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INTERCOSMOS-24: HELIUM ION PREDOMINANCE DURING EQUINOX AT LOW AND MIDDLE LATITUDES IN THE 22nd SOLAR ACTIVITY CYCLE

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ABSTRACT

The paper deals with the results of He^+ measurements using the mass-spectrometer and probe techniques aboard the Intercosmos-24 satellite (IK-24). During the 1991 vernal equinox, the measurements detected stable predominance of helium ions and their high absolute concentration (up to $3.5*10^4$ cm^{-3}) within some ranges of low and middle latitudes in both hemispheres in wide altitude intervals between 700 and 2500 km. It was shown that the He^+ predominance in the night-morning sector depends on the sign of magnetic declination. The effect of dynamic processes on He^+ dominance was confirmed by a large amount of observations.

INTRODUCTION

Nicolet /1/ was the first to suggest that the presence of He^+ in the upper atmosphere is important. Since then a number of papers have pointed to the fact that He^+ were predominant in the ionosphere during the decreasing phase of the 19^{th} solar cycle, see review /2/. During the 20^{th} solar cycle no cases of He^+ predominance were reported. At the maximum of the 21^{st} cycle, the predominance of He^+ was observed both by mass-spectrometer and probe techniques /3/, /4/. Despite the large amount of experimental data on the ion composition of the topside ionosphere, it seems difficult to trace the behaviour of He^+ in all phases of the solar cycle. This paper deals with the results of He^+ measurements using the mass-spectrometer and probe techniques aboard the IK-24 during the vernal equinox of 1991, at the end of the 22^{nd} solar cycle maximum (maximum activity R_z=157.6 in 1989). The results confirm stable domination of helium ions and their relatively high density up to $3.5*10^4$ cm^{-3} within some ranges of low and mid-latitudes in both hemispheres in wide altitude intervals between 700 and 2500 km. Our data refer to the magnetically calm conditions. Paper /5/ describes the instrumentation and main characteristics of the HAM-5 mass-spectrometer (Bennet radio-frequency analyzer) and of the KM-6 probe which contains a flat ion trap (RPA) to measure ion density and temperature. The satellite has a tri-axial orientation, its X-axis is always oriented along the velocity vector, inclination 82°, heights of perigee and apogee are 510 and 2500 km, respectively.

RESULTS AND DISCUSSION

The distribution of main ions O^+, N^+, H^+, He^+ relative to invariant latitude in orbits 6674 and 6675 in the afternoon sector (1540 MLT), 18 Mar 1991, 2125-2224 UT, longitude 267° and Kp = 0, is given in Figure 1. One can see that O^+ is predominant almost along the whole orbit. The behaviour of He^+ displays a strong asymmetry in the density between both hemispheres and a considerable equatorial trough slightly shifted towards the Northern Hemisphere. The asymmetry can be only partly explained by the change of altitude. The He^+ density reaches its maximum of $1.5*10^4$ cm^{-3} at -13^o and dominates up to $\sim-30^o$ invariant latitude (INL). The conditions for predominant He^+ in the afternoon sector at American longitudes are mainly defined by O^+ behaviour. The O^+ density decreases in the INL region within -10^o to -30^o. The particular ion density variations in the region of these longitudes are in good agreement with the conclusions drawn in /6/ which notes neutral wind

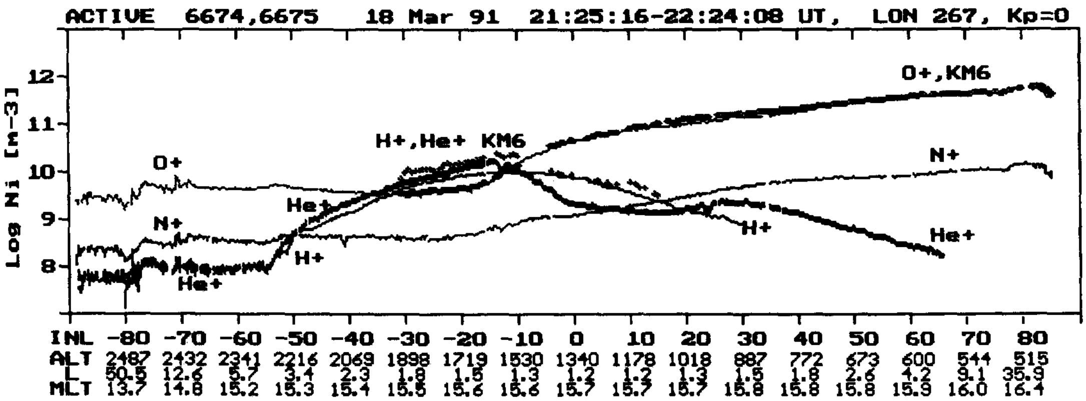

Fig.1. Concentration of major ions, measured by the HAM-5 and KM-6 along orbits 6674 and 6675 in daytime. INL-invariant latitude (degrees), ALT-altitude (km), L-McIlwain parameter, MLT-magnetic local time (hours).

effects on the ion composition. At equinox, horizontal neutral winds are strongly asymmetric with respect to the geomagnetic equator. Hence a downward drift component drives the ionospheric plasma to lower altitudes (where the recombination rate increases) to a larger extent in the Southern Hemisphere than in the Northern Hemisphere. Cases of He^+ domination in the afternoon sector were observed only in the Southern Hemisphere for a narrow longitude interval from 245^o to 290^o, and only in a short time period from 7 to 18 Mar 1991, for local times from 1540 to 1644 MLT. Figure 1 shows the He^+ predominance over other ions by a factor of 1.6. In these cases, the altitudes ranged from 1500 to 2100 km, the INL ranges were from -5^o to -30^o.

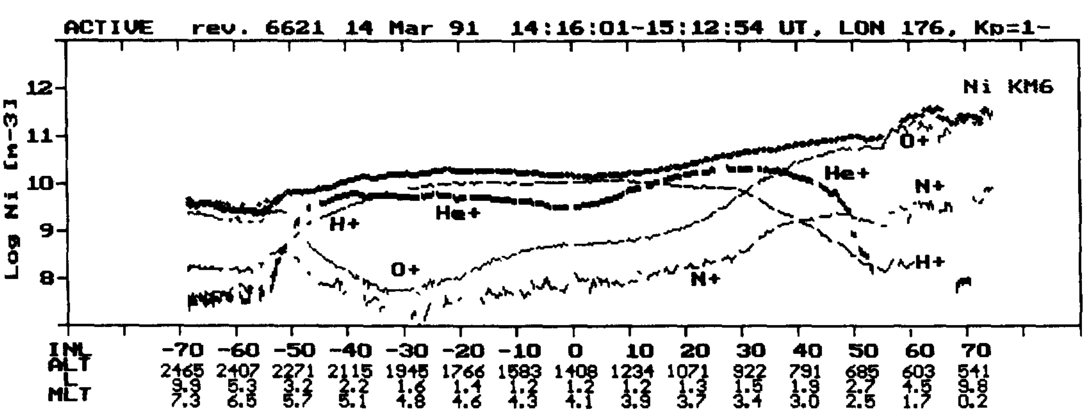

Fig. 2. Concentration of major ions and total ion density measured by the HAM-5 and KM-6 along orbit 6621 after midnight. Abbreviations as in Fig.1

The distribution of the main ions O^+, N^+, H^+, He^+ for the night-morning sector 0414 MLT, 14 Mar 1991, is shown in Figure 2. Again, the He^+ behaviour is asymmetric with respect to the INL equator and displays a considerable equatorial trough. The He^+ density reaches its maximum value of $2.7*10^4$ cm^{-3} at 30^o invariant latitude. The highest excess of He^+ over other components is 2.5. As opposed to the afternoon sector, He^+ predominance regions can be seen in both hemispheres. Figure 2 is typical for the behaviour of He^+ in many other orbits, but there are some differences between them. He^+ dominates either in one or in both hemispheres; latitudes, altitudes and longitudes of He^+ domination differ, the values of its domination are different. For the night-morning sector the possibility of He^+ predominance is also determined by the O^+ behaviour. The O^+ behaviour has been analysed for night and daytime conditions and indicates that night conditions are more appropriate for the dominance of He^+. The altitudes of He^+ predominance in this sector range from 700 to 2500 km. The latitude region is also large enough - from about 5° up to the light ion trough in both hemispheres. Unlike in the afternoon sector, in the night-morning sector the He^+ domination occurs over a large range of longitudes.

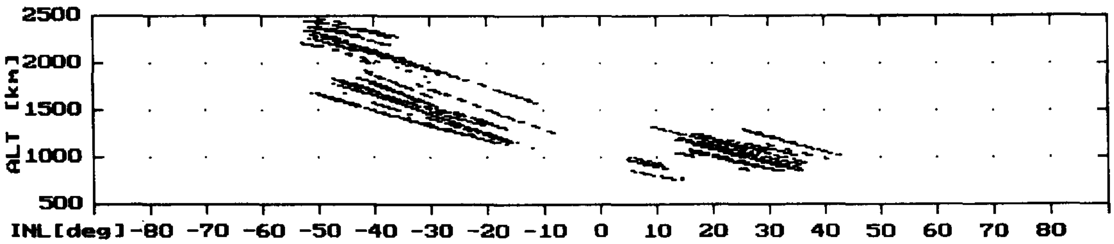

Fig. 3. A map of altitude-invariant latitude regions with predominance of He^+ according to the HAM-5 data for the night-morning sector (40 orbits).

He^+ domination was not observed on the INL equator. This is clearly seen in Figure 3 which gives a map of altitude-latitude regions with predominant He^+ for the night-morning sector according to the mass-spectrometer measurements. The map presents parts of 40 orbits where He^+ became dominant. The phenomenon of He^+ domination from RPA results aboard the DE-2 satellite was analyzed in paper /4/. According to /4/, the composition of the neutral atmosphere and the photoionization rates during high solar activity are responsible for the formation of the He^+ layer. This phenomenon also depends on neutral winds and the **ExB** drift. The experimental results of DE-2 relate to 900 km altitude and 2200 local time. In our case, the predominance of He^+ at night was observed in a considerably larger altitude range and at different local times.

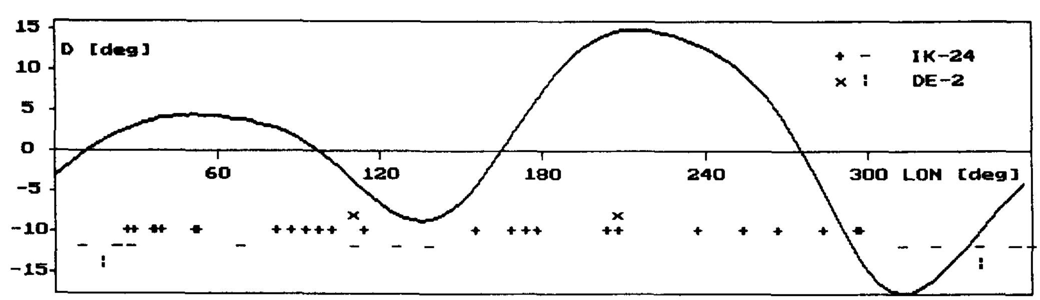

Fig. 4. The He^+ domination regions depending on the geomagnetic declination at 35° of invariant latitude for different geographic longitudes.

The influence of magnetic declination, i.e. of dynamic processes, is depicted in Figure 4, showing the presence/absence of He^+ dominance and the value of the magnetic declination. The orbits with a dominance of He^+ are designated +, those without dominance -. This graph also includes the data from /4/, the designation of orbits with/without dominance of He^+ being x and ¦, respectively. This figure shows the important role of the dynamic processes connected with neutral winds for the domination of He^+. Since our results indicate the correlation between the phenomenon of He^+ dominance and the sign of declination for the late night sector, we suppose the eastward zonal wind component large enough to move the O^+ layer downward into the region of enhanced recombination rates for this MLT sector.

CONCLUSIONS

The paper presents the results of He^+ measurements using two independent methods - mass-spectrometer and RPA on board of the IK-24 satellite. The absolute predominance of helium ions in a wide longitude -altitude -latitude range during equinox was demonstrated for the first time with the help of direct measurements using the mass-spectrometer technique. The results for the vernal equinox of 1991 at the end of the 3-year period of the 22nd solar cycle maximum point to stable domination of helium ions and their high absolute concentration, up to $3.5*10^4$ cm^{-3}, at low and middle latitudes in both hemispheres in specific longitude ranges and within a large altitude region. He^+ dominance in the afternoon sector was observed only in the Southern Hemisphere for a narrow longitude sector from 245° to 290° and only in a short time period 7 to 18 Mar 1991, for local times from 1540 to 1644 MLT. The He^+ predominance over other ions reached the value of 1.6. For these cases, the altitudes were from 1500 to 2100 km, and the INL from -5° to -30°. In the night-morning sector, the dominance of He^+ is more frequent and was observed in both hemispheres. For the Northern Hemisphere the ranges of INL are from 4° to the light ion trough, altitudes from 700 to 1300 km, while for the Southern Hemisphere the INL ranges from -8° to the light ion trough and the altitudes from 1000 to 2500 km. The domination of He^+ occurs in a large longitude region. In this local time sector, the domination of He^+ over other ions increases to 3. The paper gives a map of the altitude-latitude distribution of dominating He^+ in the form of orbit tracks. The He^+ dominance is the result of a number of factors (neutral composition, temperatures of neutral and ionized components, dynamic processes). Our results show that the conditions for He^+ dominance are more appropriate during the maximum of solar activity, when the He^+ density is increased relatively to the H^+ density for higher altitudes (see / 7/) and for O^+ density decreasing in some space-time regions by transport processes. The sign of magnetic declination was shown to be very important for the He^+ dominance in the period of equinox for high solar activity. For the Northern Hemisphere and night-morning sector, we have found: a) for positive declination, the downward transport of bulk ionosphere plasma is strong enough to support He^+ dominance due to the increase of recombination rates at lower altitudes, b) inversely, negative declination acts as an important masking factor of He^+ dominance.

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