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During the funding period for NASA Grant NAG5-1480 which prior to December, 1, 1990 was known as NASA Grant NAGW-78, the group has made substantial progress on the various topics originally proposed. The research performed has resulted in two Ph.D. theses for UCLA students Margaret Chen and Zhi Wang, more 50 refereed papers in various journals and conference proceedings, 31 invited and 104 contributed talks at conferences and symposia throughout the world. The main results from this work are summarized in each of the following sections as outlined in the original proposal, followed by a complete list of the group publications associated with this grant, a list of all invited talks given during the last three years, and finally a listing of the contributed talks.

A. Global Magnetohydrodynamic Simulations

The goals of this research were to provide a global picture of magnetospheric behavior and to elucidate the interconnections among various magnetospheric processes by means of three-dimensional (3D) magnetohydrodynamic (MHD) simulations. It has long been recognized that the interplanetary magnetic field (IMF) orientation controls magnetospheric dynamics. We have concentrated our MHD modeling efforts on determining the relation between the IMF orientation and the nature of magnetospheric dynamics, particularly in the near Earth part of the magnetotail and on the dayside.

The case of southward IMF has been studied in detail [*Walker et al.*, 1992; 1993]. The simulations reproduced many features of the near Earth neutral line model of substorms. Both our results and the model start with reconnection at the dayside magnetopause. The polar cap increases as open magnetic flux is added to the tail lobes. The magnetic field (B_z) in the neutral sheet determines the onset of reconnection. When the neutral sheet B_z has been reduced sufficiently, reconnection begins on closed plasma sheet field lines. It was found that the convection of the reconnected field lines was three dimensional. Even for a purely southward IMF the reconnected field lines are draped across the entire magnetopause. Reconnection leads to the formation of a plasmoid which propagates tailward due to the tension on reconnected tail lobe field lines which drape over it. The plasmoid is slightly concave towards the Earth because the reconnection began first near midnight where B_z is smallest.

If the IMF B_y is non-zero, a large B_y forms in the center of the plasmoid even in the noon-midnight meridian. The magnetic field lines then have a helical shape extending across the tail from dawn to dusk, resulting in a long twisted "flux rope" configuration [*Ogino et al.*, 1990].

Images of the auroral oval provide a global diagnostic of the substorm process. The global MHD model has been used to calculate the energy flux into the auroral ionosphere [*Walker et al.*, 1992]. This quantity, which should correspond most closely to the diffuse auroral precipitation, has a distribution in the ionosphere which agrees well with the observed oval.

The quieter magnetosphere which occurs for northward IMF has received less attention in both observation and theory. The global MHD code has also been used to investigate this case [*Ogino et al.*, 1992]. For this situation the magnetospheric configuration is dominated by magnetic reconnection at the tail lobe magnetopause tailward of the polar cusp. This results in a local thickening of the plasma sheet equatorward of the region of reconnection and the establishment of a convection system with two cells in each lobe. Just outside of the magnetopause both the density and the pressure decrease while the magnetic field increases. The decrease in pressure and density results from the compressional stresses exerted on the magnetic flux tubes as they are convected up to and around the obstacle. This depletion region does not occur when the IMF is southward; in that case reconnection dominates the region at the subsolar magnetopause.

In addition, when the IMF is northward, flows along the flanks of the magnetosphere are accelerated to values larger than the solar wind velocity [*Chen et al.*, 1993]. This property is not found in gas dynamic simulations of the magnetosheath and is caused by the tension on magnetosheath field lines which drape around the magnetosphere but which are not involved in the cusp reconnection.

B. Structure of the Dayside Magnetopause

The goal of the research that was proposed in this section was to better elucidate the field structure of the dayside magnetopause and also to examine plasma transport through the region. To help achieve these goals, one project undertaken examined the chaotic diffusion of magnetic field lines and particles through the dayside magnetopause by using analytical and numerical approaches; this resulted in a Ph.D thesis [*Wang*, 1992].

Initially a dayside field configuration was constructed by adding magnetic field perturbations with simple sine and cosine variations onto a Harris neutral sheet magnetic field model. In the limit of the number of wave modes becoming infinite, the field lines undergo a series of infinitesimal jumps that cause them to wander through the current sheet region. This stochastic field line region is characterized by nearby field lines that deviate from one another at an exponential rate. Analytical calculations showed that the stochastic zone occurred only within the current sheet and the field lines in the surrounding regions did not experience this divergence. By calculating the divergence rate of the field lines, the diffusion rate, analogous to quasi-linear theory, was estimated. It was found that the diffusion rate was greatest at the field minimum and then decreased as the field strength increased, falling to zero in the regular field line area. The diffusion rate and the width of the stochastic zone both increased as the perturbation amplitude was increased.

In order to confirm the analytical results concerning field line stochasticity and to understand how particles moving through this region would be affected, a series of numerical calculations were performed. Although an infinite number of modes was included in the analytic calculation so that closed form solutions could be obtained, only a small number of modes are needed to actually generate stochastic field lines. In plots of the successive crossings of a field line through a two-dimensional plane as it passes through the periodic system, it was found that the stochastic field region becomes filled with points while the regular field zones outside the current sheet were apparent as lines. Trajectories of a series of particles moving through this magnetic field region were examined and it was found that particles underwent a rapid diffusion within the current sheet at a rate corresponding to that found from the analytical calculations. The results imply that particle diffusion that occurs in the region of stochastic field lines can be large enough to provide the necessary transport through the dayside magnetopause.

Another study was undertaken to examine the effects of wave turbulence excited by field aligned electron beams observed in the dayside region known as the low latitude boundary layer (LLBL) [*Peroomian et al.*, 1991; 1992]. The LLBL is a transition region that separates solar wind plasma in the magnetosheath from plasma in the Earth's magnetosphere. In collaboration with the Lockheed group, a detailed examination of data from the AMPTE/CCE satellite determined that counterstreaming electron beams were present in cases of southward interplanetary magnetic field (IMF) and coincided with enhanced parallel polarized electrostatic waves near the electron plasma frequency. A linear theory study using the observed distribution functions found a beam--plasma type instability would be driven in the LLBL at frequencies near where the waves were observed. Kinetic particle simulations showed that the saturation mechanism was due to thermalization of the beam. For a particular range of parameters it was found that the beam could retain its beam-like shape and propagate away from the LLBL source region.

C. Merging at the Dayside Magnetopause

In this section research was proposed to better understand kinetic reconnection processes at the dayside magnetopause. This was done using a normal-mode analysis of topological variations in the magnetic field at the magnetopause in the presence of a sheared velocity flow; for this analysis the external plasma response was treated using the drift-kinetic formalism [*Wang*, 1992; *Wang and Ashour-Abdalla*, 1992; *Wang et al.*, 1992]. Using this model it was found that the growth rates for both neutral point tearing and guide field tearing are strongly reduced (by roughly an order of magnitude) when a shear flow is included. For realistic magnetopause conditions, the results show that it is difficult to excite the collisionless tearing instability in the presence of shear flow. It was found, however, that another instability, the twisting (or Kelvin-Helmholtz) mode, can be enhanced for magnetopause conditions. This leads to a twisting of the magnetic field and the formation of flux ropes with a characteristic scale of 1 Earth radii (R_E). These flux ropes typically possess a larger guide field than do tearing-generated flux ropes, so that the ratio B_z/B_y is approximately 0.5 rather than > 5 as in the tearing case. This smaller value is consistent with observations.

Another study involved constructing an analytic magnetic and electric field model for an open magnetosphere which accurately reproduces a dayside reconnection field configuration [*Wang*, 1992; *Wang et al.*, 1993]. The magnetic field configuration used as a starting point was that of a dipole magnetic field superimposed with a uniform southward IMF; this type of magnetic field model was developed for cases both with and without the shielding effects of the magnetopause currents. The electric field was included on closed field lines by allowing for continuity of the electrostatic potential between open and closed field line regions. This condition results from the requirement that the reconnected flux from the magnetosheath to the magnetosphere should equal that from the magnetosphere to the magnetosheath. The final result was a three dimensional analytic dayside electric and magnetic field configuration for the southward IMF canonical separator line model of magnetospheric merging.

D. Polar Wind

The primary goal of this research was to examine in detail the outflow of H^+ and O^+ in the Earth's polar cap region using both a kinetic and hydrodynamic formalism. Over the last three years significant progress has been made on the understanding of polar wind outflow [*Chen and Ashour-Abdalla*, 1990; *Chen et al.*, 1990; 1992] and resulted in another Ph.D thesis [*Chen*, 1990]

Observations from the Dynamics Explorer (DE-1) satellite of O^+ and H^+ ion beams (~10 – 100 eV) in the polar cap at altitudes of about 2.5 – 3.5 R_E, in a joint study with groups at the NASA Marshall Space Flight Center and at Lockheed, motivated the kinetic study of ion beam instabilities. The upflowing field-aligned O^+ and H^+ beams, which may have been formed as upflowing-energetic ions from the dayside cusp convect into the polar cap, can provide free energy to the polar cap plasma. First to be examined were linear instabilities associated with an O^+ and H^+ polar wind plasma in the presence of O^+ and H^+ beams for a range of beam densities, temperatures, and beam speeds. It was found that in the presence of O^+ and H^+ beams, the slow ion acoustic and slow ion cyclotron modes can couple to the normal modes of the plasma and be driven unstable. When the O^+ beam density is dominant over the H^+ beam density, which is sometimes observed [*Chen et al.*, 1990], the slow O^+ acoustic and/or slow O^+ cyclotron modes are triggered unstable while the H^+ beam modes are damped. The slow O^+ beam modes are unstable for a large range of wavenumbers due to their coupling with several O^+ and H^+ cyclotron harmonics associated with the polar wind. To investigate the nonlinear consequences of these instabilities on the polar wind, particle simulations were invoked. It was found that through resonant interactions of the slow O^+ acoustic mode, both the O^+ and H^+ polar wind ions are significantly bulk heated. In fact, when the O^+ beam density is dominant over the H^+ beam density, the polar wind O^+ ions are preferentially heated over the H^+ polar wind ions.

The effects of the kinetic ion heating on the outflow of the polar wind were examined using a time-dependent hydrodynamic model. A numerical code was developed that solves the O^+ and H^+ continuity and momentum equations in a flux tube from ionospheric altitudes (~ 200 km) to magnetospheric altitudes (~ 6–7 R_E). The effect of ion heating was included by allowing for the altitudinal variation of the ion temperatures in the momentum equation. The ion temperature profiles were specified based on the ion heating characteristics found from the kinetic simulations. It was assumed that the heating occurred above 1500 km and increased to a saturated value of temperature obtained directly from the kinetic simulation study. Since electrons were not significantly heated due to the ion beam instabilities, the electron temperature was kept constant. Two physically limiting cases were considered: preferential H^+ heating ($T_H > T_O$) and preferential O^+ heating ($T_O > T_H$). These cases correspond to when the O^+ beam density is comparable to and dominant over the H^+ beam density in the kinetic study. It was found that when the H^+ ions are heated, the H^+ velocity increases since heating increases the upward pressure gradient force and accelerates the H^+ ions at higher altitudes. However, the H^+ density decreases slightly because the amount of H^+ which can escape the polar ionosphere is limited by charge exchange of neutral hydrogen with O^+ in the collisional ionosphere. Since ion heating occurs where the plasma is collisionless, H^+ heating does not affect the outflow that much. For O^+ ions, there is not only an increase of O^+ velocity but a dramatic increase of O^+ scale height above the heating region. This is because the O^+ ions were essentially gravitationally bound and the O^+ heating which increases the upward pressure gradient can help enhance the O^+ outflow. It turns out that as long as there is significant O^+ heating, the O^+ ion escape from the polar ionosphere is enhanced. These results represent a viable mechanism which can lead to enhanced polar wind O^+ fluxes in the polar magnetosphere.

E. Waves in the Distant Tail

The research proposed for this part was concerned with understanding the generation and propagation of plasma waves driven by various types of unstable particle distributions in the Earth's magnetotail. This included distributions found from observations and from theoretical models in various regions of the magnetotail, such as the plasma sheet and near slow shocks. The research focused on different types of observed wave emissions in the magnetotail, including broadband electrostatic noise (BEN), narrowband electrostatic noise (NEN), electron cyclotron harmonics (ECH), and magnetic noise bursts (MNB).

A comprehensive study of the generation of broadband electrostatic noise (BEN) and its effects, has been made using observations, theoretical distribution modeling, plasma linear theory, and self-consistent numerical particle simulations [*Schriver and Ashour-Abdalla*, 1990; *Schriver et al.*, 1990*a*; *Berchem et al.*, 1991; *Schriver and Ashour-Abdalla*, 1991; *Ashour-Abdalla et al.*, 1993*a*]. The BEN wave emissions are most commonly observed in the Earth's magnetotail region known as the plasma sheet boundary layer (PSBL) in conjunction with field aligned energetic ion beams. A detailed study of ion beam driven instabilities in the PSBL found that if cold plasma of ionospheric origin is present in the PSBL, two ion beam driven instabilities, the electron acoustic and ion/ion acoustic instabilities, will be excited creating a broadbanded wave spectrum similar to BEN; the primary effects of these waves are to heat the cool background plasma to typical PSBL temperatures. A case study comparison of PSBL wave and particle observations from the AMPTE/IRM satellite with the simulation results supported the ion beam – cold plasma interaction model of BEN. Further improvements of the simulation wave diagnostics also found that in addition to the electron acoustic and ion/ion acoustic instabilities that can be driven by an ion beam in the PSBL, electron cyclotron harmonic waves (ECH) can also be generated; this was an important finding because it previously had been believed that the ECH waves were an independent wave emission from BEN. Another study of BEN involved using as initial simulation conditions particle trajectory results from a model of how the magnetotail is populated. In the magnetotail population model, it was found that ion "beamlets", a series of distinct ion beams at different velocities, were formed in the PSBL. The goal was to examine the lifetime and stability of these beamlets as they are affected by wave-particle interactions, as well as to look for distinct wave signatures that may appear in the wave spectrum caused by the beamlets. It was found that the beamlets were heated by plasma instabilities and merged together to form one ion beam, and in addition, the ion beamlets themselves excited a distinct instability in the intermediate frequency range between the ion and electrons plasma frequencies, whether cold plasma was present or not.

While BEN is a broadbanded emission observed in the PSBL, narrowband electrostatic noise (NEN) has been observed in the distant tail region associated with slow shocks at frequencies between the ion and electron plasma frequencies; as its name implies NEN occupies a narrow frequency range. The apparent lack of strong free energy sources in the region led to a non-conventional explanation for this wave mode. A detailed linear theory and kinetic simulation study determined that a small hole in electron velocity space that may be produced near slow shocks can lead to the generation of waves with the properties of NEN [*Coroniti et al.*, 1993; *Richard et al.*, 1993]. A phase space hole in the electron distribution, containing perhaps only a few percent of the total number of particles, was found from analytical and numerical linear theory to lead to a weak narrow banded instability at frequencies below the plasma frequency, consistent with NEN. It can be driven unstable by a region of positive slope in the parallel electron distribution function due to the hole or by a weak ion beam. The weakness of the instability led to it being a challenging problem to simulate numerically. A quiet start initial condition as well as a large number of particles (up to 3.2 million) were necessary in order to observe it in the simulation. The instability saturated at a level consistent with the observed amplitude of NEN. The explanation of the instability's low level of saturation is that it saturates due to a smoothing of the hole boundary rather than by a complete filling of the hole. When driven by an ion beam, the instability hardly affects the beam. This rapid saturation is consistent with the bursty nature of the instability.

Work has also been carried out to examine the generation and propagation of yet another wave emission observed in the Earth's magnetotail, magnetic noise bursts (MNB). These waves are often detected closer to the center of the central plasma sheet (neutral sheet) than BEN, although they are also believed to be generated by ion beams in the PSBL. A study has been made to examine not only the generation of MNB by ion beams, but their propagation characteristics to see whether the waves could be generated in the PSBL and then propagate into the central plasma sheet where they are often observed [*Burinskaya et al.*, 1993]. This work was performed using linear theory to calculate the growth rate of electromagnetic whistler waves driven by PSBL ion beams and ray tracing to follow the wave once it is generated. Wave damping by the ambient plasma background was also included. Using a model magnetotail that consisted of a PSBL with a uniform ion beam and a Harris type magnetic field profile that decreases towards the central plasma sheet (with a neutral line at $z = 0$), it was found that electromagnetic whistler waves generated by the ion beam in the PSBL were naturally guided towards the central plasma sheet by the global plasma gradients and the higher frequency part of the wave spectrum penetrated the closest to the neutral sheet, in agreement with observations.

F. Slow Shocks in the Distant Tail

In this section the goal was to examine the formation and evolution of slow shocks observed in the magnetotail by using kinetic particle simulations that included full electron dynamics to see how much of an effect the electrons have on processes related to slow shocks, such as dissipation and plasma heating. This led to a study of slow shocks by using a one dimensional electromagnetic full particle simulation code.

The simulation was set up so that particles enter the system from the left end and hit a reflective wall on the right end causing a stream of reflected ions and electrons to interact with the injected plasma. The appropriate magnetic and electric field conditions for a switch-off shock were maintained at the wall on the right end of the system and at the upstream boundary. The heated plasma in the low magnetic field region near the wall forms the downstream plasma. The results showed that a slow shock was formed under these conditions with a thickness of about 2 ion Larmor radii, which is equal to two ion inertial lengths in the simulation, and the slow shock was observed to move away from the wall. The shock thickness was found to scale with these lengths for different parameters. There was strong heating of both ions and electrons at the shock, and ion beams were formed in the vicinity of the shock. The density and magnetic changes across the shock front were found to be roughly consistent with the Rankine-Hugoniot conditions for a slow shock. The results indicate that the rapid formation and small thickness of the shock would not have been possible without the active participation of the electrons.

G. Collisionless Tearing Instabilities in the Magnetotail

The goals of this work were to understand how and when a new neutral line forms within the pre-existing closed field lines of the plasma sheet and to investigate the important question of whether steady convection can in principle occur in the plasma sheet. A number of aspects of these problems were studied by means of particle simulations and analytic theory.

Previous analytical studies of the collisionless tearing instability have dealt with thick current sheets, where the ion gyroradius based on the lobe field is much smaller than the current sheet half-thickness; recent observations, however, have found that the near-Earth plasma sheet can become much thinner just before substorm onset. Simulations of the pure ion tearing mode (neglecting electron dynamics) in thin current sheets have been performed [*Pritchett et al.*, 1991*a*] starting from a two-dimensional (2D) equilibrium configuration in which the normal field (B_z) changes sign in the lobes (this being a necessary condition for tearing). The underlying growth rate was shown to be an order of magnitude smaller than expected based on the thick current sheet results, and as a consequence the presence of a normal field in the neutral sheet of even a few percent of the lobe field strongly inhibits the growth of the instability.

It is known that if the electron motion is adiabatic, as is normally the case during quiet-time magnetotail conditions, then electron compressibility stabilizes the ion tearing mode. This result has now been generalized to apply to an arbitrary two-dimensional time-independent configuration without the need to assume adiabaticity [*Pellat et al.*, 1991]. It was shown that the stabilizing effect of electron compressibility can be removed only by spatial diffusion across magnetic flux surfaces, not by wave turbulent pitch-angle scattering or by non-adiabatic stochastic first-invariant diffusion. To reach the ion tearing regime, however, requires diffusion rates which are inconsistent with the initial assumed equilibrium. The implication of these simulation and analytic results is that it is extremely doubtful that the spontaneous ion tearing instability can explain tail reconnection.

The time-independent analysis, however, does not include the effects of convection. Two dimensional particle simulations of plasma sheet convection into regions of increasing tail lobe magnetic field strength [*Pritchett and Coroniti*, 1990] showed that changes in the particle distribution first drive B_z to zero on axis and then cause the equilibrium to break due to the rapid growth of tearing modes driven by the induced temperature anisotropy. Thus the effects of convection compressibility could trigger rapid tail reconnection.

An alternative (to the modified Harris) tail equilibrium model is the 1D firehose marginally stable current sheet. Using a 2D particle simulation code which followed only the dominant current-carrying ions, it was demonstrated [*Pritchett and Coroniti*, 1992*a*; 1993] that the idealized cold 1D current sheet is unstable to 2D kink perturbations driven by the anisotropic pressure distribution produced by the chaotic nature of the particle orbits in a field reversal region. In the presence of a finite thermal spread $(T_i/m_i)^{1/2}/v_{x0} \approx\gtrsim 0.1$ (where v_{x0} is the inflow speed of the ion stream), however, the current sheet is broadened, and the 2D perturbations do not alter its essentially 1D character. The firehose marginal stability condition is then satisfied outside of the current sheet.

A critical aspect of the 1D current sheet solution is that the accelerated particles escape and never return to re-encounter the current region. This assumption fails on the earthward side of the distant reconnection neutral line where the accelerated ions mirror in the geomagnetic dipole field and return to the current sheet at distances up to about 30 R_E down the tail. 2D particle simulations were used [*Pritchett and Coroniti*, 1992*b*] to demonstrate that these reflected ions drive a "shock-like" structure in which the incoming flow is decelerated and the B_z field is highly compressed. The resulting kinetic inhibition of steady plasma sheet convection is similar to the previously discussed pressure-induced choking of fluid adiabatic convection, and it strengthens the argument that steady plasma sheet convection may be impossible.

H. Other Problems

One of the problems listed under this section was the study of field-aligned currents and the motion of ions in the magnetotail as it relates to ion precipitation. Although at the time of writing the original proposal the importance of this work was not fully realized, it led to a fairly substantial and rewarding avenue of research. The approach used was to follow ions as they moved through a static model of the large scale electric and magnetic fields of the Earth's magnetotail. This method, where the field model is fixed and non-interacting charged particles move through a global field configuration, has come to be called large scale kinetics.

The initial studies [*Ashour-Abdalla et al.*, 1990; 1991*a*; *Karimabadi et al.*, 1990; *Büchner*, 1991; *Savenkov et al.*, 1991] employed simple analytical equilibrium magnetic field models of the magnetotail, and an initial source distribution located in the distant tail (100 R_E) was used. This work established that chaotic scattering in the field reversal region provides a continuous supply of ions to the boundary layer and leads to a significant coupling between the central plasma sheet (CPS) and plasma sheet boundary layer (PSBL) plasma populations. These results provided a unified view of the formation of the CPS and the PSBL from the same plasma source.

Further work [*Ashour-Abdalla et al.*, 1991*b*; 1993*a*; 1993*b*; 1994*a*] employed the much more realistic Tsyganenko magnetic field model and a constant uniform dawn-dusk electric field to follow particles from a mantle source. The results showed that energization and chaotic scattering can cause a significant restructuring of the tail ion distributions, both in space and in velocity coordinates. The model reproduced the large scale spatial distribution and velocity dispersion of fast ion beams moving both earthward and tailward in the PSBL. Quantitative estimates of the moments (density, bulk flow, fluxes) of the distribution functions obtained from the large scale kinetic calculations were in good agreement with magnetotail particle observations. Analysis of the distribution functions obtained at different locations along the magnetotail have shown that in addition to the large scale features, fine scale structuring of the plasma distributions can also occur. For example, the ion beams formed in the PSBL are highly structured into smaller "beamlets" with distinct velocities. Another study which used a snapshot from an MHD simulation for the magnetospheric electric and magnetic fields found that in the deep tail beyond the X-line reconnection region a plasma sheet and boundary layer analogous to that found in the near-Earth region forms [*Ashour-Abdalla et al.*, 1994*b*].

The consequences of the precipitating fluxes from the CPS and PSBL plasma flows have also been examined [*Ashour-Abdalla et al.*, 1992*a*; 1992*b*; 1992*c*; 1992*d*; *Bosqued et al.*, 1993]. Analysis of the model results and high time resolution data from auroral satellites indicate the presence of a velocity dispersed ion structure (VDIS) at the poleward edge of the auroral oval. The results show that the region of VDIS is associated with the ion beamlets in the PSBL. In addition to signatures of the beamlets in the VDIS precipitation pattern, there are also patterns formed in the VDIS due to multiple mirror reflections. The main portion of the PSBL ion population which is reflected (not precipitated) is effectively thermalized after multiple reflections near the Earth and many interactions with the magnetotail current layer. After each reflection cycle some part of the distribution is precipitated and forms echoes of VDIS shifted to lower and lower latitudes. The results also showed that at auroral latitudes below where the VDIS was seen, a minimum in ion precipitation appeared which maps to a region in the magnetotail where ion motion is highly non-adiabatic. This region has been called the `"wall" region (located at $x \approx 10\ R_E$) and demarcates the area in the magnetotail where ion motion is adiabatic closer to the Earth and quasi-adiabatic deeper in the tail. A strong enhancement of the cross-tail current occurs on the tailward side of the wall and the calculated pressure profiles indicate that the non-adiabatic processes operating in this region may contribute significantly to a pressure balance relief in the course of quasi-steady magnetospheric convection.

The other problem listed in this section in the original proposal dealt with auroral processes, in particular wave-particle interactions that are involved in electron precipitation. A separate study apart from the large scale kinetics was undertaken to deal with this problem that involved the development of a fully self-consistent particle simulation that could include large scale effects occurring over thousands of kilometers, as well as local effects such as instabilities [*Schriver et al.*, 1990*b*; *Schriver and Ashour-Abdalla*, 1993]. To study auroral dynamics in a self-consistent manner, a one dimensional electrostatic kinetic code with full dynamics for both ions and electrons was developed. The force equation explicitly included a term for the mirror force caused by the convergence of the Earth's dipolar field lines at low altitudes, as well as a gravitational term. A very long system was used, over 16000 grid points, which scaled to a system length greater that 5000 kilometers. At the high altitude end of the simulation system, energetic plasma from the plasma sheet magnetotail was injected towards the Earth and at low altitudes a cool ionospheric plasma in gravitational equilibrium was present. The mirroring of the injected magnetotail plasma at different altitudes resulted in a charge separation between ions and electrons that created a large scale potential drop across the system of many kilovolts. The parallel electric field caused by the potential drop was directed away from the Earth with a magnitude of a few mV/m, in agreement with observations. Ions were pulled out of the ionosphere by the parallel electric field and formed a field-aligned ion beam, while electrons were accelerated down the field lines towards Earth. The low altitude electron distribution, however, did not show evidence of a downgoing electron beam, but instead a high energy tail of precipitating electrons was formed. This lack of a beam in the downgoing electron distribution may be due to wave-particle interactions caused by a beam/background instability.

Work on other topics not explicitly mentioned in the original proposal and which do not fall under the purview of the other sections includes: the general role computer simulations will play in future space satellite programs that will study the magnetosphere [*Ashour-Abdalla and Coroniti*, 1990], computer simulations of electromagnetic waves during the CRRES active experiment mission [*Pritchett et al.*, 1991*b*], a study of relativistic wave-particle interactions as related to auroral kilometric radiation [Pritchett, 1990], simulations of magnetic reconnection driven by current sheet repulsion [R*ichard et al.*, 1990] and a simulation study of the behavior of ions downstream of a low Mach number quasi-perpendicular shock [*Motschmann and Raeder*, 1992].

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4. Ashour-Abdalla, M., J. Raeder, and J. Berchem, Modeling the multiple ion dynamics of the magnetosphere, Fourth International School for Space Simulation (ISSS-4), Nara, Japan, April 2-6, 1991.

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6. Ashour-Abdalla, M., Stochasticity and nonlocal kinetics in the magnetosphere, 1991 Cambridge Workshop on Nonlinear Phenomena and Active Experiments, Cambridge, MA, June 24-28, 1991.

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1. Chen, M. W., M. Ashour-Abdalla, and T. E. Holzer, The effects of ion heating on the polar wind outflow, 1990 Fall AGU, San Francisco, CA, December 1990 (EOS, 71, 1493).

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