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ANALYSIS OF THE CONNECTIONS BETWEEN IONIZATION RATE, ELECTRON CONCENTRATION, THE NEUTRAL COMPOSITION AND WINDS ON THE GROUND OF THE ROCKET STUDY IN F-REGIO'

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As a result of a few rocket experiments carried out from 1965 to 1971, the information on the ultraviolet fluxes, the composition and temperature of the neutral upper atmosphere, the electron concentration n_e and electron temperature T_e was obtained.

All experiments were performed in the middle latitudes of the European part of USSR, in the same geographycal point, early in the morning at the solar zenith distance $\sim 82°-78°$.

The uniform experiments series had shown that the observed variatious of the neutral composition are of semi-annual character and for a quiet ionosphere much less depends on the solar and geomagnetical activity.

Variations of the neutral gas composition are likely to influence the $n_e(h)$-profile mainly above the F2-region maximum. The $n_e(h)$-profile is determined mainly by the neutral winds for the F2-region maximum in the autumn-winter periods.

In autumn and winter the ionospheric drift of the charged particles essentially affects both the altitude distribution of the effective recombination coefficient and its absolute values.

It's known that the different characetristics of the upper atmosphere are closely connected with each other. One of the actual problems of the upper atmopshere physics in at present the problem of the definition more precise the causes and the character of the basic ionospheric parameter interconnections, the determination of dynamics of these interrelations dependent on solar activity, magnetic disturbances, seasonal-time conditions, etc.

From this point of view it is intersting to consider the results of the simultaneous uniform measurements of the different ionospheric parameters performed during several years under the same conditions.

As a result of a few rocket experiments carried out from 1965 to 1971 at altitudes 80-500 km the information on the solar ultra-violet fluxes the composition and temperature of the neutral upper atmosphere [1-4] , electron concentration n_e and electron temperature T_e was obtained using a dispersion interferometer [5] and probe instruments [6] . All experiments were performed in the middle latitudes of the European part of the USSR in the same geographic point early in the morning at the zenith distance 82° ÷ 78°. The detailed review of these experiments is contained at Gringauz's report [7] .

Before discussing the interconnection character between the ionized and neutral components of the upper atmosphere it is expediently to consider the primary experimental data on behaviour of these components separately.

The given (in Fig.1) normalized values of the photoelectric saturation currents based on the photoelectron analyzer data show for the experiment-to-experiment variations solar radiation absorption character at 100-400 km altitudes, i.e. for the variations of the neutral atmosphere density and composition.

The information on the altitude dependences of the solar radiation spectral intensity registered by photoelectron analyzer was used for the definition of the neutral particle concentrations. Fig. 2 shows the values of photoemission density $\dot{j}_i$ (h) for several intervals of wave-lengths for λ<1100 Å. The definition accuracy of the values was not worse than ± 15%. The observed difference in variations of the solar radiation spectral intensity for λ 1100-900 Å and λ < 900 Å does not.

exceed the uncertainty of the absolute values of the platinum quantum efficiency for the given wavelength intervals [8] .

The obtained dependences were used for the determination of the altitude profiles [O] and $[M]=[O_2]+[N_2]$ according to the procedure described earlier [4] . Unfortunately this procedure cannot provide the desired absolute accuracy $n_j(h)$ definition because of some available uncertainty of the values used for calculations of the absorption effective cross-section coefficients due to both the uncertainty of the spectral boundaries of the wave-length intervals considered and the possible variations in the distribution of the solar radiation spectral intensity within pointed $\Delta\lambda$. However since the relative error of the obtained dependences $j_i(h)$ does not exceed ± 15% the application of the same procedure to these dependence processing allows to follow rather reliably the variations of concentrations of atomic oxygen and molecular components from experiment to experiment.

As it is seen from Fig.2 the dependences obtained from the experiments allow to define [O] and [M] independently only in the limited height interval 200 + 300 km. To obtain the profiles [O] and [M] throughout the height interval these experimental values of [O] / [M] ratio were compared with the data of international Standard atmosphere, 1966 for different temperatures and then for each experiment such a concrete model chosen for which in the indicated intervals of altitudes [O] / [M] ratio values coincided with the experimental ones *).

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*) At estimations of the neutral particle concentrations for atomic oxygen unlike papers [1,2] the experimental data on the cross-section coefficients were taken into account also [9,10].

Supposing that such a conformity remains true for the heights 120-400 also it is not difficult to estimate [M] and [O] values for those heights where the experimental absorption curves allow to define eigther only [M] values or $[\sum] = [O] + [M]$. The obtained profiles are shown in Fig.3.

The variation of both the total concentration and the composition was observed from experiment to experiment. So the comparatively lower concentrations took place on 20.IX.65 in altitudes $h > 250$ km. The experiment on 28.XI.70 is characterized by the highest relative values of molecular concentrations. As a whole for the described measurements in altitudes of 130-400 km [O] / [M] ratio varied from 0.15 to 300.

Unfortunately a small number of the considered experiments makes difficult the finding of the possible reasons of the observed variations of the neutral gas density and its composition.

The performed comparison of the obtained results with the data on solar and geomagnetical activities showed that the synonymous correlation between the concentration variation dynamics of neutral particles and their composition and solar and geomagnetical activities for the described experiments was not observed. Comparing the results of the summer experiment on 20.VIII.71 with the others carried out during the autumn time it can be also noted that these data are beyond the well known notion on the neutral gas seasonal variations.

In Fig.4 the obtained data are given dependent on the experimental data (location and measurement time were practically the same). From Fig. it is seen that the rather clear increase of both the total concentration and [O] / [M] ratio during the period close to the autumn equinox. It is known that the variations of density and composition with the period of 6 months are observed in the atmosphere and the maximum values fall within the spring-autumn periods [11] .

It's quite possible that the observed variations of the concentration and composition of the neutral particles reflect the semi-annual variations of the upper atmosphere structure which practically undepend on solar activity [11, 12] . The sharp increase of concentration and [O] / [M] ratio at the end of September - the beginning of October can evidence in favour of the equinox hypothesis for the upper atmosphere semi-annual variations according to which the gain of geometrical velocity is associated with increasing the Earth magnetic axis inclination to a fluxes of solar corpuscles [11] .

For comparison the data obtained in experiments on the ionized neutral components the dependences of electron concentration $n_e(h)$ [5] and the ionization rate q(h) are given in Fig. 5. It is seen from this Fig. that above maximum of F_2-layer q(h) values proportional to the absolute concentration of all neutral particles n(h) differed from each other insignificantly as the difference in $n_e(h)$ values rached the factor of 3. It is significant that the data on the neutral atmosphere structure given above do not allow to explain the observed difference in profiles $n_e(h)$ near maximum of F-region. Namely the relative concentration of molecular particles was, for example, the highest on 28.XI.70 with the least values $n_e(h)$ and q(h). It may be seem that on 28.XI.70 $n_e(h)$ values must be the least because of the expected (in this case) higher velocity for disappearance of charged particles. However, on 28.XI.70 the values turned out to be essentially more than that on 20.VIII.71. These circumstances must obviously evidence for the fact that $n_e(h)$ profiles observed in the ionosphere not in all cases can be explained only by the photochemical processes, i.e. that the use for the description of the recombination processes in F_2-region of the well known expression for an effective recombination coefficient [13] $\beta_{eff} = K_1 [O_2] + K_2 [N_2]$ where K_1 and K_2 are the corresponding coefficients for reaction rates does not give a full notion on the processes occuring at these altitudes.

It was shown in [14] that in some cases the charged particles drift essentially influences on the structure ionosphere at 180-400 km altitudes.

The performed calculations of the vertical distributions of the neutral wind velocities and ionization drift for a series of the considered experiments showed that in all cases at 180-400 km in autumn the horizontal velocities of neutral wind were higher than in summer. The greatest component of velocity was always directed to the West that is typical for the middle-latitudinal F-region. The higher values of the vertical velocity of the ionospheric plasma drift were also observed in autumn. It should be also noted that the vertical components of the neutral wind velocity were small (didn't exceed 1.5 m/sec). And the vertical component of the neutral wind velocity was the greatest on 28.XI.70 and the smallest on 20.VIII.71. At present time the observed increase of the atomic oxygen concentration in winter is explained by its transfer from the southern hemisphere to the northern under the action of the vertical velocity of neutral wind [15] . The obtained values of the neutral wind vertical velocity evidence for that during the performed measurements the additional flux of atomic oxygen wasn't be observed.

The obtained $n_e(h)$ profiles are in well agreement with $q(h)$ profiles taking into account the directions and the velocities of charged particle drift. It was the rather clear correlation of the F_2-layer form with the value of ionization drift directed dowhward at $h < 400$ km altitudes. Fig.6 gives the altitude dependences β_{eff} defined by solving the equation of the ionization balance using $n_e(h)$ and $q(h)$ experimental values and the ionization drift calculation results [14] . It turned out that the negative dependence of the β_{eff} absolute values on the drift velocity takes place: the higher velocity is the lower β_{eff} . For experiment on 20.VIII.71 when the drift velocity didn't exceed 10 m/sec the drift motions practically uninfluence on β_{eff} . It's clear from this why at altitude of F-region for this experiment practically full coincidence of the $n_e(h)$ and $q(h)$ profile forms took place. It's significant that in 250-350 km interval independently from the ionization drift values β_{eff} varies less than twice-that essentially differs from the altitude profiles β_{eff} calculated theoretically [13] . The highest possible range of variations β_{eff} is $\sim (3 \div 0.3) \cdot 10^{-3}$ sec^{-1}. If the drift velocity exceeds 10 m/sec it results in the corresponding proportional decrease of β_{eff} absolute values.

So the performed series of uniform experiments evidences in favour of the fact that for the periods of the lower and middle solar activity in the middle-latitudinal undisturbed F-region the observed variations of density and composition of neutral gas are explained in the best way under assumption on the presence of semi-annual variations. At $h < 350$ km in the autumn-winter period of time the profiles $n_e(h)$ were defined to a great extent by ionization drift which evidently favours to the decrease of the absolute values β_{eff} by 2 ÷ 3 times higher of F_2max altitudes. The absence of the correlation between various of neutral composition and concentration n_e shows evidently different character of upper atmosphere semi-annual and seasonal variations.

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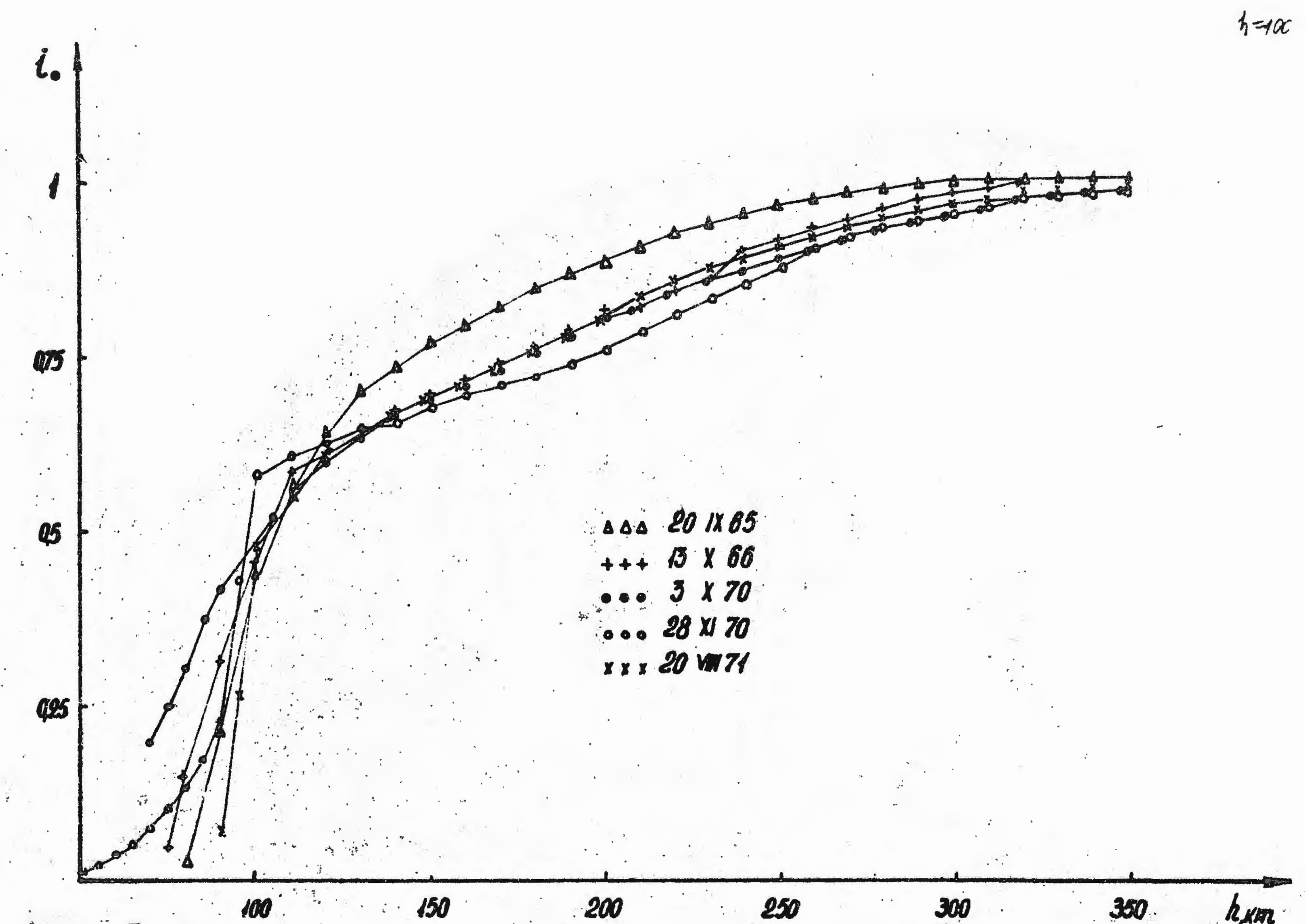


h=1α
i.
1
0.75
0.5
0.25
100
150
200
250
300
350
h,km
ΔΔΔ 20 IX 65
+++ 13 X 66
●●● 3 X 70
○○○ 28 XI 70
xxx 20 VIII 71

Fig. 1

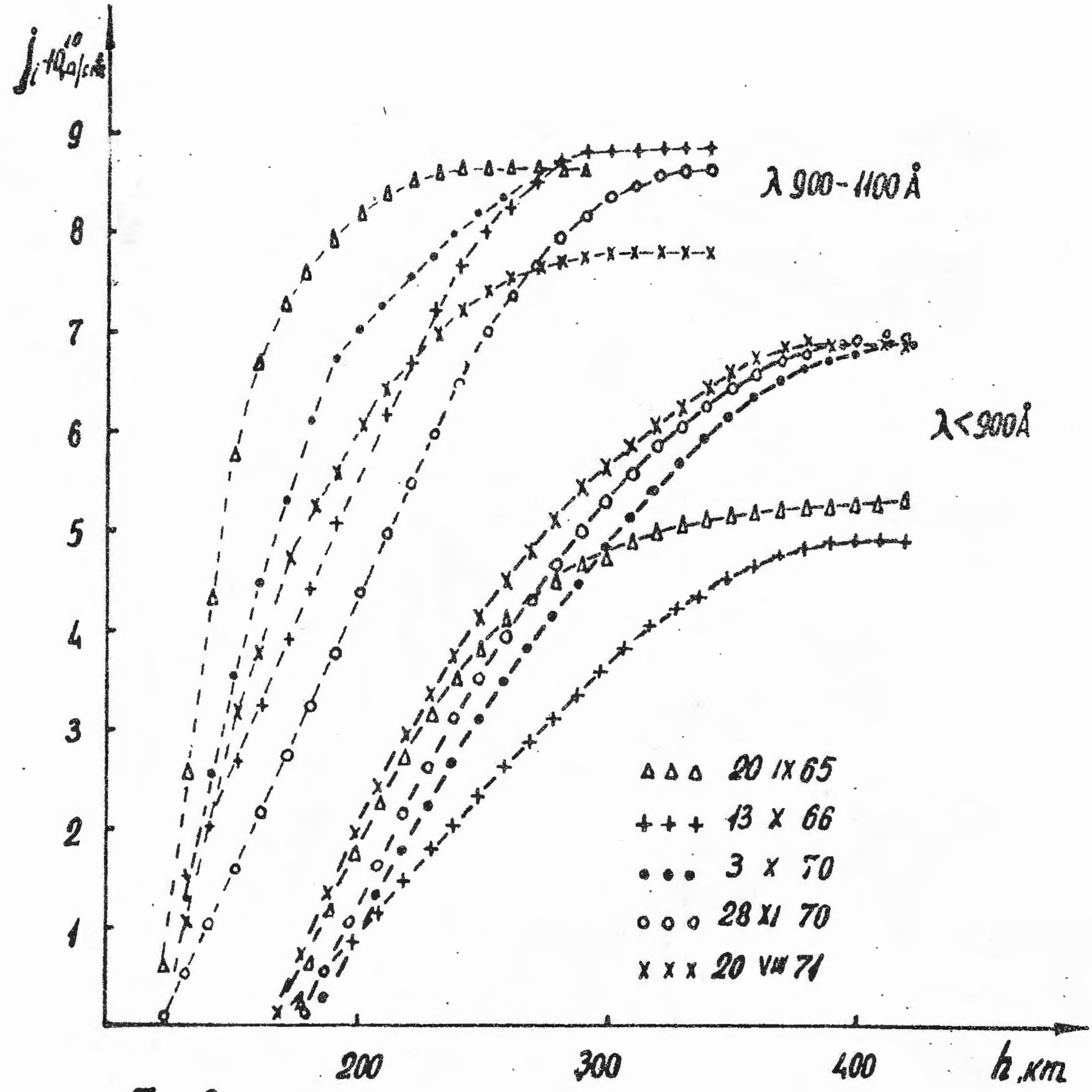

$j_i \cdot 10^{10}$ q/cm
9
8
7
6
5
4
3
2
1
λ 900–1100 Å
λ<900Å
ΔΔΔ 20 IX 65
+++ 13 X 66
••• 3 X 70
ooo 28 XI 70
xxx 20 VIII 71
200
300
400
h, km

Fig. 2

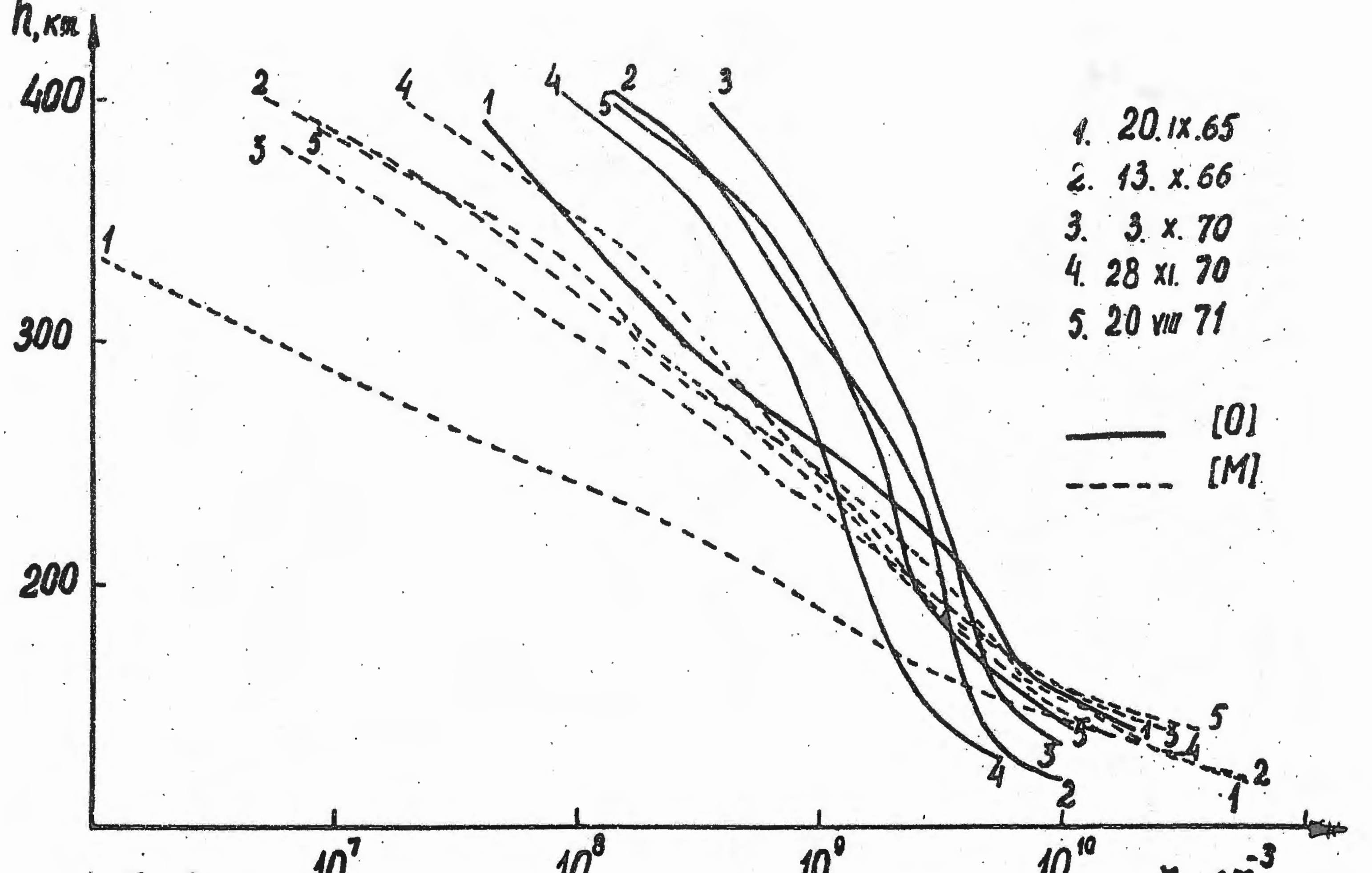
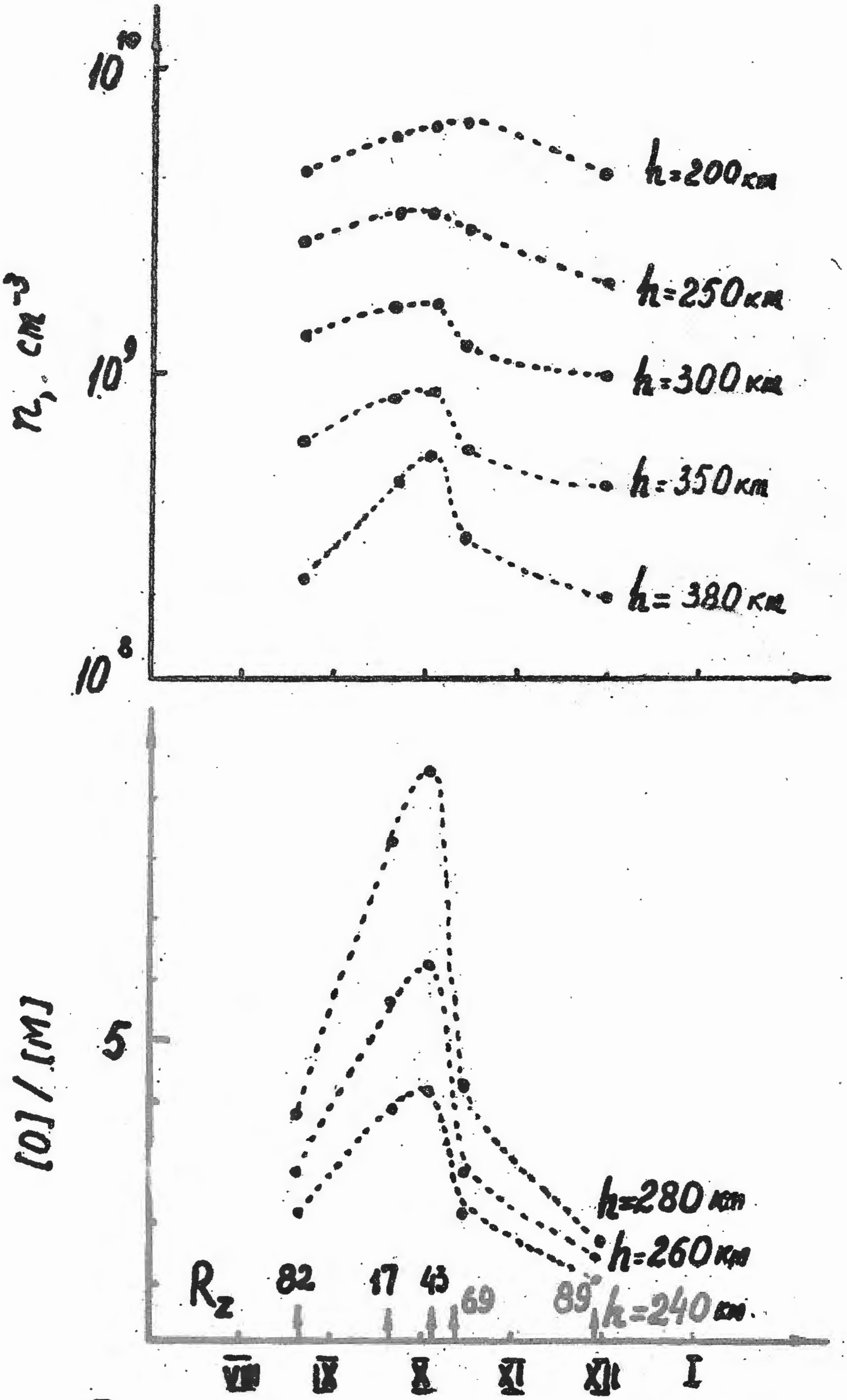

h, km
400
300
200
10^7
10^8
10^9
10^{10}
n_i, cm^{-3}
1. 20.IX.65
2. 13.X.66
3. 3.X.70
4. 28 XI.70
5. 20 VIII 71
[O]
[M]

Fig. 3



10^{10}
10^{9}
10^{8}
n, cm^{-3}
h=200 km
h=250 km
h=300 km
h=350 km
h= 380 km
[O] / [M]
5
h=280 km
h=260 km
h=240 km
R_z
82
17
43
69
89
VIII
IX
X
XI
XII
I

Fig 4

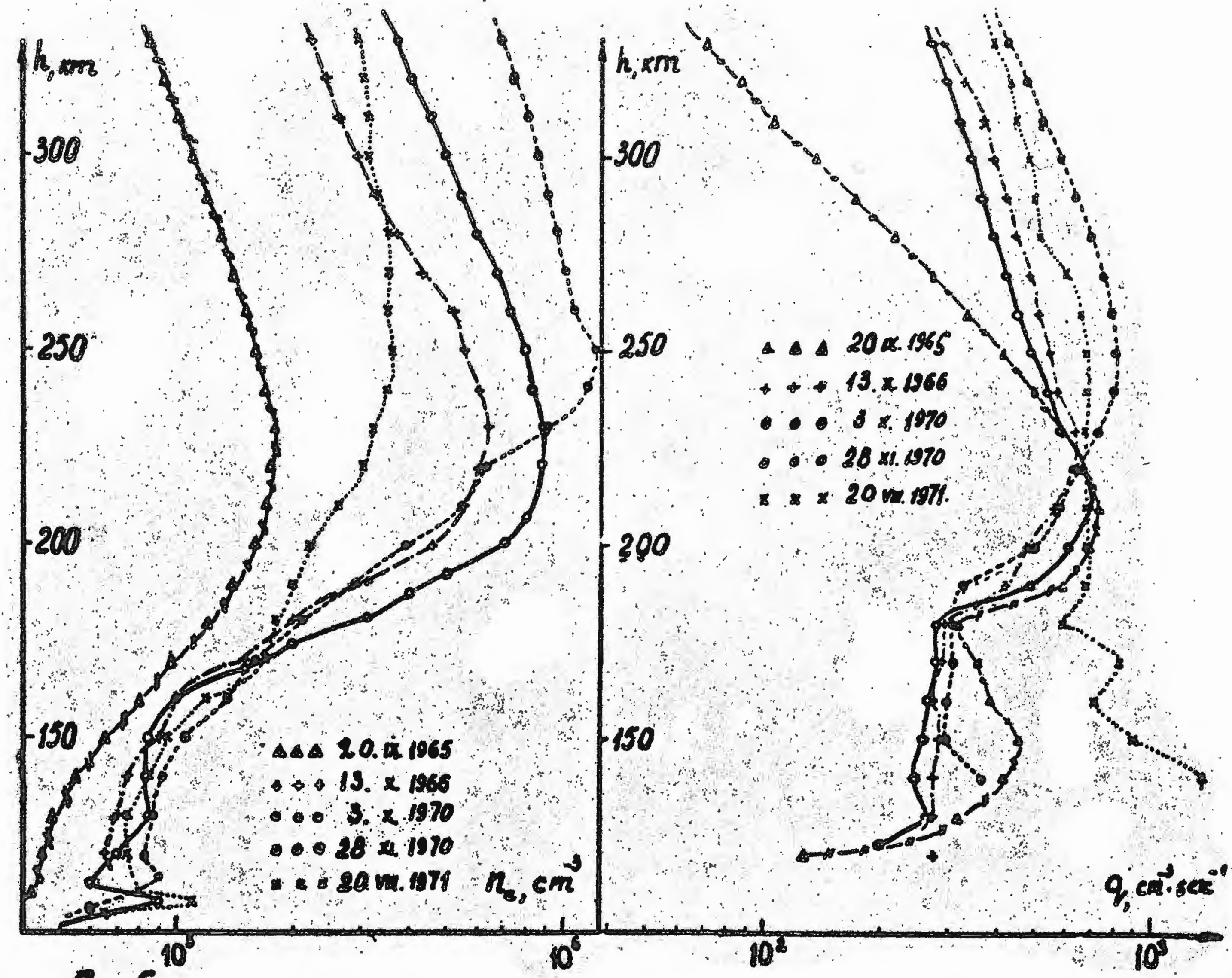

h, km
300
250
200
150
10^5
10^6
n_e, cm^{-3}
20.IX.1965
13.X.1966
3.X.1970
28.XI.1970
20.VIII.1971
h, km
300
250
200
150
10^2
10^3
q, $cm^{-3}\cdot sec^{-1}$
20.IX.1965
13.X.1966
3.X.1970
28.XI.1970
20.VIII.1971

Fig. 5

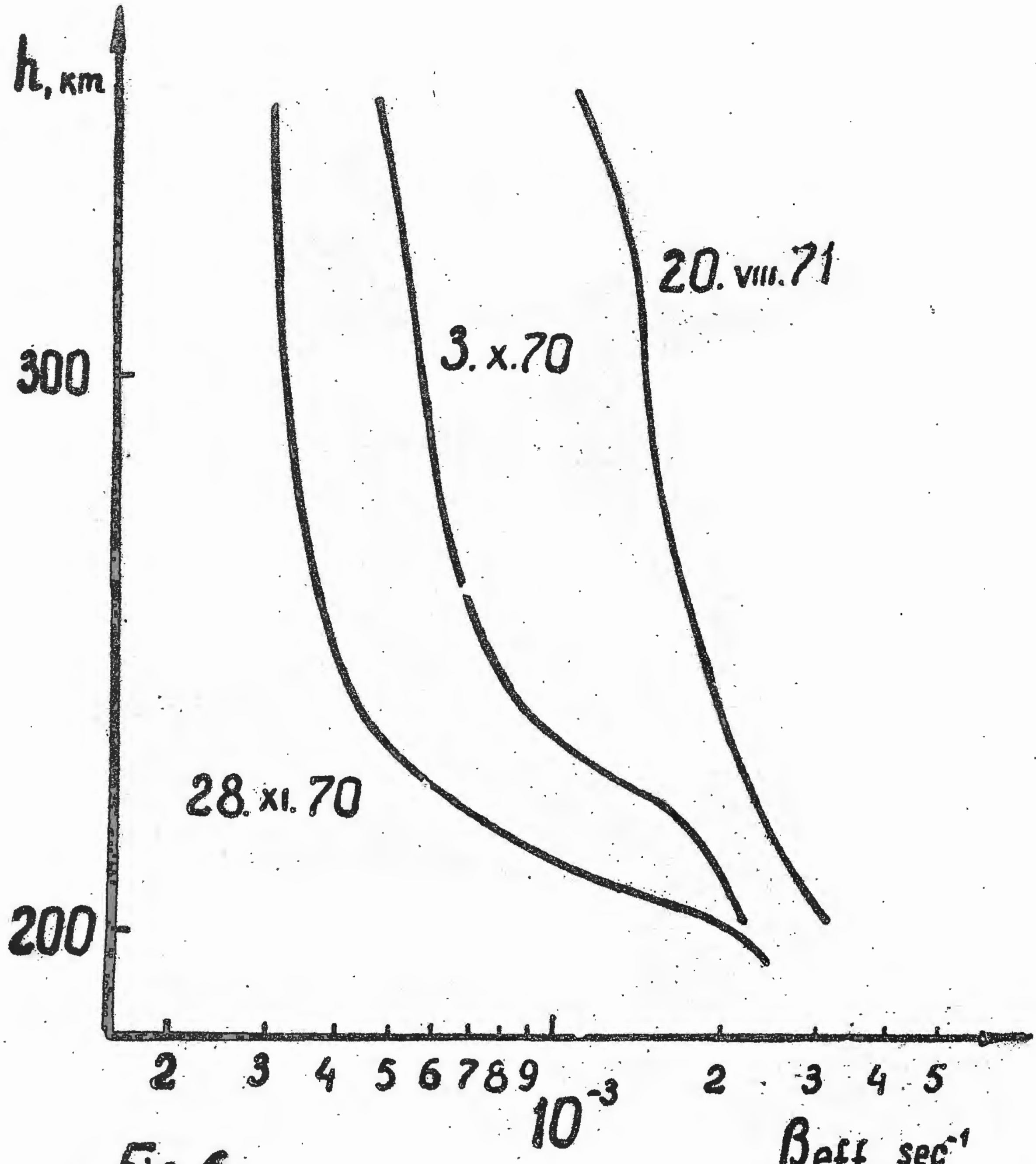

h, km
300
200
20. VIII. 71
3. X. 70
28. XI. 70
2
3
4
5
6
7
8
9
10^{-3}
2
3
4
5
βeff, sec⁻¹

Fig. 6