TROPICAL CYCLONE INFLUENCE ON THE ATMOSPHERE AS ONE OF THE MAJOR PARTS OF THE CLIMATE PROCESSES

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We suppose that the tropical cyclone's influence on the atmosphere can be found tens of kilometers in a vertical direction and thousands horizontally. It changes the structure of the neutral atmosphere and this alters the electron concentration of the ionosphere. The tropical cyclone, it's influence on climate processes, and an indication of the associated dangers are the subject of this report.

1. INTRODUCTION

Studying the global energy transport, which is a very important problem of the Earth's atmosphere physics, is based on the investigation of the processes and mechanisms of interaction between various atmospheric layers.

The interaction problem between layers (e.g. troposphere, stratosphere, mesosphere, and ionosphere) was considered in many publications, which demonstrate an integrity (including the thermodynamic one) of the Earth's atmosphere [Vanina and Danilov, 2001]. Depending on the location of the impact source, the interaction of such layers is possible both from below and from above. The waves (planetary, tidal, gravity) propagating upward, penetrating through the zonal wind systems, and reflected from these winds are considered as a physical basis of the influence from below. Intense dynamical processes in the troposphere are considered as a source of these waves, and the transmission characteristics depend on the thermodynamic regime of the middle atmosphere. Many investigators showed that the interaction between meteorological and ionospheric fields is most evident in the extratropical winter atmosphere [Danilov et al., 1987]. In this paper we, on the contrary, study the equatorial tropical zone of the troposphere–stratosphere–mesosphere–ionosphere system.

It is known that the whole spectrum of powerful dynamical phenomena is originated in the tropical zone of the atmosphere. The most intense of these phenomena are tropical cyclones (TCs), which are possible potential sources of the influence from below. Catastrophic atmospheric vortices, which originate near the equator and develop in the tropical zone of the Earth's atmosphere, present a peculiar mechanism of effective heat effluence under such atmospheric conditions, when the action of ordinary mechanisms (the main mechanisms are turbulent convection and global circulation) becomes evidently insufficient. Thus, the catastrophic atmospheric vortex systems play an important (and possibly determining) role in the formation of the climatic emperature regime of the Earth (the greenhouse effect), removing excess heat and preventing the atmosphere (its tropical part) and the surface ocean layer in the tropical zone from strong overheating [Balebanov et al., 1997; Sharkov, 1997, 2006].

The aim of this paper is to find the response to the impact of the intense energy released during the TC active phase on the adjacent troposphere and stratosphere, which, in turn, possibly influence the lower ionosphere (mesosphere heights).

The data of the rocket sounding of the ionosphere and satellite monitoring of the tropical cyclogenesis were used to solve this problem.

2. DATABASE OF ROCKET SOUNDING OF THE IONOSPHERE

The measurements considered in this paper were conducted by the Central Aerological Observatory (CAO) of the State Committee on Hydrometeorology at Thumba equatorial rocket site (8° N, 77° E). The initial data are part of the database, the description of which can be found in [Borisov et al., 1981; Kokin et al., 1988]. The CAO database is based on the bank of electron concentration [*e*] measurements on board the M100B meteorological rockets using the probe method, which is based on the application of the Langmuir electrostatic probe. The probe was installed at the top end of the meteorological payload of the rocket, which protected this probe from the influence of electric and magnetic fields of the rocket itself [Pakhomov, 1981]. The probe method has systematic errors, which are revealed by comparing the measurements, performed using this method, with the most accurate measurements made using the Faraday rotation method. The estimated standard error of an individual measurement of the electron concentration (the CAO databank) is ~35% [Knyazev et al., 1994]. During the routine atmospheric sounding, the temperature sensors and the equipment for measuring wind parameters were also installed on board meteorological rockets.

3. VARIATIONS IN THE ELECTRON CONCENTRATION VERTICAL PROFILE IN MAY–JUNE 1985 AGAINST A BACKGROUND OF TROPICAL TROPOSPHERIC DISTURBANCES

In the our first step we tried to find out the response of allocated intensive energy during an active phase of tropical cyclones on adjoining stratomesosphere, which, predictably, should influence the lower ionosphere [Vanina-Dart et al.,2008]. We analyzed simultaneous measurements of electron concentration (from the rocket testing ground Thumba, India (8^0N, 77^0E)), thermodynamic parameters of the layer D of the equatorial ionosphere, and also remotely-sensed data on tropical cyclogenesis in the northern part of the Indian Ocean. As a result of this complex analysis it was revealed for the first time that there was a downturn of [e]-electron concentration in the D-region at a distance of about 1000 km (in a horizontal projection) from a kernel of the tropical cyclone, which was in an active phase in the Arabian sea. Electron concentration downturn at heights 71±3 km was on average 3-4 times greater (fig.1).

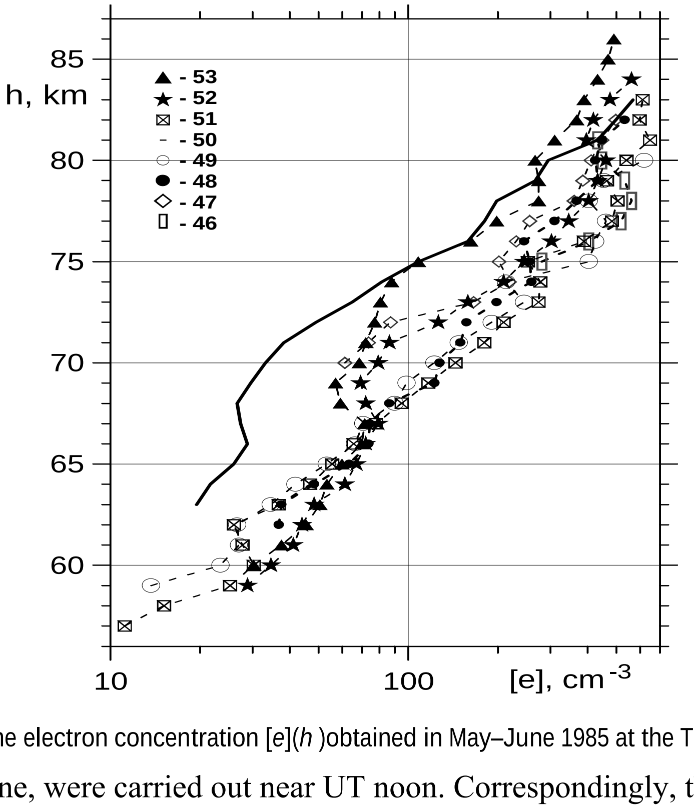


Fig. 1. Vertical profiles of the electron concentration [e](*h*)obtained in May–June 1985 at the Thumba rocket site.

All flights, except one, were carried out near UT noon. Correspondingly, the values of the solar

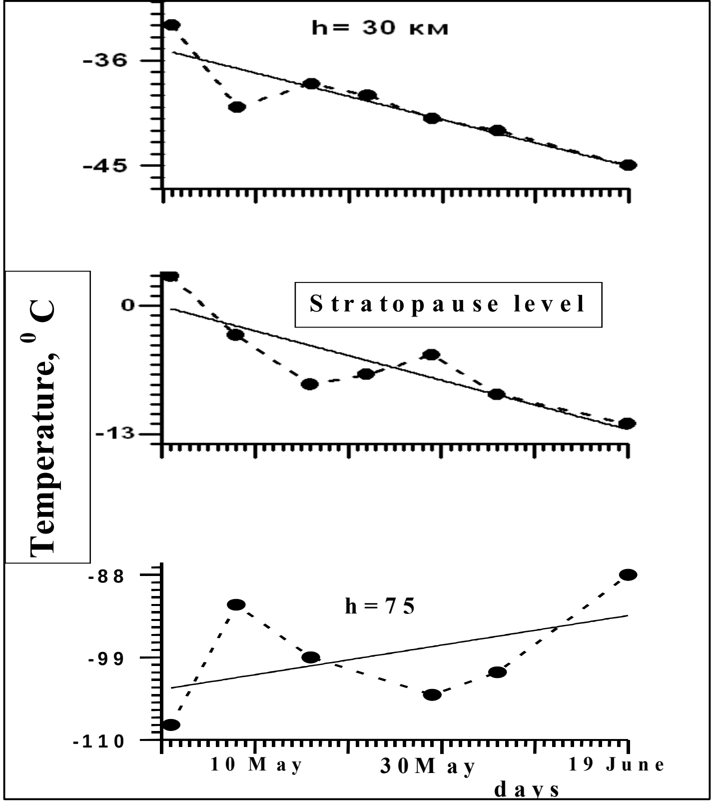


Fig.2. Variations in the atmospheric temperature at various altitudes in May–June 1985.

zenith angle χ are slightly scattered (χ_{av} = 73° ± 4°). The values of the solar activity index ($F_{10.7,av}$= 82.5 ± 12.5) and the geomagnetic activity index (Ap_{av} = 8 ± 5 and Kp_{av}= 1.5±1.5) indicate that solar and geomagnetic conditions were quiet during the flights. The [*e*] profiles (Fig. 1) should be comparable with the averaged profile, obtained by Knyazev et al. [1993, 1994] at the same Thumba rocket site at low solar activity ($F_{10.7,av}$ =78 ± 9, Ap_{av} = 15, and χ_{av} = 71 ± 2°).

A small rise in temperature (3 K) during the action of a tropical cyclone at stratopause height was also noted (fig.2).

4. SOLAR ACTIVITY INFLUENCE ON THE LOWER IONOSPHERE

Attempts to model the behavior of the equatorial *D* region for various solar and geomagnetic conditions were undertaken repeatedly (Kniazev et al., 1994; Watanabe and Oyama, 1995).The question of how solar activity affects electron concentration in the D-layer is still unresolved [Smirnova and Danilov, 1998]. It is known that the intensity of the ionizing radiation with different wavelength varies from minimum solar activity to maximum. For the interval of 1.2 - 100 nanometers (X-rays) it multiplies by 7 times, for the interval 102.7 -111.8 nanometers it doubles, and for 121.6 nanometers (line Lα) it increases to 1.7 times. These are the main ionizing radiations in the D-region.

How does the solar activity level change [e] in the lower ionosphere? This question cannot be answered yet. There are opposite points of view about the influence of solar activity on the lower ionosphere. Authors [Knyazev,1994] consider that the influence of Sun wave radiation on the D region can be estimated more clearly at the equator. In the present article, as well as in [6], we analyze the same databank. It has been demonstrated [Knyazev,1994] that electron concentration has negative correlation with solar activity (a F-daily index, a stream of a radio emission of the Sun at 10,7 cm) at a height of 54 km. Above 60 km and up to 80 km the electron concentration has positive correlation with solar activity.

5.COMPARISON OF THE ELECTRON CONCENTRATION MEASUREMENTS IN THE LOWER IONOSPHERE IN YEARS OF DIFFERENT SOLAR ACTIVITY WITH THE TROPOSPHERE PERTURBATION BACKGROUND

It is known that in the ionosphere, gravitational waves influence the speed of ionization at any given point. This occurs because of changes under the influence of neutral gas density and, probably, a stream of ionizing radiation reaching the given point. The vertical stream of energy from the troposphere is sufficient to explain the observable amplitudes of internal gravitational waves in the top atmosphere. Waves extend upwards on an inclined direction. Therefore effects in the top atmosphere can be shown not only for many hundreds of kilometres from a tropospheric source, but also some days after the occurrence [Danilov and al., 1987]. One intense source of such waves can be TC - a tropical cyclone. Waves arising at it can reach the top ionosphere.

The atmospheric density in the lower D-region is higher than in the upper D-region. The electron concentration response on the internal gravitational waves passage is stronger here. The internal gravitational waves dissipation in the lower ionosphere changes the thermodynamic and turbulent regime, and the speed of chemical reactions, the neutral structure. It should also affect the electron concentration of D-region.

In our article we analyze the [e] rocket data, received from the rocket testing ground in the Northern Indian Ocean. We expect to find an influence on the lower ionosphere above this region from internal gravitational waves, which were born above the Indian and Northwest Pacific oceans.

For analysis of such possibility and to what degree of tropical cyclone influence we divided the rocket data into two groups - with TC and without TC. The data about stages, location, and Δt - the time interval between fixed stage of TC and rocket measurement (for how many hours before rocket launching) - are presented in table 1. Also in this table you can find information about the wind speed. The TC information we took from this site: http://weather.unisys.com/hurricane.

We have chosen only two years with the greatest quantity of measurements (1985 and 1988) from the whole bank of rocket data. Values of index $F_{10.7}$ in 1985 varied from 68 up to 105 (the average value - 77); in 1988 - from 100 up to 245 (average value - 140).

The result of correlation between the electron concentration and the solar activity index F (in days with TC and without them in 1985 and 1988) is presented on fig. 3 – 12.Days with TC are marked by asterisks. We numerated these asterisks – it is the stage of TC, which you can find in table 1. Days without TC are presented by circlet. Also in figures are marked: h-height of measurement of electronic concentration, Rtc ([e], F)- the correlation coefficient between [e] and index F in days with TC, Rq([e],F) - the correlation coefficient between [e] and index F in days without TC.

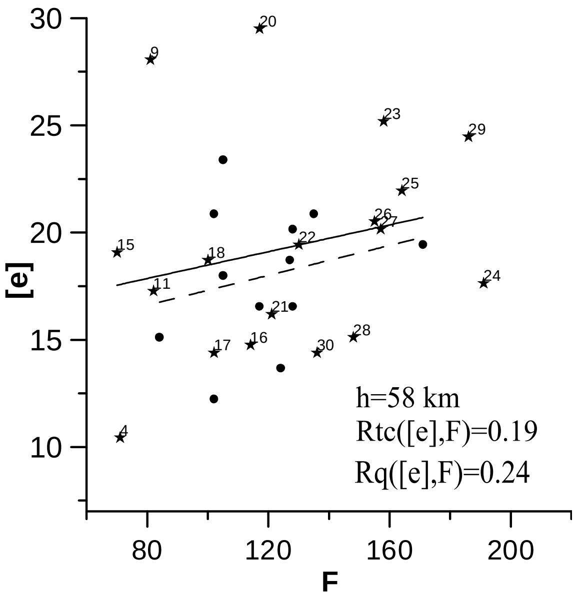


Fig.3.1.

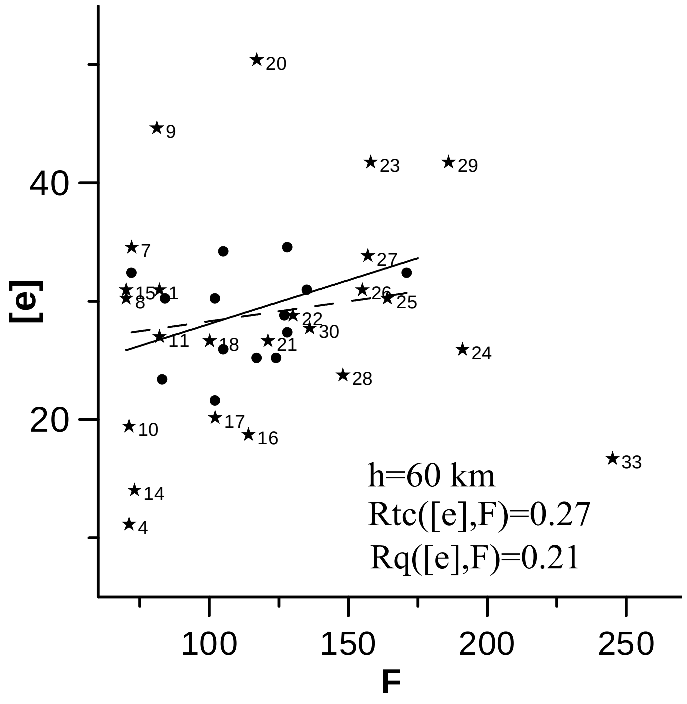


Fig.3.2.

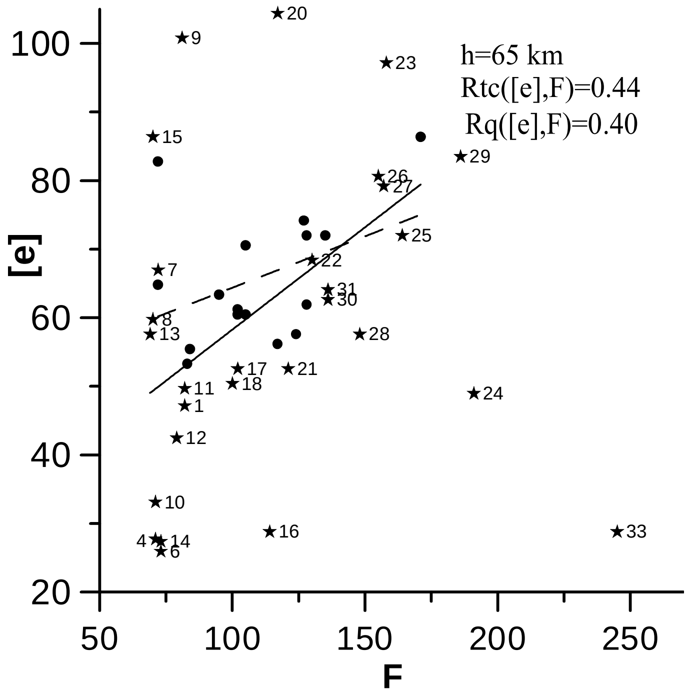


Fig.3.3.

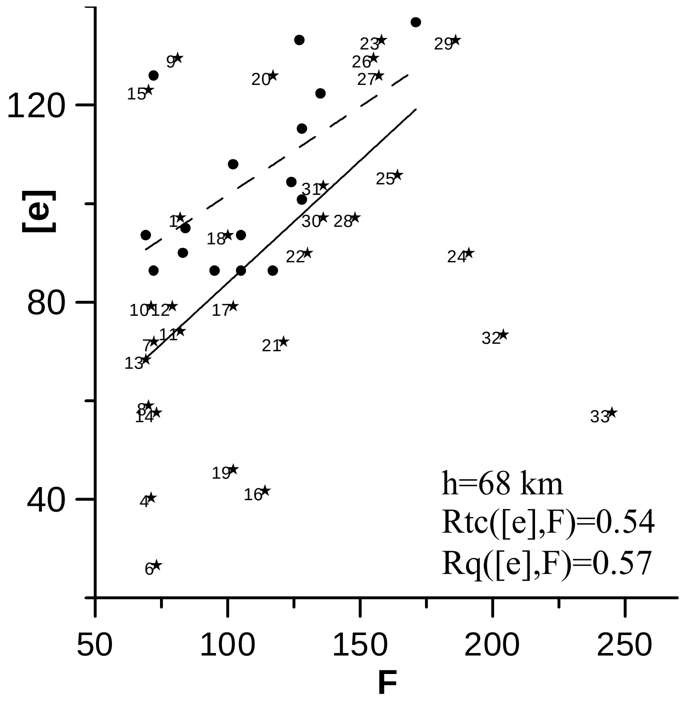

[e]
120
80
40
F
50
100
150
200
250
23
29
9
26
20
27
15
25
31
1
30
28
18
22
24
10
12
17
11
7
21
32
13
8
14
33
19
16
4
6
h=68 km
Rtc([e],F)=0.54
Rq([e],F)=0.57

Fig.3.4.

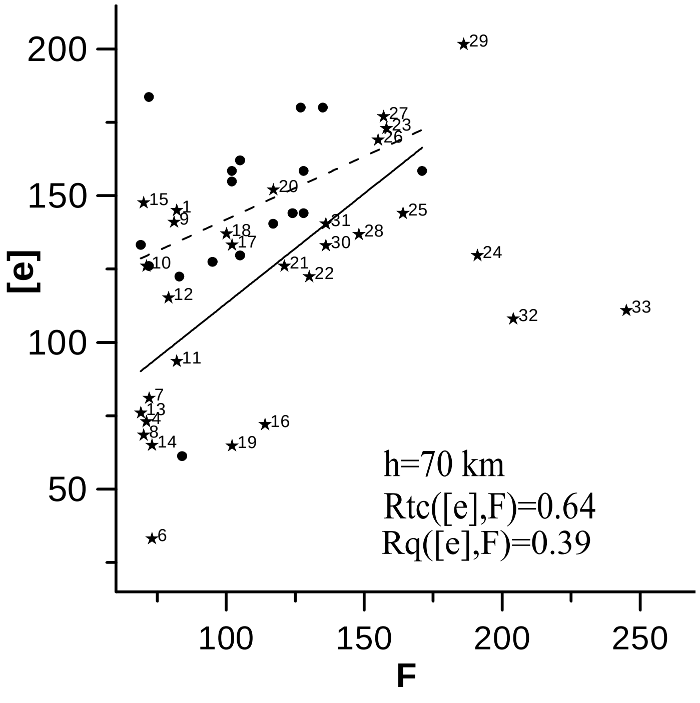

[e]
200
150
100
50
F
100
150
200
250
29
27
23
26
20
15
1
9
31
18
25
28
17
30
24
10
21
22
12
32
33
11
7
13
4
8
14
16
19
6
h=70 km
Rtc([e],F)=0.64
Rq([e],F)=0.39

Fig.3.5.

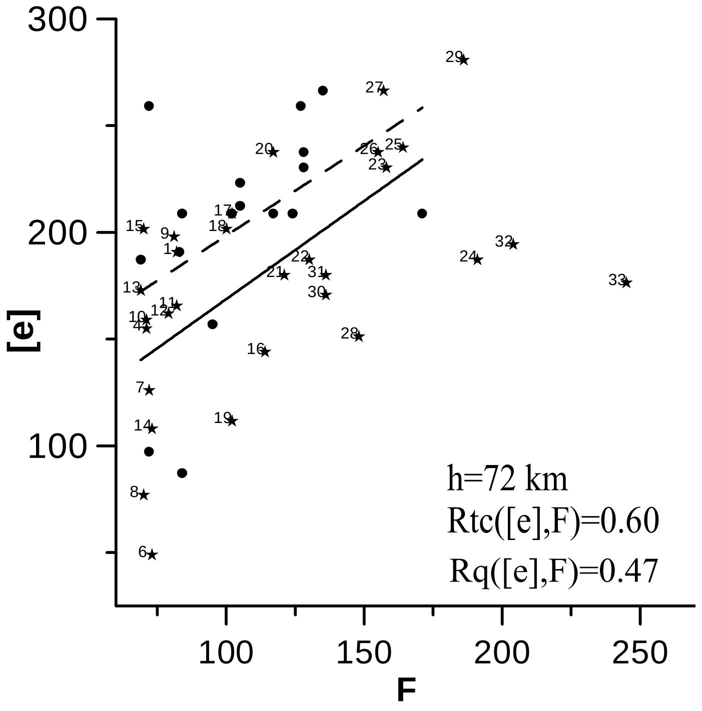
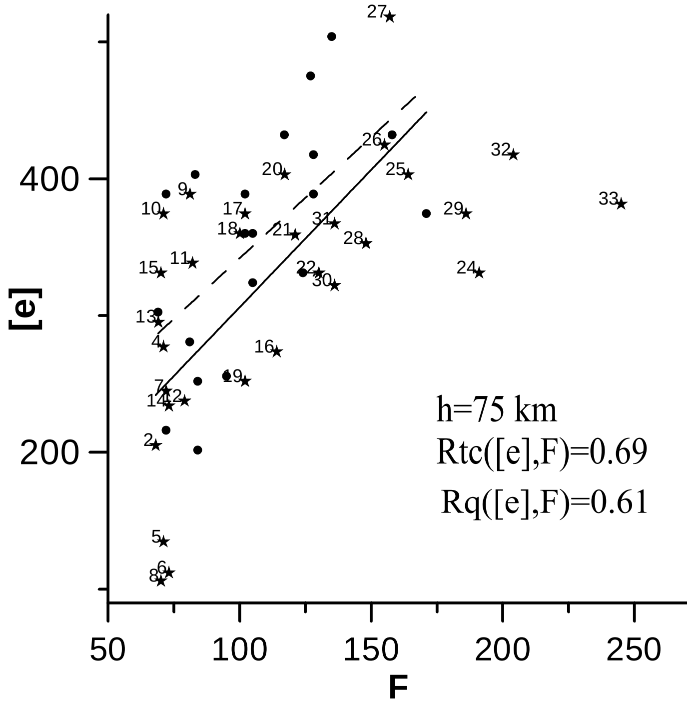

300
200
100
[e]
100
150
200
250
F
h=72 km
Rtc([e],F)=0.60
Rq([e],F)=0.47
29
27
20
26
25
23
17
18
15
9
1
22
21
31
30
32
24
33
13
11
12
10
4
16
28
7
19
14
8
6

Fig.3.6.


400
200
[e]
50
100
150
200
250
F
h=75 km
Rtc([e],F)=0.69
Rq([e],F)=0.61
27
26
32
20
25
9
10
17
18
21
31
29
33
28
11
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22
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16
7
19
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12
2
5
6
8

Fig.3.7.

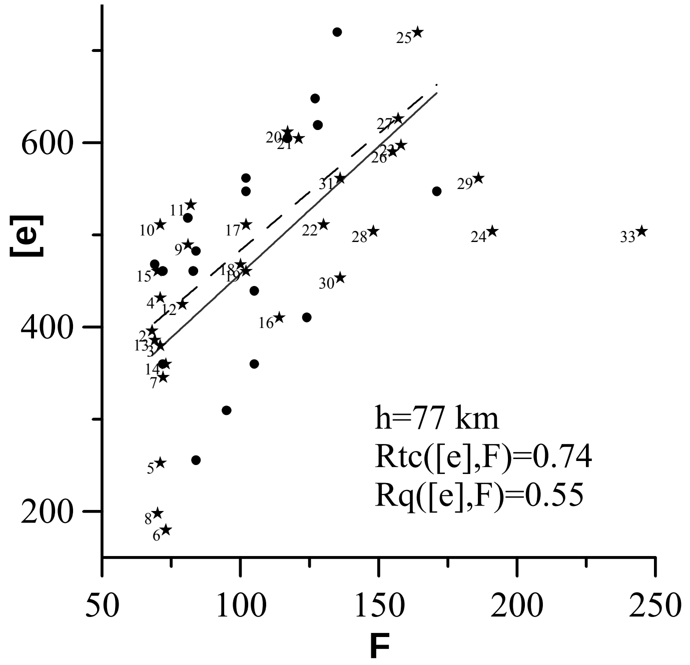

Fig.3.8.

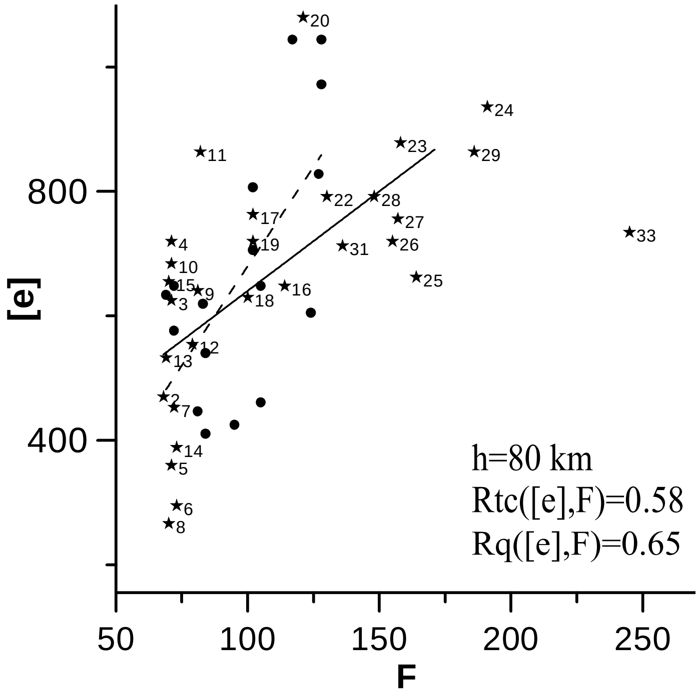

Fig.3.9.

Tabl.1. The information about TCs, which were registered before the [e]-mesurements.

Number of [e] mesur.	Latitude,^{0}	Longitude,^{0}	**Δt**, hour	**Wind speed**, km/h	Stage of TC	**Ocean of TC location**	Distance, km

1	-27,3	53,3	42	65	tropical storm	South Indian	4725
2	-19,3	64,1	18	130	cyclon-1	South Indian	3356
3	-13,8	68,2	12	65	tropical storm	South Indian	2613
4	-15,4	121,6	12	74	tropical storm	South Indian	5598
5	-16,5	116,3	24	102	tropical storm	South Indian	5147
5	-16,3	58	12	65	tropical storm	South Indian	3428
5	-13	100,3	12	65	tropical storm	South Indian	3486
5	-14,9	45,1	12	65	tropical storm	South Indian	4364
6	18,6	68,1	0	93	tropical storm	North Indian	1538
7	16,6	110,7	12	56	tropical depression	Northwest Pacific	3865
8	11,5	131,5	36	111	tropical storm	Northwest Pacific	6070
9	40,1	146,5	30	102	tropical storm	Northwest Pacific	8508
10	25,5	146,7	24	111	tropical storm	Northwest Pacific	7987
11	27,5	121,9	30		cyclone-1	Northwest Pacific	

				139			5440
12	29,1	132,4	24	130	cyclone-1	Northwest Pacific	6589
13	34,2	124,3	18	111	tropical storm	Northwest Pacific	6010
14	24,1	128	24	167	cyclon-2	Northwest Pacific	5944
15	21,7	118,9	24	65	tropical storm	Northwest Pacific	4899
16	15,2	141	24	185	cyclon-3	Northwest Pacific	7158
16	-14,4	52,3	12	83	tropical storm	South Indian	3706
17	-14,9	45,1	6	65	tropical storm	South Indian	4364
18	-15,8	95	12	83	tropical storm	South Indian	3316
19	-17,7	36	30	74	tropical storm	South Indian	5378
20	-14	66,8	12	93	tropical storm	South Indian	2695
21	-27	72,9	12	74	tropical storm	South Indian	3916
22	25	143,9	24	194	cyclon-3	Northwest Pacific	7672
23	19,3	119,1	24	74	tropical storm	Northwest Pacific	4845

24	20	124,7	24	259	Super cyclon-5	Northwest Pacific	5467
25	15,6	133,2	18	65	tropical storm	Northwest Pacific	6303
26	16,4	118	24	120	tropical storm	Northwest Pacific	4651
27	-9,8	76,7	12	102	tropical storm	Northwest Pacific	1979
28	15,2	113,7	24	167	cyclon-2	North Indian	4157
28	-6,7	94,1	24	102	tropical storm	South Indian	2506
29	-12,9	73,4	12	176	cyclone-2	South Indian	2357
29	-16,5	115,2	18	120	cyclone-1	South Indian	5044
30	8,7	95	0	93	tropical depression	South Indian	2002
31	23,7	90,2	12	111	tropical storm	South Indian	2280
32	-16,5	120	24	65	tropical storm	South Indian	5500
33	-20,2	116	96	157	cyclon-2	South Indian	5349

Tabl.2. Results of statistical processing and regression dependences [e] =f (F) in days with TC and without TC

	Quantity of the [e] measurement		$[\bar{e}]$		$\sigma_{[e]}$		$[e]o_F$		K_F		$R_{([e],F)}$	
Altitude, km	Without TC	With TC	Without TC	With TC	Without TC	With TC	Without TC	With TC	Without TC	With TC	Without TC	With TC
58	12	18	17.97	19.08	3.27	5.19	13.82	16.16	0.035	0.019	0.24	0.12
60	14	21	28.75	28.7	4.06	9.47	24.95	20.69	0.034	0.074	0.21	0.27
63	15	20	47.04	49.43	8.26	20.60	27.28	24.36	0.177	0.231	0.53	0.41
65	16	25	65.79	59.82	9.68	22.87	49.40	28.42	0.150	0.298	0.40	0.44
68	17	26	104.3	86.46	17.05	30.62	65.96	34.33	0.358	0.496	0.57	0.54
70	18	26	145.1	117.2	28.15	38.92	101.8	39.16	0.409	0.742	0.39	0.64
72	18	26	203.4	173.6	48.58	51.26	114.2	77.28	0.843	0.917	0.47	0.60
75	20	26	354.4	313.1	83.27	99.94	164.9	103.4	1.770	2.028	0.61	0.66
77	19	28	494.3	463.8	122.3	126.8	229.7	181.6	2.534	2.762	0.55	0.74
80	17	26	671.3	641.4	204.9	188.0	40.38	321.1	6.392	3.193	0.65	0.58

In the table.2: $[\bar{e}]$- the average mean of electron concentration for every high-altitude level; $\sigma_{[e];-}$ - the standard deviation of [e]; $[e]o_F$ and K_F - the constant and coefficient in the equation of linear regression between [e] and F; $R_{([e],F)}$ – the coefficient correlation between [e] and F.

6. DISCUSSION OF THE RESULTS.

In the fig. 3.1.-3.9. you can find the linear approximations of [e] from index F for both groups of data - "without TC" (a continuous line) and " with TC " (dashed line). We used only those [e] data which have been received at values of index F <175 for these approximations Firstly, we had data (without TC) only when values of index F <175; secondly, the electron concentration stops the growth with the increase in solar activity above 175 (see fig.3.1.-3.9.).

The important results of comparison [e] with F at different high-altitude levels in days with TC and without TC are presented in table 2.

As we see from the table, the quantity of measurements in days with TC exceeded those days without TC, and that accordingly this gives a more reliable statistical importance of factor of correlation between [e] and F.

With confidential probability, which is more or equal to 95%, the constant and coefficient in the equations of regression from table.2 are significant at high-altitude levels 63, 68, 72, 75,77 and 80 km in the days without TC, and at all levels above 63 km for data with TC.

At levels 60-78 km the correlation coefficient between [e] and F in days without TC is less, than in days with TC.

7. CONCLUSION

In the article end we present the following conclusions.

At comparison of [e] the behavior of the dependence on solar activity in days without TC and with TC at different at high-altitude levels of D-layer of an equatorial ionosphere it has been received:

1) the TC influence on an equatorial ionosphere on enough big distances (up to 8000 km). The stage of a cyclone, its remoteness from a place of [e] measurement had no essential value;
2) on the average, in days without TC the electronic concentration more than [e] in days with TC at heights from 60 up to 80 km (the maximal distinction at the level 70 ±3 км);
3) the dependence of [e] from solar activity in days with TC a little bit above, than in days without TC at heights from 65 up to 80 km (it is maximal about 70 km);
4) the [e] data variability in days with TC bigger, than in days without TC at heights from 60 up to 80 km (it is maximal about 70 km).

So, on the basis of comparison of the main ionospheric parameter behavior in days without tropical cyclones and in days with TC was received, that the greatest distinction the electron concentration reaches at heights about 70 km. The influence of TC reduces value [e]. The TC presence increase the solar activity influence on the region D at heights from 65 up to 80 km in day time conditions. The influence of tropical cyclones on the lower equatorial ionosphere does not depend from capacity of cyclones and its remoteness (within the limits of 8000 km) across. We can say that the tropical cyclone is certain " the starting mechanism " influences on the lower ionosphere. These conclusions once again confirm the basic idea that TC- "provider" of the internal gravity waves.

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