THE Mg II EQUATORIAL AIRGLOW ALTITUDE DISTRIBUTION

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Abstract. Four occasional measurements of the altitude distribution of the 2796-2803-Å doublet equatorial airglow have been made with the astronomical TD-1A satellite during winter 1973-1974. The observations indicate the presence of layers of Mg^+ ions in the evening twilight F region in the African sector. Horizontal column densities reaching 8×10^9 Mg^+ ions/cm^2 are observed with peak altitudes varying from 230 to 480 km. Steep topside gradients with scale heights of about 5 km are observed on three occasions.

Introduction

The existence of clouds of iron ions in the topside equatorial ionosphere was discovered by Hanson and Sanatani [1970] using the Ogo 6 retarding potential analyzer. They observed that Fe^+ ions could be found occasionally at altitudes greater than 1100 km and in densities sometimes exceeding 2×10^3 cm^{-3}, although the peak was normally at lower altitudes and in concentrations less than 1×10^2 cm^{-3}. Another ion of intermediate mass (presumably Si^+ or Mg^+) was also detected and showed covariation with Fe^+, but it was not possible to identify it unambiguously.

The importance of metallic ions in the formation of spread F was pointed out by Hanson and Sanatini [1971], who found that the presence of Fe^+ ions above 400 km is one of the conditions necessary for generation of irregularities typical of spread F occurrence. A possible mechanism for these irregularities involves instabilities caused by plasma convection due to a nonuniform distribution of metallic ions below the F layer [Hanson et al., 1973].

The transport of meteoritic ions from 100 km into the topside F region may be explained by the upward motion set up by the polarization electric field in the E region followed by the $\underline{E} \times \underline{B}$ vertical drift in the noncollisional region [Hanson et al., 1972].

The presence of Mg^+ ions above 500 km in the equatorial zone was detected photometrically by the ultraviolet telescope onboard the Esro TD-1A satellite [Boksenberg and Gérard, 1973] and confirmed by a study of ultraviolet spectra taken with the Ogo 4 spectrometer [Gérard, 1976]. The Mg II 2796-2803-Å doublet is excited by resonance scattering of ground state Mg^+ ions fluorizing in the ultraviolet sunlight. It was observed in the photometric 2600 to 3000-Å channel of the S2/68 spectrophotometric stellar experiment.

However, since the optical axis of the telescope was continuously pointing zenithward, only the ion column density above 540 km could be determined. In this note, we report on measurements obtained during a period when the spacecraft was in the spinning mode, which allowed the altitude distribution of the Mg^+ airglow to be observed down to the lower F region.

Observations

During the period December 1973 through January 1974, the TD-1A satellite was spinning at a rate of 1.89°/s about its sun-pointing axis. Consequently, the optical axis of the telescope scanned a plane parallel to the terminator, and the solar zenith angle varied from 121° to 90° as the spacecraft moved from the north pole to the equator. Figure 1 illustrates the observing geometry for winter conditions in the northern hemisphere when the satellite approaches the dusk terminator. At this time of the year the satellite was normally in the hibernation mode, and no observations were made with the UV spectrophotometer. However, during a few orbits the experiment was activated at high latitudes and turned off by equatorial stations. For operational reasons the data recovery was limited to the West African sector.

When the line of sight crossed the dark lower thermosphere, a signal peaking near 95 km was observed in the photometric channel extending roughly from 2500 to 3000-Å. It was caused by the O_2 Herzberg I nightglow excited by three-body recombination of atomic oxygen [Gérard,

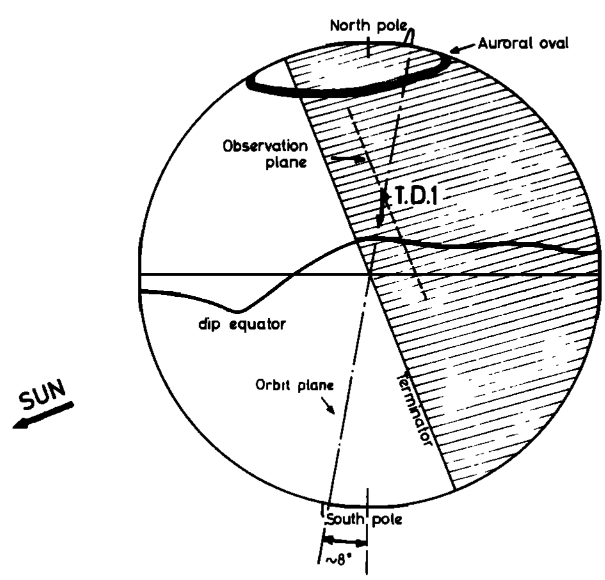

Fig. 1. Geometry of the twilight observations for winter solstice in the northern hemisphere. The spacecraft spins about the solar axis, and the observation plane is parallel to the teminator.

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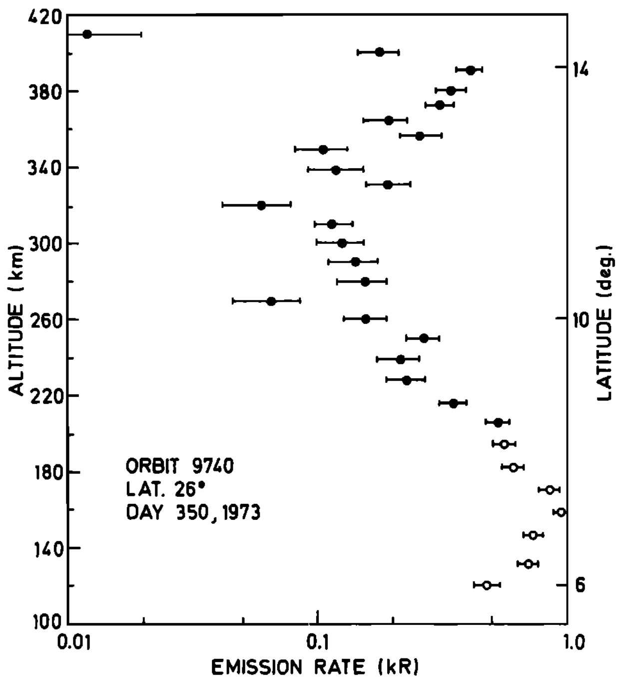

Fig. 2. Altitude distribution of the Mg II 2800-Å airglow. The scales refer to the altitude and latitude of the tangent point of the optical axis. The open circles correspond to observations made with the tangent point in the shadow. The error bars correspond to a 1σ deviation in the observed counting rate. The solar zenith angle is 101.5°, and the longitude is 10.2°W.

1975]. Above this altitude, only a weak background is usually observed due to particles and scattered light. However, when the telescope scans the equatorial ionosphere, a signal due to the 2800-Å Mg II airglow is observed. The range of latitude where the ions may be observed is limited on the equatorial side by operational strains and on the poleward side by the maximum value of the solar zenith angle required to illuminate the F region. In fact, only four scans may be effectively used for determining the Mg II airglow vertical distribution. A more complete description of the observing conditions and a brief account of the preliminary results were given by Monfils and Gérard [1975].

The measurements of the Mg II airglow altitude distribution are shown on Figures 2 to 5. The latitude mentioned in each figure refers to the position of the spacecraft during the scans, whereas the latitude scale on the right-hand side indicates the latitude of the tangent point as the optical axis scans the observation plane. One data point is obtained each 0.148 s, corresponding to an angular displacement of about 17 arc min of the optical axis. Consequently, the spatial resolution is determined by the satellite spin rather than the field of view of the telescope (1.8 arc min.). The altitude of the shadow is given by the sum of the geometrical shadow height and the ozone screening height of approximately 65 km. Different symbols have been used to indicate the measurements whose tangent point is in the shadow. The g factor

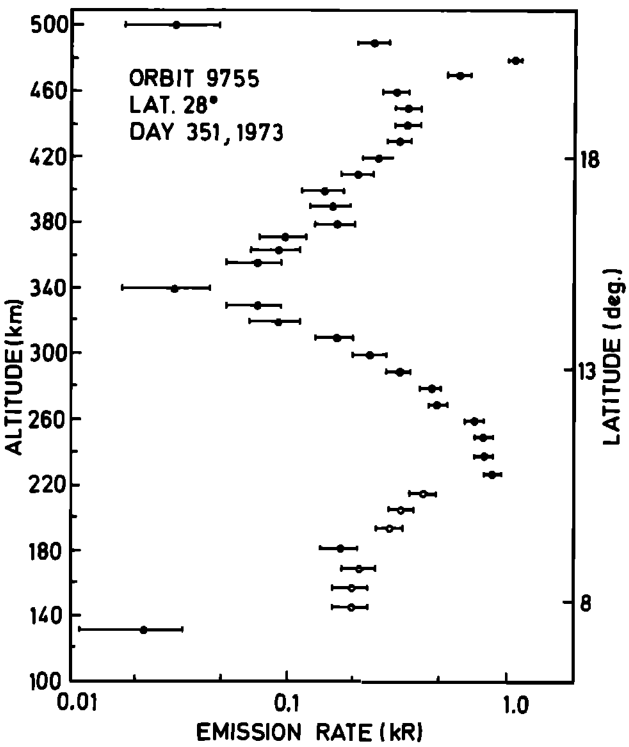

Fig. 3. Same as Figure 2, but the solar zenith angle is 102.5°, and the longitude is 6.9°W.

for resonance scattering of the Mg II λ2800-Å doublet is 0.13 ph/s; consequently, an emission rate of 1 kR corresponds to a column density of 7.7×10^9 ions/cm^2.

Orbit 9740 (Figure 2) shows a double peak with maxima at 160 and 390 km. The altitude of the lower maximum is such that its tangent point is situated about 50 km below the shadow height. Consequently, only about two thirds of the satellite-tangent point distance is directly illuminated by the sunlight. In this case the

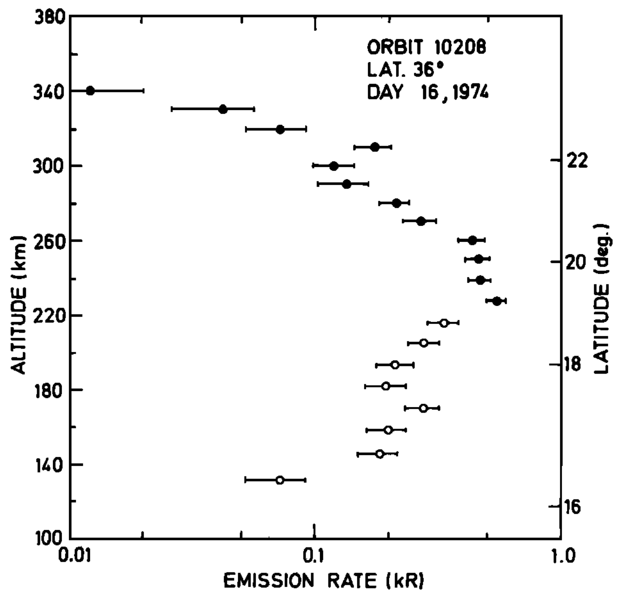

Fig. 4. Same as Figure 2, but the solar zenith angle is 102.4°, and the longitude is 9.8°E.

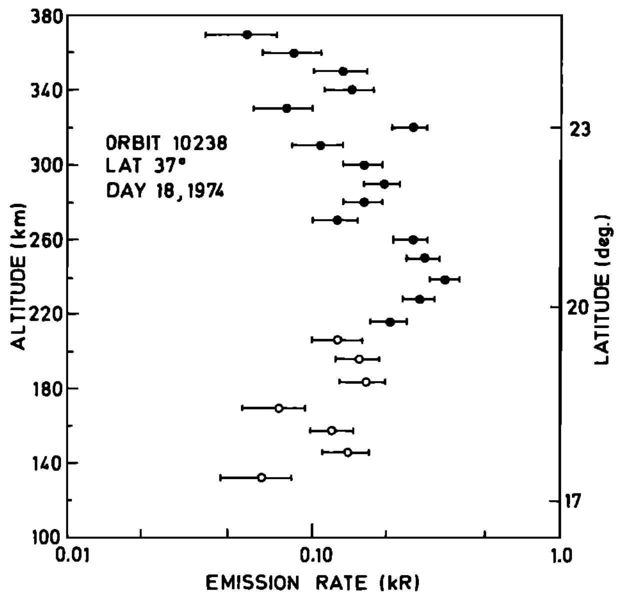

Fig. 5. Same as Figure 2, but the solar zenith angle is 100.1°, and the longitude is 12.7°E.

emission rate cannot be simply related to the ion column density. The maximum rate of the upper peak is approximately 500 R, corresponding to a column of 4×10^9 ions/cm^2. The topside of the distribution exhibits a steep intensity gradient characterized by a scale height of about 5 km.

Orbit 9755 (Figure 3) is for the day following orbit 9740. The distribution is fairly similar, with peaks at about 230 and 480 km and a maximum column density of 8×10^9 ions/cm^2. For a path length of 400 km the largest column density observed in orbits 9740 and 9755 yields an average ion density of about 200 cm^{-3}. A topside scale height of 6 km is again observed.

Orbits 10208 and 10238 (Figures 4 and 5) show a less pronounced and structured airglow, although a single peak is still observed near 240 km in both cases. The top of the distribution of orbit 10208 is again characterized by a sharp decrease.

Conclusions

Observations of the altitude distribution of the 2800-Å equatorial airglow excited by resonance scattering have been made in the African sector on four occasions. They show a single or double peak in the F region reaching intensities of 1 kR or 8×10^9 ions/cm^2 in the horizontal direction. Satellite mass spectrometer observations of the meteoritic ions together with in situ measurements of the plasma characteristics should, in the future, allow the factors controlling the distribution of metallic ions in the F region to be determined and their importance in the generation of spread F to be specified.

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