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Influence of a Tropical Cyclone on the Upper Ionosphere According to Tomography Sounding Data over Sakhalin Island in November 2007

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Abstract—Tomography sounding data for the first half of November 2007 are presented. The sounding was conducted over three points located at the same meridian—Yuzhno-Sakhalinsk (47° N, 143° E), Poronaisk (49° N, 143° E), and Nogliki (51° N, 143° E)—in order to find the possible influence of a tropical cyclone on the upper ionosphere. A change in the *foF*2 parameter by on average no more than 10–20% is a possible response of the upper ionosphere localized over the tropical cyclone (TC) zone (in the given case, 25°–30° northward and 5°–20° eastward) at a distance of approximately 3800–5500 km from it. A decrease or, vice versa, an increase in *foF*2 is related to the delay of the measurement moment relative to the beginning of the TC action. The complexity of a morphological analysis of the given event is that a tropical cyclone is a "wide-band" (in the longitudinal and, to a lesser degree, in the latitudinal directions) and lasting disturbance source.

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1. INTRODUCTION

The study of atmospheric–ionospheric interactions is one of the most interesting and perspective applied directions in geophysics. Because of its nature, being a product of ionization of various neutral gas components, the Earth's ionosphere rapidly enough (for example, at heights of the *E* layer, the characteristic time of a reaction to changes in the ionization rate by auroral discrete-type electrons is a few seconds) reacts to changes in space radiation and also in the composition of the neutral atmosphere. Respectively, deviations in the behavior of ionospheric parameters due to atmospheric events (thunderstorms, cyclones, tornados, hurricanes, etc.) are detected. Much attention has been recently paid to such tropospheric events as tropical cyclones (TCs). There are different points of view regarding its possible influence on the ionosphere. In some papers, authors find possible responses of tropical cyclones in the lower (Mikhailov et al., 2005; Vanina-Dart et al., 2007a, 2007b, 2008), upper (Bauer, 1957, 1958; Shen, 1982), and even topside (Mikhailova et al., 2002) ionosphere, whereas, for example, Afraimovich et al. (2008) found no response. In spite of the fact that searches for the results of the tropical cyclone–ionosphere interaction have been performed since the middle of the previous century, the number of publications on this problem is small. Certainly, it is not only related to the deficit of corresponding data, but to the absence of a reliable theoretical mechanism of such interaction. Nevertheless, searches in this direction are continuing (to a substantial degree, in the publications of Chinese scientists) (see, for example, (Tian et al., 2009)).

The previous publications of the authors of this paper were dedicated to TC manifestations in the lower *D* region of the ionosphere. A version of a hypothetical physical mechanism of "rapid" interactions between tropospheric disturbances and the ionospheric state (internal gravity waves (IGW) induced by a TC) was proposed in these publications.

The data used in this paper were obtained by the method of phase-difference tomography. The peculiar feature of the ionospheric tomography method based on signals of low-orbiting navigation systems gives a possibility to reveal the variations in the ionospheric electron concentration caused, for example, by the propagation of strong cyclones in the Earth's troposphere. It principally could not be done using global satellite navigation systems—GLONASS and GPS. Unlike phase tomography, where the total phase is an integral value, the phase-difference method is more sensitive to relatively small irregularities of the electron concentration, which provide an insignificant input into the phase and a more substantial input into its derivative.

The goal of this paper is to search for possible influences of TCs on the topside ionosphere on the basis of tomography data obtained on Sakhalin Island in 2007. Observations were conducted over three points located at the same meridian: Yuzhno-Sakhalinsk (47° N, 142° E), Poronaisk (49° N, 143° E), and Nogliki (51° N, 143° E).

2. DATABASE AND METHOD OF OBTAINING EXPERIMENTAL RESULTS

2.1. Description of the Method

The known relationships for phases and amplitudes of radiowaves in the geometrical optics approximation (Andreeva et al., 1992; Kunitsyn et al., 2007) are a theoretical basis for ray radio tomography. The following pair of equalities determines the linear integrals of the distribution of electron concentration and effective collision frequency ν:

$$\phi = \lambda r_e \int N_e d\sigma, \quad (1)$$

$$\chi = -\frac{\lambda r_e}{\omega} \int N_e \nu d\sigma, \quad (2)$$

where λ is the wavelength of the sounding wave, r_e is the classical electron radius, $\omega = kc$, k is the wave number in free space, c is the velocity of light, and $\int d\sigma$ is the symbol of integration along the path of signal propagation. Here, the phase difference $\phi = \Phi_0 - \Phi$ and level χ, which is a logarithm of the ratio of signal amplitudes $\chi \sim \ln(A/A_0)$ of the measured field ($E = A\exp(i\Phi)$) and the field of the sounding wave ($E_0 = A_0\exp(i\Phi_0)$), are linear integrals.

In the process of studies, linear integral (1) multiplied by a constant of the order of unity (Kunitsyn et al., 2007), which is related to phase recalculations from one frequency to another, is calculated. The main difficulty in the determination of this integral is that the phase value is rather high. For typical values $N_e \sim 10^{12}$ m^{-3}, $\lambda = 2$ m, and a ray length of a thousand kilometers in the ionosphere, ϕ is thousands of radians.

There appears to be a problem associated with revealing the initial phase, which stays constant during a radio transillumination seance ($\phi_0 = 2\pi n$), which should be added to the measured phase (within the 2π limits) Δϕ in order to obtain the absolute (total) phase $\phi = \phi_0 + \Delta\phi$ or linear integral (1) (Andreeva et al., 1992; Kunitsyn et al., 2007).

To solve the problem regarding the unknown initial phase, Andreeva et al. (1992) and Kunitsyn et al. (2007) proposed a method of phase-difference tomography, the essence of which was in using the phase derivative $d\phi/dt$ as an integral characteristic (which evidently contains no unknown constant corresponding to the initial phase of the signal). Unlike phase tomography, where the total phase is an integral value, the phase-difference method is more sensitive to relatively small irregularities in the electron concentration, which provide an insignificant input into the phase and a more substantial input into its derivative. In reconstructions of the electron concentration field performed using the phase tomography method, details with dimensions smaller than a few hundred kilometers do not appear, whereas phase-difference tomography makes it possible to accurately reconstruct structures with a dimension of 100 km and an electron concentration value of 4–6% of the maximum concentration (Andreeva et al., 1992; Kunitsyn et al., 2007). Thus, the method of phase-difference tomography is fairly accurate and efficient for reconstructing the electron concentration distribution in the ionosphere (Andreeva et al., 1992; Kunitsyn et al., 2007; Romanov et al., 2008).

The mathematical side of the problem assumes the quantization of a set of integrals of types (1) and (2) and the following solution of the system of linear equations $Ax = b$, where A is the matrix of approximation of the projection operator, b is the vector of measured values, and x is the vector of reconstructed values of the electron concentration.

According to the estimates presented by Kunitsyn et al. (2007), the use of the ionospheric tomography method on the bases of signals of low-orbiting navigation systems makes it possible to reconstruct the N_e vertical distribution along a satellite flight path with a resolution not less than $\Delta\tau = 20 \times 10$ km. Therefore, there appears a possibility for the revealing of the variations in N_e in the ionosphere caused by the propagation of strong cyclones in the Earth's troposphere, which principally could not be done only using global satellite navigation systems—GLONASS and GPS.

2.2. Results of a Numerical Simulation of the Reconstruction of the Electron Concentration Distribution in the Ionosphere

To estimate the processing quality of radio transillumination data using the method proposed by Urlichich et al. (2006), reconstructions of the model distribution of the electron concentration in the ionosphere were performed using a program and mathematical complex developed by Romanov et al. (2008) for conditions identical to the real geometry of the experiment described by Romanov et al. (2008) and Urlichich et al. (2006).

The errors in the reconstruction were estimated through calculating the discrepancy between the initial and restored functions and were determined by the following relationships (Kunitsyn et al., 2007):

$$\delta_2 = \frac{\sqrt{\sum_i (F_i - \tilde{F}_i)^2}}{\sqrt{\sum_i F_i^2}}; \quad \delta_m = \frac{\max_i |F_i - \tilde{F}_i|}{\max_i |F_i|},$$

where F and $\tilde{F}$ are the values of the initial and reconstructed functions, respectively.

The study results showed that at the reconstruction of the model distribution describing the disturbed state of the ionosphere (the presence of irregularities and a

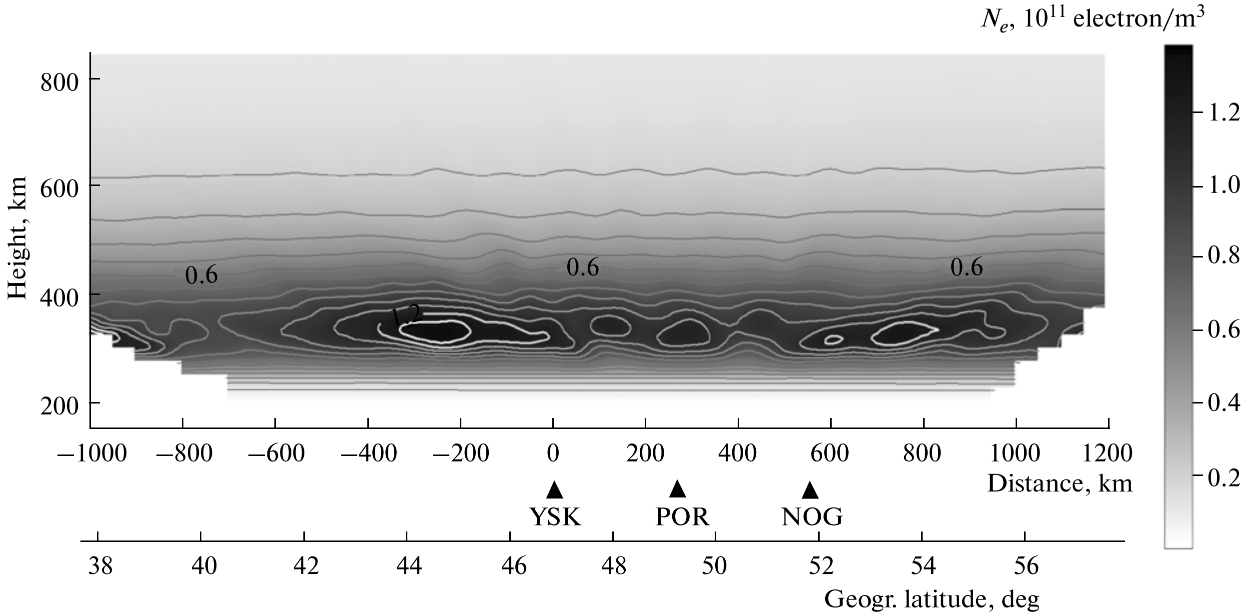

Fig. 1. Electron concentration distribution on July 29, 2007, at 0030 LT in the region of Sakhalin Island (YSK, POR, and NOG are the Yuzhno-Sakhalinsk, Poronaisk, and Nogliki points).

horizontal gradient of the electron concentration), the errors in the reconstruction of the electron concentration values were characterized by the values $\delta_2 = 0.08$ and $\delta_m = 0.10$.

2.3. Results of Experimental Studies

Experimental studies conducted on the reliability of the developed system for collection and processing of data on the radio transillumination of the ionosphere were performed using a network of receiving installations located on Sakhalin Island (Romanov et al., 2008; Urlichich et al., 2006).

The operation results of the system of collection and processing of data on the radio transillumination of the ionosphere present the altitude–latitude distribution of the electron concentration (Fig. 1). Figure 2 shows the comparison results of the data obtained by the Wakkanai ionosonde located on Hokkaido Island 150 km southwards from the tomography chain with the data obtained using the program and mathematical complex.

Data on 90 reconstructions were used in the analysis, 50 and 40 of which were obtained in July–August 2007 and January 2008, respectively. For comparison with the ionosonde data, the maximum values of the electron concentration in the region of the ionosonde location were recalculated into the critical frequency *foF*2 values.

The *foF*2 determination results are in good agreement: the mean discrepancy and δ_2 were 15% and 0.13, respectively. The correlation coefficient between the two series of data $R = 0.84$. These results agree well with the estimates of the accuracy of reconstructions of the electron concentration on the basis of ionosonde data ($\delta_2 = 0.9$–0.11) obtained in independent studies (Kunitsyn et al., 2007).

Independent estimates were obtained using the phase-difference approach and without using the automated processing method. The agreement between these results indicates the fact that the method developed makes it possible to restore the electron concentration distribution in the ionosphere in automatic mode with an accuracy typical for the phase-difference tomography method.

3. ANALYSIS OF THE TOMOGRAPHY SOUNDING DATA OBTAINED IN THE FIRST HALF OF NOVEMBER 2007

Analysis of ionospheric data is a multiparameter problem. The electron concentration in the *F* region depends on the solar zenith angle (time of the day), season, solar and geomagnetic situation, and other parameters. Bearing in mind the location of Sakhalin Island, we should also have data on the seismic activity in the region considered. In the last decades, much attention has been paid to the problem of the lithosphere–atmosphere–ionosphere interaction, and it has been proved that processes in the lithosphere have an electrodynamic influence on the ionosphere. Liperovskii et al. (1992), Gokhberg et al. (1983), Pulinets et al. (1998, 2002), and Pulinets and Boyarchuk (2004) enumerated the main characteristics of ionospheric precursors of strong earthquakes. For example, the results obtained by Smirnov (2011) show that in an epicenter region 3–5 days prior to an earthquake, an increase in the electron concentration in the maximum of the $F2$ layer is observed with its later decrease 1–3 days prior to the earthquake. At the same time, on the eve of an earthquake (1–2 days prior to it), a break in the spatiotemporal behavior of the electron concentration maximum occurs.

In order to find the possible "pure" effect of TCs on the ionosphere, it was decided to reject data, which contained seismic events, and to use for analysis in this work only the series of data when for a long period of time there were no earthquakes in the region of the receiving installation of ionospheric radio transillumination. The seismic data, which were used in this paper, are presented on the website of the Sakhalin Hydrometeorological Service (www.sakhmeteo.ru). In November 2007, earthquakes were absent in the region of Sakhalin Island. Taking into account this factor, the authors considered four series of measurements, which were conducted in the first half of November 2007. Table 1 presents information on the solar and geomagnetic situation for these series of tomography sounding. For each sounding, Table 1 shows the solar activity $F10.7$ index and the geomagnetic activity Dst and Kp indices. One can see in Table 1 that the situation at the given moments was very quiet and, respectively, the influence of solar and geomagnetic activity on changes in the $F2$ layer could be neglected.

Table 2 shows the geographic position, wind velocity, and the stage of tropical cyclones, which were the closest in their location to Sakhalin Island. Table 2 also shows the measurement dates and times of the data on TCs. More complete information on these TCs could be found at http://weather.unisys.com/hurricane/. We have selected the part of information, which is most interesting and significant.

We took for analysis the data for November 5, 7, 8, and 11, 2007. On these days, in the western part of the Pacific Ocean, two TCs were acting. The information on these cyclones is presented in Tables 3 and 4. The critical frequency of the $F2$ layer ($foF2$) was chosen as a studied parameter. All sessions of tomography sounding were conducted in one season. In this period, in the region of Sakhalin Island, earthquakes were absent for a long period of time. On November 5, 8, and 11, 2007, one can also neglect the N_e dependence on the solar position, because the measurements were conducted near local noon. Certainly, it would be more correct to compare the results at midnight, because the daytime ionization process (mainly depending on the solar radiation in the short-wavelength range) is much less sensitive to disturbances from other ionization sources. Nevertheless, the following morphological results within the 45°–53° N latitudinal range (namely, this range was chosen, because it was present in all measurements) were obtained. We have chosen the $foF2$ parameter for analysis.

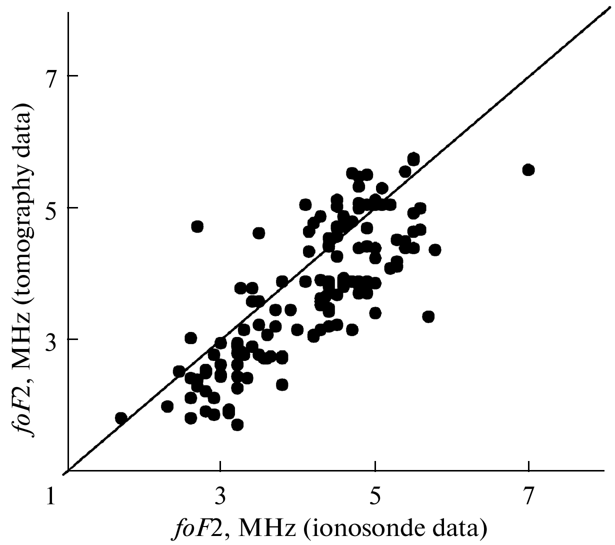

Fig. 2. Comparison of the critical frequency $foF2$ values obtained as a result of ionospheric tomography with the data of a Wakkanai ionosonde.

On November 5, measurements were conducted at an interval of 1 h 25 min (Fig. 3). Within the latitude range 45°–53° N, the change in the $foF2$ parameter during the first (1225 LT) and second (1350 LT) series of measurements had average values of 5.04 and 3.98 MHz, respectively. Maxima of 5.47 MHz (at 1225 LT) and 4.09 MHz (at 1350 LT) were registered. The correlation coefficient between the series of measurements

Table 1. Solar and geomagnetic situation during tomography sounding

N_e measurement data	N_e measurement time, UT	$F10.7$	Dst, nT	Kp
Nov. 5, 2007	0225	66	–2	1
	0350		0	
Nov. 7, 2007	2117	67	2	0
	2306		5	
Nov. 8, 2007	0205	68	8	0
	0324		11	
Nov. 11, 2007	0145	68	–1	0
	0257		–2	

Table 2. Data on the tropical cyclones, which were located near the place and on the date (or nearby) of conducting tomography sounding

Date of N_e measurements	Data on TCs				
	Latitude, deg	Longitude, deg	Time, mm/dd/hh (UT)	Wind velocity, knots	TC stage
Nov. 5, 2007	16.8	122.5	11/04/12	33	Ò-1
Nov. 7, 2007	18.0	116.2	11/07/06	33	Ò-1
Nov. 8, 2007	16.8	114.1	11/08/00	21	TS
Nov. 11, 2007	20.0	139.9	11/11/06	15	TD

within the above-indicated latitude range is $R = 0.38$ (the number of measurements is 18). Figure 3 also shows the model latitudinal dependencies of *foF*2 (solid and dashed curves correspond to 1225 and 1350 LT, respectively). The model lines were drawn using the IRI-2007 international ionospheric model (http://omniweb.gsfc.nasa.gov/vitmo/iri_vitmo.html).

On November 7 (Fig. 4), measurements were conducted at an interval of 1 h 49 min. Within the 45°–53° N latitudinal range, the *foF*2 parameter varied with average values of 2.90 MHz (at 0717 LT) and 4.03 MHz (at 0906 LT). Maxima were registered with values of 3.07 MHz (at 0717 LT) and 4.35 MHz (at 0906 LT); $R = 0.16$ (the number of measurements is 17).

On November 8 (Fig. 5), measurements were conducted at an interval of 1 h 19 min. Within the 45°–53° N range, the critical frequency of the *F*2 layer varied both at 1205 and 1324 LT with average values of 5.33 and 4.63 MHz, respectively. Maxima were registered with values of 5.74 MHz (at 1205 LT) and 5.0 MHz (at 1324 LT); $R = 0.94$ (the number of measurements is 18).

On November 11 (Fig. 6), measurements were conducted at an interval of 1 h 12 min. Within the 45°–53° N latitude range, the *foF*2 parameter varied both at 1145 and 1257 LT with average values of 5.25 and 4.81 MHz, respectively. Maxima were registered with values of 5.39 MHz (at 1145 LT) and 5.46 MHz (at 1257 LT); $R = 0.26$ (the number of measurements is 18).

Figure 7 shows the dependences of the *foF*2 parameter (measured near local noon) on the latitude for November 5, 8, and 11, 2007. As we have noted above, the curve obtained at 1350 LT on November 5, 2007, strongly differs from the other curves (it is by a factor of ~1.5 lower in value). Publications are known in which decreases in *foF*2 are related to the passage of TCs. The result obtained by us confirms the decrease in *foF*2, which emphasizes its importance. Note that on November 5, 2007, a TC in its first stage was localized approximately 30° southwards and 20° westwards

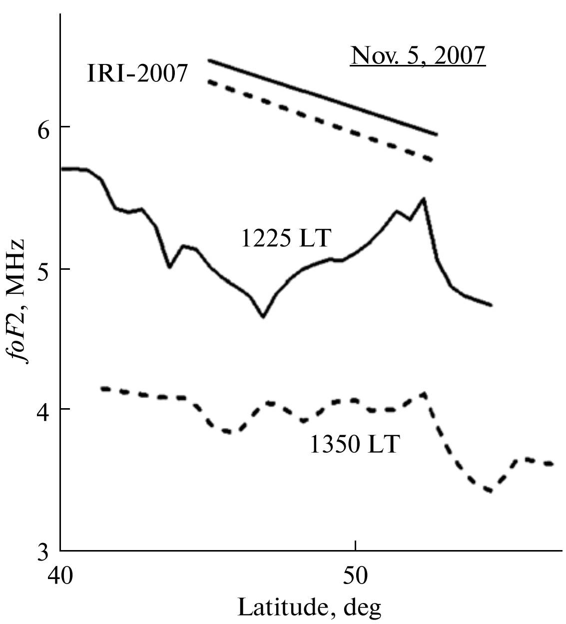

Fig. 3. Latitudinal dependence of the critical *foF*2 frequency measured on November 5, 2007, over Sakhalin Island.

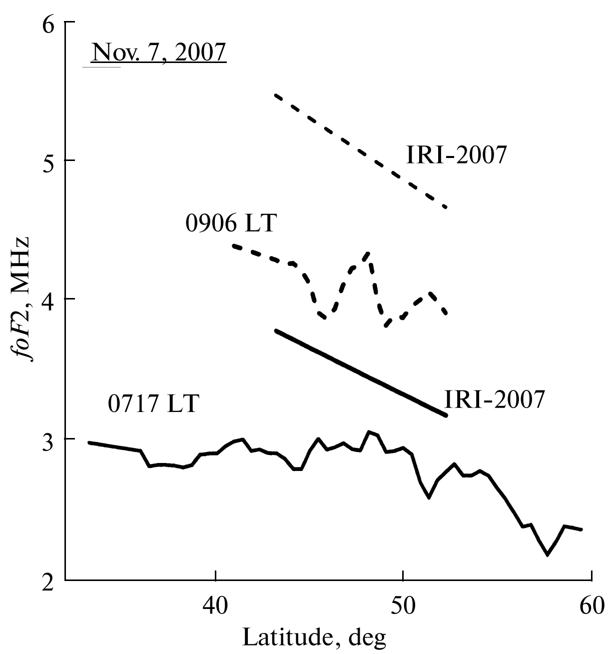

Fig. 4. The same as in Fig. 3, but for *foF*2 measured on November 7, 2007.

Table 3. Data on the passage of a tropical cyclone on November 1–10, 2007, over the area of the western Pacific Ocean

No.	Latitude, deg	Longitude, deg	Time, mm/dd/hh (UT)	Wind velocity, knots	TC stage
1	17.7	132.90	11:01:18	15	TD
2	18.0	132.60	11:02:00	15	TD
3	18.3	132.30	11:02:06	20	TD
4	18.5	131.40	11:02:12	15	TD
5	18.8	130.50	11:02:18	20	TD
6	18.4	129.60	11:03:00	20	TD
7	18.2	128.50	11:03:06	25	TD
8	18.1	127.20	11:03:12	35	TS
9	17.5	126.10	11:03:18	45	TS
10	17.0	124.90	11:04:00	50	TS
11	16.8	123.60	11:04:06	60	TS
12	16.8	122.50	11:04:12	65	T-1
13	17.2	120.90	11:04:18	65	T-1
14	17.5	120.00	11:05:00	55	TS
15	17.6	119.60	11:05:06	55	TS
16	17.7	119.20	11:05:12	55	TS
17	18.0	118.80	11:05:18	60	TS
18	18.4	118.60	11:06:00	70	T-1
19	18.6	118.40	11:06:06	75	T-1
20	18.7	118.20	11:06:12	75	T-1
21	18.5	117.70	11:06:18	75	T-1
22	18.3	117.10	11:07:00	70	T-1
23	18.0	116.20	11:07:06	65	T-1
24	17.6	115.40	11:07:12	55	TS
25	17.3	114.70	11:07:18	50	TS
26	16.8	114.10	11:08:00	40	TS
27	16.3	113.40	11:08:06	35	TS
28	15.8	112.80	11:08:12	35	TS
29	14.8	112.20	11:08:18	35	TS
30	13.7	111.60	11:09:00	30	TD
31	12.6	111.40	11:09:06	25	TD
32	12.2	111.10	11:09:12	25	TD
33	11.8	110.30	11:09:18	25	TD
34	11.5	109.60	11:10:00	20	TD
35	11.5	108.50	11:10:06	20	TD

from the place of obtaining the experimental data in the horizontal projection over Sakhalin Island. It is also worth noting that during the almost 1.5-h interval of measurements, the critical frequency of the *F*2 layer reached a maximum difference by a factor of 1.35 in the 51.5° N region and a minimum difference by a factor of 1.15 in the 47° N region. In Figs. 6 and 7, the evident disturbance (“a swell”) in *foF*2 registered on November 11, 2007, also draws attention. As it has been noted above, the measurements were conducted

Table 4. Data on the passage of a tropical cyclone on November 9–12, 2007, over the area of the estern Pacific Ocean

No.	Latitude, deg	Longitude, deg	Time, mm/dd/hh (UT)	Wind velocity, knots	TC stage
1	16.3	147.70	11:09:06	15	TD
2	17.0	146.00	11:09:12	20	TD
3	17.5	144.60	11:09:18	20	TD
4	18.0	143.40	11:10:00	20	TD
5	18.5	142.20	11:10:06	20	TD
6	18.9	141.40	11:10:12	20	TD
7	19.4	140.60	11:10:18	25	TD
8	19.7	140.20	11:11:00	25	TD
9	20.0	139.90	11:11:06	30	TD
10	20.4	139.90	11:11:12	30	TD
11	21.2	140.60	11:11:18	35	TS
12	22.2	142.00	11:12:00	35	TS
13	23.2	143.60	11:12:06	35	TS
14	24.1	146.00	11:12:12	35	TS
15	26.4	149.70	11:12:18	25	TD

at an interval slightly longer than one hour. At the same time, the critical frequency obtained in the first series at 1145 LT slightly exceeded (by no more than 10%) the values of this parameter obtained in the second series at 1257 LT within the latitudinal range from 47° to 54° N with a maximum at a latitude of 48° N. In the 1257 LT series, three distinct maxima are observed at latitudes of 45°, 50°, and 53° N. The fact that there is one higher maximum in the 36° N region is interesting. It is, most probably, a confirmation of the disturbance propagation from the south. At the same time, a TC at the depression stage nearly came from the west to the meridian of the measurement zone and was located 25°–30° southwards. It is worth remind once more that the observations were conducted at the same meridian, that is, we observed a "pure" latitudinal dependence, which was manifested in various periods of oscillations in the *foF*2 parameter. In such a "meridional cut off," we could expect the disturbances of the given parameter to be propagating southwards (or

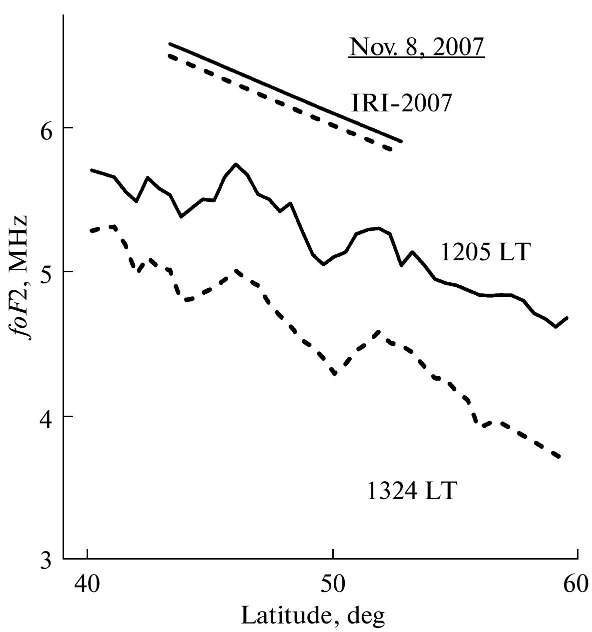

Fig. 5. The same as in Fig. 3, but for *foF*2 measured on November 8, 2007.

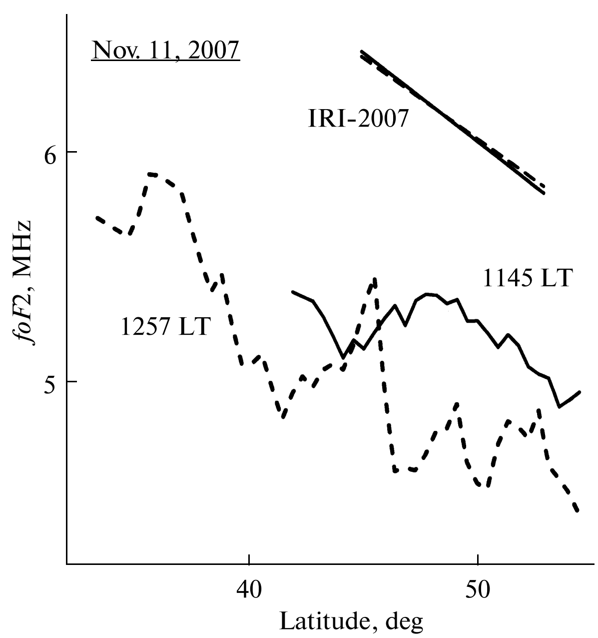

Fig. 6. The same as in Fig. 3, but for *foF*2 measured on November 11, 2007.

northwards) in the form of discrepancies between the curves of the same measurement when the correlation coefficient is close to unity (as, for example, on November 8, 2007) (see Fig. 5).

4. DISCUSSION

Figures 3–6 show that the measured values of the *foF*2 parameter corresponding to certain measurements are lower than the values calculated using the model for the same measurements.

It has been mentioned above that the results obtained on November 5 and 11, 2007, are the most interesting. According to Table 3, on November 5, 2007, the tropical cyclone was in the tropical storm stage, but less than a day before the measurements, it had been at the TC-1 stage (near 121° E). One should also take into account that the given tropical cyclone was born at a longitude of 133° E.

It should be noted that a TC is not a point-instantaneous disturbance, but should be considered as an "extended" and lasting disturbance. It is reasonable to search for a ionospheric response in the zone over an acting TC. We will conventionally call this zone "broad-band." The localization of this zone (10°–20° westwards or eastwards from the TC location) depends on the disturbance propagation direction.

We assume that the decrease in the *foF*2 parameter obtained experimentally as compared to the model values (IRI-2007) is not occasional. Figure 3 shows that at 1350 LT on November 5 the critical frequency of the *F*2 layer was less than the assumed one by a factor of ~1.35. It has been shown that, a day after the TC passage over the zone, a decrease in N_e was observed. Vanina-Dart et al. (2008) for the first time registered the experimental fact of depletion in N_e in the *D* region at a distance of about 1000 km (horizontally) from the nucleus of a tropical cyclone operating in an active phase.

Besides the fact of depletion of the *foF*2 parameter value, we observed also an increase in the *foF*2 values (a latitudinal "swell") at 1145 LT on November 11, 2007, from 45° to 55° N and a very irregular behavior at 1257 LT (Fig. 6). On that day, the tropical cyclone was at the tropical depression stage (see Table 4) at a longitude of 140° E (whereas it was born at 147° E). In other words, along longitude, the TC came close enough to the observation points on Sakhalin Island. These results also agree with the publication by Tian et al. (2009). They think that a decrease or increase in the total electron content (TEC) in the ionosphere depends on the position of the TC from the point of view of its "landing" (crossing the land in the horizontal projection relative to the Earth's surface). The main conclusion of Tian et al. (2009) is the following: before the "landing" of a typhoon, the TEC value is above the corresponding monthly median value, but after the "landing" of the TC, it becomes much lower,

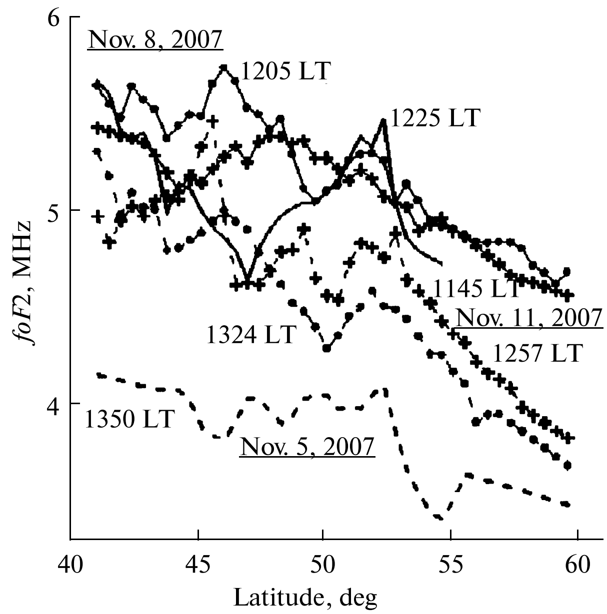

Fig. 7. Comparison of the latitudinal dependencies of the *foF*2 critical frequency measured on November 5, 8, and 11, 2007, over Sakhalin Island.

reaching a minimum one day later. Observations exactly over the zone of the cyclone itself were considered.

In our case, on November 5, 2007, the tropical cyclone had actually crossed the continent one day before the ionospheric parameters were registered, but it was by 20° westwards from the place of measurements. We think that it would be too premature to relate the electron concentration decrease to the "landing" of the TC. Most probably, the mechanism of TC influence on the ionosphere is much more complicated and is a result of the summated impact of waves of various nature and various periods (from hours up to a few days) from the disturbance source during several days.

5. CONCLUSIONS

On the basis of the performed analysis of the data obtained by the phase-difference tomography method in the first half of November 2007 on Sakhalin Island, the authors of this paper came to the following conclusion: The possible response of the topside ionosphere localized over a tropical cyclone zone (in the given case, by 25°–30° northwards and by 5°–20° eastwards) at a distance from ~3800 to 5500 km is a change in its parameter *foF*2 by on average no more than 10–20%. Nevertheless, it is a substantial response at such distances from the disturbance source. A decrease or, vice versa, an increase in *foF*2 is related to the "delay" of the measurement moment relative to the beginning of TC action.

We think that the complications associated with finding a tropical cyclone response in the ionosphere (and its very complicated morphology) are related to the fact that a TC is a "broad-band" disturbance source acting during a long time. That is, if we assume that IGWs are sources of disturbance transport from below, we have the result of their summated impact.

We plan to conduct a more serious discussion of the hypothetic mechanisms of TC influence on the ionosphere in the following paper, where we will present the rest of the series of measurements conducted in 2007.

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