investigation of these images reveals a considerably dynamic auroral oval, with the promise of some clear correspondences with upstream Cassini data that will provide unique insight into Saturn's magnetospheric dynamics. The results will also provide impetus to interpretation of in situ field and plasma data once we arrive in Saturn orbit.

SM33A-15 1330h POSTER

A Self-Consistent Approach to Modeling Ion Outflows Associated with Electromagnetic Ion Cyclotron Waves

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Energetic heavy ion outflows detected by satellites in the auroral region are commonly associated with electromagnetic ion cylotron wave activity (1-100Hz) observed by the same spacecraft. Because the Poynting flux of the waves is into the ionosphere, the waves can provide an energization source for the concomitant ion heating. One difficulty with relating the ion outflows to the wave activity is the nonlocality of the heating process—much of the heating occurs between the ionosphere (where the ions originate) and the spacecraft. A common approach is to obtain a heating rate based on the assumption that the wave spectral density is invariant along the auroral field lines, which provides an estimate of the local ion heating rate. However, wave propagation and dissipation depends strongly on the heavy ion concentrations in the topside ionosphere as well as the collisional ionospheric model, and therefore the wave spectrum—and heating rate—at a given altitude is also strongly dependent on the plasma model. Thus, the plasma background modifies the wave propagation and heating rate. However, the heating rate determines the background plasma profiles. To account for this feedback, we successively iterate (1) a wave propagation code based on background plasma profiles (which solves the full electromagnetic equations including a realistic ionospheric model) and (2) a Monte Carlo simulation code to obtain the ion profiles based on heating rates obtained from the results of the wave propagation code. The method converges rapidly to a stable state, and the results suggest that temporal evolution of the plasma profiles would involve a two-step process where helium is first heated then oxygen. The results also suggest that helium is typically preferentially heated compared with oxygen as is observed.

SM33A-16 1330h POSTER

A One-dimensional Ionosphere Solution with Self-consistent Neutral Motion

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We take a systematic approach to study the coupling from the solar wind and the magnetosphere to the ionosphere and thermosphere, based on three-fluid treatment: electrons, ions, and neutrals, with collisions among the three species. The momentum equations of the three species are converted into the generalized Ohm's law and the plasma momentum and neutral momentum equations. By allowing the collision frequencies and the densities to vary as functions of height, this formulism continuously and smoothly describes the plasma conditions from the collisionless solar wind and magnetospheric plasma to the partially ionized ionosphere/thermosphere gases. We solve this equation set in one-dimension to model the magnetosphere-ionosphere/thermosphere coupling at high latitudes near the poles where Birkeland (field-aligned) currents and precipitating particles are not important. Since the solution is self-consistent, the neutral wind speed is a function of height and time and thus cannot be taken as specifying a single frame of reference. In the ionosphere, the plasma velocity is also a function of height and cannot be treated as a constant. The results show that the F- and E-layers of the ionosphere may behave differently. For example, when the IMF reverses its direction after a long period of steady state, there is a transient enhancement of Pedersen current in the F-layer.

SM33A-17 1330h POSTER

Modeling the Direct Penetration of Electric Fields to the Equatorial Ionosphere

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The interplanetary electric field has been observed to penetrate directly to the equatorial region where it affects the generation of plasma bubbles which, in turn, cause the scintillation of transionospheric electromagnetic signals. We use the approach of Nopper and Caravillano [1978] to model the effect of the Region I and Region II currents on the global electric field. We find, consistent with observations, the well-known shielding of the equatorial region by Region II currents. Numerically, two approaches are taken. The first approach is to solve N-squared simultaneous linear algebraic equations for each of the grid points. The second approach is to use the Multigrid technique, which allows a rapid convergence of the SOR (successive over- relaxation) iterations. The advantage of the algebraic approach is accuracy , while the advantage of the second approach is speed. Further comparisons between these two approaches will be made. Effects of the magnetic dipole tilt relative to the polar cap, the presence of a sub storm current wedge, the saturation of the transpolar potential, and seasonal effects will be discussed . Nopper R.W. and R. L. Carovillano, Geophys. Res. Ltrs., 5, 699, 1978.

SM33A-18 1330h POSTER

Monte Carlo Study of Secondary Electrons and X Rays Produced by Vertical vs. Horizontal Arrival of Precipitating Electrons at the Top of the Atmosphere

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Electron precipitation from the outer belt is an important input of energy and electric charge to the atmosphere. The ionization profile (ionization rate vs. altitude) may be affected by the direction at which electrons enter the top of the atmosphere. Definitive measurements of the angular distribution of precipitating electrons at the top of the atmosphere have not been made; studies of the problem have made a number of assumptions in this regard. Consideration of the mechanism by which electrons in the drift loss cone enter the atmosphere due to eastward drift suggests horizontal entry: an electron in the process of mirroring near the top of the atmosphere encounters a region where its gyro-circumference is equal to its mean-free- path and it collides with an atmospheric molecule. In order to study whether horizontal entry at the top of the atmospere could have a significant effect, we have investigated this question by comparing horizontal to vertical entry with a Monte Carlo study using the FLUKA code. Assuming an energy spectrum typical of outer belt electrons up to 10 MeV at entry, both electrons and X rays were followed down to energies of 100 keV. The Monte Carlo results are compared to measurements in the atmosphere of electrons made below 80 km on rocket-boosted, parachute-deployed payloads, and to measurements of X rays made on balloon payloads at altitudes of about 35 km.

SM33A-19 1330h POSTER

Energy transfer through the LFM MHD model

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We present analyses of energy transfer through the solar wind-magnetosphere-ionosphere system using the Lyon-Fedder-Mobarry global magnetohydrodynamic model. We define magnetospheric regions based on plasma parameters or locations (plasma sheet, magnetic lobes, magnetopause), and calculate the thermal, magnetic, and kinetic energy content of those regions as a function of time during a simulation of an isolated substorm on December 10, 1996. We will compare the model results to previous energy budget analyses based on multipoint spacecraft observations.

SM34A CC: 517 A Wednesday 1530h

Parker Lecture *(joint with SA, SH)*

Presiding: **D N Baker,** Laboratory for Atmospheric and Space Physics

SM34A-01 1540h INVITED

The Sun and Heliosphere as Revealed by Suprathermal Electrons

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Solar wind electron distributions near 1 AU are generally well described as a superposition of two distinct components: a cool core or thermal component and a relatively hot suprathermal component. The breakpoint between these two populations commonly occurs at about 60 eV at 1 AU. The suprathermal component carries the solar wind electron heat flux, is almost always nearly collisionless, behaves largely as a test particle population streaming freely through the solar wind along the heliospheric magnetic field, and is commonly highly anisotropic in the solar wind rest frame. In this lecture I demonstrate some of the remarkable spatial and temporal intensity and pitch angle variability of the suprathermal electron component at energies below about 1.4 keV, relate that variability to different solar and heliospheric processes, and illustrate aspects of the large-scale magnetic topology of the heliosphere revealed by suprathermal electron observations.

SM41A CC: 220 C-E Thursday 0830h

Relativistic Electrons in the Earth's Inner Magnetosphere: Observations, Models, and Space Weather Implications III Posters

Presiding: **S G Kanekal,** Catholic University of America**; X Li,** University of Colorado

SM41A-01 0830h POSTER

Long-Term Prediction of MeV Electrons in Geostationary Orbit

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The flux of MeV electrons at geostationary altitude represents a gauge of the radiation levels associated with severe solar and geomagnetic disturbances. Several techniques have been developed to forecast MeV electron flux, mostly aiming at giving a one to three

day forecast. In this work, we present a semi-empirical technique to forecast the daily average MeV electron flux at geostationary orbit 27 days in advance. This technique is built upon the procedure documented by Li et al. [2001] with a slight improvement. A statistical test of its accuracy shows the correct prediction probability to be rather high ($\sim$ 70%), even out to 27 days in advance. For the year 1995, for instance, the linear correlation coefficient is found to be 0.87, with a prediction efficiency of 0.75, and the true skill score is 0.77.

SM41A-02 0830h POSTER

Data-derived forecasting model for relativistic electron intensity at geosynchronous orbit

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In this paper we present a data-derived model of relativistic electron flux at geosynchronous orbit. The model is driven by multiple solar wind and magnetospheric inputs and combines the deterministic approach of nonlinear dynamics with conditional probability (Bayesian) consideration. The model is used for one-day predictions of daily flux maxima for the years 1995-2000. The deterministic part of the model yields average prediction efficiency of 0.77 and linear correlation coefficient of 0.89. It identifies solar wind velocity and SymH index as most relevant input parameters. The probabilistic part of the model yields deviations of the flux from the predicted values together with their probabilities and can therefore be used in risk analysis forecasting.

SM41A-03 0830h POSTER

Comparison of a ULF Wave Index With Dynamics of Geostationary Relativistic Electrons During Space Weather Month

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A new ULF wave index, characterizing the turbulent level of the geomagnetic field, has been calculated and applied for the analysis of relativistic electron enhancements during Space Weather Month (10-30 September 1999). The wave index has been produced from the INTERMAGNET, MACCS and CPMN dense arrays of ULF magnetometers in the Northern hemisphere. During the analyzed period two magnetic storms occurred (on September 12 and 22), and several significant increases of relativistic electron flux at geostationary orbit (up to 2-3 orders of magnitude) were detected by geostationary monitors. However, these electron enhancements were not related to the magnetic storm intervals. Instead, and rather unexpectedly, they correlated well with intervals of elevated ULF wave index, caused by the occurrence of intense Pc5 pulsations in the magnetosphere. This comparison is an additional indication of the possible importance of magnetospheric turbulence in energizing relativistic electrons.

SM41A-04 0830h POSTER

Comprehensive investigation of dramatic MeV electron loss events

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We investigate episodes of dramatic loss of MeV electrons from the outer radiation belts. We have selected more than 50 events observed at GEO similar to the case studied by Onsager et al. [2002]. These events appear to be associated with weak to modest magnetic activity following long periods of quiescence, and several events overlap with the superdense plasma sheet events identified by Thomsen et al. [2003]. We examine the extent of the dropouts in energy and L using Polar, NOAA/GOES, LANL/GEO, and HEO. We also examine precipitation signatures observed by SAMPEX and NOAA/POES. We investigate 5 possible mechanisms to explain the loss: adiabatic energy changes, magnetopause shadowing, scattering off curved magnetic field lines, interaction with n+1/2 electrostatic (or electron cyclotron harmonic, ECH) waves, and interaction with electromagnetic ion-cyclotron (EMIC) waves. We adjust for adiabatic effects by examining phase-space densities calculated from fluxes observed by the Polar and GOES satellites. We use the Shue et al. [1998] magnetopause model to assess the likelihood of shadowing. We employ a simple pitch-angle diffusion calculation after Birmingham [1984] to assess scattering by field line curvature. We perform a quasilinear pitch-angle diffusion calculation after Lyons [1974] to assess the impact of ECH waves. We explore the EMIC wave mechanism by statistically associating in situ wave observations (e.g. by CRRES in Meredith et al. [2003]) with precipitation observed at low altitude by SAMPEX and NOAA/POES.

SM41A-05 0830h POSTER

A Simulation Study of Drift-Resonant Acceleration of Magnetospheric Relativistic Electrons by ULF Waves

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To understand the resonant acceleration of magnetospheric relativitic electrons by ULF waves, we need to combine the observations and simulations together. Recent work by Tan et al. [2004] showed that an interval of enhanced relativistic-electron fluxes (by up to an order-of-magnitude) was observed simultaneously with strong Pc-5 ULF oscillations, whose electric field is mainly in the radial direction. The acceleration continues for more than 2 hours. Elkington et al. [2003] suggested that the interaction of magnetospheric relativistic electrons and the global toroidal mode ULF wave (with radial electric field component) in a a simple compressed dipole model can result in resonant acceleration. In this paper, we use particle tracing simulation to investigate the acceleration of relativistic electrons by ULF waves locally concentrated on dawn-dusk flanks in a more realistic magnetosphere. The relation between the spectrum of the ULF wave and the drift period of acclerated electrons will be discussed. The simulation model was then applied to understand the interval reported in Tan et al. [2004] by incorporating the electric field observed by CRRES satellite. Tan L. C., Shing F. Fung, and X. Shao, Space Observation of Magnetospheric Relativistic Electrons Accelerated by Pc-5 ULF Waves, this AGU meeting, Spring, 2004. Elkington, S. R., et al., Resonant acceleration and diffusion of outer zone electrons in an asymmetric geomagnetic field, J. Geophys. Res., 108 (A3), 2003.

SM41A-06 0830h POSTER

Space Observation of Magnetospheric Relativistic Electrons Accelerated by Pc-5 ULF Waves

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The acceleration of magnetospheric relativistic electrons remains an outstanding question in radiation belt physics. In particular, it is unclear how relativistic electrons in the outer radiation belt are accelerated within a few hours. We hence investigate the production of up to 2 MeV magnetospheric electron fluxes after a storm-sudden commencement (SSC) event by using magnetic field, electric field and energetic electron measurements from CRRES, GOES-6 and -7 satellites. On August 27, 1991 an interval of enhanced relativistic-electron fluxes (by up to an order-of-magnitude) was observed simultaneously with strong Pc-5 ULF oscillations, whose electric field is mainly in the radial direction. The enhanced electron fluxes are found to have a pancake-like pitch angle distribution, which is consistent with the fluxes being accelerated near the equatorial plane. The observed phases of ULF waves in both dawn and dusk flanks are opposite to each other and the wave frequency is about three times of the electron drift frequency. Thus a scenario of electron acceleration can be drawn in terms of a drift-resonant interaction of the electrons with the toroidal-mode Pc-5 ULF waves. Our paper discusses this acceleration scenario in details.

SM41A-07 0830h POSTER

Diffusion of Relativistic Electrons in Three Dimensions

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The three dimensional dynamics of relativistic electrons are simulated using guiding center approximation equations to track the bounce and drift motion of particles. The effects of latitude, L value and magnetic field configuration on diffusion rates are examined. Two different dynamic field configurations will be compared. One field model is an analytic model based on a compressed dipole magnetosphere with modeled poloidal mode ULF wave oscillations, including time-varying magnetic and electric field components. The frequency and L dependence of the Ultra Low Frequency (ULF) wave power is included in this model by incorporating published ground-based magnetometer data. The second model employs the Lyon-Fedder-Mobary (LFM) 3D MHD code which uses solar wind data at the upstream boundary as input. Comparisons between models and observations of the effects of ULF (below 10 mHz) wave fields on radial transport and energization of radiation belt electrons will be presented.

SM41A-08 0830h POSTER

Properties of Low Density Chorus Waves and Quasilinear Diffusion Coefficients

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Energy diffusion by whistler-mode chorus waves is considered a promising candidate for explaining the production of energetic electrons following magnetospheric storms. This mechanism is expected to be most effective under low density plasma conditions, but quasilinear diffusion coefficients had not been calculated in that regime until recently. As in the high density case, these calculations are computationally demanding unless special effort is made to pre-identify resonant frequencies and wavenormal angles. Such techniques have been generalized from high density whistler-mode hiss, and are are presented along with resulting diffusion coefficient values.

SM41A-09 0830h POSTER

Phase Space Distribution of Relativistic Electrons near Geosynchronous Orbit in Storm Times

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Understanding the behavior of relativistic electrons in the Earth's radiation belts in geomagnetic storms is of keen interest to the space physicists' community due to both theoretical and practical concerns. After decades of efforts to describe the relativistic electrons dynamics in storm times, currently existing models succeed in either fitting parts of the observations or in simulating one storm only. The differentiation of competing theories calls for a data-assimilation based global electron phase space density model. Since the calculation of phase space density greatly relies on the accuracy of the storm magnetospheric field, a new approach is established to choose the best model by comparing with the multiple measurements from GOES and POLAR satellites. Then the output from the model is optimized by fine-tuning input parameters in a time-dependent fashion, to obtain the best fit dynamic model. The choice of the magnetic field model is also tested by Liouville's theorem, which requires the conserved phase space density for the fixed phase space coordinates. The calculation of phase space density is based on the choice of the storm-time magnetic field model and, as the first step of the global model development, data from LANL geosynchronous SOPA instruments. By employing a technique developed previously , we can deduce the electron phase space density distribution for the region around geosynchronous orbit, covering a range of L* 6-7, which also establishes the radial PSD gradient as a function of both universal time, local time in storm-time.

SM41A-10 0830h POSTER

Modeling the Radiation Belts

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Using the University of Michigan's BAT-S-RUS Model to drive the Fok Radiation Belt Model, we will investigate the mechanisms for energy gains in the Earth's inner magnetosphere for recent storms. In addition, using simulated solar wind to drive substorms, we will study the effects of multiple substorms on relativistic electrons. In particular we will compare energy gains due to adiabatic acceleration versus energy gains due to changes in the number of particles. We will also compare the results of the model to LANL geosynchronous observations.

SM41A-11 0830h POSTER

Empirical Models of Plasma Wave Amplitudes From SCATHA and AMPTE/IRM Observations

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Various VLF plasma wave modes have been cited as one of the causes of particle acceleration and precipitation in the inner magnetosphere. Current theories model these effects as a wave-induced quasilinear diffusion of the particles in energy and/or pitch angle. The models depend mainly on the wave amplitude as their primary input parameter. We are developing an empirical model of the wave amplitudes as functions of position and geomagnetic activity in the magnetosphere. Such information may be input to the particle diffusion models to assess the acceleration and loss effects on the particles. The plasma wave observations by the AMPTE/IRM and SCATHA satellites are used to obtain statistical estimates of two of the most intense wave modes: whistler-mode chorus emission and electrostatic electron cyclotron harmonics (ECH). The average chorus amplitudes mapped in L and local time from SCATHA and AMPTE are very similar to the CRRES observations of chorus in the local morning [Meredith et al., 2000]. These statistical averages are compared to SCATHA passes during several storm intervals. In most cases, the wave amplitudes during storms are similar to the non-storm intervals at the same activity level in the Kp or AE indices. We highlight in detail a few cases in which the chorus emissions are substantially more intense than that predicted by the location and activity level. The chorus results are then compared with similar statistics for the ECH waves. The peak electrostatic emissions occur just post-midnight in a much smaller region than the chorus but with similar amplitudes. To obtain a preliminary assessment of the effects on the particles we scale the statistical wave amplitudes by the strong pitch angle diffusion limit.

SM41B CC: 518 C Thursday 0830h

Double Layers in Space and Astrophysical Plasmas I *(joint with SA)*

Presiding: **N Singh,** University of Alabama in Huntsville**; C Falthammar,** Royal Institute of Technology

SM41B-01 0840h INVITED

Auroral Particle Acceleration by Strong Double Layers: The Upward Current Region

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Satellite observations have established that parallel electric fields of both upward and downward current regions of the aurora are supported, at least in part, by strong double layers. The purpose of this talk is to examine the role of strong double layers in auroral acceleration and to study the accompanying particle distributions, electrostatic waves, and nonlinear structures. The concentration is on the upward current region. Direct observations of the ionospheric boundary of the auroral cavity suggest that a stationary, oblique double layer carries a substantial fraction (10% to 50%) of the auroral potential. An order of magnitude density gradient results in an asymmetric structure. Oblique double layers with amplitudes greater than 100 mV/m have been verified in 3% and may occur in up to 10% of auroral cavity crossings, so it is feasible if not probable that strong double layers are a principal acceleration mechanism. Furthermore, a second type of strong double layer (symmetric potential structure) is seen inside of the auroral cavity. These structures are a possible signature of the high-altitude acceleration mechanism. Numerical solutions of the Vlasov-Poisson equations indicate that trapped electrons control the mid-cavity or high-altitude double layer structure. The numerical solutions support the possibility a high-altitude double layer.

SM41B-02 0900h INVITED

A Review of Recent Studies on Double Layers Using Modeling and Simulations

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The observations of electron phase-space holes and recent direct detection of double layers (DLs) in the auroral plasma have renewed interest in modeling and simulations of the DLs and related topics. Reviewing the field, we find the major efforts include the following topics: (i) DL formation in current- and voltage-driven plasmas and resulting plasma dynamics, (ii) Acceleration in the upward current region involving a rarefaction shock at the ionosphere-magnetosphere (I-M) transition of the auroral density cavity, (iii)BGK modeling of oblique DLs and comparison with data, and (iv) Transverse filamentation of planar DLs by plasma instabilities and its application to the auroral return current plasma. Under the first topic above we discuss the role of current-cavity interaction in DL formation in current- and voltage- driven plasmas highlighting the cavitational instability. The basic physics highlighted in the second and third topics is the role of a hot electron population in the upward acceleration of ionospheric ions, like in the expansion of plasmas having two electron populations. The fourth topic deals with the generation of transversely narrow accelerating potential structures in the auroral plasma; we highlight here the role of ion-beam driven ion-cyclotron modes below a planar DL in fragmenting the DL and hence in generating filamentary density cavities with accelerated electrons and electron holes in them. Applications of this to the physics of the auroral return current plasma, including transverse acceleration of ions, are visited.

SM41B-03 0920h INVITED

Downward Accelerated Ions: on Acceleration Mechanism and Source

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The main purpose of this report is to present a solution to the problem how the observed quasi-stationary downward flow of ions through a potential difference between the magnetosphere and the ionosphere, ions which originate below the potential difference, can be understood. First, a summary of the observations of downward accelerated ions with keV or sub-keV energies at altitudes of about 1700 km is given and the mechanism causing the accelerating quasi-static potential difference is described. Thereafter it is shown that the ionospheric ions may be transported upward through the potential region in a process sometimes called the ?pressure-cooker? mechanism involving wave turbulence within the region. The turbulence also gives rise to pitch-angle scattering of the ions so that a fraction of them are precipitated into the altitude range where they are observed by the satellite. This process gives the observed spectral characteristics of the accelerated ions.

SM41B-04 0940h INVITED

Parallel Electric Fields and Shocks in Downward Auroral-Current Regions From Theoy and Satellite Data

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A method for determining the parallel electric field ($E_{||}$) and/or electrostatic shocks for downward auroral-current regions that includes wave-particle interactions is given. We derive the multimoment fluid equations for a weakly inhomogeneous, magnetized plasma where the Vlasov-Maxwell hierarchy is used to treat the particle dynamics and the Fokker-Planck method is used to calculate the momentum (anomalous resistivity) and energy (anomalous heating) transfer rates between the waves (turbulence) and the particles. Two major assumptions are necessary: (1) a renormalized kinetic theory for the turbulence either exists or can be developed; and (2) both the length and frequency scales between the single-particle distributions and the fluctuations are separable. Some implications of these assumptions are briefly discussed: for example, we can show that the multimoment fluid equations for a plasma in thermal equilibrium obey the Fluctuation-Dissipation Theorem. For electrostatic turbulence, both the momentum and energy transfer rates are functionals of the renormalized spectral density of the fluctuating electric field and the renormalized dielectric function. For downward currents, we may approximate the momentum and energy transfer rates by using FAST satellite data for the renormalized spectral density, the conservation laws, and a scaling assumption for the renormalized dielectric function. Using FAST data for the particle velocity moments as a boundary condition, we may integrate the multimoment fluid equations both upward and downward from the satellite altitude in order to determine the potential and the particle velocity moments as functions of distance along the geomagnetic field line. We analyzed a winter FAST satellite pass near local midnight at ∼4130 km which shows a downward current region having a latitudinal width of about 45 km. At each subinterval (∼1.5 km) along the pass, we found a double layer (DL) below the satellite altitude; a transition (T) region just above the DL region where strong electron thermalization and intense ion heating occur; and a long range potential (LRP) region extending from the top of the T region to several earth radii and beyond. In the LRP region, ion conics are produced and further electron thermalization occurs. The average altitude of the DL/T region is in good agreement with experimental observations. Our analysis suggests that the formation of the DL, the particle dynamics, and the turbulence are intermittent in space and time. We also calculated the anomalous