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The High Latitude Outer Zone Boundary for ≥ 40 keV Electrons as Observed by Satellite Injun 3*

by

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ABSTRACT

The relationship of locally mirroring and precipitating ≥ 40 keV electrons was studied on magnetically quiet days at the high latitude outer zone boundary with satellite Injun 3. There was usually an enhancement of precipitating ≥ 40 keV electrons observed at the high latitude boundary for all local times. On the night side the flux of ≥ 40 keV electrons was always observed to approach isotropy over the upper hemisphere at the position of the satellite at this boundary. The condition of isotropy at the boundary was found to be strongly dependent on local time, being always present on the night side and being less frequently observed with increasing local time around to local dusk (1800 hours) where isotropy was seldom observed at the boundary. During magnetically quiet periods large intensities of ≥ 40 keV electrons were observed precipitating into the atmosphere for $\Lambda \geq 65°$ and the position of the high latitude boundary (intensity cutoff) was observed to vary by $\Delta\Lambda \simeq 7°$ while little magnetic activity was occurring. On the night side the latitude where the ratio of the trapped to the precipitated ≥ 40 particle fluxes breaks toward one (φ-boundary) is introduced as a more meaningful concept of the high latitude limit to durably trapped ≥ 40 keV electrons than the usual intensity cutoff and

the concept that the high latitude outer zone boundary at all local times is controlled or driven by a mechanism(s) acting primarily on the night side is introduced.

I. INTRODUCTION

Properties of the fluxes of electrons which constitute the outer Van Allen radiation zone at low altitudes have been investigated by many experimenters [see reviews by O'Brien, 1963a; Farley, 1963; Brown, 1966]. In the present study, characteristics of the high latitude outer zone boundary for ≥ 40 keV electrons as observed by satellite Injun 3 are presented. Previous studies of the high latitude boundary [O'Brien, 1963b; Frank, Van Allen, and Craven, 1964; McDiarmid and Burrows, 1964 a and b; Armstrong, 1965; Williams and Mead, 1965; Williams, 1967; Rao, 1967; McDiarmid and Burrows, 1968] were performed using a single detector and defining the boundary as an intensity cutoff, and if more than one detector was used, the responses of the individual detectors were studied separately. In the present study, the responses of two detectors, one oriented perpendicular and the other parallel to the local geomagnetic B-vector, are studied together and the relationship of locally mirroring and precipitating ≥ 40 keV electrons is determined for geomagnetically quiet conditions.

II. DESCRIPTION OF EXPERIMENT

Satellite Injun 3 was launched on 13 December 1962 into an orbit with apogee altitude 2785 km, perigee altitude 237 km, orbital inclination 70.4°, and period 116 minutes. The satellite was magnetically oriented by the use of a permanent magnet, and detector look-angle orientations on the satellite were referenced to this magnetic axis by the angle θ. When the satellite was properly aligned, the $\theta = 0°$ axis was parallel to the geomagnetic B-vector and was directed down into the atmosphere in the northern hemisphere. The orientation of the satellite with respect to the B-vector was measured with two Schonstedt flux-gate magnetometers mounted with their axis parallel to $\theta = 90°$ and $\theta = 130°$, respectively. After alignment was obtained, the orientation system of the satellite maintained alignment to the extent that the rms deviation from alignment was less than 5° under almost all conditions for the ten month active lifetime of the satellite [see Appendix I, Fritz, 1967]. A description of the Injun 3 satellite was given by O'Brien, Laughlin, and Gurnett [1964].

Two of the charged particle detectors included in the satellite payload were used in the present study. Detector 1 was a thin windowed directional 213-type Geiger-Müller tube with a conical fiew of view of 26° diameter centered at the $\theta = 90°$ position and was sensitive to electrons with $E_e \geq 40$ keV which mirrored near the satellite. Detector 5 was similar to Detector 1 but had a conical field of view of about 86° diameter centered on the $\theta = 180°$ axis. By numerically integrating the experimentally determined angular response function for Detector 5 it has been shown [Fritz, 1967] that in this position Detector 5 was responding only to precipitated particles (i.e., particles which mirrored below 100 km and therefore were lost to the atmosphere) when

$$\begin{aligned} B_{local} &\geq 0.26 \text{ guass at } \Lambda \simeq 45° \\ &\geq 0.28 \text{ gauss at } \Lambda \simeq 55° \\ &\geq 0.31 \text{ gauss at } \Lambda \simeq 65° \\ &\geq 0.31 \text{ gauss at } \Lambda \simeq 75°. \end{aligned}$$

These conditions were satisfied during portions of the Injun 3 orbit. A more detailed description of these detectors has been given by O'Brien, Laughlin, and Gurnett [1964] and by Fritz [1967].

III. DESCRIPTION OF RELEVANT PARAMETERS

The data transmission system on Injun 3 operated for seventeen minutes after reception of a properly coded command from a receiving station below the satellite. Each of the detectors on the satellite had its own twelve bit accumulator which was sampled once every one-fourth second for the data used in this study [O'Brien, Laughlin, and Gurnett, 1964]. The orbital parameters of the satellite including the L, B coordinates of McIlwain [1961] were assigned to each one-fourth second (frame) of data, using the ephemeris supplied by the Goddard Space Flight Center. For most of the data presented in this study, the data were summed over consecutive eight second intervals due to a lack of sufficient counting statistics on a frame by frame (one-fourth second) basis. In undertaking this study a set of parameters was introduced to organize the problems under investigation.

The Dumping Parameter, φ

A dumping or precipitation parameter, φ, was calculated by dividing the flux of particles measured with Detector 5 by the flux of particles measured with Detector 1. The parameter, φ, was therefore the ratio of the flux of electrons with $E_e \geq 40$ keV being precipitated into the atmosphere to the flux of electrons with

$E_e \geq 40$ keV mirroring near the position of the satellite. As the amount of "dumping" increased, the parameter, φ, approached unity in agreement with the observation of O'Brien [1964] and of Parthasarathy, Berkey, and Venkatesan [1966] that during periods of enhanced precipitation the precipitation process is such that the angular distribution of electrons tends to approach isotropy over the upper hemisphere at the altitude of the satellite.

The Latitude Parameter, Λ

In the present study, the invariant latitude, Λ, [O'Brien, 1962] is used exclusively. This coordinate is related to the L coordinate of McIlwain [1961] by the relationship, $L \cos^2 \Lambda = 1$.

The Local Time Parameter, MLT

Because the motion and behavior of the particles under study in this paper are governed by the geomagnetic field, magnetic local time (MLT) is used here instead of the usual geographic local time. Magnetic local time is defined as the angle between the planes which are defined by the geomagnetic dipole axis and the earth-sun line and by the geomagnetic dipole axis and the earth center-satellite line. MLT takes into account both the daily and the seasonal variations in the orientation of the geomagnetic dipole axis with respect to the earth-sun line. For the orbit of Injun 3, MLT differed by as much as ± 2 3 hours from the corresponding geographic local time at high latitudes. At lower latitudes the two local times were approximately equal. For further remarks on magnetic local time, see Appendix I, Fritz and Gurnett [1965].

IV. THE STUDY

All data obtained from the Injun 3 detectors discussed above were plotted for each traversal of the outer zone made by the satellite during its 10 month active lifetime. These plots were generated automatically by The University of Iowa IBM 7044 computer and plotted on Calcomp Digital Incremental plotters.

With the data organized in this manner the plots were examined for data obtained on each of the ten designated geomagnetically quiet days per month [Lincoln, 1963]. Figure 1 is presented as an example of an undisturbed pass. The K_p index was 1_o for the period of the pass and 16 August 1963 was designated as one of the five magnetically quiet days (Q) for the month. The characteristic behavior observed for the intensity of electrons with $E_e \geq 40$ keV is displayed by the pass of Figure 1. The intensity of ≥ 40 keV electrons both mirroring and precipitating at the position of the satellite decreased with increasing latitude from $\Lambda = 45°$ (L = 2.0) reaching a minimum at $\Lambda = 55°$ to $\Lambda = 60°$ (L = 4.0) after which these intensities increased somewhat before falling off with varying degrees of sharpness at the high latitude termination of observable fluxes of these outer zone electrons. The ratio of the dumped to the trapped ≥ 40 keV fluxes was nearly constant as a function of increasing latitude. The dumping parameter φ, was approximately equal to 10^{-2} when Detector 5 was responding primarily to precipitated electrons for latitudes below the high latitude outer zone termination. This apparent invariance of φ at the lower latitudes will be discussed in a subsequent paper and no further discussion of it will be given here.

At the high latitude termination of observable fluxes in Figure 1, the intensity of ≥ 40 keV electrons being precipitated into the atmosphere increased sharply by a factor of ten. This increase in the precipitated electron flux accompanied by a decrease in the locally mirroring flux caused the fluxes of ≥ 40 keV electrons to achieve isotropy over the upper hemisphere at the position of the satellite as this boundary was crossed. The dumping parameter, φ, for the pass in Figure 1 increased sharply from 10^{-2} to approximately 1 as the boundary was crossed.

This sharp increase or "spike" in the intensity of precipitating electrons was observed on many of the boundary crossings obtained by Injun 3 on geomagnetically quiet days. The dumping parameter, φ, also exhibited the same behavior as shown in Figure 1 on these same passes.

Local Time Dependence

A search was made to determine whether these boundary spikes of precipitated electrons occurred at all local times during magnetically quiet periods. Examples from this investigation are presented in Figure 2. A list of the passes presented in Figure 2 is given in Table I. It will be noted that there was usually some enhanced precipitation occurring at the outer zone boundary at all local times. On the night side (2000 hours to 0400 hours) however the precipitated flux usually increased sharply, resulting in a spike with the trapped and precipitated fluxes becoming equal (isotropic over the upper hemisphere). The dumping parameter, φ, broke sharply from 10^{-2} and increased toward unity at the boundary, and usually remained equal to one on and outside the boundary. This indicated that the fluxes of ≥ 40 keV electrons usually were isotropic at and beyond this boundary spike.

As the boundary was crossed nearer dawn the tracking of the trapped and precipitated ≥ 40 keV fluxes as a function of latitude was less frequently observed. From dawn around to noon, the dumping parameter, φ, was observed to approach 1 but it seldom remained equal to 1 and usually varied by large amounts over short distances. As the boundary was crossed nearer to 1800 hours, the ≥ 40 keV electron fluxes were very anisotropic and there was seldom a sharp break in the dumping parameter, φ, to a value near unity associated with the boundary.

The impression obtained from Figure 2 is that the high latitude boundary on the night side was characterized by a sharp break in the dumping parameter, φ, from 10^{-2} toward unity with the ≥ 40 keV electron fluxes remaining isotropic at latitudes above this sharp break. As the local time of the boundary crossing was varied from local night through dawn, to noon, and around to dusk, the change in the value of φ associated with the boundary became less distinct and the ≥ 40 keV electron fluxes became more anisotropic.

In order to assure that this impression was accurate, each of the Injun 3 passes through the high latitude boundary obtained on magnetically quiet days (M and Q) was re-examined. The magnetic local time of each boundary crossing was determined, and the following conditions were investigated.

(1) Were the ≥ 40 keV electron fluxes isotropic or nearly isotropic at the boundary? (Specifically, did the value of φ exceed 0.5 at the boundary?)

(2) Was there a spike or large increase in the flux of precipitating electrons? (Specifically, did the value of j ($E_e \geq 40$ keV) dumped increase by at least a factor of five in association with the boundary?)

(3) Was there an increase in precipitation associated with the boundary? (Specifically, did the value of φ increase by at least a factor of five in association with the boundary?)

While the above three conditions were interrelated, they did describe different features associated with the ≥ 40 keV electron high latitude boundary. This can be seen most readily by asking these questions of each of the examples presented in Figure 2.

The results of re-examining each of the boundary crossings occurring on magnetically quiet days (M and Q) are presented in Table II. These data indicate the percentage of boundary crossings occurring within each of the magnetic local time intervals for which the above three questions could be answered in the affirmative. It will be noted that the fluxes of ≥ 40 keV electrons were always isotropic or nearly isotropic on the night side, and that fewer cases for which the fluxes were nearly isotropic were observed as the local time increased from night through dawn and noon. A minimum was obtained at dusk where the fluxes were seldom observed to be isotropic at the boundary. The spikes of precipitating electrons were found at all local times but not on all passes at given local times (an example of the absence of the spike near local midnight is given in Rev. 2381 of Figure 3). In general, the presence of the spike displayed a similar dependence on local time as discussed above for the condition of isotropy at the boundary. From column 3 of Table II it may be noted that enhanced precipitation was occurring at boundary in a majority of the crossings at all local times, but in general the condition of enhanced precipitation displayed the same local time dependences as discussed for the previous two conditions. Therefore, the results of Table II support and strengthen the impression of the high latitude boundary obtained from Figure 2.

The φ Boundary

Another type of variation that was observed to occur during periods of low magnetic activity was the variation of the position of the high latitude boundary. In Figure 3, four passes through the boundary near the midnight meridian recorded on 22 June 1963 are presented. During the period of these passes the K_p index was 1+ or less and for the eighteen preceding hours and in the following 48 hours it was never greater than 2-. Both 22 June and 23 June were each one of the five magnetically quiet days (Q) of the month. Magnetograms recorded at Sitka, Alaska ($\lambda_m = 60°$), College, Alaska ($\lambda_m = 65°$), and Barrow, Alaska ($\lambda_m = 68°$) during the period of the passes in Figure 3 indicated that little magnetic activity was occurring at any of these stations, although there was a small amount of magnetic activity occurring at Fort Churchill, Manitoba, Canada ($\lambda_m = 68°$) 3 to 4 hours to the east of these other stations. During this period the boundary was first observed at $\Lambda \simeq 74°$ on Rev. 2378 which was taken during a large precipitation event. Two hours later on

Rev. 2379 the precipitation was not as intense and the boundary was observed at $\Lambda \simeq 71°$. On the following pass, Rev. 2380, the large precipitation had disappeared and the boundary had collapsed to $\Lambda \simeq 67°$. The following pass, Rev. 2381, found the boundary had moved outward again to $\Lambda \simeq 70°$.

In this sequence of four passes the apparent outer zone boundary for ≥ 40 keV electrons was observed to change in position from 74° to 67°, a change of $\Delta\Lambda = 7°$, in four hours during a period of low geomagnetic activity. It will be noted in each of the four passes that the point at which the dumping parameter, φ, started to increase sharply was approximately 65° for each pass.

Previous measurements of the position of the outer zone boundary have attempted to correlate changes in the position with the various magnetic activity parameters [Maehlum and O'Brien, 1963; Williams and Ness, 1966; Willians, 1967; and Rao, 1967]. Williams [1967] found a change $\Delta\Lambda = 7°$ in a shift of the ≥ 280 keV electron boundary from 67° to 60° associated with the 18 April 1965 magnetic storm which had a maximum Dst depression of $\simeq -140\gamma$. Rao [1967] examined the position of the ≥ 40 keV electron outer zone boundary for the same 18 April 1965 storm and found there was a inward movement of the boundary to $\Lambda = 65°$ and an overall change of $\Delta\Lambda \leq 8°$ in position associated with the storm. It is noted from the results of the present study that such a change can occur without an accompanying geomagnetic storm, even during periods of very low magnetic activity.

In Figure 3 it will be noted that there were no variations in the values of $j_\perp$ ($E_e \geq 40$ keV) and $j_\parallel$ ($E_e \geq 40$ keV) for $\Lambda < 65°$ from pass to pass but very large variations in these quantities occurred for $\Lambda > 65°$. For example at $\Lambda = 70°$, $j_\perp(E_e \geq 40$ keV) varied from 3.0×10^5 electrons/cm^2 sec ster on Rev. 2378 to $< 10^2$ electrons/cm^2 sec ster on Rev. 2380. This represented a change of over three and a half orders of magnitude in $j_\perp(E_e \geq 40$ keV) in less than four hours and therefore it would be difficult to call the electron fluxes observed at $\Lambda > 65°$ durably trapped (i.e., capable of drifting one or more times around the earth).

The concept of a high latitude outer zone "trapping" boundary for ≥ 40 keV electrons has usually been associated with a point where the counting rate of a given detector decreased rapidly as a function of latitude toward background. This concept probably should be revised to include two regions, the trapping region and the auroral zone, which overlap somewhat in latitude. The auroral zone can be disturbed by a variety of mechanisms but the lower latitude trapping region remains undisturbed during these quiet periods.

The position at which the dumping parameter, φ, is observed to break sharply from $\simeq 10^{-2}$ toward 1 should be a more meaningful concept of the high latitude limit to durably trapped particles on the night side than the usual intensity cutoff.

V. SUMMARY AND DISCUSSION

A summary of the characteristics of the outer zone ≥ 40 keV electron boundary observed by Injun 3 during magnetically quiet days is presented in Figure 4 as a function of magnetic local time and invariant latitude. The ≥ 40 keV electron fluxes were observed to be isotropic at the high latitude termination of the outer zone on the night side with a sharply defined φ boundary usually separating the isotropic region from the lower latitude anisotropic trapping region. As local time increased from night through dawn to noon, the φ boundary became less well defined, and disappeared altogether in the afternoon sector during magnetically quiet days.

Taylor [1966] has demonstrated that the six degree latitude shift observed on the average in the high latitude boundary for ≥ 40 keV electrons as a function of local time [O'Brien, 1963b; McDiarmid and Burrows, 1964a and b; Frank, Van Allen, and Craven, 1964; Armstrong, 1965] could be reproduced by taking a known intensity profile at a given local time and allowing the electrons to drift adiabatically in a semi-empirically determined model of the geoelectric and geomagnetic fields. Using this result, the characteristics of the high latitude boundary presented in this paper can be interpreted to indicate that the high latitude outer zone intensity cutoff was controlled by a mechanism or mechanisms acting primarily on the night side and presumably in or due to the presence of the magnetospheric tail. Assume that a population of ≥ 40 keV electrons was introduced isotropically into the night side region at altitudes where the Injun 3 measurements were made. These electrons would drift in an eastward direction from the night side through dawn with the electrons in the loss cone (i.e., those which would mirror below 100 km) undergoing collisions with the atmosphere. That portion of the electron population within the loss cone would be reduced in number as a function of increasing local time, giving rise to the increasing anisotropy with local time noted in the present paper.

This mechanism(s), which was active on the night side, must have been operative at all times since the condition of near isotropy was always satisfied. There was however a large variation in the intensity of the isotropic flux which this mechanism(s) was able to produce (e.g., Figure 3). Further studies using similar detectors on different satellites displaced from one another in local time should prove to be valuable in discerning the properties of such a mechanism.

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TABLE I

Magnetic Local Time at Boundary	Date	Injun 3 Rev. No.	Magnetic Activity Index	K_p	at Λ = 65° UT	B
0.5	3/14/63	1132	Q	0+	10:02	.396
1.2	6/14/63	2280	M	2	10:26	.278
2.0	6/11/63	2242	M	1	9:28	.296
3.3	1/27/63	560	Q	0	8:20	.470
5.5	5/22/63	1994	Q	1	13:21	.355
6.2-7	1/8/63	326	M	1	11:30	.407
7-9	6/16/63	2308	Q	2-	16:36	.198
10-11	5/7/63	1811	M	2	21:50	.336
11-13	9/6/63	3338	Q	3+	22:26	.218
13-14.5	5/22/63	1997	Q	0+	19:31	.206
15-16	5/16/63	1920	Q	0+	15:31	.220
16-17	9/6/63	3327	Q	3	1:42	.337
17-18	9/7/63	3339	Q	1	0:41	.339
18-19.5	9/4/63	3302	Q	2-	1:51	.332
20.0	7/15/63	2666	Q	1-	6:52	.210
20.7	7/12/63	2627	M	2-	4:01	.230
22.0	8/16/63	3066	Q	1	5:53	.276
23.2	7/2/63	2506	Q	1-	12:05	.216

TABLE II

Magnetic Local Time	No. of Passes	Condition 1 $\varphi > 0.5$	Condition 2 Spike of precipitating particle present	Condition 3 $\frac{\varphi}{\varphi_o} > 5$
20-23	30	100%	91.3%	100%
23-02	49	100%	88.6%	100%
02-05	50	82.0%	65.3%	92.4%
05-08	61	50.8%	73.8%	82.2%
08-11	57	51.0%	70.2%	83.3%
11-14	43	46.5%	63.6%	80.0%
14-17	39	23.1%	45.7%	70.0%
17-20	34	11.8%	42.8%	62.8%

REFERENCES

Armstrong, T., "Morphology of the outer zone electron distribution at low altitudes from January through July and September, 1963 from Injun 3," J. Geophys. Res. 70, 2077-2110 (1965).

Brown, R. R., "Electron precipitation in the auroral zone," Space Sci. Rev. 5, 311-387 (1966).

Farley, T. A., "The growth of our knowledge of the earth's outer radiation zone," Reviews of Geophys. 1, 3-34 (1963).

Frank, L. A., J. A. Van Allen, and J. D. Craven, "Large diurnal variations of geomagnetically trapped and of precipitated electrons observed at low altitudes," J. Geophys. Res. 69, 3155-3167 (1964).

Fritz, T. A., and D. A. Gurnett, "Diurnal and Latitudinal effects observed for 10 keV electrons at low satellite altitudes," J. Geophys. Res. 70, 2485-2502 (1965).

Fritz, T. A., "Spectral, spatial, and temporal variations observed for outer zone electrons from 10 to 100 keV with satellite Injun 3," Ph.D. Thesis, U. of Iowa Res. Rept.67-42 (1967).

Lincoln, J. Virginia, "Geomagnetic and solar data," J. Geophys. Res. 68 (1963).

Maehlum, B. and B. J. O'Brien, "Study of energetic electrons and their relationship to auroral absorption of radio waves," J. Geophys. Res. 68, 997-1010 (1963).

McDiarmid, I. B., and J. R. Burrows, "High latitude boundary of the outer radiation zone at 1000 km," Can. J. Phys. 42, 616-626 (1964a).

McDiarmid, I. B., and J. R. Burrows, "Diurnal intensity variations in the outer radiation zone at 1000 km," Can. J. Phys. 42, 1135-1148 (1964b).

McDiarmid, I. B., and J. R. Burrows, "Local time asymmetries in the high-latitude boundary of the outer radiation zone for the different electron energies," Can. J. Phys. 46, 49-57 (1968).

McIlwain, C. E., "Coordinates for mapping the distribution of magnetically trapped particles," J. Geophys. Res. 66, 3681-3691 (1961).

O'Brien, B. J., "Lifetimes of outer-zone electrons and their precipitation into the atmosphere," J. Geophys. Res. 67, 3687-3706 (1962).

O'Brien, B. J., "Review of studies of trapped radiation with satellite-borne apparatus," Space Sci. Rev. 1, 415-484 (1963a).

O'Brien, B. J., "A large diurnal variation of the geomagnetically trapped radiation," J. Geophys. Res. 68, 989-995 (1963b).

O'Brien, B. J., "High latitude geophysical studies with satellite Injun 3. 3. Precipitation of electrons into the atmosphere," J. Geophys. Res. 69, 13-43 (1964).

O'Brien, B. J., C. D. Laughlin, and D. A. Gurnett, "High-latitude geophysical studies with satellite Injun 3. 1. Description of the satellite," J. Geophys. Res. 69, 1-12 (1964).

Parthasarathy, R., F. T. Berkey, and D. Venkatesan, "Auroral zone electron flux and its relation to broadbeam radiowave absorption," Planet. Space Sci. 14, 65-83 (1966).

Rao, C. S. R., "Study of the temporal variations of 40 keV electrons in the magnetosphere during and after the magnetic storm on April 18, 1965," U. of Iowa Res. Rept. 67-16, 1-60 (1967).

Taylor, Harold E., "Adiabatic motion of outer-zone particles in a model of the geoelectric and geomagnetic fields," J. Geophys. Res. 71, 5135-5147 (1966).

Williams, D. J., and G. D. Mead, "Nightside magnetosphere configurations as obtained from trapped electrons at 1100 kilometers," J. Geophys. Res. 70, 3017-3029 (1965).

Williams, D. J., and N. F. Ness, "Simultaneous trapped electron and magnetic tail field observations," J. Geophys. Res. 71, 5117-5128 (1966).

Williams, Donald J., "On the low-altitude trapped electron boundary collapse during magnetic storms," J. Geophys. Res. 72, 1644-1646 (1967).

FIGURE CAPTIONS

FIGURE 1. A sample pass through the outer zone exhibiting undisturbed electron characteristics.

FIGURE 2. Examples of passes obtained on magnetically quiet days at various magnetic local times.

FIGURE 3. Four consecutive passes through the high latitude boundary obtained near the midnight meridian on 22 June 1963, a magnetically quiet day.

FIGURE 4. A summary of the characteristics of the outer zone ≥ 40 keV electron boundary as a function of magnetic local time and invariant latitude observed by Injun 3 during magnetically quiet days.

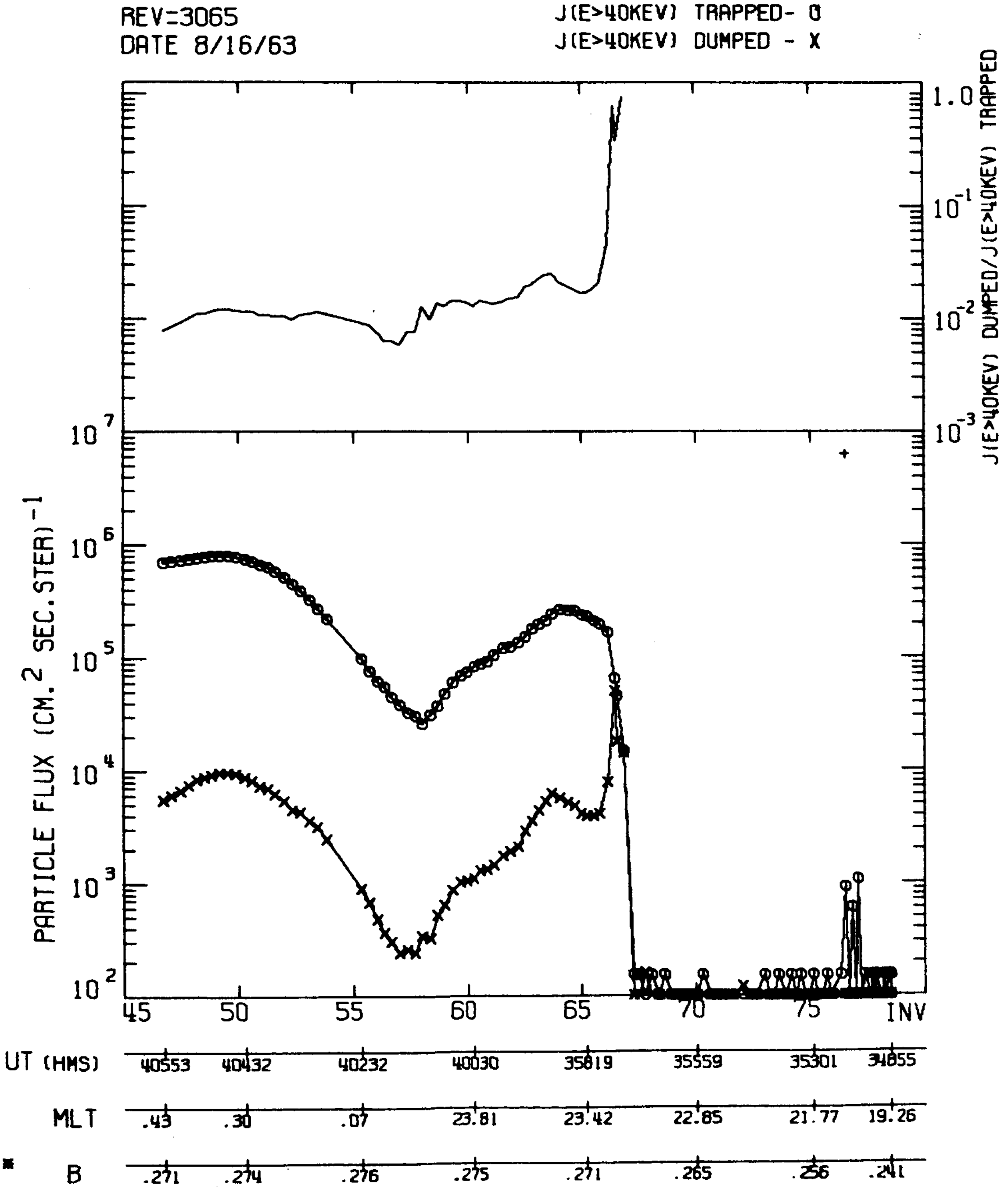

REV=3065
DATE 8/16/63
J(E>40KEV) TRAPPED- O
J(E>40KEV) DUMPED - X
1.0
10^{-1}
10^{-2}
10^{-3}
J(E>40KEV) DUMPED/J(E>40KEV) TRAPPED
10^{7}
10^{6}
10^{5}
10^{4}
10^{3}
10^{2}
PARTICLE FLUX (CM.^{2} SEC.STER)$^{-1}$
45
50
55
60
65
70
75
INV
UT (HMS)
40553
40432
40232
40030
35819
35559
35301
34855
MLT
.43
.30
.07
23.81
23.42
22.85
21.77
19.26
B
.271
.274
.276
.275
.271
.265
.256
.241

FIGURE 1

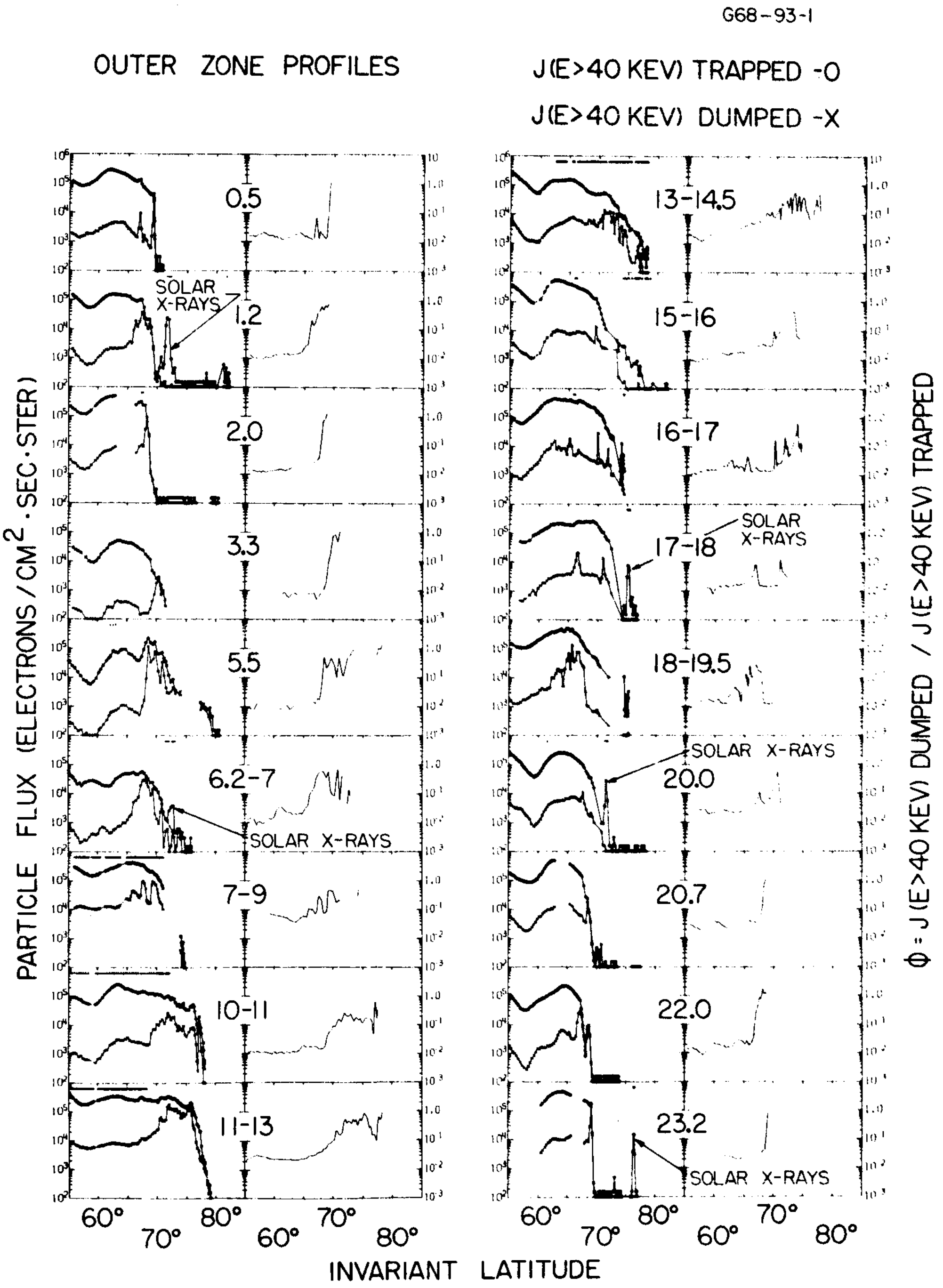

G68-93-1
OUTER ZONE PROFILES
J(E>40 KEV) TRAPPED -O
J(E>40 KEV) DUMPED -X
PARTICLE FLUX (ELECTRONS/CM^2·SEC·STER)
ϕ = J(E>40 KEV) DUMPED / J(E>40 KEV) TRAPPED
0.5
1.2
2.0
3.3
5.5
6.2-7
7-9
10-11
11-13
13-14.5
15-16
16-17
17-18
18-19.5
20.0
20.7
22.0
23.2
SOLAR X-RAYS
SOLAR X-RAYS
SOLAR X-RAYS
SOLAR X-RAYS
SOLAR X-RAYS
60°
70°
80°
INVARIANT LATITUDE

FIGURE 2

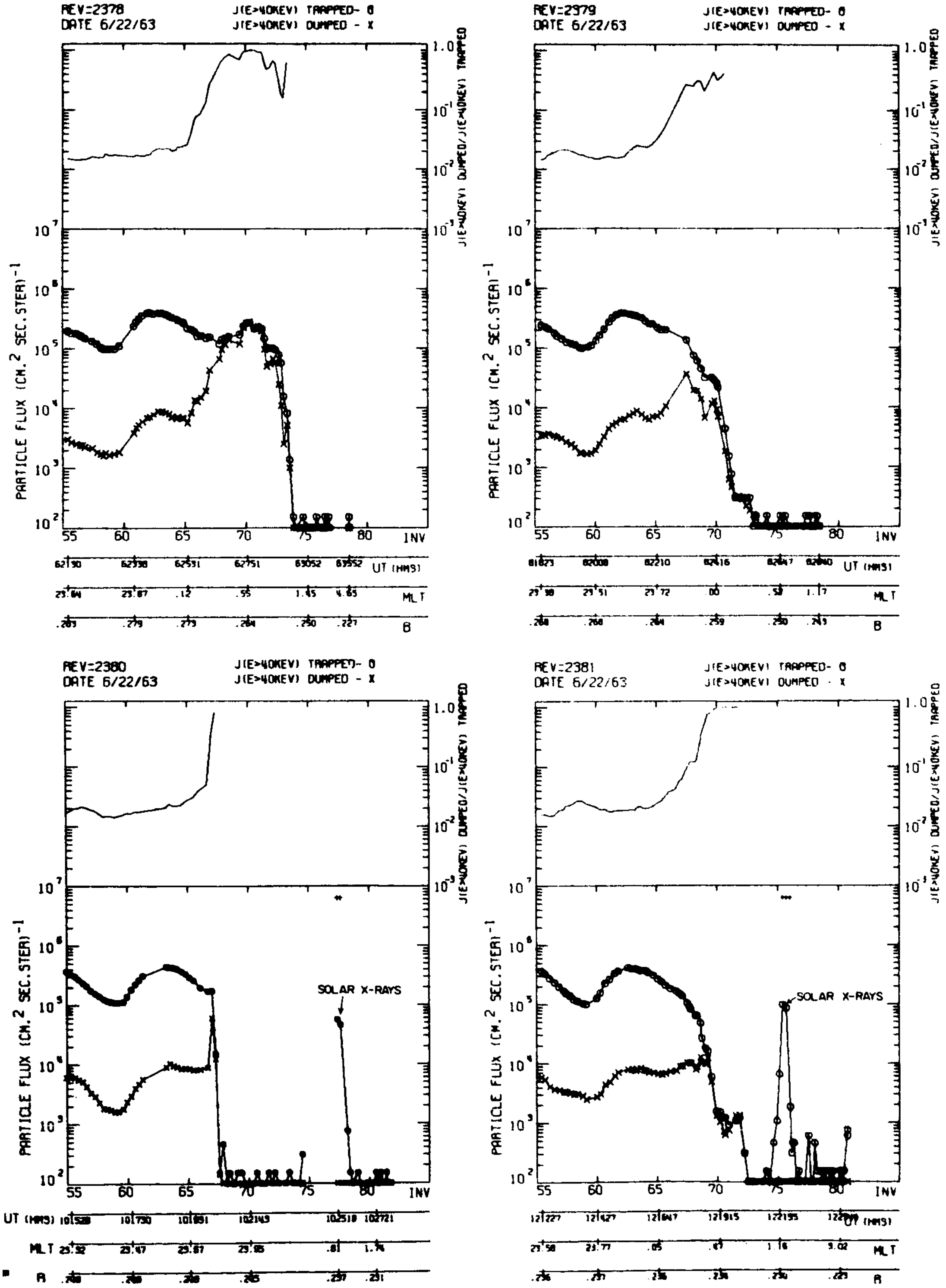
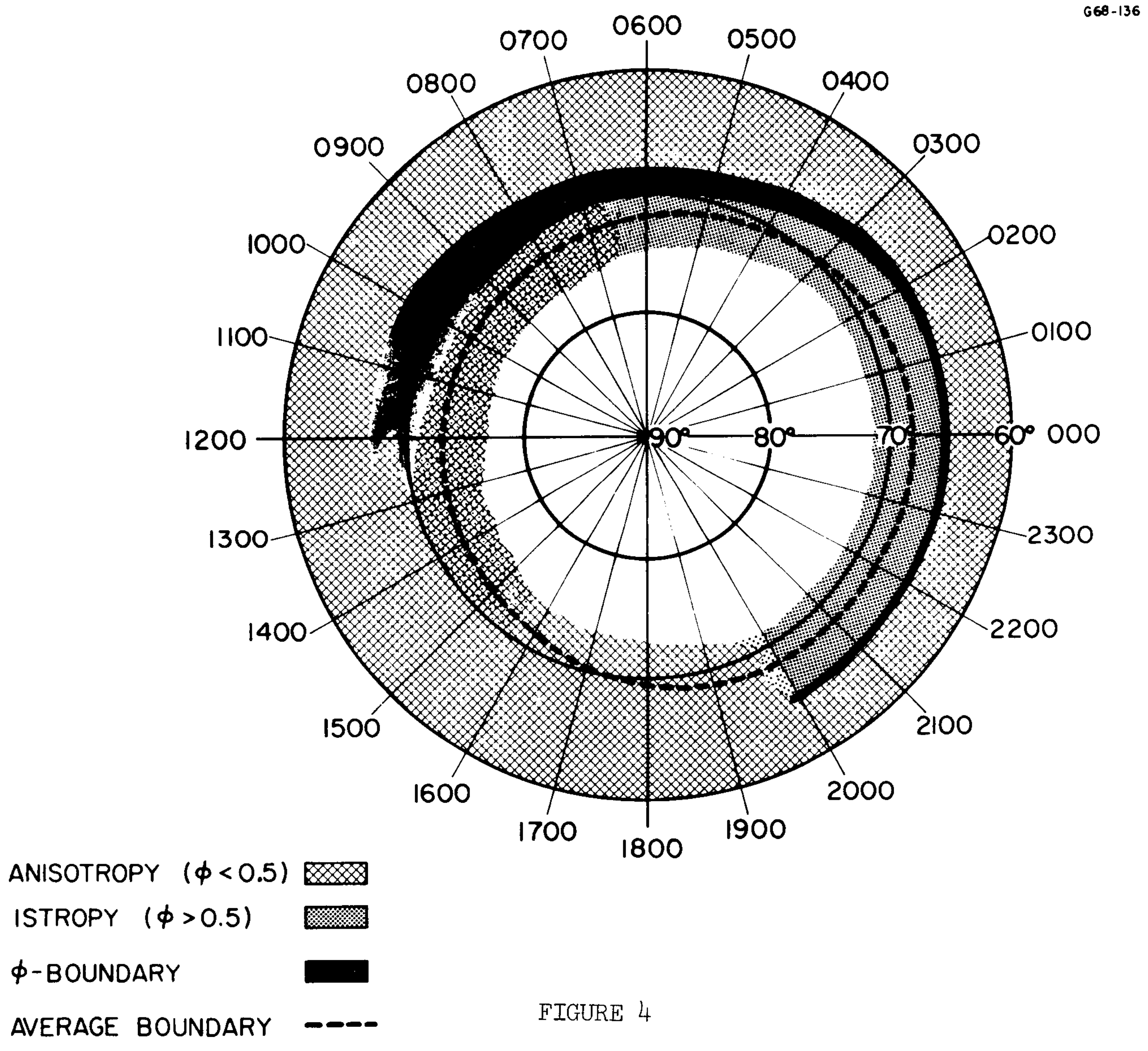

REV:2378
DATE 6/22/63
J(E>40KEV) TRAPPED- O
J(E>40KEV) DUMPED - X
REV:2379
DATE 6/22/63
J(E>40KEV) TRAPPED- O
J(E>40KEV) DUMPED - X
REV:2380
DATE 6/22/63
J(E>40KEV) TRAPPED- O
J(E>40KEV) DUMPED - X
REV:2381
DATE 6/22/63
J(E>40KEV) TRAPPED- O
J(E>40KEV) DUMPED - X
PARTICLE FLUX (CM.^{2} SEC.STER)$^{-1}$
J(E>40KEV) DUMPED/J(E>40KEV) TRAPPED
1.0
10^{-1}
10^{-2}
10^{-3}
10^7
10^6
10^5
10^4
10^3
10^2
55
60
65
70
75
80
INV
UT (HMS)
MLT
B
SOLAR X-RAYS

FIGURE 3



(McDiarmid and Burrows, 1964a)

FIGURE 4

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Security Classification

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13. ABSTRACT

The relationship of locally mirroring and precipitating ≥ 40 keV electrons was studied on magnetically quiet days at the high latitude outer zone boundary with satellite Injun 3. There was usually an enhancement of precipitating ≥ 40 keV electrons observed at the high latitude boundary for all local times. On the night side the flux of ≥ 40 keV electrons was always observed to approach isotropy over the upper hemisphere at the position of the satellite at this boundary. The condition of isotropy at the boundary was found to be strongly dependent on local time, being always present on the night side and being less frequently observed

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14. KEY WORDS	LINK A		LINK B		LINK C	
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with increasing local time around to local dusk (1800 hours) where isotropy was seldom observed at the boundary. During magnetically quiet periods large intensities of ≥ 40 keV electrons were observed precipitating into the atmosphere for $\Lambda \geq 65°$ and the position of the high latitude boundary (intensity cutoff) was observed to vary by $\Delta\Lambda \simeq 7°$ while little magnetic activity was occurring. On the night side the latitude where the ratio of the trapped to the precipitated ≥ 40 particle fluxes breaks toward one (φ-boundary) is introduced as a more meaningful concept of the high latitude limit to durably trapped ≥ 40 keV electrons than the usual intensity cutoff and the concept that the high latitude outer zone boundary at all local times is controlled or driven by a mechanism(s) acting primarily on the night side is introduced.