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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.

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

† Deceased.

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	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°