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COMPREHENSIVE INVESTIGATION OF THE BASIC PARAMETERS OF THE UPPER ATMOSPHERE AT THE TIME OF THE FLIGHT OF THE GEOPHYSICAL ROCKET "VERTICAL-6"

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ABSTRACT

Ion temperature and total ion concentration measured on 25th October 1977 during the flight of the geophysical rocket "Vertical-6" are analyzed. The solar EUV fluxes determined in five wave-length bands with a photoelectron analyzer are also given. The observed anomalous variation of ion temperature between 700 and 900 km and the measured ion concentration can be explained, if the charge exchange reactions $H^+ \rightleftharpoons O^+$ and diffusion are taken into account.

INTRODUCTION

The geophysical rocket "Vertical-6" was launched on 25th October 1977, 15 15 LMT from the midlatitude area of the European part of the USSR for a comprehensive 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°. The rocket was three-axis stabilized with an accuracy of $\pm 3^\circ$. The measurements, the results of which are analyzed here, were carried out by means of five planar retarding potential analyzers (RPA) looking into different directions of space and by a photoelectron analyzer, which allowed the determination of the solar EUV flux in five different wave-length bands [1] . The ion temperature and total ion concentration have been determined from the characteristic curves of the RPA looking vertically upwards, using a multi-parameter curve fitting [2, 3, 4] , as well as from the results 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 during 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($10^{-22}Wm^{-2}Hz^{-1}$), and 0, respectively. The launch time was preceded and followed by a period of low solar activity.

Since rocket experiments reaching altitudes above 500 km and especially those, by which the ion temperature is determined, too, are rare, the results of such measurements are useful both from the point of view of aeronomical studies and the checking of models.

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 values given in Table 1 were obtained. Because of the known limited resolving power of the method comparison of these values with the results of more direct EUV measurements [6, 7] shows that the fluxes given by us for the wave-length bands 60-90, 90-110 and 110-135 nm are in this order 1.4, 2.4 and 0.76 times of the values published in [7] . These data indicate that the input of energy by solar EUV radiation was similar to that found during the flights of Vertical 1 and 2, when the solar radio fluxes at 10,7 cm were 89 and 82 ($10^{-22}Wm^{-2}Hz^{-1}$) respectively. Thus, the agreement noted above proves that during the flight of "Vertical-6" quiet conditions prevailed in the upper atmosphere. At the same time it justifies the use of atmospheric models [8] .

In Fig. 1 the variation of total ion concentration with height is shown. For comparison the total ion concentrations 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. In addition, the electron temperature profile taken from [5] is also plotted. The ion temperature shows values equal to the neutral temperature to an unusually high altitude of about 550 km. It begins to differ from the neutral temperature only above this height, where a relatively steep increase in 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 at about 900 km.

DISCUSSION

The variation of electron temperature with height is affected by the electron (ion) density profile to a height of about 500 km. The decrease of electron (ion) density above the maximum of the F2 layer is reflected by the electron temperature in Fig. 2, as a steep increase at the same altitude, indicating that due to the decrease of electron (ion) density the cooling of the electron gas decreases considerably. A region of almost constant electron temperature is formed [9] , as the ion temperature begins to increase at a height of 550 km due to the heating by the ambient

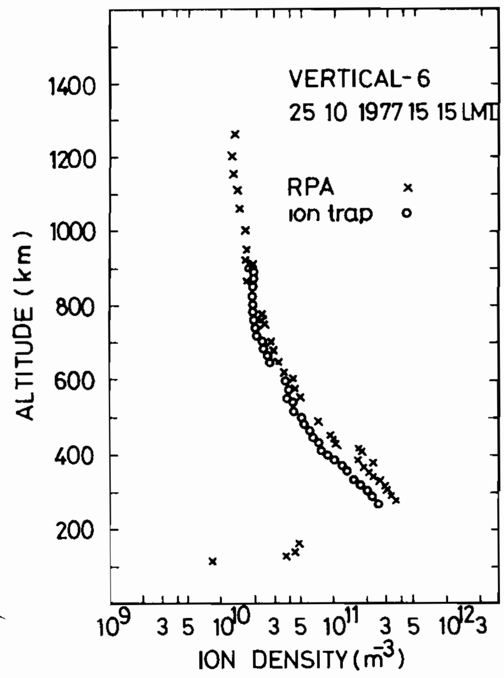

Fig. 1
Total ion density profile, measured by planar retarding potential analyzers and ion densities, obtained with an ion trap and taken from [5] .

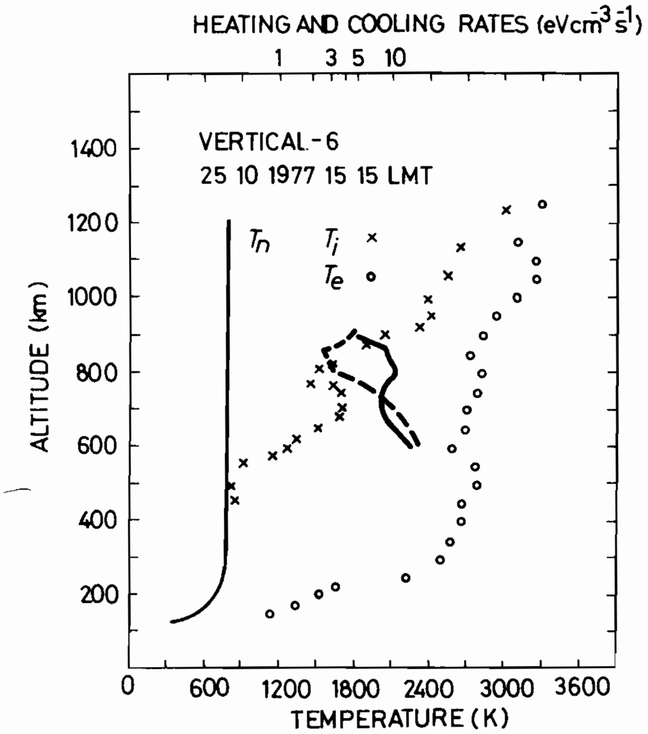

Fig. 2
Variation of ion temperature with altitude, determined by means of a planar retarding potential analyzer (x) and the electron temperature profile, taken from [5] (o) . The heating rate (——) and cooling rate (----) of the ion gas are also shown.

electrons. This process holds, till the steep increase in ion temperature does not cease. Above this region, 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 in the 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 especially anomalous variations between the altitudes of 700 and 1000 km, this region will be discussed in more detail. This region lies just above the critical height [10] , below which chemical processes are dominant and above which diffusion begins to control the distribution of plasma. The ion composition is yet largely determined by the charge exchange reactions $H^+ + O \rightarrow O^+ + H$, and $O^+ + H \rightarrow H^+ + O$ respectively. These reactions can affect the ion temperature, too. It is known [11] 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 [12] . Thus, the heating and cooling of the ion gas also depends on the ratio of the concentration of hydrogen ions to the concentration of oxygen ions. Therefore, in the upper part of 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, consequently the cooling less intense (see steep increase of the ion temperature in Fig. 2) , than in the lower part of this region, where in a small height interval the reverse reaction is prevailing [13] (see ion temperature minimum in Fig. 2). The altitude of transition between the dominant charge exchange reactions may change due to the counterstreaming of O^+ and H^+ ions [13, 14, 15] . It should be noted that in this case the ion composition does not reliably indicate the variation of ion temperature, since the rate coefficient for the reaction $O^+ + O \rightarrow O + O^+$ is comparable to that of the charge transfer $H^+ + O \rightarrow O^+ + H$ [16] . In Fig. 2 the heating and cooling rates, computed according to [11, 12] with the observed total ion 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 900 km increased heating and somewhat decreased cooling take place. This shows that the height region mentioned is a region of non-steady conditions like a transitional zone. (Quasi-adiabatic heating due to plasma compression [17, 18] can also not be excluded, as the RPA measurements indicate strong downward flow of plasma.) Further investigations are needed to clarify the observed features of the ion temperature profile.

REFERENCES

1. N.M. Shutte, in: Proc. Int. Symp. on Physics of the Earth's Ionosphere and Magnetosphere and of the Solar Wind, Inst. Space Res. Acad. Sci. USSR, Geophys. Inst. Slovac. Acad. Sci., Hurbanovo, 1977, p. 263.
2. W. C. Knudsen, J. Geophys. 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. 291 (1979).
6. G. Schmidtke, Geophys. Res. Letters, 3, 573 (1976).
7. L. Heroux and H. E. Hinteregger, J. Geophys. Res. 83, 5305 (1978).
8. CIRA 1972, COSPAR International Reference Atmosphere 1972, Akademie Verlag, Berlin, 1972.
9. G. L. Gdalevich, N.M. Shutte, Space Research XI, 1117 (1971).
10. W. B. Hanson and I. B. Ortenburger, J. Geophys. Res., 66, 1425 (1961).
11. A. Dalgarno, M. B. McElroy, M.H. Rees and J.G.G. Walker, Planet. Space Sci., 16, 1371 (1968).
12. P. M. Banks, Ann. de Geophys., 22, 577 (1966).
13. E. R. Young, D. G. Torr and P. G. Richards, Geophys. Res. Letters, 6, 925 (1979).
14. J. F. Vickrey, W. E. Schwartz and D. T. Farley, J. Geophys. Res., 84, 7307 (1979).
15. G. J. Bailey, R. J. Moffett and J. A. Murphy. Planet. Space Sci., 25, 967 (1977).
16. H. C. Carlson and R. M. Harper, J. Geophys. Res., 82, 1144 (1977).
17. W. B. Hanson, A. J. Nagy and R. J. Moffett, J. Geophys. Res., 78, 751 (1973).
18. H. Rishbeth, T. E. Van Zandt and W. B. Hanson, Planet. Space Sci., 25, 629 (1977).

TABLE 1 Solar EUV Fluxes

wave-length (nm)	< 60	60-90	90-110	110-135	>135
flux (10^{12} photons $m^{-2}s^{-1}$)	53	190	710	4110	3830