The long-term variations of critical frequency in the F2 region of ionosphere and solar activity.

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ABSTRACT

The work is devoted to the analysis of ionospheric parameters on the basis of the National Geophysical Data Centre (NGDC). There is a quantitative assessment of the long-term variations in the critical frequency of F2 region of the ionosphere as a function of an 11 year old cycle of solar activity.

Keywords: the ionosphere, the long-term variations, F2 layer of the ionosphere, the critical frequency, quantitative analysis, the model of the ionosphere IRI, latitudinal variation.

INTRODUCTION

The modern age is closely related to the terms "informatization" and "information society". A huge role of this society is on the production, storage, processing and marketing information. This can be fully attributed to the scientific research sphere of human activity. The history of the first database management systems (DBMS) consists of about fifty years and one of the main tasks of those years is the systematization of information related to geophysical research. So in 1965 in Boulder, Colorado the National Geophysical Data Center (NGDC) [1] was established specializing in information "from the Sun and to the bottom of the oceans".

This article provides an analysis of the data of National Geographic Data Center (NGDC), produced by the vertical radio sounds and data of solar activity. As a basic setting F2-region of the ionosphere is selected for critical frequency. All information of the Geophysical Center is free and in the public domain.

INITIAL DATA. CORRECTION DATA

For analysis the measurements of F2 were taken in the period from 1957 to 2012. Their temporal accumulation period begins around the middle of the 20th century. It is very important to calculate the long-term variations [2]. Total number of ionospheric stations are (224) shown in Figure 1. Blue circle is the current ionospheric stations. Yellow circles are the stations which does not provide information to the data center over the past three years. Red circles are the stations which does not provide information for the past five years. Next, the data were corrected for their authenticity.

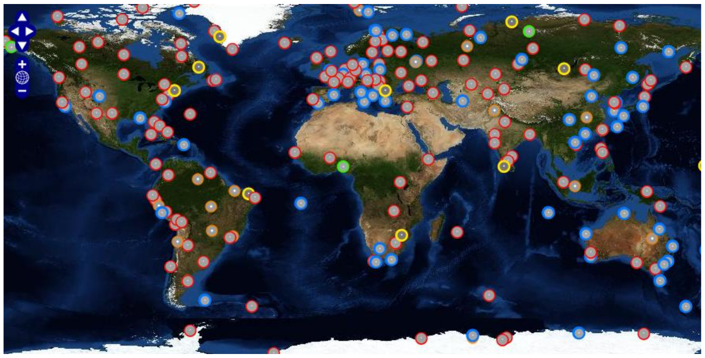

Figure 1. The Planetary distribution of ionospheric stations [1].

Correction data was carried out in two stages. On the initial stage selected stations with continuous measurement period of not less than 33 years. This criterion started from the objectives of the work to be able to carry out a quantitative analysis of at least three 11-year cycle of solar activity. As a result of the 224 stations there are only 49, with which it was necessary to carry out further adjustment.

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Second stage of the adjustment data was visual. And adjustment was in deleting and correcting data. The most common mistake in database was multiplication or division by 10 but here it did not required big visual analysis. Values were across postscript extra digits and in this case the adjustment values was still possible. In some occasions data were deleted which did not complied with the logic. These corrections took a long time but thanks to them because of which it was possible to quantitatively analysis of data became possible.

COMPARISON OF DATA WIH THE EMPIRICAL MODEL IRI

After adjusting the data, the model values obtained were analyzed by the model IRI (y) [3] with the experimental data (x) taken from the Geophysical Data Center.

First, on the model of IRI, model values of the ionosphere were calculated for the critical frequency of F2. The calculation was performed using the code model IRI.

Figures 2-5 shows the average values of F2 model and experimental data for the four local time points depending on the latitude (green -model data red - experimental).

Then, the correlation coefficient was calculated. As a result of calculation, the following dependence of correlation coefficients on the latitude of four local time points (Figure 6) (black - 00:00 LT, red - 06:00 LT, green - 12:00 LT, blue - 18:00 LT) was obtained.

The correlation analysis shows that greatest concordance model with experimental data is present in the equatorial and mid-latitude ionosphere. In Polar Regions, the correlation coefficient is lowered to a value of 0.3-0.4 which is caused by the insufficient number of ionospheric stations in these regions.

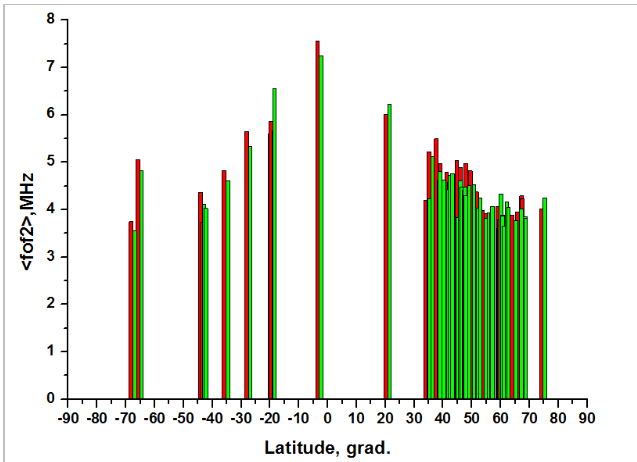

Figure 2. Average values foF2 of latitude at 00:00 LT

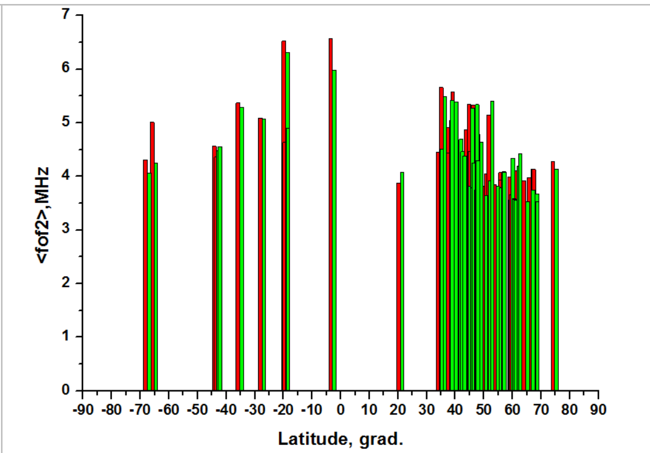

Figure 3. Average values foF2 of latitude at 06:00 LT

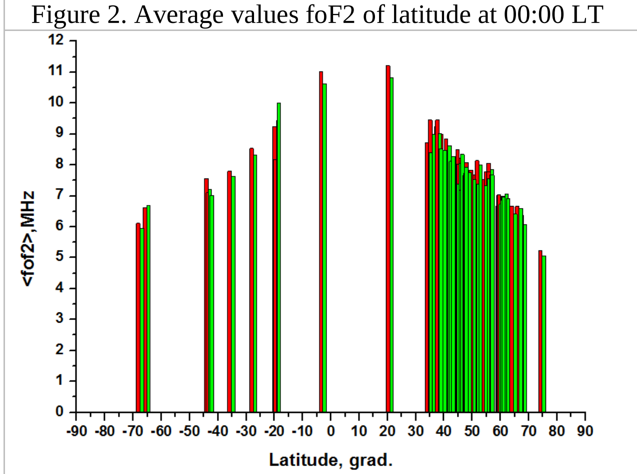

Figure 4. Average values foF2 of latitude at 12:00 LT

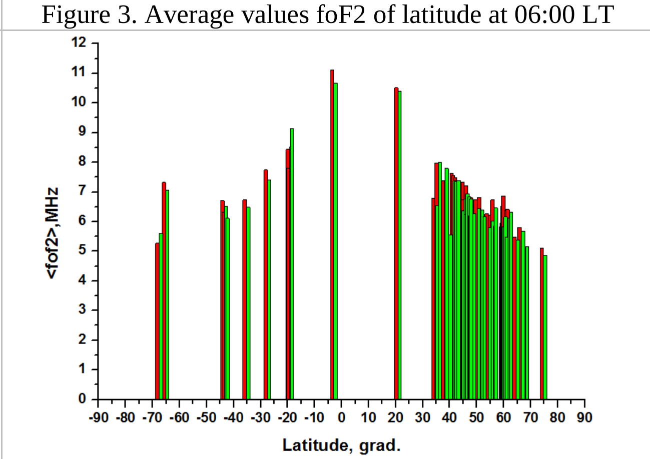

Figure 5. Average values foF2 of latitude at 18:00 LT

From these dependences it was observed that the maximum values of F2 is in the equatorial region and fall to the middle latitudes but on the poles there is a slight growth. In general, the experimental data quite well correlated with the model. The values of coefficients correlation were basically greater than 70% and only at the poles this values were below 50%.

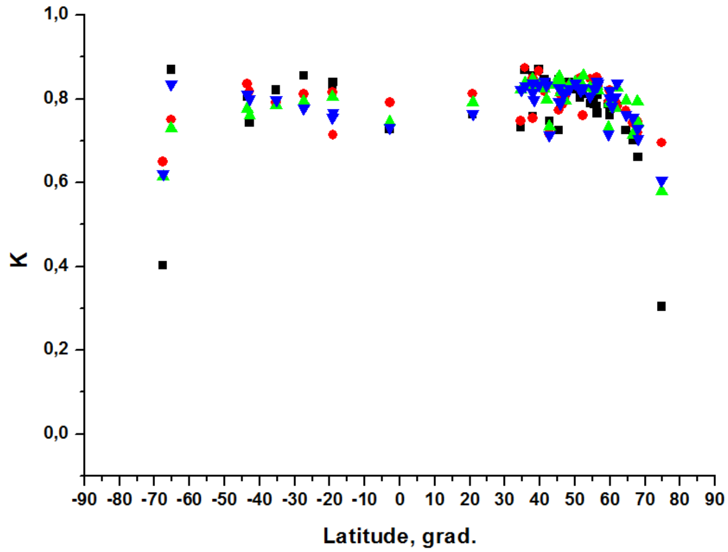

Figure 6. The correlation coefficient between the average of F2 model and the experimental data.

CALCULATING THE AMPLITUDE OF THE 11-YEAR HARMONIC VARIATIONS FOF2

To calculate the amplitude we used the least squares method (LSM). We assumed that our source set of data has the form of a harmonic signal x (t) at a frequency corresponding to the 11-year cycle of solar activity.

A similar analysis was conducted for the simulated data. And as a result the following dependences of the amplitudes of 11-year-harmonic variations of F2 for model and experimental data as a function of latitude (Figures 7-10) (green -model data, red - experimental) was obtained.

From the data obtained it was observed that the latitudinal variation of the amplitude of 11-year-harmonic variations of F2 were depending differently on the local time, which is not observed when considering similar latitudinal variations in average values of F2. Common to all variations at different points of the local time is the decline amplitude in 11-year harmonic variations of F2 at the poles.

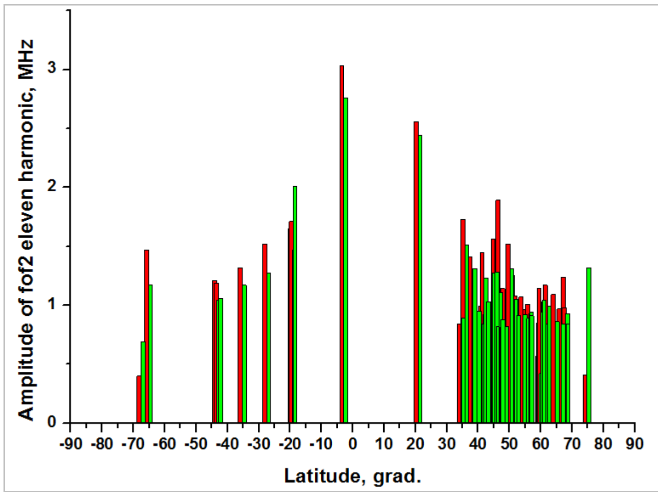

Figure 7. The amplitudes of the 11-year-harmonic variations foF2 at 00:00 LT

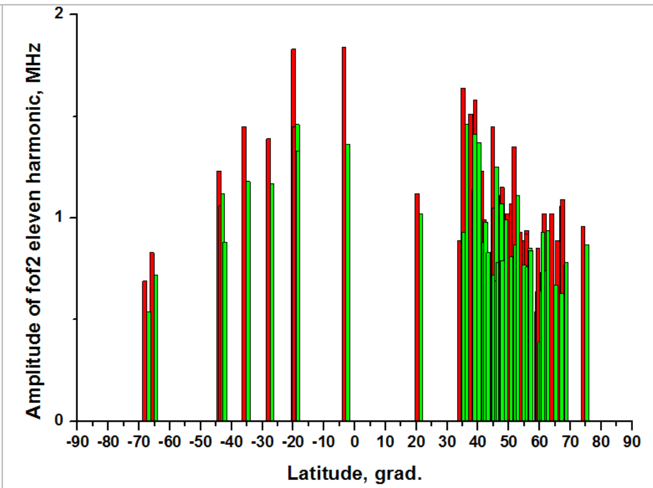

Figure 8. The amplitudes of the 11-year-harmonic variations foF2 at 06:00 LT

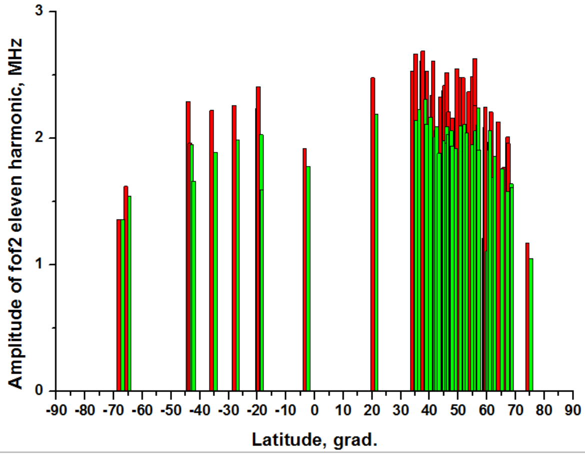

Figure 9. The amplitudes of the 11-year-harmonic variations foF2 at 12:00 LT

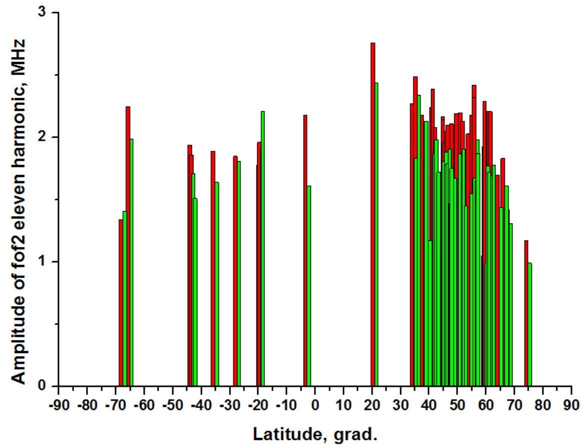

Figure 10. The amplitudes of the 11-year-harmonic variations foF2 at 18:00 LT

At 00:00 LT (Figure 7), the maximum value of amplitude of the 11-year-harmonic variations of F2 is observed in the equatorial region and fall to the middle latitudes i.e. they behave like the average values of F2. In 06: 00LT (Figure 8) in the latitudinal variation of the amplitude of 11-year-harmonic of F2 minimum is observed at a latitude of 20 °. At 12:00 LT (Figure 9) in the equatorial region there is a minimum and at mid-latitudes there is a maximum. At 18:00 LT (Figure 10) latitudinal variation of the amplitude of the 11-year-harmonic of F2 is mostly uniform.

The quantitative ratio of amplitude of the 11-year-harmonic of F2 average is maximum at latitude in 12:00 LT and 18:00 LT (~ 2 MHz) and low in 06:00 LT (~ 1 MHz). In general the experimental data quite well correlated with the model.

CONCLUSION

Cooperative analysis of the results of number modeling of critical frequency latitudinal variations of F2 layer, calculated by empirical model of the ionosphere IRI and observational data obtained at 49 stations of the world led to the following conclusions. The highest concordance model with experimental data is present in the equatorial and mid-latitude ionosphere. In Polar Regions, the correlation coefficient is lowered to a value of 0.3-0.4 which is due to the insufficient number of ionospheric stations in the region. Maximum values of F2 was observed in the equatorial region and fall to the middle latitudes in the poles there is a slight growth. In general, the experimental data quite well correlated with the model. Correlation coefficient was substantially greater than 70% but on poles values below 50%. From the analysis of 11-year-harmonic variations of F2 shows that the latitudinal variation of the amplitude of the 11-year-harmonic is differently depending on the local time which is not observed when considering similar latitudinal variations in average values of F2. Common to all variations at different points of the local time is the decline in 11-year amplitude harmonic variations of F2 to the poles.

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REFERENCE LINKING

[1]. National Geophysical Data Center (NGDC) http://spidr.ngdc.noaa.gov/spidr/ is free and in the public domain.

[2]. Rustam K. Khaitov; Valeri T. Sarychev and Sergei Kolesnik "Long-term trends of the critical frequency of the F2-layer of the ionosphere", Proc. SPIE 9292, 20th International Symposium on Atmospheric and Ocean Optics: Atmospheric Physics, 92924W (November 25, 2014); doi:10.1117/12.2075442; http://dx.doi.org/10.1117/12.2075442

[3]. Program code the model IRI http://radiokontrol.narod.ru/IRI2011.htm is free and in the public domain.