SPA-Magnetospheric Physics

SM51A MCC: Hall D Friday 0830h

Radiation Belt Dynamics Posters

Presiding: **J L Roeder,** Aerospace Corporation**; T G Onsager,** NOAA Space Environment Center

SM51A-0499 0830h POSTER

Identifying the Source and Loss Regions for Radiation Belt Electrons

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The radiation belt electrons are maintained through a competition of multiple source and loss processes occurring within the magnetosphere. Although many different possible source and loss processes have been identified, a quantitative understanding does not yet exist of which processes dominate under various solar wind driving conditions. This research focuses on identifying the location of source and loss processes in order to constrain the possible mechanisms that are acting on the radiation belt electrons. We have used multiple GOES satellites at geosynchronous orbit to determine the radial gradient of electron phase space density. Our initial effort has concentrated on a few time periods of low geomagnetic activity when there were elevated electron flux levels. We find that during these times the radial gradient was predominantly positive, indicating a source location outside of geosynchronous orbit. As the radiation belts decayed, the loss occurred initially at the lower L values, suggesting that the dominant loss mechanism was operating inside geosynchronous orbit. Variations in the measured radial gradient of phase space density with geomagnetic activity and the implications for radiation belt source and loss processes will be discussed.

SM51A-0500 0830h POSTER

Shock-induced Trapping of Solar Energetic Particles in the Earth's Magnetosphere

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The recent SAMPEX report of prompt trapping of solar energetic Fe at L=2 in association with a Storm Sudden Commencement (SSC) during the Bastille Day 2000 event[1] has led to examination of other recent Solar Energetic Particle (SEP) trapping events, which include two in November 2001 with trapped Fe signatures. While the the November 6 storm had a larger -Dst value (-277 vs. -213 nT), the second storm was preceeded by a strong SSC impulse (+ 20 nT hourly averaged preliminary Dst), known to be a necessary condition for shock trapping of SEPs[2,3]. Other necessary conditions for radial transport by a magnetopause compression-induced electric field impulse are examined. Both November SEP trapping events were characterized by an ICME shock speed exceeding 1200 km/s and > 10 MeV GOES proton fluxes exceeding 10^4. The larger Dst value for the earlier event is likely to affect the minimum cutoff latitude and minimum L-value of the SEP source population[4]. Coupled MHD-guiding center test particle simulations of the November 24 storm injection are compared with those of the Bastille Day event. Solar wind conditions, the minimum L-value and time scale for trapping in the magnetosphere are examined. The rarity of such events for electrons is also explained.

[1]Lorentzen et al., JGR, in press, 2002. [2] Li et al., GRL, 20, 2423, 1993. [3]Hudson et al., GRL, 22, 291, 1995; JGR, 102, 14,087, 1997. [4]Leske et al., JGR, 106, 30,001, 2001

SM51A-0501 0830h POSTER

Observations of Ion Injections During Large Solar Energetic Particle Events

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Using data from the Polar spacecraft, the highly elliptical orbit 1997-068 (HEO) spacecraft, and the Solar, Anomalous, and Magnetospheric Particle Explorer (SAMPEX), we have examined the impact of 11 large solar energetic particle (SEP) events on the inner zone radiation belts of the Earth. The 11 SEP events, which occurred between 4 April 2000 and 31 May 2002, are associated with the formation of new radiation belts with L values between approximately 2.0 and 3.5 . We have investigated the elemental composition and other characteristics of the new radiation belts at energies of ∼1–10 MeV/nucleon, and have summarized these observations. We have also examined the compositional and spectral properties of the 11 SEP events, as well as concurrent geomagnetic and interplanetary conditions, to determine how these parameters influence the effects of SEP events on the Earth's radiation belts. We discuss the relevance of these observations in modeling the effects of SEP events on the inner zone radiation belts. This work was supported through NASA grant NAS5–30368 and by cooperative agreement Z628302 between the University of Maryland and the Aerospace Corporation, funded through NASA grant NAG5–2963.

SM51A-0502 0830h POSTER

Cluster-Polar Simultaneous Observations of Energetic Particles in the Plasma Sheet - Evidence for Radiation Belt Leakage?

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Fortuitously Polar and Cluster orbits are close to co-planer. As one result, quite frequently Polar and Cluster s/c are near the magnetic equator and the same local time but they differ in radial distance by 10 RE. In the magnetotail regions, a low flux of energetic electrons and ions, E > 30 keV is routinely observed punctuated during a several hour period by short bursts of greatly enhanced particle intensities. These bursts are time coincident at Polar and Cluster and frequently are associated with a change in the magnitude/direction of the magnetic field at Polar. At these times Polar is near the trapping boundary. An obvious origin for these energetic particles is leakage from the radiation belts, with enhanced leakage occurring during re configurations of the geomagnetic field near the trapping boundary. It has long been speculated that these losses would result from a breakdown of adiabatic motion. An estimate for the loss rate from the radiation belts will be discussed.

SM51A-0503 0830h POSTER

Large–Amplitude Magnetospheric Energetic Electron Flux Events

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Using the SAMPEX database from 1993–2000, we consider the statistics and solar–wind driving of large–amplitude energetic electron flux events in the *L*–shell range of $2 < L < 8$. A superposed epoch study of large events is presented that shows a large–flux response to be dependent on both the shape and amplitude of the solar–wind velocity waveform. Motivated by this, we develop a nonlinear response filter that can capture this amplitude dependence. Based on these nonlinear response functions, a search is made for precursors in the solar–wind signal which precede large–amplitude energetic electron events. A method is presented for computing such precursors to large events based on a nonlinear filters driven by time–history of solar wind velocity and IMF measurements.

URL: http://orion.ph.utexas.edu/weigelr

SM51A-0504 0830h POSTER

Diffusion and injections in the radiation belts: L shell coupling

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The outer zone of the electron radiation belts is divided in three main regions in L shell: the P0 region (L=3-4 approx.), the P1 region (L= 4 − 7) or heart of the outer zone, and the P2 region (L> 7) which is related to the cusp and plasma sheet [Vassiliadis et al., JGR 2002; Phys. Plasmas, 2003]. We measure the correlation between fluxes at adjacent and nearby L shells. We use autoregressive models to account for the coupling. The correlation values and the model coefficients are interpreted in terms of slow diffusion (time scales ≥2 days) and rapid injections (<1 day). We parametrize the response by the electron energy measured by SAMPEX/PET fluxes at 2-6 MeV and EXOS-C/HEP at 0.19-3.5 MeV.

SM51A-0505 0830h POSTER

Modulation of >30 KeV Electron Precipitation by Pc5 Magnetic Pulsations

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For 13 years fluxgate magnetometers and single beam 30 MHz RIOMETERS have been operated at 13 locations across northwestern Canada as part of the CANOPUS program. Using data from these instruments, we have investigated the modulation of high energy electron precipitation by ULF waves in the Pc5 frequency band. For one station (Gillam - 67.2° invariant), we identified all RIOMETER Pc5-band pulsations over 13 years. All had a corresponding magnetometer pulsation: a magnetic pulsation is a necessary condition for a RIOMETER pulsation (in the Pc5 Band). We identified ∼1700 Pc5 pulsation events in the CANOPUS Churchill line magnetometer data, ∼ 250 of which

had associated RIOMETER pulsations. Roughly 95% of the RIOMETER pulsations occurred in the morning sector compared to 70% in the magnetometer. Given a magnetometer pulsation at Gillam in the morning sector, there is a 65% chance of there being a corresponding RIOMETER pulsation. The morning sector probabilities at Rankin (74°) and Pinawa (61°) are 3% and 5% respectively. This suggest that there is a localized region in the pre-noon magnetosphere where Pc5 band ULF activity can modulate high energy electron precipitation. Our results are easily explained by considering the drift paths of the precipitating electrons and the occurrence statistics of magnetic pulsations. Furthermore, our results shed some light on the interaction of ULF waves and high energy electrons in the inner magnetosphere.

SM51A-0506 0830h POSTER

Effects of Wave-Particle Interactions on Radiation Belt Development

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In this presentation, the effects of wave-particle interactions on radiation belt development will be investigated. The tool of this investigation is the kinetic Radiation Belt model that solves the convection-diffusion equation of plasma distributions in the 10keV to MeV range, with the addition of a plasmasphere model and a diffusion coefficient model. The boundary condtions of the Radiation Belt model are driven by solar wind and IMF. The purpose of the plasmasphere model is to provide the density profile of the cold core plasma, which is used in the diffusion coefficient model for calculating the diffusion coefficients of different types of wave-particle interactions. Therefore the effects of wave-particle interactions on the development of the Radiation Belt can be incorporated and modeled in a more realistic fashion. We will present the model logic and the model validation by comparing measured particle fluxes with the model calculations for several magnetic storms. We hope, through this modeling effort, that the comparison study will shed light on the evolution of the Radiation Belt and on the contribution of different physical processes involved, particularly wave-particle interactions.

SM51A-0507 0830h POSTER

Thunderstorm Driven Relativistic Electron Beams in the Inner Magnetosphere

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Gamma ray observations from the BATSE experiment on the Compton Gamma Ray Observatory indicate that some gamma ray bursts originate in the Earth's atmosphere near large-scale thunderstorm systems. It is believed that these gamma ray bursts consist of bremsstrahling from relativistic electrons accelerated to MeV energies by the intense quasi-static electric fields which temporarily exist above thunderclouds after intense positive cloud to ground discharges. If so , most of these relativistic electrons would escape the atmosphere and enter the Earth's radiation belts without much loss of energy. In the radiation belts the relativistic electron beam will interact with the cold background plasma through the two-stream instability, and some of the relativistic electrons may become trapped in the radiation belts. In the present paper we carry out a theoretical analysis of how relativistic electron beams, which form in the earth's atmosphere, might couple to the magnetosphere. The primary motivation for this study is to assess the contribution of this phenomenon to the relativistic electron population in the inner radiation belts. The interaction of the beam and the cold magnetoplasma results in changes in the beam's velocity distribution. A 1D electrostatic, particle-in-cell (PIC) simulation is run to calculate the evolution of the beam's velocity distribution due to electrostatic interactions for a full traverse of the beam through the magnetosphere (L=2.5). We also assess the importance of other electromagnetic beam/plasma interactions through the use of a 2D, periodic, electromagnetic PIC simulator. On the basis of these interaction models, we estimate the fraction of the original relativistic electron beam that can be trapped in the radiation belts.

SM51A-0508 0830h POSTER

Electromagnetic and Electrostatic Plasma Wave Amplitudes in the Magnetosphere: An Updated Survey of AMPTE/IRM and SCATHA Observations

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The diffuse electron auroral precipitation is generally thought to be caused by the pitch angle diffusion of magnetospheric electrons into the atmospheric loss cone by plasma waves. But there has been some controversy concerning which plasma wave mode is responsible for the diffusion and whether the observed wave amplitudes are large enough to account for the observed levels of precipitation. The two primary candidate wave modes are whistler-mode chorus and electrostatic electron cyclotron harmonic waves. Some previous studies have concluded that the observed waves are too weak to account for the diffuse precipitation [Belmont et al., 1983; Roeder and Koons, 1989]. Recent analysis of CRRES measurements showed that the waves within four hours of a substorm particle injection may be strong enough to cause the precipitation [Meredith et al. 2000]. Chorus emissions have also been cited as a possible energy source for the acceleration of electrons to relativistic energies in the inner magnetosphere. The plasma wave observations by the AMPTE/IRM and SCATHA satellites are used to obtain statistical estimates of the wave amplitudes for these emission modes during substorm events. These results are compared against the Meredith et al. [2000] conclusions. The effects of the observed waves for electron precipitation and energization are then assessed using several model calculations of quasilinear diffusion rates.

SM51A-0509 0830h POSTER

Outer Belt Variation Along Solar Cycle Inferred From Akebono (EXOS-D) Observations

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The most dramatic intervals of particle energization in the vicinity of the Earth occur episodically within the inner magnetosphere during periods of CMEs and high speed solar wind. Since 1989 we have been measuring radiation particle environment by means of Akebono (EXOS-D) satellite and following long-term variations were revealed. (1) Location of the outer radiation belt has a strong dependence on the solar activity, i.e. the outer belt approaches toward the Earth during the solar maximum periods. (2) Correlation between the peak position of the outer radiation belt and the magnitude of Dst index is quite good, i.e. large Dst causes a new outer belt closer to the Earth. (3) Sufficient supply of intermediate-energy electrons is made during and after storm main phase. These seed electrons are accelerated internally up to the high energy range during the storm recovery phase. (4) Increase in the intensity of outer belt electrons strongly depends on the magnetic activity during the storm recovery phase. Sector structure of high speed solar wind as well as CME stricture, i.e N-S type or S-N type with respect to the magnetic field, are key parameters for the large increase of relativistic electrons in the outer radiation belt.

SM51A-0510 0830h POSTER

Outer Zone Electron Spectra from CEASE/TSX5

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The Air Force Research Laboratory developed the Compact Environmental Anomaly Sensor (CEASE) to broadly characterize the space radiation environment and issue real-time warning flags. CEASE includes a particle telescope (two stacked solid state detectors) that provides several electron channels with threshold energies from 50 keV to 700 keV, and two dosimeters that respond to >1 and >3 MeV electrons. The first CEASE to fly was launched on the USAF Space Test Program TSX-5 spacecraft on 7 June 2000 into a 410 km by 1750 km, 69 degree inclination orbit. The mission was initially manifest for a 1-year flight, but was extended to October 2002, yielding a database with over 2 years of data. An extensive Monte Carlo simulation of the instrument response function (complementing the pre-launch laboratory calibration results) has recently been completed, thus enabling the determination of energy spectra. Mission survey plots for various channels will be presented to highlight a number of magnetic storm periods. Select storm intervals will be examined in greater detail, with spectral fits from roughly 100 keV to 1 MeV presented as a function of time for various L ranges.

SM51A-0511 0830h POSTER

Results from the Compact Environmental Anomaly Sensor (CEASE) on TSX-5

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The Compact Environmental Anomaly Sensor (CEASE) was launched on-board the USAF Space Test Program (STP) Tri-Service Experiment-5 (TSX-5) satellite on June 7, 2000 into a 410 X 1710 km orbit with a 70 degree inclination. CEASE is a small (10X10X8.2 cc), low-power (1.5 W), low-mass (1 kg) instrument that measures the local space radiation environment and generates warnings of radiation damage, dielectric charging, and single event effects (SEE). CEASE uses a complement of five silicon, solid-state sensors to measure the radiation environment: two independent dosimeter detectors, a two-element energetic particle telescope, and an SEE detector.

The low-earth, highly inclined orbit is ideal for demonstrating the instruments capabilities. Apogee occurs in the inner proton belt, perigee occurs in a very benign environment, and the high inclination portions of the trajectory pass through the auroral oval and the horns of the outer electron belt. Over two years of flight data and its interpretation will be presented.

SM51A-0512 0830h POSTER

Using GPS Occultations to Measure Relativistic Electron Precipitation from the Radiation Belts

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Precipitating electrons with 1 MeV energy can penetrate to below 60 km in the Earths atmosphere. There, they produce ionization visible using global positioning satellite (GPS) occultation measurements. When the line of sight from a low-earth orbiting satellite to a GPS satellite passes through the Earths limb, ionospheric remote sensing of electron densities is possible. The phase and amplitude of GPS signals are affected by changes in the index of refraction as they pass through the ionosphere. Using the Abel inversion technique and assuming spherical geometry, these occultation measurements can be converted into electron density profiles. Density enhancements in the D region

of the ionosphere are associated with relativistic electron precipitation from the radiation belts and can be detected using GPS occultation measurements.

The Ionospheric Occultation Experiment (IOX) is a dual-frequency GPS receiver with a single Earth-limb viewing antenna. It is one of four experiments to be flown as part of the US Air Force Space Test Program PICOSat mission. The spacecraft is in a 67-degree inclination, 800-km altitude orbit, and has been making measurements at all local times since November 2001. We will present IOX observations from geomagnetically quiet and active periods. These measurements will be compared with in situ observations of relativistic electron precipitation (> 500 keV and > 1 MeV) from the SAMPEX satellite, in order to validate this new method for monitoring losses from the Earths radiation belts.

SM51A-0513 0830h POSTER

The GPS Energetic Particle Environment

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The Global Positioning System (GPS) satellites include two new charged particle instruments, the Low (LEP) and High (HXP) Energy Particle sensors, that permit to estimate the omnidirectional energetic particle fluxes in the energy range 0.14 to 6 MeV for electrons, and 6 to 100 MeV for protons. The first instruments were launched in February 2000, and up to eight additional instruments are expected on GPS orbit in the next few years. The inclined (55 degree) circular (20,000 km radius) orbits of the GPS satellites pass through the peak intensity region of the radiation belts four times per day. Hence, the LEP and HXP sensors sample the energetic particle environment in the range L = 4 to 10.

We describe in this paper the design and the responses of the LEP and HXP sensors. The responses are obtained by combining calibration data with Monte-Carlo (MCNP) and Analytical Probability (AP) calculations. The latter permit to include the contributions of the passive instrumental box and of the satellite to the electron responses. Examples of the main features of the GPS energetic particle environment observed during the first two years of operation will be presented, including energetic particle fluxes, high-latitude electron injections, electron energy spectra, and cosmic background.

SM51A-0514 0830h POSTER

Estimating Equatorial Electron Radiation Belt Fluxes in the Outer-Zone Using Navstar 10 BBDI Data

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When studying the outer electron radiation belt it is desirable to have both high time resolution and global coverage. In-situ satellites, such as those in geosynchronous orbit, constantly monitor the small region in which they exist, but do not give global coverage. However, medium and low Earth orbiting satellites, which slice through sections of the radiation belts at high latitudes, can be used to gain relatively global coverage with fairly reasonable time resolution. Unfortunately, in order to do this, assumptions must be made about the magnetic field and the equatorial particle distribution. To try to understand how accurately equatorial fluxes can be estimated from the data collected by these satellites, we compare data from the Navstar 10 (NS10) Global Positioning Satellite and the Combined Release and Radiation Effects Satellite (CRRES). We map data from the CRRES Medium Electrons A (MEA) sensor and High Energy Electron Fluxmeter (HEEF) to the latitude of NS10 and create average differential fluxes which can be compared to those estimated from the Burst Detector Dosimeter I (BBDI). In this poster we present the results of this study.

SM51A-0515 0830h POSTER

The trapped He flux dynamics observed on the TSUBASA satellite

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TSUBASA satellite was launched on February 2002. TSUBASA is placed in a geostationary transfer orbit having roughly a perigee of 500 km, an apogee of 37,000km, a 28.5 inclination, and a 645 minute period. The Standard Dose Monitor (SDOM) onboard TSUBASA has carried out measurements of energetic electrons, protons, and alpha particles.

He flux distribution greatly changed the substorm on April 19, 2001 event for the boundary. Possible source of the fluxes including remnants of solar particle population trapped during substroms, acceleration of hot plasma from the outer magnetosphere, and pitch-angle scattering from the top of the magnetic field line are discussed.

URL: http://sees.tksc.nasda.go.jp

SM51A-0516 0830h POSTER

TSUBASA(MDS-1) observations of the radiation belt during magnetic storms

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Recently, in situ observation is required to investigate the fluctuation of the radiation belt. TSUBASA(MDS-1) measures magnetic field and high energy charged particle (electron, proton, alpha-particle) in equatorial plane from 500 to 36000km, so that, particle flux, pitch angle distribution, phase space density and itfs equatorial distribution can be measured. Information of these measurement results is very useful in order to clarify the cause of the radiation belt fluctuation, especially high-energy electron. TSUBASA was successfully launched by H-IIA launch vehicle from the Tanegashima Space Center on February 4, 2002. TSUBASA was injected into an elliptical orbit called a geostationary transfer orbit (GTO), with a spin rate of 5rpm, which makes the satellite attitude stable. We will report the observation result of TSUBASA during magnetic storms, and which is applicable in proposed theory about radiation belt fluctuation will be examined.

SM51A-0517 0830h POSTER

TSUBASA (MDS-1) Observations of Pc5 Pulsations in the Inner Magnetosphere

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Although it is known that variations of relativistic electron flux in the outer radiation belt correlate reasonably well with Pc5 pulsation power, we need more observational and theoretical supports in order to examine whether the Pc5 pulsations cause relativistic electron flux enhancements. In particular, we need to investigate spatial characteristics of Pc5 pulsations in space, since previous studies have focused on observations on the ground and at geostationary orbit. In order to approach this subject, we address Pc5 pulsations associated with enhanced relativistic electron flux by using data from the TSUBASA (MDS-1) satellite at geo-transfer orbit (500-36000km). The data includes high-energy charged particle flux (electron: 0.4-50MeV; proton: 0.9-250MeV) and high-resolution three vector components of magnetic field. We also compare these data with data from ground magnetometer networks and other satellites. The analyses showed that the relativistic electron flux depends on the L-shell parameter and time, and that drastic increases of the relativistic electron flux at L 5-7 correlate closely with occurrence of troidal-mode Pc5 pulsations with large amplitude. This is particularly noticeable when Pc5 pulsation activity is high because of interplanetary CME arrival at the Earth. The results imply that these Pc5 pulsations are a possible source accelerating energetic electrons in the regions.

SM51A-0518 0830h POSTER

TSUBASA (MDS-1) observations of energetic electrons and magnetic field variations in outer radiation belt

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We have investigated variations of energetic electrons (> 0.4 MeV) and magnetic field in the radiation belt obtained from the Standard DOse Monitor (SDOM) and the MAgnetoMeter (MAM) of the Space Environment Data Acquisition equipment (SEDA) onboard TSUBASA (the Mission Demonstration Test Satellite (MDS)-1) launched on February 4, 2002. Since TSUBASA is operated in the geostationary transfer orbit, it has provided rare opportunities of directly observing near-equatorial radiation belt plasma particles and magnetic field, having already included several large magnetic storms. The energetic electrons in the outer radiation belt are contributors to the total radiation dose deposited in lightly shielded spacecraft electronics for high altitude orbits and are known to have a drastic variability associated with geomagnetic storm and high speed solar wind streams. The abrupt energetic electron flux decreases in the outside of outer radiation belt show characteristic variations of in situ magnetic field. These observations have implications for the possible mechanisms of the depletion and the following recovery and/or buildup of energetic electrons in the outer radiation belt.

SM51B MCC: Hall D Friday 0830h

Spacecraft Charging and Related Instrumentation Posters

Presiding: **S T Lai,** Air Force Research Laboratory**; K R Lorentzen,** The Aerospace Corporation

SM51B-0519 0830h POSTER

Representation of the Geosynchronous Plasma Environment for Spacecraft Charging Calculations

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We are using the Los Alamos National Laboratory (LANL) Magnetospheric Plasma Analyzer (MPA) dataset to determine the best spectral representation of the charged particle environment for calculating spacecraft potential during magnetospheric substorms.

For 12 years LANL has been accumulating measurements of electron and proton spectra from MPA instruments aboard a series of geosynchronous satellites. These data provide both a plasma characterization and the potential of the instrument ground. Here we focus on data during eclipse periods in Sept. 2001, containing 970 measurements of charging to potentials ranging from 3 V to nearly 10 kV.

Our ability to predict and "postdict" charging has suffered from both a lack of reliable secondary emission and backscattered electron yields and poor characterization of the plasma environment. One difficulty lies in the common practice of fitting the plasma data to a Maxwellian or Double Maxwellian distribution function, which may not represent the data well for charging purposes.

The net current to the spacecraft is the sum of the incident electron and ion fluxes, secondary and backscattered electron fluxes, and photoelectron flux. The integral of the incident spectrum against the yield functions gives the secondary and backscattered fluxes. At equilibrium, the net current is zero.

We calculate the spacecraft potential using the measured fluxes, either directly or through a fit, with appropriate correction for the difference between the measured and postulated potential. The ratio of the calculated to the measured potential tests the accuracy of