Modification of the ionosphere near the terminator due to the passage of a strong tropical cyclone through the large Island

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Abstract. Earlier by the authors according to the Intercosmos Bulgaria-1300 and Cosmos-1809 satellite data it's been shown that the ionosphere is modified above the tropical cyclones (TC). Local perturbations of the plasma density, the appearance of the electric fields and the development of ELF-VLF zone of turbulence were observed. These effects were due to the injection of up stream of neutral particles from TC. In this paper the data of the Cosmos-1809 satellite when tropical cyclone Harry (1989) passed through the island of New Caledonia was examined. Influence of evening and morning terminators on the structure of the ionosphere from TC was discussed. It is detected: 1 - the appearance of latitude belt (up to 5000km) of structured perturbations in the night ionosphere; 2 - simulation in the illuminated ionosphere of periodic oscillation of the electric field with a scale ~ 400 km, passing beyond plasma pause. Model for the formation above TC in the lower ionosphere vertical submerged jet that injects neutral particles of different varieties into the upper ionosphere on ballistic trajectories was proposed. Changing of the ionization of neutral particles near the terminator and the deviation of the jet under the interaction of the TC with the island are confirmed in the proposed model.

Keywords: satellite, external ionosphere, tropical cyclones, island, terminator

Introduction

Currently, the basic physical processes that lead to the formation of hurricanes or typhoons, are well known, for example, (Holton et al., 2003). The World Meteorological Organization (WMO) provides information about the cyclone, obtained at the centers that control their dynamics. All of these materials and references to works can be found on the websites http://www.wmo.int,
http://climate.gstc.nasa.gov,
http://www.nhc.noaa.gov/climo,
http: / / www.usno.navy.mil.

Recently, a fundamental monograph on Tropical Cyclones and their space monitoring (Bondur and Krapivin, 2014) was published. Earlier, the perturbations of the upper ionosphere caused by TC were studied by the authors (Isaev et al., 2010), (Belyaev et al., 2011; 2012) according to satellite Cosmos-1809 and Intercosmos Bulgaria-1300 data, and an extensive bibliography was presented. In the authors works it was suggested that in some cases, changes in the electron density Ne, temperature T_e, the electric field oscillations at frequencies ≤ 20 kHz can be explained by an additional supply of the neutral particles of the atmosphere at the height of the ionosphere and its ionization.

TC intensification takes place, if in the process of self-organization of TC altitude anticyclone is formed at the tropopause over the center of the depression and the rising jet of neutral particles (convection) consistently achieves greater heights. In this case, the harbingers of a solitary TC strengthening can be found in the ionosphere, as shown below. In this paper an event when a solitary TC Harry (1989) amplified to IV category when passing through the large island of New Caledonia in the Pacific Ocean is covered in detail. Particular attention is paid to the hours when morning and evening terminator crossed the ionosphere structure above TC and magnetically conjugated area. The orbit of the Cosmos-1809 satellite in this period was in the midnight-noon plane. In these cases, if there is an additional supply of neutral particles to the height of the ionosphere, then its ionization will lead to abnormal structures that are not in this day at other orbits.

The structure of the ionosphere above the terminator is complex (Gulyaeva, 1985), (Somsikov, 2011). An important element of this structure is the instability to the excitation of extremely low-frequency oscillations (Leonovich and Kozlov, 2012). An additional stream of neutral particles over a separate and strong TC is most noticeable on the terminator. The appearance of oscillations with characteristic scales of TC impact on the ionosphere can be expected here.

The periodic disturbances can be distinguished even at distances of 5000 - 7000 km from the TC meridian near the terminator separating unlighted midlatitude ionosphere from polar ionosphere. Wide belt of ELF-VLF fluctuations in the ionosphere resulting from the action of TC is given in a series of papers by the authors (Mikhailova et al., 2002).

Currently, investigations of TC impact on the ionosphere using GPS sounding are conducted. In the paper a sharp change in the wave spectrum of electron content in the ionosphere above the strongest hurricanes in the water area of the Atlantic Ocean in 2004-2008 when passing Cuba island, the

Bahamas and the coast areas was shown in (Zakharov and Kunitsyn, 2012). The reaction of the ionosphere on the strongest hurricanes of V-category Rita (2005) and Vilma (2005) was analyzed in paper (Perevalova et al., 2011), and Katrina (2005) - in a series of papers (Bondur et al., 2008).

It should be noted that for interacting TC such as typhoons of V-category Page and Owen (1990) the $\mathbf{N_e}$ structure in the ionosphere is changed in another way (Belyaev et al., 2011). Important results on energy features of multiple tropical cyclogenesis according to multispectral satellite observations are given in (Sharkov et al., 2011).

Experimental data and discourse

Map of cyclone motion was taken from the www.meteo.nc/cyclone/site.

The experimental data presented below can be interpreted together if we assume that self-organization of the TC is enhanced by increasing of the vertical transport of neutral particles.

The initial development of the TC takes place at the heights of the tropopause. The significant strengthening of the vertical flow happens when the air in the stratosphere over the TC was warmed up and stratospheric anticyclone was formed.

High-altitude discharges modify the composition of the mesosphere, and the arising IGW are propagated upward. Calculations show that at high amplitudes of IGW self-structuring process begins and nonlinear vortex structures are generated in inhomogeneous ionosphere (Aburjania et al., 2013). If the horizontal wind penetrates into the structure, then it deflects IGW from vertical downwind.

In aerodynamics and hydrodynamics the movement of the flow in the environment is usually treated as a submerget jet (Landa, 1996), (Broman and Rudenko, 2010). The stability of this structure is due to the excitation of surface waves propagating along the jet, and in the direction to the source it is due to the excitation of volume infrasonic waves. We shall consider an upward stream of neutral particles above the stratospheric anticyclone as a vertical submerget jet.

Acoustic beam heats the medium due to partial loss of its energy. Temperature increases and the environment becomes with the lens-like properties (Rudenko and Sapozhnikov, 2004). If rising submerged jet taking into account the boundary layer forms the nozzle then particles will be accelerated at the outlet. In this case, if the jet is blown by the latitude wind and its lower part is slowed by the Island the resulting structure as a whole under the action of the moment of forces will be deflected along the meridian. This situation is shown in Fig. 2.

This takes into account that at a height of more than 230 km the motion of the neutral gas particles can be regarded as the motion of individual non-interacting particles emitted on ballistic trajectories with the most likely directional speed $\mathbf{V_T=(2kT/m)^{1/2}}$. This probable speed at $T=1000^0K$ is for oxygen $\mathbf{V_O}$ = 1016 m/s, for helium $\mathbf{V_{He}}$ = 2038 m/s, for hydrogen $\mathbf{V_H}$ = 4076 m/s. Accordingly, the oxygen atom can reach the height of 52 km, helium - 208 km, and of hydrogen - 831km from the injection height of about 230 km. In the diagram it is assumed that the thermal variation of the emitted particles is much smaller than the directional velocity.

To avoid cluttering the figure the departing particles of the return jet boundary layer are shown schematically above and to the south of this layer. Directed velocity of neutral particles of the boundary layer is less than the velocity of the jet. They cross the sloping jet and fall closer to the injection region. Only the particles from the southern boundary of the jet can be caught in a remote region of the boundary layer.

Vertical winds in the lower ionosphere with velocities of hundreds of km/s on scales of hundreds of kilometers have been observed previously. Large vertical velocities in the equatorial ionosphere up to 10^3 m/s were recorded for the ions in the structures of bubbles. Selection in the neutral component of narrow beams in the upper ionosphere with velocities close to the most probable represents the experimental difficulties. Let us consider the some effects of such beams, which may explain the observation of electromagnetic effects above TC from satellites. Consider the following situations:

1. The growing TC which moves freely in the ocean.

Earlier in (Isaev et al., 2010) the parameters of the ionosphere in the vicinity of the IV category TC Harry were considered in detail the day before it crossed the island of New Caledonia.

It is known that the intensification of TC takes place at night. Therefore, an additional $\mathbf{N_e}$ peak in the zenith above the center of the TC is allocated at night when the illumination of the upper ionosphere falls the various instabilities are developed, in particular, self-organization processes can take place above stratospheric anticyclone. Criterion is weakened if the temperature of the neutral particles in the thermosphere above TC is higher than outside it. This peak was observed on a few TC during their gain from II to IV category: Tina (1992) Fig.1 (Belyaev et al., 2012), Harry (1989) Fig.1, 10850 orbit, (Isaev et al., 2010), Sina (1990) (Belyaev et al., 2011). These peaks are the typical harbingers of a solitary TC strengthening. It should be noted that if $\mathbf{u_z}$ is less than $\mathbf{(2gh_{sat})^{1/2}}$, then smoothed $\mathbf{N_{0h}}$ feature is located below satellite $\mathbf{h_{sat}}$ altitude. In this case $\mathbf{N_e}$ peak is shifted to the equator.

2. TC Harry passage of New Caledonia.

Analysis of ionosphere disturbances above the largest hurricanes 2004-2008 in the Atlantic Ocean using GPS - interferometry method has shown that the strong turbulence and AGV disturbances are observed during the TC passage of Cuba Island, the Bahamas and the coast areas (Zakharov and Kunitsyn, 2012). The plane of the descending orbit of the Cosmos-1809 satellite on February 11, 1989 passed through the midnight sector. The observed perturbations in the

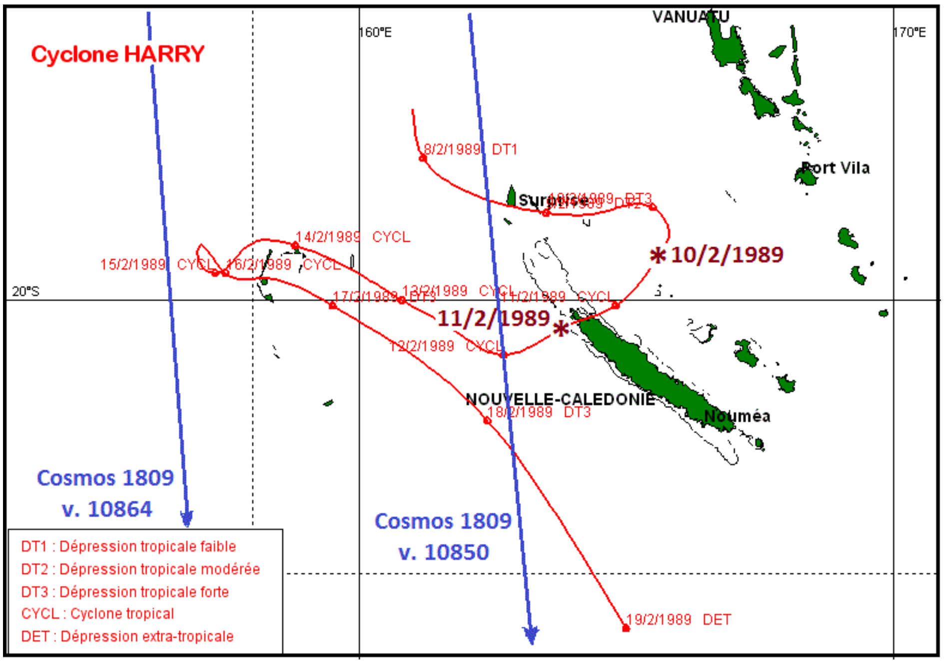

Fig.1. Trajectory of the cyclone Harry and nearest orbits of the Cosmos-1809 satellite was shown. Asterisks mark the position of the TC and the corresponding date.

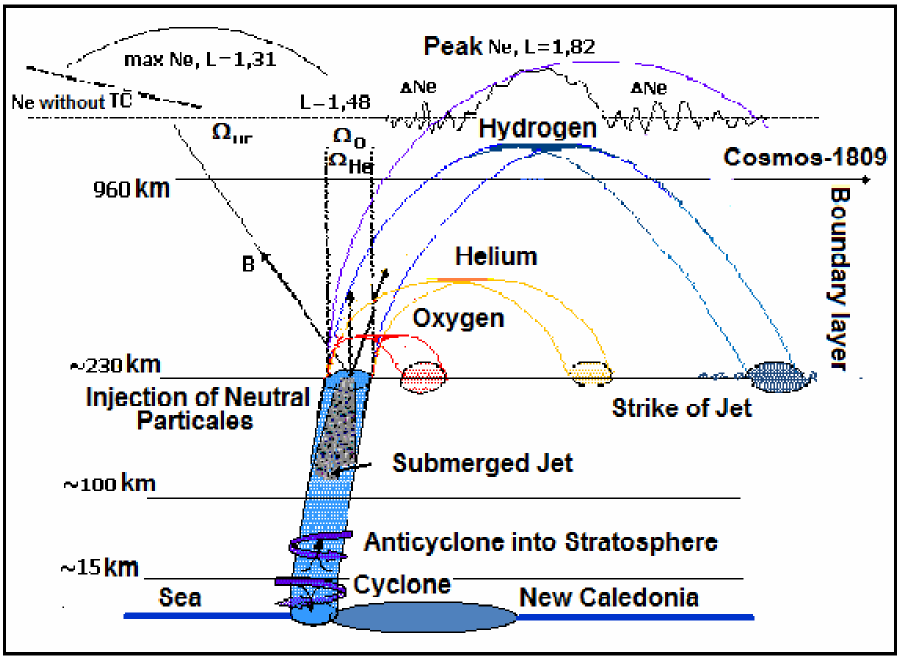

Fig. 2. Scheme of the impacts on the ionosphere TC Harry while passing the island of New Caledonia.

upper ionosphere were significantly dependent on the relative position of the TC and the satellite:

A) TC near the plane of the 10864 orbit.

On February 10-11 TC Harry moved from east to west (Fig. 1). There is a moment of forces due to deceleration of the TC base by island, which deflects a stable rotating structure to the south. Neutral particles (oxygen, helium, hydrogen) emitted at the same angle but at different speeds from a height of about 230 km will return to the lower ionosphere at different distances from the point of departure. Different spatial structure and oscillations of the plasma density can occur on the terminator because there is the additional ionization of neutral particles of the jet.

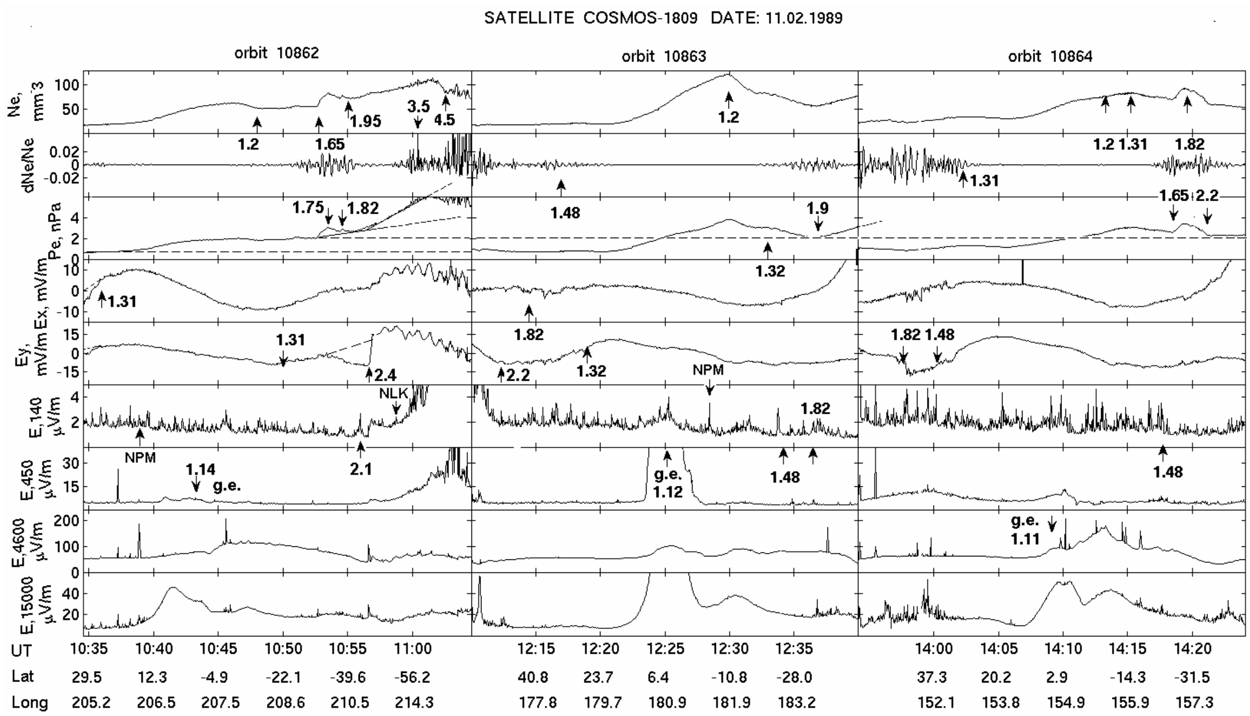

Fig. 3. Modification of the nighttime ionosphere plasma (LT = 00:27) in the eastern sector of the passage of TC Harry through New Caledonia.

If hydrogen atoms will be injected in a jet with the most probable speed at an angle of 20 degrees to the vertical then data of all devices can be collected as shown in Fig. 3.

The main structural formations in the ionosphere caused by the influence of the TC are marked by arrows. The numbers correspond to the L - shells:

L = 1.48 – the projection of the center of TC to the latitude, where increasing of $\mathbf{O^+}$ и $\mathbf{H_e^+}$ cyclotron oscillations were observed;

L = 1.82 – the center of additional $\mathbf{N_e}$ peak width ~ 800 km;

L = 1.2 – the main max of $\mathbf{N_e}$ is deflected from the geomagnetic equator;

L = 1.31 – the maximum of $\mathbf{N_e}$ is projected along the magnetic field on the latitude of TC which reaches height of $\mathbf{h_{in}}$ = 200 - 230 km;

g.e. – the satellite passage of geomagnetic equator.

Additional arrows and VLF transmitter abbreviation were placed above the separate anomalous ELF-VLF bursts. Arrows up correspond to the satellite passage of the L - shell, which is based in the lower ionosphere at latitude of zenith of transmitter and arrows down correspond L - shell in the conjugate ionosphere. Only VLF transmitters are marked remotely about 10° of longitude from satellite. Joint research of Cosmos-1809 and DE1 satellites above the RA-3 transmitter near Komsomolsk-on-Amur show that energetic particles were observed on the corresponding L - shell, and the perturbations from the Cosmos-1809 satellite are appeared in the E140 Hz channel most clearly (Sonwalkar et al., 1994).

It should be noted that the intensity of TC decreased to II category when passing New Caledonia, and it began to grow to IV category after passing.

The center of the additional narrow **Ne** peak shifts to L = 1.82 and the beginning of the peak shifts to L = 1.65. Its width is about 1200 km, which is 1.5 times more than the same width on the 10850 orbit (Isaev et al., 2010). The amplitude of the **Ne** fluctuations within the peak is 2-3 times lower than outside, where $\mathbf{\Delta N_e}$ is about 2%. The broad **Ne** maximum is located at L = 1.31 and it is projected to the magnetic field at the height of 230 km above the center of the TC. At the zenith above the TC in a strip about 300 km, adjoining to L = 1.48, there is a weak turbulence in the E450 Hz channel. This situation can take place if the concentration of helium ions decreases, which follows from Fig. 3. Accordingly, the damping of the oscillations will decrease near the cyclotron frequency of helium. The edges of the central TC area are limited with the bursts in the E140 Hz channel, where the amplitude is increased approximately 2.5 times. A reduced concentration of oxygen ions can be expected in these bursts. This requires the experimental confirmation.

In the magnetic conjugate region (1.48 ≤ L ≤ 1.82) four exactly the same peaks in the E140 Hz channel with the same period of about 300 km were recorded, and peaks are located in caverns of density. Observation of identical ELF fluctuations on the same magnetic shell, separated by opaque barrier, can be explained by the passage of ballistic waves (Krasovskiy et al., 1983). Photoelectrons from the peak will be able to provide such a link. Electrons on the shells of 1.31 ≤ L ≤ 2.6 are excited strongly that can be seen on the spectrum of turbulence in the E15 kHz channel.

The electric field is formed in the magnetic conjugate area (1.31 ≤ L ≤ 1.82). The electric field horizontal component riches up to 10 mV/m directed to the north-east and the electric field vertical component has small-scale peaks up to 2 mV/m. This electric field does not change the pressure of the electron gas, $\mathbf{P_e}$≈1 nPa. The average pressure is $\mathbf{P_e}$≈2 nPa after the geomagnetic equator in the southern hemisphere up to the latitude 45,17S (L = 3.39), after which the satellite is out of the Earth shadow. Here are the two areas. The first one is at 1.2 < L < 1.65 with a diffuse maximum at L = 1.31 and the second one is at 1.65 < L < 2.2 with a maximum at L = 1.82.

B) TC before the evening terminator, 10862 orbit.

Abnormal structure of the neutral component of the upper atmosphere above TC passing over the island of New Caledonia clearly is detected when the top of a submerged jet and its descending branch were illuminated by the sun near the evening terminator. At that time satellite was about 45 degrees to the east near the midnight meridian.

1. Let us define the following parameters of the jet: $\mathbf{V_H}$ - the speed of neutral hydrogen and **β** - the angle of deflection of the coming out jet from the vertical.

Select two regions of the 10862 orbit in the southern hemisphere at L < 2.4 where the sun shadow was over the satellite.

The first one is region where the returning neutral particles on the TC illuminated meridian will be moved along the magnetic field. Splash of drifting to the east photoelectrons should be observed here due to the increased ionization. Accordingly to the mentioned above splash we identify one in the E140 Hz and E15 kHz channels at the L = 2.1on 10862 orbit. Magnetic field is about 18.3 degrees to the vertical at this L-shell on TC meridian at a height of 230 km and 33S latitude. For further estimates we assume that **β** = 20°.

The second perturbed region (1.65 < L < 1.95) is associated with the drift of photoelectrons from area where jet neutral particles and boundary layer particles are down. It should be noted that this peak is shifted geographically at about 10° to the south and moved from the TC Harry meridian at the height of the satellite at the distance of about 5000 km. The center of this region is at L = 1.75. It intersects the latitude **φ** = 29.17 S on the TC meridian that bisecting the **Δφ** - central angle of average trajectories. Additional small $\mathbf{N_e}$ density peak at L = 1.82 coincides with the main peak at the 10864 orbit.

In the spherical geometry distance of the freely emitted neutral particle, which flies and falls at an angle **β**, can be calculated by the formula

$$s=\Delta\varphi \cdot R=\frac{R^2V^2\sin 2\beta}{gR_E^2}, \quad (1)$$

where RE=6370 km – radius of the Earth, R=6600 km, g=9.8 m/s, Δφ – central trajectory angle.

On February 11 satellite passed through the TC Harry zenith latitude at L = 1.48, which corresponds to the latitude of departure φ_o=21°S. The magnetic shell L = 2.1 is projected along the magnetic field at the latitude of the entrance φ_B=33°S. Such particles should fly a distance of s_H=1380 km and have a speed of $\mathbf{V_H}$=4400 m/c which corresponds to a temperature of atomic hydrogen T =1170° K.

In spherical geometry, the vertex of the parabola describing the trajectory of freely emitted particles can be calculated by the formula

$$h=\frac{R^2V^2\cos^2\beta}{2gR_E^2-RV^2\cos^2\beta} \quad (2)$$

Hydrogen atoms with specified parameters reached height h = 1090 km, that higher the satellite height per 360 km.

We assume that the other components of the neutral atomic jet emitted from height equal to 230 km with the same emission angles, but with their own most probable speed at the same temperature 1170° K. Then oxygen atoms come back from the point of departure a distance of s_O=86 km, and helium atoms return a distance of s_{He}=345 km. It can be assumed that the helium atoms form a periodic structure in the boundary layer and acoustic waves in the lower ionosphere with such scale. This scale will be increased to 383 km at the satellite height. Periodic disturbances of this scale can be seen most clearly in the electric field.

2. The features of the electric field at the evening terminator passage through the TC.

If a periodic structure arises in the neutral particles density at altitudes of lower ionosphere, when you turn on/off the ionization source (in this case, the passage of the terminator), periodic electric field should appear at the upper ionosphere height. Due to the electron drift to the east, this effect can be observed only on the satellite orbits, passing to the east of the TC meridian.

Indeed, when at 10:56:47 UT the satellite is out of the earth shadow, in the illuminated ionosphere quasi sinusoidal E_x and E_y components with the scale of ~ 400 km began to be registered. Synchronously with these components the VLF fluctuations amplitude in the E4600 Hz channel pulsed to the area of the plasma pause (L = 4.5). Increased growth of the plasma pressure $\mathbf{P_e}$ with changing of latitude (till L = 3.5) is observed here, which is associated with a linear increase of $\mathbf{N_e}$ and $\mathbf{T_e}$. Only on this orbit the linear growth of the magnetic component of the VLF noise in the H850 Hz channel is marked on this site, where the hydrogen cyclotron frequency was adjudged.

In the partially illuminated ionosphere by scattered radiation (1.65 < L < 2.4) a slow linear growth in $\mathbf{P_e}$ is due only by a linear increase in $\mathbf{N_e}$. The $\mathbf{T_e}$ is constant here.

Such growth was observed on the 10863 orbit when L = 1.82. Conditionally it is marked by the dotted line in the adjacent panel. Displacement of linear growth of $\mathbf{P_e}$ to the higher L-shells can be explained by tilting of the geomagnetic equator at satellite altitude from ~ 0° latitude on the 10862 orbit to ~ 6°N latitude on the 10863 orbit due to the magnetic dipole inclination.

Electric field oscillations are deformed and have short-wave components in the southern hemisphere with the illuminated ionosphere from the plasma pause to polar oval. They were observed only on the 10861-10864 orbits after TC meridian.

Oscillations are not registered in the magnetic conjugate regions of the northern hemisphere when the satellite passed these areas under solar shade. The electric field in the northern hemisphere exists on 10862-10864 orbits (1.31 < L < 2.2), it has a horizontal component directed to the west source and a vertical component directed to upward (part of the $\mathbf{E_y}$ component). The anomalous $\mathbf{E_y}$ jump at latitude 48.1°S due to the fact that satellite was out of the shadows. Since the E_y probe rod is not fully opened and the probe is close to the body satellite potential jump was equal about 0.1 V on downward orbits. The day before such effect was observed at the intersection of latitude 46.3°S due to the Earth rotation around the sun. The electric field processing program does not account for this effect, so this jump is marked in Figure 3 and in similar situations in the illustrations of paper (Isaev et al., 2010).

3. VLF transmitter effect to the neutral particles abnormal emission above the TC.

It is known that over the powerful VLF transmitters the streams of energetic charged particles are formed (Sonwalkar et al., 1994). In the night ionosphere they can be a significant source of additional ionization of the neutral component. At the 10862 orbit the satellite passed above NPM transmitter is located in Hawaii. Transmitter power was about 0.5 MW. Taking into account the magnetic declination the additional ionization effect of the neutral component is clearly observed in the southern hemisphere on the previous 10863 orbit. Unusual high level of $\mathbf{N_e}$ concentration was also observed for a day before on the 10849 orbit at the L = 1.2, when the TC Harry did not pass through island New Caledonia and it injected a submerged jet vertically upward (Isaev et al., 2010).

C) TC after the morning terminator, the 10866-10868 orbits.

Symbols in Fig.4 are the same as in Fig.3. Solar shadow over the point (163 E, 20 S) at 10:51 UT was at height H = 1890 km, at 12:35 UT at H = 4444 km, at 14:19 UT at H = 4233 km, at 16:03 UT at H = 1688 km, at 17:47 UT at H = 274 km.

In the midnight sector to the west of Harry, after the morning terminator pass above the TC, the state of ionosphere perturbation is complicated due to the work of powerful VLF transmitters. The moments of the satellite intersection of L - shells are highlighted in Figure 4 when there was an impact on the upper ionosphere following transmitters: Australia - NST and NWC; USA – NPM; Japan - JJI; China - 3SA and 3SB; Russia: RA3 - Komsomolsk-on-Amur, RA1 - Novosibirsk, RA2 - Krasnodar; India - VTX.

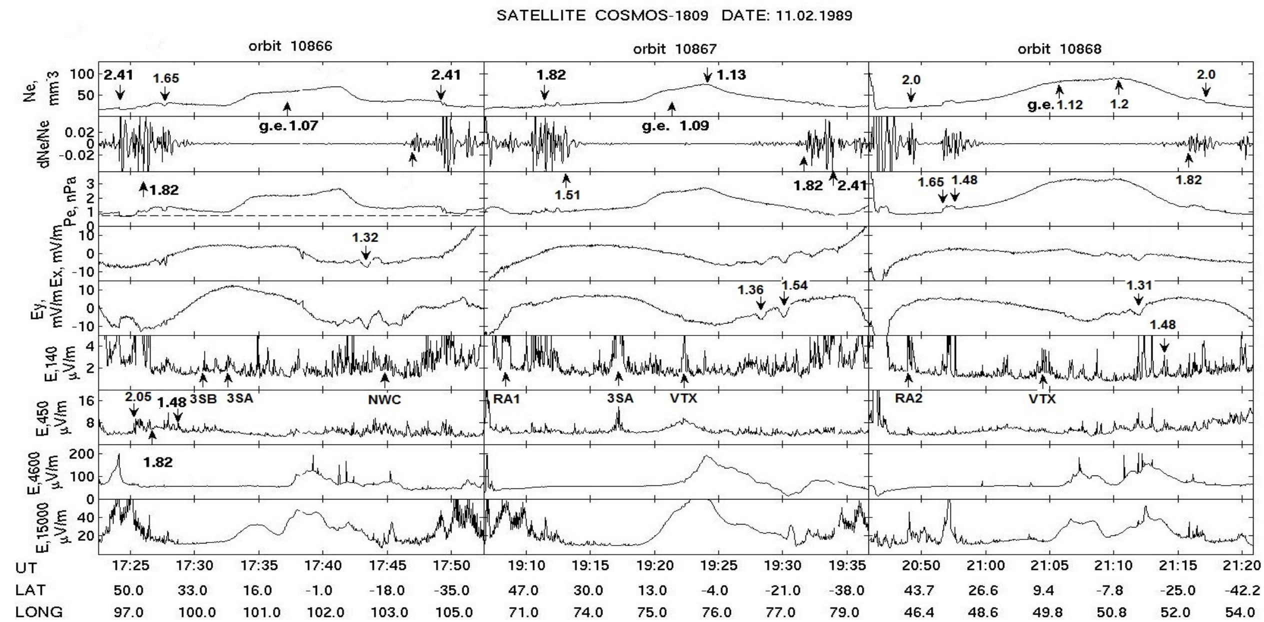

Fig. 4. Modification of the nighttime ionosphere plasma (LT=00:27) in the western sector during the TC Harry passage through the New Caledonia.

1. Solar shadow falls below the max $\mathbf{N_e}$ above the TC at the 10866 orbit.

In the southern hemisphere $\mathbf{N_e}$ fluctuations were recorded on the shells of 1.65 < L < 2.05. Maximum $\mathbf{N_e}$ fluctuations was at L = 1.82. In the more wide area of about 15° (1.48 < L) electric field of about 5 mV/m was registered. It is directed along the magnetic field to the TC and it was centered on L = 1.8. In this region the noise level in the E 140 Hz channel before passing L = 1.82 was two times lower than after it. Strong fluctuations are observed in the E450 Hz channel in the conjugate region 1.48 < L < 2.05. There is the area of the helium cyclotron frequency. This remote dependence extending to about 60^0 of longitude may be associated with the drift of helium ions. An additional factor is the density cavity appearance on the L = 1.6 with width of ~ 150 km and a depth of ~ 20%. It has an increased level of ELF-VLF noise. Such localization of the collection of all perturbations is consistent with the hypothesis of the oblique neutral particles injection in the upper ionosphere from area above the TC.

The following four specific areas observed at the 10866 orbit are associated with an additional impact of VLF transmitters on the disturbed ionosphere.

In the northern hemisphere the perturbed region 2.05 < L < 2.41 is formed between the streams of charged particles above the RA3 and NST. Both transmitters usually work at frequencies of more than 18 kHz. These frequencies get into bandwidth of the E15 kHz channel. Figure 4 shows: two powerful peaks at E15 kHz channel, the failure $\mathbf{N_e}$ density, the failure $\mathbf{P_e}$ pressure, the vertical electric field of about 7 mV/m. The horizontal $\mathbf{E_x}$ component is missing in Figure 4. The additional analysis of the $\mathbf{T_e}$ shows that there are two small peaks at the edges of the cavity.

In the southern hemisphere the same cavity of $\mathbf{N_e}$ and $\mathbf{P_e}$ was detected on the shells 2.41 < L < 2.63. They are between zones of influence NST and apparently VLF transmitter of RA1. It should be noted that the same feature was registered on 10 June, 10852 orbit (Isaev et al., 2010).

In the zone of influence of the other transmitters 3SB (L ~ 1.44) and NWC (L ~ 1.5), which usually work at frequencies slightly above 21 kHz, three solitons with decreasing amplitude, deviate to the south in the horizontal electric field. As the working frequencies of the transmitters are different from the center E15 kHz channel frequency, the amplitude of the signals from these transmitters at 17:45 UT was poorly distinguished.

Transmitter 3SA (L ~ 1.09), similarly to the transmitter NPM, increases the night equatorial ionosphere density. At 17:35 UT and at 17:42 UT wide bursts are marked in the E15 kHz channel, since the satellite trajectory passes near the geomagnetic equator (L ~ 1.07). Accordingly, the $\mathbf{N_e}$ increased latitudinal region is approximately two times wider than the same one on previous 10865 orbit and subsequent 10867 orbit. A similar situation was detected in the region at 10 February when the neutral particles injection took place vertically.

2. Solar shade comes to magnetic conjugate region of TC, 10867orbit.

Since the TC intensification takes place at night, in accordance with the proposed model, an additional pumping of neutral hydrogen in the upper ionosphere is at night. Sharp increase of hydrogen ions drifting to the west should be observed during the morning terminator passes through the ionosphere region above TC. According to the Cosmos-1809 satellite data this effect can be qualitatively detected by growth of the lower hybrid frequency and offset of these intensive oscillations upwards from the E4600 Hz channel. Indeed, only at night on the 10867 orbit in the equatorial ionosphere the sharp cone-shaped signal drop was registered in the E4600 Hz channel on the shells of 1.41 ≤ L ≤ 1.9 with a minimum at L = 1.6. The day before at 10 February the morning terminator pass above the TC, the same sharp signal drop in E4600 Hz channel were registered on the 10853 orbit. The cavity position was shifted to the equator, as TC Harry is coming to the New Caledonia Island. Minimum was split: one was observed on the shell of L = 1.36, the other one was observed on the shell of L = 1.46, corresponding to the zenith above TC.

In the conjugate region of the northern hemisphere on the shells of 1.46 ≤ L ≤ 2.0 strong $\mathbf{N_e}$ fluctuations in the E140Hz, E15kHz channels were observed. Passage of disturbances apparently due to the electric field components along the magnetic field and the three soliton structures directed towards the equator.

Analysis of ten ascending orbits, passing the equator at local midday shows that similar cavities in the E4600 Hz channel were observed only in the northern hemisphere on the 10866 and 10867 orbits. On the 10867 orbit solitary cavity centered on L = 1.42 was detected. On the 10866 orbit three cavity centered on L = 1.25, L = 1.36 and L = 1.46 were recorded. The detailed analysis of the ascending orbits requires separate consideration.

It should be noted that cavity areas in the E4600 Hz channel can be associated with the additional injection of protons (ionization of hydrogen atoms) from the morning terminator area above TC Harry and with protons drift to the west. In this case the lower-hybrid oscillations are shifted to higher frequencies and they are out of registration band of E4600 Hz channel. These effects were observed at a distance of 8000-11000 km from the TC Harry meridian.

3. Magnetic conjugate region and area above the TC are passed terminator (10868 orbit).

The main feature of Figure 4 is that additional $\mathbf{N_e}$ peak appears on the 10868 orbit in the northern hemisphere on the same shells of 1.48 < L < 1.65, when the magnetic conjugate region of TC is beyond the morning terminator. In the southern hemisphere increase of $\mathbf{N_e}$ is marked on the shells of 1.82 < L < 2.0. These areas more clearly are highlighted in the analysis of the electron gas pressure, as there has been an increase of $\mathbf{T_e}$.

The strong N_e fluctuations are marked in the northern hemisphere on the shell of L = 1.86 at the 10869 orbit by removing TC from the terminator.

Summary

1. During the passage of a powerful TC over a coastline observed electromagnetic effects in the ionosphere can be explained by the proposed model of deviations submerged jet.
2. Boundary effects when the terminator passes through the ionosphere structure above TC indicate an abnormal condition of the neutral atmosphere.
3. Abroad polar terminator in the ionosphere to the east of the TC passage meridian through the island, there is a periodic excitation fields with scales of ~ 400 km. This scale coincides with the distance from departure point to return point of He atom. Interrelation arising structures with IGW requires further investigation.
4. Observation of the same N_e structures on the TC plane (10864 orbit) and when passing the evening terminator above TC (10862 orbit), separated by 5,000 km and shifted in latitude at ~ 6^{o} S but at the same L-shells, does not contradict the submerged jet model above a powerful TC.

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