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IRREGULAR STRUCTURE OF THE IONOSPHERIC F-REGION FROM THE SATELLITE PROBE DATA

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A b s t r a c t

The study of the irregular structure of the ionospheric plasma is one of the most urgent problems of the ionospheric investigation. The present paper deals with some features of the direct measurements of the irregularities by probe techniques and gives the review of obtained results. Two basic zones of irregularities exist: high-latitudinal and equatorial. Irregularities are detected at all latitudes during magnetically disturbed periods. There is the longitudinal dependence of the probability and the intensity of irregularities; there is the altitude dependence of the probability of the irregularity detection. Small irregularities are formed from larger ones. In the conclusion the perspectives for further studies of the irregular structure of the ionosphere are discussed.

1. Introduction

The study of the irregular structure of the ionospheric plasma is one of the most urgent problems of the ionosphere investigation due to its significance for practical goals since the irregularities effect the radiowave propagation conditions and for the plasma physics because the conditions under which the irregularities are excited and disappear might be determined experimentally.

Much information on the ionospheric irregularities is acquired using ground-based techniques. However, regardless of the progress in developing measurement techniques these methods are in principle integral and due to this there are always doubts if the results of measurements of irregularity dimensions, fluctuation amplitudes and so on are correct. In addition, it is naturally difficult to obtained the global picture of the distribution of the irregularities using only ground-based techniques. Therefore, the application of a probe technique to the measurements of the irregularities made it possible i) to use with greater confidence the results of ground-based measurements and ii) to obtain new data on the morphological distribution of the irregularities and their spectra.

2. Some features of the measurement technique

Before discussing the results it should be given some attention to some features of the techniques used for measuring the irregularities. Probe techniques for measuring densities and temperatures of charged particles in the ionospheric and space plasma were previously described (Smith, 1964; Gdalevich, 1969) and the features of these techniques for measuring the irregularity were described by Gdalevich (1975).

The present paper deals with that features of the direct measurements of the irregularities by probe techniques without which it is impossible to analyze the measurement results.

2.1 The satellite or the rocket crosses magnetic field lines at different latitudes under various angles and due to this the dimensions of the irregularity are determined only in directions of their crossing. It refers to all the probes used. There have not been yet techniques of direct determination of the transverse and longitudinal dimensions of the irregularity. As an example of the possible inconsideration to this effect it can be said that in the polar regions the dimensions are obtained smaller and greater at equatorial latitudes. This may, indeed, reflect the nature of the irregularity development but one cannot take into account this effect.

2.2 Ion traps with the constant potential of electrodes have recently been applied more extensively to the study of irregularities (Hanson et al., 1970; Sagalin et al., 1974; Gringauz and Gdalevich, 1974; Clark and Raitt, 1976). In this case the variations of the ion current density j_i are measured:

$$j_i = enU$$

where U is the satellite velocity, e is the electron charge and n is the ion density.

However, if we deal with waves or with the motion of the irregularities with velocities comparable with the satellite velocity $j_i = e\tilde{n}\tilde{U}$ ($\sim$ - symbols mean the variability of n and U). Hence the dimensions of the irregularity, so obtained, can not correspond to the reality.

The results of the INTERCOSMOS-8 measurements showed that the density changes mainly at equatorial latitudes but in the polar regions the velocity changes too (Serafimov et al., 1976; Ozerov, 1977).

2.3 On measuring the frequency characteristics of the irregularities it is necessary to take into account the Doppler effect: $f_{obs.} = |f - 1/2\pi \cdot KU|$ where $f_{obs.}$ is the oscillation frequency observed on the satellite; U is the satellite velocity; $|K| = 2\pi/\lambda$ is the wave number; λ is the wavelength of oscillations observed. The Doppler shift depends naturally on the direction wave propagation of relative to the satellite velocity vector the angle between $\bar{K}$ and $\bar{U}$.

3. Review of the obtained results

The OGO-6, ISIS-1, COSMOS-378, ESRO-4, COSMOS-900 satellites provide the most valuable data.

In comparing the results it should remember that the measurement accuracy of $\Delta n/n$ and the spatial resolution are different for each satellite.

3.1 <u>The latitude dependence of the probability of the irregularity detection</u>

There are two basic zones where the irregularities can exist: high-latitudinal and equatorial. The equatorial boundary of the high-latitudinal zone coincides with the polar boundary of the mid-latitudinal trough of the ionization.

Dyson and Winningham (1974) showed that the equatorial boundary of the high-latitudinal zone at day time coincides with the boundary of precipitating electrons with energy $E \lesssim 0.3$ keV. Clark and Raitt (1976) confirmed this result for electrons with $E = 0.21$ keV. Dzhordzhio (1975) using the COSMOS-348 data showed that the irregularities appear always in the precipitation region when the flux of precipitating electrons exceeds the value critical for exciting electrostatic oscillations. Northward of this boundary the irregularities are seen up to 90° and farther up to the equatorial boundary of the high-latitudinal zone in this hemisphere. The intensity of the irregularities in the high-latitudinal zone has its maximum in the aurora oval region. There is an asymmetry of the equatorial boundary of the zone in both hemispheres which agree with the asymmetry of the polar boundary of the mid-latitudinal trough. The equatorial boundary in the southern hemisphere is, on an average, by 5° closer to the pole.

During disturbances the equatorial boundary is displaced toward lower latitudes.

Figure 1, which was constructed using the ISIS-1 (Sagalin et al., 1974) and INTERCOSMOS-8 (Stanev et al. 1976) data shows the equatorial boundary of the high-latitudinal zone of the irregularities in the northern and southern hemispheres and its Kp-index dependence.

At night-time the equatorial boundary of subauroral irregularity zone appears at 40° of a geomagnetic latitude Φ and reaches its maximum at 55°.

The subauroral zone is also well seen in ESRO-4 data at altitudes 400 to 1000 km (cf. Fig. 8 in Clark and Raitt (1976a)).

The equatorial zone of the irregularities manifests itself distinctly at night-time (Clark and Raitt, 1976 a).

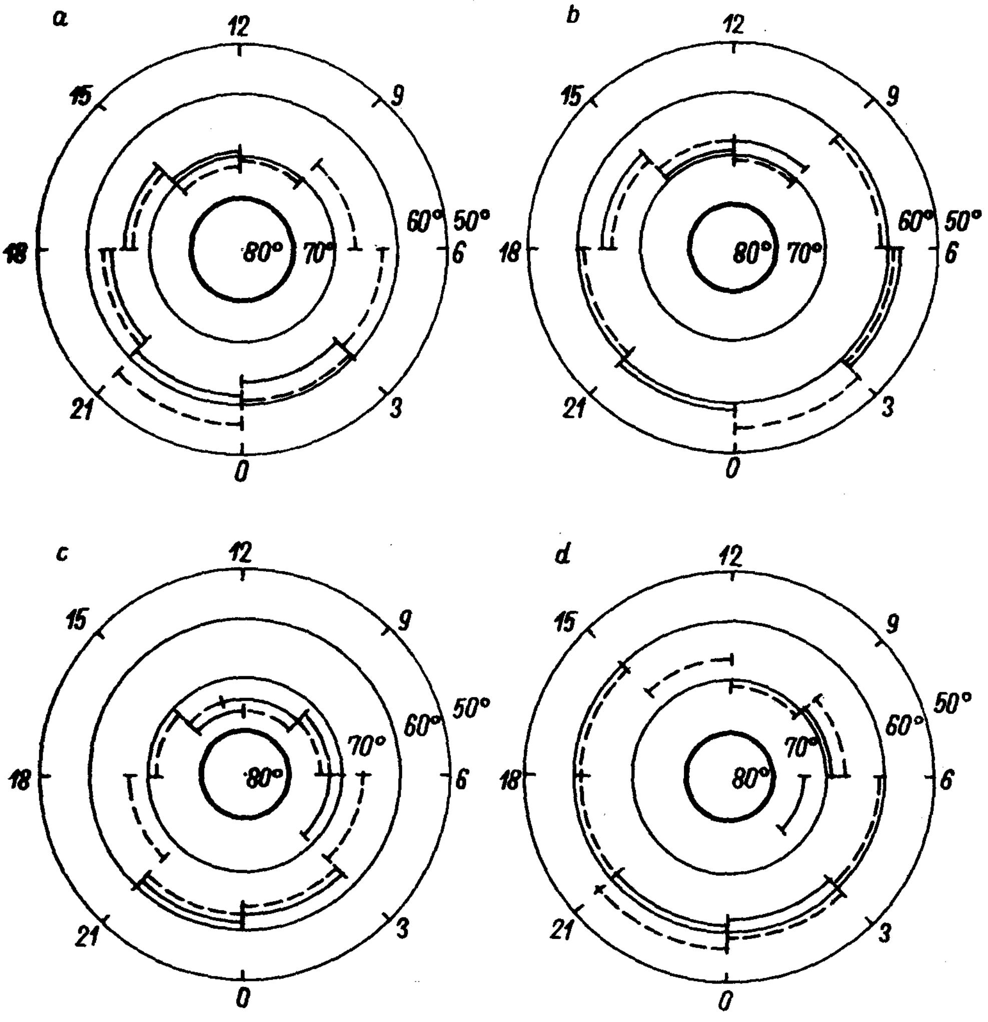

Fig. 1 Equatorial boundary of the high-latitude zone of irregularities in the coordinates local time-invariant latitude from the ISIS-1 data (——) and (- - -) from the Intercosmos-3 data. a and b - at the northern hemisphere for $K_p \leqslant 3$ and $K_p > 3$, respectively. c and d at the southern hemisphere for $K_p \leqslant 3$ and $K_p > 3$, respectively.

According to the AE-C satellite in the equatorial zone of the irregularities there were observed the plasma bubbles with sharp boundaries of electron (ion) density associated with the changes in the ion mass-content (McClure et al., 1977).

According to the INTERCOSMOS-2 (Kutiev et al., 1976), INTERCOSMOS-8 (Stanev et al., 1976) and COSMOS-378 (Ozerov, 1976) data there is the longitudinal depenedence of the occurrance probability and the intensity of irregularities. The maximum of the probability of the irregularity detection at 400 km is located at longitudes 10°E-60°W and at 170°W but at other longitudes this dependence might be different.

3.2 Altitude dependence of the probability of the irregularity detection

Figure 2 (the COSMOS-378 data) gives the altitude dependence of the probability of the irregularity detection (Ozerov, 1976). It is seen from this Figure that the maximum of the detection probabilities (P) is located at altitudes ~500 km, then at higher altitudes the detection probability somewhat decreases and at altitudes ~1100 km there is the slight increase of P. Such an altitude dependence of P indicates that the formation of the irregularities is local.

3.3 Diurnal and seasonal dependence of the probability of the irregularity detection

According to ESRO-4 data (Clark and Raitt, 1976a) at night the probability of the irregularity detection increases at all latitudes. According to the COSMOS-381 data (Komrakov et al., 1977) the probability of appearing small irregularities with dimensions up to $l \sim 50$ km at 1000 km and also throughout the ionosphere thickness is essentially greater at night than in the day-time. With increasing irregularity dimensions the diurnal dependence of the appearance rate becomes less clear. The probability of detecting the largest irregularities at night is the same as in the day-time. The irregularities after near the terminator as seen in the daily dependence (Clark and Raitt, 1976b).

The satellite probe measurements have not given yet the information about the seasonal dependence of the ionospheric

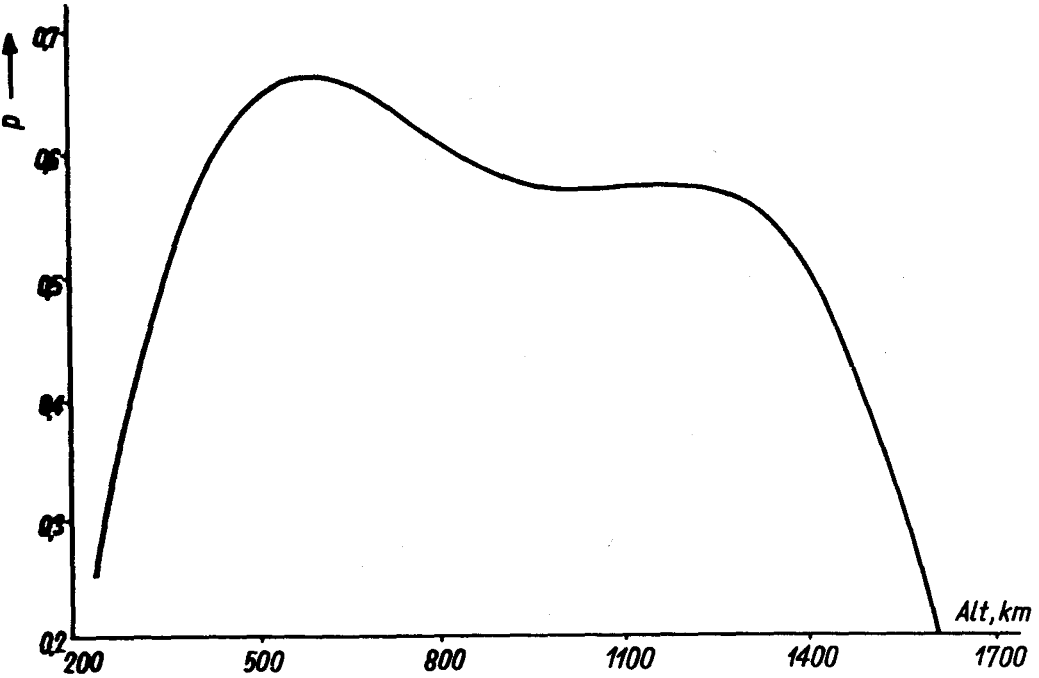

Fig. 2 Altitude dependence of the probability of the detection of irregularities from the Cosmos 378 satellite data.

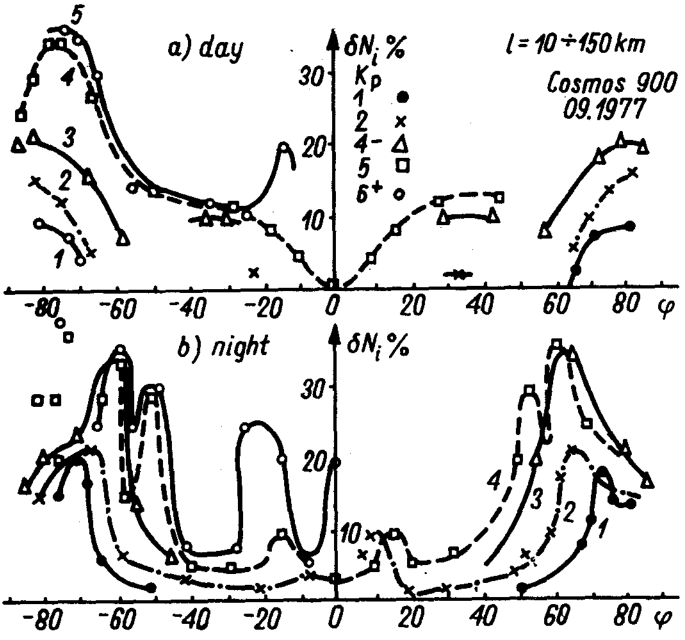

Fig. 3 Dependence of irregularity amplitude on geomagnetic latitude for various K_p.

irregularity appearance. However, the ground-based measurements of radioscintillation show that the intensity of fluctuations (irregularities) reaches its maximum in the equinox periods and coincides in the solstice periods (Aarons et al., 1971).

3.4 Magnetic disturbance effect on the irregularity structure

The ESRO-4 data (Clark and Raitt, 1976a) show that during the distrubed periods the probability of detecting the irregularities increases at all latitudes just like their amplitude.

Fig. 3 (the COSMOS-900 data, Gdalevich et al., 1980) presents the dependence of the irregularities amplitude on geomagnetic latitude for different Kp values. It is clearly seen that the irregularity amplitude is increasing and the existence zones are broadening with growing Kp-index.

3.5 Spectra of the irregularities

It is significant to know the spectrum of irregularities in order to understand the mechanism of their formation. The OGO-6 data (Dyson et al., 1974) show that most of the spectra can be approximated well by a power-law function, thus the one-dimensional irregularity amplitude $A = (\Delta n/n)$ % is proportional to the power of frequency or a size of the irregularity l, i.e. $A \sim f^{-n} \sim l^{n}$ with $n \approx 1$ for sizes of the irregularities from 7 km up to 70 km.

Such a spectral type allowed Dyson et al. (1974) to make a conclusion that the small irregularities are formed from the larger ones. Indeed, the gradient of the density variation does not depend on the irregularity dimension, i.e. the larger irregularity disintegrates into the smaller irregularities. According to the Kopernik-500 data the typical spectrum of the irregularities with sizes from 3 up to 200 km also obeys the power law with the index $n = 1.5 \pm 0.12$ (Aksenov et al., 1977). However, some spectra obtained do not obey this law. Such spectra indicate probably the formation or disintegration of the irregularities, or the higher frequency wave character of the irregularities.

4. Improvements of the further studies of the irregular structure of the ionosphere

In the further studies of the irregularities much attention should be given to measurements of spectra of the irregularities directly on board the satellite, or rocket. Note that all the spectra were up-to-date obtained after their processing on the Earth. It is necessary to extend the range of dimensions (l) and improve the intensity ($\Delta n/n$) resolution so that $3\ m \leqslant l \leqslant 100$ km and $0.01\% \leqslant \Delta n/n \leqslant 70$ to 80% are measured.

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