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Satellite Observations of Polar, Magnetotail Lobe, and Interplanetary Electrons at Low Energies

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Interim Report

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This technical report has been reviewed and is approved for publication. Publication of this report does not constitute Air Force approval of the report's findings or conclusions. It is published only for the exchange and stimulation of ideas.

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Low altitude satellite observations of the low energy electron fluxes that populate the polar regions are summarized and classified into two groups: 1, the very low intensity distributions and 2, the more intense, often structured distributions observed during magnetically disturbed conditions. High altitude observations of electron fluxes, including the solar wind and the tail lobes, are presented to suggest that class 1 observations are the result of direct access of interplanetary electrons through the lobes into the polar regions. Class 2 observations may be due in part to magnetospheric processes.

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SUMMARY

The purpose of this topical review is to summarize the diverse observations of polar electron fluxes that has appeared in the literature over the past 4 to 5 years. We have included our interpretation of this important magnetospheric phenomenon in order to stimulate more complete and coordinated studies.

PREFACE

We would like to thank E. W. Hones, Jr., R. E. McGuire, R. P. Lepping, D. M. Yeager and C. -I. Meng for the use of their data and/or figures in this report. We would also like to thank M. Schulz for many helpful discussions. The 72-1 data analysis was performed with the assistance of G. Boyd, D. R. Croley, L. Friesen, H. Hilton and A. L. Vampola.

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FIGURES

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I. Introduction

Low energy polar electrons are found at invariant latitudes above the quiet time dayside cleft whose high latitude boundary varies between $78^\circ \leq \Lambda \leq 80^\circ$ as a function of local time (Winningham, 1972). The nightside termination of the polar fluxes is the high latitude boundary of the plasma sheet (Winningham et al., 1975). The magnetic field lines from the earth's polar caps extend into the magnetospheric tail lobes (see Figure 1) where the plasma density and temperature are low. These are the same field lines where energetic charged particles are found following solar flares and constitute a topologically important region of the earth's magnetosphere. Measurements of the low energy polar electrons over the past few years have yielded a set of seemingly unrelated data. The various measurements were taken with different instrumentation, at different times, and under different magnetospheric conditions. As a result, intercomparison between different observations is difficult and the drawing of consistent conclusions virtually impossible.

The purpose of presenting a topical review covering a relatively new subject is twofold: 1) to find and assimilate the various published results and put them together into a coherent presentation before the task becomes monumental; 2) to suggest approaches for future analysis in order to utilize the data more effectively. It is the intent of this review to present data from as many experiments and satellites as possible that have dealt with the polar and tail lobe electron distributions. We do this, in as consistent a manner as possible, to understand the present status and to build a foundation on which future studies can begin. We shall attempt to maintain a chronological sequence whenever possible within the limitations of providing a consistent, simple picture.

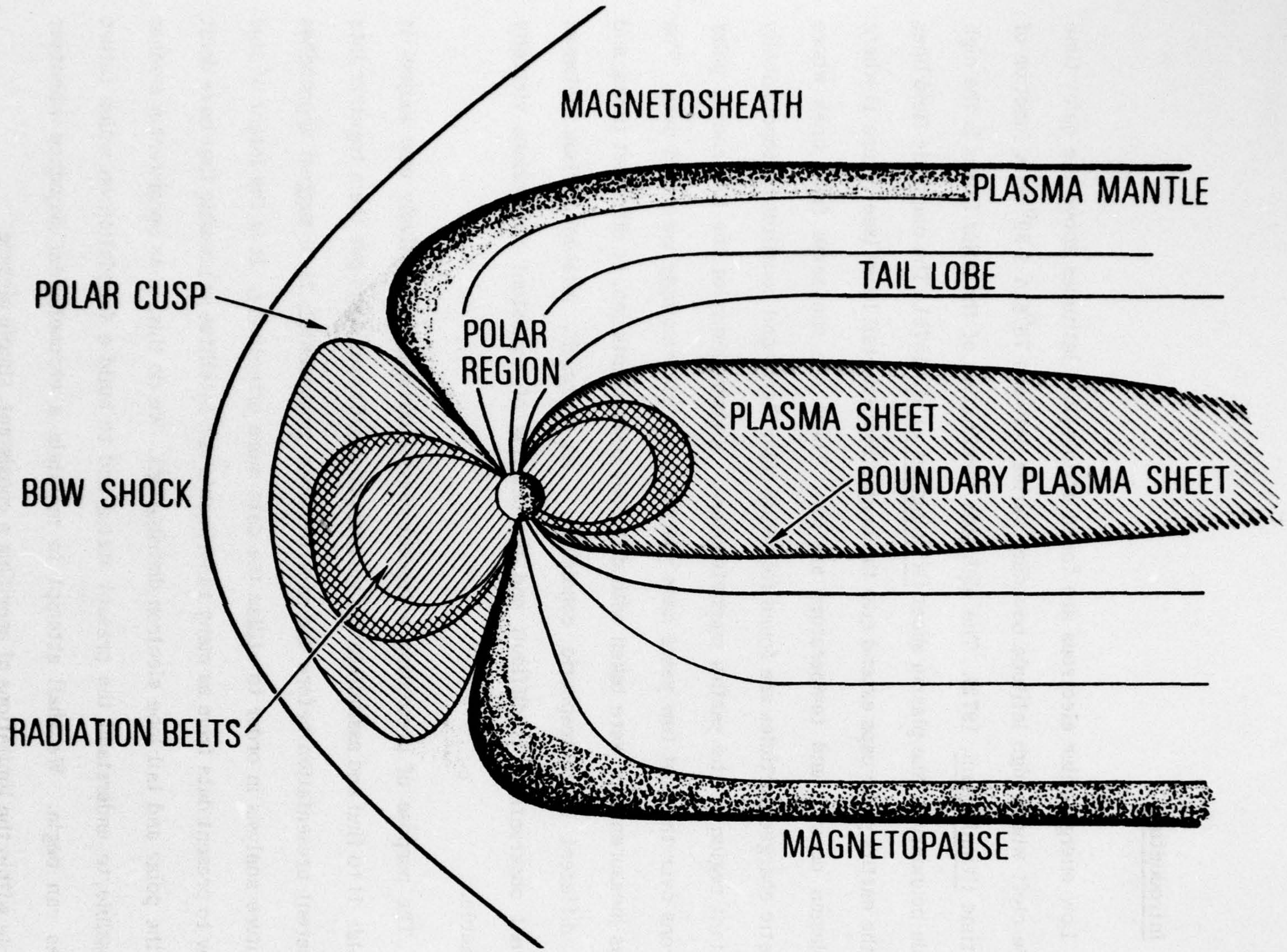

Fig. 1. Schematic diagram showing the relationship between the polar region, the tail lobe and other magnetospheric regions.

Publications of measurements of the low intensity polar electrons are only recently coming to light because comprehensive studies are difficult to make. The sensitivities of past satellite instruments are often insufficient to adequately observe the typical fluxes found in the polar regions. The reasons for studying the low energy polar electrons are that such electrons are continuously present under various magnetic conditions and have small gyroradii (~ 4-6 km for 300 eV electrons in the magnetotail lobes). These properties of the polar electrons allow sensitive probing of magnetospheric boundaries almost continuously.

The low energy polar electrons are found in a region of the magnetosphere that is an interface with a variety of plasma distributions. Figure 1 schematically shows the polar region, it's extension into the tail lobe and the important plasma regimes that surround it. On the dayside the polar cusp (cleft) is the boundary. The plasma mantle is the upper boundary of the tail lobe where the field lines inside the magnetopause are swept back to the tail (Rosenbauer et al., 1975; Sckopke et al., 1976). The lower boundary of the tail lobe is the plasma sheet.

II. Polar Electron Spectra

The common feature among the published data on low energy polar electron fluxes is the differential spectrum. Figure 2 summarizes the published data in a concise way. These spectra represent measurements taken from satellites in the solar wind, tail lobes and the earth's polar regions. Although the average spectra in Figure 2 vary in intensity by 3 to 4 orders of magnitude between each other, we suggest a classification into two types consisting of 1) the more common, low intensity electron fluxes and 2) the high intensity, often structured electron fluxes.

The bottom six distributions in Figure 2 are the quiet-time low intensity electrons most frequently found in the polar regions. The Vela spectra (Akasofu et al., 1973; E. W. Hones, Jr., private communication) are solar wind and lobe (high latitude tail) electron fluxes. The IMP-5 distributions were presented by Yeager and Frank (1976, their Figure 8) and represent the maximum and minimum of the north polar electron fluxes over a ten month period in 1970. A strong correlation between interplanetary magnetic field (IMF) sectors and the lobe intensities was found by Yeager and Frank (1976) and will be discussed later. The 72-1 satellite (1972-76B) data were presented in Mizera et al. (1974) and Fennell et al. (1975, herein called FMC) and are for magnetically quiet periods in 1972.

The Vela lobe distributions (shown in Figure 2 as a horizontal grid) represent typical tail lobe electron distributions (Akasofu et al., 1973). The solar wind and southern lobe Vela spectra shown in Figure 2 were taken on October 6 and 7 1972 during an extremely quiet magnetic period (E. W. Hones, Jr. private communication). The 72-1 distributions were taken over the south polar cap during October 5, 6, and 8 1972 (FMC). In general,

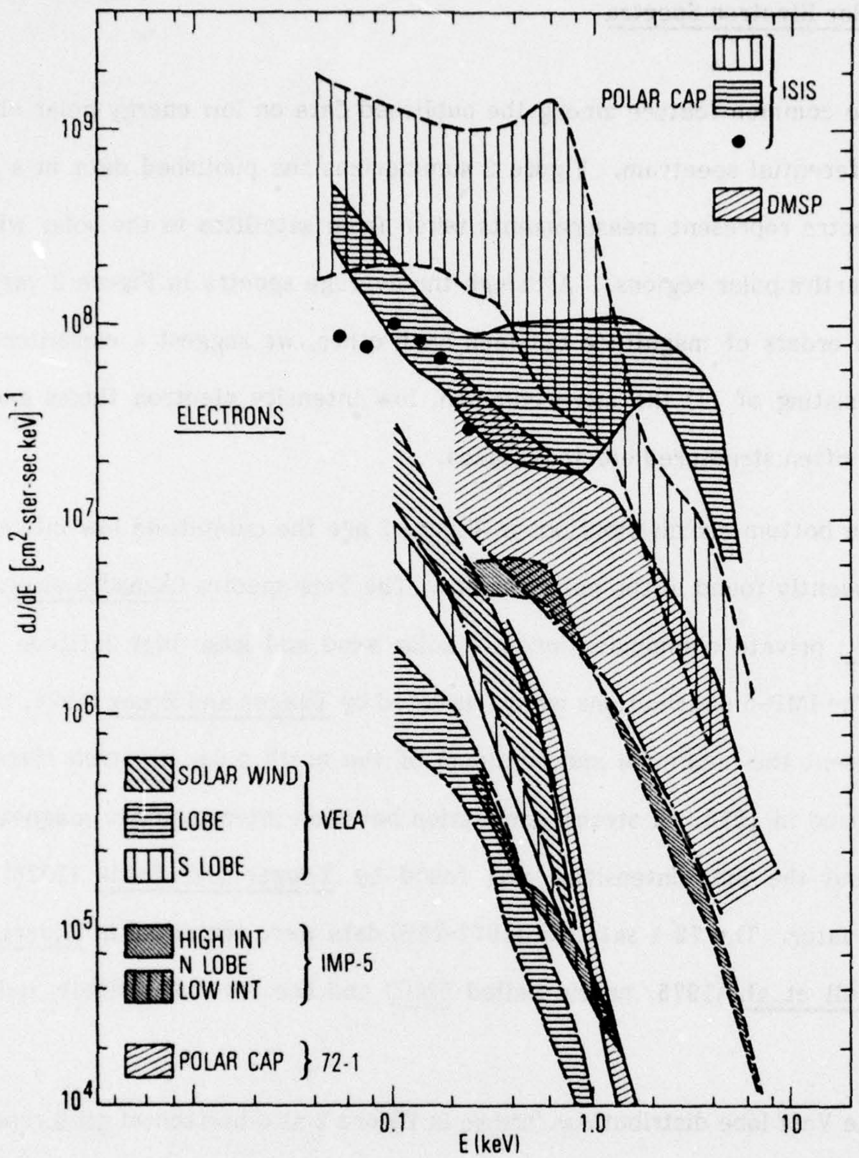

Fig. 2. Low energy electron spectra taken by the near earth polar orbiting satellites, DMSP, ISIS and 72-1 and the high altitude satellites, IMP-5, Vela 5 and Vela 6. These spectra represent interplanetary, tail lobe and polar cap electron measurements taken from material covered in this review.

the solar wind and south lobe average spectra and the 72-1 average polar spectra were within a factor of ~5 in intensity for the four day quiet period in October 1972. These data are also seen to lie between the two extremes of the IMP 5 distributions, that cover a ten month time period.

The highest intensity spectra in Figure 2 were taken on the ISIS-1, ISIS-2 and DMSP-32 polar orbiting satellites. Winningham and Heikkila (1974), using ISIS-1 data, first pointed out the structureless low energy (~100-200 eV) polar electron population that they termed the polar rain (shown in Figure 2 as solid circles). Occasionally they encountered an energized polar electron distribution that was highly structured and thought to be associated with sun aligned polar cap auroral arcs. They called such distributions polar squalls, which are designated by the upper horizontal grid in Figure 2. Foster and Burrows (1976) have presented ISIS-2 data for uniform but intense electron fluxes (shown as the upper vertical grid) following large magnetic storms. Meng and Kroehl (1977) recently published DMSP electron data (shown as upper diagonal lines) for times during magnetic storms, which show enhanced fluxes uniformly distributed over the polar caps. We note that the DMSP spectra, in Figure 2, match up well with the polar rain spectrum at low energies. We categorize the enhanced polar fluxes separately from the quiet low intensity electron fluxes.

III. Correlative Polar, Tail-Lobe, and Interplanetary Electron Observations

A quantitative study was performed between the 72-1, Vela and Apollo 15 satellite electron measurements (see FMC). The results of the study showed the tracking of the polar and interplanetary electron fluxes for electrons with energies of ~0.3 to 1.0 keV. The comparison with the Vela and Apollo 15 interplanetary measurements led these authors to conclude that the electron distributions with energies above a few hundred eV were virtually the same in the solar wind, in the high latitude tail (lobe) and in the polar regions. This result is crucial to any discussion of the access of interplanetary electrons to the polar cap field lines. It should be noted that Foster and Burrows (1976, 1977) found that high intensity polar electron fluxes (e.g. Figure 2) following a large magnetic storm were not observed in the interplanetary medium.

Correlations with interplanetary, high latitude tail, and polar electron spectra were made between the Vela satellites (E. W. Hones, Jr., private communication) and the 72-1 satellite on October 7, 1972. These data are reproduced in Figure 3 (taken from FMC). Prior to an interplanetary flux enhancement, the Vela 6B satellite measured the solar wind electron spectrum (SW 2100 UT). The Vela 6A satellite measured electron fluxes in the south tail lobe (HLT 2125 UT) while the 72-1 satellite data were taken in the north polar region at 2118 UT. The agreement between the solar wind and the high latitude tail distributions and the north polar distribution is excellent prior to an interplanetary magnetic field (IMF) direction change near 2120 UT (left panel of Figure 3). The IMF intensity measured by IMP-7 (R. Lepping private communication) decreased by ~50% and the direction changed from northward to southward. The next Vela 6B distribution (SW 2140) showed a significant enhancement (~factor of 3) in the solar wind electron flux.

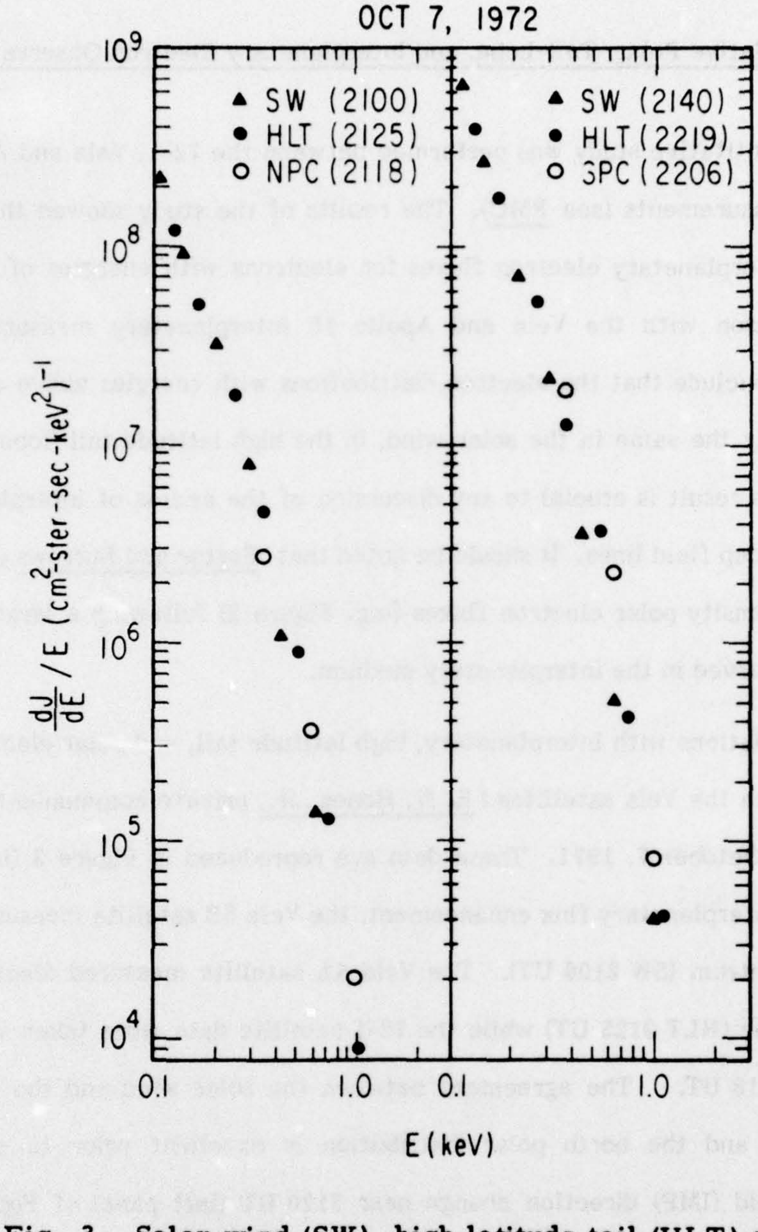

Fig. 3. Solar wind (SW), high latitude tail (HLT) and polar cap (PC) distributions taken by the Vela 6A, Vela 6B and the 72-1 satellite on October 7, 1972. These data cover times spanning an IMF change at 2120 UT measured by the IMP-7 satellite (after Fennell et al., 1975).

Vela 6A's distribution also showed a similar electron flux increase in the south tail lobe (HLT 2219 UT). The south polar electron flux (SPC 2206 UT) showed an enhancement by as much as a factor of 4-6 over the previous north polar traversal. These data are shown in the right panel of Figure 3. This single example demonstrated a direct access of interplanetary electrons into the tail lobe and to the polar cap, at least for energies above 0.3 keV (FMC).

IV. Polar Intensity Variations and Intensity Asymmetries

The polar electron intensities are highly variable with time. Yeager and Frank (1976) reported that the differential fluxes of ~ 400 eV electrons measured by IMP-5 varied by as much as a factor of ~ 50 in orbit-to-orbit comparisons (3.4 days per orbit). These variations are shown in Figure 4, which is reproduced from their paper. They also found that the intensity changes during the individual IMP-5 traversals of the high altitude polar regions (reference their Figure 7) were comparable to the orbit-to-orbit intensity variations. Yeager and Frank (1976) found that these orbit averaged intensity variations correlated with the direction of the IMF. This correlation is evidenced by the shading in Figure 4 which marks the periods when the IMF direction was predominantly antisolar. The major result of Yeager and Frank (1976), summarized in our Figure 4, shows that the northern polar cap intensities are high during the 'away' sectors and low during the 'toward' sectors. Similar IMF correlations were reported by Mizera et al., (1974), Fennell et al., (1975), and Meng and Kroehl, (1977), using low altitude satellite data.

Yeager and Frank (1976) posed a question: are the temporal variations of electron intensities out of phase in the northern and southern polar regions? The answer is yes and is provided by the low altitude satellite observations discussed below. The IMP-5 observations were limited to the northern polar regions and couldn't provide the answer. The question is relevant to the source of the tail lobe fluxes and whether the electron intensities in both the northern and southern tail lobes are controlled by the IMF direction. Since the tail lobe field lines map to the polar regions (ref. Figure 1), it would be expected that the electron fluxes measured over the polar caps are representative of the tail lobe fluxes. As was shown above in Figure 3, the tail lobe fluxes and polar fluxes agree well with each other.

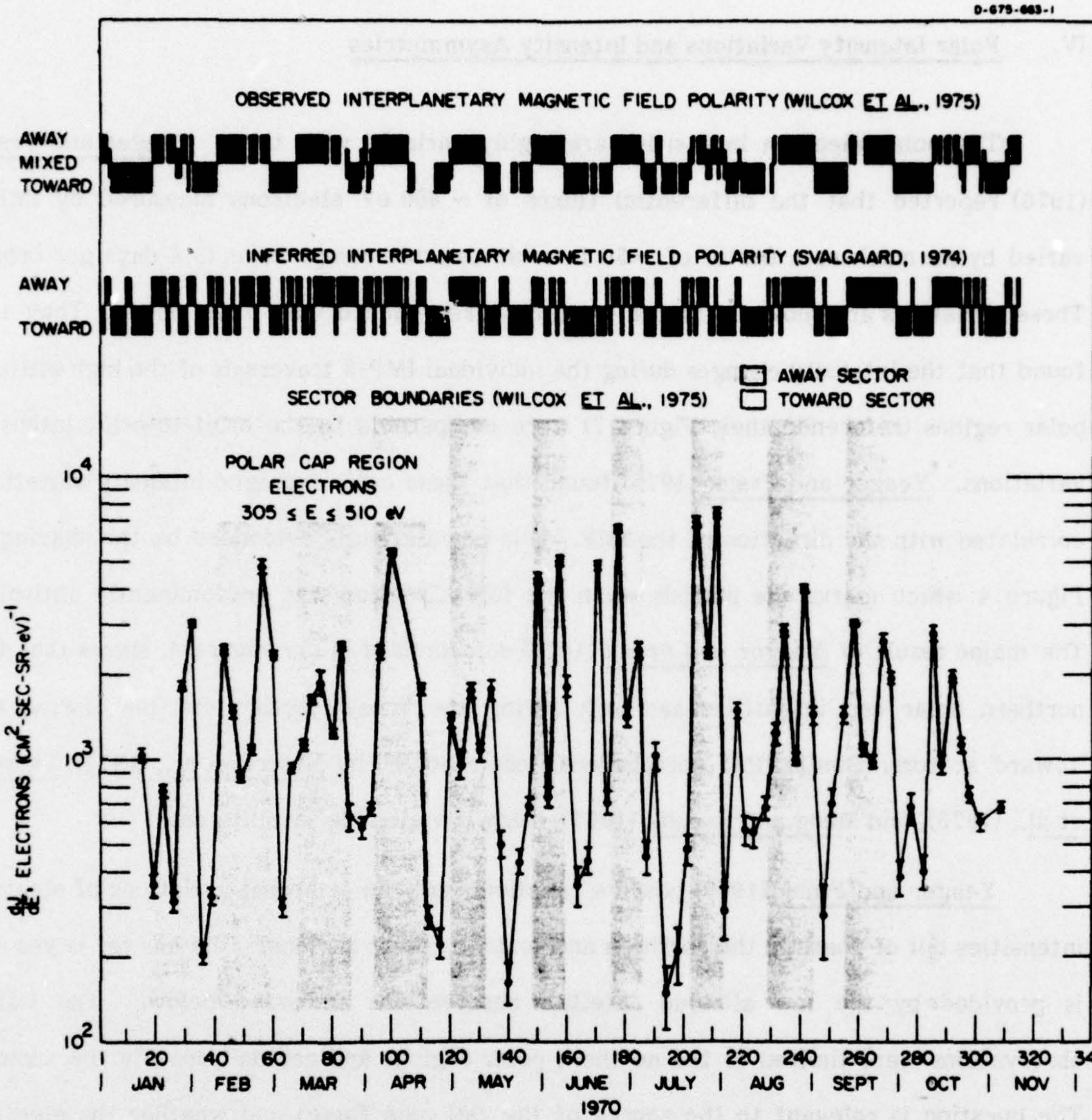

Fig. 4. In the bottom panel, average polar electron flux for the period January through October 1970 from IMP-5 in the northern high altitude polar region. The shaded bars denote IMF 'away' sectors. In the top panel, the observed and inferred IMF polarities. This figure is taken from Yeager and Frank (1976).

The low altitude satellites ($\sim$750-850 km altitude for 72-1 and DMSP) traverse the northern and southern polar regions approximately every $\sim$ 1.5 hours. Thus the low altitude satellites follow the intensity variations over both poles 'simultaneously' and, if the geometric factors of the instruments are large enough, provide observations of the intensity variations across the polar caps.

Measurements from the 72-1 and DMSP satellites showed that there are large temporal variations in the polar electron intensities and that there are also large north to south intensity differences. Figures 5a (from the 72-1 satellite) and 5b (from the DMSP satellite) show the north and south pole electron intensities for several days in 1972 and 1974 respectively. The DMSP data were taken from Meng and Kroehl (1977) and the 72-1 data from FMC were replotted in the same format as the DMSP data. Both sets of polar electron data evidence large intensity variations with time in a manner suggestive of the intensity variations observed by Yeager and Frank (1976), as shown in Figure 4. The data in Figure 5 also show that strong north/south intensity asymmetries exist, that the north and south polar intensities have similar temporal variations, and that sometimes the north and south polar intensities are virtually the same. These features indicate that the north and south polar intensities vary in a manner that is consistent with their having a common source. This is in agreement with the conclusion drawn from Figure 3 that the common source is the interplanetary electrons.

The analysis of the north/south polar intensity asymmetries was carried one step further by Fennell et al. (1975) (reference their Figure 6) and has been expanded and reproduced here in Figure 6. The north/south intensity ratios were formed from data taken during the same satellite orbit and were compared with the observed interplanetary magnetic field direction from King (1975). The ratios are divided into bins of equal width

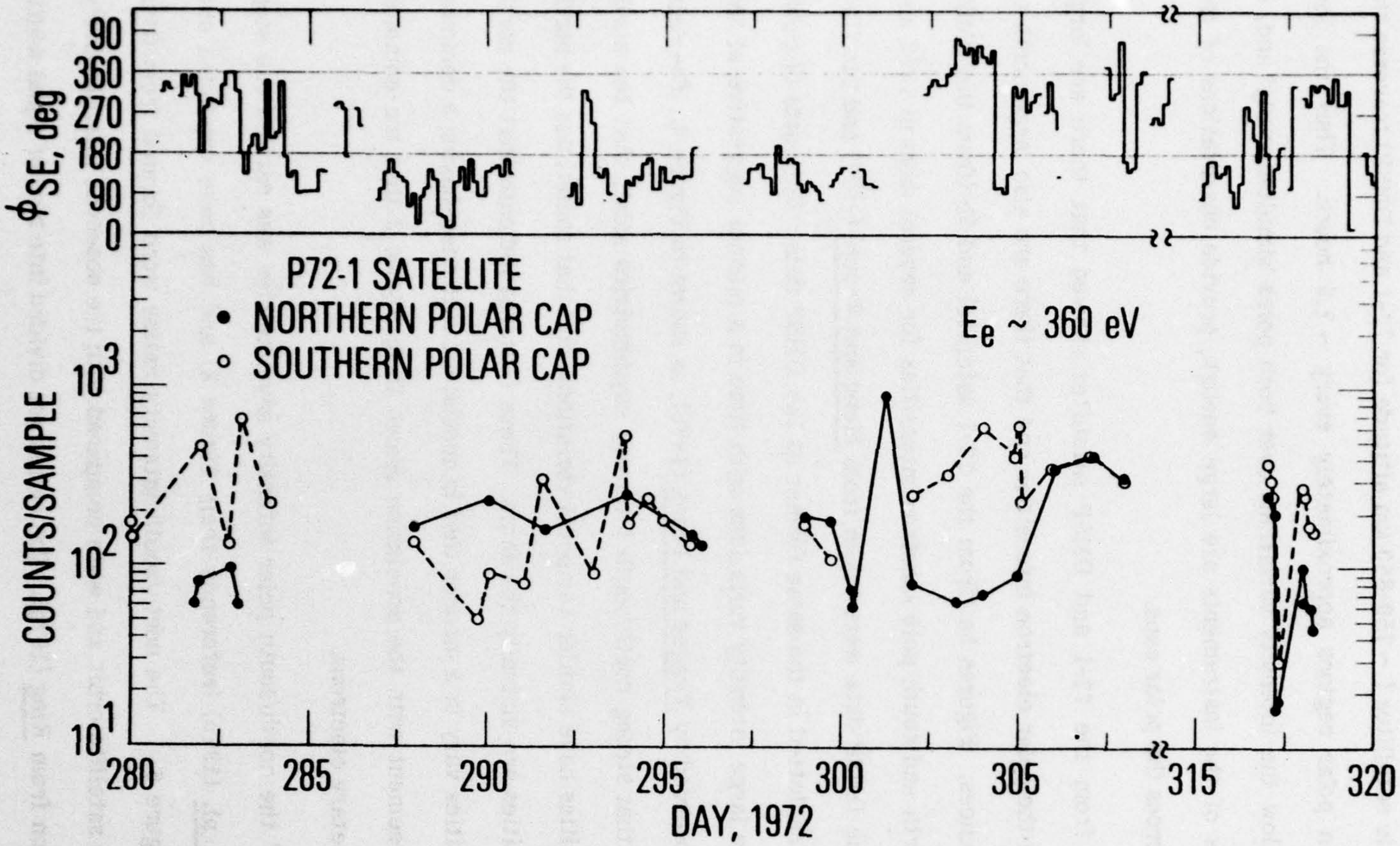

Fig. 5a. In the bottom panel, average north and south polar electron intensities are shown for October and early November 1972 from the 72-1 satellite. The upper panel shows the observed IMF direction in the ecliptic plane (King, 1975).

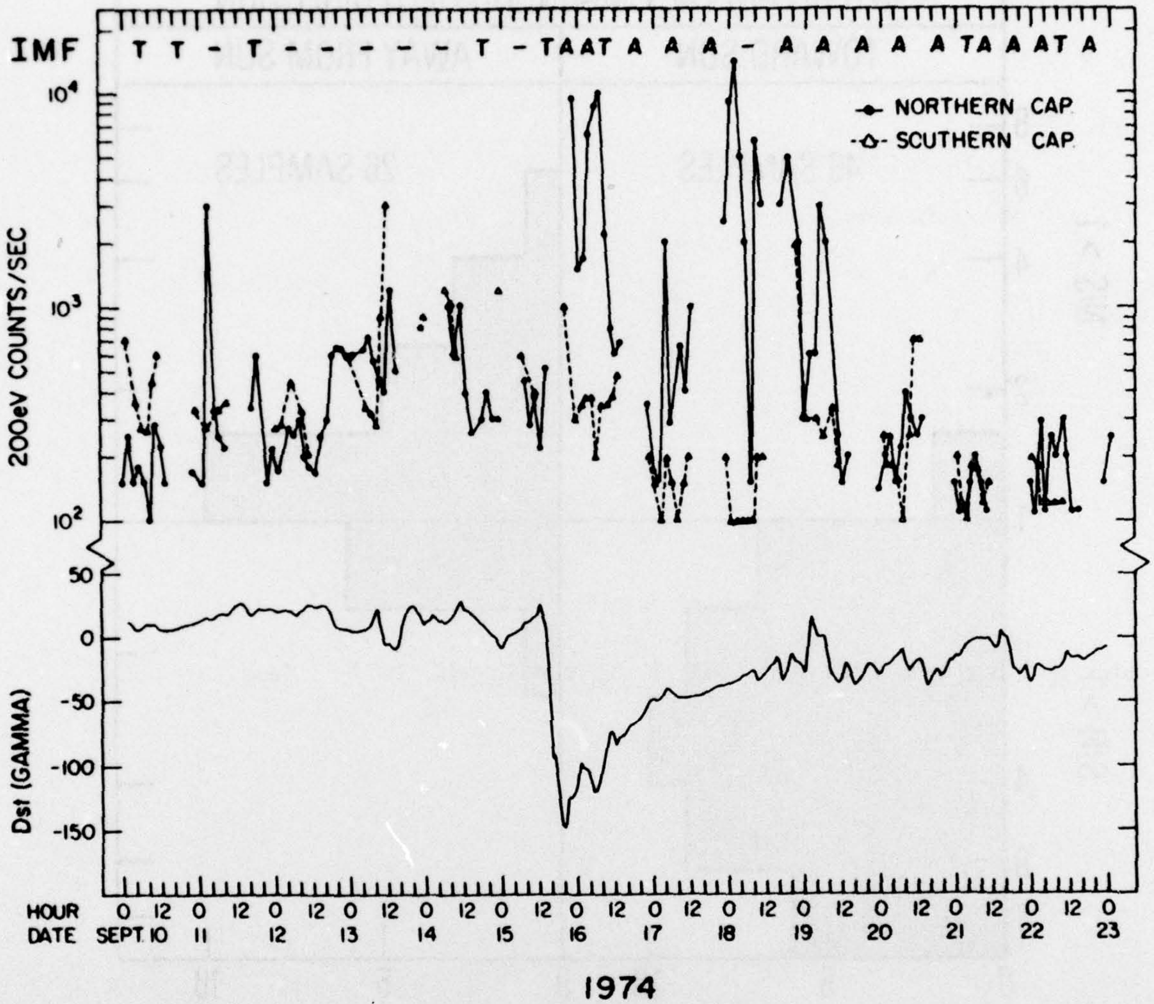

Fig. 5b. In the upper panel, the average north and south polar electron intensities are shown for September 10 - 22 1974 from the DMSP satellite (Meng and Korehl, 1977). In the lower panel, D_{st} is shown for the same time period.

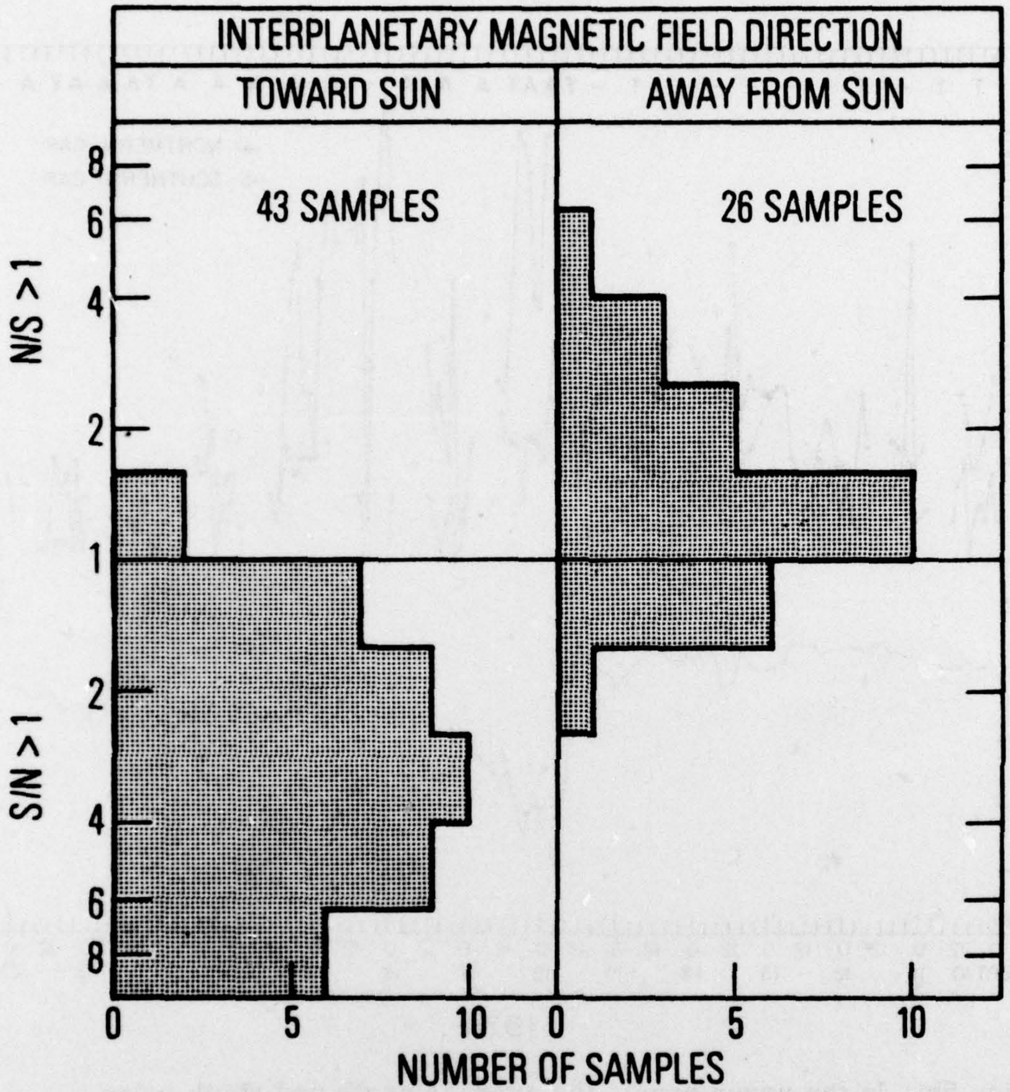

Fig. 6. Comparison of north/south (N/S) and south/north (S/N) polar electron intensity asymmetries (from 72-1 and DMSP satellites) with the interplanetary magnetic field direction (after Fennell et al., 1975).

on the vertical logarithmic scale. This figure summarizes the kind of data which are presented in Figure 5. Figure 6 shows that the north polar electron flux is generally greater than the south polar flux when the data are taken during 'away' interplanetary sectors and that the south polar flux is greater than the north polar flux during 'toward' sectors. Such ratios were interpreted (FMC) as evidence of direct access of anisotropic interplanetary electrons to the earth's polar caps via the magnetotail. Such interpretation requires that the *IMF and geomagnetic fields* be interconnected, as in an open magnetosphere, and that the low energy electron anisotropy be directed along the IMF and away from the sun. Such interplanetary electron anisotropies are known to exist and are of the same magnitudes as the observed north/south polar electron intensity ratios (for examples of interplanetary electron anisotropies see Frank and Gurnett, 1972; and especially Feldman, et al., 1975). Similar north/south polar intensity differences have been observed in solar flare protons arriving over the earth's polar caps and have been found to correlate with the IMF direction and interplanetary proton anisotropy in the same way as the polar electrons (see Fennell, 1973; and the review by Paulikas, 1974 and references therein).

The class 2 observations (see Sec. II) of Foster and Burrows (1976), Meng and Kroehl (1977) and Winningham and Heikkila (1974) suggest a relationship between the polar electron intensity and magnetically disturbed conditions. However, Yeager and Frank (1976) found no correlation between magnetic activity and polar electron intensities at high altitudes. The class 1 observations of 72-1 were taken only during magnetically quiet times (FMC) and show the same range of intensities as the IMP-5 data of Yeager and Frank, (1976). This limited set of observations indicates that there may be a relationship between the polar electron intensity and magnetic activity only at low altitude. Correlations should be made between the polar, tail lobe and interplanetary electron fluxes during both magnetically quiet and disturbed periods to test this possibility. The interplanetary measurements must be made in order to separate the interplanetary flux changes from magnetospheric effects in the polar and tail lobe regions.

The correlation of polar electron intensities with the IMF direction (ref. Figures 4, 5 and 6) suggests that the polar intensity variations are related to the variations of the interplanetary electron fluxes and their access to the magnetosphere. Yeager and Frank (1976) concluded that their minimum fluxes were considerably lower than those of the solar wind. There is evidence that solar wind electron fluxes are sometimes comparable to the polar electron fluxes as shown by the data in Figures 2 and 3. This further emphasizes the need for simultaneous interplanetary and magnetospheric observations.

Some of the Class 2 polar electron flux measurements (see Sec. II) show evidence that the low altitude polar electrons have been accelerated earthward (Winningham and Heikkila, 1974; Foster and Burrows, 1976 and 1977; Meng and Kroehl, 1977). Such accelerations are evidenced by weak field alignment of the angular distributions and/or a hardening of the electron spectra over some regions of the polar cap. Intense spikes of electron fluxes are observed superimposed on the uniform low intensity polar fluxes. These intensity spikes have been associated with 'sun-aligned' auroral arcs over the polar caps (Winningham and Heikkila, 1974; Foster and Burrows, 1976). Recent observations from the S3-3 satellite of upward flowing ions simultaneous with intense precipitating electron spikes over the polar regions (Fennell et al., 1977; Mizera and Fennell, 1977) indicate that the particle accelerations occur fairly close to the earth. While these recent observations tend to corroborate isolated polar flux accelerations they do not explain the uniformly distributed accelerated fluxes discussed by Foster and Burrows (1977). More study is required for the more intense events (see Figure 2) before firm conclusions can be drawn.

The next topic for consideration involves observations by Meng and Kroehl (1977) of an equatorward cutoff of the polar electron intensity (see their Figure 1 and Table 1) poleward of the local evening auroral precipitation, and of dawn to dusk gradients in the polar electron intensity (see also Meng et al., 1977). An equatorward cutoff of the polar electron flux has also been observed by Winningham and Heikkila (1974). Meng and Kroehl (1977) have interpreted the equatorward cutoff as a definition of the boundary of the "open" field line region, based on the assumption that the polar electrons are interplanetary in origin. The intensity gradients in the observations of Meng and Kroehl (1977) were such that the local morning fluxes were factors of 3 to 4 times the local evening fluxes at 200 eV (see their Figures 5 and 7).

In a recent paper, Meng et al. (1977) examined the dawn-dusk asymmetries of the polar electron fluxes in more detail. They found that in 89% of the polar traversals examined there was a correlation between the direction of the electron intensity gradient and the IMF B_y component. The polar electron intensities decreased from dawn to dusk over the north pole for positive B_y and dusk to dawn for negative B_y. The south pole electron fluxes showed intensity gradients opposite to those in the north pole. Hardy et al. (1976) found a similar correlation between the IMF B_y component and the appearance of lobe plasma in the distant tail ($\sim 60\ R_e$).

Meng et al. (1977) noted that the intensity gradients in the polar electron precipitation pattern are very similar to the electric field distribution along the dawn-dusk meridian observed on OGO-6 (Heppner, 1972). Heppner (1972) found that the electric field intensity in the polar cap showed marked asymmetry. The field intensity had a maximum on either the dawn or dusk side of the polar cap with the position of the maximum showing a strong correlation with the IMF B_y component (see Figures 5 to 7 in Heppner, 1972).

The tail lobe plasma observations of Hardy et al. (1976) are also consistent with a non-homogeneous electric field across the tail lobes.

Stern (1973) has attempted to explain the asymmetric polar electric fields in terms of the properties of an open magnetosphere model (for more on the electric fields see review by Stern, 1977). In an open field model one would expect to observe a dependence of the polar electron intensity on the IMF sector polarity, as discussed above. Yeager and Frank (1976) discussed their observations in the context of Stern's (1973) model and while they did observe the predicted correlation between the electron intensity and the IMF sector direction they did not find a dawn-dusk intensity asymmetry which should result from the asymmetric electric fields. The apparent discrepancy between the low altitude polar, magnetotail and high altitude polar observations that relate to dawn-dusk intensity asymmetries remains to be resolved. Also, any attempt to correlate the low altitude polar dawn-dusk intensity asymmetries directly to the polar electric fields requires simultaneous observations of the particles and the fields.

V. Discussion

The main points covered above can be enumerated as follows:

1) The polar electron distributions from ~ 100 eV to ~ 1-10 keV are subdivided into two classes: 1) low intensity, structureless fluxes that are at or near the sensitivity limits of most satellite instruments, and 2) high intensity, often accelerated fluxes, that appear to result from global magnetic disturbances.

2) Asymmetric north/south polar fluxes are correlated with the IMF sector direction. 'Away' sectors correspond to higher intensities in the north and 'toward' sectors correspond to higher intensities in the south polar regions.

3) The temporal and spatial polar electron flux changes, other than IMF related variations, may result from source variations and/or near earth acceleration processes.

4) Tracking of the low intensity north and south polar electron fluxes with interplanetary intensities suggests that there is direct access of interplanetary electrons into the tail lobes and to the polar caps.

5) There are observations of flux gradients that are related to the IMF B_y component and which may be related to the polar electric field. There are also the observations of an equatorward cutoff of the polar electron fluxes which may delineate the boundary of the open/closed field line regions.

For observations covering a period of only 3-4 years, the above list is rather impressive. However, the study of polar electrons is in its preliminary stages. It is yet to be shown that the solar wind electrons have access to the near earth's polar regions at all energies. There are a number of definitive correlations that can be made with existing satellite data that would address the topological aspect of polar electron entry. The magnetospheric electric field must be considered in any study of the access of electrons to the tail lobe and polar regions. A study of the configuration of the IMF as well as the interplanetary electron intensities and angular distributions must be a part of any comprehensive survey of polar and tail lobe electron fluxes.

The question of the existence of ion fluxes in the polar regions is an open one. Only upper limits of the low energy proton fluxes are available at this time. For example, Winningham and Heikkila (1974) rarely saw evidence of protons while Yeager and Frank (1976) never observed protons. Nevertheless, it has been shown that solar protons with energies down to 12.4 keV have access to the earth's polar region (Mizera et al. 1972). It would be useful to determine the flux of protons, or at least set a hard upper limit at solar wind energies in order to characterize the solar wind access across the magnetospheric boundaries.

We would strongly suggest that experimenters re-examine the vast amount of measurements already taken that are relevant to studies of the sources of electrons for the polar and tail lobe regions. Future satellite programs that stress simultaneous measurements in the interplanetary region, the magnetospheric tail and the near earth environs should be tasked with addressing this subject.

References:

Akasofu, S.-I., E. W. Hones, Jr., S. J. Bame, J. R. Asbridge, and A.T.Y. Liu, Magnetotail and boundary layer plasmas at a geocentric distance of 18 R_E: Vela 5 and 6 observations, J. Geophys. Res., 78, 7257, 1973.

Feldman, W. C., J. R. Asbridge, S. J. Bame, M. D. Montgomery, and S. P. Gary, Solar Wind Electrons, J. Geophys. Res., 80, 4181, 1975.

Fennell, J. F., Access of solar protons to the earth's polar caps, J. Geophys. Res., 78, 1036, 1973.

Fennell, J. F., P. F. Mizera, and D. R. Croley, Jr., Low energy polar cap electrons during quiet times, Proc. 14th Int. Cosmic Ray Conf., 4, MG8-3, 1267, 1975.

Fennell, J. F., P. F. Mizera, and A. L. Vampola, Energetic particle distributions in and near the auroral regions, EOS, Trans. AGU, 58, 472, 1977.

Foster, J. C. and J. R. Burrows, Electron fluxes over the polar cap 1. Intense keV fluxes during poststorm quieting, J. Geophys. Res., 81, 6016, 1976.

Foster, J. C. and J. R. Burrows, Electron fluxes over the polar cap II. Electron trapping and energization on open field lines, J. Geophys. Res.., to be published, 1977.

Frank, L. A. and D. A. Gurnett, Direct observations of low energy electrons associated with type III solar radio bursts, Solar Physics, 27, 446, 1972.

Hardy, D. A., J. W. Freeman, and H. K. Hills, Plasma observation in the magnetotail, Magnetospheric Particles and Fields, ed. by B. M. McCormac, P. 89, D. Reidel Publ. Co., Boston, 1976.

Heppner, J. P., Polar cap electric field distributions related to the interplanetary magnetic field direction, J. Geophys. Res., 77, 4877, 1972.

King, J. H. Interplanetary magnetic field data book, National Space Science Data Center, NSSDC 75-04, GFSC, Greenbelt, Md., 1975.

Meng, C.-I., S.-I. Akasofu, and K. A. Anderson, Dawn-dusk gradient of the precipitation of low energy electrons over the polar caps and its relation to the interplanetary magnetic field, J. Geophys. Res., to be published, 1977.

Meng, C.-I. and H. W. Kroehl, Intense uniform precipitation of low-energy electrons over the polar cap, J. Geophys. Res., 82, 2305, 1977.

Mizera, P. F., J. F. Fennell, and J. B. Blake, Polar-cap measurements of solar-flare protons with energies down to 12.4 keV, J. Geophys. Res., 77, 4845, 1972.

Mizera, P. F., J. F. Fennell, and D. R. Croley, Jr., Quiet-time polar cap electrons, EOS, Trans. AGU, 56, 1175, 1974.

Mizera, P. F., and J. F. Fennell, Signature of electric fields from high and low altitude particle distributions, Geophys. Res. Letters, 4, 311, 1977.

Paulikas, G. A., Tracing of high-latitude magnetic field lines by solar particles, Rev. Geophys. and Space Phys., 12, 117, 1974.

Rosenbauer, H., H. Grünwaldt, M. D. Montgomery, G. Paschmann, and N. Sckopke, Heos 2 plasma observations in the distant polar magnetosphere: The plasma mantle, J. Geophys. Res., 80, 2723, 1975.

Sckopke, N., G. Paschmann, H. Rosenbauer, and D. H. Fairfield, Influence of the interplanetary magnetic field on the occurrence and thickness of the plasma mantle, J. Geophys. Res., 81, 2687, 1976.

Stern, D. P., A study of the electric field in an open magnetospheric model, J. Geophys. Res., 78, 7292, 1973.

Stern, D. P., Large-scale electric fields in the earth's magnetosphere, Rev. Geophys. Space Phys., 15, 156, 1977.

Winningham, J. D., Characteristics of magnetosheath plasma observed at low altitudes in the dayside magnetospheric cusps, Earth's magnetospheric processes, ed. by B. M. McCormac, p. 68, D. Reidel Publ. Co., Dordrecht, Holland, 1972.

Winningham, J. D. and W. J. Heikkila, Polar cap auroral electron fluxes observed with Isis 1, J. Geophys. Res., 79, 949, 1974.

Winningham, J. D., F, Yasuhara, S.-I. Akasofu, and W. J. Heikkila, The latitudinal morphology of 10 eV to 10 keV electron fluxes during magnetically quiet and disturbed times in the 2100-0300 MLT sector, J. Geophys. Res., 80, 3148, 1975.

Yeager, D. M. and L. A. Frank, Low-energy electron intensities at large distances over the earth's polar caps, J. Geophys. Res., 81, 3966, 1976.

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