The oxygen-helium ion transition level during low solar activity: I. Comparison of AE-C satellite data with IRI model calculations

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Abstract. The latitudinal, longitudinal, diurnal and seasonal variations of the O^+ - He^+ ion transition level during low solar activity are analysed using *in-situ* ion density measurements from the Atmosphere Explorer - C satellite. The results are compared with the International Reference Ionosphere model calculations.

Keywords: transition level, satellite measurements, empirical modelling

1. Introduction

The X-Y ion transition height (level) is defined as the height, where the ion gas is composed of equal parts of two ion species X and Y; below this height X dominates over Y, above the height - Y dominates over X.

The transition heights are characteristic parameters of the ionospheric plasma. Therefore, the knowledge of these heights is helpful for a better understanding of the underlying chemical and transport processes, ionospheric storms, ion composition, etc. They are also important for the ion composition modelling, construction and verification of ionospheric models by serving as reference points (Booker, 1977; Bilitza, 1991). For example, when constructing the O+ density profile, the profile can be divided into altitude sections and the O^+- H^+ (or O^+- He^+) transition level can be used as a boundary between the top two sections. If the transition level is known in advance, the profile could be tied to this reference point, which would increase the model accuracy.

The ion composition demonstrates great variability especially in the outer ionosphere due to numerous factors (Banks, 1973; Chandler and Chappell, 1986; Waite et al., 1984; Anderson, 1973; Brinton et al., 1970; Taylor, 1972; Heelis et al., 1990; Gonzales et al., 1992). The factors affecting the transition heights are: *chemical processes* (resulting in ion production and loss), *plasma diffusion* (dominating the topside ionosphere, thermal difussion, inter-hemispheric flow, ion-ion drag, etc.), *electromagnetic* (**E**×**B**) *drift* (generated by the equatorial electric field and affecting the equatorial and low-latitude ionosphere), *neutral winds* (caused by pressure gradients in the neutral atmosphere and having a strong influence on the ion global distribution through the neutral-ion drag), *main trough* (explained with the change of circulation patterns between the plasmasphere and the magnetosphere), *light-ion trough* (explained by the rapid increase in the inclination of the magnetic field lines at high latitudes), etc.

In the upper ionosphere, where the basic ions are O^+, H^+, and He^+, there are two upper transition heights of interest - the oxygen-hydrogen (O^+- H^+) and the oxygen-helium (O^+- He^+) ion transition heights.

The O^+- H^+ level has been already investigated -- by means of satellite and ground based observations -- in a number of studies (Brinton *et al.*, 1970; Miyazaki, 1979; Kutiev *et al.*, 1980; Triskova *et al.*, 1998). Empirical models of this level have been also developed (Titheridge, 1976; Miyazaki, 1979; Kutiev *et al.*, 1984; Danilov and Yaichnikov, 1985; Kutiev *et al.* , 1994).

Being usually a minor constituent of the ionosphere, the He^+ ion is quite often neglected; its small values, great variability under different conditions, and insufficient measurements make studies very difficult. Much theoretical and modelling effort is required to draw proper conclusions about its behaviour (Hanson, 1962; Bauer, 1966; Taylor et al., 1970; Moffett and Hanson, 1973; Naghmoosh and Murphy, 1983; Newberry *et al*., 1989; Bailey and Sellek, 1990). There are evidences that the He^+ density may become comparable with the H^+ density, and even to dominate both H^+ and O^+ during high solar activity (Quegan *et al*., 1984; Heelis *et al*., 1990). Therefore, the He+ ion is important and should be considered for a unified picture of the topside ionosphere.

The purpose of this work is to provide more details of the He^+ behaviour during low solar activity, to derive the O^+- He^+ transition height and to analyze its variations with respect to latitude, longitude, and season, during both day and night. The results are compared with IRI calculations of the transition height. This will help the development of a new O^+- He^+ transition height model for low solar activity conditions which will be presented in another publication.

2. AE-C satellite data base

The Atmosphere Explorer - C satellite was launched on 13/12/1973 in an elliptical orbit (inclination 68.1°) collecting a large data base of ionospheric and thermospheric densities, temperatures, winds, and emissions within the altitude range of 130 - 4300 km. After the first eight months, the mode was changed and the spacecraft was kept in a circular orbit for the rest of its lifetime (re-entry date 12/12/1978): from March 1975 to December 1976 at about 300 km height, and from December 1976 to December 1978 at about 400 km height.

The O^+ and He^+ ion density data used here are obtained during the first 16 months of the AE-C mission, i.e. from 16/12/1973 to 21/3/1975 when the solar activity was low. The measurements are from a Bennett ion-mass spectrometer (Bennett, 1950; Brinton *et al*., 1973) and a Magnetic ion-mass spectrometer (Hoffman *et al*., 1973). The noon conditions are depicted by data collected within the 9:00-15:00 LT window while the midnight conditions are limited to the 21:00 - 3:00 LT window. Three seasons are considered - winter, equinox, and summer, defined as 91 day periods centred on the 356, 81 and 264, 173 day of year respectively. The periods and the corresponding F10.7 values are provided in the following Table 1.

Season (North)	**Period** (days of year)	**F10.7** (averaged)	**Standard deviation**
Summer	128 - 218 . 1974	90.20	11.73
Equinox	36 - 126 . 1974 219 - 309 . 1974 36 - 80 . 1975	84.48	14.47
Winter	350 - 365 .1973 1- 36 . 1974 311 - 365 . 1974 1 - 36 . 1975	80.18	8.18

Table 1. Definition of seasons with the corresponding average values of F10.7

During north summer the solar activity is slightly higher (F10.7 = 90.2). Considering that the data from the Northern and Southern hemispheres are averaged, it is reasonable to accept that the average solar activity for the whole period covered in this study is F10.7 ≈ 85. The equinox data set is large, thus compensating for the worse standard deviation.

3. Analysis of the O^+- He^+ transition level behaviour using AE-C data

There are two basic approaches used here to analyse the spatial, temporal and seasonal behaviour of the transition level -- by directly measuring the level and by using the averaged altitude profiles of the O^+ and He^+ ion densities.

3.1 Direct measurement of the O^+- He^+ transition level

A *direct measurement* of the transition height is defined as an encounter of a longitude, latitude and height where the O^+ and He^+ ion densities are equal. Practically, the O^+ and He^+ densities are never equal, hence the term 'equal' will mean that the difference between the ion densities is smaller than *a priori* given tolerance $\varepsilon_{dens} = | n(O^+) - n(He^+) | / n(O^+)$. Accepting tolerance $\varepsilon_{dens} = 0.01$ (i.e. relative error of less than 1%), the direct measurements of the transition level performed by AE-C satellite are given in Fig.1 (latitudinal variations) and Fig.2 (longitudinal variations). The data is polinomially approximated and presented for the three seasons defined above - winter(solid line), equinox(long dashes), summer (short dashes). To indicate how much significance should be attached to the values obtained from direct measurements, 'error bars' are also provided. The horizontal bar indicates the average transition height for the corresponding 10°-wide latitude band (Fig.1) and 60°-wide longitude section (Fig.2). The vertical bar indicates the standard deviation for the average value.

Latitudinal variations

The day-time values are provided on the top panel of Fig.1, where encounters below 350 km and above 4000 km are not considered.. During winter the level starts around 3000 km in the equatorial region and after some rise at middle latitudes, falls sharply below 2800 km in the 50-60° latitude band. The equinox values follow the opposite trend - starting from 1000 km at the equator the level is constantly rising up to above 3700 km at high latitudes (50-60°). There are no transition-height encounters during summer, which can be explained with the extremely high altitude (above 4000 km) of the transition region and/or small densities of one or both of the ion species.

The night-time transition level (Fig.1, bottom panel) is much better observed by the satellite - the direct encounters of the level are plentiful in the low and middle latitude sections. Generally, there is a peak at the equator, biggest during summer, a broad depression zone at middle latitudes, and an increase at high latitudes. The highest levels are again observed during summer, the lowest -

during winter. A small difference is observed between the winter and equinox values at middle latitudes. No encounters are detected in the equatorial region during winter and in the high-latitude region during winter and summer; this is explained with the satellite evolution leaving the transition height below the orbit.

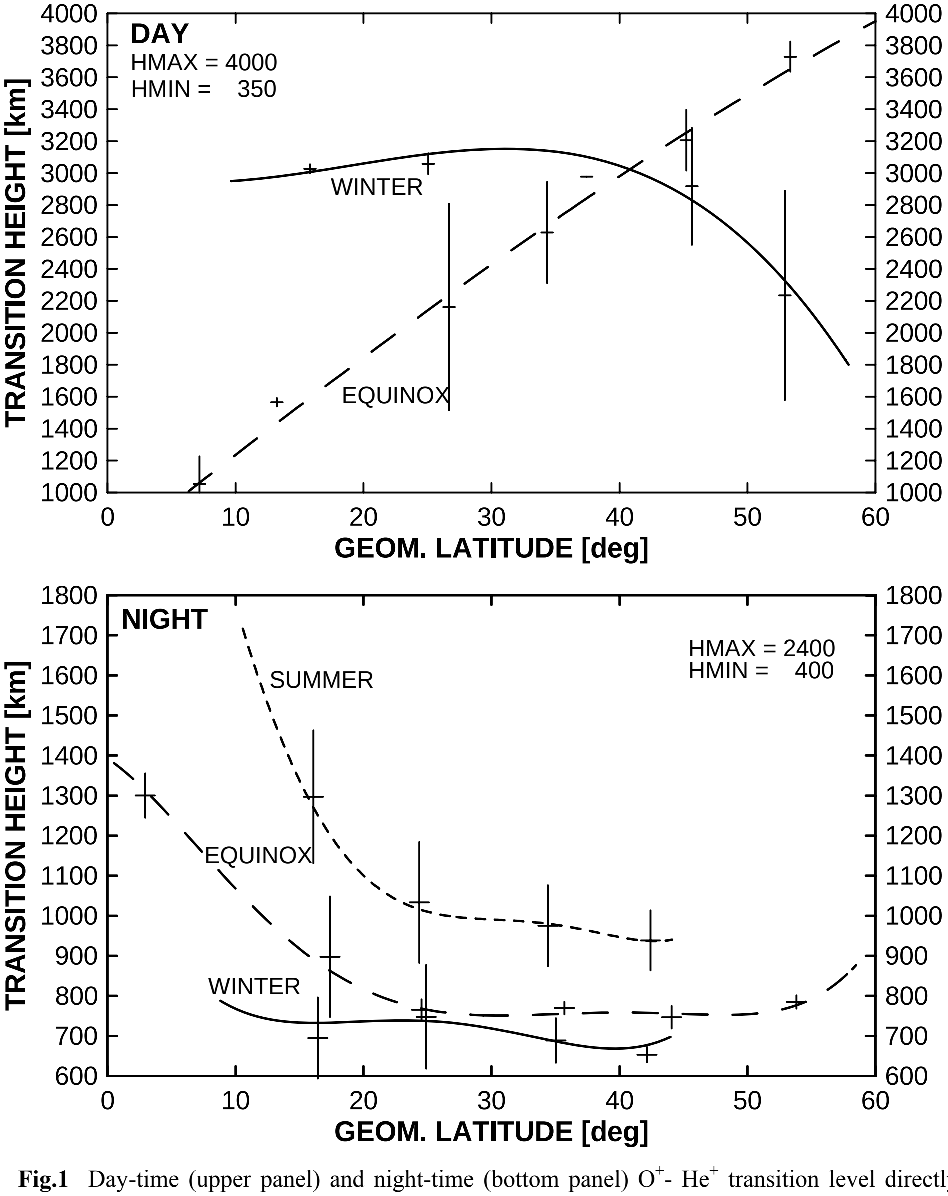

Fig.1 Day-time (upper panel) and night-time (bottom panel) O^+- He^+ transition level directly detected by AE-C. HMIN and HMAX indicate the height limits over which the data were taken. The density tolerance is $\varepsilon_{dens} = 0.01$. The crosses indicate the standard deviations (vertical bars) and the average values (horizontal bars) of the level for each (10°-wide) latitude section.

Longitudinal variations

In order to analyse the longitudinal behaviour of the O^+- He^+ transition level, the AE-C data (ε_{dens} = 0.01) from the equatorial (0-15°), middle (15-50°) and high (50-60°) latitude bands were binned according to season and local time. Comparatively rich measurements of the level exist for the night-time conditions. The available measurements in the equatorial and high-latitude region are insufficient to derive information about the longitudinal variations - the data is scarce in the equatorial region and in the high-latitude band the data scattering is very large - 1000 km and more. The middle latitudes are best represented by direct encounters (Fig.2). There, the transition level shows similar patterns for all seasons. During winter, a broad minimum is observed in the Pacific sector (between 120°E and 240°E), where the level falls below the 700 km mark. In the other longitude sectors the level increases to values of 900-950 km which are well above the equinox values for these longitudes. During equinox, there is a minimum again (700 km), this time observed around 270°E longitude. Highest values for the level are observed during summer at all longitudes - it varies between 900 km (at 280°E) and 1200 km (at 90°E). The minimum moves eastward from winter to summer, which is due to the helium ion depletion in these regions.

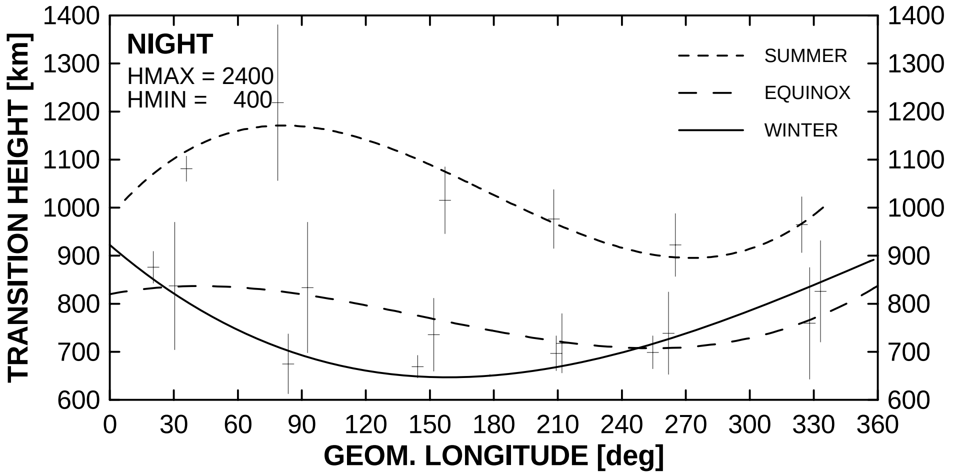

Fig.2 Longitudinal variations of the night-time O^+- He^+ transition level at middle latitudes (15-50°) as directly measured by AE-C. HMIN and HMAX indicate the height limits over which the data were taken. The density tolerance is $\boldsymbol{\varepsilon}_{dens}$ = 0.01. The crosses indicate the standard deviations (vertical bars) and the average values (horizontal bars) of the level for each (60°-wide) longitude section.

The longitudinal variations of the ion composition is still not well investigated. Theoretically, quite a few factors could play significant role in forming the longitudinal behaviour - the geomagnetic field declination, neutral winds, electromagnetic drift, substantial differences in the ion temperature at different longitudes (Sanatani and Breig, 1984), etc.

3.2 Averaged ion density profiles

For a study of this nature, it would seem that all transition heights should be determined by direct measurement; using averaged altitude profiles of the ion concentrations would seem incorrect with so much variability in the profiles. However, there are circumstances when the 'averaged profile' method can be very useful. First, sometimes there are no data from direct measurements, for example during day-time summer. In this case, approximate values of the transition level can be derived using the bottom part of the ion density profiles. Second, there are also cases when using only direct measurements could lead to arguable results (for one reason or another). For example, during daytime winter at high latitudes the direct measurements show a sharp decrease in the transition level while the profile method suggests that the level is increasing. Considering that there is plenty of composition data during daytime winter, using the ion density profiles to obtain the transition level would be more reliable.

The ion composition data are presented as altitude profiles of the O^+ and He^+ ion densities for noon and midnight conditions, six magnetic latitude ranges, and three seasons. Each symbol represents an average over 20 km altitude. No less than three measurements are considered for the averaging procedure; this condition leads to averaging over greater distance. In some cases during winter and summer, particularly at higher altitudes above 600 km, the averaging is over 50 km. To analyse the latitudinal behaviour the data from all longitudes are sorted into six magnetic latitude bands 0-10^o, 10-20^o, ... , 50-60^o . The data from the corresponding latitude bands in the Northern and Southern hemispheres are averaged together taking into account the opposite seasons in these hemispheres. The averaged altitude profiles of the O^+ and He^+ ion densities are given below in Fig.3 (winter), Fig.4 (equinox) and Fig.5 (summer). Each panel represents one of the above latitude bands. The night-time values are presented with the symbols ▲ (closed triangle) for He^+ and • (closed circle) for O^+ ions. The day-time averages are Δ (open triangle) for He^+ and o (open circle) for O^+ ions.

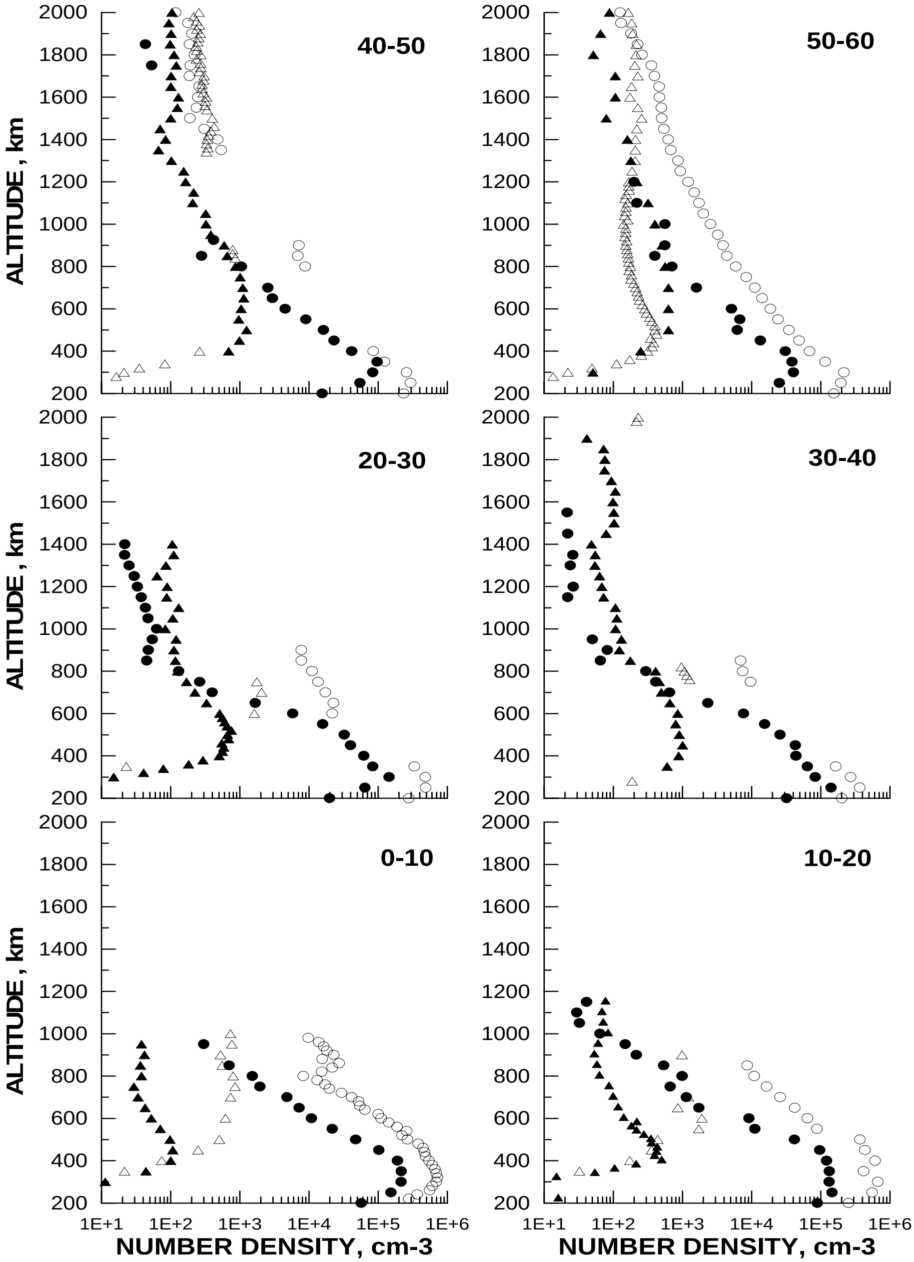

Fig.3 *Winter* altitude profiles of the O$^+$ (o - day-time, • - night-time) and He$^+$ (Δ - day-time, ▲ - night-time) ion densities as measured by AE-C.

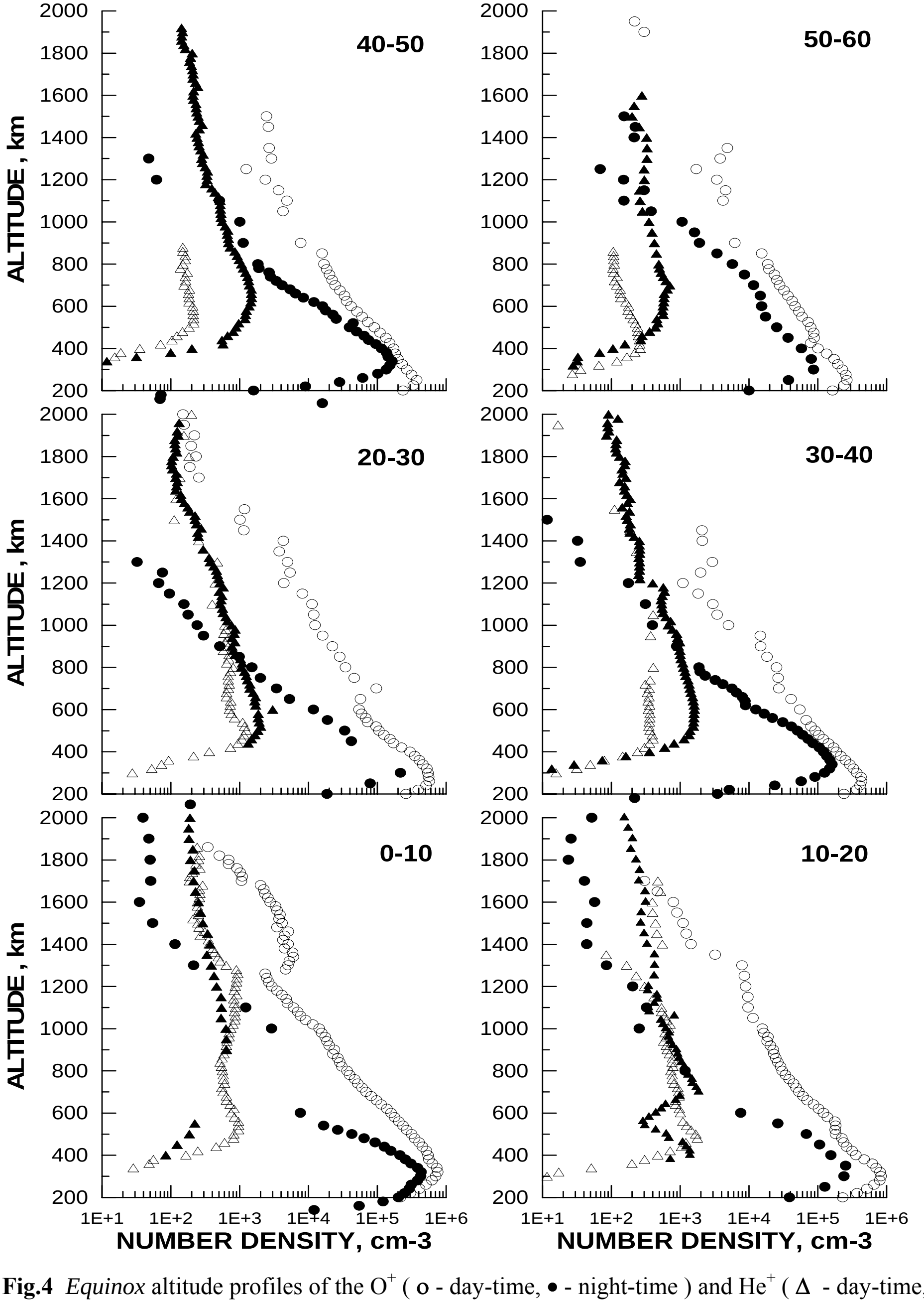

Fig.4 *Equinox* altitude profiles of the O^+ (o - day-time, • - night-time) and He^+ (Δ - day-time, ▲ - night-time) ion densities as measured by AE-C.

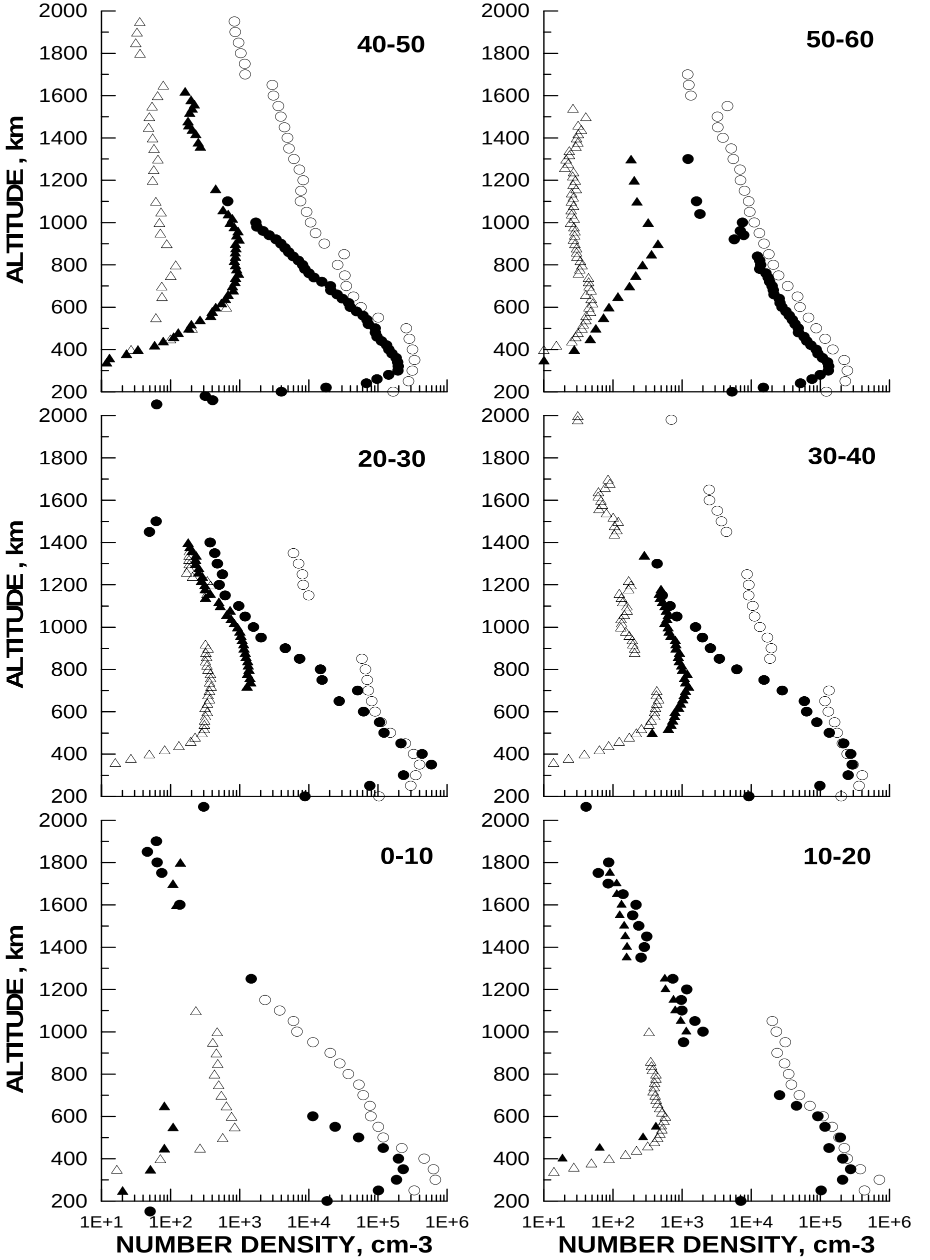

Fig.5 *Summer* altitude profiles of the O^+ (o - day-time, • - night-time) and He^+ (Δ - day-time, ▲ - night-time) ion densities as measured by AE-C.

The Atmosphere Explorer - C offers a relatively good altitude range of measurements for a study of the ion composition (Craven et al., 1995) and transition levels in particular. However, due to the satellite evolution, there are altitude regions where no measurements are carried out, or are not reliable. This fact concerns in particular the equatorial region during daytime winter and summer at higher altitudes. In these regions, extrapolation over the averaged profiles is applied by using the scale height for each of the ion species. Diffusive equilibrium conditions are assumed and the altitude distribution of the ion density is given by:

$$n_i(h) = n_i\left(h_b\right)\exp\left\{-\left(h-h_b\right)/H_i\right\}$$

where h is the altitude, h_b is the base altitude and H_i is the plasma scale height. The diffusive equilibrium assumption is a strong and limiting condition for the altitude distribution of the ion concentrations and all calculation should be done with maximum precaution because the solution may not be unique (Hanson, 1962; Bauer, 1969). However, in this case, the base altitude is well above 600 km, there are additional measurements of the temperatures, temperature gradients, neutral densities, etc., which are consistent (made under same conditions) with the ion densities. In addition, other important profile parameters such as the peak density NmF2, the peak height, hmF2, and the O^+- H^+ transition height are also available and used.

Latitudinal variations: day-time conditions

The latitudinal variability of the O^+- He^+ transition level reflects the latitudinal behaviour of the corresponding O^+ and He^+ ion density profiles. Two characteristics of each profile will be considered - the peak density and the profile gradient above the peak. Day-time, the O^+ density profiles show similar latitudinal variations during all seasons (Fig.3). The F2 peak density is largest at the equator and decreases gradually toward the poles. The minimum at 50-60^o latitudes is in the interval 2.8 - 3.0 $\times10^5$ cm^{-3} , almost half the value at low latitudes. All O^+ profiles become steeper at higher latitudes. The He^+ density distribution also experiences major latitude changes, particularly in the lower part - from the helium ion peak , at 500-600 km, to about 1400-1600 km height. The densities decrease in poleward direction. The decrease is stronger during equinox and summer; in summer (Fig. 5) the He^+ density peak (observed at 600 km) in the 50 - 60^o band is 15 times smaller than the equatorial value. The main reason for the low levels at high latitudes is the light - ion through observed under conditions in which the O^+ ion densities exhibit little or no simultaneous decrease, thus having the effect of raising the transition level in the 50-60° band. An interesting phenomenon is observed at these latitudes during all seasons, particularly during winter, when the vertical distribution is well presented in the whole 300-3000 km altitude range. It shows a strong upward flux and a thermal diffusion effect, leading to a decay in the 600-1200 km region.

How the described changes in the ion profiles affect the transition level? In general, the level starts from low values at the equator, increases gradually throughout low and middle latitudes, and reaches its maximum at 50-60° latitudes. During winter, the level begins from 1250 km and increases to about 1800 km. The equinox values are higher - starting from 1700 km and going up to 2400 km. Highest values are obtained for summer conditions; because of the steep summer O^+ profile (due to high temperatures) the transition level is not detected by the satellite. The values of the O^+-He^+ transition level, as obtained from the averaged density profiles, are summarised in the following Table 2 and cover the latitude range 0-60° and the three seasons.

DAY	0-10°	10-20°	20-30°	30-40°	40-50°	50-60°
summer	2400 *ext*	2800 *ext*	3000 *ext*	3000 *ext*	3300 *ext*	3400 *ext*
equinox	1700 *int*	1700	1850	2000 *ext*	2200 *ext*	2400 *ext*
winter	1225 *ext*	1250 *ext*	1300 *ext*	1350 *int*	1500	1750

Table 2. The day-time O^+- He^+ transition level, [km]. The extrapolated values are denoted by '*ext*' , the interpolated values - by ' *int* ' .

While at high latitudes during winter and at low latitudes during equinox the level was easily derived from the O^+ and He^+ profiles, in all other cases it was obtained after extrapolation (or interpolation) of the ion distribution. In the table, the extrapolated values are denoted by '*ext*' and the interpolated - by '*int*'. Obviously, the highest errors are expected for summer conditions when all values were calculated using extrapolation; the calculations suggest that the transition level should be expected at altitudes between 2400 and 3400 km but more data and research are required for a precise result.

Latitudinal variations: night-time conditions

In the night-time, due to lack of photo-ionisation and lower temperatures, the O^+ density is significantly lower than the observed daytime density. The peak density, maintained by the equatorward neutral winds, is at higher altitudes and gradually decreases through middle and high latitudes. Above the peak height, during all seasons, the concentrations decrease rapidly with altitude. The decrease of $n(O^+)$ is strong at the equator because of the depressing effect of the downward electrodynamic drift. The upper part of the profile becomes steeper at higher latitudes. It is clearly observed during equinox and summer; the winter values do not change significantly.

The night-time behaviour of He^+ is different. During all seasons, the light ion densities at altitudes 400-1600 km are generally higher than the daytime values (see Fig. 3, 4, and 5) because of the downward fluxes. An exception is the equatorial region, where the depletion in n(He^+) is so strong that the peak He^+ densities do not exceed 1×10^2 cm^{-3}, almost 20 times smaller during winter and summer. The concentration is almost constant above 700-800 km. The explanation is the downward **E**×**B** drift during night combined with the strong connection between the O^+ and He^+ ions through collisions (Moffett and Hanson, 1973; Heelis *et al.*, 1990). Outside the equatorial region, the helium ion density increases with latitude, although not so pronounced as during day.

The values of the O^+-He^+ transition level, as obtained from the averaged density profiles, are provided in Table 3 covering again the latitude range 0-60° and all three seasons.

NIGHT	0-10°	10-20°	20-30°	30-40°	40-50°	50-60°
summer	1200 *int*	1050	1100	1200	1200	1400 *ext*
equinox	1050	850	850	900	950	1100
winter	1100 *ext*	1000	850	800	850	950

Table 3. The night-time O^+- He^+ transition level, [km]. The extrapolated values are denoted by '*ext* ' , the interpolated values - by ' *int* ' .

There are two important features in the O^+- He^+ transition level's latitudinal behaviour - the equatorial and the high-latitude rises. The persistence of the equatorial rise during all seasons should be mentioned. It is caused by the pronounced equatorial trough in the He^+ density, in which n(He^+) decreases by as much as to a factor of 6, relative to the middle-latitude densities. This is well observed during winter from the average profiles presented in Fig.3. Other ion composition studies (e.g. Taylor et al., 1990) also prove the existence of such equatorial trough. The high latitude light-ion trough (being a typical night-time phenomenon) and the steeper O^+ profiles, are also pushing the transition height up in the (40-50°) and (50-60°) latitude bands.

The night-time transition levels derived from the averaged profiles tend to overestimate the values detected directly by the satellite by 10-15% at middle latitudes and more (15-20%) at higher latitudes, which is not surprising and is due to the nature of averaging the densities over altitude. On the contrary, the direct encounters of the level above the equator (during summer and equinox) are higher than the 'profile' values.

The 'averaged profile' method proves to be efficient when analysing the transition level behaviour. However, many factors of physical nature can impede such analysis - the topside ionosphere is dominated by complex processes. In the equatorial region, the **E**×**B** drift is a major force transporting the ionisation vertically across the magnetic field lines. On the other hand, the gravitational and pressure gradient forces move plasma downward along the field lines, thus forming the equatorial anomaly. The drift's longitudinal/diurnal variations lead to pronounced latitudinal excursions of the anomaly. Also, the Northern and Southern ionisation crests are generally not equal, due to the magnetic field inclination and inter-hemispheric neutral winds.

4. IRI model calculations of the O^+- He^+ transition level

The International Reference Ionosphere (Bilitza *et al*., 1993), is a joint project of URSI and COSPAR with the purpose of developing a reliable global representation of the electron concentrations, atomic and molecular ion concentrations, ion composition and temperatures in the Earth's ionosphere. The IRI is regarded as the most advanced ionospheric empirical model to date, embodying results of a long-span research. Currently, the ion composition is constructed on the base of rocket, satellite, and ground-based observations. It provides altitude density distribution of the five most important ion species - N_2^+, O_2^+, O^+, H^+, He^+ as a percentage of the total ion / electron density in the altitude region 60-3000 km.

Using the latest version, IRI-95, the O^+- He^+ transition height is calculated for conditions closely matching those during the AE-C satellite mission. There are two options that are available for the ion composition: IRI-86 (original) and Danilov-95.

The original option (IRI-86 ion composition model) does not offer seasonal and longitudinal variations of the transition level, which is in sharp contrast with the observations. It distinguishes only day and night conditions changed at the local sunrise and sunset (Fig.6). In respect to latitude, the model height has a broad constant minimum at the equator, displaced towards the North direction to about 40^{o}N, and two equal maxima at the high latitudes. When averaging the values from the corresponding latitude bands of the Northern and Southern hemispheres, the result is a step-wise function, with lowest values in the equatorial region (0-20°), higher values at 20-40°, and highest at 40-60°

geomagnetic latitudes. Considering the mentioned shortcomings, the original option cannot be used when modelling the O^+- He^+ transition level.

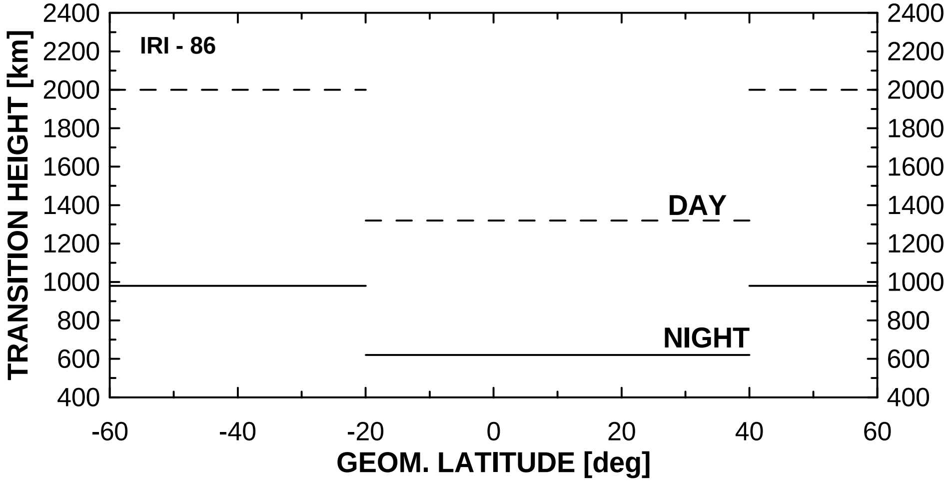

Fig.6 The O^+- He^+ transition level as calculated by the IRI using IRI-86 (original) ion composition model for day-time (dashed line) and night-time (solid line) conditions.

The other option, Danilov-95 ion composition model (Danilov and Yaichnikov, 1985), has been adopted first in IRI-90 and, after further development, in IRI-95. Firmly based on rocket and satellite measurements, the Danilov-95 model is the alternate choice in IRI-95 that offers better latitudinal, longitudinal and seasonal variations. The IRI-95 (Danilov-95 option) has been run for summer and winter solstices and equinox (vernal and autumn combined) conditions, and the averaged results are presented in Fig.7.

During day-time (Fig.7, top panel), the equinox and winter levels demonstrate similar changes - there is a maximum at the equator and two minima at high latitudes. The equinox values show very small latitudinal variations. The summer day-time behaviour is quite different from the other seasons - there is a minimum at the equator and two maxima at high latitudes. It is worth mentioning, that the equatorial values during summer are lower than the equatorial values.

During night-time (Fig.7, bottom panel), the level is modelled in a similar manner for all seasons - a minimum at the equator, elsewhere the level constantly increasing in poleward direction. The values from the Southern hemisphere are about 5% higher than their counterparts from the Northern hemisphere. At equatorial latitudes, the model offers insignificant seasonal variations - the transition level varies between 905 and 930 km; the equinox level falls slightly below the winter level.

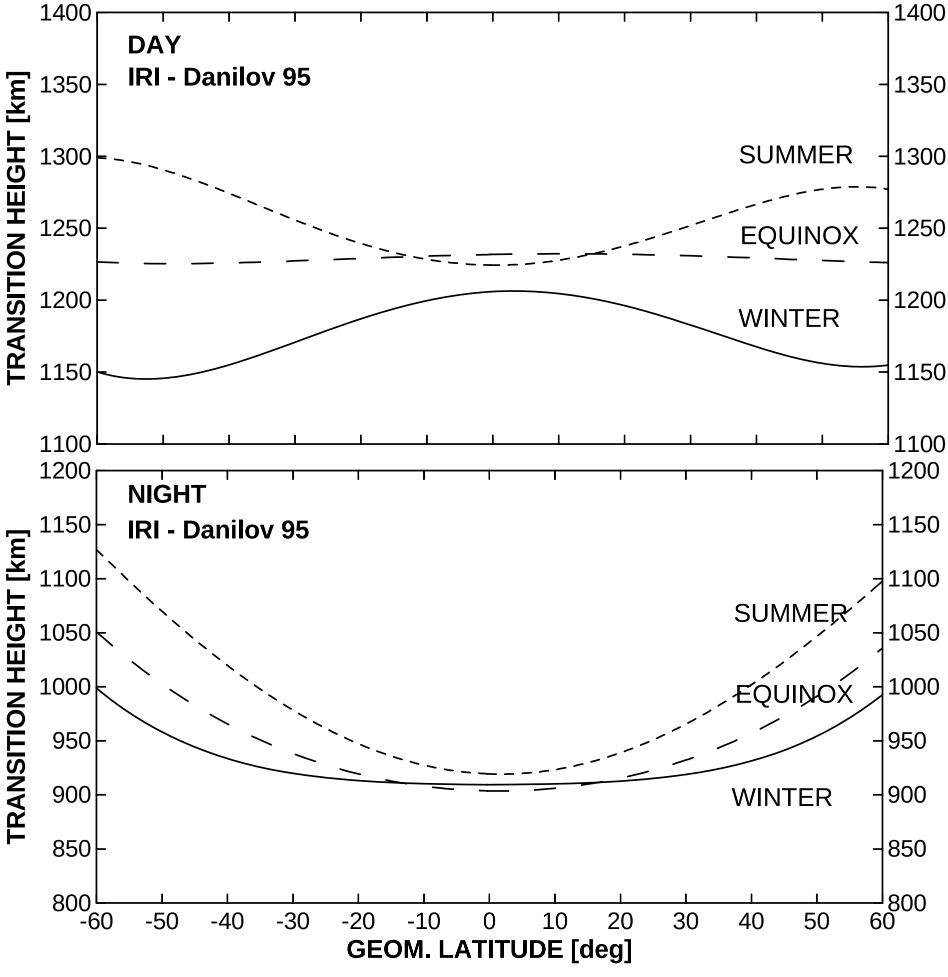

Fig.7 The O^+- He^+ transition level as calculated by the IRI using Danilov-95 ion composition model for winter (solid line), equinox (long dashes), and summer (short dashes).

The Danilov-95 option provides longitudinal variations of the transition level. There is a minimum at 0° geomagnetic longitude and a maximum at 180° geomagnetic longitude or vice versa, depending on the latitude. Also, the transition levels on the east side of the 0° geomagnetic meridian are symmetrically equal to those on the west side.

In IRI the diurnal behaviour of the transition level is modelled uniformly under all conditions - a minimum around midnight and a maximum around noon local time.

5. Comparison of AE-C data with IRI calculations

A comparison with the result provided in the previous sections, shows that the IRI model calculations deviate significantly from the measurements of the transition level both during day and night. To facilitate the comparison, the IRI model results (Fig.7) are overlaid on the direct measurements (Fig.1) and the values derived from the ion density profiles (Table 2 and Table 3). The results are given in Fig.8 (day-time) and Fig.9 (night-time).

Day-time conditions

During summer (Fig.8, top panel), the IRI calculations are much smaller than the values derived from the profiles (the difference starting from 1000km at the equator and reaching 2000 km at high latitudes). There are no direct measurements but the analysis shows a serious underestimation of the summertime values. The situation under equinox conditions (Fig.8, middle panel) is almost the same. This time direct measurements are available but the difference at high latitude is again very large - more than 2000 km. During winter (Fig.8, bottom panel), the IRI results and the 'profile' values are relatively close to each other when comparing them with the direct measurements. The 'direct' values and IRI calculations show a decrease of the level at high latitudes, while the 'profile' values suggest the opposite. Note the large data scattering (see the 'winter' curve in Fig.1, top panel) when obtaining the 'direct' values at high latitudes.

Night-time conditions

During summer, the transition level at middle latitude is represented well by IRI - the direct measurement values are almost identical with the IRI values. During equinox (Fig.9., middle panel) the middle- and high-latitude measurements are lower than the modelled by 150 - 200 km. On the opposite, during winter (Fig.9, bottom panel) the middle- and high-latitude measurements are higher. More information is required to analyze the nighttime behaviour of the transition level at equatorial latitudes - at this stage the ion density profiles suggest that there is an increase of the level above the equator which is not modelled by IRI at all.

A possible explanation of the mentioned shortcomings of IRI is the unreliability of the ion composition provided by the model. While the O^+ density near the F peak is well modelled at low solar activity, at higher altitudes it tends to be underestimated. On the other hand, the model He^+ densities are generally overestimated by about 40% , (Hoegy and Grebowski, 1994), over the AE-C BIMS measurements.

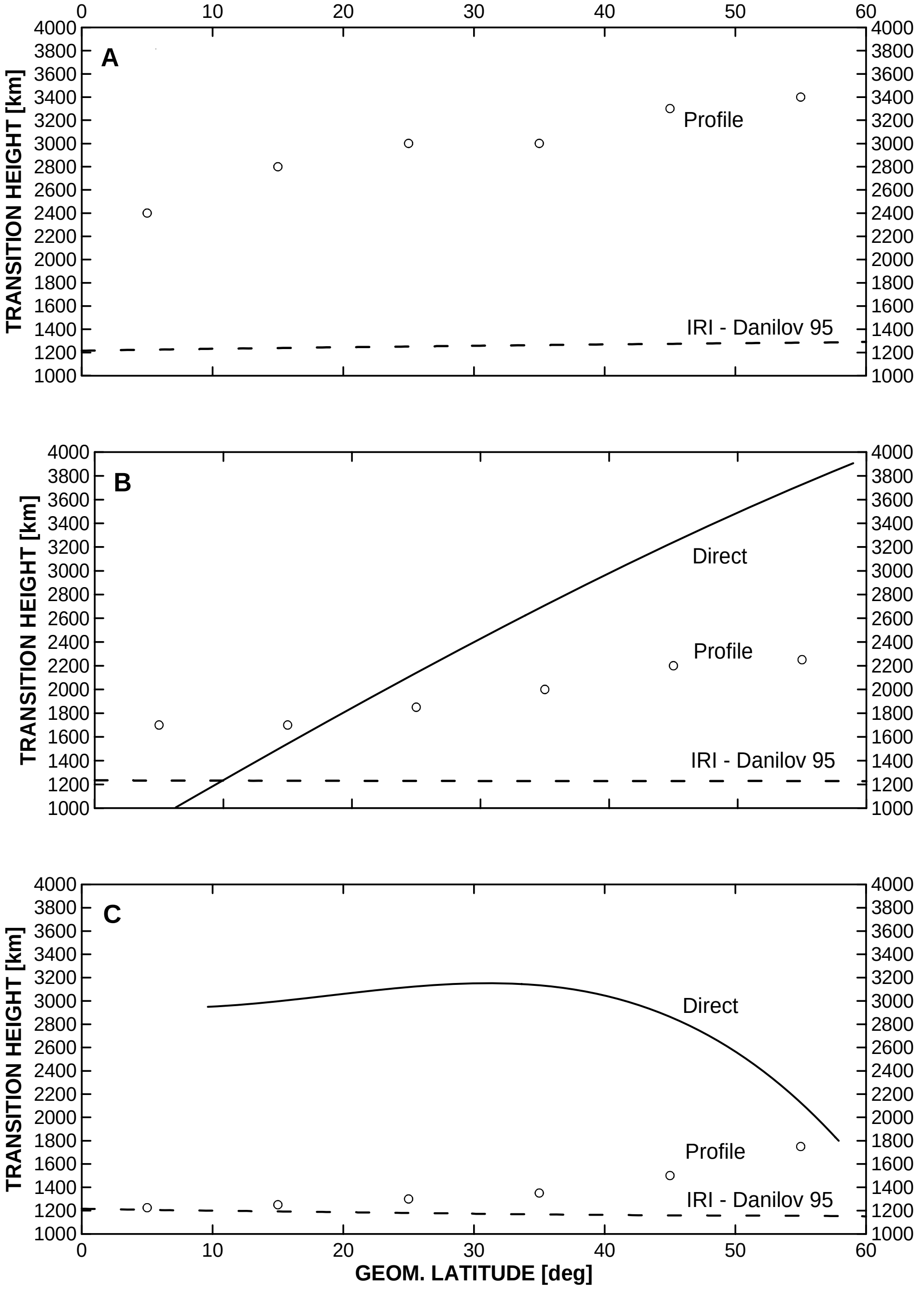

Fig.8 The *day-time* O^+- He^+ transition level as detected by the AE-C (solid line), calculated by IRI using Danilov-95 ion composition model (dashed line), and obtained from average profile (open circles) during summer (A), equinox (B), and winter (C).

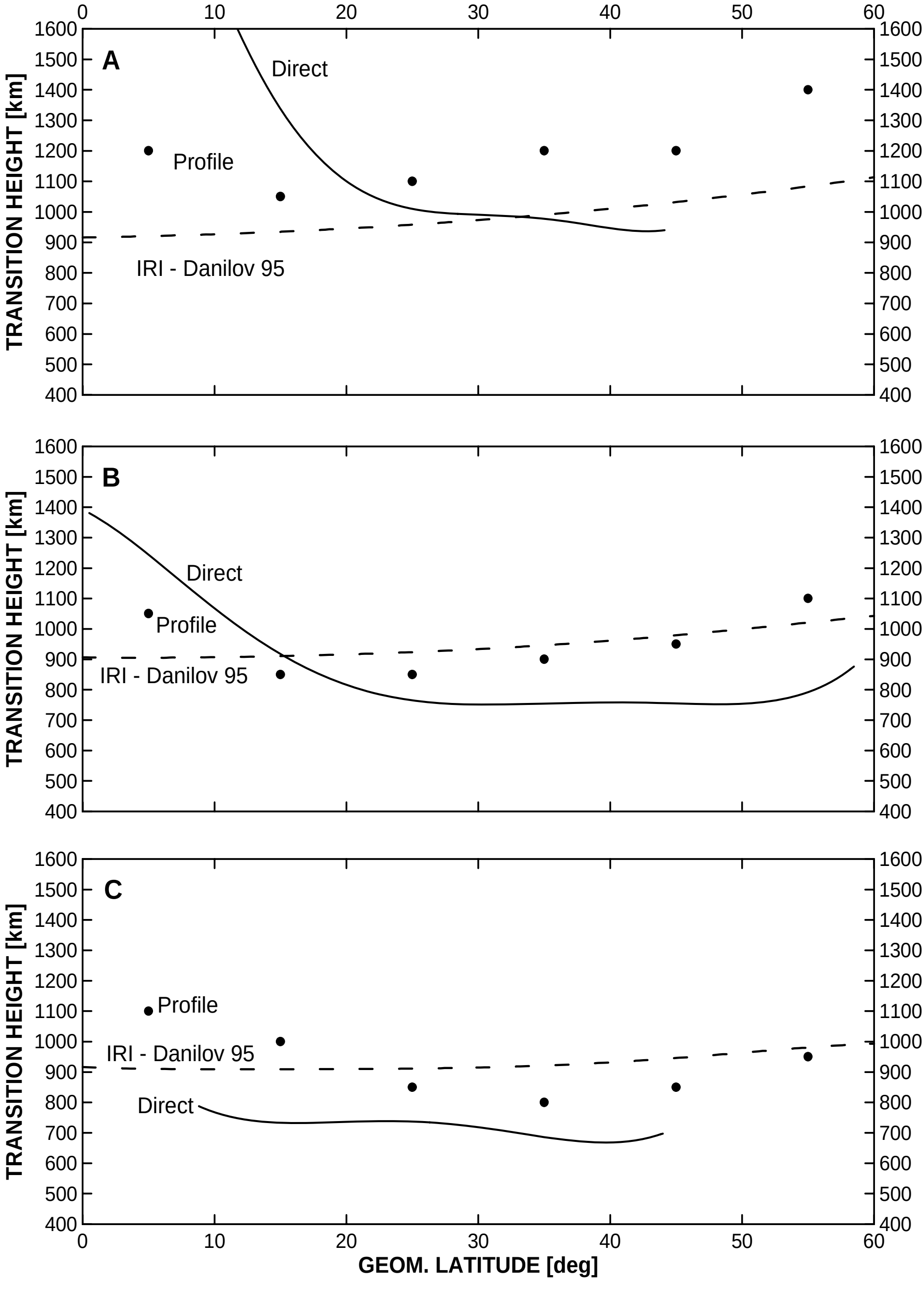

Fig.9 The *night-time* O^+- He^+ transition level as detected by the AE-C (solid line), calculated by IRI using Danilov-95 ion composition model (dashed line), and obtained from average profile (closed circles) during summer (A), equinox (B), and winter (C).

6. Conclusions

Atmosphere Explorer - C satellite measurements have been used to analyse the ion composition in the topside ionosphere for day-time and night-time conditions, magnetic latitudes -60^o to $+60^o$, and three seasons - winter, equinox and summer. The focus of this study was on the helium ion and particularly on the O^+-He^+ transition level, which was derived by using both direct measurements and averaged ion density profiles. The results have been compared with the IRI-95 model calculations.

The analysis made in the previous sections suggests the following conclusions:

(a) The direct measurements of the O^+- He^+ transition level are insufficient to examine its behaviour under all spatial and temporal conditions; the averaged ion density profiles provide additional useful information.

(b) The observed latitudinal variations of the O^+- He^+ transition level are much stronger than the latitudinal variations calculated by the IRI-95 model.

(c) The longitudinal behaviour of the transition level is very complex, the available data for day-time conditions are insufficient to model them reliably at this stage.

(d) The IRI - Danilov 95 ion composition model, providing seasonal, diurnal, latitudinal and longitudinal changes, is a better option than the original (IRI-86) ion composition model.

(e) Neither of the IRI ion composition options provides satisfactory modelling of the observed low-latitude and equatorial rise of the O^+- He^+ transition level during night.

(f) The IRI-95 model is unsatisfactory for purposes of calculating the ion composition, in particular the ion transition heights.

The above conclusions are in support of developing a new (semi-) empirical model of the O^+- He^+ transition height which will be presented in the follow-up publication.

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Преходното O^+- He^+ ниво по време на ниска слънчева активност: I. Сравнение на AE-C сателитни данни с IRI моделни пресмятания

С.М.Станков

Анализирани са ширинните, дължинните, денонощните и сезонните изменения на O^+- He^+ преходно ниво по време на ниска слънчева активност чрез изпозуване на in-situ измервания на йонните плътности извършени от AE-C сателита. Резултатите са сравнени с пресмятания на IRI модела.