Observation of Plasma Oscillating Structures in External Ionosphere over Cyclones

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Abstract. The results of the observations of density, temperature, pressure of plasma, electrical fields and low-frequency fluctuations were obtained on both Cosmos-1809 and Intercosmos-Bulgaria-1300 satellites. The complex analysis of the results of observations showed the appearance of electrical fields and intensive low-frequency fluctuations, the reaction of electron density, temperature, pressure of plasma at the height of approximately 900 km above the regions of appearance and development of tropical and extra-tropical cyclones. The cases of simultaneous observations of several cyclones, which sharply changed their direction of motion are considered. At the same time over half of the cyclones identical plasma solutions were found. These structures have a core, where the oscillations of the density reach 10% and have a transverse scale of 10 km, and the periphery with smaller amplitudes and stretched density oscillations. These density holes filled with the electrostatic turbulence at the frequency of helium. The results obtained suggest that the different stages of development of tropical and extra-tropical cyclones and the formation of individual structural formations of the ionosphere are related dynamic processes

Keywords: satellite, external ionosphere, tropical and extra-tropical cyclones, bubble

Introduction

Earlier, in papers [Rottger, 1981], [Kelley et al., 1985] was first shown that electric fields occur in the ionosphere over powerful storms. In papers [Isaev et al., 2002], [Sorokin et al., 2005] related electric field, the peak electron density and strong fluctuations of the electron density over the zone of the typhoon in the ionosphere was discovered, and a theory of the formation of such a field was also developed .

Analysis of Cosmos-1809 satellite data in recent works with the authors of this paper [Belyaev, Boytchev et al., 2010], [Isaev et al., 2010] showed that in the initial stages of formation of a tropical cyclone (TC) - Tropical Depression (TD) in some cases in the night ionosphere area of low density plasma (babble) of ~ 40% and the size of hundreds of kilometers is formed over them. A wide area of increased Ne stretched at 30° - 40 ° to the east is formed above the developed typhoon. Region of increased Ne, which is shifted ~ 60 ° 80 ° to the west and is symmetrical about the geomagnetic equator is most clearly seen on the day following the intensification of the typhoon. Narrow (~ 100 km) additional peak Ne is observed above the super typhoon Harry "eye".

In this paper data of both Cosmos-1809 and Intercosmos-Bulgaria-1300 satellites over the extra-tropical cyclone, that reach hurricane force, are analyzed. Satellite IK-Bulgaria-1300 data were obtained and pre-processed by Bulgarian scientists. Final data processing was carried out by IZMIRAN. Cosmos-1809 data were obtained IZMIRAN during communication sessions with the satellite and were processed for specific tasks. Extra-tropical cyclones are developing at mid- latitudes after TC pass through the tropical ridge and as auroral and polar weather fronts are unstable [Galitsyn, 2008], [Polar Lows, 2003].

Experimental data

The most successful on the Cosmos-1809 to work was the following device: Impedance probe (IZ-2). Device for measuring the electron density and its variation has been developed [Komrakov et al, 1970]. Sensor probe is a metal rod of length 1 m, which includes RF generator as a capacitance in the circuit. The generator worked at a frequency of 5 MHz. When you change the plasma density then capacitance circuit also changes and accordingly its resonant frequency. The time constant of the instrument was determined by high-frequency filter and was about 15-20 ms. The spatial resolution of small-scale irregularities in the mode of ZAP-4 is 1,5 km.

The satellite had a circular orbit and was solar synchronized, allowing to compare the results of measurements on the neighboring circuits. It was found that information from the satellite in the mode of remembering 2,56 s (ZAP-4) and the total session time of about 17 hours includes a fragment of a typhoon zone passing.

The most striking events, when 11 cyclones were observed by Cosmos-1809 satellite at Sept. 24, 1992 showed that, at the height of the extra-tropical cyclone, in some cases one can distinguish stable plasma structures. DC electric field and electron heating in these structures are not allocated. On the neighboring orbits they are not observed

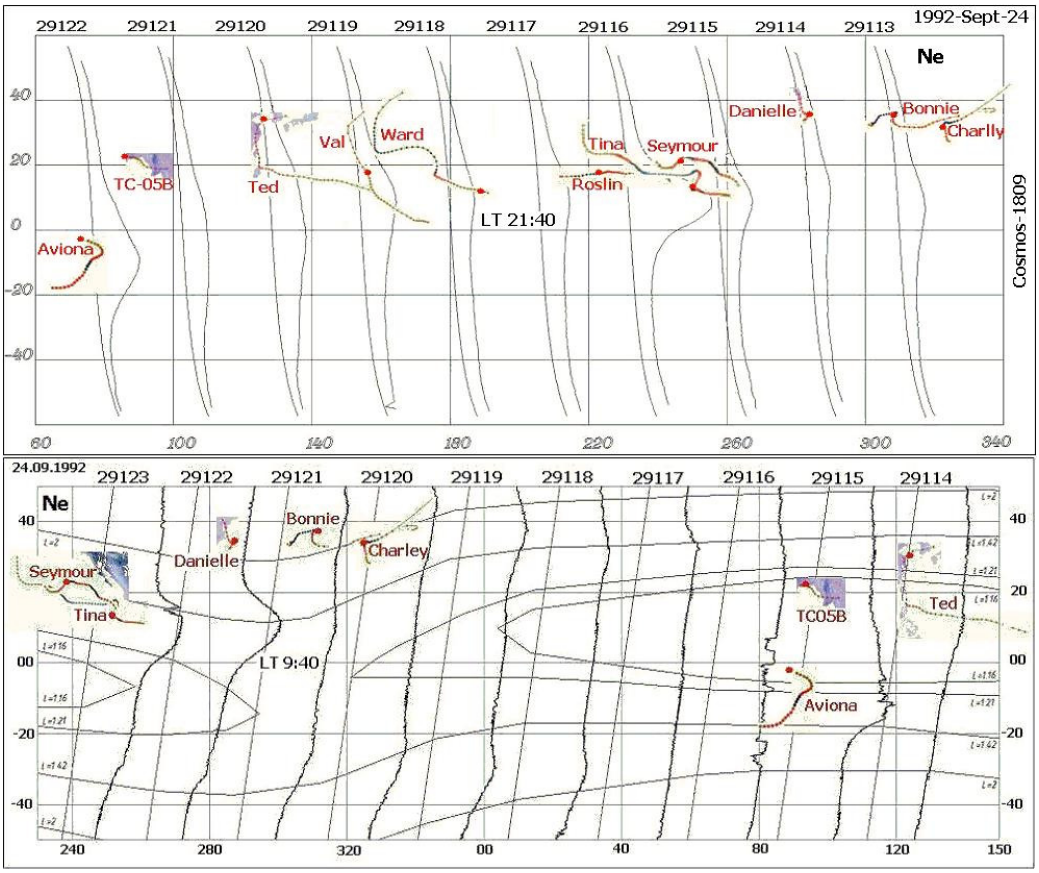

Fig.1. Variations of the electron density along the 10 satellite Cosmos-1809 turns during the 11 tropical cyclones development. Change the direction from the western to the eastern corresponds to the transition into extratropical cyclone. Bold dots mark center of the cyclone near the satellite trajectory

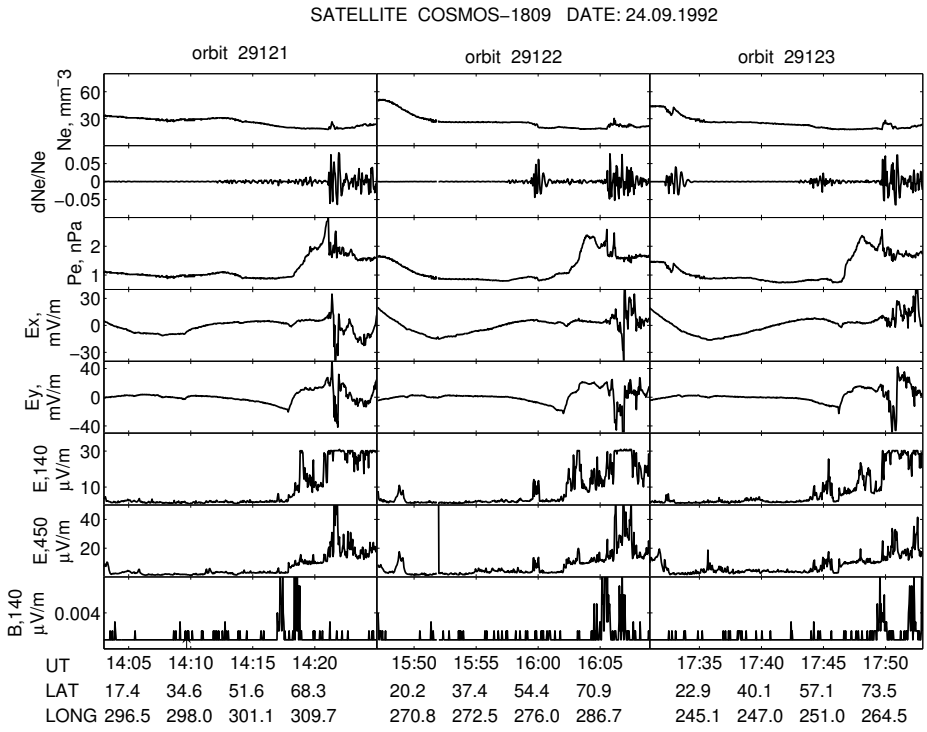

Fig.2. Parameters of ionospheric plasma in the morning sector in the vicinity of Bonnie, Dannielle, Tina hurricanes and polar oval.

The principal difference between the development of extratropical and tropical cyclones is due to different sources of energy input. For extratropical cyclones source of energy is the instability of fronts, and for tropical - heated to 27 degrees ocean water. Fig. 1 shows the observation eleven cyclones. Cyclone Bonnie was associated with the penetration of a cold front in mid-latitudes, while the rest went from a tropical cyclone to extratropical when crossed tropical ridge, and their trajectories changed from west to east. We see a series of quasi-soliton structures over the area of tropical depression Aviona that reached the hurricane intensification of convection next day.

Fig. 2 shows one of the conditions of transition of tropical depression and storm into the stage of hurricane. It turns out that quasi-soliton structure of the density of an oscillating nucleus near the "eye" and an extended peripheral-type surface waves are observed over hurricanes (orbit 29123 the hurricane Tina). These structures have a core, where the oscillations of the density reach 10% and have a transverse scale of 10 km, and the periphery with smaller amplitudes and stretched density oscillations. These density holes filled with the electrostatic turbulence at the frequency of helium. DC electric field and electron heating in these structures are not allocated. On the neighboring orbits they are not observed. Such a structure was not observed over the tropical storm Seymour, and it was not developed to the stage of the hurricane. In the data along the trajectory passing near hurricane Bonnie, you can see a quasi-soliton structure near the auroral weather front, which sharply differs from that of the auroral oval.

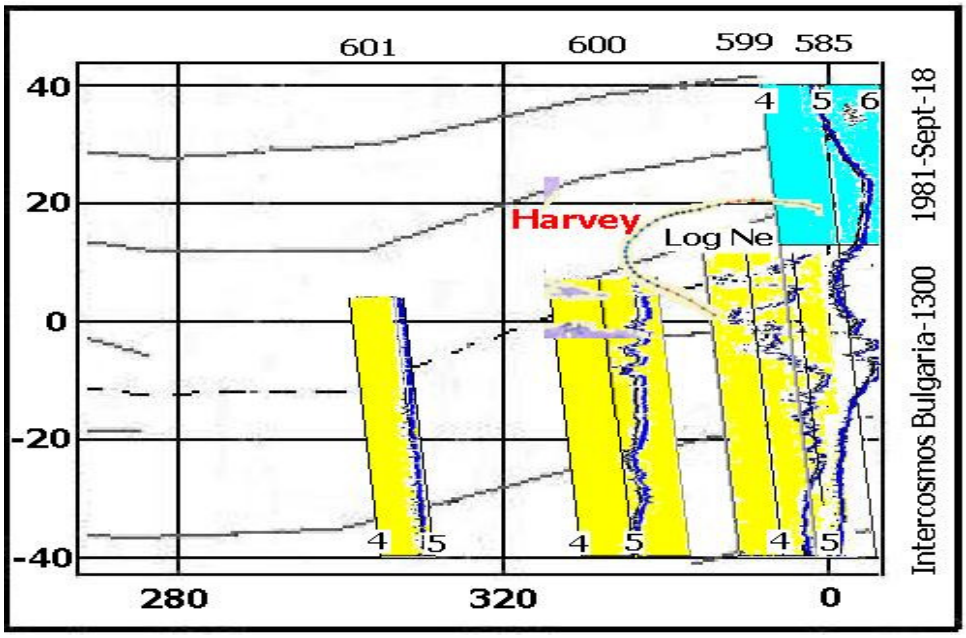

Fig.3. Variations of electron and ion density in the ionosphere over a strong fourth category hurricane Harvey in the Atlantic in 1981 (September 11-19) according to the satellite Intercosmos-Bulgaria-1300.

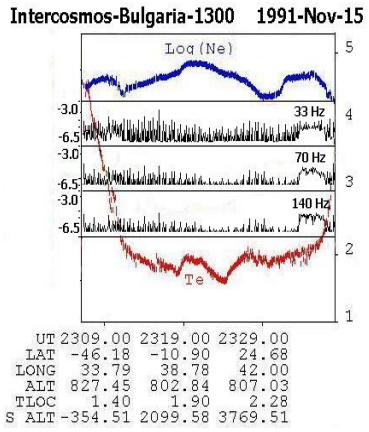

Fig.4. The dynamics of individual parameters of ionospheric plasma over subtropical storm Three according to satellites Intercosmos-Bulgaria-1300

Figure 2 shows the upward flow of helium in these structures. This is supported by the presence of sharp rise in the channel E of 140 Hz, which corresponds to the cyclotron frequency of helium.

The other group of IZMIRAN scientists showed based on VLF measurements of the Intercosmos-24 satellite that the zone of typhoon impact on the topside ionosphere is much broader than the region covered by the cyclone [Mikhailova et al., 2000].

Similar dependence can be detected by satellite IK-Bulgaria-1300" measurements. Observations of Ne and Ni 17-18 / 09/1981 during one of the strongest hurricanes of category IV in Atlantic are represented here. Harvey developed 11-19 September 1981, and its intensity reached: speed - 215 km / h, a minimum pressure - 946 hPa. Turn trajectories number 581 (blue bar) and number 599 (yellow bar) are practically identical, but in Figure 3 round number 599 is shifted to

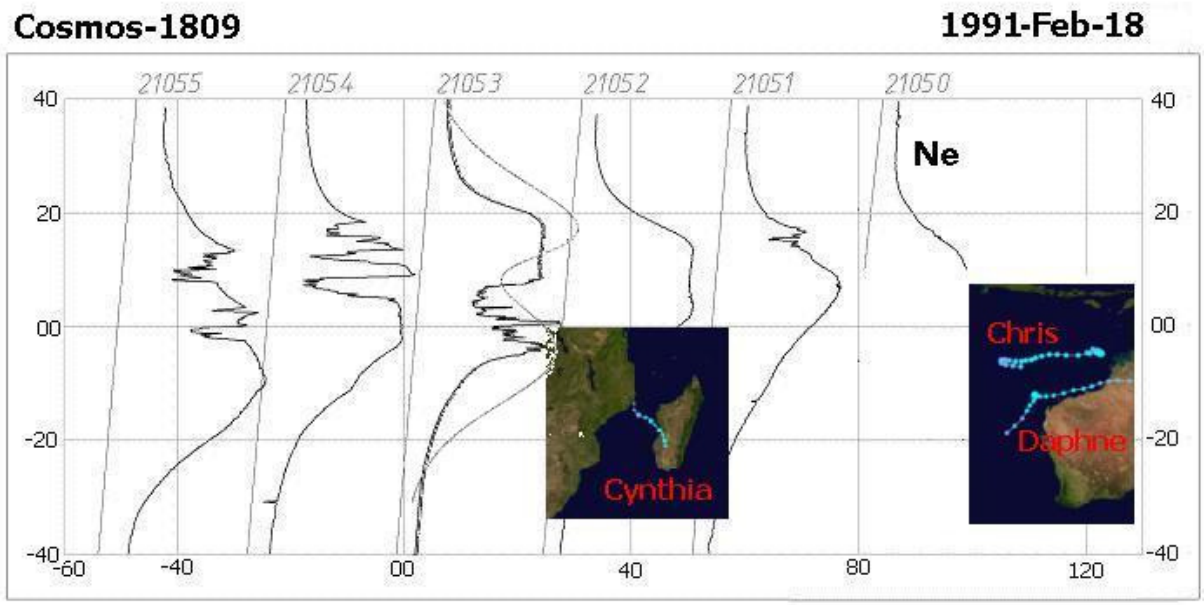

Fig.5. The development of bubbles in the upper ionosphere above tropical cyclone Cynthia at work heating facility Sura. Density Ne calculated by the model of IRI is marked along the trajectory of 21 053

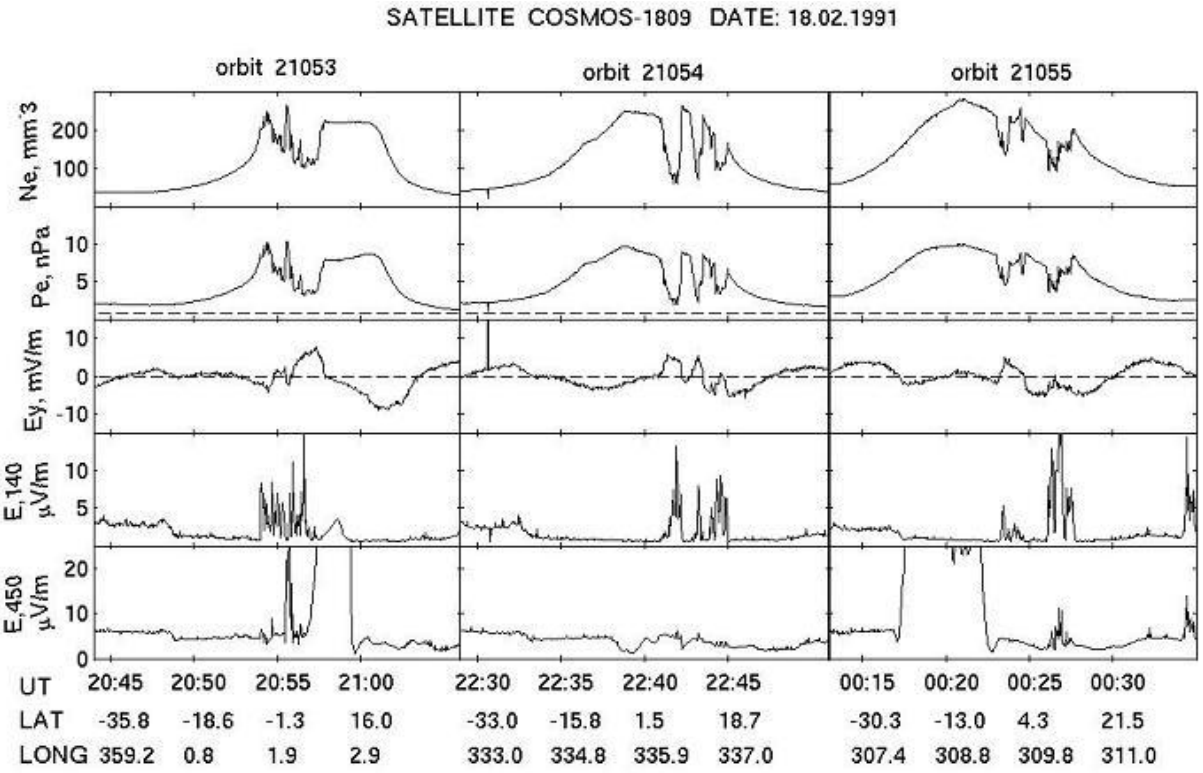

Fig.6. Variations of plasma oscillations at the cyclotron frequency of hydrogen and helium, as well as the electric field in the soliton structures

the west in order to avoid of data overlap. Most probably, there is observed a different mechanism of formation of tropical structures, which is associated with the eastern drift of the charged component.

Figure 4 shows the structure of Subtropical Storm Three, developing 12-17 November 1981, intensity 110 km / h and 978 hPa in Atlantic.

An example of the strong influence of the evening terminator at the electron density in the upper ionosphere perturbed by Hurricane Cynthia 18/02/1991 is shown. The observing dynamics of the ionosphere on three consecutive orbits can be explained by the transport of the neutral component above typhoon and its drift to the west. Development of the Rayleigh-Taylor instabilities depends strongly on the neutral component. At high solar activity it leads to the formation of structures such as "bubbles". In this case, the dynamics of the upper ionosphere in this sector is influenced by the work of heating facility Sura [Kostin et al., 1993].

Figure 6 shows, so as figure.2, that there is upward flow of helium in these structures. This is supported by the presence sharp rise in the channel E of 140 Hz, which corresponds to the cyclotron frequency of helium. Strong maximum in the channel E 450 Hz which corresponds to the cyclotron frequency of hydrogen is located outside the structures. This maximum is over the region of reflection nonchannelized whistlers associated with an intense thunderstorm activity in the vicinity of hurricanes.

Similar dependence of the ELF-VLF channels were also observed after an underground nuclear tests in the satellite Cosmos-1809 data [Belyaev, Kostin et al., 2010].].

Summary

1. The results obtained deepen the submission of meteorologists that tropical and extra- tropical cyclones affect not only the structure of the stratosphere, but also interrelated with the processes in the ionosphere.
2. Additional energy, coming from the magnetosphere and ionosphere into atmosphere, can sometimes lead to intensification of the convective atmospheric systems.
3. In many cases quasi-soliton structures of Ne with oscillating kernel of density near the storm "eye" and the extended peripherals are observed. These structures have a core, where the oscillations of the density reach 10% and have a transverse scale of 10 km, and the periphery with smaller amplitudes and stretched density oscillations.
4. These effects must be considered in the IRI model [Bilitza].

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