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IONIZATION OF THE E-LAYER AND X-RAY EMISSION OF THE SUN IN THE 44-60 Å BAND*

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SUMMARY

When computing the characteristic number of the E-layer, it is necessary to set aside the seasonal course in the aeronomic parameters and take into account the temperature variations with height and time.

To that effect it is appropriate to construct a graph of the annual dependence of the values of the characteristic number on the zenithal angle of the Sun.

The characteristic numbers, obtained in this fashion in the year (1964) of the quiet Sun at one station, correspond well to the intensity of solar X-ray emission in the 44 — 60 Å band.

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The investigation of the source of ionization and of the characteristic number of the E-layer has a significant value for heliophysics, the ascertaining of the ionization-neutralization processes in the ionosphere, for certain problems of aeronomy and also for radioprognosis.

The sufficiently well known variation of electron concentration maximum of the E-layer (N_mE) provide the possibility of improving the investigation of this question, which has been the object of numerous works [1 — 6].

However, the results obtained show a significant data scattering for the characteristic number, assumed to be proportional to the intensity of the ionization source. This scattering is in contradiction with the regular N_mE variations and this is why it is obviously necessary to

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* IONIZATSIYA SLOYA E I RENTGENOVOYE IZLUCHENIYE SOLNTSA V DIAPAZONE 44 — 60 Å.

correct the method of computation of the characteristic number. Such corrections may be made by utilizing the new aerodynamic data and the corresponding expressions of the link with the characteristic number.

For a precise determination of the characteristic number it is necessary, first of all, to start from the correct form of the ionization-neutralization balance equation. We may estimate that for the E-layer this equation has the form [7]

$$\frac{dN_mE}{dt} = q_{0m}\cos^n\chi - \alpha N_mE^2, \qquad n = 1 + \gamma - v. \qquad (1)$$

Here q_{0m} is the maximum electron production, referred to the maximum value of the scale height H_0 (the value q_{0m} is $q_{0m} = \sigma I_\infty / H_0 \exp 1$, where σ is the ionization cross section, I_∞ is the intensity of the ionizing agent beyond the absorbing medium); χ is the zenithal angle of the Sun; α is the equivalent recombination coefficient; γ is the scale height gradient; v is the exponent of the effective cosine law relative to diurnal scale height variations [7, 8]. The presence of a significant temperature gradient in the E-layer [9] and the substantial variations of the altitude distribution of the mean mass $\bar{m}$ of the ionizing components of this layer [10] show that the scale height has a gradient γ in its altitude distribution $(H_0 = kT / \bar{m}g)$, which cannot be neglected.

One usually determines and utilizes the characteristic number in the quasistationary approximation $(dN / dt \ll q_{0m} \cos^n \chi \approx dN^2)$ [1—6], which is valid for the E-layer in the course of the whole day, excluding sunrise and sunset, when the Chapman function has to be utilized [2, 3, 11]. The validity of the quasistationary approximation allows to make use of the diurnal course of critical frequencies f_0E for the determination of the characteristic number [2, 3]. However, it should be noted that the forms of the $f_0E(t)$-characteristics have substantial anomalies, that induce doubt in the possibility of application of a significant part of this number's diurnal values. Most essential in these anomalies is the pre-noon lag in the rise of f_0E [3, 12]. In order to eliminate this anomaly, a single effective value f_rE is utilized in [2], which is obtained by way of curvilinear or rectilinear extension of the diurnal dependence $\lg f_0E(\lg \cos \chi)$, and not the measured values at local noontime.

It seems that such a method contributes to elimination of random variations in the maximum value of f_0E, without disrupting the direct relationship between the characteristic number and the measured data. Besides, the seasonal variations of the aeronomic parameters, of the factor α and also the influence of altitude variation of electron concentration maximum , are not taken into account in all works. This is why the obtained results for the characteristic number J_E are not independent from seasonal variations, which increase the dispersion during the attempts to find the linear connection between J_E, the relative number R of sunspots and the Sun's radioemission [6].

Our problem consists in correcting the computation methods of the characteristic number, taking into account the possible seasonal variations, and to find, by the same token, the best correlation between J_E and the various possible ionizing agents.

<u>METHOD</u>.- The values of $f_0 E$ during local noontime are utilized. The cases with a sharply-expressed midday decrease or lag in $f_0 E$ relative to cos χ maximum are rejected. This is why, for the sake of improvement of the results, the use of values of $f_0 E$ interpolated by the logarithmic graph is not required, for the measured values contain the direct physical information, though they do have more random fluctuations.

The midday values of f_0E, comparable in their physical conditions, are obtained at a better quasistationary approximation and undergo a relatively feebler influence of the E_s- layer (which, as an average, has a pre-midday maximum [13]), of the E_2 -layer (the maximum of cases of appearance also occurs at pre-midday time [14]) and of quasiperiodical fluctuations in the ionosphere (which interfere at the beginning and end of F- region bifurcation [15]. For these midday values we have

$$J_E = \frac{q_{0m}}{\alpha} = \frac{N_m E^2}{\cos^n \chi} = \frac{K f_0 E^4}{\cos^n \chi}, \qquad K = 1{,}54 \cdot 10^8. \qquad (2)$$

The calculations may be performed by utilizing (2) and some of the existing theoretical or experimental models of T (z), n_{O_2} (z), n_O (z) and n_{N_2} (z) distribution. However, we do not subject our investigation to dependence on these models, though we tend to eliminate the seasonal course. This is why we utilize only ionospheric data. As is well known, the height of electron concentration maximum in the E-layer ($z_{max}E$) shows substantial seasonal variations [12] and that is why significant seasonal variations of H_o, σ, α can be expected. At the same time, seasonal variations of H_o and may be obtained independently from the variations of z_{max} E, for there may take place variations in the state of O_2 dissociation, of temperature and other causes. Thus, in the most general form we assume $\sigma = \sigma_0 \cos^{p_1}\chi$, $H_0 = H_{0m}\cos^{p_2}\chi$, $\alpha = \alpha_0 \cos^{p_3}\chi$, where p_1, p_2 and p_3 may have values greater and smaller than zero, but if anyone of the considered parameters should not be dependent on χ, the exponent, corresponding to it, might be zero. We exclude from the most general case only the inertial seasonal variations and the dynamic asymmetric influences on account of relatively symmetrical character of the dependence f_oE(t). Thus, for J_E we obtain

$$J_E = \frac{\sigma_0 I_\infty}{e H_0 \alpha_0}\cos^{p'}\chi = J_{E,0}\cos^{p'}\chi, \qquad p' = p_1 - (p_2 + p_3). \tag{3}$$

The characteristic number $J_{E,0}$ no longer depends on seasonal variations and it reflectes directly the intensity variations of the ionizing source. From (2) and (3) we obtain

$$J_{E,0} = K f_0^4 \sec^p \chi, \qquad p = n + p' = 1 + \gamma + p_1 - (\nu + p_2 + p_3). \tag{4}$$

The exponent p may be found by plotting the annual course of the dependence

$$\lg K f_0^4 = \lg J_{E,0} - p \lg \sec \chi. \tag{5}$$

At $p = \text{const}$ and at invariable ionizing radiation, the dependence (5) will be rectilinear. Because of the daily variations of ionizing radiation there appear regulated deflections from this straight line, that superimpose themselves on the random scatterings and deviations induced by measurement and estimate inaccuracies. This is why it is practical to effect such an analysis at low solar activity, when the variations of $J_{E,0}$ are minimal and the direct effect of solar chromospheric flares contributes insignificantly. From the straight line, obtained at these conditions in logarithmic scale of (5), we may find the exponent p. Utilizing (5) for a known p, we shall determine the annual variations of $J_{E,0}$. With the aid of the latter we may then search for a correlation with the variations of different portions of the solar spectrum.

EXAMPLE OF APPLICATION OF THE METHOD. - For the demonstration of the possibilities of this method we utilized the data of the ionospheric station Monte Capellino ($\varphi = 44°33'05''$ N, $\lambda = 8°57'29''$ E). Processed were the data for 12 00 hours UT or approximately 12 h. 30 m LT in the period of solar activity minimum (1964).. The annual data fit sufficiently well the line with $p \approx 0.72$. Hence the exponent in an equivalent cosine law for the electron density of the E-layer is approxiately equal to 0.32, which corresponds to the cosine law for critical frequencies with exponent 0.18. These results agree well with the results for the daily course obtained in [12], and point to a value of p differing substantially from the unity. The requirement of taking into account this seasonal value of p will become clearer if the investigation is conducted with the help of a well known method [1 — 5]. To that effect we investigated the dependence of the quantity $Kf_0E^4 \sec \chi$ on χ (that is, the dependence on seasonal variations). It was obtained that the dependence of $\log Kf_0E^4 \sec \chi$ on $\log \chi$ for the considered data is nearer the rectilinear with angular coefficient 0.28 . This value is exactly equal to $1 - p$, that is, it constitutes the value of $p' + \gamma - \nu$, coinciding with the results of calculations by the formula

$$\lg Kf_0^4 \sec \chi = \lg J_{E,0} - (p' + \gamma - v) \lg \sec \chi. \qquad (6)$$

From analysis it follows, that if the characteristic number is computed with the aid of the method applied to-date [2 — 6], a significant seasonal course would be present in the variations of $J_{E,0}$.

The annual course of the value of $J_{E,0}$, computed by formula (5) with $p \approx 0.72$ is shown in Fig. 1. The values of $J_{E,0}$ were averaged by five-day groups. For comparison, the variations of the relative number of sunspots are shown there too (Zürich). It may be seen that no sharply expressed relationship exists between the characteristics and the relative number of sunspots. Thus, no correspondence of any kind exists between the minima of $J_{E,0}$ at the end of January, May and November and the maximum

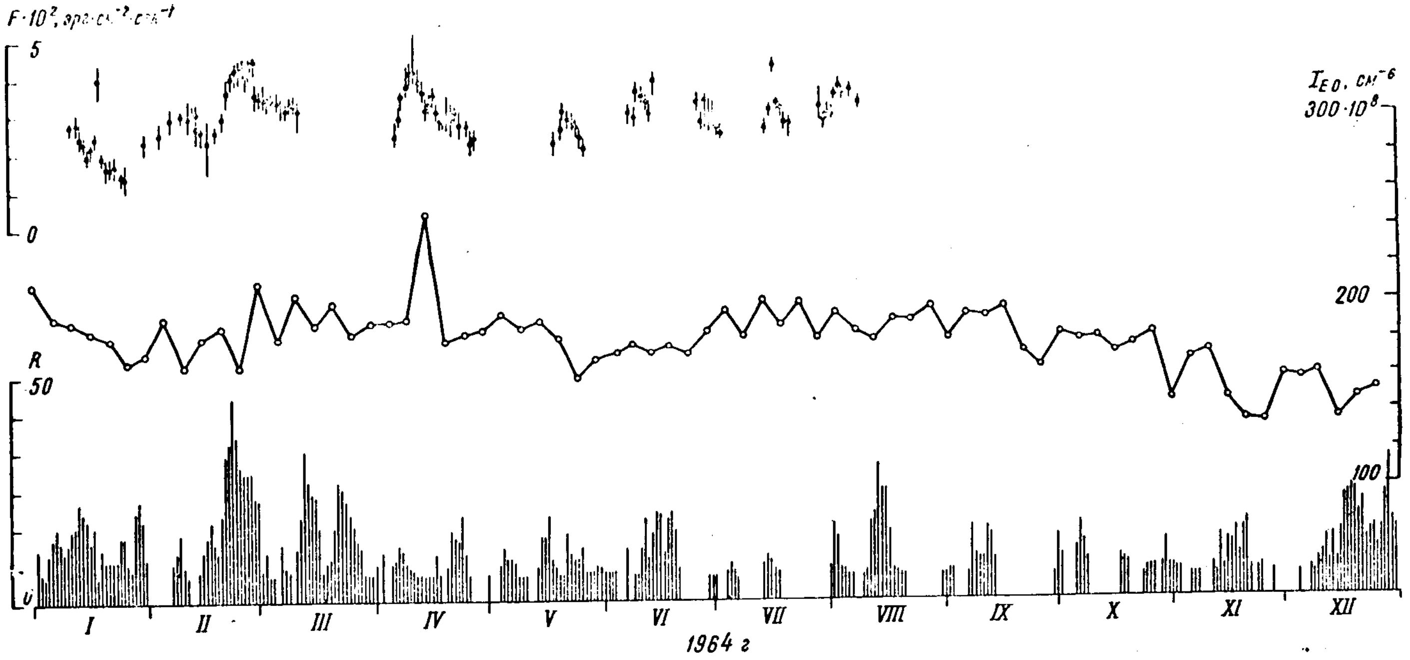
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Figure 1

of $J_{E,0}$ at mid-April and the corresponding values of R. Since the solar X-ray radiation is the probable source of ionization of the E-layer, we have shown in Fig. 1, for the sake of comparison, the variations of the soft component of that radiation (44 – 60 Å). The data on X-rays were borrowed from measurements on the AES Ariel-1 for the period from January to August 1964 [16].

It may be seen from the graph that the variations of $J_{E,0}$ correspond well the variations of intensity $F_{44-60\,\text{Å}}$. This correspondence may well explain the minima at the end of January and May, and also that of mid-April. The attempt to find a relationship between $J_{E,0}$ and the other bands of the shortwave portion of the solar spectrum failed to provide good results. The same refers to solar radio emission, for it should be borne in mind that the extremes in $F_{44-60\,\text{Å}}$ during the period considered, do not correlate with solar radio emission extremes in the frequency of 2800 Mc [16]. Hence it follows that the X-ray radiation in the 44 - 60 Å band is the most probable ionizing agent in the near-maximum region of the E-layer.

The results of investigations of ionosphere effects of the solar eclipse of 1961 [17, 18] agree well with this assertion, just as do the observed variations in the E-layer at time of chromospheric flares, when mostly the X-ray emission of the Sun is enhanced [19].

The limited precision of the utilized ionospheric data (published with a precision to 0.1 Mc) hinders the more accurate determination of the correlational link between $J_{E,0}$ and the intensity of X- radiation. However, the qualitative picture obtained here in regard to this link refutes the assertions of [2] that the standard ionospheric data fail to provide the possibility of making conclusions relative to J_E. It is however necessary to average these data over short periods of time. The ionospheric measurements allow to increase the precision to 0.02 Mc, and, by the same token, to refine the dependence obtained here.

**** THE END ****

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