydrogen ions by the acoustic wave. In the next orbits 29121 and 29122 passing over the weaker typhoon TC05B (22° N, 90° E) and the region of the Aviona

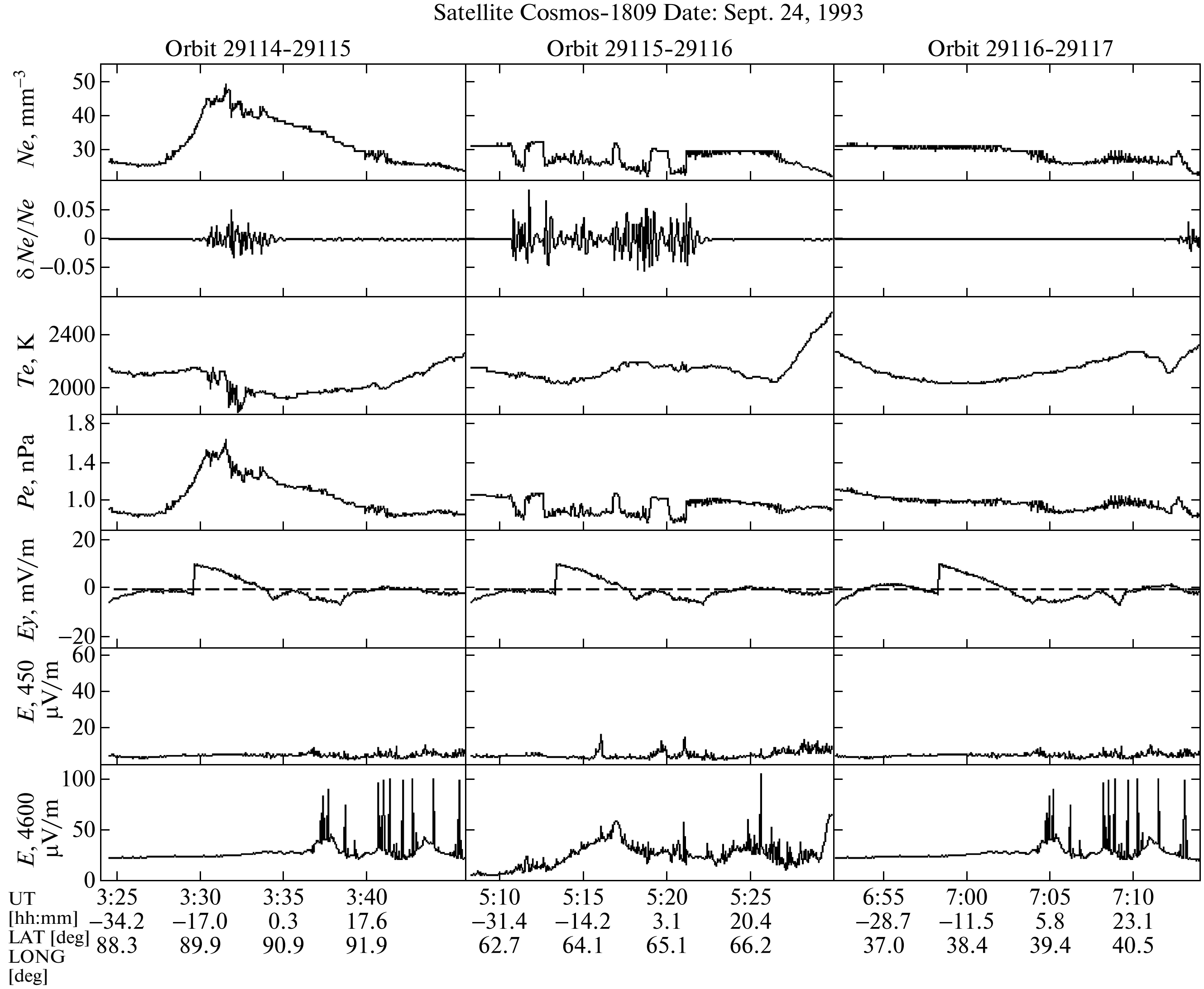

Fig. 9. Parameters of the ionospheric plasma in the dawn sector (0938 LT) in the vicinity of the TC05B typhoon (22° N, 90° E) and of the formation of the "eye" of the Aviona typhoon (4° S, 84° E).

typhoon formation (4° S, 84° N), no such impact is observed.

4. CONCLUSIONS

The results obtained confirm a strong interrelation between typhoons and the ionosphere.

1. The upwelling jet of the neutral atmosphere in the "eye" of a strong typhoon reaches at night heights of ~1000 km, this fact being manifested by the peak in *Ne* and corresponding structure of the electric field localized over the typhoon.

2. Dynamical processes within typhoon structures cause in the nighttime ionosphere in the region with a dimension of more than 1000 km a substantial increase in the density of the plasma drifting eastwards with a broad maximum shifted from the geomagnetic equator in the direction of the typhoon.

3. In the topside ionosphere over the region of a tropical storm one day prior to the transition to the hurricane stage, a formation of a cavity in the plasma density and pressure with scales of ~200 km and a depth of 40% is observed.

4. This very extra income of the neutral component into the ionosphere at the nighttime intensification of a typhoon and its transport by the westward zonal wind lead, apparently, in the daytime conditions to the increase in the equatorial plasma maximums in the regions localized westwards from typhoons.

5. The observational data confirm intensification in the thunderstorm activity prior to the typhoon intensification.

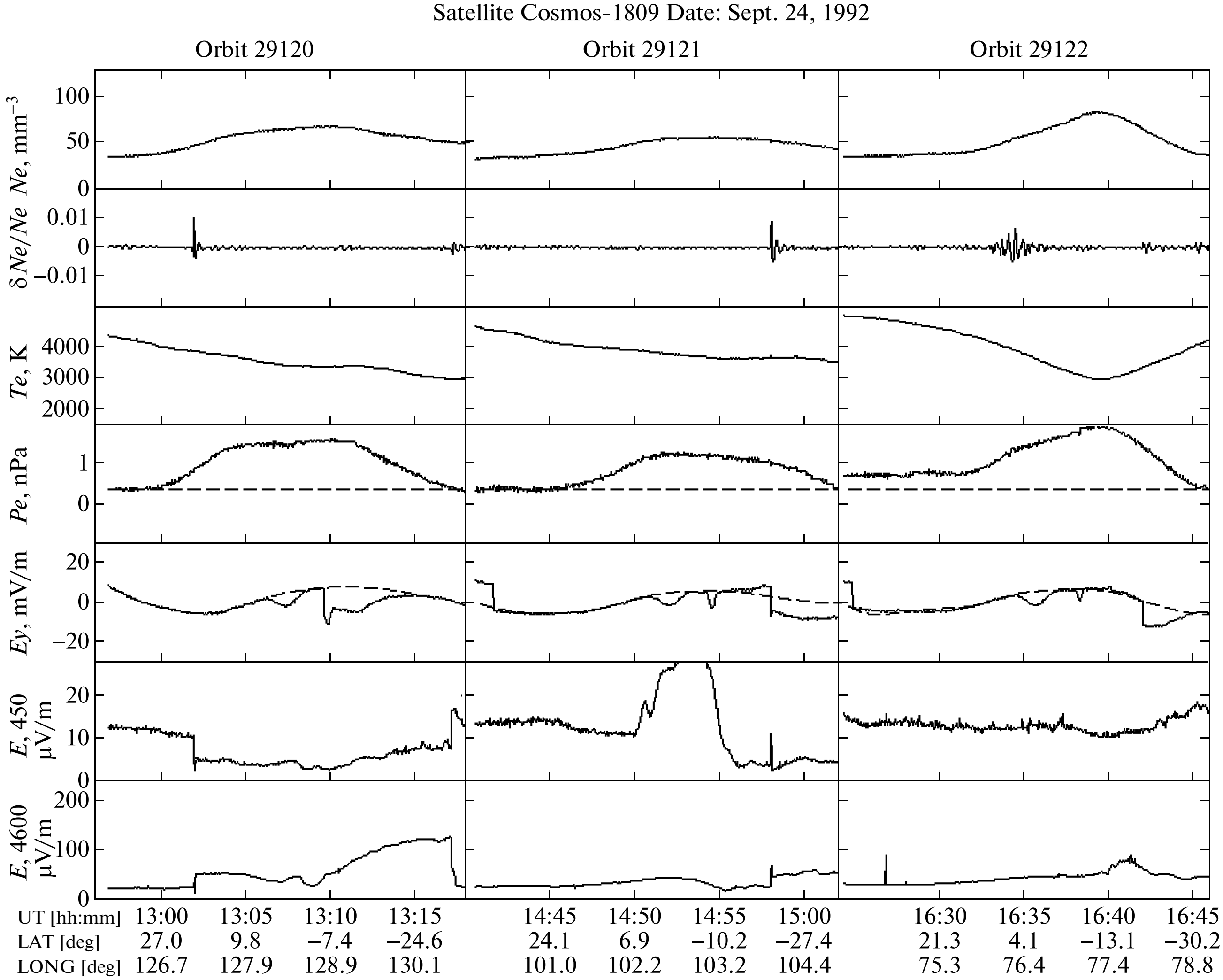

Fig. 10. Modification of the plasma over the zones of the Ted (37° N, 134° E), TC05B, and Aviona hurricanes after the passage of the evening terminator (2138 LT).

6. Satellite measurements show irregular sharp changes in the VLF-oscillations spectrum in broad regions over the typhoon zones. One could relate this to the action of internal gravity waves.

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