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SPACE RESEARCH INSTITUTE

Academy of Sciences, USSR

Д - I95

K.I.GRINGAUZ

COORDINATED INVESTIGATIONS OF THE NEUTRAL AND IONIZED UPPER ATMOSPHERE BY VERTICAL ROCKETS LAUNCHED IN THE USSR TO ALTITUDES $\sim$ 500 KM

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were launched to altitudes up to 470-500 km with the equipment that permits to obtain the information on the solar ionizing radiation and on densities and temperatures of neutral and iozed components of the upper atmosphere. The results obtained have been published as a number of separate papers for several years [I-I8] .

The aim of this reveiew is to summarize the results obtained during these flights, published in [I-I8] ,and, using them as an example, to demonstrate the possibilities of such coordinated measurements, to draw attention to the impormance of such measurements as means for checking the validity of the ionosphere models.

The neutral atmosphere parameters during rocket flights were defined by using of the altitude distributions of absorption for the different spectral bands of solar UV-radiation that were measured by the non-optical technique.

Altitude distribution of electron density was determined by a radio method (the dispersion interferometer), electron temperature T_e by the Langmuir-probe method.

During some of the rocket flights those measurements were supplemented by other experiments.

The results of the measurements mentioned above also allow to determine altitude distribution of parameters characterizing processes of ionosphere ionization, deionnization and heating. All the rockets were launched from one and the same site at midlatitudes of European territory of the USSR in the morning (with Sun elevation of about 8-I2°).

Table I gives the dates of the rocket flights the measurement results of which are used in this paper.

Table I

Year	I965	I965	I966	I970	I970	I97I
Date	9.20	IO.I	IO.I3	IO.3	II.28	8.2I

The latter two of the rockets mentioned (rockets Vertikal-I and Vertikal-II) were launched according to the Intercosmos program of space exploration, a joint programe of socialist countries; specialists from the GDR participated in the ionosphere experiments aboard these rockets.

Fig.I shows the general view of the rocket Vertikal-I at the launching site.

Rocket trajectories were very close to vertical (the angle between the line connecting the point of the launch with the trajectory vertex and the vertical of about 3°). During the measurements the rocket had 3-axes stabilization, with an accuracy of ± 3° relative to each of the axes.

As far as is known, similar investigations (including simultaneous determinations of vertical profiles of ionizing radiation intensity, parameters of the upper neutral atmosphere and the ionosphere) were carried out only to altitudes $h < 180$ km by Bourdeau et al. [I9] and to altitudes $h < 270$ km (in I969) by Timothy et al. [20] ; at altitudes $h > 270$ km they were carried out only in the USSR.

In the beginning of this review some relations are given used for the determination of such values as an ionization rate q and effective recombination coefficients α_{eff} $cm^{-3}sec^{-1}$ and β sec^{-1} based on the values measured directly; then some measurements are described and their results are given. The discussion of the data obtained and the conclusions are given in the last parts of the review.

Many details of experiments and of calculations (essential in some cases for the substantiation of conclusions) are omitted for making this review briefer;; these details one can find in the original papers. With taking into account that rocket results available obtained in F-region of the ionosphere, are extremely scanty the most attention is paid to this region.

2. SOME MAIN RELATIONS

2.I. <u>Designations</u>. At all altitudes of rocket flight in F-region (to $h \sim 420$ km) the following values were experimentally determined:

- solar UV-radiation intensity $\mathcal{J}$ (in spectral bands: $\lambda < 600$ Å; $\lambda \sim 600$ to 900 Å; $\lambda \sim 900$ to II00 Å; $\lambda <$ II00 to I350 Å; $\lambda >$ I350 Å);
- the density of neutral particles n_n cm^{-3} $= n_A + n_M$ where n_A and n_M are respectively densities of atomic and molecular particles (determined separately);
- temperature of neutral particles T_g;
- electron density n_e cm^{-3};
- electron temperature T_e *) ;
- change rate of $n_e = \frac{\partial n_e}{\partial t}$;
- the ionization rate q ;
- effective coefficient of recombination α cm^{-3}sec^{-1} (up to IIO to I80 km);
- effective coefficient of recombination β sec^{-1} (for heights I80 km);
- rate of heat inflow to electron gas Q_e *);
- rate of heat transfer from electron gas to neutral and ion gas L_e *);

- heat conduction coefficient for electron gas K_e *);
- effective collisions frequency for electrons $\nu_{e\,\mathrm{eff}}$ *).

It should be mentioned that the value n_e was determined by the dispersion radio-interferometer method [2I, 6, I5] ; the value $\frac{\partial n_e}{\partial t}$ at the altitude h was taken equal to $\frac{\Delta n_e}{\Delta t}$ where Δn_e is the difference of n_e -values at the same altitude h during the rocket ascending and descending; Δt is the time from the moment when the rocket reaches this altitude h at ascent while to that when it passes h , at descent Δt decreases with h growth; at $h > 200$ km, $\Delta t \leq 5$ min. It is often turned out that in the limits of the experiment accuracy $\Delta n_e = 0$ and, consequently, $\frac{\partial n_e}{\partial t} = 0$.

2.2. <u>To the determination of effectiv rate of recombination.</u> The equation of ionization balance for $h < 180$ km

$$\frac{\partial n_e}{\partial t} = q - \alpha_{eff}\, n^2 - div\,(n_e \bar{V}) \qquad (I)$$

and for $180 \text{ km} < h < 400$ km

$$\frac{\partial n_e}{\partial t} = q - \beta_{eff}\, n_e - div\,(n_e \bar{V}) \qquad (I')$$

where $\bar{V}$ is the particle directed movement velocity.

The value q was determined according to data on ionizing radiation and on the neutral atmosphere (see 3.I). The value $div(n_e V)$ was determined as

$$D\left(\frac{\partial^2 n_e}{\partial n^2} + \frac{3}{2H}\frac{\partial n_e}{\partial n} + \frac{n_e}{2H^2}\right) - W\frac{\partial n_e}{\partial n} \qquad (2)$$

where H is an a scale hight and diffusion coefficient $D = \frac{2KT_q}{\bar{m} n \nu_i} \sin I$; K is Boltzmann's constant; m is an average mass; ν_i is the collisions frequency; I is tne dip.

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*) the parameters marked by * were not determined in some flights

The term $W \frac{\partial n_e}{\partial h}$ determines the influence of ionospheric drifts; W - is a vertical velocity of charged particle drift.

The values β for rocket flights in 1970-71 (see Table I) were found in [18] by the use of calculations of horizontal velocities of ionospheric winds, carried out kindly by Dr.King according to the request of the experiment authors following the King's and Kohl's method [22,23]. Using Eqs.(I) and (I') α and β vertical profiles were defined for three cases:

(a) without taking into account the motion term in (I) and (I');

(b) the motion of charges was taken into account only as the vertical diffusion of electrons and

(c) besides the diffusion the influence of ionization drift caused by neutral winds was taken into consideration.

The results of Dr.King's calculations were given in [18]. The calculated velocities of neutral wind V are shown in Fig. 2, the corresponding values of W (vertical velocity components directed downwards) are shown in Fig.3; as it is seen from Fig.3 the maximum value W was observed on the Nov.28th 1970.

The influence of the plasmasphere on the process of deionization in the F-region was not taken into account.

2.3. <u>To the determination of the effectivness of the electron gas heating</u>. During the processive of the results of 1965-66 flights rate of heat inflow to electron gas at altitudes h > 180 km was estimated. The stationary equation of heat balance was used: **

** During the ascent and the descent of the rocket the values Te at the same altitudes were equal.

$$\frac{\partial}{\partial h}\left(K_e \sin^2 I \,\frac{\partial T_e}{\partial h}\right) = Q_e(h) - L_e(h) \qquad (3)$$

In the course of consideration of heat and cooling processes it was supposed that the main source of the upper atmosphere heating was ultra-violet solar radiation. To determine the rate of heat transfer Q_e in the equation (3) it was assumed that the main mechanism of energy less by electron gas are collisions with neutral particles and positive ions: elastic collisions with atomic oxygen, molecular oxyger, excitation of rotational levels of molecules N_2 , elastic collisions with oxygen ions as at altitudes 200 to 400 km this ion can be consided as basic, as well as the processes of excitation of fine structure of electron levels of atomic oxygen ^3P_J . The heat conduction of electron gas K_e was evaluated with taking into account that the real ionosphere is not a fully-ionized medium.

Using Eq. (2) the vertical profiles of rate of heat inflow to electron gas for two cases were determined: a) only local processes were taken into account; b) heat conduction was also taken into account. From the obtained values $Q_e(h)$, with average kinetic energy of generated photoelectrons $\bar{E}(h)$ and $q(\Delta\lambda, h)$ known the effectiveness of electron gas heating by photoelectrons $\varkappa(h)$ was calculated:

$$\bar{\varkappa}(h) = \frac{Q(h)}{E(h)\sum_{\Delta\lambda} q(\Delta\lambda, h)} \qquad \text{ev.cm}^{-3}\text{sec}^{-1} \qquad (4)$$

The influence of plasmasphere on the ionosphere particle temperature was not taken into account as well as the influence of the ionosphere magnetoconjugated region.

3. EXPERIMENTS ON THE DETERMINATION OF VERTICAL PROFILES OF THE UPPER ATMOSPHERE AND IONOSPHERE PROPERTIES

3.I. The measurements of the solar UV-radiation intensity by the method of photoelectron analysis. The determination of the neutral upper atmosphere parameters and q -value.

The determination of the UV-radiation intensity altitude profile was carried out by means of the measurements of photoemission of electrons emitted under the action of solar radiation from the platinum surface [8,I4] (these experiments,first from the being described, will be considered in more details that the others due to their importance for the program discussed).

The analysis of photoelectron energies by the method of retarding potentials (this method was applied for the first time on rockets by Hinteregger et al. [24]) made possible the definition of the altitude distributions of UV-radiation intensity in different spectral bands. Photoelectron analyzer represents four-electrode device with flat electrodes oriented to the Sun (with ± 3° accuracy) consisting of platinum photocathode, analyzing grid used for the photocathode protection from thermal ionospheric ions, and the outer screen-grid. The voltage on photocathode relative to the rocket body was so that thermal ionospheric electrons could not hit on it. The analyzing voltage changed linearly from I5.5 v to +4.5 v; the effective area of photocathode was $\sim$ I6 cm^2; the duration of the analysis cycle was $\sim$ I sec.

Before the flight the photoanalyser was irradiated at the laboratory by monochromatic radiation at different wave lenghts: 584, 740, I026. I2I6 Å; the photoelectron retardation curves were obtained for each of the indicated wave-lengths calibration current-voltage characteristics). Retardation curves obtained during the rocket flight were introduced in the computer's memory together with calibrating characteristics. The computer represented each flight characteristic as a sum of several characteristics each of them corresponded in shape to one of the calibrating retardion curves obtained with monochromatic irradiation. In this case the analysis was begun from the separation of that section of the flight retardation curve which at the given altitude fitted in the best way to the calibrating curve of the shortest of the wave lenths used for calibrations.

As the photoelectron energy distribution cannot be essentially different for the close wave-lengths one should regard that each of definite computed "partial" retardation curves, quite close in shape to one the calibrating curves conforms not to a monochromatic line of the solar spectrum but to some spectral band near the given wave length. Near L_α-line (I7I6 Å) such a spectral interval equal to II00-I350 Å was practically picked out. The validity of the latter statement was cheked out in following way.

Photometers of L_α-radiation of ionization chamber type developed in DDR with $\Delta\lambda$ =II50-I350 Å wave-lengths interval were installed aboard the "Vertical-I" and "Vertical-2" rockets. The comparison of L_α -radiation intensity values above L_α-absorption region of atmosphere measured by photoelectron analyzers and ionization chamber's data showed that the observed discrepancy of data from both instruments so differed in operating was ~I0% [9] . Such a discrepancy can be regarded as small as the calibrating of the instruments was performed using different laboratory installations by which a cosiderable part of the observed difference of the results obtained is possibly explained [9] . Fig. 4 shows the examples of the flight retardation curves of the photoelectron analyzer obtained from the different altitudes (a); one can see the variation of UV-radiation absorption with altitude, the laboratory calibrating curves for λ =I2I6 Å and λ =I607 Å are also given (flight on 28.XI.I974).

Fig.5 shows the example of the analyzer photocurrent height distributions for five different spectral bands (at rocket motion down; the flights on 28.XI.I970 and 2I.8.7I). It is seen from Fig.5 that on h > I20 km altitudes the absorption takes place only in three of the indicated bands.

The data given in Fig.5 contain the information on the neutral particles densities n_n. For the definition of n_n the ionosphere flat model was used in which the variation of the altitude over the Earth surface relation to the distance in beam was assumed as proportional to the cosine of the zenithal angle. The neutral particles content in the column of the single cross section over the altitude can be defined as

$$\exp\left(-\sum_j \sigma_j n_n\right)_\lambda = \frac{\Phi_n(\lambda)}{\Phi_0(\lambda)}$$

where $\Phi_n(\lambda)$ is the flux of λ wave lenght solar photons on the h altitude;

$\Phi_0(\lambda)$ is the same above the absorption zone;

σ_j is the cross-section of photons absorption by particles of j sort;

N_j is a number of particles of j sort in the verticle column ober h altitude.

σ_j cross-section were used in the different components of the upper atmosphere according to [25-28] . As the density of the neutral components is defined in our case by the radiation absorption in spectral bands indicated in Fig.4 and not in the separate monochromatic lines for every observed spectral band one had to choose some "effective" values of the cross-sections of absorption σ_{eff} and ionisation σ^{i}_{eff} in the atmospheric components.

The problems connected with estimation of influence on applicability of the method indicated of platinum photoelectric yield dependence on λ , with assumption of the ionosphere flat model applicability at large zenithal angles, with method of σ_{eff} and σ^{i}_{eff} definitions for the different spectral bands and other problems, important for estimation of accuracy of n_n definition from UV-radiation absorption measurements by photoelectron analyzer are considered by N.Shutte in papers [9] and [I4] .

Here we only note that by estimations made the n_n definition error is on the order of factor of 2 for N_2 and O_2 and on the order of 20% for O. The separate sections of n_n altitude distribution are approximated by the exponent sections and thus the altitude distribution of scale heights is obtained. From the scale height value of T_g - temperature is defined in the given altitude interval using the average mass of the neutral particles. The estimation of T_g error in [9] yielded + IOO°K value.

3.2. The definition of the height distribution of L_α-radiation intensity and molecular oxygen density by the ionization chamber method.

L_α-photometer developed in DDR consisted of ionization chamber filled up by nitrogen oxide at I7 mm pressure with the input window from MgF_2 of I.2 mm thickness oriented to the Sun. The spectral sensivity is II56 to I350 A with maximum near the L_α line.

As L_α radiation is absorbed only by molecular oxygen measuring the change with height at L_α intensity enables one to obtain the height distribution of L_α absorption and consequently the height distribution of O_2 -density.

3.3. The determination of n_e.

The electron density was determined by the method of dispersion interferometer ([2I,6,I5]). Coherent radio waves with frequencies f_1 =48 MHz and f_2 =I44 MHz were radiated from the rocket. The registration on the Earth of phase difference of recieved signals allows to determine n_e from altitude ~90-95 km to altitudes ~ 430 km with the error 5-I0%. Near the top of rocket trajectory (H > 450 km), where the vertical velocity considerably decreased the error of measurements because of nonstationary electron content of the ionosphere considerably increased, therefore the results of measurements at last ~ 30-50 km of the flight were not treated.

3.4. The determination of T_e.

The electron temperature was determined by means of Langmuir's cylindrical probe with stable period of sawtooth voltage ~ I sec [7] at all heights. In such way height-resolution of these measurements was improving during rocket ascent.

4. HIGHT DISTRIBUTIONS OF VALUES n_n, T_g, q, n_e, T_e, ν_{eff}.

4.I. Neutral particles. Although each experimental retardation curve of photoelectron analyzer, as it can ba seen from Fig.5, was given as the sum of five curves, corresponding to mentioned above five spectral bands of UV-radiation, the analysis of possible accuracy od determination of neutral atmosphere components densities by use of data on absorption, measurement in every spectral band showed that the densities of neutral particles of only 2 grouphs can be reliably determined by this method. Oxygen (O) atoms belong to the first group, and main molecular particles (O_2 and N_2) belong to the second one.

$n_0(h)$ and $n_M(h)$ are shown for five rocket launch at Fig.6.

The density of O_2 molecules has been managed to determine separately only at altitudes where L_α-radiation is absorbed. The altitude L_α-intensity distributions [II, I3] measured during the flights of rockets "Vertical" and "Vertical-2" by means of L_α-photometer (ionization chamber are shown at Fig.7. From diagrams of Fig.6 it is possible to determine vertical density distributions O_2 under some reasonable assumptions (considered in [II,I3] (Fig.8). The interpretation of peculiarities of these distributions can be found in II,I3 .

The determination of altitude distribution of O_2, made in similar way by data of radiation absorption in spectral interval L_α, measured by partial retardation curves of photoelectron analyzer gave results close to given above. The noticeable deviation of O_2-density altitude distribution at Fig.8 from barometric dependence should be noted. They are one of the evidences showing the possibility of existing of substantial differences between the neutral upper atmosphere models and its real characteristics.

4.2. Effective frequency of electron collisions in the E region of the ionosphere. The flights of rockets "Vertical-I" and "Vertical-2" (2I.8.I97I) were accompanied by measurements of absorption of radiowaves with frequencies (I; I.5; 2) $I0^6$Hz carried out near the launching site by means of German Democratic Republic installation for precise measurement of radio waves absorption by method of impulse radio sounding of ionosphere (by method A-I). As the absorption of radiowaves is determined by altitude distributions of n_e and of effective electron collisions frequency $\nu_{e\,eff}$ by using the data of measurements of absorption of radio waves and at the same time obtained from rocket $n_e(h)$ profiles the authors of [I0] and [I7] have obtained profiles ν_{eff} (h) -. As the least altitude h, at which n_e was measured, was ~ 95 km, profiles n_e(h) were extrapolated downwards (with use of literary data). Obtained values $\nu_{e\,eff}$ lie from $I0^6 sec^{-I}$ at altitude 80 km to i.5 ÷ $2.I0^4$ sec^{-I} at altitude II0 km, that are in good agreement with earlier published data on $\nu_{e\,eff}$.

4.3. The rate of ionization, electron density, particle temperature.

The altitude distributions n_e and q for two flights of I965 and three flights of I970-7I are goven accordingly at Fig.9 and I0. When the values of q in [2] ,

[I8] were defined the effects of the secondary ionization were not taken into consideration. As estimations showed made in [20] , the rate of ionization in ionosphere due to the secondary ionization was approximately by the order of magnitude less that one due to the direct solar UV-radiation, therefore the pointed disregard is possible.

$T_g(h)$ and $T_e(h)$ are given at Fig. IIa for the flights of I965-66 [3] , [4] and $T_g(h)$ for the flights of I97I [I4] is given at Fig. IIc.

5. THE EFFECTIVNESS OF ELECTRON HEATING. THE EFFECTIVE COEFFICIENTS OF RECOMBINATION.

5.I. The effectivness of electron heating. Although T_e at Fig. II grows with altitude at source regions of curves there are declinations from monotonous T_e increase which as it has been seen from the analysis made don't in all cases correlate with corresponding n_e variations. The calculations showed that in the settling of T_e value the processes of T_e cooling connected with and n_n values play the essential role.

On the basis of calculation of rates of heat inflows and electron gas cooling it was mentioned in [3] and [4] that the heat conduction influences on the altitude profile of heating effectivness only at altitudes $h >$ 300 km.

From the considered mechanisms of electron gas cooling the excitation of atomic oxygen turned to be the most effective up to altitudes $\sim$ 400 km.

In [3] , [4] rather high values of heating effectivness

~ (70-80%) for altitudes ~200 km were obtained. Its cause might be the fact that the additional heating sources,- electric fields, magnetohydrodynamic waves etc. were not taken into account values of atomic oxygen density and also at degree overestimated for which determination theoretical values of effective absorption cross-section were used the only available ones till I970.

The obtained altitude profiles $\bar{\varkappa}$ allowed to explain the observed peculiarities of altitude T_e distributions at Fig.IIa and showed that at altitudes 200-300 km the processes of electron gas interaction with neutrals in great part control the electron temperature.

5.2. The effective recombination coefficient α_{eff} (h < I80 km). By data, obtained during the rocket flight in I965-66 the values α_{eff} were determined from the equation (I) without taking into consideration of the term $div(n\bar{v})$ [5] . The obtained values α_{eff} were in the limits from $6.10^{-8}cm^{-3}sec^{-1}$ at altitude ~I00 km to $2.10^{-8}cm^{-3}sec^{-1}$ at altitude ~ I80 km.

The results of determination of α_{eff} by data of rocket flight of I970-7I are given in [I2] without taking into account for ionospheric drift and with taking into consideration for this influence - at Fig. I2. The values α_{eff} are shown by compact curves with taking into account for the term $div(n\bar{v})$ in the equation, including the term $W\frac{\partial n_e}{\partial h}$, they are shown by dot-dash line with taking into consideration for only vertical diffusion and by dotted line - in suggestion that $div(n\bar{v})=0$. For the flight of 3.I0.70 only two curves are given, as according to the calculations at considered altitudes $W=0$.

As it is seen from Fig.I2 at these altitudes the term $div(n\bar{v})$ has a slight influence on α_{eff} -value. The obtained values and altitude distribution α_{eff} are in a rather satisfactorily agreement with both α_{eff} values calculated with the use of data of laboratory measurements (e.g. given in [27] and [28]) and by Timothy's et al. data [20] . The greater value α_{eff} 20.8.I97I than in other cases apparantly is connected with higher total neutral particles density (see 4.I, Fig.6). One can see that the values α_{eff} obtained by different measurements are close to estimations in which the constants of dissotiative recombination of ions O^+_2 and NO^+ are used, which are the main ions at considered altitudes. This apparantly comfirms the rightness of side of dissotiative recombination as the main process, determining the deionization at altitudes $h \lesssim 180$ km.

5.3. <u>The effective recombination coefficient β_{eff} (h>I80 km).</u> In[I]the values β_{eff} sec^{-1} were given determined by data of rocket flights of I965, without taking into account for the term $W\frac{\partial n_e}{\partial h}$ in the equation (I') which represents the influence of the ionospheric drift, caused by neutral winds. As it is shown below there are cases, when this influence is rather important, so in this review we give only data on β_{eff} related to the flights in I970-7I [I8] .

Fig.I3 shows $\beta_{eff}(h)$ values for the indicated three flights. β_{eff} definitions were made by using of three assumption: a) $div(n_e\bar{v})=0$ b) $div(n\bar{v}) \neq 0$; $W=0$ (only the vertical diffusion takes place) and c) $div(n\bar{v}) \neq 0$, $W \neq 0$.

For all three flights the taking into account of diffusion does not change β_{eff} distribution characters, however, taking into account of $W \frac{\partial n_e}{\partial h}$ term considerably changed the curve types in Fig.I3a and I3b.

Instead of anomalous increase of β_{eff} on altitudes > 230 km β_{eff} values become monotonically decrease in altitude. It can be seen in Fig.7b that the taking into account of ionization drift varied β on altitudes > 250 km approximately in twice. The absence of the ionization drift influence on β_{eff} in Fig.7 is associated with the fact that the calculated velocity of the neutral V wind (and correspondingly W value) for summer day on 8.20.7I is low ($W <$ IO m/sec, see Fig.2 and 3). The increase of V and therefore W influences strongly β_{eff} value (possibly more strong than neutral composition variation [I8]).

Fig.I4 represents β_{eff} curve (with ionization drift taken into account) which was given in Fig.I3a (relating to 3.IO.70). The altitude β'_{eff} distribution is given for comparison here calculated as

$$\beta'_{eff} = \gamma_1 [n'_{O_2}] + \gamma_2 [n_{N_2}]$$ (see [28, 29])

where $\gamma_1 = I.5 \cdot IO^{-II} cm^{-3} sec^{-I}$, $\gamma_2 = I.7 \cdot IO^{-II} cm^{-3} sec^{-I}$; the sums of densities of oxygen molecule and nitrogen N_2 are taken according to Fig.5 and $\frac{n_{O_2}}{n_{N_2}}$ -values are defined by the neutral atmosphere model with taking into account the known T_g temperature (see [I4]). The comparison of two curves $\beta_{eff}(h)$ in Fig.I4 shows rather considerable differencies between them particularly on altitudes $\gtrsim 260$ km. Inaccuracies of the absolute β_{eff} values definition (e.g. due to uncertainty of absorption cross-sections defining q value, and inaccurately known constaint γ_1 and γ_2) evidently must not considerably influence the altitude β_{eff} -gradients. It can be supposed that on altitudes $\gtrsim$ 260 km the discrepancy between β_{eff} values defined only from the rocket experiments and by using γ_1 ,and γ_2 values becomes larger due to growth in Eq.(I) of the term describing the vertical diffusion, and decrease of ionization rate. However, it is not excluded particularly in section of β_{eff} (h) curves at altitudes below $\sim$ 250 km where q value is large comparing with diffusion effect that this decrepancy is connected with the fact that the physical conditions under which γ_1 , and γ_2 values are determined differ the conditions in the ionosphere at the altitudes $h > 180$ km.

CONCLUSIONS

The given above survey of papers on the definition of the altitude distributions of the different characteristics of the neutral upper atmosphere and ionosphere up to $\sim$ 400 to 420 km altitudes by using the experimental data from the rockets launched vertically shows that having simultaneously the measured values of the solar UV-radiation intensity in different spectral bands, electron density and electron temperature, one can define such important values for designing and checking the ionospheric models as ionization and recombination effective rates and the efficiency of electron gas heating.

In particular the obtained results give evidence in favour of that the effective recombination coefficient α_{eff} cm^{-3} sec^{-1} calculated based on assumptions of the dissociative recombination of O_2 and N_2 molecules as the fundamental deionization process at $h \lesssim 180$ km altitudes mainly describes well the real physical phenomena at these altitudes. There are doubts however in that β_{eff} values calculated according to the laboratory γ_1 and γ_2 constant measurements describe well deionization process at $h > 200$ km altitudes.

The instruments used during the rocket flights described in present paper are mainly developed by one research group. The equipment for use in similar coordinated ionospheric investigations by means of vertical rockets is desirable to add by photometers measuring the solar UV-radiation intensity at several fixed wave-lenghts (by monochromatic instruments, or with very narrow spectral intervals), sensitive gauge and mass-spectrometer of the neutral particles and ions. At in such a way supplemented programm the measurements accuracy and validity conclusions will increased.

There is no doubt in necessity of research programs of such a type for creating of the ionospheric models and their checking and for understanding the ionospheric processes.

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FIGURE CAPTIONS

Fig.I. The rocket "Vertical" at the launching site.

Fig.2. Components of horizontal velocities of neutral winds calculated by King.

Fig.3. Vertical components of ionospheric drift velocities.

Fig.4. The examples of retardation curves of photoelectron analyzer obtained from different altitudes.

Fig.5. Altitude distribution of analyzer photocurrents, created by different spectral bands of UV radiation on the Nov.28, I970 and Aug.28.I97I.

Fig.6. Altitude distributions of at oxygen atoms density and of total density of oxygen and nitrogen molecules from five rocket flights.

Fig.7. Altitude distributions of L_α -radiation intensity during the flights of rockets "Vertical-I" and "Vertical-2".

Fig.8. Altitude distribution of O_2-density (to altitudes I05 km) according to data from rockets "Vertical-I" and "Vertical-2".

Fig.9. Altitude distributions $n_e(h)$ and $q(h)$ during the rocket flights on the Oct.I3.I965 and Sept.20, I965.

Fig.I0. Altitude distributions $n_e(h)$ and $q(h)$ during the rocket flights on the Oct.3.I970, Nov.28, I970 and Aug.20.I97I.

Fig.II(a). Altitude distributions of T_g and T_e on the Oct. I.I965, Nov.20.I965 and Oct.I3.I966; (b) altitude distributions of T_g on the Nov.28.I970 and Aug.20. I97I.

Fig.I2. Altitude distributions of effective recombination rate α_{eff}

——•——•—— $div\,(n\bar{v}) = 0$

——o——o—— $div\,(n\bar{v}) \neq 0$ $W=0$

——x——x—— $div\,(n\bar{v}) \neq 0$ $W \neq 0$

Fig.I3. Altitude distributions of effective rate of recombination β_{eff}

——•——•—— $div\,(n\bar{v}) = 0$

——o——o—— $div\,(n\bar{v}) \neq 0$ $W=0$

——x——x—— $div\,(n\bar{v}) \neq 0$ $W \neq 0$

Fig.I4. Altitude distributions of β_{eff} for the flight on Oct.3.1971 according to rocket data

——x——x—— $(div\; n\bar{v}) \neq 0$, $W \neq 0$

——•——•—— according to calculated data with the use of laboratory constants of deionization velocities.

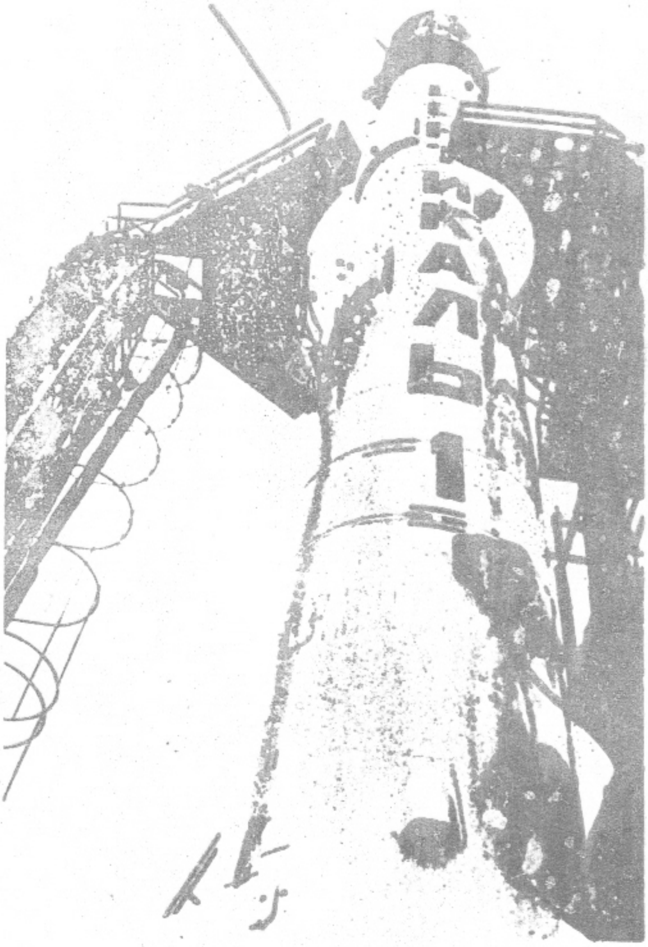
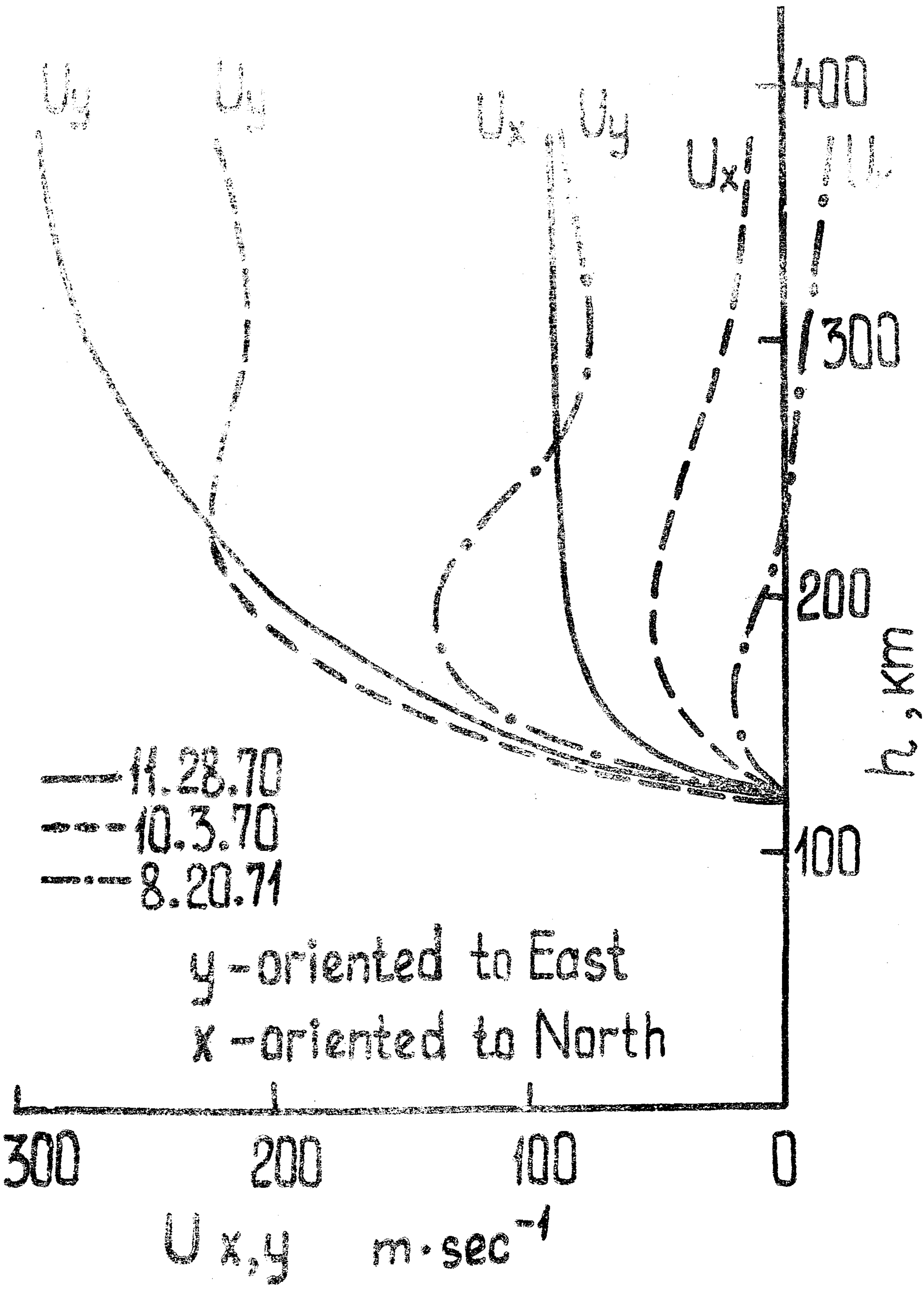


Fig. 1



U_y
U_y
U_x
U_y
U_x
U_y
400
300
200
100
h, km
——— 11.28.70
- - - - 10.3.70
-·-·- 8.20.71
y-oriented to East
x-oriented to North
300
200
100
0
$U_{x,y}$ $m \cdot sec^{-1}$

Fig.2

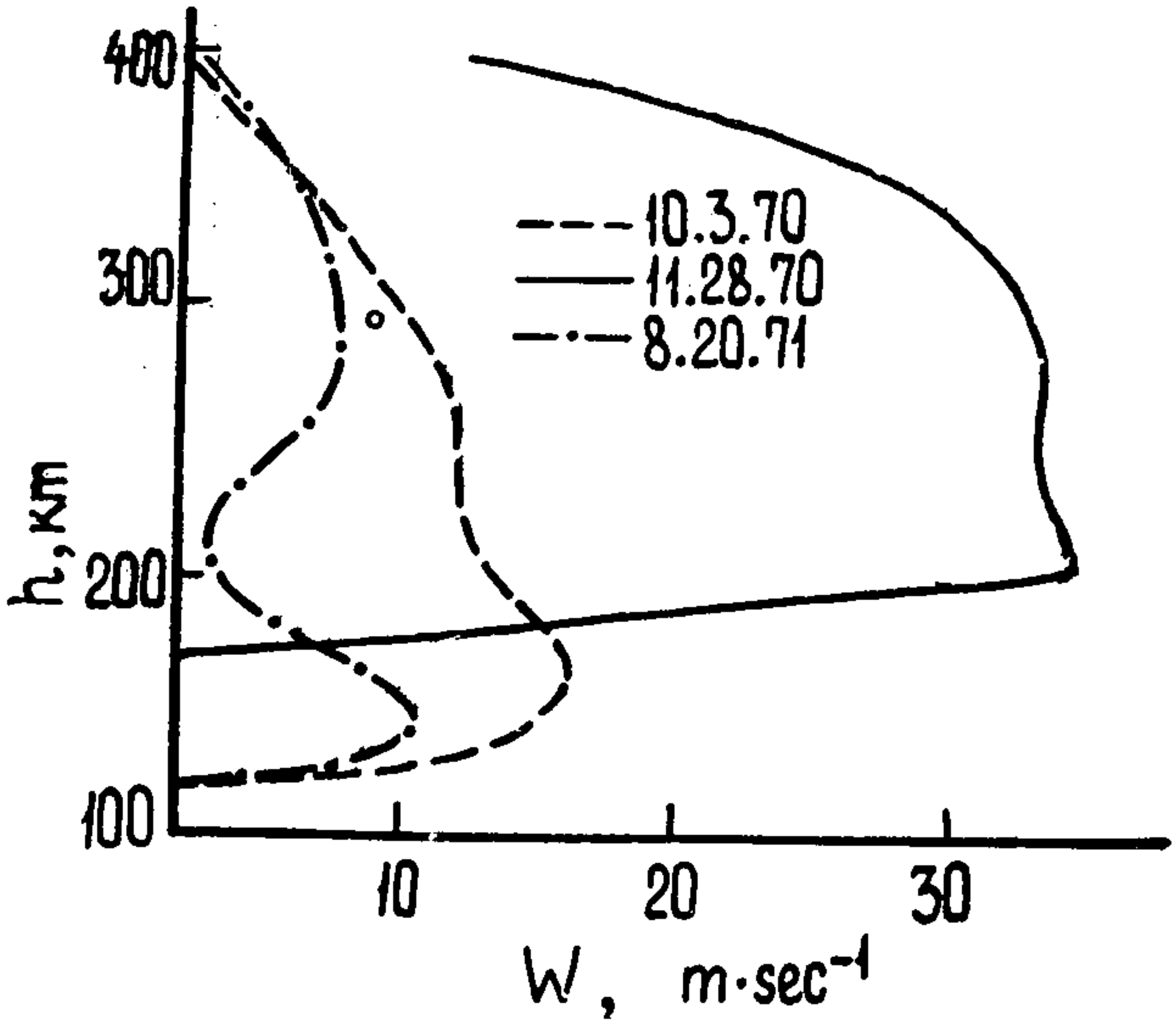


Fig.3

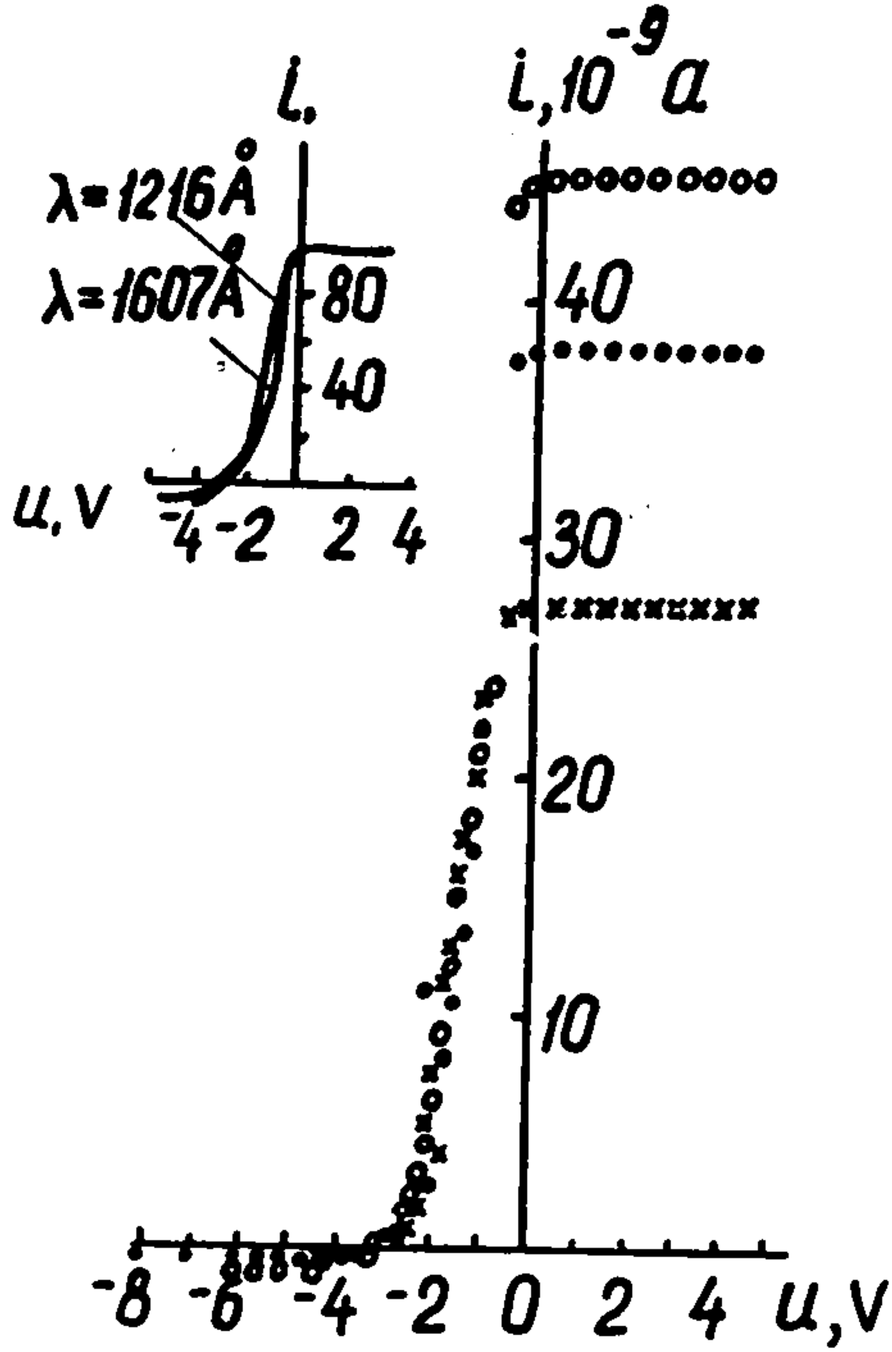


Fig.4

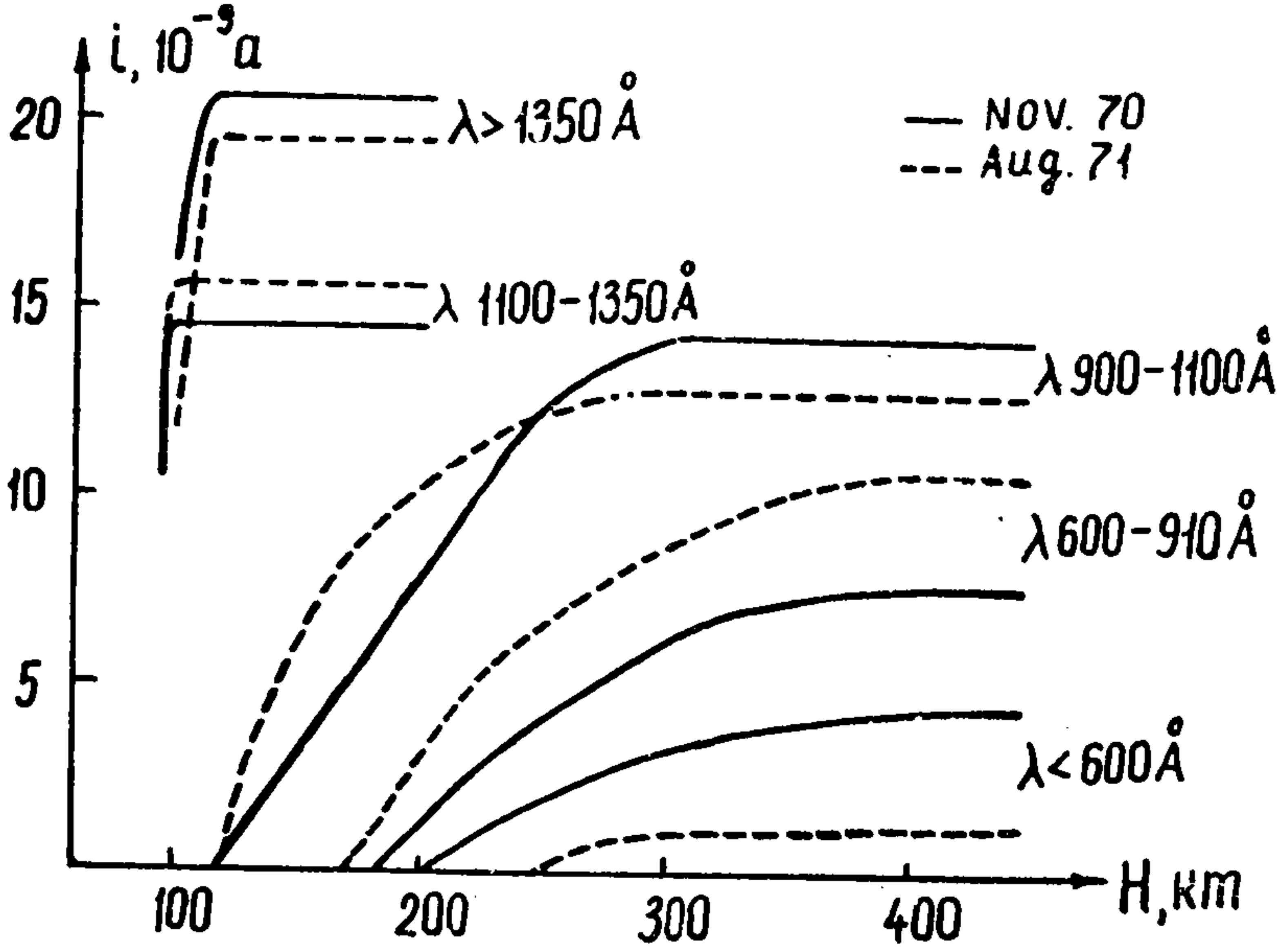

i, 10⁻⁹ a
20
15
10
5
100
200
300
400
H, km
λ > 1350 Å
λ 1100–1350 Å
λ 900–1100 Å
λ 600–910 Å
λ < 600 Å
— Nov. 70
--- Aug. 71

Fig. 5

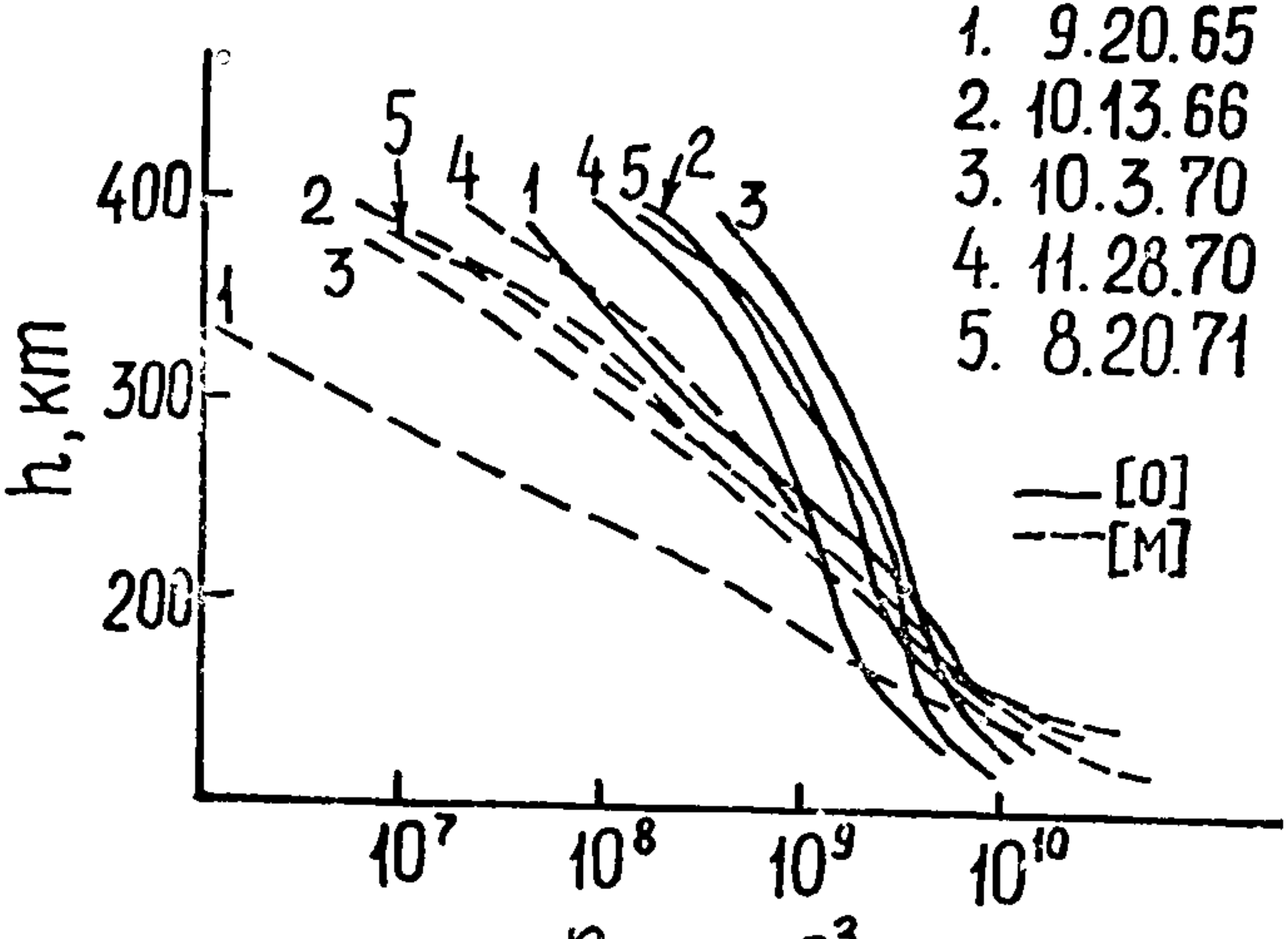

1. 9.20.65
2. 10.13.66
3. 10.3.70
4. 11.28.70
5. 8.20.71
[O]
[M]
h, km
400
300
200
10^7
10^8
10^9
10^{10}
n_i, cm^{-3}
1
2
3
4
5

Fig. 6

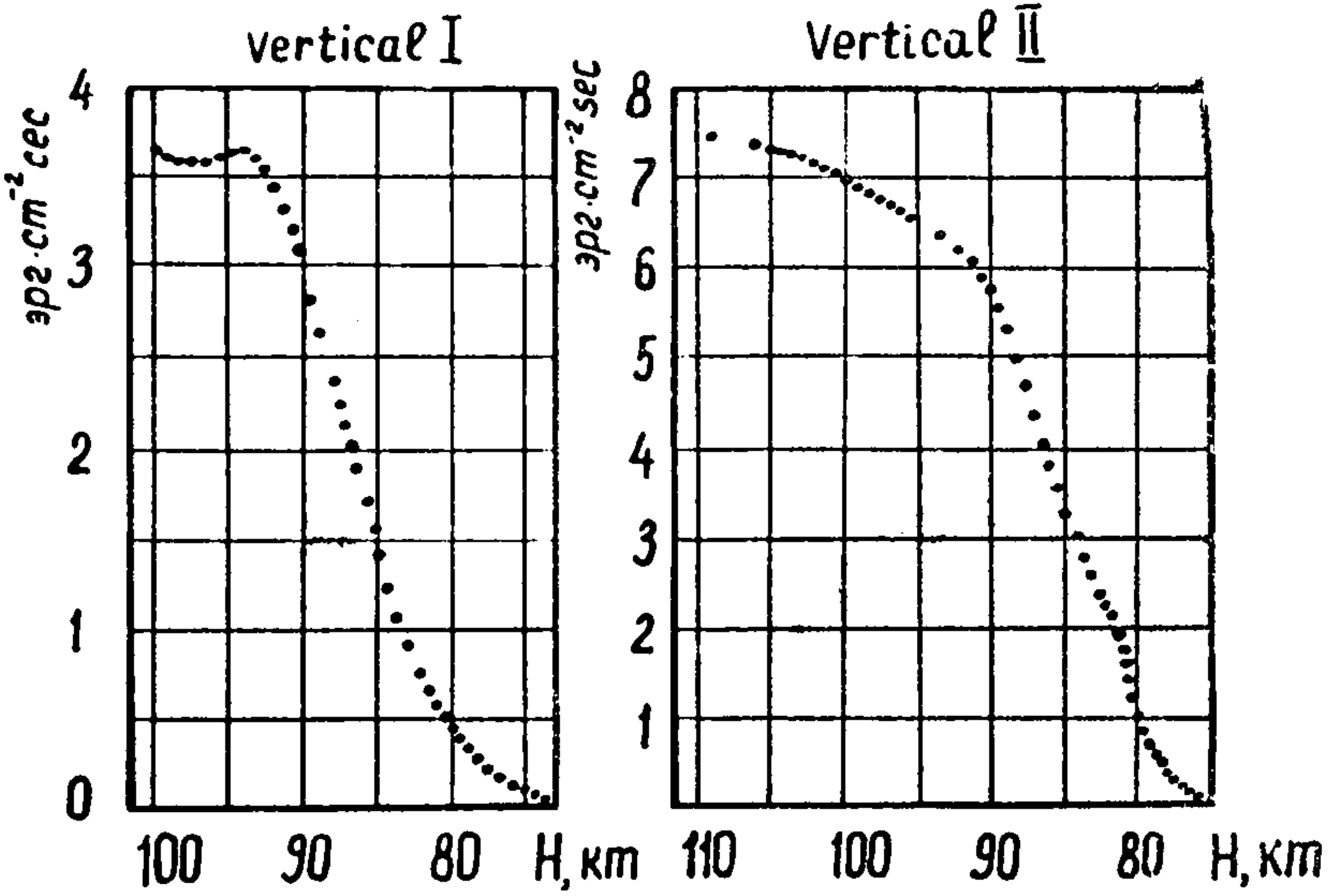

Vertical I
Vertical II
эрг·cm⁻²cec
эрг·cm⁻²sec
4
3
2
1
0
8
7
6
5
4
3
2
1
100
90
80
H, кт
110
100
90
80
H, кт

Fig. 7

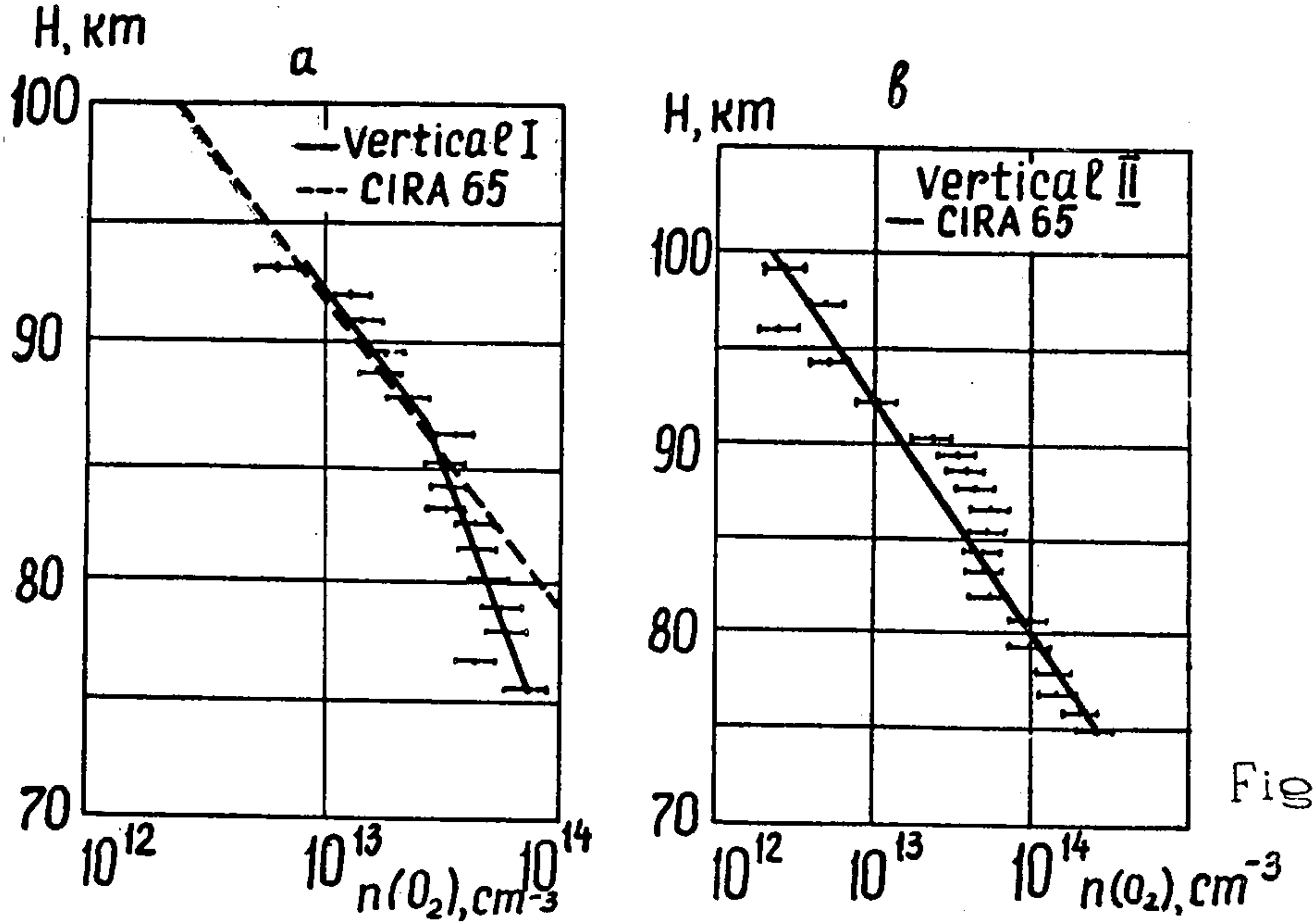

a
H, км
100
90
80
70
—vertical I
--- CIRA 65
10^{12}
10^{13}
10^{14}
$n(O_2), cm^{-3}$
в
H, км
100
90
80
70
vertical II
— CIRA 65
10^{12}
10^{13}
10^{14}
$n(O_2), cm^{-3}$

Fig.8

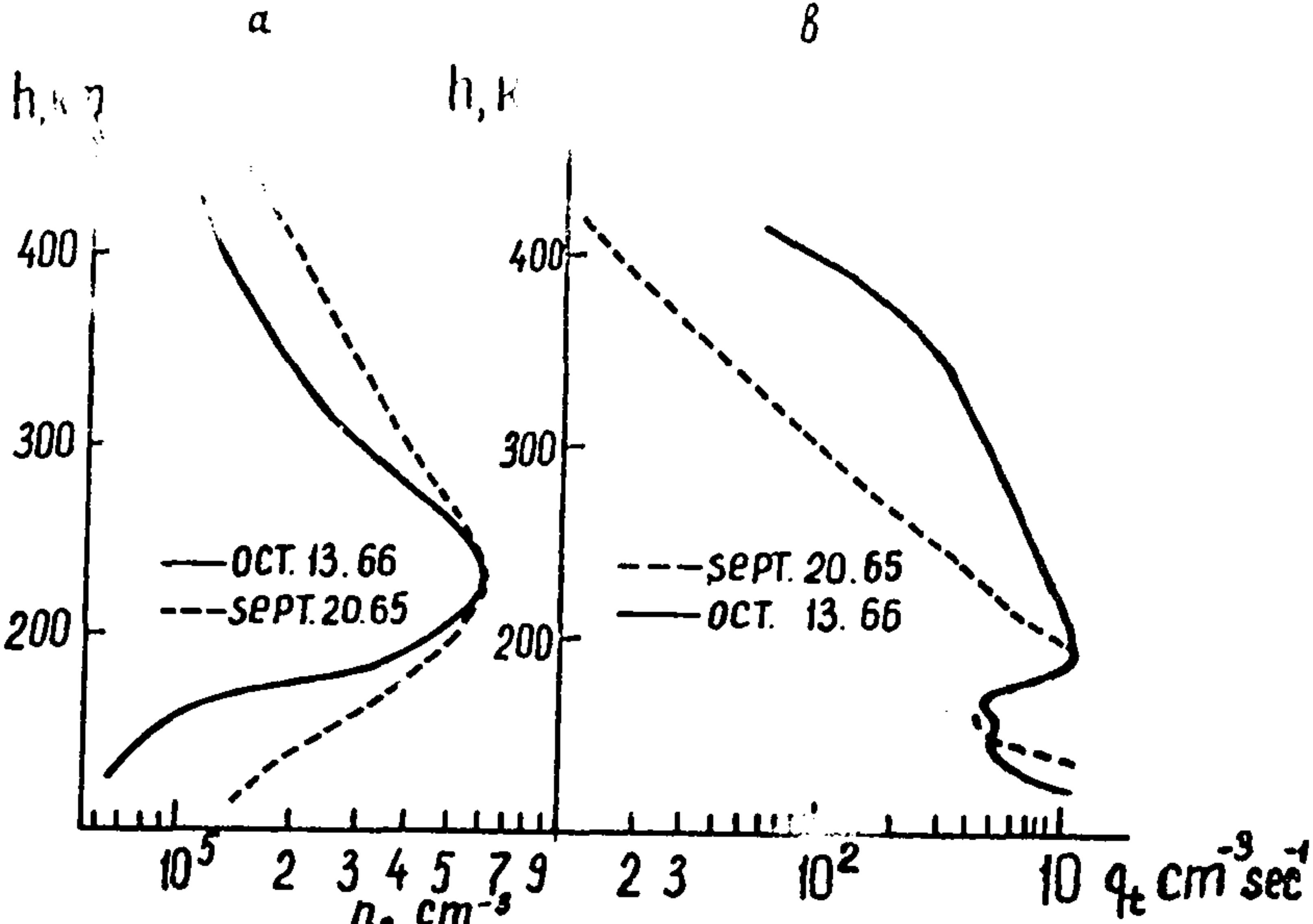

a
в
h,km
400
300
200
—OCT. 13.66
---SEPT. 20.65
10^5 2 3 4 5 7 9
n_e, cm^{-3}
h, k
400
300
200
---SEPT. 20.65
—OCT. 13.66
2 3 10^2 10
q_t cm^{-3} sec^{-1}

Fig. 9

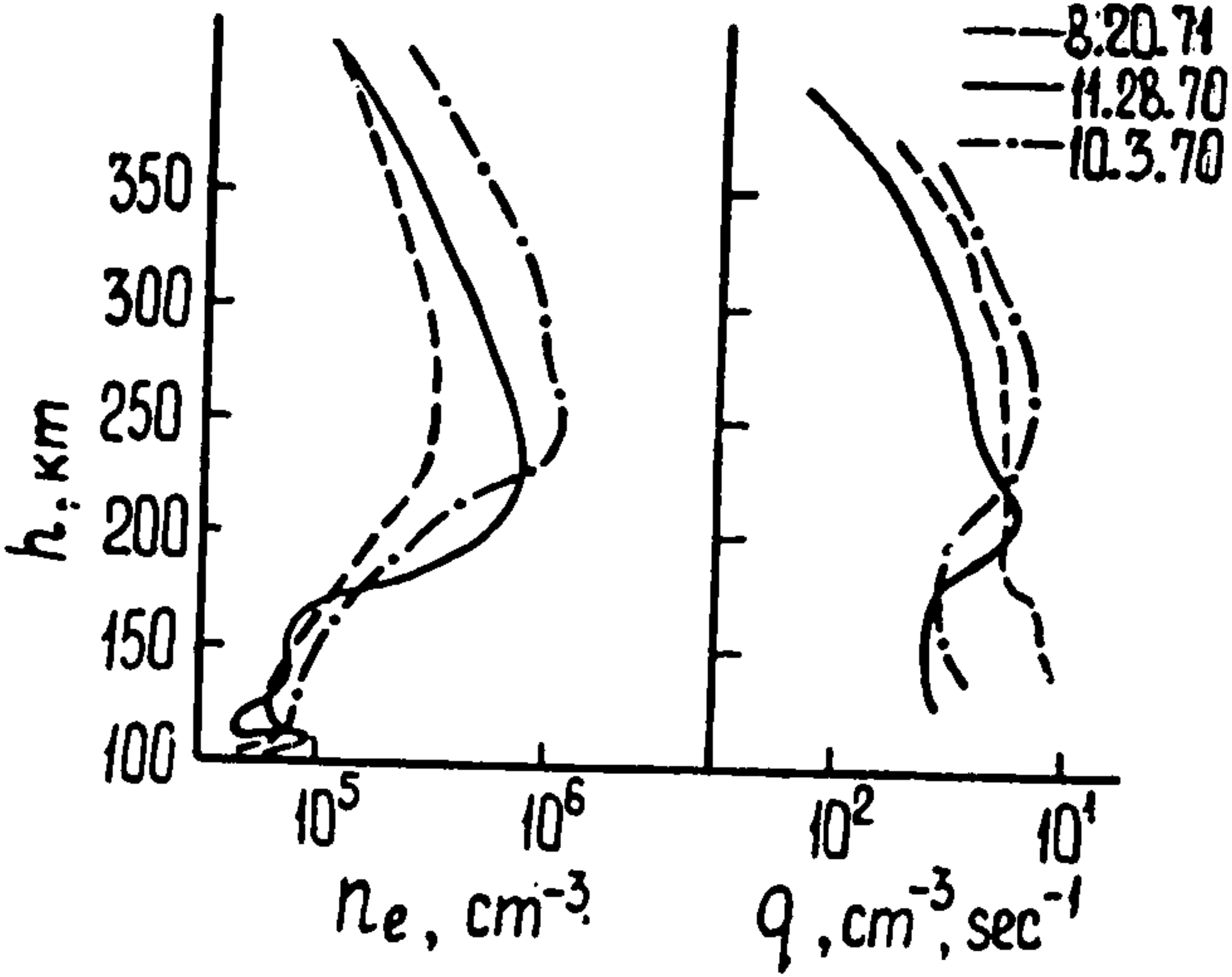

8.20.71
11.28.70
10.3.70
h, km
350
300
250
200
150
100
10^5
10^6
n_e, cm^{-3}
10^2
10^4
q, cm^{-3}, sec^{-1}

Fig 10

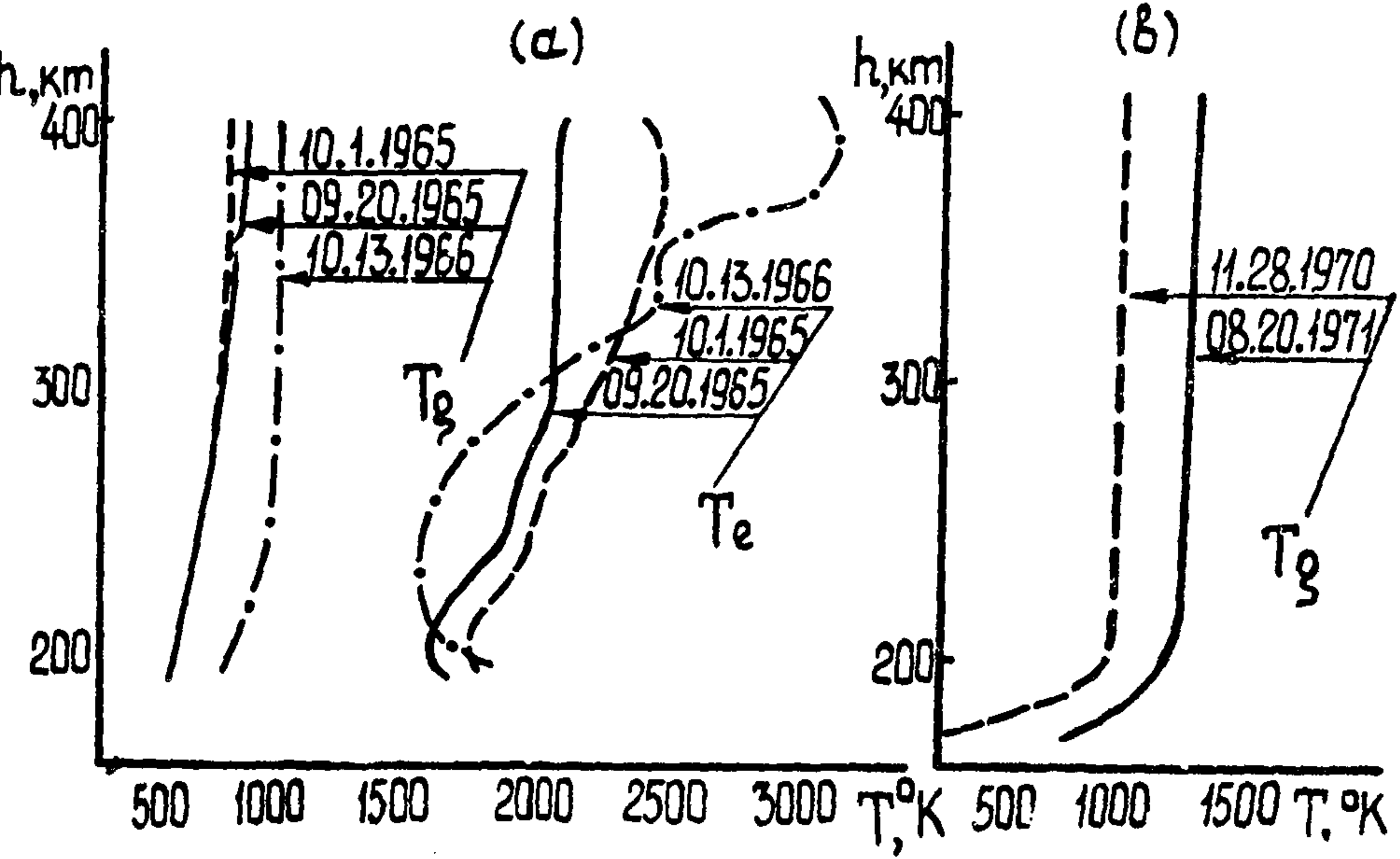
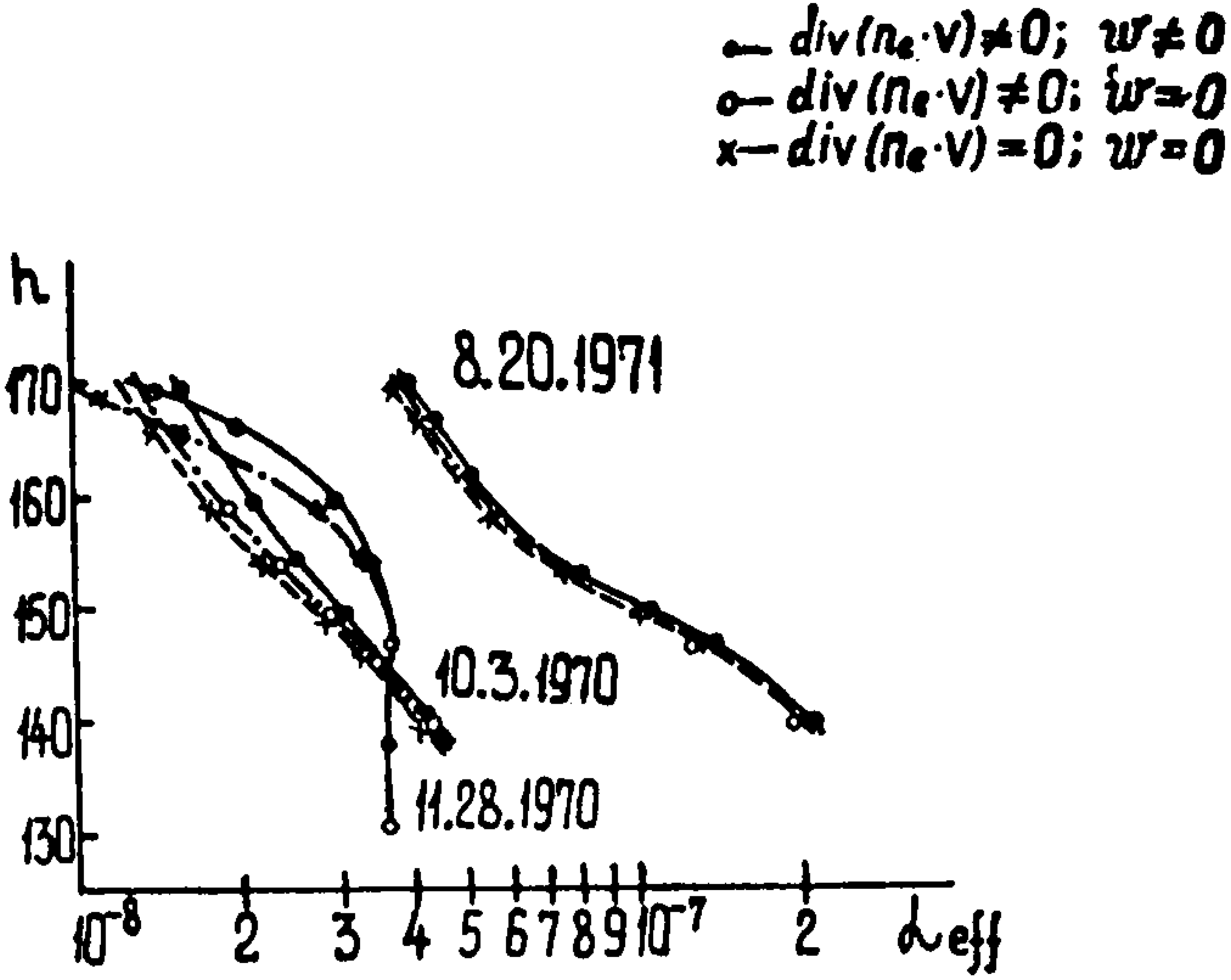

(a)
h,км
400
300
200
10.1.1965
09.20.1965
10.13.1966
Tg
10.13.1966
10.1.1965
09.20.1965
Te
500
1000
1500
2000
2500
3000
T,°K
(в)
h,км
400
300
200
11.28.1970
08.20.1971
Tg
500
1000
1500
T,°K

Fig 11



— div$(n_e \cdot V) \neq 0$; $w \neq 0$
o— div$(n_e \cdot V) \neq 0$; $w = 0$
x— div$(n_e \cdot V) = 0$; $w = 0$
h
170
160
150
140
130
8.20.1971
10.3.1970
11.28.1970
10^{-8}
2
3
4
5
6
7
8
9
10^{-7}
2
α_{eff}

Fig. 12

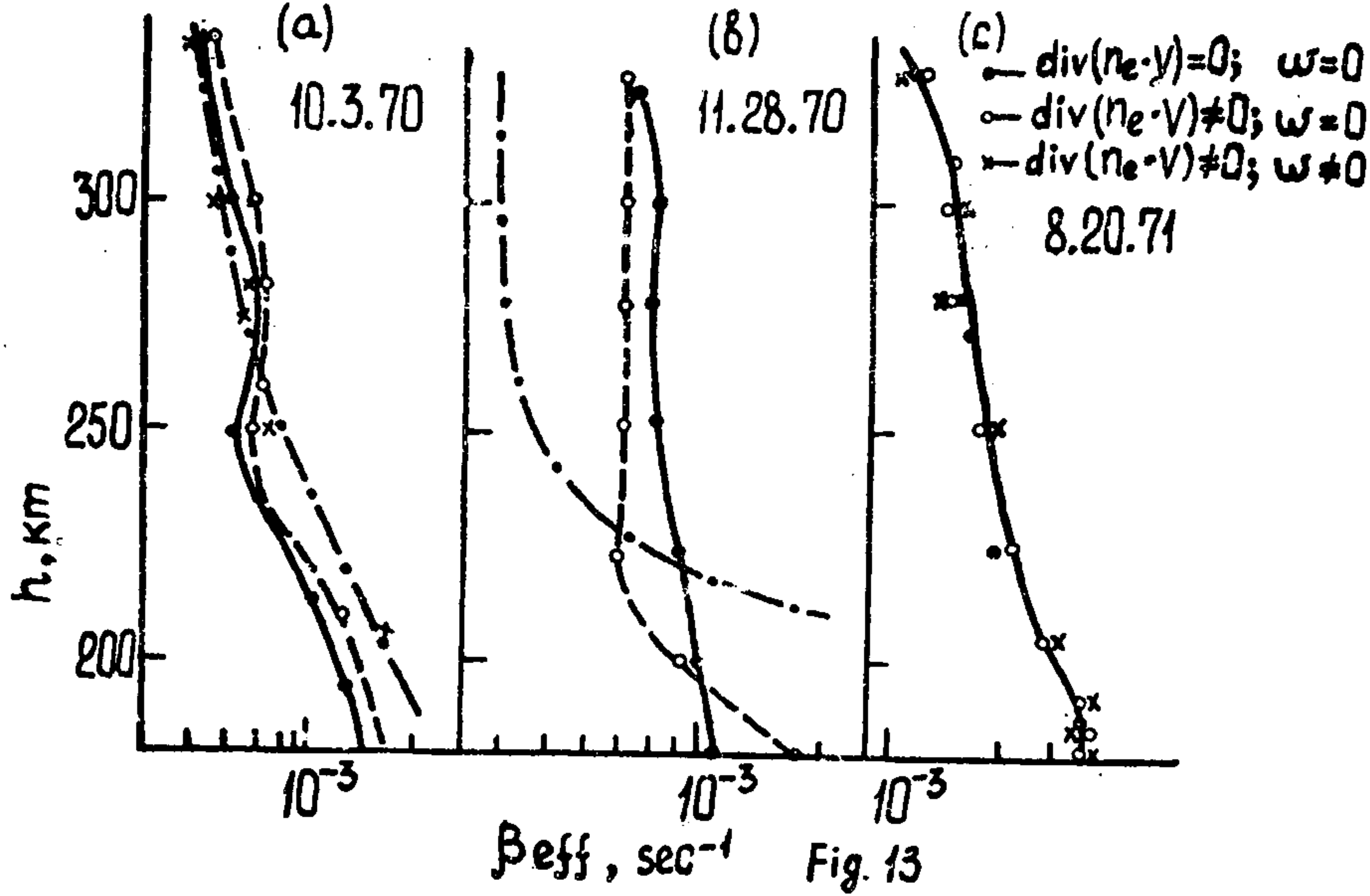

(a)
10.3.70
(б)
11.28.70
(c)
div(n_e·V)=0; ω=0
div(n_e·V)≠0; ω=0
div(n_e·V)≠0; ω≠0
8.20.71
300
250
200
h, km
10^-3
10^-3
10^-3
βeff, sec^-1

Fig. 13

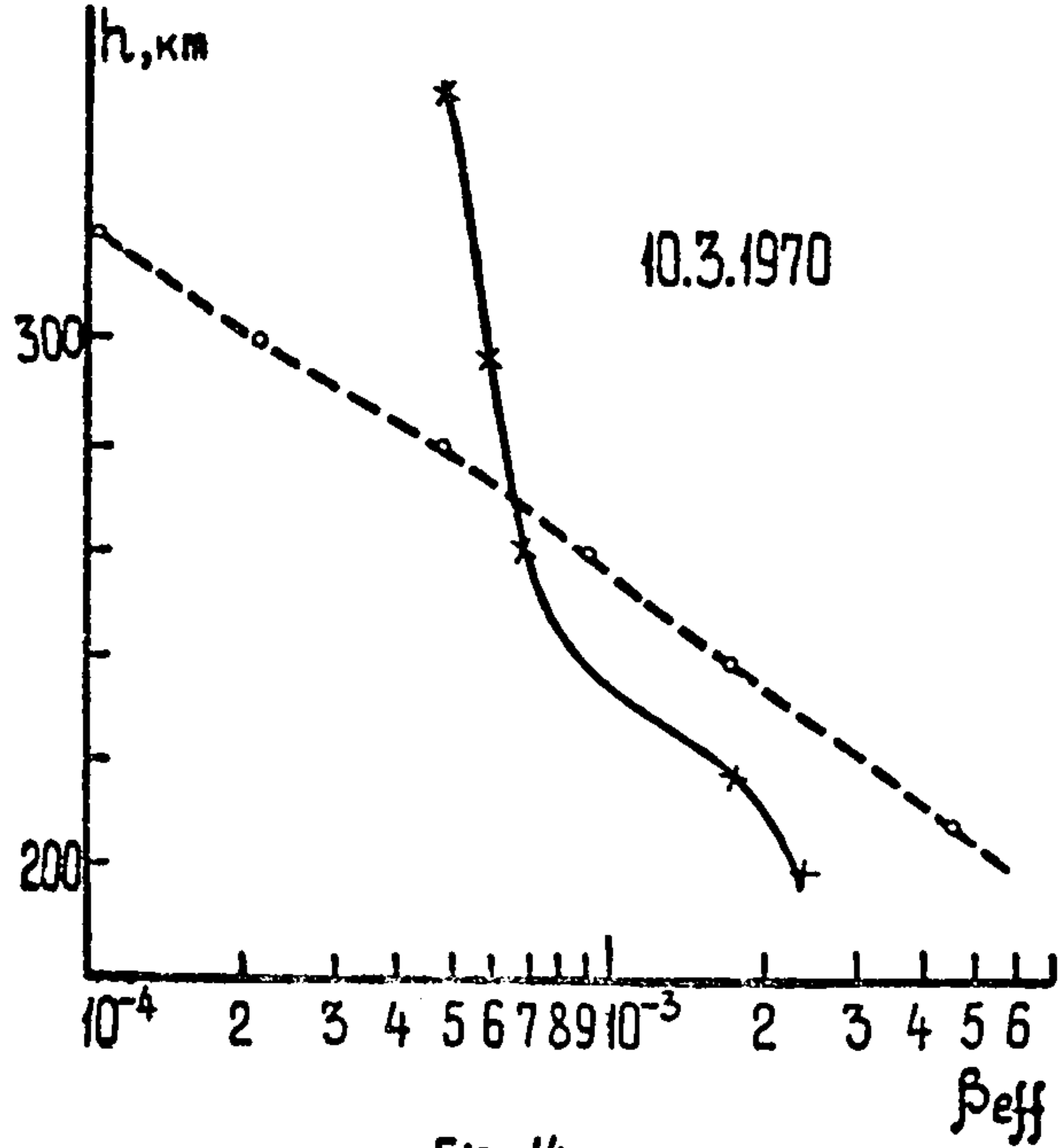


Fig. 14

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