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DISTRIBUTION OF THE F-SPREAD OCCURRENCE PROBABILITY IN THE MAIN IONOSPHERIC TROUGH REGION FOR THE WINTER MIDNIGHT CONDITIONS

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Abstract

The global distribution (in both hemispheres, at all longitudes) of the occurrence probability, P, of the F-spread at F2-layer maximum height is built. About 5000 topside ionograms obtained on board of the Intercosmos-19 satellite in a period of the high solar activity for the two winter solstices 1979-1981 around the midnight (22-02 LT) were used. The latitudinal-longitudinal variations in the F-spread occurrence probability were investigated. An analysis shows that longitudinal variations in P in the first approximation anticorrelate with foF2 variations, both in the winter and summer conditions. As a result the longitudinal sectors stand out where P is a maximum in a broad belt of the latitudes in the Northern Hemisphere (60-90°E) and in the Southern one (~300°E), and P is a minimum at mid-latitudes in the Northern Hemisphere (~300°E) and in the Southern one (180-210°E). The latitudinal variations in P show a local peak in a minimum of the main ionospheric trough in the Northern (winter) hemisphere. A comparison of the Intercosmos-19 data with the ground-based stations data was carried out. The reasons of the revealed F-spread occurrence features are discussed.

Introduction

The F-spread phenomenon on the ground-based sounding ionograms was studied repeatedly, as by experimental means, and theoretically (see, for example, the review [Gershman, et al., 1984] and the references in it). On the topside ionograms F-spread is observed even more often, than on the bottomside ones, that, taking into account specificity of the satellite observations, strongly complicates their processing. The characteristics of F-spread in the upper ionosphere are investigated poorly, there are a few works on a basis of the Alouette satellites data (see, for example, [Calvert and Schmid, 1964] and Intercosmos-19 data [Depueva, 1982], and only, apparently, one research according to ISS-b data [Maruyama and Matuura, 1981]. Therefore research of this phenomenon in the upper ionosphere is very important, both from the physical and technical point of view. The large data set of Intercosmos-19 satellite allows to carry out detailed investigation of F-spread in the topside ionosphere. The first results of this research are presented here. They concern, basically, the main ionospheric trough (MIT) region.

Data

Intercosmos-19 satellite operated since March, 1979 till February, 1981. The topside ionograms were recorded both in an analogous mode, and in a digital one. The analogous ionograms contain complete information about the upper ionosphere, but they were recorded in real time only over the ground-based stations (Moscow, Apatity and Norilsk). Digital ionograms could be recorded in any point of the satellite orbit, but because of low-capacity onboard memory they were less informative. Therefore a global distribution of F-spread was constructed from the digital ionograms, and details of the pattern were studied from the analogous ones. On fig. 1 the examples of the analogous ionograms recorded in the MIT region are shown. The first ionogram (on the top) corresponds to the equatorial wall of MIT. The additional traces on the greater distances, than the main trace are seen on this ionogram, that suggests a presence of large-scale irregularity of F2 layer. An appearance of the additional traces used to precede the strong F-spread. The traces become wide and diffuse owing to strong F-spread as the trough minimum is approached (at the bottom). On fig. 2 the example of the digital ionogram with strong F-spread nearly the critical frequency is shown. This type of spread echo is similar to the frequency type spread observing on the bottomside ionograms. This F-spread type observes most often on the topside ionograms, therefore it is a subject given investigation.

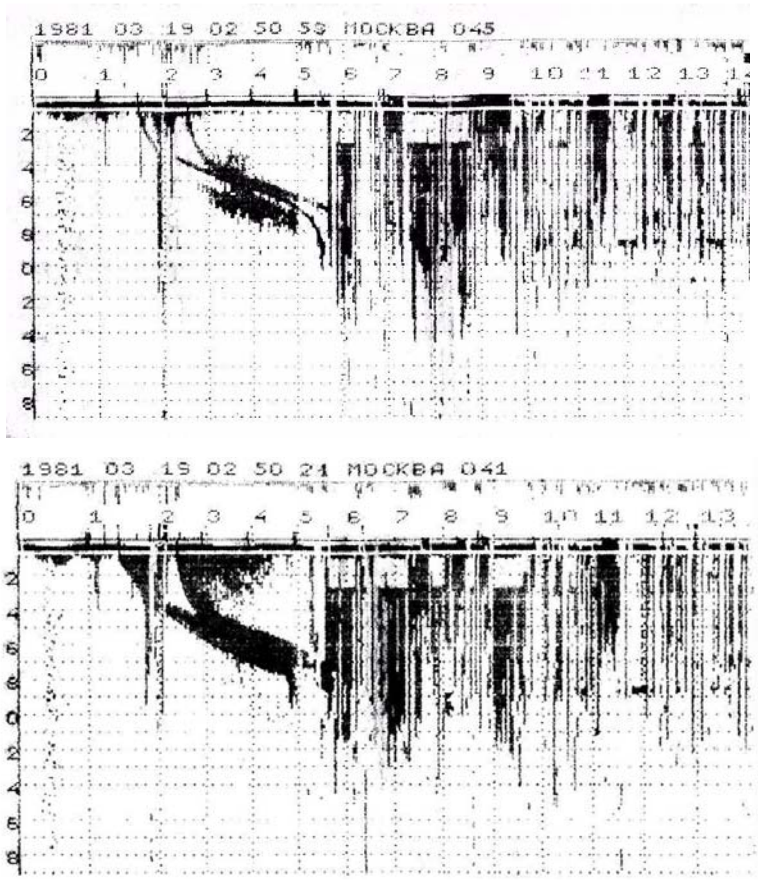

Fig. 1. Examples of the topside analogous ionograms obtained onboard of the Intercosmos-19 satellite in the trough region. X axis is frequency, Y axis is virtual height.

Experimental results

At a first stage about 5000 ionograms have been processed. All the data concern to the quiet (Kp < 3, average Kp = 2) midnight (22-02 LT) conditions of high solar activity ($F_{10.7} \sim 200$) for the winter solstice (1.5 months around December, 22, 1979 and 1980). The data practically uniformly cover all the longitudes and latitudes of the Northern and Southern hemispheres that allows to construct the global distribution of the occurrence probability (P) of the frequency type F-spread - fig. 3. For comparison foF2 distribution obtained for the same conditions is shown also. Fig.3 shows that electron concentration on average is greater in the Southern, summer hemisphere where the amount of the solar ionization is higher. In the distribution of F-spread probability an inverse tendency is observed. Two most typical longitudinal sectors of 60-90°E and 270-300°E stand out which the electron concentration almost at all the latitudes of both hemispheres is minimal and maximal correspondingly in. The latitudinal cross-sections of P for these sectors are shown on fig. 4. They differ most strongly at mid-latitudes of the winter hemisphere. It is generally believed that even at night at mid-latitudes (bottomside) F-spread is weak (see, for example, [Singleton, 1969]). From Intercosmos-19 satellite data the probability P at latitude of 40° is equal to ~0.4 even in longitudinal sector of 270-300° and reaches ~0.9 at longitudes of 60-90°E.

On fig. 3 the prominent increase of the electron concentration at latitudes of the of equatorial anomaly crests (15-20°) and its decrease above equator are seen as during the high solar activity the equatorial anomaly exists till 02-03 LT. Fig. 3 shows that at latitudes of the northern crest the F-spread occurrence probability is comparable with that above equator, despite of high foF2 values. It is generally believed that F-spread is most intense above equator. However equatorial latitudes demand more detailed analysis.

For Kp~2 the equatorial border of the auroral oval at midnight is located at invariant latitudes of 62-63°. It is seen on fig. 3, that electron concentration at 65-70°, i.e. auroral latitudes, is increased owing to the precipitation and forms the MIT polar wall. In the Southern hemisphere the most part of the auroral oval is outside of a satellite orbit, therefore the map is limited to latitude of -60°. It is however seen, that the F-spread probability is on average less in the summer Southern hemisphere, including the auroral oval.

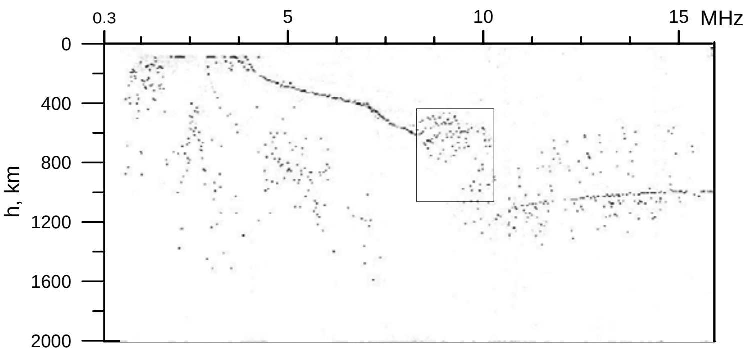

Fig. 2. Examples of the topside digital ionogram with strong F-spread of frequency spreading type (enclosed in restangle).

Minimum of the trough in the Northern winter hemisphere for Kp~2 is located at latitude of ~60°. In the summer hemisphere the trough even at the midnight is formed only at longitudes of the total shadow, i.e. at 30-60°E. At first sight there are not any

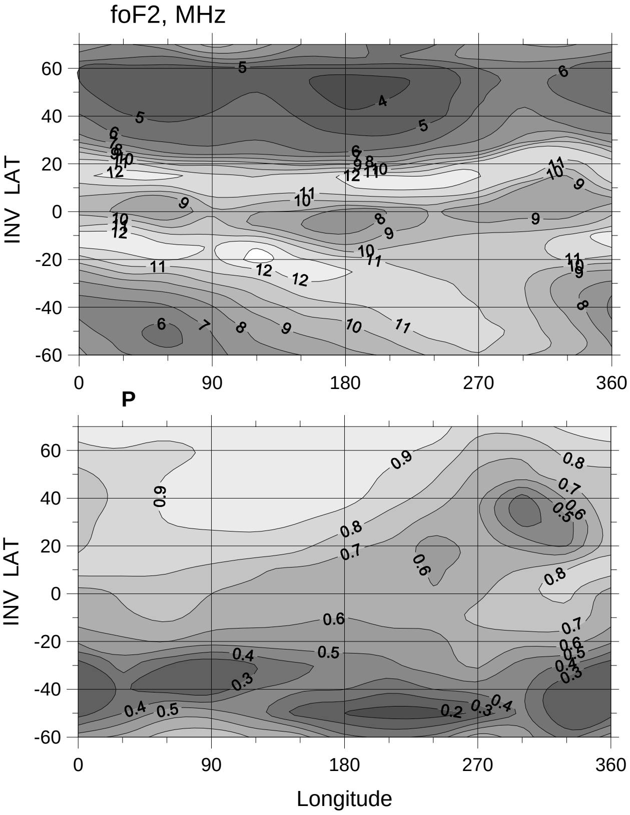

Fig. 3. Global distribution of foF2 (top) and occurrence probability of F-spread (bottom) for the winter solstice midnight (22-02 LT) quiet (Kp ~ 2)

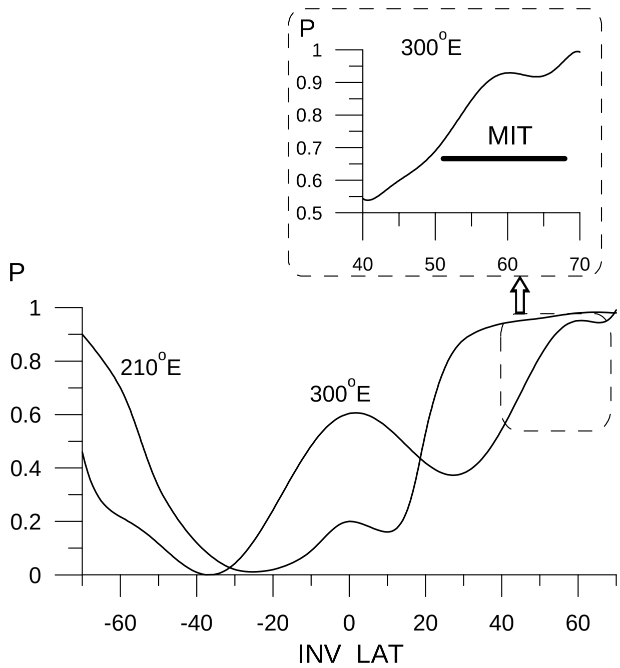

Fig. 4. Latitudinal variations of the F-spread occurrence probability in the longitudinal sectors of 60°E and 300°E. On the incut the same in the region of the winter northern trough.

peculiarities in a behaviour of P at subauroral latitudes - fig. 4. However an analysis of the ionograms shows, that in the MIT minimum they become more complex, the additional reflections appear and intensity of F-spread grows. Therefore more careful processing of the data has been curried out in the MIT region. As a position of the trough minimum strongly depends on the Kp-index, the averaging of the data has been curried out by a method similar to an superposed epoch analysis. At that MIT minimum in each case shifts to latitude of 60° which corresponds modeled latitude for Kp=2 [Karpachev et al., 1996]. Such averaging allows to present more adequately a situation in MIT region, both in foF2, and in P. The result is shown on an incut on fig. 4. It is clear seen now, that at the all longitudes in the MIT minimum small but appreciable increase in F-spread probability is observed. Therefore in the through region the additional reasons for the spread echo formation on the topside ionograms operate. It is no wonder as the MIT minimum is connected with the plasmapause near that various processes act which result in the formation of the plasma irregularities [Brunelli, Namgaladze, 1988]. There are also ground-based reasons of an occurrence of the additional diffuse traces caused by MIT geometry. Fig. 5, taken from the monography [Ben'kova et al., 1993], demonstrates as the ground noises penetrate at the satellite heights in the MIT region. They cause an occurrence of a band of the intensive noises below the critical frequency, therefore by processing of such topside ionograms the critical frequency is underestimated. This effect is especially strong nearly the MIT minimum, at its abrupt equatorial wall. On the digital ionograms an occurrence of strong noise below the critical frequency is manifested as F-spread increase, that is why the reason of this phenomenon can reveal only from the analogous ionograms [Ben'kova et al., 1993].

On fig. 6 longitudinal variations in foF2 and P are shown for the fixed latitudes of the Northern hemisphere 70°, 60° and 50°, which correspond to the polar wall of the trough, its minimum and equatorial wall correspondingly. Electron concentration in the MIT region demonstrates strong variations with longitude which character has been in detail analyzed from the Intercosmos-19 data (see, for example, [Karpachev and Gasilov, 1998]). It is seen, that in a first approximation, the variations in P and foF2 anticorrelate, i.e. the less concentration, the more probability. That is true for all MIT region though the polar wall corresponds to the auroral oval, the equatorial wall – mid-latitudes, and the trough minimum – subauroral latitudes, i.e. completely different regions of the ionosphere. Thus, despite of the probably different reasons of the F-spread generation, its intensity is controlled by the electron concentration value.

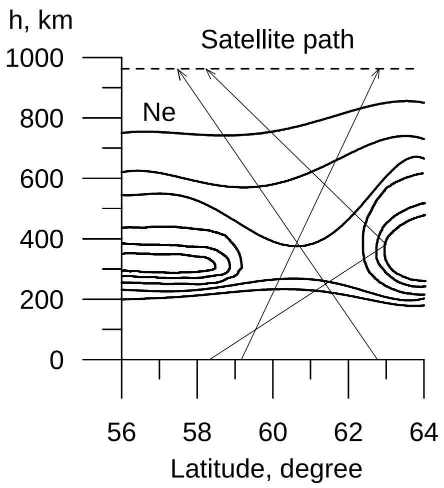

Fig. 5. Diagram of the topside sounding in the trough region. Thick curves are Ne contours, thin lines are the trajectories of the ground-based station signals.

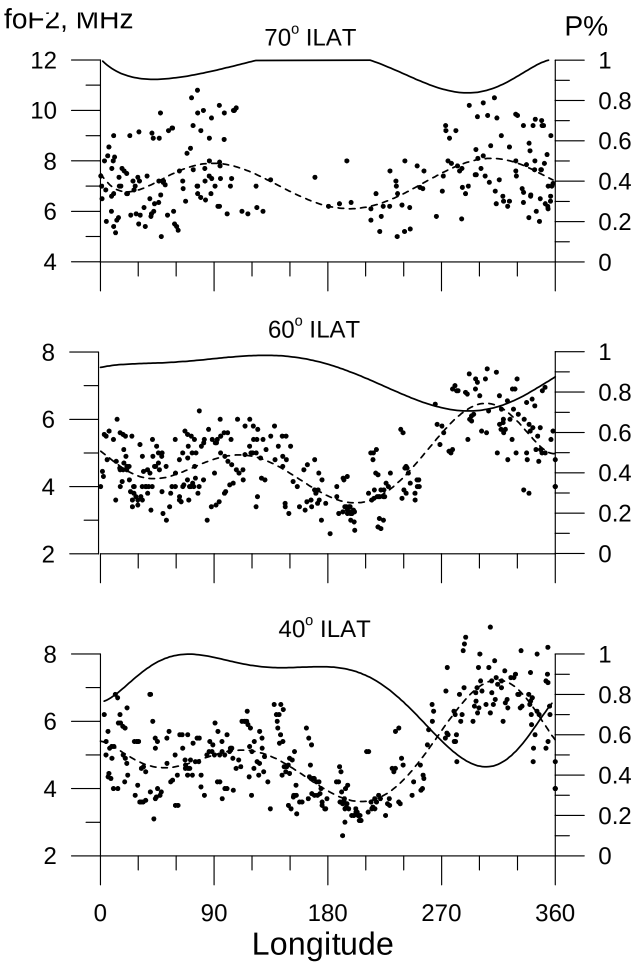

Fig. 6. Longitudinal variations in P (solid curves) and foF2 (dotes and dashed approximation curves) at the invariant latitudes of 70°, 60° and 40° in the Northern hemisphere.

Conclusion

The large data set of the Interkosmos-19 satellite allows to carry out the comprehensive investigation of the F-spread for the high solar activity conditions. The main advantage of the satellite is a global character of the obtained data. It allows studying in detail the features of this phenomenon at all the longitudes and latitudes, i.e. in the different regions of the ionosphere. In particular, at a first stage of researches the local peak of F-spread probability in the MIT minimum, the longitudinal variations in the probability, and the probability dependence on foF2 have been revealed.

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