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Variability of Mass Dependence of Auroral Acceleration Processes with Solar Activity

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INTRODUCTION

The objectives of this investigation are to improve understanding of the mass dependent variability of the auroral acceleration processes and so to clarify apparent discrepancies regarding the altitude and local time variations with solar cycle by investigating: (1) the global morphological relationships between auroral electric field structures and the related particle signatures under varying conditions of solar activity, and (2) the relationships between the electric field structures and particle signatures in selected events that are representative of the different conditions occurring during a solar cycle. The investigation is based in part on the Lockheed UFI data base of upflowing ion (UFI) events in the 500eV to 16keV energy range and associated electrons in the energy range 70eV to 24keV. This data base was constructed from data acquired by the ion mass spectrometer on the S3-3 satellite in the altitude range of 1 to 1.3 Re. The launch of the POLAR spacecraft in early 1996 and successful operation of its TIMAS ion mass spectrometer has provided us with data from within the auroral acceleration regions during the current solar minimum. The perigee of POLAR is at about 1 Re, comparable to that of S3-3. The higher sensitivity and time resolution of TIMAS compared to the ion mass spectrometer on S3-3 together with its wider energy range, 15eV to 33keV, facilitate more detailed studies of upflowing ions.

UFI LONG TERM VARIATIONS

We began by investigating the morphological relationship between upflowing ions and parallel (to **B**) electric fields. Upward directed parallel electric fields above the satellite modify the electron pitch angle distributions producing characteristic features. Records of the occurrence of such electron features have been included in the Lockheed UFI data base. This morphological study of the long term variations in energetic UFI and parallel electric fields was conducted. Measurements of energetic UFI above the auroral regions were examined for long term variations in their morphology. The results of this study indicate a decrease in the occurrence frequency of upward flowing ions by more than an order of magnitude between late 1977 and early 1979. Concurrent with this decline, the UFI pitch angle characteristics changed from predominantly field aligned to predominantly conical. Coincident with this the occurrence of parallel electric fields above the satellite in the altitude range from approximately 1 to 2 Re, as indicated by characteristic electron features declined markedly. The scarcity of energetic upward flowing ions in 1979 implies that parallel electric fields involving large (keV) potential drops became rare at altitudes < 1 Re. A plausible interpretation for these observations involves an upward displacement of the parallel electric fields regions to altitudes typically beyond 2 Re. These variations appear unrelated to geomagnetic activity but occur in conjunction with the rising phase of the solar cycle. These observations imply that solar activity has a profound effect on the principal auroral acceleration mechanisms and on the morphology of upward injected ions. A draft of a paper reporting these results has been written and is being readied for publication. This study was originated by Arthur Ghielmetti who has been on extended leave of absence for most of the period covered by this report. In consequence of the absence of this important participant work on this study has proceeded much more slowly than originally anticipated.

UFI Morphology and Plasma Density

A morphological study was conducted to examine the relative spacial and seasonal distribution of UFI's observed from POLAR by TIMAS. Maps of UFI occurrence frequency were constructed by examining each ion pitch angle distribution obtained by TIMAS during crossings of the southern auroral zone at perigee. If the pitch angle distribution was asymmetric and contained a pronounced peak in the upward direction it was identified as upflowing. If the peak fell within about 34° of the field line it was classified as a beam. Otherwise it was classified as a conic. Maps of the UFI occurrence frequency were produced for the southern hemisphere winter (April 15 1996 - October 15 1996) and for the southern summer (October 15 1996 - April 15 1997). The whole of this time period was at solar minimum and geomagnetic activity was generally low.

It was found that upflowing ion conics were most common on the morning side between midnight and noon. The frequency and distribution of conics did not change much with season. In winter ion beams were found throughout the auroral zone but were much more common in the dusk to midnight sector. In summer however, ion beams were relatively rare. Ion beams with energies above about 500eV were found almost exclusively in the premidnight sector.

The maps of UFI occurrence frequency were compared with similar seasonal maps of plasma density which were derived from spacecraft potential measurements obtained by the POLAR EFI. These maps showed the extent of the auroral density cavity and trans-polar depletions. The maps showed the auroral density cavity, which was typically well below 10 cm^{-3}, and trans-polar cap depletion surrounded by the high density plasmasphere below about 65° invariant latitude. The evening auroral cavity was much more pronounced during winter than during summer. The location of the deepest plasma depletion and its seasonal variation closely matched that of the upflowing ion beams thus providing support for the belief that the plasma depletions and ion beams are manifestations of the same auroral process.

Ion beams are associated with $E_{||}$ below the spacecraft while conics imply relatively local perpendicular heating. Yau et al. (JGR, 1985) found that at DE-1 altitudes (8000-23000km) the ion outflow increased in summer and with solar activity. They suggested that increased atmospheric scale height moved the ion source and/or the ion acceleration region to higher altitudes. The marked seasonal variation of ion beam occurrence seen by POLAR implies that the altitude of the lower boundary of $E_{||}$ varies seasonally around $1R_E$.

INDIVIDUAL UFI EVENTS

Individual UFI events in which ion beams reached energies of at least 600eV were selected for more detailed examination. For each of these events estimates were made of the ion upward fluence (the ion contribution to the total parallel current), the plasma density estimated from the spacecraft potential measured by EFI, $N_{s/c}$, and the partial densities of ions, N_{Ion}, in the TIMAS energy range, 16eV-33keV. In all these events the upflowing ions were observed to occur within the region of the density depletion. Outside of the deepest part of the depletions N_{Ion} was always very much lower than $Ns_{/c}$ indicating that there almost all the ion plasma density was contributed by ions outside, and probably below, the TIMAS energy range. However, there was no clear correspondence between the intensity of the ion outflow (fluence) and the depth of the depletion. Indeed it was difficult to find two events which resembled one another. Events were found in which the ion fluence was concentrated in narrow regions aligned with the deepest plasma depletions while in other events the most intense fluence was at the edges of the depletion and was reduced at its center while in some a broad region of high fluence spanned the depletion. The ion fluence was composed of either beams or conics in different parts of the depletion region without any clear pattern.

Some events were found in which N_{Ion} and Ns/c were comparable. In these events the velocity space distributions of the ions within the plasma depletion indicated that the UFI's were clearly defined beams. Evidently all the upflowing ions had been accelerated through a substantial $E_{||}$ and probably originated from well below POLAR. In another event N_{Ion} was less than a third of $Ns_{/c}$, indicating the presence of a substantial proportion of ions <16eV. The velocity space distributions of the upflowing ions in that event did not show a beam, but rather that the H+ was 'streaming' with a wide range of velocities suggesting that thermal ions may have been picked up over a wide range of altitudes, or that the upflow originated as a conic at a much lower altitude.

Presentations describing the individual UFI events and the relationship between the UFI morphology and plasma density depletions were given at the 1997 Spring Meeting of the American Geophysical Union and at the 8th Scientific Assembly of the International Association of Geomagnetism and Aeronomy in Uppsala, Sweden.

PRESENTATION GIVEN AT THE 1997 SPRING MEETING OF THE AMERICAN GEOPHYSICAL UNION

Upflowing Ions and Auroral Plasma Density Depletions

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The plasma density depletions which occur over the auroral zones are known to be associated with regions of upflowing ions. On the POLAR spacecraft EFI routinely measures the spacecraft potential. Rough estimates of the density can be inferred from the floating potential variation. These variations can be made more quantitative with the HYDRA electron measurements making use of this potential variation up to a time resolution of 1.5 sec. The TIMAS instrument measures energy spectra and instantaneous pitch angle distributions of ions in the 15 eV to 33 keV energy range with 3 second time resolution while HYDRA measures electron distributions over most of this energy range. During perigee passes over the southern polar regions at about 1.8Re density depletions down to a few per cubic centimeter were found which contained considerable fine structure. Simultaneously, upflowing ion beams and conics were observed by TIMAS. We investigate the detailed thermal structure of the plasma found in these cavities.

PRESENTATION GIVEN AT THE 8TH SCIENTIFIC ASSEMBLY OF THE INTERNATIONAL ASSOCIATION OF GEOMAGNETISM AND AERONOMY IN UPPSALA, SWEDEN

Upflowing Ions and Auroral Plasma Density Depletions Observed by POLAR

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