National Aeronautics and Space Administration
Goddard Space Flight Center
Contract No. NAS-5-12487

ST-AI-RWP-10570

# STATE OF THE IONOSPHERE AFTER THE RESULTS OF SIGNAL OBSERVATIONS FROM AES "ELEKTRON-1" AND "ELEKTRON-3"

by


E. E. Mityakova
V. A. Cherepovitskiy

(USSR)




28 FEBRUARY 1967

# STATE OF THE IONOSPHERE AFTER THE RESULTS OF SIGNAL OBSERVATIONS FROM AES "ELEKTRON-1" AND "ELEKTRON-3"

Izv. Vysshikh Uch.Zavedeniy
"Radiofizika"
Tom 10, No.1, pp. 7 - 13,
Izd. Gor'kovskogo Universiteta
G O R'K I Y, 1967

by E. E. Mityakova
V. A. Cherepovitskiy

## SUMMARY

The results of observations are presented of phase difference of coherent frequencies of 20 and 30 Mc, carried out from AES Electron-1 and Electron-2 during the periods February-March and July-October 1964 in the city of Gor'kiy. The course of the total electron concentration was obtained

$$N_{n\infty} = \int_0^\infty N dz.$$

The minimum values $N_{n\infty}(0.2 \div 0.3) \cdot 10^{13}$ el cm$^{-2}$ are noted at nighttime, and the maximum values $N_{\infty}(1.3 \div 1.5) \cdot 10^{13}$el cm$^{-2}$ in the afternoon hours. The dependence is presented of ionosphere's effective thickness on the time of the day. Two maxima of effective thickness of the ionosphere are observed, respectively at times of sunrise and sunset. Obtained also is the dependence of the dimensions of large-scale inhomogeneities and of the magnitude of relative variation of electron concentration $\Delta N_n/N_n$ on latitude and the time of the day.

*

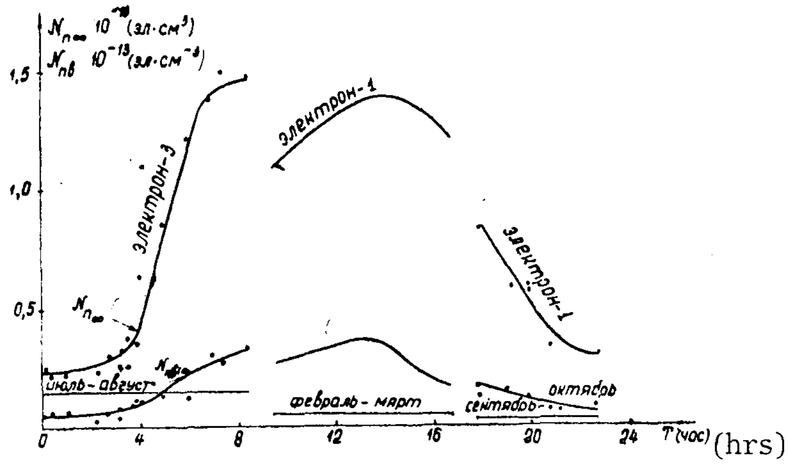
* *

Observations of signals from AES Electron-1 and -3 were carried out Zimenki during the periods from 22 February to 26 March and from 7 July to 1 October 1964 in the coherent frequencies of 20.005 and 30.0075 Mc/sec. More than 100 sessions were altogether conducted, of which 76 have been processed. The main object of observations was the investigation of the distribution of electron concentration in the ionosphere, the obtaining of the daily course of electrons in a vertical column of unitary cross section and of the effective thickness of the ionosphere above the F2-layer maximum, the study of the latter's variations in shape in the course of a day, and the ascertaining of temporal and spatial regularities in the behavior of the imhomogeneities of a "full column" of electrons to the height of the satellite.

* (SOSTOYANIYE IONOSFERY PO REZUL'TATAM NABLYUDENIY ZA SPUTNIKAMI ELEKTRON-1 i ELEKTRON-3)

The dispersion interferometer method, the receiving apparatus and the the method of experimental data are sufficiently fully described in the works [1, 2, 3]. Presented in the current paper are the results of observations of AES Electron-3 related to evening, night and morning hours for the period from July to October 1964. For comparison we also brought out the data on the integral electron concentration obtained with the aid of AES Electron-1, related to daytime hours (0930 to 1700 hours) in February-March 1964 and presented in the work [3].

The dependence of the total column of electrons $N_{n\infty} = \int_0^\infty N dz$ on the time of the day is shown in Fig.1; $N_{n\infty}$ was computed according to readings of signal phase differences in two frequencies and to the data of the station for the vertical sounding of the ionosphere using the method described in [3]. The daily course was taken down on different days and seasons. The total integral refers to the vertical profile of the ionosphere passing through the "sub-ionospheric point" (see [3]), which was located for the considered flights in the $\sim 53° \div 59°$ latitude interval. Besides the daily course, the seasonal dependence is also seen in Fig.1. In the summer months the rise of integral concentration begins somewhat earlier.




July-Aug. Febr.-March Sept-Oct.

Fig.1

The results of observations have shown that the maximum value of the total electron column at the latitude of Gor'kiy in the period of solar activity minimum correspond to the near-noon hours (1100 ÷ 1500 hours) and constitute $(1.3 \div 1.5) \cdot 10^{13}$ el$\cdot$cm$^{-2}$, and the minimum value -between 2200 and 0200 hours- constitutes $(0.2 \div 0.3) \cdot 10^{13}$ el$\cdot$cm$^{-2}$. The ratio

$$N_{n\ max} / N_{n\ min} \sim 5 \div 6.$$

The lower curve in Fig.1 corresponds to the integral electron concentration to the F2-layer maximum

$$N_{nb} = \int_{z_m}^{\infty} N dz,$$

where $z_m$ is the height of the $F_2$-layer maximum; $N_{nb}$ was computed according to the data of vertical sounding at Zimneki. The mean values of the ratio $N_{na}/N_{nb}$, where $N_{na} =$ Ndz is the integral electron concentration above the $F_2$-layer maximum, are compiled in Table 1.

TABLE 1

| | ELECTRON-1 | | | ELECTRON-3 | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| t (hrs, min.) | 09 30 | 12 30 | 15 30 | 18 00 | 20 00 | 23 00 | 0100 | 0400 | 0730 |
| $N_{na} / N_{nb}$ | 2.8 | 2.6 | 4.2 | 6.2 | 3.6 | 2.25 | 2.7 | 5.2 | 4.0 |

Comparison of the obtained daily course of $N_{n\infty}$ with the measurement data related to solar activity maximum of 1960 (see, for example [4]), shows that the ratios $N_{n\max}/N_{n\min}$ and $N_{na}/N_{nb}$ depend little on the activity of the Sun while the values of $N_{n\infty}$ in the period of the minimum are 3 -6 times smaller than in the period of the maximum.

Data on integral concentration of electrons to satellite height

$$N_{ns} = \int_0^{z_s} N \, dz \quad (z_s \sim 1000 \text{ km})$$

obtained in the period of decreased solar activity (1962) with the aid of AES Transit 4A. These data agree well with the results of our own measurements.

We assumed, as was done in [3], that above the $F_2$-layer maximum, and up to $\sim 1000$ km, electron concentration is distributed according to the exponential law

$$N = N_{max} \exp\left(-\frac{z - z_m}{H}\right),$$

where H is the effective thickness of the ionosphere above the $F_2$-layer maximum; $H_{max}$ and $z_{max}$ are respectively the concentration of electrons and the height of the $F_2$-layer maximum.

The daily course of the effective thickness of the upper part of the ionosphere (H) is plotted in Fig.2 by a solid line. Plotted in the same graph is the daily course of the effective thickness of the entire ionosphere ($\tau$), defined as $\tau = N_{n\infty} / N_{max}$ (dashed line).

It may be seen from the graph that ionosphere "expansion" takes place twice a day: after sunrise (0500-0700 hrs) and during sunset (1700-1900 hrs). In daytime (100 $\div$ 1600 hrs) the effective thickness of the ionosphere is $\tau \sim 250 \div 300$ km.

Qualitatively the presence of maxima and minima at sunrise and sunset may apparently be explained by the irregular illumination of the the entire thickness of the ionosphere at these hours. Sunrise, and consequently, also the ionization of the upper layers of the ionosphere by ultraviolet radiation, begins earlier than in the lower part and at the altitude of the $F_2$-layer maximum. Analogously, at sunset too the upper layers of the ionosphere are subject to the action of solar radiation during a more prolonged time than the lower ones.

It is interesting to compare the curve for $\tau$ in Fig.2 with an analogous dependence obtained in the period of solar activity maximum in [4]. The diurnal values brought out in this work and the morning maximum just about coincide with our results. The evening maximum is more spread out, practically merging with the morning one. Apparently, the enhancement of solar activity is more manifest in the nighttime concentration of the layer.

The daily dependence of the parameter $\tau$ is also brought out in [5], but, contrary to our data, the effective thickness of the ionosphere is determined here to the height of the satellite, that is

$$\tau = \int_0^{z_s} N\,dz \,/\, N_m.$$

This may explain the discrepancy in the value of $\tau$ maximum in morning hours (420 km). There is no clearly expressed evening hour maximum in the work [5].

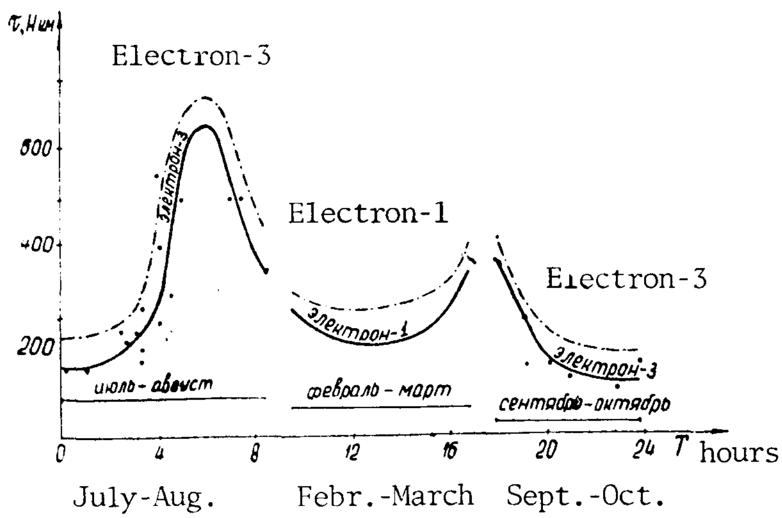



Fig.2

The variation in shape of the $F_2$-layer in the course of 24 hours is shown in Fig.3. The lower part of the profile to the $F_2$-layer maximum is computed for each case with the aid of a computer. The average profile is plotted in Fig.3 for a given time of the day. Above the $F_2$-layer maximum the shape of the layer was considered exponential with the mean value of H corresponding to the given time.

In our opinion, great interest is offered by the comparison of the profiles obtained with the recently published result of impulse sounding of the ionosphere with the aid of AES Alouette [6]. The data of the latter show that the upper part of the $F_2$-layer has a completely smooth course up to $\sim$ 1000 km, which is well described by the exponental law and which does not reveal any secondary maxima [7].

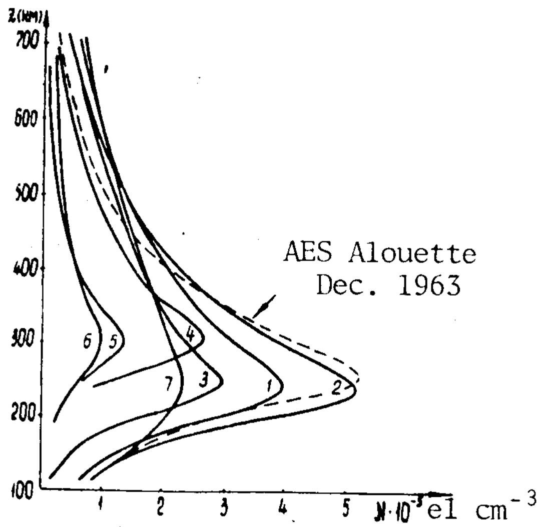



Fig.3. The first profile 1) corresponds to 0900 ÷ 1000 hours; 2) — to 1200 ÷ 1400 hours; 3) — to 1700 ÷ 1800 hours; 4) — to 1900 ÷ 2000 hours; 5) — to 2300 ÷ ÷ 0100 hours; 6) — to 0200 ÷ ÷ 0400 hours; 7) 0600 ÷ 0700 hrs.

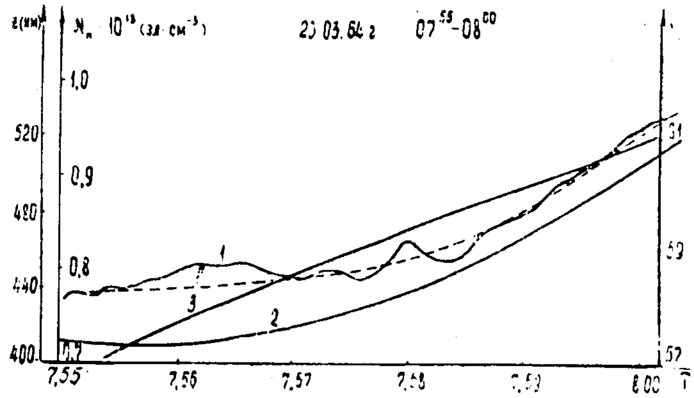



Fig 4. Total integral $N_{ns} = \int_0^{z_s} N\,dz$ to satellite's height as a function of time for the period of one sess. (curve 1). Satellite height variation (curve 2). Latitude of the sub-ionosphere point for the same period (curve 3)

For comparison we plotted in Fig.3 the profile obtained in [6] at 40° latitude at 1314 hours local time in December 1963 (dashes). A certain discrepancy is quite easily explained by the latitude and seasonal course.

The investigation of the irregular course of the total column of electron concentration included the study of the fluctuations of the total electron concentration column as a function of the time of the day and of latitude. The total integral to the height of the satellite

$$N_{ns} = \int_0^{z_s} N\,dz$$

as a function of time for the period of a single observation session is shown in Fig.4. It may be seen that large-scale as well as tiny fluctuations of the total column of electrons take place. The smoothed dependence $N_{ns}(t)$ is shown in the diagram by a dashed line. The relative fluctuations of the total electron column $\Delta N_{ns}/N_{ns}$ were determined for each inhomogeneity; here $\bar{N}_{ns}$ is the relative value of the integral on each portion, and $\Delta N_{ns}$ is the maximum deflection from it. The horizontal dimension of these inhomogeneities was computed by the formula

$$l_i = \Delta t_i \frac{z_m}{z_s} v_r,$$

where $\Delta t$ is the duration of the i-th inhomogeneity, $z_m$ is the height of the "sub-ionospheric" point; $z_s$ is the height of the satellite and $v_r$ is its horizontal velocity. Moreover determined was the parameter $\Delta T/T$ of inhomogeneity appearance, where T is the total observation time and $\Delta T$ is the time in the course of which inhomogeneities were observed.

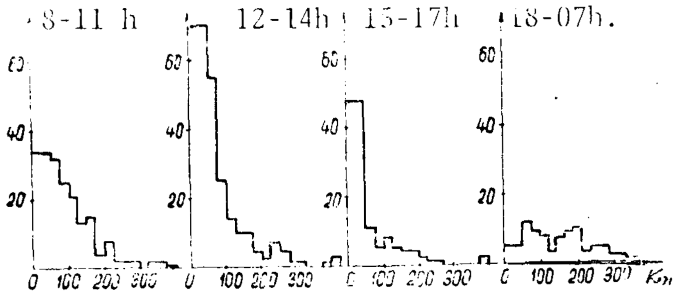



Fig.5

Shown in Fig.5 is the histogram of the parameter T/T of inhomogeneities with various dimensions in the course of different periods of a day*. It may be seen that for inhomogeneities with dimensions to 50 km there is observed a maximum in diurnal hours, which then gradually spreads out. More probable in the nighttime is the appearance of inhomogeneities with dimensions $\sim 100 \div 200$ km. These results agree well with the data earlier obtained by us on AES Cosmos-1 and Cosmos-2 [8].

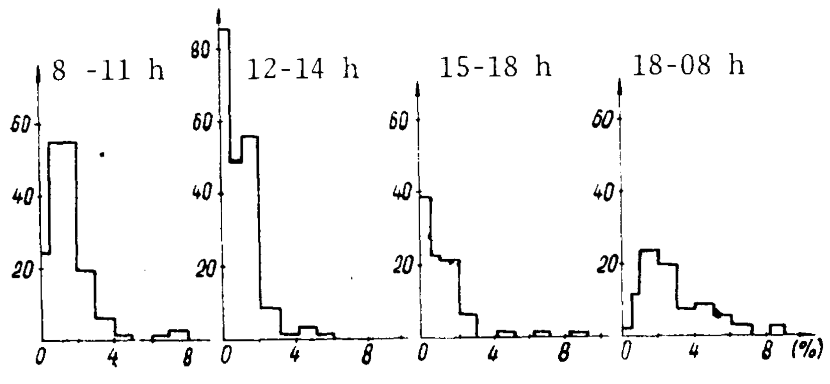



Fig.6

Analogous histograms for the parameter $\Delta N_n/N_n$ are brought out in Fig.6. The number of cases is plotted in ordinates, and $\Delta N_n/N_n$ is shown in percent in the abscissa axis. A clearly expressed maximum $\Delta N_n/N_n < 1\%$ is seen in daytime hours, which then becomes wider; relative fluctuations $\Delta N_n/N_n \sim 1 \div 2\%$ are most probable in nighttime, but values $\Delta N_n/N_n \sim 3 \div 6\%$ are also encountered.

---

* Only large-scale inhomogeneities with dimensions from 20 to 500 km were fixed.

In the flight considered the "sub-ionospheric" point was situated in the $\sim 53° \div 59°$ latitude interval. This provided the possibility of constructing the latitude distribution of inhomogeneity dimensions $l$ and of fluctuations $\Delta N_n/N_n$ for 20-minute intervals of geographic latitude. The increase of inhomogeneity dimensions and of relative fluctuations $\Delta N_n/N_n$ in the direction to the North could be traced.

We compiled in Table 2 the mean values of the parameter of inhomogeneity appearance for various times of the day.

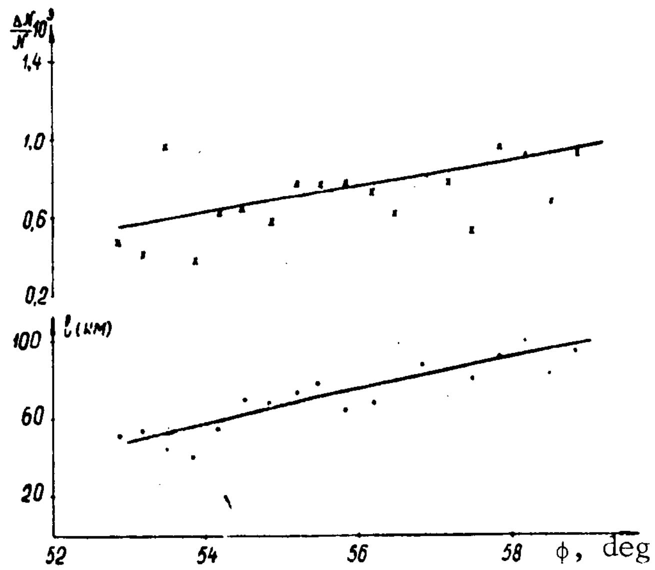



Fig.7

TABLE 2

| | ELECTRON - 1 | | | | | | ELECTRON - 3 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| t, hrs | 0930 | 1100 | 1230 | 1400 | 1530 | 1700 | 1800 | 2000 | 2300 | 0100 | 0300 | 0430 |
| ΔT/T | 0.68 | 0.75 | 0.73 | 0.63 | 0.62 | 0.63 | 0.75 | 0.7 | 0.6 | 0.7 | 0.5 | 0.45 |

Contrary to small-scale inhomogeneities with $l \sim 1$ km, which have a clearly expressed maximum of $\Delta T/T$ in nighttime, the parameter of large-scale inhomogeneity ( $l \geqslant 20$ ) depends little on the time of the day.

The authors are grateful to L. M. Yerukhimov and N. A. Mityakov for useful discussions, and also to L. M. Gonobobleva, V. A. Vasin, L. M. Barsukova and L. I. Grekova for assistance in data processing.

*** THE END ***

## REFERENCES

1. Ya. L. AL'PERT., UFN, 3, 64, 1958
2. N. A. MITYAKOV, E. E. MITYAKOVA. Geom. i Aeronom., 3, 858, 1963
3. N. A. MITYAKOV, E. E. MITYAKOVA ET AL. Kosm.Issl. 3, 2, 249, 1966.
4. RASPREDELENIYE ELEKTRONNOY KONTSETRATSII V IONOSFERE I EKZOSFERE (Distribution of Electron Concentration in the Ionosphere and Exosphere). M., Izd-vo "MIR", 1964.
5. R. V. BHONSLE, ALDO VDA ROSA ET AL. Radio Science J. of Res. NBS/USNC-URSI, 69 D, 929, 1965.
6. P.R. ARENDT & A. PAPAVOANOV. J. Geophys. Res., 70, 3675, 1965.
7. Ya. L. AL'PERT, V. M. SINEL'NIKOV. Geom. i Aeronom., 5, 209, 1965.
8. N. A. MITYAKOV, E. E. MITYAKOVA et AL. Ibid. 3, 816, 1963.
9. L. M. YERUKHIMOV, IVUZ, Radiofizika, 5, 839, 1962.

---

Contract No.NAS-5-12487
VOLT TECHNICAL CORPORATION
1145 19th St.NW
D.C.20036. Tel: 223-6700; 223-4930

Translated by ANDRE L. BRICHANT

on 28 February 1967

---

DISTRIBUTION

as ST-AI-PF-10568 + new addressees