PLASMASPHERIC AND MAGNETOSPHERIC DENSITY AND DENSITY STRUCTURES DETERMINED FROM ISEE, CRRES, AND POLAR PLASMA WAVE OBSERVATIONS

Roger R. Anderson[(1)] and J. Douglas Menietti[(2)], Donald L. Carpenter[(3)], Wynne Calvert[(4)], and Mark B. Moldwin[(5)]

[(1)]The University of Iowa, Department of Physics and Astronomy, 615 Van Allen Hall, Iowa City, IA 52242-1479, USA, and e-mail: roger-r-anderson@uiowa.edu

[(2)]As (1) above, but E-mail: jdm@space.physics.uiowa.edu

[(3)]Space Telecommunications and Radioscience Laboratory, Department of Electrical Engineering/SEL, 319 Durand Building, Stanford University, Stanford CA 94305-4055, USA, and e-mail: dlc@nova.stanford.edu)

[(4)]219 Friendship Street, Iowa City, IA 52245, USA, and e-mail: wcx@home.com

[(5)]University of California, Los Angeles, Institute of Geophysics and Planetary Physics, Earth and Space Sciences Department, Los Angeles, CA 90095-1567 USA, and e-mail: mmoldwin@igpp.ucla.edu

ABSTRACT

Plasma wave measurements from ISEE, CRRES, and POLAR over two decades have yielded electron density up to 2000/cc independent of spacecraft charging as a function of location, time, and geomagnetic activity. In the outer magnetosphere the density was determined from the lower cutoff of the trapped continuum radiation at the local plasma frequency. Within the plasmasphere, emissions detected at the upper hybrid resonance frequency were used. Much variability and structure were observed frequently, especially near the plasmapause, as the geomagnetic conditions changed. These included multiple plasmapauses and "detached" plasma regions. Depressions in number density are often found deep in the plasmasphere while enhanced number densities often occur outside the plasmapause.

INTRODUCTION

In its nearly ten-year life from launch on October 22, 1977, to re-entry in September 1987, the International Sun Earth Explorer 1 (ISEE-1) spacecraft with its 22.6 Re apogee, 700 km perigee altitude, and 30 degree inclination, made two passes, one outbound and one inbound, through the plasmasphere and magnetosphere every 57 hours. The ISEE-1 Plasma Wave Investigation (PWI) included a 215 meter tip-to-tip long-wire antenna connected to a Sweep Frequency Receiver (SFR) that swept from 100 Hz to 400 kHz every 32 seconds. Observations of low level emissions related to the plasma frequency provided nearly continuous measurements of plasma density during the perigee portion of the orbit.

The Combined Release and Radiation Effects Satellite (CRRES), during its 15-month life from launch on July 25, 1990, into a 6.3 Re apogee, 350 km perigee altitude, 18 degree inclination orbit, until mid-October 1991, made an outbound and inbound pass every nine hours and 50 minutes for a total of nearly 2000 passes. The CRRES Plasma Wave Experiment (PWE) provided measurements of plasma density in the Earth's near-equatorial and low-latitude plasmasphere and magnetosphere using a 100 meter tip-to-tip long-wire antenna connected to a SFR that swept from 6.4 kHz to 400 kHz every eight seconds.

The International Solar Terrestrial Physics (ISTP) POLAR spacecraft was launched into a 2 x 9 Re polar orbit with a nominal period of 18 hours on February 24, 1996. The POLAR PWI included a SFR that was connected usually to either the Electric Field Instrument (EFI) 130 meter tip-to-tip two-sphere spin-plane antenna or 14 meter tip-to-tip two-sphere spin-axis antenna. The POLAR PWI SFR swept up to 800 kHz every two seconds and provided plasma density measurements for about 18 months from late-March 1996 through mid-September 1997 when a DPU power supply intermittently failed. Since then useful data have been acquired for intervals ranging from tens of minutes to many hours only in September and October of each successive year when the spacecraft and PWI are unusually cold.

DATA ANALYSIS

The plasma wave measurements from these three experiments yielded the total electron density independent of spacecraft charging. Beyond the plasmapause in the outer magnetosphere the density was determined from the lower cutoff of the trapped continuum radiation at the local plasma frequency (Fpe) using the relation Fpe = 8.98 kHz x $(Ne)^{1/2}$ where Ne is in electrons/cc. Within the plasmasphere, emissions detected at the upper hybrid resonance frequency, Fuhr, were used to determine Ne via the relation $Fuhr^2 = Fpe^2 + Fce^2$ where the local electron cyclotron frequency Fce = 28 Hz x |B(nT)|. Equivalently, $Fp = \sqrt{(Fuhr^2 \& Fce^2)}$ and $Ne(e/cc) = (Fp(kHz)/8.98)^2$.

RESULTS

The ISEE-1 and CRRES receivers provided measurements of the total electron density up to 2000 electrons/cc independent of spacecraft charging while the POLAR receiver could measure up to 8000 electrons/cc. The ISEE-1 measurements primarily covered the mid-latitude region. CRRES tended to cover the Earth's near-equatorial and low-latitude plasmasphere and magnetosphere out to geosynchronous orbit. POLAR traversed only the outer portion of the plasmasphere and beyond. Plasma wave data from the three spacecraft have provided a comprehensive survey of the electron density in the magnetosphere as a function of location, time, and geomagnetic activity that are valuable data for generating and testing models of plasma dynamics. In the data, much variability and structure were observed frequently in the plasmasphere and magnetosphere, especially near the plasmapause, as the geomagnetic conditions changed. These included multiple plasmapauses and "detached" plasma regions. Depressions in number density are often found deep in the plasmasphere while enhanced number densities often occur outside the plasmapause. During geomagnetically active times multiple plasmapauses were often observed indicative of successive erosions of the plasmasphere.

The location of the plasmapause and the density profiles within the plasmasphere determined by the CRRES and POLAR measurements as a function of local time and geomagnetic activity are being compared with ISEE results acquired over a nearly-ten-year period and with other satellite and ground measurements in order to study plasma dynamics in the magnetosphere as a function of geomagnetic activity, ring current intensity, and substorm activity. Evolving models of the depletion and filling of flux tubes either resulting from or tested by these observations are being examined. Ducted auroral kilometric radiation, auroral myriametric radiation, trapped terrestrial continuum radiation, newly identified kilometric continuum radiation, and other waves associated with the density structures have also been observed.

ACKNOWLEDGMENTS

The work at the University of Iowa was supported by NASA Grants NAG5-6127, NAG5-6369, NAG5-7710, NAG5-7943, NAG5-11379, and NAG5-11707 with Goddard Space Flight Center and NASA Headquarters.