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FINAL REPORT

for the

Continued Reduction and Analysis of Data from the
Dynamics Explorer Plasma Wave Instrument

June 1994

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THE DYNAMICS EXPLORER PLASMA WAVE
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INTRODUCTION

This document constitutes the final report for the NASA Grant No. NAG5-310: Continued Reduction and Analysis of Data from the Dynamics Explorer (DE) Plasma Wave Instrument. This report will summarize the in-orbit operations, data reception and submission, data archiving, and scientific results related to the University of Iowa plasma wave experiments for the time period April 15, 1983 through June 30, 1994.

The University of Iowa Plasma Wave Instrument (PWI) was built by the Department of Physics and Astronomy under the direction of Professor Stanley D. Shawhan, Principal Investigator, under NASA Contract No. NAS5-24294, awarded October 14, 1977 through September 3, 1981. A second NASA Contract NAS5-25690 provided support for pre-launch programming, in-flight operations, and data reduction and analysis from March 5, 1980 through July 31, 1983. Professor Shawhan moved to NASA Headquarters and Professor Donald A. Gurnett was named to succeed him as Principal Investigator in September 1984.

The Plasma Wave Instrument on the Dynamics Explorer-1 spacecraft was designed to provide measurements of the electric and magnetic components of plasma waves in the Earth's magnetosphere. Five antennas were used for performing the plasma wave measurements: a 200-m tip-to-tip electric dipole antenna perpendicular to the spacecraft spin axis; a 9-m tip-to-tip electric dipole antenna parallel to the spacecraft spin axis; a 0.6-m short electric antenna oriented to measure electric fields parallel to the long wire antenna; a search coil magnetometer parallel to the spin axis; and a loop antenna perpendicular to the spin axis.

Signals from these antennas were processed by four receiver systems. When connected to the electric sensors, the Low Frequency Correlator and the Step Frequency Correlator together provided amplitude and phase measurements of electric and magnetic fields over a frequency range of 1 Hz to 410 kHz every 32 seconds. This frequency range includes most of the important characteristic frequencies of plasma encountered along the orbit of this spacecraft. The wideband receiver was designed to transmit wideband waveform signals with bandwidths of 10 or 40 kHz from selected frequencies up to 2 MHz for high-resolution frequency time analysis. The Linear Wave Receiver measured plasma wave amplitudes in the frequency range of 1.5-16 kHz. A description of the PWI and the major subsystems is included in "The Plasma Wave and Quasi-Static Electric Field Instrument (PWI) for Dynamics Explorer-A" by Stanley D. Shawhan, Donald A. Gurnett, Daniel L. Odem, Robert A. Helliwell and Chung G. Park, Space Science Instrumentation, 5, 535, 1981.

The in-orbit operations, government furnished data, data reduction, archiving and data submission to NSSDC, and the scientific results related to the plasma wave experiments will be discussed in Sections I through VI. Section VII lists the publications and abstracts resulting from efforts under this grant. Section VIII lists presentations given during the period of this grant.

I. In-Orbit Operations

Efforts to obtain plasma wave data from the University of Iowa Plasma Wave Instrument on Dynamics Explorer-1 ceased on March 15, 1991, when spacecraft operations were terminated. Throughout the years of DE operations the PWI continued to acquire plasma wave measurements, although access to the entire spectrum of measurements was not consistently available. On June 23, 1984, a failure in the circuitry of the spacecraft data-handling system led to intermittent acquisition of high frequency data from the PWI after this date. From June 1984 until November 1989, the Sweep Frequency Correlator (SFC) was not functioning properly, although internal monitors indicated that the rest of the PWI data appeared to be satisfactory. For several brief periods in 1987, the SFC data were restored to the telemetry frame. In late 1989, the SFC operation returned to normal until mid-November of 1990 when difficulties in commanding the spacecraft were encountered due to internal temperature problems.

Until March 15, 1991, the PWI provided three-component DC electric field measurements and digital amplitude and phase data from 1 Hz to 410 kHz. Additionally, the PWI analog wideband subsystem operated within specification throughout the DE mission. During periods of reduced frequency capability, PWI operations concentrated on observations of low frequency phenomena. When available, the SFC data were utilized to provide observations of high frequency phenomena as well. The instrument modes used provided digital electric and magnetic spectra from 1 Hz - 410 kHz. High resolution wideband analog data with bandwidths of 10 kHz and 40 kHz were available throughout the DE mission.

II. Government Furnished Data

In the period from April 1984 through September 1991, we received DE PWI decommutated telemetry data and merged the data to create 275 high-density 9-track tapes. The data on these tapes covers the entire span of the DE mission although the coverage is sporadic, especially in the later years, and there are many data gaps. The method of acquiring the telemetry data, over the Sigma 9, was slow and unsatisfactory and resulted in an incomplete in-house database when operations on the Sigma 9 were terminated in 1990. Only 50% of the PWI data for the first three years of the DE mission resides on 9-track tapes.

During the ten years of the DE operation, we received 6786 wideband analog tapes. The tapes contain more than 350,000 minutes of the original raw wideband data. The data were processed in our Spectral Processing Facility to create 8mm film spectra. These original tapes continue to be stored at the University of Iowa and no other copies of the wideband data exist. Since the quality of the tapes had been deteriorating in recent years, we have requested and received additional funds to digitize and archive a small percentage of the DE wideband data.

III. Data Reduction

Routine PWI data products which currently reside in-house include two-hour electric and magnetic field spectrograms, wave polarization and Poynting flux spectrograms, and 80-minute plots showing the DC electric field components parallel and perpendicular to the Earth's magnetic field. Color slides of the first three data products and black-and-white plots of the DC electric field components have been created for the 1981 and 1982 PWI data. Approximately 50% of the 1983 and early 1984 PWI data has also been similarly processed.

At the completion of our archiving tasks, gif files were created for the color spectrograms of the first three data products. 100% of the PWI data from September 16, 1981 through June 23, 1984 now resides in the form of gif files on 4mm and 8mm DAT tapes. Software was developed to display the spectrograms on our SUN workstations and produce hard copy prints of the desired spectrograms. Routine PWI data processing has been terminated. Requests from other investigators for PWI data are now handled through NSSDC, where the archived telemetry data and the processing software now reside.

The last wideband analog tape was received at Iowa in May 1991. During the period of this grant, 6786 tapes containing DE PWI wideband analog data were received at Iowa and 70mm film spectra have been created from the processed data. Routine wideband analog data processing and the wideband database listing were completed in late 1991. Work continues on the digitizing and archiving of selected wideband data intervals under a separate grant to archive the PWI analog data.

IV. Data Submission to NSSDC

From 1989 - 1992, the DE investigative teams were required to prepare and submit their data to NSSDC for archiving on optical platters. In order to complete our archiving obligations, we received copies of 212 DE telemetry platters, as well as several platters containing the orbit and attitude data. We stripped the PWI data from these platters, re-formatted and merged the data with the corresponding orbit and attitude data and wrote the re-formatted data to the archival platters. Our archiving obligation included all of the PWI digital electric and magnetic field spectrum measurements and the DC electric field data for the period of September 16, 1981 through June 23, 1984. We completed our NSSDC archiving tasks and submitted our final installment of the DE PWI data on optical platter on July 6, 1992, along with the required format documentation and software metadata files.

V. Wideband Data Archiving

In April 1992, NASA Headquarters attached an increment to this grant to be used for the purpose of digitizing and archiving the PWI wideband analog data. As of June 30, 1994, 2% of the PWI wideband data has been digitized and archived. The digitized data has been archived on 8mm DAT tapes which will remain in storage at the University of Iowa under the terms of the archiving grant. Software to perform fast Fourier transform on the digitized data and to display the data on the SUN workstation was completed in 1993. Supplemental funds to continue this archiving task were received in June 1994 under a new grant. The goal is to complete the archiving of 10% of the DE PWI wideband data by June 1995.

The archiving process which has been developed at The University of Iowa over the past year and a half (and similar to the archiving going on at Stanford University) is based on digitizing the analog signals from instrumentation data tapes and treating the data as a serial digital data stream. In fact, this process is a value-added benefit since in their original analog form, the wideband data could only be analyzed in a small number of labs with a large investment in highly specialized equipment. In analog form, photographically changing time scales of hardcopy spectrograms is virtually the only way of attempting correlative studies with other data sets such as the magnetic field and energetic particle distribution function. Now, the digitized version of the data set can be used as any other digital data stream and correlated with other information using modern computer workstations.

In the first year of this effort, hardware procured by University of Iowa institutional funds was used as a digitizing workstation, around which a system was developed that provides 8-bit digital samples at sampling rates as high as 100,000 samples/s thereby ensuring that aliasing is not a problem. Software was written to decode the NASA time code at the same time and convert this into digital time tags inserted into the data stream every 10ms. Also produced was a simple analysis tool which reads the digital files, computes the Fourier transform, and displays a frequency-time spectrogram with a fair degree of flexibility. The platform for this software is an IBM-compatible personal computer running DOS and Microsoft Windows 3.1. This software demonstrates that it is now no longer necessary to have a lab filled with specialized equipment to read and manipulate the waveform data and provides a minimal access capability to a wide range of scientists with little or no capital investment.

In the second year of the effort, we began the production of archival products on a regular basis and have concentrated on archiving examples of wave phenomena which have been previously published or requested for study by our colleagues under the assumption that these events must be good or typical examples of a wide variety of different phenomena. This set of data also ensures that retrospective studies of the original data can be performed. We have just begun more systematic processing of small fractions of data from a number of spacecraft having wideband receivers to enable minimal surveys of the wideband data

DE-1

START - 1984 029 16:28 (29 January)



Figure 1

DE-1

START - 1984 029 16:28 (29 January)

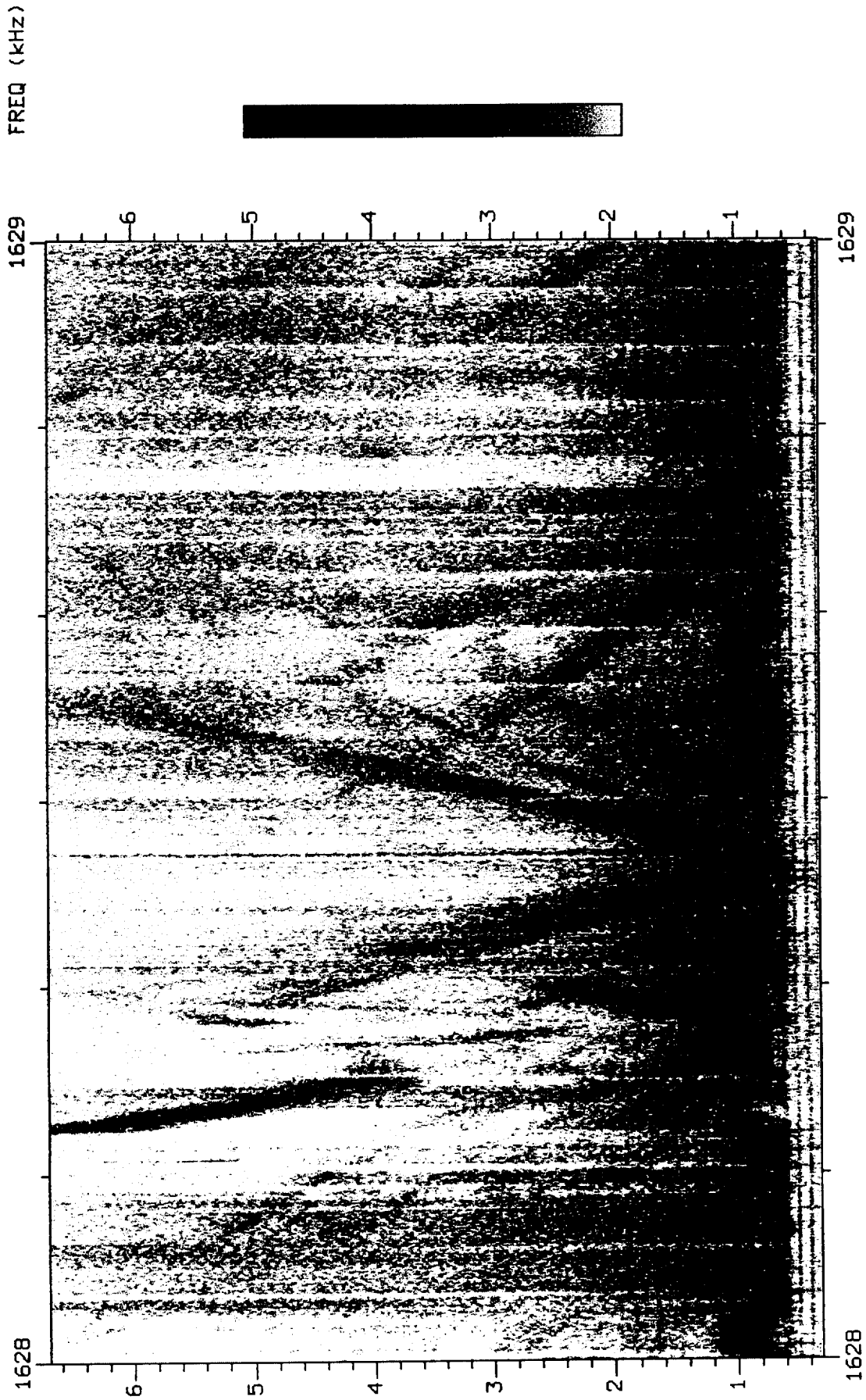


Figure 2

which reflect the primary focus of the various missions. We have also begun, largely under the auspices of the Galileo project which produces digital wideband data products in a similar format, the development of a Unix-based analysis tool. The Unix tool is already more capable than the PC demonstration software mentioned above and allows an almost continuous level of flexibility in terms of selecting analysis time periods and spectral ranges. A dynamically variable color bar is also being developed to enable straightforward optimization of the display to maximize the dynamic range of the data or to enhance a specific feature. The tool also makes use of a browse data set, a pre-Fourier transformed data set, as a basis for more detailed study. The browse spectrogram covering several minutes to one hour can be displayed almost instantly and allow the user to isolate the feature of interest for more detailed study. In Figure 1, a browse spectrogram is presented covering about 5 minutes of Dynamics Explorer observations of VLF saucers. Superimposed on the spectrogram is a square opened by the use of a mouse which highlights the feature to be studied in greater detail. Figure 2 shows the higher resolution spectrogram covering the region defined by the square in Figure 1. The higher resolution spectrogram is computed in real time from the original, full resolution data set, hence, affords the full capability of the entire data set. Additional features to be added to the software include the ability to display an amplitude vs. frequency spectrum for a selected time or averaged over a selected time interval, or the ability to display the temporal variation of signals integrated over a selected interval of frequency, in some ways duplicating the function of a fixed filter in a spectrum analyzer, but with much higher temporal resolution.

We have now processed some 16,000 minutes of data (of the order of 30 Gbytes) from ISEE 1 and 2, DE 1, Plasma Diagnostics Package on Spacelab 2, IMP 6, S³-1, AMPTE and have demonstrated the ability to digitize Hawkeye and Injun V data. The data processed to date includes the initial pass to digitize the data into 12 bit samples and a second pass to decode the time signal and format the data. We have also passed the existing data through a third process which reduces the sample size to 8 bits. In the future, this pass will be incorporated into one of the first 2 passes and this will not be an extra step. The reason for doing the reduction is to reduce the data volume. There is no net loss of signal in doing this, since the dynamic range of the original downlink data is generally not much greater than 20 dB. We have performed tests which demonstrate no significant differences in the spectrograms using 8 bits as compared to the original 12 bit data.

Finally, as a dual purpose activity, we have begun calculating time-averaged Fourier transforms which are used to produce summary or browse spectrograms such as that in Figure 1. We use the summary spectrogram for quality control purposes--enabling a large quantity of data to be reviewed at once--and we save the time-averaged Fourier transform information as browse files. We plan to have at least 1 browse file with pre-calculated Fourier components for every hour of data in the archive. This file will be used to quickly review the contents of the archive and enable users to search for features of interest, such as with the software demonstrated in Figures 1 and 2.

VI. Scientific Results

The plasma wave research efforts supported by this grant have been very productive. During the years of this NASA grant, research efforts involving the plasma wave data from the PWI have provided basic new information on a wide variety of magnetospheric plasma wave phenomena. Sixty-seven scientific publications, reports, and theses involving the University of Iowa plasma wave data were prepared during this grant period and are listed in Section VII. Oral and poster presentations related to research performed under this grant are given in Section VIII.

Highlights of the discoveries made and research undertaken during this grant period include:

- Identification of left-hand-polarized AKR, usually at frequencies just below the frequencies of simultaneously occurring right-hand-polarized AKR
- Comparison of the AKR wideband spectra, showing that the spectra of both AKR modes exhibit fine structure and have similar spectra characteristics
- Identification of harmonic structure in the AKR spectrum showing a reversal in polarization, indicating that the second harmonic component, an L-O mode emission, is of natural origin
- Use of the DE 1 auroral images and the two-dimensional direction-finding capability of DE 1 to determine that the AKR source is located on magnetic field lines associated with discrete auroral arcs
- Development of the radio lasing theory for the generation of auroral kilometric radiation
- Identification of the upper frequency cutoff of the auroral hiss emissions as the electron plasma frequency
- Determination of the radial dependence of the electron density profile at high altitudes in the polar region
- Use of plasma wave cutoffs to confirm the existence of a plasma density cavity along auroral field lines above $2 R_E$ and the correlation of the cavity with the observation of upward directed ion beams and conics
- Observation of the flaring of the auroral hiss funnel as the wave frequency approached the electron plasma frequency, determination of the auroral hiss source position at auroral altitudes of $0.7-0.9 R_E$ and the use of Poynting flux observations to confirm that the hiss emissions are propagating upward above this position
- Correlation between the observance of upward-directed electron beams and the occurrence of funnel-shaped auroral hiss emissions, confirming the generation of the hiss emissions via Landau resonance with upward moving electrons
- Investigation of the Landau damping of auroral hiss, indicating that the hiss is limited to longer wavelengths and greater energies equatorward of the auroral oval, explaining the one-sided auroral hiss funnels observed by DE
- Observation of funnel-shaped auroral hiss and broadband electrostatic noise associated with the presence of transpolar arcs
- Observation of broad bandwidth Z-mode radiation in the low density regions over the auroral zone and polar cap and the horizontal propagation of Z-mode emissions below the electron cyclotron frequency
- Use of direction-finding studies to confirm that Z-mode radiation is generated over the auroral zone and may originate from auroral hiss via a coupling window near the electron plasma frequency
- Evidence that the cyclotron maser emission theory is not consistent with the observed spectra of Z-mode emissions deep in the polar cap and evidence, using ray tracing techniques, that the Z-mode emissions originate at low altitudes near the plasma frequency inside the auroral cavity
- Evidence for locating the source of the four auroral wave propagation modes near the poleward edge of the auroral plasma cavity, with AKR originating in the X mode and O mode near the electron cyclotron frequency and the whistler mode and the Z mode originating at frequencies well below the local cyclotron frequency on the same source field lines
- Confirmation of two predictions of the linear conversion theory for the generation of terrestrial myriametric (continuum) radiation (TMR) by coupling from intense upper hybrid resonance emissions near the plasmopause: the verification of the equatorial beaming of the TMR in two meridional beams at equal angles with respect to the magnetic equator at the plasmopause; and the confirmation of the expected L-O mode polarization of the TMR
- Observation of an absence of a minimum in the occurrence and intensity of terrestrial myriametric radiation (TMR) at the equator and the emergence of several TMR beams at distinct angles from a single source, indicating that the radio window theory for the generation of TMR is not sufficient to explain the beaming pattern
- Observation of generation of O+ conic distribution by equatorially confined ion cyclotron waves
- Observation of hydrogen ion cyclotron harmonic bands up to the tenth harmonic within very low frequency (VLF) saucers in the auroral zone

- Observation of double-peaked electrostatic H⁺ cyclotron harmonic waves below the lower hybrid frequency in the auroral zone, an uncharacteristic signature produced by Doppler shifts arising from the satellite velocity relative to the plasma rest frame
- Demonstration of a close correspondence between a strongly heated equatorially trapped H⁺ plasma population and the occurrence of ion Bernstein waves
- Investigation of a magnetic structure at the equatorward edge of the polar cusp, consistent with an interpretation of a standing Alfvén wave
- Analysis of electrostatic auroral emissions as electron acoustic mode waves excited by field-aligned electron beams
- Observation of wave intensifications near the electron cyclotron frequency within the polar cusp and the correlation of these enhancements in the narrowband electrostatic wave spectra with the velocity distribution of the energetic cusp electrons
- Generation of broadband electrostatic bursts in the auroral zone by accelerated ions and electrons in the upward field-aligned current region and in the return current region
- Use of correlator measurements to show that the north-south electric field fluctuations of the broadband low frequency auroral zone noise are closely correlated with the east-west magnetic field fluctuations and that the Poynting flux (electromagnetic energy flow) is directed downward, with an associated energy flow of approximately 10^8 watts
- Correlation between the onset of low frequency waves in the cusp/cleft region and the onset of O⁺ heating and the development of a Monte Carlo simulation to explain the ion heating via a cyclotron resonance with broadband low frequency waves near the ion gyrofrequency
- Theory for oxygen ion conic formation through cyclotron resonance with low-frequency magnetospheric plasma turbulence
- Analysis of an O⁺ ion conic distribution in terms of ion acceleration along auroral field lines by the broadband low frequency electric field noise
- Observation of the heating of oxygen ions equatorward of the central cusp/cleft region and the development of a resonant heating theory using heating rates inferred from the observed low-frequency electric field spectra on time scales consistent with the measured poleward drift rate of the thermal oxygen ions
- Observation of funnel-shaped low frequency equatorial waves, consistent with generation by protons with a ring-type velocity space distribution
- Demonstration, using magnetic conjunction techniques with DE 1 and DE 2 dc electric field data, that long-wavelength electric fields map from high to low altitudes with little or no attenuation and that short-wavelength fields are strongly attenuated, providing evidence for a magnetic field-aligned potential drop between the two satellites
- Examination of the current-voltage relationship within narrow auroral current sheets using dc electric field data, revealing an "Ohm's law" relationship between the current density and the parallel potential drop along the magnetic field line
- Statistical investigation of large-amplitude auroral electric fields, which are found to exhibit a strong radial dependence with the largest amplitudes found below $2.5 R_E$, a characteristic considered to be evidence for the existence of parallel electric fields

VII. Publications

1. Magnetospheric Electric Fields Measured with Dynamics Explorer-1

D. R. Weimer

M.S. Thesis, Department of Physics and Astronomy, The University of Iowa, Iowa City, Iowa, May 1983.

The Plasma Wave Instrument (PWI) on the Dynamics Explorer-1 satellite has been used to measure DC electric fields in the earth's magnetosphere. The DE-1 spacecraft is in an elliptical polar orbit with a radial range of 1.106 to 4.67 R_E . The DC electric field measurements are obtained with two sets of double probes. A long wire antenna with a tip-to-tip length of 215 m measures the electric field in the satellite spin plane. A tubular antenna with a length of 9 m is used for measurements along the spin axis. Data from the sensitive long wire electric field probe is given the most attention. This antenna is rotating with the spacecraft at a rate of one revolution every 6 seconds. By applying a least square error fit to the sinusoidal waveform, the magnitude and orientation of the electric field in the spin plane of the spacecraft is determined. Further computations reduce the measured electric field to components perpendicular and parallel to the magnetic field. Due to the short length of the tubular antenna, the electric field measured along the spin axis shows interference from a non-uniform electric potential around the body of the spacecraft. A simple averaging approach is used to filter some of the interference from the DC measurements. The results of the computations are plotted on graphs with several different formats. One type of graphical output show the plasma convection velocity component which is calculated from the electric field measured in the spin plane. These graphs are used extensively in a discussion on polar cap plasma convection. The DE-1 observations affirm the existence of a two-cell circulation pattern. Flow velocities over 2 km/s are seen near the reversals which occur at the center of the convection cells. But the plasma convection pattern is found to be highly variable; the two-cell circulation is often absent. The variations which occur on an orbital and daily basis are compared to changes in the Interplanetary Magnetic Field (IMF) and geomagnetic activity indices. The north-south polarity of the IMF appears to correlate better than the geomagnetic activity with a stronger and more uniform flow. Electric field measurements in the auroral zone are discussed. Oppositely directed fields with a magnitude of 100 to 200 mV/m are a common feature, but the absence of "paired electrostatic shocks" of a greater magnitude contradicts measurements with the S3-3 satellite reported in the literature. Electric fields having the paired shock structure which are found in association with field-aligned currents have the characteristics of an "auroral vortex." Spectrograms from the Plasma Wave Instrument indicate these events produce localized plasma waves over a wide frequency range. The final chapter on the observations discusses the relationship between unusual electric fields detected at low latitude concurrent with Stable Auroral Red (SAR) arcs. The electric fields are associated with plasma flows of over 8 km/s. The phenomenon had been reported before under the name of "Subauroral ion drift", but there had been no previous connection with SAR arcs.

2. Polar Cap Densities from DE-1 Plasma Wave Observations

A. M. Persoon

M.S. Thesis, Department of Physics and Astronomy, The University of Iowa, Iowa City, Iowa, May 1983.

Electric field spectrum measurements from the Plasma Wave Instrument on the Dynamics Explorer-1 spacecraft are used to determine the plasma frequency cutoff of whistler mode radiation at high altitudes over the northern polar cap region. This cutoff provides an accurate (less than 12%) determination of the local electron density. The median electron density over the polar cap at L greater than 10 is found to vary from $35.2 \pm 8.5 \text{ cm}^{-3}$ at 2.1 R_E to $0.99 \pm 0.51 \text{ cm}^{-3}$ at 4.66 R_E . Variations up to a factor of four occur from these median values. The steady state radial outflow model is examined for consistency with the observed density profile. The model predicts an inverse dependence on the

product of the plasma velocity and the cube of the radial distance. Comparison of the observed density profile with the radial outflow model yields a power law distribution for the electron density with an exponent of -3.85 ± 0.32 , which implies a flow velocity increasing nearly linearly with increasing radial distance. Comparison of the observed electron densities with theoretical polar wind densities yields consistent results up to $2.8 R_E$, although the steady-state solutions for supersonic H^+ outflow are slightly lower than the observed median densities. Recent DE-1 measurements contradict polar wind predictions of ion composition and energies, although a thermal polar wind component in the polar cap plasma is also present.

A comparison of observed electron densities with low-altitude density profiles from the Alouette II and ISIS-1 spacecraft indicates a transition in the radial dependence of the electron density at $1.16 R_E$ and another transition between $1.55 R_E$ and $2.0 R_E$. These transitions are due to changes in the basic processes of plasma transport with increasing radial distance in the polar cap region. A combination of a near diffusive equilibrium distribution and a subsonic outward plasma flow in the high density region below $1.16 R_E$ becomes a supersonic, collision-dominated outward flux as the plasma density diminishes above $1.16 R_E$. A second transition in the density profile is expected between $1.55 R_E$ and $2.0 R_E$ when the collision-dominated radial outflow model below $1.55 R_E$ develops into a collisionless power law distribution in the very low density regions of the polar cap at the height of the DE-1 orbit.

3. Polar Cap Electron Densities From DE 1 Plasma Wave Observations
A. M. Persoon, D. A. Gurnett, and S. D. Shawhan
J. Geophys. Res., **88**, 10,123, 1983.

Electric field spectrum measurements from the plasma wave instrument on the Dynamics Explorer 1 spacecraft are used to study the local electron density at high altitudes in the northern polar cap region. The electron density is determined from the upper cutoff of whistler mode radiation at the electron plasma frequency. Median density values over the polar cap at L greater than 10 are found to vary from $35.2 \pm 8.5 \text{ cm}^{-3}$ at $2.1 R_E$ to $0.99 \pm 0.51 \text{ cm}^{-3}$ at $4.66 R_E$. The steady state radial outflow model is examined for consistency with the observed density profile. A power law fit to the radial variation of the electron density yields an exponent of -3.85 ± 0.32 , which for the radial outflow model implies a flow velocity increasing nearly linearly with increasing radial distance. Comparison of the observed electron densities with theoretical polar wind densities yields consistent results up to $2.8 R_E$. A comparison of the observed electron densities with low-altitude density profiles from the Alouette II and ISIS 1 spacecraft illustrate transitions in the slope profile at $1.16 R_E$ and between 1.55 and $2.0 R_E$. The changes in the density profile suggest that changes occur in the basic radial transport processes at these altitudes.

4. Observations of Plasma Heating at the Earth's Magnetic Equator
R. C. Olsen, S. D. Shawhan, D. L. Gallagher, J. L. Green, and C. R. Chappell
J. Geophys. Res., submitted, 1983.

No abstract available

5. **Correlated Low-Frequency Electric and Magnetic Noise Along the Auroral Field Lines**
 D. A. Gurnett, R. L. Huff, J. D. Meniotti, J. L. Burch, J. D. Winningham, and S. D. Shawhan
J. Geophys. Res., **89**, 8971, 1984.

Plasma wave and plasma measurements from the Dynamics Explorer 1 (DE 1) spacecraft are used to investigate an intense broadband spectrum of low-frequency, < 100 Hz, electric and magnetic noise observed at low altitudes over the auroral zones. This noise is detected by DE 1 on essentially every low-altitude pass over the auroral zone and occurs in regions of low-energy, 100 eV to 10 keV, auroral electron precipitation and field-aligned currents. The electric field is randomly polarized in a plane perpendicular to the static magnetic field. Correlation measurements between the electric and magnetic fields show that the perpendicular (\sim north-south) electric field fluctuations are closely correlated with the perpendicular (east-west) magnetic field fluctuations and that the Poynting flux is directed downward, toward the earth. The total electromagnetic power flow associated with the fluctuations is large, approximately 10^8 W. Two general interpretations of the low-frequency noise are considered: first, that the noise is produced by static fields imbedded in the ionosphere and, second, that the noise is due to Alfvén waves propagating along the auroral field lines. For the static interpretation the ratio of the magnetic to electric field strengths at the base of the ionosphere is determined by the Pedersen conductivity, $B/(\mu_0 E) = \Sigma_p$, whereas for the Alfvén wave interpretation it is determined by the Alfvén index of refraction, $cB/E = n_A$. Measurements show that the magnetic to electric field ratio decreases rapidly with increasing height. This height dependence is in strong disagreement with the static model if the magnetic field lines are assumed to be equipotentials ($E_{\parallel} = 0$). At present, no satisfactory model is available for comparison with the data if an electrostatic potential drop is assumed to exist along the magnetic field ($E_{\parallel} \neq 0$). The Alfvén wave model is in good agreement with the general form of the height dependence of the magnetic to electric field ratio but disagrees in certain details. The cB/E ratio tends to decrease with increasing frequency and is usually somewhat larger than the computed value of the Alfvén index of refraction. Some of these difficulties could be accounted for by reflections at the base of the ionosphere or propagation at large angles to the magnetic field (kinetic Alfvén waves). For both the static model and the Alfvén wave model the source must be located at high altitudes, since the average Poynting flux is always directed downward, even at radial distances up to $2 R_E$.

6. **Auroral Zone Electric Fields From DE-1 and -2 At Magnetic Conjunctions**
 D. R. Weimer
 Ph.D. Thesis, Department of Physics and Astronomy, University of Iowa, Iowa City, Iowa,
 December 1984.

Nearly simultaneous measurements of auroral zone electric fields are obtained by the Dynamics Explorer spacecraft at altitudes below 900 km and above 4500 km during magnetic conjunctions. The measured electric fields are approximately perpendicular to the magnetic field lines. The north-south meridional electric fields are "projected" to a common altitude by a mapping function. When plotted as a function of invariant latitude, graphs of the projected electric fields measured by DE-1 and DE-2 show that the large-scale electric field is the same at both altitudes. However, superimposed on the large-scale fields are small-scale features with wavelengths less than 100 km which are larger in magnitude at the higher altitude. Fourier transforms of the electric fields show that the magnitudes depend on wavelength. Outside of the auroral zone the electric field spectrums are nearly identical. But within the auroral zone the spectrums of the high and low altitude electric fields have a ratio which increases with the reciprocal of the wavelength. The small-scale electric field variations are associated with field-aligned currents. These currents are measured with both a plasma instrument and magnetometer on DE-1. The spectrum of the east-west magnetic field component measured on the high altitude satellite is found to be nearly identical to the spectrum of the north-south electric field measured on the low altitude satellite, with a ratio that is independent of wavelength. This ratio is proportional to the ionospheric conductivity.

The experimental measurements are found to agree with a steady-state theory which postulates that there are parallel potential drops associated with the variations in the perpendicular electric fields. It is assumed that there is a linear relationship between the field-aligned current and the total parallel potential drop, and that the field-aligned currents close through Pedersen currents in the ionosphere. The theory predicts that the ratio between the low and high altitude electric fields varies with the wavelength. Due to the excellent agreement between the theory and observations, it is concluded that the linear relationship between the current density and potential drop is a good approximation.

7. **Enhanced Ion Outflows Measured by the DE 1 High Altitude Plasma Instrument in the Dayside Plasmasphere During the Recovery Phase**
J. D. Menietti, J. D. Winningham, J. L. Burch, W. K. Peterson, J. H. Waite, Jr., and D. R. Weimer
J. Geophys. Res., 90, 1653, 1985.

Ion flow velocities both parallel and perpendicular to the magnetic field and including the effects of spacecraft charging and spacecraft velocity have been measured during the recovery phase of two large magnetic storms on October 14 and 21 of 1981. These measurements were made both inside and outside the plasmasphere and indicate unreported yet substantial outflows of ions within the dayside plasmasphere (October 14). Combined data from instruments on board the Dynamics Explorer satellite, including the high altitude plasma instrument (HAPI), the energetic ion composition spectrometer (EICS), the retarding ion mass spectrometer (RIMS) and the plasma wave instrument (PWI), indicate that these ions are most likely dominantly O^+ at energies at least as low as 5 eV. The nightside pass (October 21), which occurred during the recovery phase of a similar storm, showed no plasmaspheric outflows. The results indicate that a large contribution to the outflux into the dayside plasmasphere during the recovery period is due to $E > 5$ eV ions.

8. **DE-1 Measurements of AKR Wave Directions**
W. Calvert
Geophys. Res. Lett., 12, 381, 1985.

In addition to its wave rotation sense, the direction of auroral kilometric radiation (AKR) can also be measured with the plasma wave instrument on Dynamics Explorer 1, from the relative phase of the signals received by its orthogonal electric dipole antennas. By this method, which differs in principle from the previous spin-null method for measuring wave directions, it has been found possible to pinpoint the AKR source by triangulation, using measurements from different points along the DE-1 orbit. The resulting apparent source, in one instance, seemed to occupy a well-defined auroral-zone invariant magnetic latitude and showed the expected increase of altitude with decreasing frequency. An analysis of the method also confirmed the validity of the previous rotation sense measurements.

9. **Auroral Zone Electric Fields From DE-1 and -2 At Magnetic Conjunctions**
D. R. Weimer, C. K. Goertz, D. A. Gurnett, N. C. Maynard, and J. L. Burch
J. Geophys. Res., 90, 7479, 1985.

Nearly simultaneous measurements of auroral zone electric fields are obtained by the Dynamics Explorer spacecraft at altitudes below 900 km and above 4500 km during magnetic conjunctions. The measured electric fields are usually nearly perpendicular to the magnetic field lines. The north-south meridional electric fields are "projected" to a common altitude by a mapping function which accounts for the convergence of the magnetic field lines. When plotted as a function of invariant latitude, graphs of the projected electric fields measured by both DE-1 and DE-2 show that the large-scale electric field is

the same at both altitudes, as expected. Superimposed on the large-scale fields, however, are small-scale features with wavelengths less than 100 km which are larger in magnitude at the higher altitude. Fourier transforms of the electric fields show that the magnitudes depend on wavelength. Outside of the auroral zone the electric field spectrums are nearly identical. But within the auroral zone the high and low altitude electric fields have a ratio which increases with the reciprocal of the wavelength. The small-scale electric field variations are associated with field-aligned currents. These currents are measured with both a plasma instrument and magnetometer on DE-1. A Fourier transform of the east-west magnetic field component measured on the high altitude satellite is found to be nearly identical to the Fourier transform of the north-south electric field measured on the low altitude satellite, with a constant ratio. This ratio is proportional to the ionospheric conductivity.

The experimental measurements are found to agree with a steady-state theory which postulates that there are parallel potential drops associated with the variations in the perpendicular electric fields. It is assumed that there is a linear relationship between the field-aligned current and the total parallel potential drop, and that the field-aligned currents close through Pedersen currents in the ionosphere. The theory predicts that the ratio between the low and high altitude electric fields varies with the wavelength. Below a "critical" wavelength the electric field is not effectively transmitted to low altitudes. Due to the good agreement between the theory and observations, it is concluded that the linear relationship between the current density and potential drop is a valid approximation.

10. The Auroral Kilometric Radiation: DE-1 Direction Finding Studies
M. M. Mellott, R. L. Huff, and D. A. Gurnett
Geophys. Res. Lett., 12, 479, 1985.

We have determined the directions of arrival of auroral kilometric radiation during three separate intervals using data from the DE 1 plasma wave instrument. In the case of the dominant extraordinary mode component, these directions were consistent with generation at the local electron cyclotron frequency on nightside auroral field lines. The ordinary mode component appeared to have a similar source in one case, but in other cases came from different directions. These other cases were consistent with reflection at the plasmopause and the wall of the auroral plasma cavity.

11. The Hidden Ion Population: Revisited
R. C. Olsen, C. R. Chappell, D. L. Gallagher, J. L. Green, and D. A. Gurnett
J. Geophys. Res., 90, 12,121, 1985.

Satellite potentials in the outer plasmasphere range from near zero to +5 to +10 V. Under such conditions ion measurements may not include the low energy core of the plasma population. In eclipse, the photoelectron current drops to zero, and the spacecraft potential can drop to near zero volts. In regions where the ambient plasma density is below 100 cm^{-3} , previously unobserved portions of the ambient plasma distribution function can become visible in eclipse. A survey of the data obtained from the retarding ion mass spectrometer (RIMS) on Dynamics Explorer 1 shows that the RIMS detector generally measured the isotropic background in both sunlight and eclipse in the plasmasphere. Absolute density measurements for the "hidden" ion population are obtained for the first time using the plasma wave instrument observations of the upper hybrid resonance. Agreement in total density is found in sunlight and eclipse measurements at densities above 80 cm^{-3} . In eclipse, agreement is found at densities as low as 20 cm^{-3} . The isotropic plasma composition is primarily H^+ , with $\sim 10\%$ He^+ , and 0.1 to 1.0% O^+ . A low energy field-aligned ion population appears in eclipse measurements outside the plasmasphere, which is obscured in sunlight. These field-aligned ions can be interpreted as field-aligned flows with densities of a few particles per cubic centimeter, flowing at 5-20 km/s. The problem in measuring these field-aligned flows in sunlight is the masking of the high energy tail of the field-aligned

distribution by the isotropic background. Effective measurement of the core of the magnetospheric plasma distributions awaits satellites with active means of controlling the satellite potential.

12. Electric and Magnetic Components of ULF Standing Waves in the Magnetosphere
L. J. Cahill, Jr., M. J. Engebretson, D. R. Weimer, and N. G. Lin
J. Geophys. Res., in preparation, 1985.

No abstract available.

13. Evidence of High Densities and Ion Outflows in the Polar Cap During the Recovery Phase
D. L. Gallagher, J. D. Menietti, A. M. Persoon, J. H. Waite, Jr., and C. R. Chappell
J. Geophys. Res., 91, 3321, 1986.

During the recovery phase of a large storm on October 14, 1981, instruments on board Dynamics Explorer 1 (DE 1) the Retarding Ion Mass Spectrometer (RIMS), the High Altitude Plasma Instrument (HAPI), and the Plasma Wave Instrument (PWI) detected unusually high plasma densities and ion flows in the polar cap. At the time of detection, DE 1 was located at a radial distance of about 3.5 earth radii, a magnetic local time near midnight, and between 70° and 80° invariant latitude. Total plasma density was found to be about 50 cm⁻³, an order of magnitude above median polar cap densities at the altitude of observation. In addition, highly collimated flows of hydrogen and oxygen are found flowing through a background hydrogen plasma. The O⁺ component of the plasma discussed is not directly identified but is inferred to be O⁺ through the combined analysis of data from three instruments. Results of the combined instrument analysis indicate that the detected plasma was composed of outflowing H⁺ with a density of 6-10 cm⁻³ with a temperature of about 0.15 eV; isotropic H⁺ with a density of about 15-20 cm⁻³; and outflowing and strongly convecting O⁺ with an average density of about 20 cm⁻³ and a temperature of about 0.26 eV. The flux of outflowing H⁺ and O⁺ are both about 10⁷ cm⁻² s⁻¹. The data indicate that the O⁺ detected by HAPI seems to originate in the dayside ionosphere, while the H⁺ detected by RIMS has a source in the nightside polar cap.

14. The Theta Aurora
L. A. Frank, J. D. Craven, D. A. Gurnett, S. D. Shawhan, D. R. Weimer, J. L. Burch, J. D. Winningham, C. R. Chappell, J. H. Waite, Jr., R. A. Heelis, N. C. Maynard, M. Sugiura, W. K. Peterson, and E. G. Shelley
J. Geophys. Res., 91, 3177, 1986.

The theta aurora is a remarkable configuration of auroral and polar cap luminosities for which a generally sun-aligned transpolar arc extends contiguously from the dayside to nightside sectors of the auroral oval. Four individual occurrences of theta aurora over earth's northern hemisphere are examined in detail with the global auroral imaging instrumentation on board the high-altitude, polar-orbiting spacecraft DE 1. Simultaneous measurements of fields and plasmas with this high-altitude spacecraft and its low-altitude, polar-orbiting companion, DE 2, are examined in order to establish an overview of auroral and polar cap phenomena associated with the appearance of the theta aurora. For these series of observations, two general states of the polar cap are found corresponding to (1) a bright, well-developed transpolar arc and (2) a dim or absent transpolar arc. During periods of a relatively bright transpolar arc the plasma convection in the polar cap region associated with the transpolar arc is sunward. Elsewhere over the polar cap the convection is antisunward. The convection pattern over the auroral zones and polar cap is suggestive of the existence of four cells of plasma convection. Field-aligned electron acceleration into the polar atmosphere and field-aligned current sheets are present in the transpolar arc plasmas. This electron precipitation and these current sheets are relatively absent over the rest of the polar

cap region. The transpolar arc plasmas exhibit similar densities and ion compositions relative to those plasmas observed simultaneously over the poleward zone of the auroral oval. The ion compositions include hot H^+ , He^{++} , and O^+ ions and thus are of both ionospheric and solar wind origins. Principal hot ions in the remainder of the polar cap region are H^+ and He^{++} , indicating access from the magnetosheath for these ions. Low-energy electrons identified with a magnetosheath source are also present in this region. The dominant thermal ions in the polar cap region are O^+ ions flowing upward from the ionosphere. These thermal ions are heated along magnetic flux tubes within the transpolar arc plasmas. Pairs of current sheets with oppositely directed current densities occur in the transpolar arc region and with magnitudes similar to those associated with the poleward zones of the auroral oval. The upward currents are carried by electrons accelerated by a field-aligned potential. Funnel-shaped auroral hiss and broadband electrostatic noise are associated with the presence of the transpolar arc plasmas. Energetic solar electrons are employed to show that the magnetic field lines threading both the transpolar arc and the poleward zone of the auroral oval are probably closed. In contrast, the accessibility of these electrons to the remainder of the polar cap indicates that these polar regions are characterized by a magnetic topology that is connected directly to field lines within the interplanetary medium. Thus the overall character of the transpolar arc region appears to be very similar to that observed over the poleward zones of the auroral oval. This latter region is currently thought to be magnetically mapped into the boundary layer of the plasma sheet in the magnetotail, namely, the boundary layer of high-speed ion beams and field-aligned currents. When the transpolar arc is dim or at its initial stages of brightening, there is a severe corresponding change in the character of luminosities, convection electric fields, fields, and plasmas over the polar cap region. The plasma convection is no longer the signature of a simple four-cell convection pattern. Plasma convection is generally turbulent or sunward in the polar cap. Remarkably, the zone of hot H^+ , He^{++} , and O^+ ions, which is a unique signature of the presence of a transpolar arc, is still present for the two examples of dim or absent transpolar arc luminosities presented here.

15. Upwelling O^+ Ion Source Characteristics

T. E. Moore, M. Lockwood, M. O. Chandler, J. H. Waite, Jr., C. R. Chappell, A. M. Persoon, and M. Sugiura
J. Geophys. Res., **91**, 7019, 1986.

Recent observations from the Dynamics Explorer 1 (DE 1) spacecraft have shown that the dayside auroral zone is an important source of very low-energy superthermal O^+ ions for the polar magnetosphere. When observed at 2000- to 5000-km altitude, the core of the O^+ distribution exhibits transverse heating to energies on the order of 10 eV, significant upward heat flux, and subsonic upward flow at significant flux levels (exceeding $10^8 \text{ cm}^{-2} \text{ s}^{-1}$). The term "upwelling ions" has been adopted to label these flows, which stand out in sharp contrast to the light ion polar wind flows observed in the same altitude range in the polar cap and subauroral magnetosphere. We have chosen a typical upwelling ion event for detailed study, correlating retarding ion mass spectrometer observations of the low-energy plasma with energetic ion observations and local electromagnetic field observations. The upwelling ion signature is colocated with the magnetospheric cleft as marked by precipitating energetic magnetosheath ions. The apparent ionospheric heating is clearly linked with the magnetic field signatures of strong field-aligned currents in the vicinity of the dayside polar cap boundary. Electric field and ion plasma measurements indicate that a very strong and localized convection channel or jet exists coincident with the other signatures of this event. These observations indicate that transverse ion heating to temperatures on the order of 10^5 K in the 2000- to 5000-km ionosphere is an important factor in producing heavy ion outflows into the polar magnetosphere. This result contrasts with recent suggestions that electron heating (to temperatures of order 10^4 K) is the most important parameter with regard to O^+ outflow.

16. Transverse Auroral Ion Energization Observed on DE-1 With Simultaneous Plasma Wave and Ion Composition Measurements
 W. K. Peterson, E. G. Shelley, S. A. Boardsen, and D. A. Gurnett
Ion Acceleration in the Magnetosphere and Ionosphere; Geophysical Monograph 38, Chapman Conference on Ion Acceleration in the Magnetosphere and Ionosphere, AGU Monograph, 38, 43, 1986.

The abundance of oxygen ions observed flowing into the magnetosphere can not be explained by a single-step, parallel-acceleration mechanism. Some transverse energization of ionospheric ions is required and has been observed from ionospheric altitudes to the plasma lobes in the earth's magnetotail. Progress in understanding the nature of the various transverse energization mechanisms has been slow because of the relative lack of examples with sufficiently resolved (in time, energy, and frequency) particle and wave data. Starting in early 1984 the Dynamics Explorer-1 systematically acquired a coordinated set of high time resolution plasma and plasma wave observations from the earth's auroral zone. We have selected several intervals from the 0 to 10 kHz wideband data from the Dynamics Explorer-1 satellite with intense low frequency emissions with evidence of harmonic structure and have examined in detail the high resolution ion data obtained simultaneously. In this report we present detailed data from events in the cusp and evening auroral zone and comment briefly on how these data can be used to more fully understand auroral acceleration processes.

17. The Conductance of Auroral Magnetic Field Lines
 D. R. Weimer, D. A. Gurnett, and C. K. Goertz
Ion Acceleration in the Magnetosphere and Ionosphere; Geophysical Monograph 38, Chapman Conference on Ion Acceleration in the Magnetosphere and Ionosphere, AGU Monograph, 38, 108, 1986.

Recent results from the Dynamics Explorer satellites have indicated that in the auroral zone a linear relationship exists between the field aligned current density and the potential drop parallel to the magnetic field lines. Evidence for this "Ohm's law" relationship was found in the mapping of perpendicular electric fields and field-aligned currents between high and low altitudes. The mapping depends on the perpendicular wavelength of the electric field variations. A scale length in the mapping formula is determined by the ratio of the parallel field line conductance and the ionospheric Pedersen conductance. The wavelength and the conductivity ratio also control the relationship between the perpendicular electric and magnetic fields at high altitudes.

We show here that at the short-wavelength limit the ionospheric conductivity is no longer important in the relationship between the north-south electric field and the east-west magnetic field at high altitudes (i.e., above the parallel potential drop). At the short-wavelength limit the relationship takes on a simple form: The integral of the perpendicular electric field results in a potential profile which, according to the linear theory, is proportional to the current density. Assuming that the currents are in the form of "infinite sheets" orientated east-west, the second integral of the electric field is proportional to the magnetic field.

High time-resolution data from the DE-1 satellite are shown here for two events with very large electric fields which reversed directions within a short distance. The results agree very well with the linear theory. The field line conductance is determined to be of the order of 10^{-9} mho/m². The same conductance appears to be valid for both upward and downward currents. Ions are accelerated from the ionosphere to magnetosphere by the potential drops in regions of upward current.

18. Plasma and Field Observations of a Pc 5 Wave Event

J. H. Waite, Jr., D. L. Gallagher, J. F. E. Johnson, R. C. Olsen, R. H. Comfort, C. R. Chappell, W. K. Peterson, D. R. Weimer, and S. D. Shawhan
J. Geophys. Res., 91, 11,147, 1986.

Micropulsation measurements of a Pc 5 wave event on July 14, 1982, in the afternoon magnetosphere are reported as observed by wave and particle instruments on board the Dynamics Explorer 1 (DE 1) spacecraft. The overall structure of the Pc 5 event as noted in the low-energy particle and quasi-static electric field data seems to order the event into two distinct halves. The appearance is reminiscent of a wave packet and suggests a temporal or spatial variation of the micropulsation, which has a scale of 20 min or 3000 km. The wave packet structure is also well correlated with a variation in the pitch angle distribution of the low-energy plasma with single direction field-aligned flow associated with the maximum amplitude of the wave packet structure and bidirectional field-aligned flows associated with the nodal point of the wave packet structure. The field-aligned velocities of the observed H^+ , He^+ , O^+ , N^+ , and O^{++} ions combined with the elliptical $E \times B$ wave oscillation in the first half of the event produce a helical motion of the plasma along the field line. In the second half of the event although all ion species are still present, strong magnetospheric convection seems to have a significant effect on the field-aligned motions and Pc 5 oscillations of the low-energy plasma. The event is characterized in the low-energy plasma by a left-hand to near-linear polarized rotation of the plasma over the first half of the event. Variations of the low-energy particle detector suggest that the center of resonance lies just radially inside of the DE 1 orbit ($L = 4.7$) and just outside of the dayside plasmopause, which appears to be located at $L = 4$ as indicated by experiments on board the DE 2 spacecraft. Comparisons of the measured Pc 5 wave period to the theoretical period derived from in situ evaluation of the plasma mass loading factor yield values of 190 s and 192 s, respectively. This is consistent with the center of resonance being nearly coincident with DE 1 orbit. The second half of the event occurs in a region of enhanced magnetospheric convection, which makes determination of the eccentricity of the wave difficult and harder to interpret. The wave is found to be right-hand or linearly polarized during this portion of the event, which suggests DE 1 is just radially inward of the resonance center. However, disagreement between the measured period of 233 s and the derived period of 189 s does not necessarily support this interpretation. Density variations of plasma along the field line which are hemispherically asymmetric may explain the inconsistencies between the measured and derived period in this half of the event.

19. DE 1 Observations of Harmonic Auroral Kilometric Radiation

M. M. Mellott, R. L. Huff, and D. A. Gurnett
J. Geophys. Res., 91, 13,732, 1986.

The plasma wave instrument onboard the DE-1 spacecraft has observed several intervals of auroral kilometric radiation (AKR) during which harmonic structure is clearly present. Evidence, some of which is based on unique capabilities of the DE instrument, is presented which argues strongly that the harmonic structures are natural rather than instrumental in origin. The harmonic emissions occur infrequently, but when present may persist for intervals of up to an hour. The emissions are relatively narrow band, and consist of a relatively weak fundamental ($10^{-14} - 10^{-11} \text{ V}^2/\text{m}^2\text{Hz}$) accompanied by an even weaker second harmonic. The ratio of power in the fundamental band to the power in the harmonic ranges from 10 to 100. In all cases, polarization data indicates that the fundamental is a left-hand ordinary (L-O) mode emission while the harmonic is a right-hand extraordinary (R-X) mode. These observations are consistent with predictions based on the cyclotron maser mechanism.

20. Plasma Density Depletions in the High-Latitude Magnetosphere: A Comparison with the DE-1 Particle Data
A. M. Persoon, D. A. Gurnett, W. K. Peterson, J. H. Waite, Jr., and J. L. Burch
EOS, 67, 1135, 1986.

DE-1 plasma wave measurements are used to study regions of diminished plasma densities at polar and auroral latitudes in the northern hemisphere. Regions of significant plasma depletion, with steep density gradients at one or both edges, are predictable features on auroral field lines from the pre-dusk hours through the early morning hours at $70^\circ \pm 5^\circ$ invariant latitude. Minimum densities in these auroral cavities frequently drop to 0.1 cm^{-3} at radial distances of $2 R_E$ to $4.7 R_E$. Poleward of the auroral zone, regions of diminished plasma densities are transient and highly variable in location and depth. Some depletions have steep density gradients at one or both edges, are confined to widths of several degrees in invariant latitude, and have minimum densities which rarely fall below 1 cm^{-3} . In addition to these polar cap cavities, broad transient regions of diminished polar cap densities, often as low as 0.1 cm^{-3} , are found to occur poleward of the cusp. These regions can extend over a large portion of polar cap and are distinguished from the auroral and polar cap cavities by their broad latitudinal extent. A comparison of the auroral density depletions with the DE-1 particle data indicates a correspondence between low auroral plasma densities, the appearance of energetic ion and electron components in the total plasma population, and the occurrence of field-aligned H^+ beams and conics with energies up to 1 keV. Similar ion and electron energies and ion distributions are found to correlate with the polar cap activities. Examples of both auroral and high-latitude cavities and the corresponding particle data will be shown.

21. Dynamics Explorer Observations of the Diffuse Auroral Equatorward Boundary, the Midlatitude Trough, and the Plasmapause
J. R. Sharber, J. D. Winningham, J. L. Burch, W. R. Hoegy, R. A. Heelis, A. M. Persoon, and J. H. Waite, Jr.
EOS, 67, 1139, 1986.

In a study of the region between auroral and plasmaspheric latitudes using experiments aboard the DE-1 and 2 satellites during four magnetic conjunction cases, we examine the relationships between particle and plasma boundaries at high and low altitudes and electric and magnetic field, plasma, and wave signatures of the auroral boundary, mid-latitude trough and plasmapause regions. A significant finding is the observation at DE-2 altitudes of a population of low-energy electrons at the plasmapause. This is indicative of plasma sheet/ring current coupling with the plasmasphere, and its persistence during quiet times suggests that even during these times a "SAR arc-like" process is operational although the threshold for producing 63 nm emission may not always be reached. This feature corresponds at disturbed times with the T_e peak observed at the equatorward trough wall.

22. Satellite Observations of New Particle and Field Signatures Associated with SAR Arc Field Lines at Magnetospheric Heights
J. U. Kozyra, T. E. Cravens, A. F. Nagy, D. A. Gurnett, R. L. Huff, R. H. Comfort, J. H. Waite, Jr., L. H. Brace, J. D. Winningham, J. L. Burch, W. K. Peterson
Advances in Space Research, 7, 3, 1987.

Enhancements in thermal ion densities, an oxygen dominated ring current at energies below 17 keV, and invariant latitude-limited bands of intense ELF hiss have been discovered on Stable Auroral Red (SAR) arc field lines at magnetospheric heights. These new signatures were revealed by an examination of 31 coordinated data sets taken simultaneously at magnetospheric and ionospheric heights by the DE-1

and -2 satellites during SAR arc traversals within the period September 1981 through April 1982. Data sets from DE-2, for the first time, provide information on the location of a SAR arc (determined by the F region electron temperature enhancement) during the nearly simultaneous passage of these field lines by DE-1 in the magnetosphere. These new high altitude signatures are examined in the context of possible magnetospheric SAR arc energy source mechanisms.

23. The Current-Voltage Relationship in Auroral Current Sheets
D. R. Weimer, D. A. Gurnett, C. K. Goertz, J. D. Menietti, J. L. Burch, and M. Sugiura
J. Geophys. Res., 92, 187, 1987.

The current-voltage relation within narrow auroral current sheets is examined through the use of high-resolution data from the high altitude Dynamics Explorer 1 satellite. The north-south perpendicular electric field and the east-west magnetic field are shown for three cases in which there are large amplitude, oppositely directed paired electric fields which are confined to a region less than 20 km wide. The magnetic field variations are found to be proportional to the second integral of the high-altitude perpendicular electric field. It is shown that at the small-scale limit, this relationship between ΔB and E is consistent with a linear "Ohm's law" relationship between the current density and the parallel potential drop along the magnetic field line. This linear relationship had previously been verified for large-scale auroral formations greater than 20 km wide at the ionosphere. The evidence shown here extends our knowledge down to the scale size of discrete auroral arcs.

24. Plasma Observations at the Earth's Magnetic Equator
R. C. Olsen, S. D. Shawhan, D. L. Gallagher, J. L. Green, C. R. Chappell, R. R. Anderson
J. Geophys. Res., 92, 2385, 1987.

The magnetic equator provides a unique location for thermal plasma and plasma wave measurements. Plasma populations are found to be confined within a few degrees latitude of the equator, particularly the ions. The equatorially trapped ion population is found to be primarily hydrogen, and we find little evidence for preferential heating of heavier ions. Helium is occasionally found to be heated along with the protons and forms about 10% of the equatorially trapped populations at such times, similar to the percentage of He^+ in the cold, core plasma of the plasmasphere. One case of a heated O^+ component was found; at the 0.1% level it generally comprises in the outer plasmasphere core plasma. The heated H^+ ions can be characterized by a bi-Maxwellian with $kT_{\parallel} = 0.5$ to 1.0 eV, and $kT = 5-50$ eV, with a density of $10-100 \text{ cm}^{-3}$. The total plasma density, as inferred from the plasma wave instrument measurements of the upper hybrid resonance (UHR), is relatively constant with latitude, occasionally showing a local minimum at the magnetic equator, even though the ion flux has increased substantially. The first measurements of the equatorially trapped plasma and coincident UHR measurements show that the trapped plasma is a feature of the plasmopause region, found at plasma densities of $20-200 \text{ cm}^{-3}$. The warm, trapped plasma is found in conjunction with equatorial noise, a plasma wave feature found at frequencies near 100 Hz, with a broad spectrum generally found between the proton gyrofrequency at the low frequency edge and the geometric mean gyrofrequency at the high frequency edge. This latter frequency is generally the lower hybrid resonance (LHR) for a proton-electron plasma. Sharp spatial boundaries are occasionally found with latitude, delimiting the equatorially trapped plasma. In such cases, the equator is a region with a relative minimum in density, and it appears that field-aligned ions found at higher latitudes are "bounced" from these boundaries, indicating a positive plasma potential of a volt or two in the equatorial region.

25. Observed Beaming of Terrestrial Myriametric Radiation
Dyfrig Jones, W. Calvert, D. A. Gurnett, and R. L. Huff
Nature, 328, 391, 1987.

Observations by the Dynamics Explorer 1 satellite provide validation of the theory that terrestrial myriametric radiation is produced by the linear conversion of electrostatic upper hybrid waves to electromagnetic radiation via a radio window. This theory predicts that the myriametric radiation is beamed relative to the magnetic field lines.

26. Further Boundary Conditions on the Low-Energy Electrons in the Plasmapause Region
J. R. Sharber, J. D. Winningham, J. L. Burch, W. R. Hoegy, A. M. Persoon, and J. H. Waite
Physics of Space Plasmas, 7, 289, 1987.

Data from instruments on the Dynamics Explorer satellites are used to describe particle precipitation and plasma properties in the plasmapause region for two cases of plasmapause crossings late in storm recovery phases. A low-energy population of electrons (< 10 eV), previously identified with SAR arcs, was observed by the Low Altitude Plasma Instrument on DE-2 on both crossings. The relationship between these electrons and enhancements in the high-energy particle fluxes, the electric field amplitude variations, and the ambient plasma temperature are examined.

27. Auroral Precipitation Caused by Auroral Kilometric Radiation
W. Calvert
J. Geophys. Res., 92, 8792, 1987.

An explanation is proposed for the external triggering of the auroral kilometric radiation (AKR) by solar radio bursts; for the development of the auroral plasma cavity which seems to accompany the AKR, and also for the formation of discrete auroral arcs—all based upon the generation of AKR by radio lasing, the consequent pitch-angle scattering of energetic electrons into the loss cone, and the subsequent precipitation of those electrons into the ionosphere.

28. Electron Density Depletions in the Nightside Auroral Zone
A. M. Persoon, D. A. Gurnett, W. K. Peterson, J. H. Waite, Jr., J. L. Burch, and J. L. Green
J. Geophys. Res., 93, 1871, 1988.

Measurements from instruments on board Dynamics Explorer 1 are used to study regions of diminished electron density in the nightside auroral zone. Local electron densities are obtained from the electron plasma frequency cutoff of the whistler mode auroral hiss. Electron density profiles are highly variable through the nightside auroral zone. Sharply defined regions of low electron densities are a common feature of auroral zone crossings from the predusk hours until the early morning hours at all radial distances up to at least $4.6 R_E$. Electron densities in these regions are strongly depleted in relation to the adjacent polar cap and plasmaspheric densities, forming a low-density cavity at $70^\circ \pm 5^\circ$ invariant latitude. Minimum densities in the auroral cavity frequently fall to values below 0.3 cm^{-3} and rarely exceed 3 cm^{-3} at radial distances of $2\text{--}4.6 R_E$. Within the cavity the electron density profile exhibits extreme variability, with variations of a factor of 2 or more on spatial scales of tens of kilometers. Electron plasma frequency to electron cyclotron frequency ratios of $0.02\text{--}0.4$ are found inside the auroral cavity, consistent with the values required by theory for the generation of auroral kilometric radiation and Z mode radiation. A comparison of the electron density depletions with simultaneously measured low- and high-energy particle measurements indicates a correspondence between low auroral plasma densities and upward directed ion beams and conics. Low-energy (< 1 keV) upflowing H^+ ions are strongly

correlated with the poleward edge of the auroral cavity. Although the energetic (> 1 keV) precipitating auroral electrons do not correlate with the poleward edge of the auroral cavity, the peak energies of the precipitating electron population do occur inside the cavity interval. These correlations show that density depletions in the nightside auroral zone are directly associated with auroral with auroral acceleration processes.

29. Plasma Wave Observations with the Dynamics Explorer 1 Spacecraft
D. A. Gurnett and U. S. Inan
Reviews of Geophysics, 26, 285, 1988.

This paper reviews the results from the plasma wave instrument on the Dynamics Explorer 1 (DE-1) spacecraft. The DE-1 spacecraft was launched on August 3, 1981, into an elliptical polar orbit with initial perigee and apogee radial distances of 1.09 and 4.65 R_E . In the roughly six years since the launch of the spacecraft, DE-1 has provided basic new information on a wide variety of magnetospheric plasma wave phenomena. These include auroral kilometric radiation, auroral hiss, Z-mode radiation, narrowband electromagnetic emissions associated with equatorial upper hybrid waves, whistler-mode emissions, wave-particle interactions stimulated by ground VLF transmitters, equatorial ion cyclotron emissions, ion Bernstein mode emissions, and electric field turbulence along the auroral field lines. To carry out this review, we first give a brief review of the basic plasma wave modes that can exist in the equatorial and polar regions of the magnetosphere. After the basic terminology is established, each of the above areas of plasma wave research is discussed in detail, first by reviewing the state of knowledge at the time of the DE-1 launch, and then by describing the contribution made by DE-1 in the six years since the spacecraft was launched.

30. Ordinary Mode Auroral Kilometric Radiation Fine Structure Observed by DE 1
R. F. Benson, M. M. Mellott, R. L. Huff, and D. A. Gurnett
J. Geophys. Res., 93, 7515, 1988.

The fine structure observed with intense right hand-extraordinary (R-X) mode auroral kilometric radiation (AKR) has received major theoretical attention. Data from the Dynamics Explorer 1 plasma wave instrument indicate that left hand-ordinary (L-O) mode AKR possesses similar fine structure. Several theories have been proposed to explain the fine structure of the R-X mode AKR. In order to account for the L-O mode fine structure, these theories will have to be modified to produce the L-O mode directly or will have to rely on mode-conversion processes from the R-X to the L-O mode.

31. Plasma Waves Associated with Diffuse Auroral Electrons at Mid-Altitudes
J. R. Sharber, J. D. Menietti, H. K. Wong, J. L. Burch, D. A. Gurnett, J. D. Winningham, and P. J. Tanskanen
Adv. Space Res., 8, (9)447, 1988.

Using simultaneous observations from the High Altitude Plasma Instrument and the Plasma Wave Instrument onboard the Dynamics Explorer-1 satellite, we have examined 28 auroral zone crossings equally divided among dayside and nightside cases covering a range of K_p values from 1- to 8. We find that in the diffuse auroral region (CPS) electrostatic emissions of frequencies up to a few kHz are associated with low-energy, field aligned electron beams. Of 18 cases (11 nightside; 7 dayside) examined at high resolution in the particle data, 15 (9 nightside; 7 dayside) exhibited the field aligned beams with the electrostatic waves. In most cases the beams were upward-directed, but occasionally they traveled both up and down the field line. The three cases showing no beams occurred during intervals of $K_p < 20$. We interpret the electrostatic emissions as electron acoustic mode waves excited by the field aligned

beams. A stability analysis based on the plasma parameters of one of the passes supports this interpretation.

32. Mapping of Auroral Kilometric Radiation Sources to the Aurora
R. L. Huff, W. Calvert, J. D. Craven, L. A. Frank, and D. A. Gurnett
J. Geophys. Res., **93**, 11,445, 1988.

Auroral kilometric radiation (AKR) and optical auroral emissions are observed simultaneously using plasma wave instrumentation and auroral imaging photometers carried on the DE-1 spacecraft. The DE-1 Plasma Wave Instrument (PWI) measures the relative phase of signals from orthogonal electric dipole antennas, and from these measurements, apparent source directions can be determined with a high degree of precision. Wave data are analyzed for several strong AKR events and source directions are determined for several emission frequencies. By assuming that the AKR originates at cyclotron resonant altitudes, a candidate source field line is identified. When the selected source field line is traced down to auroral altitudes on the concurrent DE-1 auroral image, a striking correspondence between the AKR source field line and localized auroral features is produced. The magnetic mapping study provides strong evidence that AKR sources occur on field lines associated with discrete auroral arcs, and it provides confirmation that AKR is generated near the electron cyclotron frequency.

33. Transverse Ion Energization and Low-Frequency Plasma Waves in the Mid-Altitude Auroral Zone: A Case Study
W. K. Peterson, E. G. Shelley, S. A. Boardsen, D. A. Gurnett, B. G. Ledley, M. Sugiura, T. E. Moore, and J. H. Waite
J. Geophys. Res., **93**, 11,405, 1988.

The transport of ions from the ionosphere to the magnetosphere requires that ions acquire significant energy in directions both transverse and parallel to the magnetic field. There is a considerable body of experimental evidence that shows that transverse energization occurs over a wide range of altitudes on auroral field lines. Many recent analytical and simulation studies have addressed the microphysics involved in transverse ion energization. There are, however, remarkably few published high-resolution plasma and plasma wave observations obtained in the mid-altitude auroral region available to compare with the analytical and simulation studies. Several hundred hours of high-resolution plasma data obtained from the Dynamics Explorer 1 satellite have been surveyed. A wide variety of plasma environments that are difficult to simply characterize were found. We present here a comprehensive set of high-sensitivity, high-resolution plasma wave, ion, and magnetometer data obtained from an evening auroral zone crossing at $r/R_E \sim 3$. The total density, thermal structure, and composition of the plasma in this representative interval varied rapidly, as did the character (mode) of low-frequency plasma waves observed. We did not find an unambiguous particle and wave signature of local transverse ion energization, but we did frequently find intervals where local transverse ion heating was consistent with the observations. We also found a downward flowing ion distribution that occurred simultaneously with a region of intense plasma wave emissions primarily below the lower hybrid resonance frequency.

34. Planetary Radio Lasing

W. Calvert

Planetary Radio Emissions II, ed. by H. O. Rucker, S. J. Bauer, and B. M. Pedersen, Verlag der Oesterreichischen Akademie der Wissenschaften, 407, 1988.

Both the Earth's auroral kilometric radiation (AKR) and Jupiter's decametric radio S-bursts are attributed to natural radio lasing. Presumably consisting of self-excited, closed-loop wave feedback oscillations between local irregularities of the source plasma density, this radio lasing is comparable to that which occurs in man-made optical lasers, although at radio, rather than optical wavelengths. As a result, it should produce a multiple discrete emission spectrum and intense, coherent beams. Recent observations of the AKR's discreteness and coherence have clearly ruled out the previous open-loop amplifier model for such emissions, and recent observations of the Jovian S-bursts have shown the expected, regularly-spaced, longitudinal laser modes. These new observations thus confirm the proposed planetary cyclotron radio lasing at both planets.

35. The Polarization of Escaping Terrestrial Continuum Radiation

D. A. Gurnett, W. Calvert, R. L. Huff, D. Jones, and M. Sugiura

J. Geophys. Res., **93**, 12,817, 1988.

Plasma wave measurements from the DE-1 (Dynamics Explorer 1) spacecraft are used to determine the polarization of an escaping terrestrial continuum radiation event that occurred on March 2, 1982. The source of the radiation was determined by direction-finding to be located near the magnetic equator on the nightside of the Earth at a radial distance of about 2.8 to 3.5 R_E . The radiation was emitted in two meridional beams, one north and the other south of the magnetic equator. Polarization measurements using the two orthogonal electric antennas on DE-1 show that the radiation is right-hand polarized with respect to an outward directed E-plane normal in the northern hemisphere, and left-hand polarized in the southern hemisphere. Comparisons with the local magnetic field show that both the northern and southern hemisphere beams are propagating in the L-O mode at the spacecraft. The mode of propagation has also been confirmed using measurements of the E-plane normal angle and ellipse ratio. Because the angle between the magnetic field and the E-plane normal rotates through perpendicular as the radiation propagated from the source to the spacecraft, mode coupling effects must be evaluated when considering the mode of propagation in the source. Estimates of the spatial gradients over the $\sim 1 R_E$ distance between the source and the spacecraft indicate that the radiation has not reached the region of limiting polarization. Therefore, the mode of propagation must be the same at the source and at the spacecraft: i.e., the L-O mode. These observations support the linear conversion model of Jones in which the radiation is produced by coupling from intense upper hybrid resonance emissions near the plasmopause. This conversion mechanism predicts that continuum radiation generated in the vicinity of the plasmopause should be emitted primarily in the L-O mode. Remote-sensing analyses based on Jones' model yield source locations in agreement with those derived by the direction-finding method.

36. Particle Acceleration and Wave Emissions Associated with the Formation of Auroral Cavities and Enhancements

R. M. Winglee, P. L. Pritchett, P. B. Dusenbery, A. M. Persoon, J. H. Waite, Jr., T. E. Moore, J. L. Burch, H. L. Collin, J. A. Slavin, and M. Sugiura

J. Geophys. Res., **93**, 14,567, 1988.

Observations from DE-1 and electrostatic particle simulations are combined in an effort to provide a unified model for (nightside) auroral particle acceleration and wave emissions in association with the formation of plasma cavities and enhancements. Enhanced electron precipitation during inverted-V events are observed to be associated with broadband electrostatic bursts (BEB), upward field-aligned currents

and density enhancements. These regions are flanked by return current regions where the density is depleted (i.e., a plasma cavity). Perpendicular acceleration of ambient plasma ions can be observed in both upward and return current regions.

It is shown through the simulations that these processes are integrally related and not independent of each other. The free energy is provided by energetic ion beams in the plasma sheet boundary layer with non-zero perpendicular energy. The perpendicular energy allows charge-separation between the beam ions and co-streaming electrons to occur. The resultant space-charge fields accelerates electrons on the same field lines as the co-streaming electrons downwards toward the ionosphere. Ambient plasma electrons on adjacent field lines are accelerated upwards forming a return current. Because these currents are spatially separate, a perpendicular electrostatic shock, which accelerates the plasma ions across the field lines, develops in an effort to close the currents. This acceleration creates ion conics in velocity space and, in coordinate space, plasma cavities are formed in the return current regions and plasma enhancements in the positive current regions. Strong broadband electrostatic waves are generated with a spectral maxima being generated near the local electron plasma frequency by the accelerated electrons and near the lower hybrid frequency by the accelerated ions, similar to that seen in BEB. Note that the auroral particle acceleration and induced wave emissions can be produced without the ion beam actually entering the auroral zone.

37. Auroral E-Fields From DE-1 and -2 at Magnetically Conjugate Points
D. R. Weimer
Adv. Space Res., 8, (9)373, 1988.

The results of studies of the electric field measurements from the two Dynamics Explorer satellites are reviewed. There are times at which DE-2 measured electric fields at the auroral ionosphere while DE-1 obtained nearly simultaneous measurement at a higher altitude on the same magnetic field lines. When these electric fields are mapped to a common altitude it is found that the large-scale electric fields are similar, but the small-scale electric fields have a larger amplitude at the higher altitude. Through the use of Fourier analysis it is shown that these results are evidence for a magnetic field-aligned potential drop between the two satellites. While these results were made possible by the satellites' altitude separation, it is also possible to take advantage of the fact that the satellites may pass through the same geomagnetic location with a time separation. This was useful for confirming that sinusoidal electric field oscillations which were detected near one conjunction were due to spatial rather than temporal variations, since similar oscillations were found at the same location at different times. The observed spatial oscillations can be explained by a simple model of magnetosphere-ionosphere coupling.

38. Electron Density Distributions in the High-Latitude Magnetosphere
A. M. Persoon
Adv. in Space Res., 8, 79, 1988

Electric field spectrum measurements from the plasma wave instrument on Dynamics Explorer 1 are used to study the local electron density at high altitudes in the polar cap and nightside auroral zone. The electron density is derived from the upper cutoff of the whistler-mode auroral hiss emissions at the electron plasma frequency. In the nightside auroral zone, sharply defined regions of low electron densities are commonly found to occur. Electron densities in these regions are strongly depleted in the relation to the adjacent plasmaspheric and polar densities, forming a low density cavity at $70^\circ \pm 5^\circ$ invariant latitude. A comparison of these density depletions with simultaneous particle measurements indicates a correspondence between low auroral plasma densities, upflowing ion distributions and an energetic precipitating electron population. These correlations show that density depletions in the nightside auroral zone are directly associated with auroral acceleration processes. Inside the polar cap, density values are found to vary inversely with increasing radial distance, falling by more than two orders

of magnitude over an altitude range of 1.75–4.66 R_E . The observed variation indicates a power law distribution of densities, consistent with a steady-state radial outflow of ionospheric plasma along polar magnetic field lines.

39. Impulsive Plasma Waves Observed by DE 1 in Nightside Magnetosphere
T. Ondoh, Y. Nakamura, S. Watanabe, and K. Aikyo
J. Geophys. Res., 94, 3779, 1989.

Impulsive plasma waves with a frequency range of 1–9 kHz were found in the wide-band electric field data (650 Hz to 10 kHz) from the DE 1 satellite received at the Kashima station in Japan. The impulsive plasma waves were often accompanied by a strong hiss band at about 1 kHz, but not by a chorus. The frequency-time spectra of these waves are very similar to those of electrostatic bursts associated with ELF chorus in the outer dayside magnetosphere, but these impulsive waves were observed at low geomagnetic latitudes in nightside magnetospheric regions much nearer the Earth for geomagnetic quiet and disturbed times. Local plasma densities ($\sim 1 \text{ cm}^{-3}$) obtained from the characteristic frequency of VLF emissions associated with the impulsive plasma waves agree with those observed simultaneously by the DE 1 retarding ion mass spectrometer. It is inferred from the local plasma density and the empirical relation of the plasmopause position with K_p that the impulsive plasma waves are occurring just outside the plasmopause. The impulsive plasma waves are discussed in terms of a resistive medium instability caused by Landau resonant trapping of thermal electrons by the associated hiss band at about 1 kHz, since this mechanism seems to be plausible from the available data and the frequency-time spectra are similar to electrostatic bursts identified previously. Some of the events do not seem to have a strong ELF hiss band accompanying the impulsive plasma waves. It is suggested that these events may be due to electrons bunched by an ELF hiss band in nearby region or may be caused by space discharges in the vicinity of the long-wire antenna on the DE 1 spacecraft.

40. Discrete Electromagnetic Emissions in Planetary Magnetospheres
Roger R. Anderson and William S. Kurth
Plasma Waves and Instabilities in Magnetospheres and at Comets, ed. by B. T. Tsurutani and H. Oya, Geophysical Monograph 53, American Geophysical Union, Washington, D.C., 81, 1989.

A common feature of electromagnetic plasma instabilities in planetary magnetospheres is the occurrence of discrete emissions. Discrete emissions were first observed with telephone receivers connected to telephone and telegraph lines late in the last century. The first concentrated studies of whistlers and discrete emissions were conducted using ground based very-low-frequency receivers in the early part of this century. Many of these emissions were given names such as "chorus", "risers", and "hooks", which attempted to describe the sound of the received signals when they were routed through an amplifier and speaker system. We now know that these emissions are generated by whistler-mode plasma instabilities in the Earth's magnetosphere. Despite the advanced state of our understanding of plasma instabilities, the reasons that the waves organize themselves into intense narrow band packets and the detailed explanation of the frequency variations and are still the subject of study and debate. The most widely accepted present view is that the narrowband spectral features are caused by a nonlinear process which enhances the growth of one spectral component at the expense of nearby components. After more than 25 years of study by spacecraft which have now visited almost all of the planets in the solar system, we now know that the discrete emissions are a very common feature of planetary magnetospheres. Discrete whistler-mode emissions, widely referred to as "chorus", have been observed in the magnetospheres of Earth, Jupiter, Saturn, and Uranus. Although differing in some details, the basic character of the emission, consisting of a series of narrowband tones each rising or falling in frequency on a time scale ranging from tenths of a second to several seconds, is essentially the same. Often a gap occurs in the frequency spectrum at almost exactly one-half the electron cyclotron frequency.

Another type of discrete emission called "lion roars" also occurs in the Earth's magnetosheath with characteristics very similar to chorus except it tends to occur at a lower frequency. Typical energies for electrons resonating with these waves range from a few hundred eV to as high as several hundred keV. In the Earth's magnetosphere discrete whistler-mode emissions have been shown to play an important role in the pitch-angle scattering and loss of energetic electrons from the radiation belt. Discrete spectral features also occur in other electromagnetic modes. Electromagnetic ion cyclotron waves in the Earth's magnetosphere have intense narrowband features similar in some respects to chorus. At frequencies above the electron cyclotron frequency and the electron plasma frequency, terrestrial auroral kilometric radiation, which propagates in the free space (R-X) mode, has a very complex, frequency-time structure consisting of many discrete emissions. A similar type of radio emission at Jupiter called S-burst has been studied for many years by radio astronomers and is characterized by discrete tones drifting downward in frequency. Whether these free space mode emissions are fundamentally similar to the discrete ion cyclotron and whistler-mode emissions is an open question. Discrete electromagnetic emissions have also been observed to be triggered in the magnetosphere by signals from ground transmitters.

41. Simulations and Observations of Heating of Auroral Ion Beams
R. M. Winglee, P. B. Dusenbery, H. L. Collin, C. S. Lin, and A. M. Persoon
J. Geophys. Res., 94, 8943, 1989.

In the auroral zone, quasi-static parallel electric fields produce beams of ionospheric ions (e.g., H^+ , He^{++} , and O^+) which flow outwards into the magnetosphere, providing a significant source of ions for the ring current and plasma sheet. Because the velocities to which these are accelerated is dependent on the mass of the ions, differential flows between the various ion species can develop which are unstable to an ion-ion streaming instability. Particle simulations and observations from DE-1 are used to investigate the heating of the ion beams produced by this instability. It is shown that there is net transfer of energy from the light ions to the heavy ions, with the heavy ions reaching maximum velocities near the beam velocity of the light ions. Bulk heating of the heavy ions occurs when the relative density is weak while high energy tails are produced when the relative density is high. The heating is primarily in the parallel direction if the difference in the heavy and light ion beam velocities is subsonic while both perpendicular and parallel heating can occur if it is supersonic. Comparisons with observations show features consistent with heating via the ion-ion instability in both the subsonic and supersonic regimes. This heating is however not always observed in association with enhanced wave emissions. This lack of waves is attributed to reabsorption of the waves as the ions become heated.

42. Heating of Thermal Oxygen Ions Near the Equatorward Boundary of the Mid-Altitude Polar Cusp: Dynamics Explorer Observations
W. K. Peterson, M. Andre, G. B. Crew, A. M. Persoon, M. Engebretson, and C. Pollock
Electromagnetic Coupling in the Polar Clefts and Caps, NARO ASI Series, Series C: Math & Phys. Sci., ed. by A. Egeland and P. E. Sandholt, Kluwer Academic Publishers, 278, 103, 1989.

Intense, energetic oxygen ions are frequently observed to be heated near the equatorward boundary of the mid-altitude polar cleft on the Dynamics Explorer-1 satellite. These observations confirm reports from the VIKING satellite. In this paper we present examples of heating of oxygen ions equatorward of the 'central' cusp/cleft region and use simultaneously obtained low-frequency electric and magnetic field observations to quantitatively test resonant and non-resonant heating processes. We find that, within observational and model uncertainties, the heating rates inferred from observed electric field spectra are large enough to produce the observed perpendicular oxygen temperatures in time scales determined by the measured poleward drift rate of thermal oxygen ions. The examples presented provide a good comparison of basic plasma theory and observation.

43. Observation of the Z Mode with DE 1 and Its Analysis by Three-Dimensional Ray Tracing
Kozo Hashimoto and Wynne Calvert
J. Geophys. Res., 95, 3933, 1990.

Certain Z-mode wave emissions in the earth's magnetosphere have been identified using the wave spectra and polarization measurements of the DE-1 satellite. Although such emissions accompany the aurora, and thus presumably originate from the evening sector auroral zone, they are found to occur over much wider ranges of latitude and longitude. Since the predicted cyclotron maser emission at the cyclotron frequency could not have produced waves which travel such great distances, as we have shown by three-dimensional ray tracing, it is proposed instead that these emissions must originate from lower altitudes within the auroral zone and probably from near the plasma frequency inside the auroral plasma cavity.

44. Ion Cyclotron Resonance Heated Conics: Theory and Observations
G. B. Crew, T. Chang, J. M. Retterer, W. K. Peterson, D. A. Gurnett, and R. L. Huff
J. Geophys. Res., 95, 3959, 1990.

A general theoretical treatment of energetic oxygen ion conic formation through cyclotron resonance with magnetospheric electromagnetic plasma turbulence is presented. With suitable assumptions, there exists a similarity regime in which the process may be profitably characterized by two parameters n_o and s , corresponding roughly to the velocity scale and pitch angle of the ion distribution. These may be independently determined from the wave and particle observations of a conic event, as is illustrated here using typical auroral passes of the Dynamics Explorer 1 satellite. The predictions of theory are found to be in excellent agreement with the observations.

45. The Magnetoionic Modes and Propagation Properties of Auroral Radio Emissions
W. Calvert and K. Hashimoto
J. Geophys. Res., 95, 3943, 1990.

The different magnetoionic wave modes which accompany the aurora are identified using DE-1 not only by their appearance on satellite radio spectrograms, but also by concurrent measurements of their wave polarization and arrival directions, and by ray-tracing models of their expected propagation behavior. Of the four possible propagation modes, designated O, X, W, and Z for the ordinary, extraordinary, whistler and Z modes, respectively, all four are found to occur in the auroral zone, as follows: The most intense, of course, is the well-known auroral kilometric radiation, (AKR), which originates primarily in the X mode near the electron cyclotron frequency, but which is frequently also accompanied by a weaker O-mode component from the same location. The next most prominent auroral emission is the W-mode auroral hiss originating from altitudes always well below the DE-1 satellite at frequencies below the local cyclotron frequency. For a particular case which was studied in detail, both of these components were found to originate from approximately the same source field lines near the poleward edge of the auroral plasma cavity, with the latter exhibiting a funnel shape on the radio spectrograms, centered on the source field lines but having different shapes inside and outside the cavity because of the differing plasma densities of these two regions. Equatorward of the cavity and at frequencies above the minimum plasma frequency within the cavity, this upcoming W-mode exhibits a shadow zone which is attributed to the blockage of W-mode propagation at the plasma frequency. The previously-reported Z-mode auroral radiation was also detected, but from sources also below the satellite and at the poleward edge of the cavity, and not from the expected AKR source at the cyclotron frequency. A weaker O-mode component seems to accompany these emissions also, both within the polar cap poleward of the source and inside the cavity, the latter seemingly being guided upward by the cavity's lower plasma densities. Finally, exactly on the source field lines at the poleward edge of the cavity, there

also occasionally seems to be localized Z-mode emissions extending from the Z-mode cutoff at quite low frequencies up to and above the plasma frequency.

46. Plasma Characteristics of Upflowing Ion Beams in the Polar Cap Region
M. W. Chen, W. K. Peterson, M. Ashour-Abdalla, T. E. Moore, and A. M. Persoon
J. Geophys. Res., **95**, 3907, 1990.

The plasma characteristics of O^+ , H^+ , and He^+ beam events in the polar cap region observed near solar maximum by the Dynamics Explorer 1 (DE 1) satellite are analyzed in this paper. The data analyzed were taken from both the energetic ion composition spectrometer (EICS), which operates in the 10 eV - 17 keV energy range, and the retarding ion mass spectrometer (RIMS), which operates in the low energy spectrum of less than 50 eV. Electron densities measured by the plasma wave instrument (PWI) provided limits on estimates of ion densities. Because the upflowing ion energies are sometimes comparable to the spacecraft potentials and the fluxes involved are close to the instrumental thresholds, it has been difficult to measure the densities and temperatures of these low energy ions. A subset of upflowing polar cap ion streams was identified from which it was possible to make estimates of the plasma characteristics using the three DE 1 instruments described above. In this paper, the data for two polar ion streams are presented in detail. The plasma was found to consist of multiple streaming and quasi-isotropic components. In both cases, estimates of temperatures and densities were made taking into account possible spacecraft potentials. The ion densities of several other events were also estimated. It was found that (1) the plasma often had a large content of upflowing O^+ , (2) there was a significant amount of O^+ in the plasma even during quiet auroral conditions when the AE index was only 37 nT, (3) in one event presented, the upflowing O^+ population had both a cold and a warm field-aligned distribution, (4) in another event presented, the O^+ and H^+ temperatures (for an assumed spacecraft potential of 5 eV) were estimated to be 5 eV and 7.6 eV, respectively, suggesting the ionospheric ions were heated, (5) the cold upflowing ion stream component observed in some of the polar ion streaming events exhibited a filamentary nature (with a time scale ranging from tens of seconds to minutes, which corresponds to spatial scales of tens to hundreds of kilometers in the ionosphere) and (6) there also often was a significant amount of He^+ found in the plasma. The observations provide important plasma characteristics of the polar cap region, which will be useful in future theoretical and simulation work.

47. Wave Intensifications Near the Electron Cyclotron Frequency Within the Polar Cusp
W. M. Farrell, D. A. Gurnett, J. D. Menietti, H. K. Wong, C. S. Lin, and J. L. Burch
J. Geophys. Res., **95**, 6493, 1990.

As DE-1 flew through the polar cusp, enhanced narrowband electrostatic waves were sometimes observed just above the electron cyclotron frequency, f_{ce} . In this report, we present wave and particle measurements from three representative cusp transits in order to characterize these signals and understand the conditions that favor their generation. In these representative cases, narrowband emission intensifications occurred at frequencies between 1.1 to 1.3 f_{ce} . The emission intensities ranged between $.5 \times 10^{-14}$ to 10^{-12} V^2/m^2Hz , such waves being 50 to 1000 times greater than the narrowbanded cyclotron-related signal levels detected in adjacent regions. Simultaneously occurring with the wave enhancements was energetic cusp electrons with energies extending up to about 500 eV. It was found that the form of the local cusp electron velocity distribution had a direct influence on the wave spectral character. Based on an examination of many cusp transits, the occurrence of these enhanced signals appeared to have some dependency on Kp index, indicating that increased particle flows (associated with increased geomagnetic activity) seem to affect their generation. Although the exact wave/particle coupling mechanism responsible for these enhancements is difficult to identify, it is evident that the generation is directly related to the energetic cusp electrons.

48. Observations of Reconnected Flux Tubes Within the Midaltitude Cusp
N. A. Sافلةkos, J. L. Burch, M. Sugiura, D. A. Gurnett, and J. L. Horwitz
J. Geophys. Res., **95**, 8037, 1990.

Dynamics Explorer 1 observations within the midaltitude polar cusp provide indirect evidence of reconnected flux tubes (RFT) envisioned to be extensions of the flux transfer events reportedly found near the magnetopause. In this study, low-energy plasma, high-energy plasma, magnetic fields, and electric fields were used to identify the signatures of reconnected flux tubes in the midaltitude cusp. Inside isolated flux tubes, low-energy plasma was observed to be transferred from the magnetosheath to the magnetosphere, and relatively hot plasma was observed to be transferred from the magnetosphere to the magnetosheath. The cool magnetosheath plasma and the relatively hot magnetospheric plasma shared the same magnetic flux tube. The RFT signature is most easily identified in electron and ion energy fluxes plotted versus time for all pitch angles. The electron signature of an RFT is characterized by a drop in energy at the upper side of the energy band. The ion energy signature is similar to the electron signature except the ions form distinct Vs within the RFTs which differ from Vs outside the RFTs by the fact that the thickness of the lines forming the sides of the Vs is thinner inside the RFTs in comparison to that outside, and the height of these Vs is shorter inside the RFTs. The characteristics of spatial scale, time duration, and frequency of occurrence between flux transfer events and midaltitude cusp reconnected flux tubes are consistent, although they differ in the direction of motion. However, the merging cell topology and the interplanetary magnetic field B_y effect can explain this difference. Larger-scale (space and time) events can be explained by motion of the cusp resulting from a quasi-steady reconnection process. The field-aligned currents associated with reconnected flux tubes at midaltitudes within the cusp are consistent with twisting of magnetic field lines and with closure by Pedersen currents. It is possible that what appear to be field-aligned currents closing by Pedersen ionospheric currents may also be interpreted as currents carried by Alfvén waves.

49. Double-Peaked Electrostatic Ion Cyclotron Harmonic Waves
S. A. Boardsen, D. A. Gurnett, and W. K. Peterson
J. Geophys. Res., **95**, 10591, 1990.

Electrostatic H^+ cyclotron harmonic waves are often observed along the auroral field lines at altitudes of 1-3.5 R_E by the Dynamics Explorer 1 satellite. A small fraction of these waves are found to have two peaks associated with each harmonic instead of one peak. The waves occur below the lower hybrid frequency and are usually relatively weak, about a factor of 4 smaller than typical electric field amplitudes of other H^+ cyclotron harmonic wave events. For two events the separation between the spectral peaks is found to be proportional to the harmonic number. The double-peaked spectral signature is believed to be produced by Doppler shifts arising from the satellite velocity relative to the plasma rest frame. The wavelength and phase velocity of the harmonics can be determined by measuring the separation between the peaks. The waves were found to have wavelengths of the order of 300 m and phase velocities of the order of 150 km/s. The proportionality between the peak separation and the harmonic number indicates that the phase velocity is approximately constant, independent of harmonic number. Assuming that the phase velocity is constant, it is shown that as $\Delta k/k$ increases, the double peaks merge to form a single spectral peak. For the wave events presented in this paper, $\Delta k/k$ is estimated to be less than 0.1.

50. A Survey of Upwelling Ion Event Characteristics
C. J. Pollock, M. O. Chandler, T. E. Moore, J. H. Waite, Jr., C. R. Chappell, and D. A. Gurnett
J. Geophys. Res., **95**, 18,969, 1990.

Ionospheric ion upwelling in the vicinity of the dayside cleft has been studied, based primarily on data from the Dynamics Explorer 1 spacecraft. Using retarding ion mass spectrometer low-energy ion data and plasma wave instrument DC electric field data, bulk ion plasma parameters, including ion species density and field aligned bulk velocity and flux, have been derived at points within a number of observed upwelling ion events for the ion species H^+ , He^+ , O^+ and O^{++} . The ion species bulk parameters near the source latitude are examined and compared. We find that the upwelling plasma is rich in O^+ , which typically comprises $\sim 90\%$ of the particle density, followed by H^+ , at somewhat less than 10% and then He^+ and O^{++} , each comprising $\sim 1\%$ of the upwelling ion particle density. The upwelling O^+ ion flux is also commonly dominant over that associated with the other species, with normalized values near the source region which are typically near $10^9 \text{ cm}^{-2} \text{ sec}^{-1}$. The fractional upward H^+ flux is not as small as the fractional H^+ density due to the much larger H^+ upward flow velocities. Integration of the product of the normalized upward ion species flux and the upwelling ion occurrence probability [Lockwood et al., 1985] over the source area yields an estimate of the source strength of this low-altitude cleft region magnetospheric plasma source of $2.6 \times 10^{25} \text{ ions s}^{-1}$.

51. Characteristics of Wave-Particle Interactions During Sudden Commencements: 2. Spacecraft Observations

W. B. Gail and U. S. Inan

J. Geophys. Res., **95**, 139, 1990.

Wave data from the DE-1 spacecraft of 50 sudden commencements were analyzed for amplitude and spectral modifications and correlated with data from ground-based observatories. Changes in wave activity were identified in 14 of the events studied. The changes, which were commonly observed at frequencies below the local electron gyrofrequency, exhibited a complex structure both in frequency and in time and varied considerably among events. The typical event lasted 1-10 minutes with a maximum narrowband amplitude increase or decrease of 10-30 dB. The onset time of the wave growth was correlated with the arrival of the magnetic disturbance at the spacecraft. Changes were most commonly observed at L shells in the range $3 < L < 6$. Growth was observed on the nightside as well as the dayside, and no clear local time dependence was found. In several cases, growth at frequencies above the local gyrofrequency was noted and identified as auroral kilometric radiation.

52. Ion Cyclotron Bands in VLF Saucers

Kaichi Maeda, Shing F. Fung, and Wynne Calvert

Planet. Space Sci., **38**, 507, 1990.

In the wideband VLF data obtained from the polar orbiting DE-1 satellite over the polar night ion trough region of the upper ionosphere, conspicuous frequency-band structures are found to occur both in absorption and emission, particularly associated with VLF saucers. These proton-cyclotron harmonic bands are sometimes observable up to the 10th harmonic. The attenuation bands, which appear in both the magnetic and electric field data from DE-1, presumably indicate that the ions of atomic hydrogen from the polar ionosphere are accelerated by the AC electric fields of VLF waves oscillating normal to the static magnetic field, analogous to a cyclotron accelerator. The observed frequencies of the cyclotron harmonics are generally higher than the local cyclotron frequencies computed from the onboard magnetometer data, suggesting that the acceleration is taking place in the layer below the satellite at a geocentric distance of less than about 1.5 Earth radii. This example indicates the existence of upward propagating hiss at those altitudes inside the auroral zone. On the other hand, the frequency shifts of the emission bands are found to be space and time dependent, with the harmonic frequencies inside the V-shaped saucers being somewhat higher than those outside. These frequency shifts are attributed to a combination of two different types of Doppler shift, one due to the orbital motion of the satellite and the other due to the upward motion of the medium at the emission source. This indicates the existence of

an upward plasma flow at the source, with a velocity of the order to 20 km s^{-1} inside the saucer. The amount of this frequency shift decreases with increasing harmonic order, indicating a higher phase velocity for the electrostatic waves of higher harmonic order.

53. Ion Heating by Broadband Low-Frequency Waves in the Cusp/Cleft
M. Andre, C. B. Crew, W. K. Peterson, A. M. Persoon, C. J. Pollock, and M. J. Engebretson
J. Geophys. Res., **95**, 20,809, 1990.

Ion conic distributions are often observed in the cusp/cleft region of the dayside magnetosphere. We show that these ions can be heated via the process of cyclotron resonance with broadband low-frequency (near the ion gyrofrequency) waves. Data from two cusp/cleft crossings of the polar orbiting DE-1 satellite are studied in detail. There is very good agreement between the onset of low-frequency waves and the onset of ion heating. Observed cool O^+ distributions and observed wave intensities from one orbit are used as input to a Monte Carlo simulation. Given the assumptions underlying the simulation model, the resulting hot O^+ distributions are in good agreement with the corresponding observed distributions. We explore this agreement using a further simplified analytic model which accounts for much of the agreement and many of the discrepancies. The mean ion energies of about 200 eV obtained from the simulation agree well with several minutes of observations, corresponding to a distance of nearly 1000 kilometers along the satellite orbit. The O^+ distribution functions from both simulation and observations show that heating near the equatorward edge of the cusp/cleft region is rather local, while ions observed well inside this region may be heated over altitudes of several thousand kilometers. This resonant heating by broadband low-frequency waves is important for the outflow of ionospheric ions into the magnetosphere.

54. Auroral Plasma Waves
D. A. Gurnett
Auroral Physics, ed. by C. I. Meng, M. J. Rycroft, and L. A. Frank, Cambridge University Press, 241, 1991

A review is given of auroral plasma wave phenomena, starting with the earliest ground-based observations and ending with the most recent satellite observations. Two types of waves are considered, electromagnetic and electrostatic. Electromagnetic waves include auroral kilometric radiation, auroral hiss, ELF noise bands, and low-frequency electric and magnetic noise. Electrostatic waves include upper hybrid resonance emissions, electron cyclotron waves, lower hybrid waves, ion cyclotron waves and broadband electrostatic noise. In each case, a brief overview is given in describing the observations, the origin of the instability, and the role of the waves in the physics of the auroral acceleration region.

55. Magnetospheric Radio and Plasma Wave Research: 1987-1990
W. S. Kurth
Rev. Geophys., Suppl., 1075-1086, 1991.

This report summarizes radio and plasma wave research in planetary magnetospheres during the interval of 1987-1990.

56. The Source Location and Beaming of Terrestrial Continuum Radiation
D. D. Morgan and D. A. Gurnett
J. Geophys. Res., 96, 9595, 1991.

Plasma wave data from the spacecraft Dynamics Explorer 1 was used to study the source location and beaming of terrestrial continuum radiation. This study shows that the radiation usually is generated near the magnetic equator at radial distances ranging from 2.0 to 4.0 R_E . The radiation is beamed outward in a broad beam directed along the magnetic equator with a beamwidth of about 100 degrees. The overall frequency of occurrence of continuum radiation was found to be 60% with a sharp increase near the midnight meridian, increasing in the dawnward direction. Several case studies are presented to illustrate various characteristics of continuum radiation. The observed characteristics are then compared with the radio window model of Jones. Several characteristics not predicted by Jones' model are observed. These include large latitudinal asymmetries, an absence of a minimum in the occurrence and intensity at the equator, a tendency for higher frequency bands to come from larger and more diffuse source regions, and the emergence of several distinct beams from a single region. In particular the absence of a minimum in the occurrence and intensity minima at the equator and the emergence of beams of radiation at sharply distinct angles from one source region constitute strong evidence against the radio window model. Also, the basic equation for the beaming angle with respect to the magnetic equatorial plane is found to be a poor predictor of the observed beaming angle. The evidence against the radio window model is partially mitigated by the facts that the source of radiation is probably extended in space and frequency and that sometimes radiation from the sun interferes with the direction finding. Overall, these observations imply that the radio window model does not fully explain the beaming pattern of continuum radiation.

57. Association of Electron Conical Distributions With Upper Hybrid Waves
J. D. Menietti, C. S. Lin, H. K. Wong, A. Bahnsen, and D. A. Gurnett
J. Geophys. Res., 97, 1353, 1992.

The particle and plasma wave data of the DE-1 and Swedish Viking satellites have been examined and several conclusions can be drawn. First, we note that intense (> 1 mV/m) upper hybrid emissions are present in the mid-altitude polar magnetosphere on both the dayside cusp/cleft and the nightside auroral regions. Secondly, upper hybrid waves are often associated with electron conical distributions. These observations are consistent with the production of at least some electron conical distributions by perpendicular heating of the electrons by upper hybrid waves. Examination of the wave data to establish the role of parallel heating remains to be performed.

58. Planetary Radio Emissions
D. A. Gurnett
Van Nostrand Astronomy and Astrophysics Encyclopedia, ed. by S. Maran, Van Nostrand, Reinhold, New York, 535, 1992.

No abstract.

59. The Quiet-Time Polar Cap: DE 1 Observations and Conceptual Model
 J. L. Burch, N. A. Saflekos, D. A. Gurnett, J. D. Craven, and L. A. Frank
J. Geophys. Res., 97, 19,403, 1992.

Auroral activity increases over the polar caps during quiet times, which are associated with northward interplanetary magnetic field (IMF) components. Polar cap auroras (Sun-aligned arcs, theta auroras, and horse collar auroras) occur under these conditions. DE 1 data show that the theta and horse collar auroras are generally characterized by sunward convection, closed field lines, auroral hiss, and inverted-V events. These phenomena are similar to those observed along the auroral oval but have somewhat lower electron energies. Adjacent dark regions of the polar caps appear to contain open field lines and antisunward convection. A conceptual northward IMF merging model containing lobe cells, merging cells, and viscous cells is shown to be consistent with the observations. As the IMF becomes more northward, the polar arc configuration changes from the "horse collar" pattern to the theta aurora pattern in the model, and this is shown to be generally true for the set of published data on these phenomena. The model involves dayside merging both at high latitudes on open field lines and at lower latitudes on closed field lines. The ratio between the merged flux produced by the high-latitude merging to that produced by the lower-latitude merging increases as the IMF becomes more northward. Two types of open field lines, equator-crossing and non-equator-crossing, are produced by the higher- and lower-latitude merging, respectively. The equator-crossing field lines have a strong azimuthal component of convection as they flow around the magnetopause, while the non-equator-crossing field lines can convect more or less directly across the polar cap, leading to an antisunward flow channel across the central polar cap. This antisunward flow region grows as the IMF becomes less northward, causing dual polar cap arcs to spread out into the horse collar configuration. The sunward flow segments of the lobe cells are associated with induced electric fields, thus account for the particle energization leading to auroral forms.

60. The Polar Cap Environment of Outflowing O^+
 J. L. Horwitz, C. J. Pollock, T. E. Moore, W. K. Peterson, J. L. Burch, J. D. Winningham,
 J.D. Craven, L. A. Frank, and A. M. Persoon
J. Geophys. Res., 97, 8361, 1992.

Ion composition measurements by Dynamics Explorer 1 often show upward O^+ beams at polar latitudes, with streaming energies of 1-20 eV or more. Here we utilize measurements of core (0-50 eV) and "energetic" (~ 0 -1 keV) ion composition, plasma waves, and auroral images from DE 1 and plasma ions and electrons from DE 2 to examine some of their properties in the context of the polar cap environment. It is found that two distinct populations of O^+ beams are observed: "high-speed" (10-30 eV or higher streaming energies) and "low-speed" (generally < 10 -eV streaming energies). The "high-speed" polar beams show an "auroral" connection; i.e., they are observed on or near field lines threading auroral arcs seen in DE 1 images. The "low-speed" streams are on or near field lines threading the dark polar cap and may be convected from the cleft ion fountain. The low-speed streams are generally much more stable in energy and flux, while the high-speed streams tend to be bursty. In general, the streams are convecting antisunward, with velocities of 5-14 km/s in the orbital plane. We sought to obtain plasma density estimates from plasma wave measurements, through analysis of features of auroral hiss as well as upper hybrid emissions. Densities in the range 1-5 el/cm^3 were indicated for one segment of a DE 1 polar cap pass; however, the measurements generally indicate little auroral hiss or upper hybrid emissions in the polar cap for the other cases considered here. Estimates of electrostatic potential drops above the DE 2 satellite have been made using energy-angle spectrograms of photoelectron data, under the assumption that the field lines of observation are "effectively" open. Potential drops often are in the 20- to 40-V range. At other times the potential falls below the ~ 5 -V instrument threshold, or there are insufficient photoelectron fluxes for estimation. These limited data suggest that the largest potential drops are just poleward of the cleft or near its poleward edge and there is a decline of the drop in the

antisunward direction. No obvious correlation between the potential estimates and "nearby" O^+ streaming energies is seen.

61. Field and Thermal Plasma Observations of ULF Pulsations During a Magnetically Disturbed Interval

N. Lin, M. J. Engebretson, L. A. Reinleitner, J. V. Olson, D. L. Gallagher, L. J. Cahill, Jr., J. A. Slavin, and A. M. Persoon
J. Geophys. Res., **97**, 14859, 1992.

ULF pulsations were observed by DE 1 between 1600 and 1830 UT, October 31, 1982, during a magnetically disturbed interval. Ground observations suggested that the pulsations were excited by a sudden increase in the solar wind velocity and pressure. During the pulsation interval DE 1 traveled near apogee from -55 to 20° geomagnetic latitude and from $L \sim 13$ to $L \sim 4$ at about 0900 LT. The waves observed were azimuthal oscillations preceded by gradually decaying long period compressional waves which lasted for more than 1 hour. Phase relations between magnetic and electrical field oscillations and calculated Poynting flux indicate that in the outer magnetosphere ($L > 8$) DE 1 observed propagating waves which contained strong poloidal components, while the quasi-sinusoidal toroidal waves seen later for $L < 10.3$ were standing along field lines. The toroidal waves appeared as four wave packets, each of which corresponded to a region with a distinct plasma distribution. The observed wave periods decreased with L over an extended magnetospheric region. The seemingly weak interaction between magnetic shells suggests that the source was a broadband one. Magnetometer data from several high latitude observatories located near the footpoints of the magnetic shells crossed by DE 1 were also examined. The magnetic pulsations indicates that the stations also detected oscillations of the adjacent field lines. The major frequencies seen at ground stations seemed to be roughly constant for about 2 hours but L dependent. This suggests that the changing periods seen in space by DE 1 were clearly L related and not temporally varying.

62. Funnel-Shaped, Low-Frequency Equatorial Waves

S. A. Boardsen, D. L. Gallagher, D. A. Gurnett, W. K. Peterson, and J. L. Green
J. Geophys. Res., **97**, 14967, 1992.

Funnel-shaped low frequency radiation, as observed in frequency time spectrograms, are frequently found at the Earth's magnetic equator. At the equator the radiation often extends from the proton cyclotron frequency up to the lower hybrid frequency. Ray tracing calculations can qualitatively reproduce the observed frequency-time characteristics of these emissions if the waves are propagating in the fast magnetosonic mode starting with wave normal of $\sim 86^\circ$ at the magnetic equator. The funnel shaped emissions are consistent with generation by protons with a ring-type velocity space distribution. A ring-shaped region of positive slope in the velocity space density distribution of protons is observed near the Alfvén velocity, indicating that the ring protons strongly interact with the waves. Ray tracing calculations show that for similar equatorial wave normal angles, lower frequency fast magnetosonic waves are more closely confined to the magnetic equator than higher frequency fast magnetosonic waves. For waves refracted back toward the equator at similar magnetic latitudes, the lower frequency waves experience stronger damping in the vicinity of the equator than for higher frequency waves. Also, wave growth is restricted to higher frequencies at larger magnetic latitudes. Wave damping at the equator and wave growth off the equator favors equatorial wave normal angle distributions which lead to the funnel-shaped frequency time characteristic.

63. Landau Damping of Auroral Hiss

David DeWitt Morgan

Ph.D. Thesis, Department of Physics and Astronomy, University of Iowa, Iowa City, Iowa, December 1992.

Auroral hiss is observed to propagate over distances comparable to an Earth radius from its source in the auroral zone. In this paper the role of Landau damping is investigated for upward propagating auroral hiss. Using a ray tracing code and a simplified model of the distribution function, the effect of Landau damping is calculated as the wave propagates through the environment around the auroral zone. It is found that Landau damping puts a lower limit on the wavelength of auroral hiss. Poleward of the auroral zone, the particle energy is found in a typical case to limit the resonance energy to a value of ~ 3.2 keV or greater and to limit the wavelength to a value of about 2 km or greater. For equatorward propagation, the resonance energy must be greater than 10 keV and the wavelength must be greater than 3 km to avoid unacceptably large damping. Landau damping is found to be a likely mechanism for explaining some of the one-sided auroral hiss funnels observed by Dynamics Explorer 1, although we cannot account in detail for cases showing equatorward propagation. Upgoing electron beams of energy high enough to generate hiss in the inferred wavelengths are not usually observed. Partial transmission involving interfaces oblique to the magnetic field is considered as a possible wavelength conversion mechanism.

64. Large-Amplitude Auroral Electric Fields Measured with DE 1

D. R. Weimer and D. A. Gurnett

J. Geophys. Res., **98**, 13557, 1993.

A large fraction of the available electric field data from the Plasma Wave Instrument (PWI) on the Dynamics Explorer (DE 1) satellite has recently been searched for events with large-amplitude (over $100 \text{ mV}\cdot\text{m}^{-1}$) electric fields. The magnitude and distribution of these peak events as functions of altitude have been determined. The largest amplitudes were found between 1.4 and $2.5 R_E$ and the probability of finding large electric fields was greatest in the range of 1.5 to $1.7 R_E$. However, when the measured electric field values are "mapped" to the earth's surface in order to account for the geometry of the geomagnetic field lines, then the mapped values always increase with increasing altitude. This radial dependence is considered to be evidence for magnetic field-aligned electric fields. The largest electric field that was detected with the DE 1 instrument had a magnitude exceeding $840 \text{ mV}\cdot\text{m}^{-1}$, and was found at $1.45 R_E$. This field appears to be associated with a low-frequency wave, whereas the more commonly observed large-amplitude events have longer durations, are generally found at higher altitudes, and appears to be due to static electric fields. It appears that two types of phenomena are being observed. A study of all electric field measurements, rather than those with large amplitudes, was also conducted. It was found that at subauroral latitudes the average mapped electric field is nearly constant with altitude, as it should be where there are no magnetic field-aligned potential drops. Small variations can be accounted for by long-term changes in geomagnetic activity. But within auroral latitudes the average value of the mapped electric field increases as altitude increases. The largest gradients are found between 1.3 and $2 R_E$. There is evidence for a "split" potential distribution, with an additional potential drop located above $2.7 R_E$.

65. Nonlinear Radio Emission Processes in Planetary Magnetospheres
 D. A. Gurnett
Research Trends in Physics: Nonlinear Space Plasma Physics, ed. by R. Z. Sagdeev, American Institute of Physics, 229, 1993.

Rapid advances have been made in the observations and understanding of radio emissions from planetary magnetospheres. It is now known that there are two primary types of coherent planetary radio emissions: (1) cyclotron maser radiation and (2) mode conversion radiation. In recent years the primary emphasis has been on linear analyses of these radio emission mechanisms. In this paper we review evidence of nonlinear processes in the generation of planetary radio emissions. In the case of the cyclotron maser radiation, the spectrum shows an extremely complex fine structure, including narrowband emissions with extremely rapid temporal variations, and emission lines at harmonics of the ion cyclotron frequency. This fine structure strongly suggests that nonlinear processes, such as particle trapping, play an important role in the generation of this radiation. For the mode conversion radiation, which involves the conversion of electrostatic wave energy to electromagnetic radiation, recent estimates show that linear conversion has an efficiency that is three orders of magnitude too small to explain the observed intensities. A nonlinear mode conversion processes, such as wave-wave coupling, must therefore be responsible for generating the radiation. However, at the present time the exact mechanism involved has not been identified.

66. Plasmasphere Dynamics in the Duskside Bulge Region: A New Look at an Old Topic
 D. L. Carpenter, B. L. Giles, C. R. Chappell, P. M. E. Decreau, R. R. Anderson, A. M. Persoon, A. J. Smith, Y. Corcuff, and P. Canu
J. Geophys. Res., **98**, 19243, 1993.

Data acquired during several multiday periods in 1982 at ground stations Siple, Halley, and Kerguelen and on satellites DE 1, GEOS 2 have been used to investigate thermal plasma structure and dynamics in the duskside plasmasphere bulge region of the Earth. The distribution of thermal plasma in the dusk bulge sector is difficult to describe realistically, in part because of the time integral manner in which the thermal plasma distribution depends upon the effects of bulk cross-B flow and interchange plasma flows along B. While relatively simple MHD models can be useful for qualitatively predicting certain effects of enhanced convection on a quiet plasmasphere, such as an initial sunward entrainment of the outer regions, they are of limited value in predicting the duskside thermal plasma structures that are observed. Furthermore, use of such models can be misleading if one fails to realize that they do not address the question of the formation of the steep plasmopause profile or provide for a possible role of instabilities or other irreversible processes in plasmopause formation. Our specific findings, which are based both upon the present case studies and upon earlier work, include the following: (1) during active periods the plasmasphere appears to become divided into two entities, a main plasmasphere and a duskside bulge region. The latter consists of outlying or outward extending plasmas that are the products of erosion of the main plasmasphere; (2) in the aftermath of an increase in convection activity, the main plasmasphere tends (from a statistical point of view) to become roughly circular in equatorial cross section, with only a slight bulge at dusk; (3) the abrupt westward edge of the duskside bulge observed from whistlers represents a state in the evolution of sunward extending streamers; (4) in the aftermath of a weak magnetic storm, 10 to 30% of the plasma "removed" from the outer plasmasphere appears to remain in the afternoon-dusk sector beyond the main plasmasphere. This suggests that plasma flow from the afternoon-dusk magnetosphere into the boundary layers is to some extent impeded, possibly through a mechanism that partially decouples the high altitude and ionospheric-level flow regimes; (5) outlying dense plasma structures may circulate in the outer duskside magnetosphere for many days following an increase in convection, unless there is extremely deep quieting; (6) a day-night plasmatrough boundary may be identified in equatorial satellite data; (7) factor-of-2-to-10 density irregularities appear near the

plasma pause in the postdusk sector in the aftermath of weak magnetic storms; (8) during the refilling of the plasmatrough from the ionosphere at $L=4.6$, predominantly bi-directional field aligned and equatorially trapped light ion pitch angle distributions give way to a predominantly isotropic distribution (as seen by DE 1) when the plasma density reaches a level factor of about 3 below the saturated plasmasphere level; (9) some outlying dense plasma structures are effectively detached from the main plasmasphere, while others appear to be connected to that body.

67. Observations of a Transverse Magnetic Field Perturbation at Two Altitudes on the Equatorward Edge of the Magnetospheric Cusp

W. K. Peterson, T. Abe, M. Andre, M. J. Engebretson, H. Fukunishi, H. Hayakawa, A. Matsuoka, T. Mukai, A. M. Persoon, J. M. Retterer, R. M. Robinson, M. Sugiura, K. Tsuruda, D. D. Wallis, and A. W. Yau

J. Geophys. Res., **98**, 21463, 1993.

On January 28, 1990, the Dynamics Explorer 1 and Akebono satellites crossed a magnetic field structure at the equatorward edge of the polar cusp at altitudes of 22,000 and 5000 km, respectively, within 6 min of each other. Locally measured plasma particles and fields and magnetometer data from a ground station near the foot of the magnetic field line are more consistent with an interpretation of the structure as that of a standing Alfvén wave than that of a quasi-steady field-aligned current sheet. We discuss the observations supporting this conclusion and other related observations of field-aligned currents, Alfvén waves, and ion energization near the equatorward edge of the cusp. These observations suggest that Alfvén waves are commonly present near the equatorward edge of the cusp.

68. Landau Damping of Auroral Hiss

D. D. Morgan, D. A. Gurnett, J. D. Menietti, J. D. Winningham, and J. L. Burch

J. Geophys. Res., **99**, 2471, 1994.

Auroral hiss is observed to propagate over distances comparable to an Earth radius from its source in the auroral oval. The role of Landau damping is investigated for upward propagating auroral hiss. By using a ray tracing code and a simplified model of the distribution function, the effect of Landau damping is calculated for auroral hiss propagation through the environment around the auroral oval. Landau damping is found to be the likely mechanism for explaining some of the one-sided auroral hiss funnels observed by Dynamics Explorer 1. It is also found that Landau damping puts a lower limit on the wavelength of auroral hiss. Poleward of the auroral oval, Landau damping is found in a typical case to limit ω/k_{\parallel} to values of 3.4×10^4 km/s or greater, corresponding to resonance energies of 3.2 keV or greater and wavelengths of 2 km or greater. For equatorward propagation, ω/k_{\parallel} is limited to values greater than 6.8×10^4 km/s, corresponding to resonance energies greater than 13 keV and wavelengths greater than 3 km. Independent estimates based on measured ratios of the magnetic to electric field intensity also show that ω/k_{\parallel} correspond to resonance energies greater than 1 keV and wavelengths greater than 1 km. These results lead to the difficulty that upgoing electron beams sufficiently energetic to directly generate auroral hiss of the inferred wavelength are not usually observed. A partial transmission mechanism utilizing density discontinuities oblique to the magnetic field is proposed for converting auroral hiss to wavelengths long enough to avoid damping of the wave over long distances. Numerous reflections of the wave in an upwardly flared density cavity could convert waves to significantly increased wavelengths and resonance velocities.

69. A Survey of Electrostatic Ion Cyclotron Waves and Ion Cyclotron Harmonic Waves With DE 1 S. Boardsen, D. A. Gurnett, and W. K. Peterson
J. Geophys. Res., resubmitted, 1994.

Using data from the Dynamics Explorer-1 (DE-1) satellite, a survey of electrostatic H⁺ cyclotron waves (EHC) and electrostatic H⁺ cyclotron harmonic (HCH) waves was made for the year of 1984. During this period, complete coverage was obtained along the auroral field lines exists over the altitude range of 1 R_E to 3 R_E for magnetic local times from 12 hrs to 24 hrs. Detailed examination of energetic ion mass spectrometer data from a subset of EHC and HCH wave emission events confirmed earlier observations that EHC waves are highly correlated with upward directed ion beams and that HCH waves are associated with precipitating protons. As expected, both types of waves were found to be associated with the auroral oval, and occur at higher invariant latitudes near noon and lower latitudes near midnight. As the K_p index increases, the distribution of the waves shifts to lower latitudes as the polar cap expands. Near dusk, the distribution of EHC waves was observed to be shifted toward the polar edge of the oval, a region associated with discrete auroral arcs. Near dusk, the distribution of HCH waves was observed to be shifted toward the equatorward edge of the oval. This region is associated with diffuse aurora in which proton precipitation can make a significant contribution. EHC waves were observed between 20% and 40% of the auroral zone crossings, and HCH waves were observed between 10% and 20% of the crossings. The percentage of occurrence depended on invariant latitude, magnetic local time, and altitude. As first reported by Kintner et al., the low altitude boundary for the occurrence of EHC waves at ~ 1 R_E near dusk shifted to about 1.5 R_E near midnight magnetic local time. Auroral cavities, which have been observed at altitudes below 1.5 R_E and which are quite frequent in occurrence, could explain the location of low altitude boundary near midnight. In a comparison of thirteen EHC wave events, no events were found that are clearly associated with a density cavity. Typically, the proton background density is very low in auroral density cavities, which tends to decrease the likelihood of a proton beam-driven EHC instability.

VIII. ORAL PRESENTATIONS

1. A Generation Mechanism for the Z-Mode Radiation
N. Omid, C. S. Wu, and D. A. Gurnett
1983 American Geophysical Union Meeting, May 30-June 3, 1983, Baltimore, MD
2. The Response of Polar-Latitude Electron Density Profiles to Interplanetary Plasma Parameters
A. M. Persoon and D. A. Gurnett
1983 Fall American Geophysical Union Meeting, December 5-10, 1983, San Francisco, California
3. Low Frequency Electromagnetic Emission on the Auroral Field Lines
D. A. Gurnett, S. D. Shawhan, J. D. Menietti, J. D. Winningham, and J. L. Burch
1983 Fall American Geophysical Union Meeting, December 5-10, 1983, San Francisco, CA
4. Evidence for Magnetosphere-Ionosphere Coupling By Alfvén Waves
D. R. Weimer, D. A. Gurnett, C. K. Goertz, and M. Sugiura
1984 Spring American Geophysical Union Meeting, May 14-17, 1984, Cincinnati, Ohio
5. DE-1 Observations of Simultaneous Ordinary and Extraordinary Auroral Kilometric Radiation
M. M. Mellott, W. Calvert, and D. A. Gurnett
1984 Spring American Geophysical Union Meeting, May 14-17, 1984, Cincinnati, Ohio
6. The Latitudinal Structure of Ion Inverted-V's
D. M. Klumppar, J. L. Burch, D. A. Gurnett, M. Sugiura, and J. H. Waite
1984 Fall American Geophysical Union Meeting, San Francisco, CA, May 14-17, 1984
7. Polar Cap Electron Densities at High Altitudes
A. M. Persoon and D. A. Gurnett
Chapman Conference on Magnetospheric Polar Cap, Fairbanks, Alaska, August 6-9, 1984
8. Auroral Kilometric Radiation: Source Locations
M. M. Mellott, W. Calvert, R. L. Huff, and D. A. Gurnett
1984 Fall American Geophysical Union Meeting, December 3-7, 1984, San Francisco, CA
9. Correlated Equatorial Electromagnetic Ion Cyclotron Waves and Transverse O⁺ Acceleration
E. G. Shelley, W. K. Peterson, and D. A. Gurnett
1984 Fall American Geophysical Union Meeting, December 3-7, 1984, San Francisco, CA
10. Auroral Zone Electric Fields Measured With the Dynamics Explorer Satellites at Magnetic Conjunctions
D. R. Weimer, D. A. Gurnett, N. C. Maynard, and M. Sugiura
Chapman Conference on Solar Wind-Magnetosphere Coupling, February 1985, Pasadena, CA
11. Transverse Auroral Ion Energization Observed on DE 1 with Simultaneous Plasma Wave and Ion Composition Measurements
W. K. Peterson, E. G. Shelley, S. A. Boardsen, and D. A. Gurnett
Chapman Conference on Ion Acceleration, June 3-7, 1985, Boston, MA

12. Measurements of the Conductance of Magnetic Field Lines in the Auroral Acceleration Region
D. R. Weimer
Chapman Conference on Ion Acceleration, June 3-7, 1985, Boston, MA
13. Observations of Electrostatic Emissions at the O⁺ + Cyclotron Harmonics
S. Boardsen, D. A. Gurnett, R. Chappell, and J. Green
1985 Fall American Geophysical Union Meeting, December 9-13, 1985, San Francisco, CA
14. DE-1 Observations of Harmonic AKR
R. L. Huff and M. M. Mellott
1985 Fall American Geophysical Union Meeting, December 9-13, 1985, San Francisco, CA
15. High-Latitude Plasma Density Depletions from DE-1 Plasma Wave Observations
A. M. Persoon, D. A. Gurnett, and W. K. Peterson
Chapman Conference on Ionospheric Plasma in the Magnetosphere: Sources, Mechanisms, and Consequences, February 1986
16. Transverse Energization of Upflowing Oxygen Beams Observed on Dynamics Explorer 1
W. K. Peterson, E. G. Shelley, J. H. Waite, Jr., T. E. Moore, S. A. Boardsen, and D. A. Gurnett
Chapman Conference, February 1986, Yosemite National Park, CA
17. Observations by the Dynamics Explorer Satellite of Correlated High and Low Altitude Signatures on SAR Arc Field Lines
J. U. Kozyra, T. E. Cravens, A. F. Nagy, D. A. Gurnett, R. L. Huff, R. H. Comfort, J. H. Waite, Jr., L. H. Brace, R. A. Hoffman, J. D. Winningham, J. L. Burch, W. K. Peterson
1986 Spring American Geophysical Union Meeting, May 19-23, 1986, Baltimore, MD
18. DE-1 Observations of Electrostatic Ion Cyclotron Waves
S. A. Boardsen, D. A. Gurnett, and W. K. Peterson
1986 Spring American Geophysical Union Meeting, May 19-23, 1986, Baltimore, MD
19. Physics of Thermal Plasma in the Magnetosphere
W. Calvert, J. D. Craven, R. L. Huff, M. R. Dvorsky, L. A. Frank, D. A. Gurnett
COSPAR, Toulouse, France, 30 June - 12 July 1986
20. Observations by the Dynamics Explorer Satellites of New Signatures in Particle and Field Measurements Associated with SAR ARC Field Lines at Magnetospheric Heights
J. U. Kozyra, T. E. Cravens, A. F. Nagy, D. A. Gurnett, R. L. Huff, R. H. Comfort, J. H. Waite, Jr., L. H. Brace, R. A. Hoffman, J. D. Winningham, J. L. Burch, and W. K. Peterson
COSPAR, Toulouse, France, June 30-July 12, 1986
21. Plasma Waves of Possible Importance to Magnetosphere/Ionosphere Models
D. A. Gurnett
The First Huntsville Workshop on Magnetosphere Plasma Models, October 13-16, 1986, Guntersville State Park Lodge, Guntersville, Alabama

22. The Generation of an O+ Conic Distribution by Equatorially Confined Electromagnetic Waves as Observed by DE-1
J. M. Quinn, E. G. Shelley, H. L. Collin, D. A. Gurnett
1986 Fall American Geophysical Union Meeting, December 8-12, 1986, San Francisco, CA
23. Plasma Density Depletions in the High-Latitude Magnetosphere: A Comparison with the DE-1 Particle Data
A. M. Persoon, D. A. Gurnett, W. K. Peterson, J. H. Waite, Jr., and J. L. Burch
1986 Fall American Geophysical Union Meeting, December 8-12, 1986, San Francisco, CA
24. Dynamics Explorer Observations of the Diffuse Auroral Equatorward Boundary, the Midlatitude Trough, and the Plasmapause
J. R. Sharber, J. D. Winningham, J. L. Burch, W. R. Hoegy, R. A. Heelis, A. M. Persoon, and J. H. Waite, Jr.
1986 Fall American Geophysical Union Meeting, December 8-12, 1986, San Francisco, CA
25. Magnetic Mapping of AKR Sources to the Aurora
R. L. Huff, W. Calvert, J. D. Craven, L. A. Frank, and D. A. Gurnett
1986 Fall American Geophysical Union Meeting, December 8-12, 1986, San Francisco, CA
26. Z-mode Observations with the DE-1 Satellite
K. Hashimoto, W. Calvert, R. Huff
Solar Terrestrial Environment Workshop, January 22, 1987, ISAS, Tokyo, Japan
27. Transverse Ion Energization and Low Frequency Plasma Waves in the Mid-Altitude Auroral Zone: A Case Study
W. K. Peterson, E. G. Shelley, S. A. Boardsen, D. A. Gurnett, B. G. Ledley, J. H. Waite, Jr.
1987 Cambridge Workshop on Ionosphere-Magnetosphere-Solar Wind Coupling Processes
28. Excitation of Electromagnetic Auroral Hiss in the Dayside Cusp
C. S. Lin, J. Koga, J. L. Burch, D. Winske, M. Mellott, and D. A. Gurnett
1987 Spring American Geophysical Union Meeting, May 18-21, 1987, Baltimore, MD
29. Ordinary Mode Auroral Kilometric Radiation-Direct or Indirect Generation?
R. F. Benson, M. D. Desch, M. L. Kaiser, M. M. Mellott, D. A. Gurnett, and R. L. Huff
1987 Spring American Geophysical Union Meeting, May 18-21, 1987, Baltimore, MD
30. Observations of Reconnected Flux Tubes within the Midaltitude Cusp
N. Saflekos, J. L. Burch, M. Sugiura, D. A. Gurnett, and J. L. Horwitz
1987 Spring American Geophysical Union Meeting, May 18-21, 1987, Baltimore, MD
31. Polar O+ Beams
J. L. Horwitz, T. R. Reyes, T. E. Moore, J. H. Waite, Jr. W. K. Peterson, J. L. Burch, J. D. Winningham, J. D. Craven, L. A. Frank, and A. Persoon
IAGA Symposium, August 9-22, 1987, Vancouver, Canada
32. Z-Mode Observations with the DE-1 Satellite
K. Hashimoto, W. Calvert, and R. Huff
Fall Annual Meeting of the Society of Terrestrial Magnetism and Electricity of Japan, October 14-16, 1987, Fukuoka, Japan

33. **On the Parallel Conductivity of Auroral Field Lines**
M. Million, C. K. Goertz, A. Persoon, and D. A. Gurnett
1987 Fall American Geophysical Union Meeting, December 6-11, 1987, San Francisco, CA
34. **Ion Conics: Theory and Observations**
G. B. Crew, T. Chang, J. M. Retterer, W. K. Peterson, D. A. Gurnett, and R. L. Huff
1987 Fall American Geophysical Union Meeting, December 6-11, 1987, San Francisco, California
35. **Electron Density Measurements Using the Plasma Frequency Cutoff of Auroral Hiss**
D. A. Gurnett and A. M. Persoon
1987 Fall Geophysical Union Meeting, December 6-11, 1987, San Francisco, California
36. **The Mode Identification and Propagation of Auroral Waves**
K. Hashimoto and W. Calvert
Society of Geomagnetism and Earth, Planetary and Space Sciences, April 26-28, 1988, Japan
37. **DE-1 Observations of Double Peaked H⁺ Cyclotron Harmonics**
S. A. Boardsen, D. A. Gurnett, and W. K. Peterson
1988 Spring American Geophysical Union Meeting, May 16-20, 1988, Baltimore, MD
38. **The Polarization of Escaping Terrestrial Continuum Radiation**
D. A. Gurnett, W. Calvert, R. L. Huff, D. Jones, D. L. Gallagher, M. Sugiura
1988 Spring American Geophysical Union Meeting, May 16-20, 1988, Baltimore, MD
39. **Poleward Expansion of the Auroral Plasma Cavity Detected at the Equator with DE-1**
W. Calvert
1988 Spring American Geophysical Union Meeting, May 16-20, 1988, Baltimore, MD
40. **Upwelling Ion Plasma Characteristics: A Statistical Survey**
C. J. Pollock, M. O. Chandler, C. R. Chappell, D. A. Gurnett, T. E. Moore, and J. H. Waite, Jr.
1988 Spring American Geophysical Union Meeting, 16-20 May 1988, Baltimore, MD
41. **Pulsations in the 0.1 to 8 Hz Frequency Range Observed in the Magnetosphere with the DE 1 Spacecraft and on the Ground in the Antarctic**
L. J. Cahill, Jr., M. J. Engebretson, J. A. Slavin, R. L. Huff, G. R. Ludlow, R. L. Arnoldy, and M. Sugiura
1988 Spring American Geophysical Union Meeting, 16-20 May, 1988, Baltimore, MD
42. **Particle Acceleration and Wave Emissions Associated with the Formation of Auroral Cavities and Enhancements**
R. M. Winglee, P. B. Dusenbery, P. L. Pritchett, M. M. Mellott, D. A. Gurnett, A. M. Persoon, J. H. Waite, T. E. Moore, C. S. Lin, J. A. Slavin, and H. L. Collin
1988 Spring American Geophysical Union Meeting, May 16-20, 1988, Baltimore, MD

43. Broadband Electrostatic Bursts Associated with Auroral Currents, Density Cavities and Enhancements
R. M. Winglee, P. B. Dusenbery, P. L. Pritchett, A. M. Persoon, J. H. Waite, T. E. Moore, J. L. Burch, H. L. Collin, J. A. Slavin, and M. Sugiura
International Chapman Conference on Auroral Physics, July 11-15, 1988, Cambridge, United Kingdom
44. Auroral Plasma Waves
D. A. Gurnett
International Chapman Conference on Auroral Physics, July 11-15, 1988, Cambridge, United Kingdom
45. Electron Density Distributions in the High-Latitude Magnetosphere
A. M. Persoon
COSPAR XXVII Plenary Meeting, July 18-29, 1988, Espoo, Finland, 'Distribution of Low Energy Plasma in Earth Space: Theory, Experimental Models' session of Symposium #7
46. Auroral Particle Acceleration and Wave Emissions Associated with the Formation of Plasma Cavities and Enhancements
R. M. Winglee, P. L. Pritchett, and P. B. Dusenbery
Poster presented in 'Energy Transfer in Planetary Magnetospheres' session of Symposium Number 9, COSPAR XXVII Plenary Meeting, July 18-29, 1988, Espoo, Finland
47. Multispacecraft Studies of Auroral Kilometric Radiation
D. A. Gurnett
COSPAR XXVII Plenary Meeting, July 18-29, 1988, Espoo, Finland
48. Auroral E-Fields from DE-1 and -2 at Magnetically Conjugate Points
D. R. Weimer
COSPAR XXVII Plenary Meeting, July 23-30, 1988, Espoo, Finland
49. Heating of Thermal Oxygen Ions Near the Equatorward Boundary of the Mid-Altitude Polar Cusp: Dynamics Explorer Observations
W. K. Peterson, M. Andre, G. B. Crew, A. M. Persoon, M. Engebretson, and C. Pollock
Poster presented at NATO Cusp Symposium, September 1988, Lillehammer, Norway
50. Ion Cyclotron Bands in VLF Saucers
K. Maeda, S. F. Fung, and W. Calvert
1988 Fall American Geophysical Union Meeting, December 5-9, 1988, San Francisco, CA
51. Cyclotron Resonant Interactions Between Ring Current Protons and Ducted Plasmaspheric Hiss - Possible New Loss Process for the Ring Current
J. U. Kozyra, A. F. Nagy, R. Huff, R. H. Comfort, and M. Temerin
1988 Fall American Geophysical Union Meeting, December 5-9, 1988, San Francisco, CA
52. Ion Conics: Detailed Comparison of Theory and Observations
G. B. Crew, Tom Chang, J. M. Retterer, W. K. Peterson, D. A. Gurnett, and R. L. Huff
1988 Fall American Geophysical Union Meeting, December 5-9, 1988, San Francisco, CA
53. Heating of Thermal Oxygen Ions Near the Equatorward Boundary of the Mid-Altitude Polar Cusp: Dynamics Explorer Observations

- W. K. Peterson, M. Andre, G. B. Crew, A. M. Persoon, M. Engebretson, and C. Pollock
1988 Fall American Geophysical Union Meeting, December 5-9, 1988, San Francisco, CA
54. Evidence for the Heating of Auroral Ion Beams by the Ion-Ion Instability
A. M. Persoon, R. M. Winglee, P. B. Dusenbery, H. L. Collin, and C. S. Lin
1988 Fall American Geophysical Union Meeting, December 6-11, 1988, San Francisco, California
55. A Study of the Plasma Characteristics of Upflowing Ion Beams in the Earth's Polar Cap Region
M. W. Chen, W. K. Peterson, M. Ashour-Abdalla, T. E. Moore, and A. M. Persoon
1988 Fall American Geophysical Union Meeting, December 6-11, 1988, San Francisco, California
56. DE-1 Study of Electrostatic H⁺ Cyclotron Waves
S. A. Boardsen and D. A. Gurnett
1988 Fall American Geophysical Union Meeting, December 6-11, 1988, San Francisco, California
57. Observations of Electric and Magnetic Field Signatures in Association with Upwelling Ion Events
C. J. Pollock, T. W. Moore, D. A. Gurnett, J. A. Slavin, and J. H. Waite, Jr.
1988 Fall American Geophysical Union Meeting, December 6-11, 1988, San Francisco, California
58. Source Location and Beaming Studies of Terrestrial Continuum Radiation
D. D. Morgan and D. A. Gurnett
1989 Spring American Geophysical Union Meeting, May 8-12, 1989, Baltimore, MD
59. Dayside Ordinary Mode Emissions: Viking and DE-1 Observations
H. D. Wong, J. D. Menietti, A. Bahnsen, E. Ungstrup, D. A. Gurnett, and W. M. Farrell
1989 Spring American Geophysical Union Meeting, May 8-12, 1989, Baltimore, MD
60. The High-Resolution Frequency Spectrum of Z Mode Radiation
A. M. Persoon and D. A. Gurnett
1989 Spring American Geophysical Union Meeting, May 8-12, 1989, Baltimore, MD
61. A Comparison of the Fine Structure in the Earth's Auroral Kilometric Radio Emission to Striated Spectral Activity in the Outer Planets
J. R. Thieman, J. L. Green, S. F. Fung, R. M. Candey, and A. M. Persoon
1989 Fall American Geophysical Union Meeting, December 4-8, 1989, San Francisco, CA
62. Coordinated Observations of Low Frequency Wave Turbulence and Ion Energization during a Magnetospheric Substorm
W. K. Peterson, H. L. Collin, G. B. Crew, M. Andre, J. Woch, P.-A. Lindqvist, M. J. Engebretson, A. M. Persoon, and R. E. Erlandson
1989 Fall American Geophysical Union Meeting, Dec. 4-8, 1989, San Francisco, CA
63. Plasma Waves in Planetary Magnetospheres
D. A. Gurnett
Goddard Space Flight Center Scientific Colloquium, January 19, 1990, in Greenbelt, Maryland
64. Radio Emissions from Planetary Magnetospheres
D. A. Gurnett

Research Trends in Space Plasma Physics, February 25-27, 1990, in La Jolla, CA

65. Cyclotron Maser Radiation from Planetary Magnetospheres
D. A. Gurnett
8th American Physical Society Meeting, May 6-10, 1990, Hyannis, Massachusetts
66. Study of Funnel Shaped Low Frequency Waves at the Earth's Magnetic Equator
S. A. Boardsen, D. L. Gallagher, and D. A. Gurnett
1990 Spring American Geophysical Union Meeting, May 26-June 1, 1990, Baltimore, Maryland
67. Terrestrial Auroral Kilometric Radiation
Donald A. Gurnett
SCOSTEP Meeting, The American Geophysical Union, Netherlands, June 25-June 30, 1990
68. A Comparison of the Fine Structure in the Earth's AKR Emission to SSA Emission of the Outer Planets
J. R. Thieman, J. L. Green, L. Aist, S. F. Fung, and R. M. Candey
Magnetospheres of the Outer Planets Fred Scarf Memorial Symposium, August 20-24, 1990, in Annapolis, Maryland
69. Planetary Radio Emissions: A Review of the Work of Dyfrig Jones
D. A. Gurnett
23rd General Assembly of the URSI, American Geophysical Union, Czechoslovakia, August 28-September 5, 1990
70. On Outflowing O⁺ Beams in the Polar Cap Regions
J. L. Horwitz, C. J. Pollock, T. E. Moore, W. K. Peterson, J. L. Burch, J. D. Winningham, J. D. Craven, L. A. Frank, and A. M. Persoon
1990 Fall American Geophysical Union Meeting, December 3-7, 1990, in San Francisco, CA
71. DE 1 Observations of Polar Rain Associated with Polar-Cap Convection and ELF/VLF Electrostatic Noise
N. A. Saflekos, J. L. Burch, and D. A. Gurnett
1990 Fall American Geophysical Union Meeting, December 3-7, 1990, in San Francisco, CA
72. New Interpretation of Dynamic Explorer (DE) Narrow Band Magnetospheric Emissions
V. A. Osherovich and A. M. Persoon
1990 Fall American Geophysical Union Meeting, December 3-7, 1990, in San Francisco, CA
73. Planetary Radio Emissions
D. A. Gurnett
Naval Research Laboratory, April 24, 1991
74. Electromagnetic Plasma Wave Emissions
D. A. Gurnett
International Conference on Plasma Experiments in the Laboratory and in Space, July 1-6, 1991, in Alpbach, Austria

75. Landau Damping of Terrestrial Auroral Hiss
D. D. Morgan, D. A. Gurnett, J. D. Winningham, and J. D. Menietti
Chapman Conference on Auroral Plasma Dynamics, October 21-24, 1991, in Minneapolis, MN
76. Auroral Plasma Waves
D. A. Gurnett
Chapman Conference on Auroral Plasma Dynamics, October 21-24, 1991, in Minneapolis, MN
77. Simultaneous Observations of Field-Aligned Currents and Density Fluctuations in the Auroral Zone
A. M. Persoon, D. A. Gurnett, and J. L. Burch
Chapman Conference on Auroral Plasma Dynamics, October 21-25, 1991, in Minneapolis, MN
78. Landau Damping in Asymmetrical Auroral Hiss Events
D. D. Morgan, D. A. Gurnett, J. D. Winningham, and J. D. Menietti
1991 Fall American Geophysical Union Meeting, December 9-13, 1991, in San Francisco, CA
79. Plasma Wave Electric Field Measurements
D. A. Gurnett
1991 Fall American Geophysical Union Meeting, December 9-13, 1991, in San Francisco, CA
80. The Quiet-Time Polar Cap: DE 1 Observations and Conceptual Model
J. L. Burch, N. A. Saflekos, D. A. Gurnett, and J. D. Craven
1991 Fall American Geophysical Union Meeting, December 9-13, 1991, in San Francisco, CA
81. Observations of a Quiet Magnetosphere and Polar Cap by CRRES, DE-1, and DMSP
A. M. Persoon, R. R. Anderson, W. K. Peterson, H. L. Collin, R. M. Robinson, H. J. Singer, K. Kerns, D. A. Hardy, W. F. Denig, N. C. Maynard, J. R. Wygant, J. A. Slavin, C. J. Pollock, and T. E. Moore
1991 Fall American Geophysical Union Meeting, December 9-13, 1991, in San Francisco, CA
82. Landau Damping of Terrestrial Auroral Hiss
D. D. Morgan and D. A. Gurnett
The First Iowa Space Conference, January 24-25, 1992, in Iowa City, IA
83. The Attenuation Mechanism of Terrestrial Auroral Hiss
D. D. Morgan, D. A. Gurnett, J. D. Winningham, and J. D. Menietti
1992 Spring American Geophysical Union Meeting, May 12-15, 1992, in Montreal, Canada
84. An Explanation of Asymmetrical Auroral Hiss Events
D. D. Morgan and D. A. Gurnett
Iowa Academy of Science Annual Meeting, Cedar Falls, IA, April 24-25, 1992