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ABSTRACT

Ion temperature and ion density, measured the 25th October 1977 during the flight of the geophysical rocket "Vertical-6" by means of five retarding potential analyzers looking into different directions of space, are analyzed. The solar EUV fluxes determined in five vawe length bands with a photoelectron analyzer are also given. Using the ion composition and electron temperature, measured simultaneously, it is shown that the average variation of ion temperature with altitude is in agreement with the heating of the ion gas by the ambient electrons. The observed anomalous variation of ion temperature between 700 and 900 km and the measured ion concentration might be explained, if the charge exchange reactions $H^+ \rightleftharpoons O^+$ and diffusion are also taken into consideration.

АННОТАЦИЯ

При помощи пяти анализаторов с тормозным потенциалом, установленных в различные направления на геофизической ракете "Вертикаль-6", запущенной 25 октября 1977 года, были проведены измерения и анализ ионной температуры и ионной плотности. Ультрафиолетовое излучение Сольнца было определено в пяти областях длины волн при помощи анализатора фотоэлектронов. При использовании данных по ионному составу и электронной температуре, измеренной одновременно с измерением ионной температуры, результаты показывают, что изменением высоты среднее изменение ионной температуры соответствует возбуждению ионного газа, образуемого от окружающих электронов. Необычное изменение ионной температуры между 700 и 900 км, а также измеренная ионная концентрация может быть объяснено при учете реакции обмена заряда $H^+ \rightleftharpoons O^+$ и диффузии.

KIVONAT

Az 1977. október 25-én felbocsátott "Vertikál-6" geofizikai rakéta repülése során öt, különböző irányba néző fékezőpotenciálos sikanalizátor segitségével ionhőmérsékletet és ionsürüséget mértek, majd analizáltak. A Nap UV sugárzását öt hullámhossz tartományban egy fotoelektron analizátorral kapjuk. Felhasználva az egyidejüleg mért ionösszetételt és elektronhőmérsékletet, az eredmények azt mutatják, hogy az ionhőmérséklet átlagos változása a magassággal összhangban van az iongáznak a környező elektronok által történő fütésével. A 700 és 900 km között észlelt különleges ionhőmérséklet változás és a mért ionkoncentráció megmagyarázható, ha figyelembe vesszük a $H^+ \rightleftharpoons O^+$ töltéscsere reakciót és a diffuziót.

INTRODUCTION

The geophysical rocket "Vertical-6" was launched the 25th October 1977, 15 15 LMT from the middle latitude area of the European part of the USSR for the complex investigation of the upper atmosphere in the framework of the Intercosmos program. The rocket reached an altitude of 1500 km and its trajectory was very close to the vertical, the deviation being not greater than about 3^{o}. The rocket was three axially stabilized with an accuracy of $\pm 3^{o}$. The measurements, the results of which are analyzed here, were carried out by means of five retarding potential analyzers /RPA/ looking into different directions of space and by a photoelectron analyzer, which enabled the determination of the solar EUV flux in five different wave length bands [1]. The ion temperature and total ion density have been determined from the characteristic curves of the RPA looking upwards, using a multi parameter curve fitting [2, 3, 4], as well as from the indications of one of the analyzers looking horizontally. In addition, electron temperature and the concentration of different ions, measured on "Vertical-6" [5], are also used.

"Vertical-6" was launched in a geomagnetically very quiet period. The relative sunspot number was 28, the solar radio flux, measured at 10,7 cm, and the three-hourly geomagnetic index Kp were $88{,}1/10^{-22} Wm^{-2} Hz^{-1}/$, respectively 0. The launch time was preceded and followed by a period of low solar activity. Thus, the state of the upper atmosphere during the flight of the rocket corresponds really to undisturbed conditions.

Since rocket experiments, reaching altitudes above 500 km and especially those, where the ion temperature is also determined, are rare, the results of such measurements are useful both from the point of view of aeronomical studies and the checking of models. As regards aeronomical studies, rocket measurements reproduce the altitude profiles of the main parameters of the upper atmosphere and thus enable the detection of variations with altitude, which cannot be revealed by means of satellite observations.

RESULTS AND ANALYSIS

For the determination of energy input by the solar EUV radiation into the upper atmosphere, the fluxes in five different ranges of the spectrum have been determined by means of the photoelectron analyzer. Above the absorbing region of the atmosphere the following values were obtained:

wave length /Å/	<600	600-900	900-1100	1100-1350	>1350
flux /10^{10} photon $cm^{-2}s^{-1}$/	0,525	1,9	7,1	41,1	38,3

These data indicate that the input of energy by solar EUV radiation was similar to that found during the flight of Vertical 1 and 2, when the solar radio fluxes, measured at 10,7 cm, were 89, respectively 82/$10^{-22}Wm^{-2}Hz^{-1}$/. Thus, the agreement noted above proves that during the flight of "Vertical-6" really quiet conditions governed in the upper atmosphere. At the same time it justifies the use of atmospheric models [6].

In *Fig. 1* the variation of total ion density with height is shown, determined partly by means of the RPA looking upwards, partly on the basis of the data, measured by one of the RPA-s looking in horizontal direction. For comparison the ion densities obtained with an ion trap on the rocket [5], are also plotted. The maximum of the F2 layer was located at an altitude of about 230 km.

In *Fig. 2* the ion temperature profile is shown. Additionally, the electron temperature profile taken from [5] is also plotted. The ion temperature shows values equal to the neutral temperature to a height of about 550 km. It begins to differ from the neutral temperature only above this height, where a relatively steep increase of ion temperature is observed. Then at 700 km an isothermal region follows, above which at about 800 km a minimum occurs and the ion temperature shows a steep increase again. Thus the isothermal region at 700 km may also be interpreted as a local maximum. A less steep height gradient of the ion temperature is reached then about 900 km.

DISCUSSION

The variation of electron temperature with height is affected by the ion density profile to a height of about 500 km. The decrease of ion density above the maximum of the F2 layer is indicated by the electron temperature in *Fig. 2* as a steep increase in the same altitude, which shows that due to the decrease of ion density the cooling of the electron gas decreases considerably. A region of almost constant electron temperature is formed [7], as the ion temperature begins to increase at the height of 550 km due to the heating by the ambient electrons. This process holds, till the steep increase of ion temperature does not cease. Above this height, at an altitude of about 800 km a small maximum occurs in the electron temperature profile. This small maximum of electron temperature coincides with a minimum of ion temperature, above which an ion temperature gradually approaching the electron temperature may be observed with smaller fluctuations superposed on both profiles.

Since the ion temperature shows anomalous variations between the altitudes of 600 and 900 km, this region will be discussed in more detail. This region lies just above the critical height [8], below which chemical processes are dominant and above which diffusion begins to control the distribution of plasma. The ion composition is largely determined by the charge exchange reactions $H^+ + O \rightarrow O^+ + H$, respectively $O^+ + H \rightarrow H^+ + O$ yet. These reactions can affect the ion temperature, too. It is known [9] that the heating rate of hydrogen ions due to the ambient electrons is sixteen times larger than that of the oxygen ions. At the same time the cooling rate of the oxygen ions, attributed to elastic collisions with neutrals and moving in this height region practically in their parent gas, is about two to three times larger than that of the hydrogen ions [10]. Thus, the heating and cooling of the ion gas depends on the ratio of the concentration of hydrogen ions to the concentration of oxygen ions. Therefore, in the height region considered, where $O^+ + H \rightarrow H^+ + O$ is the dominant charge exchange reaction, the heating of the ion gas may be more effective, respectively the cooling less intense, than there, where the reverse reaction is prevailing. In the former region the loss of O^+ is greater than its production, while in the latter case the reverse conditions occur. In *Fig. 2* the heating and cooling rates, computed with the observed electron density, ion composition, electron and ion temperatures, as well as taking the neutral number density and neutral temperature from CIRA 1972, are also plotted. The data show that between 700 and 800 km increased heating and somewhat decreased cooling take place. This might be explained by taking into consideration that the height region mentioned is the transitional zone from the point of view of the dominant charge exchange reactions [11] and hence a region of non steady conditions. The altitude of the transitional zone may change due to the counterstreaming of O^+ and H^+ ions [11, 12]. Further investigations are needed to clear the observed feature of the ion temperature profile.

REFERENCES

[1] N.M. Shutte, Proc. Int. Symp. on Physics of the Earth's Ionosphere and Magnetosphere and of the Solar Wind. Hurbanovo, 1977. p. 263.

[2] W.C. Knudsen, J. Geiphys. Res., 71, 4669 /1966/

[3] S.J. Moss and E. Hyman, J. Geophys. Res., 73, 4315 /1968/

[4] W.B. Hanson, S. Sanatani, D. Zuccaro and T.W. Flowerday, J. Geophys. Res., 75, 5483 /1970/

[5] K. Serafimov, I. Kutiev, S. Chapkunov, D. Teodosiev, L. Bankov, Tz. Dachev, G. Gdalevich, V. Gubskii, W. Istomin, V. Ershova and J. Smilauer, Space Research XIX. Pergamon Press, London, 1979. p. 291.

[6] CIRA 1972, COSPAR International Reference Atmosphere. Akademie Verlag, Berlin, 1972.

[7] G.L. Gdalevich, N.M. Shutte, Space Research XI. Akademie Verlag, Berlin, 1971. p. 1117.

[8] W.B. Hanson and I.B. Ortenburger, J. Geophys. Res., 66, 1425 /1961/

[9] A. Dalgarno, M.B. McElroy, M.H. Rees and J.G.G. Walker, Planet. Space Sci., 16, 1371 /1968/

[10] P.M. Banks, Ann. de Geophys., 22, 577 /1966/

[11] E.R. Young, D.G. Torr and P.G. Richards, Geophys. Res. Letters, 6, 925 /1979/

[12] J.F. Vickrey, W.E. Schwartz and D.T. Farley, J. Geophys. Res., 84, 7307 /1979/

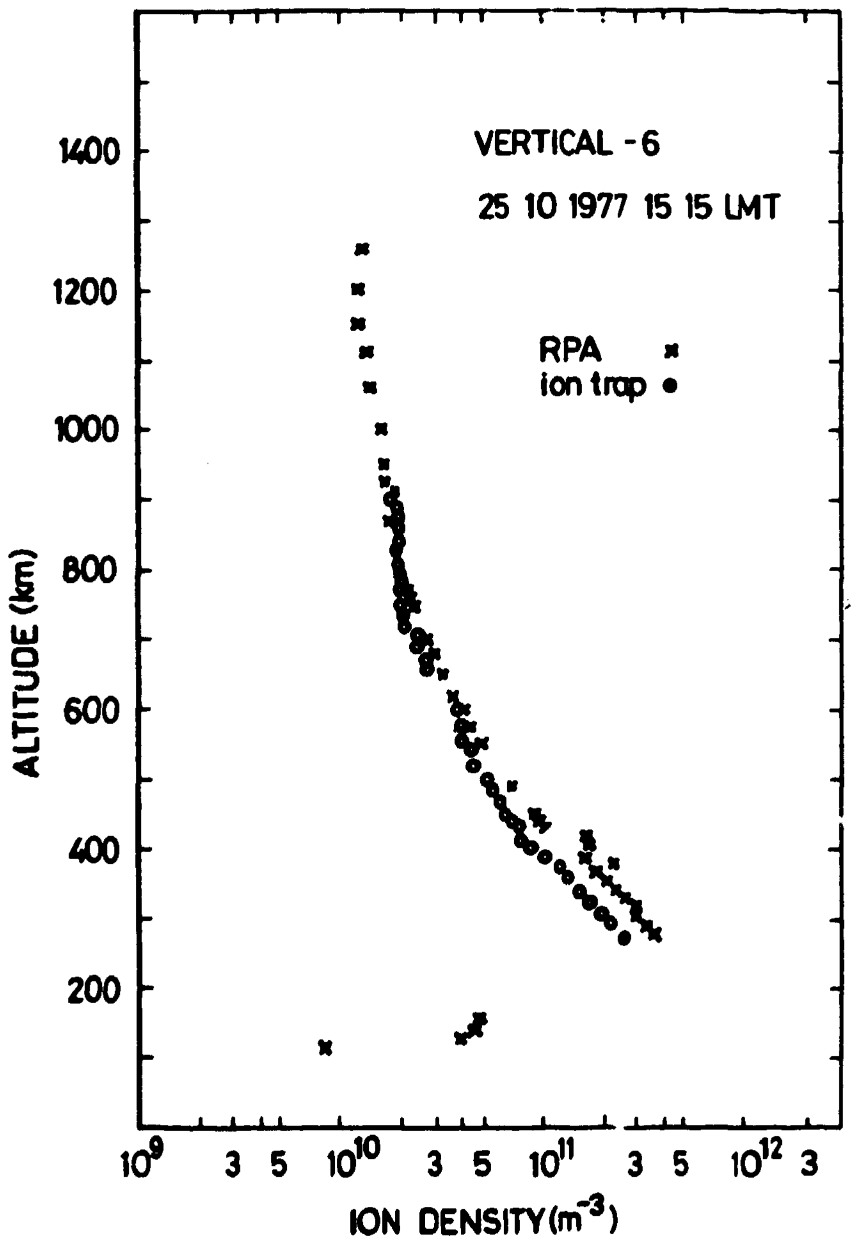

Fig. 1 *Total ion density profile, measured by retarding potential analyzers, flown on the geophysical rocket "Vertical-6". The ion densities, obtained with an ion trap on the rocket [5] are also shown.*

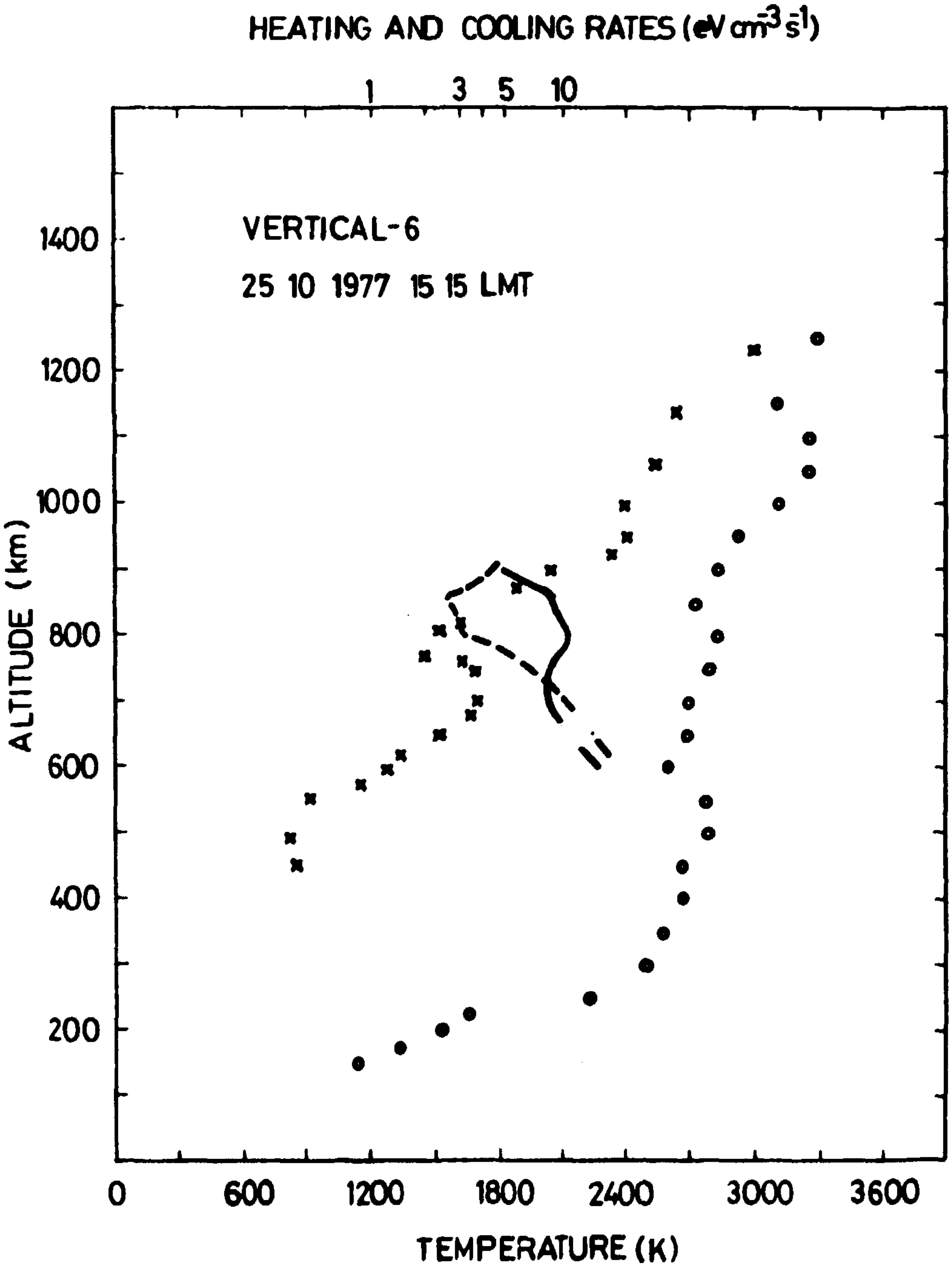

Fig.2 Variation of ion temperature with altitude, determined by means of a retarding potential analyzer, flown on the geophysical rocket "Vertical-6" /crosses/ and the electron temperature profile, taken from [5] /open circles/. The heating rate /solid line/ and cooling rate /dashed line/ of the ion gas are also shown.

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