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Abstracts

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Magnetotail plasma sheet energetic electron (>40 keV) response to substorms

Aasnes, A. (Los Alamos National Laboratory), R. H. W. Friedel, G. D. Reeves, B. Lavraud, L. Kistler, and P. Daly **[Talk; Tuesday PM]**

A superposed epoch study for substorm intervals is performed for Cluster RAPID (>40 keV) electrons when Cluster is in the tail plasmasheet. Substorm onset times are found using a combination of IMAGE FUV auroral images and LANL geosynchronous particle injections. An association between energetic electrons and geomagnetic activity is known to exist, but here we can investigate the temporal evolution of the electrons relative to substorm onsets. This study also intends to shed light on how effective the substorms are in accelerating electrons to high energies, compared to observations at non-substorm times.

The Association of Substorm Chorus Events with Drift Echoes

Abel, G. A. (British Antarctic Survey), M. P. Freeman, A. J. Smith, and G. D. Reeves **[Talk; Friday AM]**

Over recent years Substorm Chorus Events (SCEs) have been proposed as a useful indicator of substorm onset. The events are regularly seen in the data from the VELOX (VLF/ELF Logger Experiment) instrument at Halley, Antarctica, which has provided over a decade of near continuous observations. SCEs are generally thought to be excited by the injection of electrons near midnight as they gradient-curvature drift towards dawn. On close one-to-one inspection of SCEs seen at Halley and energetic electron signatures seen with the LANL geostationary spacecraft we have found that many events are associated with the drift echo of the injected electrons rather than the initial injection. In this paper we present some example events as well as the relative statistics. We find that approximately 1/4 of SCEs where a clear signature can be seen in the LANL data are associated with drift echoes rather than the initial substorm injection. We argue that, rather than being a direct signature of substorm onset, SCEs are a signature of enhanced electron fluxes in the chorus generation region, which are often, but not exclusively, associated with substorm injections.

A characterisation of ionospheric velocity from small to global scales.

Abel G., M. P. Freeman, G. Chisham and N. W. Watkins **[Poster; Thursday, Session 3]**

It is widely acknowledged that features in the magnetospheric/ionospheric system are seen on a variety of scales. There is a growing body of evidence that many such features display some characteristics of scale free systems i.e. fluctuations are seen on all scales (below the global scale at least). Here we present a structure function analysis of 8 years of ionospheric line-of-sight velocity data from the Halley SuperDARN radar in Antarctica comparing contemporaneous measurements of meridional velocities at different range separations. We find strong evidence for scale free behaviour both poleward and equatorward the open-closed field line boundary, though with different scaling exponents, and show that it is possible to collapse the distributions of fluctuations at different separations to a single distribution using appropriate scaling. Due to the limitations of the measurements we have had to limit our distributions of fluctuations to 3 standard deviations to reveal the scale free behaviour. We investigate, using a fractional Lévy generator, the effect of this and other limitations on our ability to characterise a scale free system. A characterisation of this scale free behaviour could be utilised in global models to parameterise fluctuations on scales smaller than the model resolution.

Ionospheric dynamics of substorms and IMF control

Aikio, Anita (Department of Physical Sciences, University of Oulu, Finland), Timo Pitkänen, Olaf Amm, and Alexander Kozlovsky **[Talk; Friday AM]**

By utilising the EISCAT low-elevation beam mode together with the EISCAT Svalbard field-aligned measurement, we can deduce the location of the polar cap boundary (PCB) in the nightside ionosphere with good temporal (1-2 min) and spatial resolution at one longitude. The PCB location is placed in the context of electrojets within the same longitude, calculated from the 1D upward continuation of MIRACLE magnetometer data, in three different events. Solar wind data is obtained from the ACE satellite. In the first event (6 Nov 2002), the substorm onset takes place deep within the region of closed magnetic field lines, separated by 6 - 7 deg in latitude from the PCB in the ionosphere. After the substorm onset, the reconnection in the near-Earth neutral line (NENL) reaches within 3 min the open-closed field line boundary and then the PCB expands further poleward together with the substorm current wedge. The poleward expansion occurs in a form of individual bursts, which are separated by 2 - 10 min, indicating that the reconnection in the magnetotail neutral line is impulsive. The poleward expansions of the PCB are followed by latitude dispersed intensifications of the westward electrojet (WEJ) in the main oval with high latitudes affected first, indicating that the NENL is the primary driver of substorm development. In the substorm expansion phase of the second event (27 Feb 2004), the PCB exhibits zig-zag-type motion with a period of 25 - 30 min and amplitude of 2.5 deg Lat. The poleward motions are associated with short-period intensifications of the WEJ. The origin of these fluctuations and the possible role of the IMF in controlling this motion is discussed. The beginning of substorm recovery phase is not associated with clear changes in the PCB location. In the third event (18 Feb 2004), several substorms occur during 21 - 02 MLT. During this time interval, the IMF has several abrupt poleward turnings. Detailed analysis of this event is underway, but it seems that even though these northward turnings may not trigger the substorms, they have a clear effect on substorm development (the PCB location and the WEJ magnitude).

A study of magnetosphere - ionosphere reconnection during night-time absorption spike events

Aminaei, Amin (Lancaster University, UK), and Farideh Honary **[Poster; Monday, Session I]**

Using IRIS riometer data and geomagnetic field model T96_01, 500 night-time absorption spike events in the ionosphere were mapped to the magnetosphere. Events occurred between 18-06 magnetic local time (MLT) during 1994-2003 in Kilpisjärvi, Finland (L~6.1). Results are in good agreement with reported locations of source of substorms and magnetic dipolarizations in the magnetotail. The mapped points were found strongly dependent to the geomagnetic activity according to the Kp index variations during spike events. The variation of the mapped points of spike events in the magnetotail versus geographic latitude of occurrence of spikes was also studied using 20 night time spike events occurred in SGO(Sodankylä Geophysical Observatory) chain of riometers. Linear relationship between corresponding mapped points and L-shell of location of riometers was observed suggesting simultaneous reconnections in a range of near earth magnetotail possibly cause spike events appeared on different latitudes in auroral zone.

Analysis of mesoscale ionospheric substorm signatures

Amm, O.(Finnish Meteorological Institute, Helsinki, Finland), A. Aikio, H.U. Frey, R. Nakamura, and H. Vanhamäki **[Invited Talk; Thursday PM]**

Within the large-scale evolution of substorms in the magnetosphere and in the ionosphere, a

number of distinct features in terms of current systems and aurora can be discriminated that cause specific mesoscale signatures in the auroral ionosphere. Using both ground-based and space-based data, we analyse in detail the electrodynamics of several of such features. In particular, we show that the field-aligned currents inside a westward travelling surge (WTS) are connected to a comparable amount with ionospheric Pedersen and Hall currents, and therefore they cannot solely be fed by remote currents that are carried through a Cowling channel, in which case the Hall current feeding should be clearly dominant. Using a new scheme that solves the ionospheric induction problem for arbitrary geometries and allows for non-uniform conductances, we demonstrate that in a localized area around the head of the WTS, the induced currents in the ionosphere can be of the same order of magnitude as those due to the potential electric field. In the case of auroral omega bands, the induced currents are less strong than in the WTS case, but still locally not negligible. Further, we demonstrate that a flux rope in the magnetosphere causes a topological correspondence in the ionosphere that manifests itself in a region of decreased auroral luminosity and conductance, which is moving with the mapped flux rope velocity, and we discuss the relative evolution of the open-closed field line boundary and the ionospheric current system during the different substorm phases.

Open questions on substorms and the upcoming panoply to address them

Angelopoulos, Vassilis (Space Sciences Laboratory, UC Berkeley) **[Invited Talk; Wednesday AM]**

With the upcoming launch of THEMIS and the extended life of Cluster, Geotail, FAST and POLAR, an unprecedented armada of comprehensively instrumented satellites will be available to resolve fundamental questions pertaining to substorm onset, dynamics and evolution. I will summarize lessons learned and open questions from fortuitous conjunctions of past missions, and detail how THEMIS orbits, space and ground instrumentation and data plans will help make progress on substorm physics in the upcoming few years.

Onset of substorm expansion phase: Theory predictions and results of experimental observations

Antonova, E.E.(Skobeltsyn Institute of Nuclear Physics Moscow State University, Moscow, Russia and Space Research Institute RAS, Moscow, Russia) **[Talk; Monday PM]**

The problem of substorm expansion phase onset continues to be one of the most actual problems of the physics of magnetospheric substorm. It is deeply connected with the problems of the plasma transport in the magnetosphere, stability of magnetospheric magnetic and plasma configurations. The most popular mechanisms of substorm expansion phase onset are based on the analysis of the stability of magnetospheric currents and distribution of plasma pressure. The results of experimental observations of substorm expansion phase onset are summarized and compared with predictions of different theories. It is shown that the existence of high level of plasma sheet turbulence produces the limitation on the action of possible mechanisms of substorm expansion phase onset. The development of the processes during substorm growth phase leading to the substorm expansion phase onset on the equatorial boundary of auroral oval is analyzed. The role of the increase of large-scale magnetospheric convection during substorm growth phase in the stabilization and destabilization of magnetospheric configuration is discussed.

Multi-satellite observation of plasma injection/dipolarization in the inner magnetosphere

Apatenkov, S.(Institute of Physics, St Petersburg State University, Russia), V. Sergeev, M. Kubyshkina, R. Nakamura, W. Baumjohann, I. Alexeev, A. Fazakerley, H. Frey, P. W. Daly, S. Muhlbacher, J.-A. Sauvaud, A. Runov, N. Ganushkina, T.Pulkkinen, and G. D.Reeves. **[Talk; Thursday PM]**

Addressing the origin of the energetic particle injections into the inner magnetosphere we investigate 23 February 2004 event with favorable constellation of four Cluster (near perigee), LANL and Geotail spacecrafts. Both an energy-dispersed and a dispersionless injection were observed by four Cluster spacecrafts crossing the plasma sheet horn, being mapped to 7-12Re at equatorial plane close to midnight meridian. An associated narrow equatorward auroral tongues/streamers propagating from the oval poleward boundary were observed by IMAGE/WIC. As compared to energy-dispersed event the dispersionless injection front has important distinctions consequently repeated at 4 spacecrafts: simultaneous increase in electron fluxes at energies 1..300keV, ~25nT increase in Bz and increase by a factor ~1.7 in plasma pressure. We evaluated the change of magnetic configuration during the dipolarization by fitting flux increases observed by PEACE and RAPID instruments assuming adiabatic heating and Liouville theorem. Mapping locations of the injection front detected by 4 spacecrafts to the equator (at 8-10Re) we estimated the injection front thickness to be ~0.8Re and the earthward propagation speed to be ~300km/s. Injected flux tube carrying accelerated particles found to be underpopulated in comparison with its neighbors in terms of the flux tube parameter pV^1.67. Based on observed injection properties we suppose the underpopulated flux tubes (bubbles with enhanced magnetic field and sharp inner front propagating earthward at n*100km/s speed) to be the mechanism responsible for particle acceleration and transport into the strong dipole-like magnetic field region.

Formation of the thin current sheets in substorms and its relation to the magnetic reconnection

Asano, Yoshihiro(Space Research Institute, Austrian Academy of Sciences, Graz, Austria), R. Nakamura, A. Runov, W. Baumjohann, T. Takada, I. Shinohara, A. Balogh, B. Klecker, and H. Reme. **[Invited Talk; Monday PM]**

Formation of thin current sheets with a vertical scale of an ion inertial length is one of the most important processes in substorm onsets and evolution. In particular, it is believed to be closely related to the occurrence of the magnetic reconnection in the magnetotail. With the recent satellite observations of the current sheet structure, we have revealed not only average characteristics of the gradual thinning but also dynamical structures of the current sheet during substorms. From 4 years of observations by the Cluster multi-satellites between 2001 and 2004, frequent occurrence of over-intense current embedded in the center of the current sheet as well as bifurcated current sheets are found to be mostly associated with substorm activities. While there are several previous reports that a sausage-mode-like oscillation of the current sheet is observed during substorm expansion and fast flows, it is also observed in the substorm growth phase. They are mostly concentrated within the neutral sheet region, and frequently coexists with large amplitude kink-mode-like waves or flapping motion as well as gradual thinning of the current sheet. The time period of the variation in the growth phase is several minutes, usually longer than that in the expansion phase (T = 30 to 60 seconds).

The dependence of magnetospheric topology and convection properties (including reconnection) on flux-transfer rates

Atkinson, Gerry (University of British Columbia) **[Talk; Tuesday AM]**

Magnetic flux transfer is the physical process that is basic to convection. The average transfer rate (∫E.dl) through the parts of the system be equal. The plasma and the conducting ionosphere act as impediments to the flux transfer from the tail to the dayside. The distortion of the magnetosphere from a non-convecting topology is consistent with stresses (and hence currents) which can maintain an appropriate flux transfer rate through the system, despite the impediments. The currents due to the impediments can be considered as two systems: 1) the region 1 and 2 Birkeland currents closed by ionospheric currents and the near-earth plasma-sheet "shielding" current (or partial ring current), and 2) the further-out plasma-sheet cross-tail current. The first requires an excess of magnetic flux on the nightside (compared to a non-convecting magnetosphere) to maintain the flux transfer rate, and the second requires reconnection (or other energy-removal process) distributed throughout the tail. For a tail-like configuration, reconnection is controlled by outflow conditions from a potential reconnection site (if outflow is blocked in both uptail and downtail directions, there can be no reconnection). At the nearest-earth neutral lines, the earthward boundary condition is essential to the physics in order to maintain the average flux transfer rate. The earthward outflow is strongly affected by curvature and gradient drifts. Energy transport out of the nightside by these drifts is of the same order as by ExB drifts. An understanding of convection near the Harang discontinuity is essential to reconnection at the nearest-earth neutral lines since the upward Birkeland current indicates a divergence of the drifts and hence probably of energy transport. Models of this convection and the related reconnection are discussed.

Nonlinear dynamics in the magnetosphere

Baker, D. N. (LASP/Univ. of Colorado), A. J. Klimas, D. Vassiliadis, and V. Uritsky. **[Invited Talk; Friday AM]**

Observational evidence and numerical modeling demonstrates that substorms are a global, coherent set of processes within the magnetosphere and ionosphere. This supports the view that substorms are a configurational instability of the coupled global system. The magnetosphere progresses through a specific sequence of energy-loading and stress-developing states until the entire system suddenly reconfigures. This energy loading-unloading sequence is the essential basis of nonlinear dynamics models that have been quite successful in describing the fundamental behavior of substorms without invoking detailed treatments of the internal substorm instability mechanism. Present-day MHD models also are seen to produce substorm-like global instabilities despite the fact that they do not treat realistically the extremely thin current sheets that play such an essential role in the near-tail dynamics prior to substorm onset. Recent trends in data analysis and modeling show quite clearly that powerful concepts in statistical physics and applied mathematics are being incorporated into space plasma physical research. Growing numbers of methods for modeling complex systems, data assimilation, system estimation, and predictive methods have been applied to the recent wealth of ionospheric and magnetospheric data. These methods work by representing global modes of a space plasma process in terms of a dynamical system. Nonlinear prediction schemes have greatly improved space weather forecasting and in most instances they remain more accurate and faster than physics-based models. In terms of basic understanding, self-organized criticality has recently been used to explain power law spectra observed in space plasma domains such as the plasma sheet and its low-altitude extension in the ionosphere. It appears that self-organized criticality arises in the bursty transport of magnetic energy (flux) from the tail lobes, through the plasma sheet, and out of the mid-tail region where reconnection occurs. Avalanches of local reconnection are implied and this behavior demands new tools for multi-point observations.

Multi-point measurements are required to determine the spatial and temporal development of global phenomena that constitute substorms. Hence, collective behavior and nonlinear dynamics in magnetospheric plasmas using modern theoretical tools will be invaluable in the general study of space plasmas and the specifics of magnetospheric substorm dynamics.

Multi-spacecraft measurements of magnetospheric substorms and their implications for the near-Earth neutral line model

Baker, Daniel N. (LASP/Univ. of Colorado), Nathan Farr and T. I. Pulkkinen **[Poster; Tuesday, Session 2]**

The substorm research community has long sought the capability to view the magnetosphere-ionosphere system in a global way and concurrently to probe the microphysical details of key physical regions. This objective has been substantially realized with the combination of the CLUSTER constellation and global magnetospheric imaging missions. With the addition of ACE, POLAR, and various geostationary orbit spacecraft, there is an ability to apply both global and local observational principles. Many recent examples serve to illustrate the observational power of these new tools. Using tail crossing events in 2001-2005, CLUSTER has observed numerous clear substorm sequences of events in the mid-magnetotail region (X~19RE). In this paper we focus on a global substorm onset event on 11 August 2002. CLUSTER data reveal microphysical details while other spacecraft show the global, macroscopic context for a substorm expansion phase onset shortly after 1400 UT. We have used the Lyon-Fedder-Mobarry MHD simulation code to numerically model this specific event. The new observations and model comparisons lead to improved understandings of three-dimensional magnetospheric substorm processes. This event shows global features consistent with the present-day near-Earth neutral line (NENL) model of substorm dynamics, but the specific details reveal heretofore unappreciated aspects of magnetic reconnection and particle acceleration near the neutral line.

Convection in the Earth's Magnetotail

Baumjohann, W. (Space Research Institute, Graz, Austria), and R. Nakamura **[Poster; Thursday, Session3]**

The flow of plasma in the Earth's magnetotail cannot reach a steady state, since adiabatic convection would lead to exceedingly high pressure of the associated magnetic flux tubes closer to the Earth, the so-called pressure catastrophe. The natural way to avoid the pressure catastrophe is to significantly re-duce the flux tube volume by reconnection, and observations show a near-Earth reconnection line typi-cally around 20-25 Earth radii down tail. Earthward flows from this reconnection line are rather bursty and typically seen outside of 10 Earth radii. At this point they are strongly braked by the here dominant dipolar magnetic field. The pressure gradients piled up by the flow lead to the substorm current wedge, and possibly other substorm phenomena observed in the Earth's ionosphere. When more and more flux tubes are piled up, the dipolarization front moves tailward and finally shuts off near-Earth reconnection.

Role of Nonlinear Ballooning Modes and Collisionless Reconnection at Substorm Onset

Bhattacharjee, A. (Space Science Center, University of New Hampshire), L.-J. Chen, M. Fillingim, K. Germaschewski, L. Kistler, R. Lin, Z. W. Ma, C. Mouikis, G. Parks, K. Sigsbee, and P. Zhu **[Invited Talk; Monday PM]**

The role of magnetic reconnection and ballooning instabilities at substorm onset is studied within the framework of the Hall MHD model using analysis as well as high-resolution simulations. Theoretical predictions are compared with data from Wind, Polar and Cluster. It is shown that

collisionless reconnection facilitates the growth of an extended and dynamic Y-type thin current that exhibits an impulsive pre-onset enhancement at near-Earth distances. Subsequently, the thin current sheet appears to be unstable to a Hall MHD (or drift-ballooning) instability which provides a possible mechanism for substorm onset at near-Earth distances. The Hall MHD ballooning instability is characterized by a real frequency that corresponds to a westward propagating wave. A new numerical simulation of nonlinear ballooning modes shows that the mode continues to grow nonlinearly at the linear growth rate, producing large sheared flows, and a reduction of the pressure gradient nearly everywhere except at the local stagnation point of the flow where a shock-like coherent structure forms. We compare the predictions of theory and simulation with several substorm events observed by Wind, Polar, and Cluster. By analyzing the time delay between earthward and tailward flux enhancements of energetic ions, the propagation velocity of the westward surge is estimated to be several kilometers per second, consistent with observations. A large anisotropy between the duskward and dawnward fluxes of energetic ions is observed to persist until local onset. The anisotropy is seen to be reduced significantly after onset, suggesting a local reduction of the pressure gradient that is known to drive ballooning modes. The reduction process is impulsive, suggesting that the underlying mode dynamics is strongly nonlinear, which is also consistent with a wavelet analysis of the magnetic fluctuations. The picture that emerges suggests a synergistic role for ballooning and reconnection during substorm dynamics.

Finalizing the Digital Imaging Riometer at Andøya (AIRIS), Norway.

Kolbjorn Bekkelund(Michael Gausa(Andøya Rocket Range), Peter Chapman, and Steve Marple **[Poster; Thursday, Session 3]**

Riometer investigations have a long tradition at Andøya Rocket Range (ARR), often correlated with the sounding rocket activity. These measurements started as early as in the 1960s. The Danish Meteorological Institute (DMI) installed four riometers close to the ARR rocket launchers in the 1970s. During the 1990s a decrease in the interest in ionospheric phenomena took place, and this concerned both riometer data and sounding rockets. Presently we experience an increasing interest on research activities in the ionosphere. Consequently, ARR as a provider for scientific services is improving its ground based instrumentation by adding a brand new imaging riometer to its toolbox, hence improving our ground support under all kinds of rocket campaigns. All scientific ground based instrumentation at Andøya is co-ordinated by the ALOMAR Observatory; a department of ARR. ALOMAR, the Arctic Lidar Observatory for Middle Atmosphere Research comprise an advanced set of atmosphere radars, lidars and passive instruments. In general the whole cluster of scientific instruments at Andøya takes advantage of this new instrument. Scientific co-operation The AIRIS project (Andøya Imaging Riometer for Ionospheric studies) started as a co-operation between the Andøya Rocket Range and the Department of Communication Systems (DCS) at Lancaster University in early 2002. DCS is operating several imaging riometers and stands for the technological and scientific conduction of our new instrument, whereas ARR is the main investor and the local operator of the system. DCS operates the imaging riometer in Kilpisjaervi (Finnland) and is building a new system (ARIES) close to Tromsø. Both AIRIS, ARIES and IRIS will have partly overlapping field of views when finally in operation. Figure 1shows the overlap between AIRIS and IRIS. The instrument The new instrument is a state of the art riometer by using digital amplifiers and receivers as well as a newly DCS developed Field Programmable Gate Array (FPG). This device, initially intended for the ARIES riometer in Tromsø, has replaced the standard butler matrix conventionally used in similar systems. The major FPG advantage is the opportunity to change beam patterns “on the fly” by software due to it’s digital nature. In addition the AIRIS 64 antenna array is constructed of a steel wire mesh supported by 36 surrounding rigid wooden poles and 64 individual star posts. The main idea behind this type of array is to minimize possible damages due to snow and ice experienced using traditional aluminium antennas. Location A major part of building a highly sensitive and flexible riometer was to find the optimum location taking

into consideration both induced noise from the surroundings as well as making sure that the site is rather easy accessible, allowing regular visits for maintenance purposes. In our case this task stretched over an entire year and resulted in several locations being tested on the island of Andøya. On January the 17th 2006, after some final noise reduction work, AIRIS became operational after 2 ½ years of development and construction. The initial checks shows that the instrument delivers good data, but further tests are necessary to establish AIRIS as a success. GLORIA The ARR Imaging Riometer will, as part of the Global Riometer Array network – GLORIA, initiated by DCS.

On the role of entropy conservation and entropy loss governing substorm phases

Birn, Joachim (Los Alamos National Laboratory), Michael Hesse, and Karl Schindler
[Talk; Thursday AM]

MHD theory and simulations have shed light on the role of entropy conservation and loss during the course of a substorm. Entropy conservation appears to be a crucial element leading to the formation of thin embedded current sheets in the late substorm growth phase and the potential loss of equilibrium. Entropy loss (in the form of plasmoids) is essential in the earthward transport of flux tubes (bubbles, bursty bulk flows), while entropy gain from general magnetic reconnection may contribute to the tailward transport of plasmoid/flux ropes (blobs). Entropy loss may also change the tail stability properties and render ballooning modes unstable and thus contribute to cross-tail variability. We illustrate these effects through results from theory and simulations. We also verify that the entropy conservation as used in MHD remains a valid concept in particle simulations.

FUV remote sensing of the proton isotropy boundary and magnetotail stretching during growth phases

Blockx, C. (University of Liege), J. C. Gérard, V. Coumans, B. Hubert, and M. Meurant
[Poster; Monday, Session I]

In a previous study, Blockx et al. [2005] showed that the SI12 (Spectrographic Imager) camera on board the IMAGE (Imager for Magnetopause-to-Aurora Global Exploration) spacecraft is an excellent tool to remotely determine the position of the isotropy boundary (IB) in the ionosphere during quiet conditions. Since this boundary was shown to be an indicator of the amount of magnetic field line stretching, SI12 images are thus able to provide a good idea of the amount of stretching of the magnetic field lines in the nightside magnetosphere. We analyze the growth phase of a few substorms in order to determine if the SI12 camera is appropriate to predict the stretching of the magnetic field lines before the onset. The relation between the position of the maximum proton precipitation as well as the intensity of this maximum and the magnetic field stretching is determined by comparison with GOES data at geosynchronous orbit. By combining the Tsyganenko-2001 (T01) magnetospheric model with the Sergeev's criterion, it is also possible to obtain a theoretical position of IB in the ionosphere, for known conditions in the solar wind. A short comparison is made between the latitude of IB derived from SI12 global images near local midnight during growth phases, with that calculated from the T01 model and the Sergeev's criterion.

Meeting the Modellers Half Way: Maximising the Potential of Ground Observations for Substorm Studies

Boteler, D. H. (NRCan Geomagnetic Laboratory) **[Talk; Wednesday AM]**

Modelling to explain magnetic substorms involves consideration of the links from the solar wind to the magnetosphere, from the magnetosphere to the ionosphere, and from the ionosphere to the

ground. A lot of effort is put into the first two, but the last link is often modelled poorly. This results in poor overall results that undervalue the work done in modelling the first two steps. In this presentation I will focus on the third part of the process: the link between the ionosphere and the ground. Problems arise because a major part of the magnetic field variations observed on the ground are produced by currents induced in the Earth. The exact expressions for the fields produced by a specified ionospheric currents involve integrals over all wavenumbers, but representing the induced currents by an image current at a complex depth leads to simple approximate (but surprisingly accurate) expressions. These are used to examine the relative size of the "external" and "internal" contributions to substorm magnetic feilds observed on the ground. Effects of 2-D and 3-D ground conductivity structure on the observed magnetic fields are also considered. The alternative to extending substorm modelling down to the ground is to meet the modellers halfway, by using the ground observations to determine the substorm currents in the ionosphere. I will review the various approximate techniques that have been used, extending from simple rotation of the disturbance vector to using inflexion points in the Z variation to locate the edges of the electrojet. Then I will examine the possibilities of obtaining more accurate ionospheric current values using techniques that provide a separation between the external and internal components of the magnetic fields. For a chain of stations, these include the Kertz formulas for a flat earth and zonal harmonics for a curved surface. For an array of stations, spherical cap harmonic analysis can be used to determine the ionospheric current flow across the array area. Routine application of SCHA with the extensive ground magnetometer arrays now available could be used to provide a database of current parameters. The auroral electrojets could be parameterised by amplitude, latitude, and width enabling easy comparison with modelling results.

Global Ring Current Response to Storm-substorms

Brandt, Pontus C. (The Johns Hopkins University Applied Physics Laboratory), M. -C. Fok, S. Ohtani, D. G. Mitchell,and D. C. Delcourt **[Poster; Tuesday, Session 2]**

Energetic Neutral Atom (ENA) images of the ring current have been used to study the global distribution of the ring current for almost six years by the High Energy Neutral Atom (HENA) imager on board the IMAGE satellite. HENA detects hydrogen and oxygen in the 10-200 keV and ~50-264 keV ranges. While both substorms and convection appear to enhance the proton ring current around midnight during storms, HENA observes a dramatic energization of the ring current oxygen, probably due to non-adiabatic processes during the substorm dipolarization. The ultimate question is how much the substorm injection contributes to the ring current pressure (or energy density). While inversion techniques, used in conjunction with in-situ validation and constraining, are maturing and provide more and more realistic estimates for the proton pressure, the techniques are providing estimates also for the important oxygen component. We have selected a couple of different storms for study to illustrate the storm-substorm effects of protons and oxygen ions during. Modeling results of the oxygen ion behavior using a single-particle code (breaking all invariants), interface with the Comprehensive Ring Current Model (CRCM) show good agreement with the HENA observations.

Global Perspective on Storm-substorm Relationship at Earth and Beyond

Brandt, Pontus C. (The Johns Hopkins University Applied Physics Laboratory), Donald. G. Mitchell, and S. M. Krimigis **[Invited Talk; Friday PM]**

The study of the storm-substorm relationship is dominated by the question of the role of the substorm in building up the storm-time ring current. Six years of Energetic Neutral Atom (ENA) imaging of the terrestrial ring current have allowed us to address this question on a global scale. The High Energy Neutral Atom (HENA) imager on board the IMAGE spacecraft covers most of the ring current plasma pressure by detecting and resolving H and O (and heavier) atoms in the

~10-200 keV and ~50-300 keV ranges. While it appears that protons are only energized mildly, the O+ displays an outstanding intensification during storm-time substorms. We discuss the recent attempts to infer the increase of the ring current plasma pressure due to substorms using the global ENA data and in-situ data. The results of the terrestrial storm-substorm study using global ENA data has allowed us to recognize global phenomena in Saturn's magnetosphere that are similar in nature to storms and substorms. The Cassini spacecraft was inserted into orbit around Saturn in July 2004 and carries in-situ particle instruments as well as the Ion and Neutral Camera (INCA), which is practically identical to HENA. During periods when Cassini is outside Saturn's magnetosphere it samples the solar wind parameters and INCA provides ENA images of the hot plasma population. While IMF direction is the main driver of magnetic storm activityat Earth, the data from such periods indicate that solar wind dynamic pressure may play the dominant role (remember that the fluctuations in IMF are much weaker at the distance of Saturn). During periods of active solar wind conditions (enhanced solar wind dynamic pressure and perhaps northward IMF), ENA intensities build up on the nightside of Saturn at about ~8-30 Rs. As the solar wind conditions quiet down, the ENA images display a blob of plasma rotating around the planet with the approximate rotation period of approximately 10h30min to 11h15min depending on energy and species. This blob of plasma has been observed to rotate around the planet for as much as nine days. As opposed to the slow (~10 h) "storm" increases observed on the nightside, observations of more rapid increases of nightside ENA intensities as far out as 40-50 Rs have been observed. These appear to have more significant response in the oxygen channel of INCA, which leads us to believe that O+ is more effectively accelerated than protons as have been observed at Earth during substorm dipolarizations. If these events are substorms they appear to occur much less frequently at Saturn than they do at Earth. We discuss possible energization mechanisms for these events and how the observed storm and substorm features compare to the storm and substorms at Earth.

Substorm convection patterns observed by the Super Dual Auroral Radar Network

Bristow, W. A. (Geophysical Institute, University of Alaska, Fairbanks, Alaska)
[Invited Talk; Thursday AM]

A pair of studies of substorm convection patterns based upon SuperDARN data showed a characteristic pattern that appears to be repeatable [*Bristow et al*., 2001; *Bristow et al*., 2003]. The studies focused on the growth phase and early expansion phase, but did not address expansion beyond the first few minutes. It was found that the growth phase is characterized by the enhancement of the velocity shear near midnight, and its extension to low latitudes and to local times across the midnight meridian. The velocity shear was observed to diminish at expansion onset. In addition the ionospheric flow velocity magnitude was observed to be enhanced for some period of time prior to expansion onset and to decrease at expansion onset. This presentation will summarize these studies and present recent extensions of the observations. *Bristow, W. A., A. Otto, and D. Lummerzheim*, Substorm convection patterns observed by the Super Dual Auroral Radar network, J. Geophys. Res. 106, 24,593-24,609, 2001; *Bristow, W. A., G. J. Sofko, H. C. Stenbaek-Nielsen, S. Wei, D. Lummerzheim, A. Otto*, Detailed analysis of substorm observations using SuperDARN, UVI, ground-based magnetometers, and all-sky imagers, J. Geophys. Res. 108, A3, 1124, doi:10.1029/2002JA009242, 2003.

Depletion of Electrons in a Multiple Substorm Event

Bryant, C. R. (University of Calgary), J. S. Murphree, E. Donovan, and S. B. Mende
[Poster; Thursday, Session 3]

Using the IMAGE FUV instrumentation it is possible to determine the power of auroral events. Proton power can be calculated using the SI12 instrument and the power of the LBH spectrum can

be calculated using the WIC camera. The resulting power spectrums can compared, examining the relationship of the precipitating particles. Data will be presented from a multiple substorm event from November 15, 2001. The multiple substorm event consists of two breakups that are internally driven during a strong southward IMF (-10 nT). These events are then followed by two substorm events that have obvious external triggers. The peaks of the events starting at 1738 UT and 1815 UT have ratios of the protons/LBH power of roughly 45%, indicating that the aurora is primarily due to precipitating electrons. The breakup at 1915 UT has a peak of protons/LBH power of 170%. This means that the protons make up nearly all of the particle precipitation into the auroral oval as LBH power contains some power from the protons. The recovery phase after this final substorm is quick for the LBH power but the proton power shows that the decay is longer, perhaps even with another event occurring at 2140 UT with only a proton signature. Loss cone for the electrons means they are favoured to precipitate into the oval but are depleted in the later substorm and protons make up the majority of the precipitating particles. Particle measurements will be used in conjunction with images from IMAGE FUV instruments to help determine the relationship between the protons and electrons in this multiple substorm event scenario.

Magnetospheric Multiscale Mission Overview

Burch, J. L. (Southwest Research Institute) **[Invited Talk; Friday PM]**

The scientific objective of the Magnetospheric Multiscale (MMS) mission is to gain a definitive understanding of how magnetic reconnection operates in collisionless plasmas. The mission will utilize a closely-spaced cluster of four identical spacecraft to explore the magnetopause and the magnetotail reconnection regions. Three low-inclination orbital phases will be used: (1) 1.2 x 12 RE at 28° inclination with dayside apogee; (2) 1.2 x 25 RE at 10° inclination with nightside apogee; and (3) 12 x 31 RE at 10° inclination with nightside apogee. 3-D measurements of plasmas, energetic particles, electric and magnetic fields, and waves will be made at high time resolution (1 ms for fields, 25 ms for plasma electrons, and 150 ms for plasma ions) by the four spacecraft, which will be in a tetrahedral configuration with spacings between 10 and 1000 km, depending on the region under investigation. The MMS data, which will be assimilated into the latest models of magnetic reconnection, should lead to significant advances in our understanding of the role of reconnection in substorm physics.

Correlation of whistler wave characteristics with field and particle measurements at substorm current sheets

Chen, Li-Jen (Space Science Center, University of New Hampshire), Ondrej Santolik, Amitava Bhattacharjee, Chris Mouikis, Edita Georgescu, Jolene Pickett, Harald Kucharek, Bertrand Lefebvre, and Patrick Daly **[Poster; Tuesday, Session 2]**

We examine the characteristics of electromagnetic waves observed below the electron cyclotron frequency and electron plasma frequency at Cluster current sheet crossings immediately before and during substorms. In all the current sheet events we have studied, right-hand polarized whistler waves are observed. Both positive and negative signs are found for the field-aligned component of the wave vector. The wave power is concentrated in a bandwidth one to a few hundred Hz, and is embedded in broadband emission, indicating the presence of other wave modes and nonlinear effects. It has been suggested by theory that whistler waves mediate fast reconnection. Furthermore, whistler waves may also be excited as a secondary instability due to anisotropic electron heating produced by the lower-hybrid-drift instability of thin current sheets. We correlate the observed whistler characteristics with other electrostatic and magnetic structures, current densities, energetic particles, and plasma measurements to assess the roles of whistler waves in reconnection and substorm processes.

Interpretation of Automated Forward Modeling Parameters for Sawtooth Events and Substorms

Connors, Martin (Athabasca University), R. L. McPherron, and R.. Clauer. **[Poster; Monday, Session I]**

Automated Forward Modeling (AFM) is an inversion technique based on magnetic data alone, which can indicate physical parameters associated with electrojets. From perturbations along a meridian, the total electric current crossing the meridian may be determined, as well as the latitudes between which it flowed. Mid- and low-latitude perturbations may also be included to constrain the longitudinal limits of a three-dimensional current system. The technique is based on nonlinear optimization of the parameters of a forward model. It is possible to compare model output to the original input to ensure that the routine has functioned well and that output parameters are reliable and presumably have physical meaning. Characteristic behaviors of substorms are readily seen in modeling output: the current strengthens rapidly and considerably at an expansive phase onset, following a growth phase during which the electrojet borders move equatorward, usually with some strengthening of current. At onset the poleward border is often seen to move poleward rapidly. Poleward border activity may be noted then and also at other times. After an onset, the recovery phase is often marked by a retreat of the equatorward border, indicating the well-known shrinkage of the auroral oval. Sawtooth events have many of the characteristics of expansive phase onsets, but maximum poleward expansion of the poleward border is followed by equatorward movement reminiscent of a growth phase. Since this is correlated with the interplanetary magnetic field remaining southward, the difference from common expansive phase phenomenology may simply be the lack of a recovery phase. We examine differences between representative sawtooth events and substorms using primarily the AFM modeling tool.

Proton precipitation during substorm growth phase observed by IMAGE-FUV: a case study.

Coumans, Valerie (LPAP, Universite de Liege, Belgium), Jean-Claude Gerard, Caroline Blockx, and Benoit Hubert **[Talk; Friday AM]**

The IMAGE (Imager for Magnetopause-to-Aurora Global Exploration) - Spectrographic Imager SI12 globally images the Doppler shifted Lyman-a auroral emission at 121.8 nm every two minutes. We present examples of observations of proton precipitation during substorm growth phases. Every substorm is not preceded by a growth phase, but our study is based only on cases when it is present, selected on the basis of visual sorting. The morphology and dynamics of the growth phase are analyzed by determining the equatorward motion of the polar and equatorial boundaries and its relation with the solar wind and the IMF characteristics measured by ACE satellite.

Kinetic balance of the pre-breakup thin current sheet

Cully, Chris (LASP, University of Colorado), Bob Ergun, Dan Baker, Anders Eriksson, Erik Engwall, Elizabeth Lucek, Melvyn Goldstein, Harald Kucharek, and Chris Mouikis **[Talk; Monday PM]**

In the late growth phase, a thin current sheet commonly forms, embedded within the thicker plasma sheet. With a scale size comparable to the thermal ion gyroradius, the thin current sheet is typically the last stable configuration before substorm onset. In that sense, its kinetic equilibrium constitutes the "initial condition" for reconnection, current disruption or any other substorm expansion phase model. In the context of Cluster observations of thin current sheets, we discuss the applicability of several thin current sheet models. In particular, we show that the effectiveness of anisotropy-driven

models is dramatically reduced in the presence of sheet structure in the y (current-aligned) direction. Such structure is very common, and the requisite conditions for a stable anisotropy-driven sheet are rarely encountered in the Cluster data.

On magnetospheric substorms at Mercury

Delcourt, D. C. (CETP-IPSL-CNRS), K. Seki, and N. Terada **[Invited Talk; Friday PM]**

Most of our knowledge about the magnetized environment of Mercury comes from three passes of Mariner-10 in 1974-75. The data acquired during these passes revealed that Mercury possesses an intrinsic magnetic field that leads to the formation of a small-scale magnetosphere. These data also revealed that Mercury's magnetosphere may be subjected to rapid (a few minutes) dynamical reconfigurations. Most notably, they provided evidences of field line dipolarization and charged particle acceleration in the inner magnetotail, in a like manner to processes occurring during substorms at Earth. Analysis of the plasma flows and nonlinear particle dynamics under such conditions is timely with the forthcoming measurements of the MESSENGER and Bepi-Colombo missions. We will review the conjectural interpretation framework that has been developed from Mariner-10 data as well as results from recent numerical simulations (MHD, hybrid, single-particle). In particular, we will show that, during presumed dipolarization events modeled via rescaling of the Earth's environment, magnetospheric electrons may be subjected to significant energization and precipitate. The origin of the short-lived modulation identified in the energetic electron data from Mariner 10 however remains unclear. The dynamics of ions during substorms at Mercury will also be addressed. In particular, we will show that recycling of exospheric ions and consequent sputtering of the planet surface significantly depend upon the level of magnetic activity.

Storm-time and substorm cold plasma dynamics.

Dent, Zoë (Space Physics Group, University of Alberta, Canada), and Ian Mann **[Poster; Thursday, Session 3]**

The storm-time global scale erosion and subsequent recovery of the plasmasphere is well documented, although much remains to be learned about the loss and replenishment processes. The relative ratios of the ions (H+, He+, O+) are also believed to vary throughout a storm cycle, although little is understood about this. During their growth phase, and at onset, substorms are also believed to affect the cold plasma population which forms the plasmasphere perhaps through the development of dynamical substorm electric fields. Conversely, the plasmapause location is believed to affect growth and loss of radiation belt particles through their influence on wave propagation and growth rates during geomagnetic storms. The dynamics of the cold plasma population may be monitored from both ground and space. Meridional chains of ground-based magnetometers may be employed in order to determine plasma mass density profiles as a function of time through the dayside sector. Various satellite instruments allow the local cold plasma population to be monitored in-situ. The CARISMA and McMAC arrays in Canada and the USA, in combination with the Electric Field Instrument (EFI) and Electrostatic Analyser (ESA) on board the THEMIS satellite will provide the potential for a unique set of coordinated studies when THEMIS passes over North America in the dayside sector. In addition to studies of plasma dynamics, these will allow plasma mass density and particle number densities to be compared, providing information about the heavy ion (He+ and O+) component of the cold plasma population. This poster will present a summary of the cold plasma dynamics which occur during geomagnetic storms and substorms, and results from previous studies of cold plasma dynamics.

Issues surrounding the stability of the plasma sheet during the late growth phase

Dobias, P. (DRDC CORA), J. A. Wanliss, and J. C. Samson **[Poster; Monday, Session I]**

We analyze a nonlinear stability of the near-Earth plasma sheet via a Grad- Shafranov equilibrium constrained by CANOPUS data. Using a stability analysis based on comparison of various orders in a Taylor expansion of the potential energy density, we demonstrate that an occurrence of eld line resonances followed by a development of a Kelvin-Helmholtz instability at about 10 Re causes the near-Earth plasma sheet to become unstable minutes before the onset. We also discuss the importance of the proper distinction between the stability properties of the magnetotail, and the direct triggers of the instability. While these two aspects of the stability may be (and likely are) related, it is possible that they involve different types of processes that will work in a complementary fashion.

Azimuthal Extent of Substorm Expansive Phase Onset

Donovan, Eric (University of Calgary), Brian Jackel, Emma Spanswick, Stephen Mende, and Vassilis Angelopoulos **[Talk; Wednesday AM]**

We use high time (3 second cadence) and space resolution images from the THEMIS All-Sky Imager array to examine the azimuthal structure and extent of the initial brightening of the breakup arc. We compare these optical observations to riometer-based inferences of the initial azimuthal extent of the dispersionless injection. Our preliminary results indicate that the azimuthal extent of the initial brightening and that of the projection of the initial dispersionlesss injection into the ionosphere are similar.

The THEMIS All-Sky Imager Program

Donovan, Eric (University of Calgary), Stephen Mende, Brian Jackel, Harald Frey, Mikko Syrjäsuo, Stu Harris, Mike Greffen, Laura Peticolas, Igor Voronkov, Trond Trondsen, Noora Partamies, Martin Connors, and Vasilis Angelopoulos **[Poster; Tuesday, Session 2]**

The NASA Time History of Events and Macroscale Interactions in Substorms (THEMIS) MIDEX mission is scheduled for launch in the fall of 2006. This five satellite constellation is designed to address critical substorm questions. Closure of these questions demands the resolution of ambiguities related to substorm onset location and time, which in turn demands comprehensive specification of the auroral distribution and ionospheric currents. As a consequence, THEMIS includes an extensive ground component that in turn includes a continent wide array of white light All-Sky Imagers (ASIs). These ASIs will operate with spatial resolutions approaching 1 km at zenith, and a cadence of one image every three seconds. At the time of writing of this abstract ten of these ASIs have been installed and are operating, each returning real time summary data and storing full-resolution images for later retrieval via hot-swappable hard disks. The THEMIS ASI program is a collaboration between the University of Calgary and the University of California, Berkeley and is jointly funded by NASA and the Canadian Space Agency. In this paper, we describe the ASIs and the array. We present data from several example events, and samples of summary and full resolution data in the format that it will be distributed.

MHD/Particle Simulations of Substorm Injection of Energetic Ions and Electrons into the Inner Magnetosphere

Elkington , Scot R. (LASP, University of Colorado), and Michael Wiltberger **[Invited Talk; Thursday PM]**

Magnetohydrodynamic (MHD) simulations of the magnetosphere often exhibit the global storage and catastrophic release of energy characteristic of the magnetospheric substorms observed during geomagnetically active conditions. keV electrons and protons injected by substorm activity may directly contribute to the populations comprising the ring current and radiation belts, or serve as a low-energy source of particles for subsequent acceleration to ring current and radiation belt energies. Using event studies driven by actual solar wind conditions, we examine MHD simulations for characteristic properties related to the growth phase and onset of observed substorms. Test particle simulations of the energetic electrons and protons comprising the plasmasheet are conducted, examining the efficacy of the injection process in terms of particle numbers and net energization. We look in detail at the growth-phase magnetic field topology in the tail, and discuss the implications of the stretched field line geometry in the formation of a "seed population" of the energetic plasma sheet particles injected into the inner magnetosphere. We examine the dependence of the particle injection process on properties of the substorm injection front, and where possible, compare the simulated evolution of the particle injection boundary with in situ, ground-based, and ENA observations.

Flux-Tube Depletions During Substorms

Erickson, Gary M.(Prairie View A&M University), Alena Savoie (Prairie View A&M University) Richard A. Wolf and Stanislov Sazykin (Rice University) **[Poster; Monday, Session 1]**

We report on early results from an investigation of the role of interchange during substorm injections. This investigation uses observations taken onboard the Geotail satellite near perigee (−9 RE > XGSE > -15 RE) in the midnight sector of the plasma sheet near times of dipolarizations/injections. We introduce a method to obtain the instantaneous pV5/3 of flux tubes from single-satellite measurements of the plasma and magnetic field and present some early findings. Injections are comprised of low-content flux tubes (“bubbles”) that have lower pV5/3 than their pre-onset predecessors. Injected flux tubes have pV5/3 levels typical of geosynchronous values.

ULF waves associated with a storm sudden commencement: Cluster observations

Eriksson, P. T. I. (Royal Institute of Technology, Stockholm), L. G. Blomberg, S. Schaefer, and K.-H. Glassmeier **[Poster; Monday, Session I]**

We study the onset and development of a ULF pulsation excited by a storm sudden commencement. On the 30 August 2001 1410 UT the Cluster spacecraft are located in the dayside magnetosphere and observe the excitation of a ULF pulsation by a threefold enhancement in the solar wind dynamic pressure. Two different harmonics are observed by Cluster. We observe a compressional wave and the development of a toroidal and poloidal standing wave mode. The toroidal mode is observed over a narrow range of L-shells whereas the poloidal mode is observed to have a much larger radial extent. By looking at the phase difference between the electric and magnetic fields we see that for the first two wave periods both the poloidal and toroidal mode are traveling waves and then suddenly change into standing waves. We estimate the azimuthal wave number for this event to be m=10±3. This is consistent with the length scale of the perturbations at

the magnetopause. We conclude that the enhancement in solar wind pressure excites eigenmodes of the geomagnetic cavity/waveguide that propagates tailward and that these eigenmodes in turn couple to toroidal and poloidal mode waves. Thus our observations firmly support the cavity/waveguide theory.

On the role of nonmaxwellian forms of distribution functions in the process of acceleration of auroral particles

Ermakova, N.O.(Skobeltsyn Institute of Nuclear Physics Moscow State University, Moscow, Russia; Space Research Institute RAS, Moscow, Russia),and E.E. Antonova **[Poster; Thursday, Session 3]**

Most theories of auroral particle acceleration are based on the suggestion of maxwellian form of distribution function of accelerated particles. At the same time in most cases experimentally measured distribution functions are better described by kappa distribution. The formation of kappa distributions is connected with the action of relaxation processes in the turbulent magnetosphere in the conditions of the absence of collisions. Field-aligned acceleration of ionospheric ions leads to the appearance of particle population with plato-type distribution functions. The trapping of particles inside the region of acceleration also leads to the appearance of nonmaxwellian distributions. The model of auroral particle acceleration is developed taking into account the processes of modifications of distribution functions. The existence of conjugate regions of acceleration in the north and south hemispheres is suggested. It is shown that the kinetic treatment and the formation of nonmaxwellian distributions with reduced number of low energy particles gives the possibility to reanalyze the criteria of the formation of field-aligned jumps of electrostatic potential.

Substorm studies with Cluster and Double Star

Fazakerley, A.(Mullard Space Science Lab., University College London), A. Marchaudon, I Alexeev, C Owen, A Lahiff, R Wilson, A Walsh, C Carr, E Lucek, H Reme, H Frey, J Watermann **[Talk; Tuesday AM]**

Double Star is an international collaboration between the China National Space Agency (CNSA) and the European Space Agency (ESA), which has produced and launched two magnetospheric research spacecraft, TC-1 and TC-2. TC-1, was launched in late December 2003, and is in a near-equatorial highly elliptical orbit, with apogee at 13.4 Earth radii. TC-2 was launched in late July 2004 into a polar orbit with apogee at 7.1 Earth radii, initially at a high magnetic latitude. These orbits were designed so that the magnetic local time of their apogees coincide closely with that of ESA's Cluster flotilla. Cluster, launched in 2000, is also in a polar orbit, but with apogee at about 19.6 Earth radii. These six spacecraft, together with Polar, and sometimes Geotail, provide excellent opportunities for magnetotail science such as exploring the sequence of events in a substorm, by enabling simultaneous co-ordinated observations at different distances along the magnetotail in conjunction with ground based datasets and global auroral imaging. We are studying several events and will illustrate the possibilities by presenting a case study of a magnetotail disturbance observed during a radially aligned conjunction close to the midnight sector, observed on 03 September 2004.

Observations of tail dynamics using ground and space based instruments during a period of multiple substorms.

Forsyth, C. (University of Leicester), M. Lester, S. E. Milan, A. Grocott, H. U. Frey, E. Lucek, H. Reme, and J. Watermann **[Talk; Thursday AM]**

We present preliminary observations from an ongoing investigation into the dynamics of the magnetotail during a period of multiple substorms. The investigation coordinates data from ground and space based instruments including the Cluster and IMAGE spacecraft, SuperDARN and ground magnetometers during the period 00:00UT to 05:00UT on 25th August, 2003. The first expansion phase, which is preceded by three pseudo-breakups at 00:40UT, 00:50UT, 00:55UT, takes place between 01:11UT and 01:50UT during which time IMAGE WIC(FUV) data for the Southern auroral oval shows enhanced auroral activity almost solely in the post-midnight sector. At the same time, Northern hemisphere SuperDARN data shows that the turning point for the return convection flow from duskwards to dawnwards, taken as an indicator of the Harang discontinuity, is also in the post-midnight sector. This implies that during this period, when the IMF has a strong positive By component, the tail has been diverted in the negative Y direction. During this time, Cluster CIS detects a temporal variation of the plasma sheet and the FGM detects a dipolarisation of the field. A second expansion phase onset occurs near 04:00UT and is accompanied by quasi-periodic variations in the GSM BX¬ component measured by Cluster. The relevance to current models of tail dynamics is discussed.

Auroral complexity and the substorm

Freeman, Mervyn (British Antarctic Survey) **[Invited Talk; Friday AM]**

Auroral fluctuations occur across a wide range of temporal and spatial scales. Over the years, certain auroral patterns have been given names (curls, spirals, substorm bulge, etc) and associated with characteristic scales. In particular, the substorm bulge is defined as an auroral fluctuation on the magnetotail system scale and consequently is traditionally treated as a distinct class of auroral fluctuation. However, recently, it has been observed that general fluctuations in auroral current and brightness above an arbitrary fixed threshold are self-similar across a wide range of scales. Such self-similarity is a hallmark of a complex system – a system of many interacting parts – in which the correlation length extends up to the system scale such that coherent collective events may be of arbitrary size. Here we ask whether we should regard the substorm as (merely) part of a self-similar continuum of auroral fluctuations or whether it is necessary or advantageous to consider it as a separate phenomenon.

Substorm onsets as observed by IMAGE-FUV

Frey, Harald U. (Space Sciences Laboratory, University of California, Berkeley), and Stephen B. Mende **[Talk; Tuesday AM]**

The FUV instrument observed more than 4000 substorm onsets during the 5.5 years of the IMAGE mission. About 2/3 were observed during the first 3 years in the northern hemisphere, while 1/3 were observed towards the end of the mission in the southern hemisphere. The locations of individual substorms are influenced by the external solar wind conditions, primarily the B_y and B_z components of the IMF. However, when averaged over all seasons and several years, the average substorm onset locations are the same in both hemispheres with respect to magnetic latitude and local time. This result signifies that the source region of substorms and the final onset location in the ionosphere, are primarily determined by the internal properties of the magnetosphere, and only secondarily influenced by external conditions.

Preliminary study of energetic particles embedded in magnetic structures observed in the near Earth plasmasheet

Fu, Suiyan (Peking University), Q.-G. Zong, Z. Y. Pu, A. Korth, and P. W. Daly **[Poster; Monday, Session I]**

Energetic ions embedded in plasmoids with By bipolar have been observed near the Earth when the IMF has a strong By component during a substorm active time period on Nov. 8, 2004. In the earthward flowing plasmoid that is observed before the substorm onset, the ratio of heavy ions to protons is lower than that in its environment, while for the tailward plasmoids, the ratio is always higher in the magnetic structures. This is consistent with the distribution of heavy ions in the plasmasheet obtained by a statistic study based on plasma sheet crossing events. It is found that in the earthward flowing plasmoid, oxygen ions are relatively cold with a higher kinetic pressure than thermal pressure inside the structure. It is therefore suggested that oxygen ions in the tailward flowing plasmoid might be heated in the near earth current sheet. Energetic electrons are found being trapped in the plasmoid with a strong core field, demonstrating its good character as an indicator for magnetic structures with closed field lines. A multiple x-line reconnection could be employed to explain the observed results.

Polar Spacecraft Observations Near 9 RE: Rapid Multiple Dipolarizations and their Interpretation

Ge, Yasong (Institute of Geophysics and Planetary Physics, University of California, Los Angeles), and C. T. Russell **[Talk; Thursday AM]**

The Polar spacecraft has probed the near-Earth tail region at 9 RE with its orbit in the meridian plane and apogee near the magnetic equator. The onboard magnetometer frequently recorded dipolarizations of the magnetic field during the crossing of the current sheet, including rapid multiple dipolarizations. The interval between two rapid dipolarizations is about 30 minutes, which is close to the time interval of multiple Pi 2 pulsations in a substorm. In several events, three or more dipolarizations occur within 2 hours, but most events have two rapid dipolarizations. The normal component of the magnetic field to the current sheet rises in a stepwise manner in some events. Otherwise it recovered to the previous level before the next dipolarization. Rapid multiple dipolarizations may occur in a single substorm. We interpret these dipolarizations in terms of the initial onset of reconnection in the near-Earth plasma sheet, followed later by more rapid reconnection as lobe plasma reaches the x-point and reconnection on open field lines releases the plasmoid.

Solar wind-magnetosphere coupling and auroral signature

Gérard, J.-C. (LPAP, Université de Liège, Belgium), and D. Grodent **[Invited Talk; Friday PM]**

The interaction of the solar wind with the magnetospheres of the giant planets differs from the interaction with the terrestrial magnetosphere in the role of the interplanetary magnetic field. While coupling occurs in both instances, the magnetospheres of the outer planets are dominated by the planetary rotation that can provide much of the energy for the processes acting within these magnetospheres. Also the circulation of plasma may be driven by mass loading of the magnetosphere by moons and rings rather than by reconnection with the IMF. Io provides most of the mass loading inside the Jovian magnetosphere and therefore is the ultimate source of plasma present in the magnetosphere. Jupiter's aurora appears relatively shielded from solar wind influences, except inside the auroral oval where transient bright emission is observed following magnetospheric compressions. Reconnection events have also been observed in the nightside sector, causing events similar to substorms such as plasmoid ejections and localized auroral enhancements. Instead, Saturn's aurora is quite responsive to solar wind perturbations as was observed during the joint HST-Cassini campaign in 2004. It is believed that the Dungey and Vasyliunas cycles both control the magnetospheric convection pattern and the morphology of

Saturn's aurora. Auroral intensification events however appear triggered by sudden solar dynamic pressure increase more tnan by changes in the IMF.

Characterizing the Classical Auroral Substorm: Ground magnetic field perturbations

Gjerloev, Jesper W (The Johns Hopkins University Applied Physics Lab), R A Hoffman J B Sigwarth, and L A Frank **[Talk; Wednesday AM]**

We present a large statistical study of the spatial and temporal morphology of the ground magnetic field perturbations during classical bulge-type auroral substorms. Images obtained by the Polar VIS Earth camera and ground based magnetometers are utilized in the study of 118 carefully selected events. Smearing of the key emission features is minimized using both temporal and spatial normalization techniques. Our empirical time dependent model of the ground magnetic field perturbations displays a number of interesting features. The perturbations are clearly organized in two different latitude bands: 1) a primarily pre-midnight band near the poleward edge of the bulge and moving poleward with the UV emissions; 2) a post-midnight/midnight band that stays fixed in latitude. These can overlap in local time and vary in relative strength from event to event. Sub-auroral perturbations are used to indicate the feeding and drainage of the auroral electrojet system.

Characterizing the Classical Auroral Substorm: UV Emissions

Gjerloev, Jesper W (The Johns Hopkins University Applied Physics Lab), R A Hoffman J B Sigwarth, and L A Frank **[Poster; Thursday, Session 3]**

We present a large statistical study of the spatial and temporal morphology of the auroral UV emissions during classical bulge-type auroral substorms. Images obtained by the Polar VIS Earth camera are utilized in the study of 118 carefully selected events. Smearing of the key emission features is minimized using both temporal and spatial normalization techniques. Our empirical time dependent model displays a number of interesting features. Relative to the onset location the bulge spreads evenly eastward and westward. The asymmetry with respect to midnight is apparent from onset through early recovery phase. Two separate bright emission regions are apparent: 1) a pre-midnight region near the poleward edge of the bulge originating at the onset at moving poleward with the poleward expanding bulge; and 2) a post-midnight/midnight region which stays at the same latitude throughout the substorm. Events will be show to support the statistical picture.

The Magnetotail-Driven Inner Magnetosphere

Goldstein, J. (Southwest Research Institute), B. R. Sandel, S. B. Mende, P. C. Brandt, M. F. Thomsen, and M. R. Hairston **[Invited Talk; Thursday PM]**

In recent years, much has been learned about the ways in which the dynamics of the ring current and plasmasphere are controlled by convection enhancements that are in turn directly driven by the solar wind and interplanetary magnetic field (IMF) conditions. However, the substorm-driven component of inner magnetospheric convection is not as well characterized, especially with regard to the plasmaspheric response. To examine the substorm component from a systems-level perspective, we use data obtained by the Imager for Magnetopause-to-Aurora Global Exporation (IMAGE) satellite. Used together, images of the aurora, ring current, and plasmasphere demonstrate how these different plasma populations respond to substorms as a single coupled system. This coupled response of the inner magnetosphere hints at the global spatial and temporal properties of the electromagnetic impulse that sweeps sunward from the magnetotail during substorms. To characterize this electromagnetic impulse and its effects requires in situ observations to complement the global images. We include observations from the Los Alamos National Laboratory (LANL), Geostationary Operational Environmental Satellites (GOES), and the Defense

Meteorological Satellite Program (DMSP). In conjunction with simple modeling these various data sources are used to investigate the magnetotail-driven inner magnetosphere.

Understanding the relationship of Storms, SMC and Sawtooth events in the Magnetosphere through Numerical Simulations

Goodrich, C. C. (Boston University) **[Invited Talk; Monday AM]**

In recent years our picture of how the magnetosphere dissipates the energy transferred into it during periods of southward IMF has expanded. It is generally agreed that for limited periods of modest driving, substorm events corresponding to the classic picture with growth, onset, expansion, and relaxation phases predominate. Extended periods of strongly southward IMF produce magnetic storms, with significant impact on the inner magnetosphere in particle acceleration, ring current development, and ionospheric outflow. However, for intermediate driving, we also find periods of steady magnetospheric convection (SMC) in which a steady state balance of energy inflow and dissipation appears be attained in contrast to the storage and release substorm pattern. These same conditions also produce what are called Sawtooth events, in which there are periodic injections of energetic particles into the inner magnetosphere. While we have identified these apparently different modes of the magnetosphere in individual events, we have yet to understand differences in magnetospheric response responsible for them, i.e., whether Sawtooth event are periodic substorms, or whether they and/or SMCs occur during storms. We will explore the similarities and differences of storm, SMC, and sawtooth behavior through global MHD simulations of 3 specific events. The first is the Halloween storm (Oct 29-30) of 2002, which is particularly interesting due to the apparent Sawtooth activity late on Oct 29. The second is the February 3 SMC event studied by the NSF GEM program. The final event is the well known Sawtooth period of April 18, 2002. After verifying the accuracy of the simulations for these events through detailed data comparisons, we will use the results to explore the magnetospheric configuration and evolution for these events.

SuperDARN observations of the global response of ionospheric convection to magnetospheric substorms

Grocott, Adrian (University of Leicester) **[Invited Talk; Tuesday AM]**

The coupled nature of the magnetosphere-ionosphere system makes measurements of ionospheric convection, such as those provided by the SuperDARN HF radars, extremely useful in diagnosing magnetospheric dynamics. Flux Transfer Events (FTEs) at the dayside magnetopause, for example, are well-resolved in ionospheric flow data as Pulsed Ionospheric Flows (PIFs). Similarly, Bursty Bulk Flows (BBFs) associated with the earthward transport of flux in the tail have a discernable flow signature in the nightside ionosphere. The large-scale convection associated with magnetospheric substorms is also readily identifiable in ionosphere flow data. During the growth phase, for example, the expansion of the polar cap due to enhanced open flux production is evidenced in the equatorward motion of radar backscatter. On the nightside, fast equatorward flows emanating from the polar cap after substorm onset, followed by a poleward contraction of the flow reversal boundary, provide evidence for tail reconnection and the closure of open flux. The complex electrodynamics associated with substorms, however, ensures immense variety in the nature of the flow signatures which are observed. Some studies, for example, have reported a reduction in the nightside flows at the time of substorm onset, possibly resulting from enhancements in auroral conductivity associated with substorm energetic particle precipitation which imposes a limit on the size of the local electric field. Enhanced electric field phenomena such as Substorm-Associated Radar Auroral Surges (SARAS) and Auroral Westward Flow Channels (AWFC) provide additional constraints on the global substorm picture. This paper will provide an overview of these and other important convection signatures associated with substorms and briefly

discuss how future developments of SuperDARN can further develop our understanding of substorm physics.

Towards a synthesis of substorm electrodynamics: HF radar and auroral observations

Grocott, Adrian (University of Leicester), M. Lester, M.L. Parkinson, T.K. Yeoman, P.L. Dyson, and H.U. Frey **[Poster; Tuesday, Session 2]**

Detailed observations of the HF radar convection signature of the substorm auroral westward flow channel (AWFC) are presented. At 0835 UT on 21 November 2004, the onset and subsequent expansion of an auroral substorm was captured in the southern hemisphere by the Far UltraViolet (FUV) instrument on board the IMAGE spacecraft. This was shortly followed at 0838 UT by the onset of Pi2 activity and magnetic bays, evident in ground magnetic data from both hemispheres. Further intensifications were then observed in both the auroral and ground magnetic data over the following ~3 h. During this interval the fields-of-view of the two southern hemisphere TIGER radars move through the evening sector towards midnight. Whilst initially low, the amount of backscatter from TIGER increased considerably during the early stages of the expansion phase such that by ~0920 UT an enhanced dusk flow cell was clearly evident. During the expansion phase the equatorward portion of this flow cell develops into a narrow high-speed flow channel, indicative of the AWFC as identified in previous studies. As the interval progresses the flow reversal region and 'harang' discontinuity become very well defined. These flow observations and their relationship to the substorm aurora and currents are discussed.

Three dimensional model of a substorm

Heikkila, Walter J. (University of Texas at Dallas) **[Poster; Monday, Session I]**

It is very important to develop a model of a substorm in 3-D for several reasons. For one, we need to look at the source of energy E.J<0 to power the electrical load E.J>0. I presented such a model at ICS1 in 1992, updated by Heikkila et al. [SSR, 2001]. We noted that the current carriers of the enhanced cross-tail filament in a thin plasma sheet are ions and electrons with small pitch angles (they cause the breakup auroras). Delcourt and Belmont [1998] have shown that the energized ions may become non-magnetized at some point and time. They could cause a current meander in the tailward direction. This perturbation current is associated with an inductive electric field, everywhere opposed to the current perturbation by Lenz's law, E.J<0 where the local current is increasing and E.J>0 the current is decreasing. The meander in the equatorial plane has only x and y components, everywhere, similar to a magnetic dipole antenna. In the mid-plane the inductive electric field is transverse to B, similar to a magnetic dipole antenna. However, because the electric field is continuous across any surface the inductive electric field will reach above and below the mid-plane. There, the magnetic field lines are bent toward the earth because of the tail-like geometry; consequently, the inductive electric field will have a large component parallel to B. This is the beginning of the familiar substorm current diversion, current into the ionosphere on the dawn side (downward ion fluxes associated with omega band aurora), and current out of the ionosphere on the dusk side (downward electron flow, the westward traveling surge WTS). The magnitude of this induction electric field is an important question. This effect is a macroscopic instability of the plasma, having the possibility of rapid response; we call this an electromotive instability, a switch to free the magnetic energy stored in the highly stressed magnetotail. With E.J<0 the plasma is doing work, it has to overcome the opposing J x B force. The enhanced dusk-dawn electric field promotes tailward convection, eventually to an escaping plasmoid. By Newton's third law, there is a reaction on the earthward side with E.J>0, and shortly, to the auroral ionosphere after the transit time delay.

Westward Traveling Surge

Heikkila, Walter J. (University of Texas at Dallas) **[Talk; Tuesday AM]**

The westward traveling surge (WTS) is a dramatic phenomenon at the onset of a magnetospheric substorm; precipitating electrons are abruptly energized locally to high energies, over 100 keV. This is the beginning of the familiar substorm current diversion, current into the ionosphere on the dawn side (downward ion fluxes associated with omega band aurora), and current out of the ionosphere on the dusk side (downward electron flow, the WTS). For a tailward meander of the cross-tail current the topology of the solenoidal electric field is in the correct sense to explain the observed diversion. Spacecraft data in the magnetotail show energies over 1 MeV for both electrons and ions, often counter-streaming. There are significant changes in the magnetic field topology, and it is likely that an induction electric field is the cause of all these outbursts. We have studied the response of thermal plasmas to an induction electric field via one-dimensional particle simulations [Omura et al., 2003]. Due to the acceleration of electrons and ions in the opposite direction along the field line, there arises counter streaming that causes the Buneman instability. A large E||ind (the cause) enables charge separation to produce an opposing electrostatic field E||es (the effect). However, this has very little effect on particle energization to high energies. A substantial part of the electrons are grouped together at higher energies, forming a distinct bump in the electron distribution. The implication for substorms is that the field-aligned voltage difference (NOT potential difference implying a conservative field) can reach 1 MV on a transient basis. We propose that such an electrons beam is the cause of the WTS.

Are we on the right approach to solve the substorm problem?

Heikkila, Walter J (University of Texas at Dallas) **[Poster; Monday, Session 1]**

Are we on the correct approach to solve the substorm problem, including the initial localization in time and space, and the rapidity of the onset of the expansion phase? "Explaining the sudden onset of the expansion phase of magnetospheric substorms has proved to be one of the most intractable problems in magnetospheric physics to date" (Vasyliunas, 1998). It may be time to some serious appraisal, bearing in mind as to what happened with continental drift some four decades ago. We must deal in 3-D, not 2-D (the basis of the reconnection model). We must close the currents to treat cause vs effect ($E.J < 0$ vs $E.J > 0$). We need to face some harsh realities.

Substorms, poleward boundary activations and geosynchronous particle injections during sawtooth events

Henderson, M. G. (Los Alamos National Laboratory) **[Poster; Monday, Session I]**

During sawtooth events, the auroral distribution is typically comprised of an active and dynamic double oval configuration. In association with each tooth, the double oval evolves in a repeatable manner in which a wide double-oval configuration gradually thins down in association with an expansion of the polar cap and stretching of the tail field lines. This is followed by a localized substorm-like brightening of the auroral distribution in the dusk to midnight sector on the lower branch of the double oval which subsequently expands rapidly poleward and azimuthally. A new expanded double oval configuration emerges from this expansion phase activity and the cycle repeats itself for the duration of the sawtooth event. This behavior is highly consistent with the Akasofu picture of substorm onset occurring deep within the closed field-line region on the equator-most arc. Due to the large separation between the poleward boundary and the onset region during these types of substorms, the interaction between the onset region and poleward boundary intensifications, auroral streamers, inclined arcs, torches and omega bands are more easily determined. Here, we show that: (1) Sawtooth injections can be produced by the copious production

of auroral streamers, without a substorm onset; (2) Auroral streamers typically evolve into torches and omega bands rather than leading to onsets; (3) Equatorward-moving "inclined arcs" can feed into the onset region. We propose that these observations might be explained by the scale-size-dependent behavior of earthward-moving depleted flux tubes in the tail. In this hypothesis, streamers can penetrate rapidly toward the earth (via interchange) and mitigate the pressure crisis in the near-earth region, while the slower-moving inclined arcs map to large-scale depleted flux tubes that do not efficiently penetrate earthward and hence do not alleviate the pressure crisis in the pre-midnight sector.

What Triggers Sawtooth Substorms and What Sets their Periodicity?

Henderson, M. G. (Los Alamos National Laboratory) **[Invited Talk; Thursday AM]**

During prolonged intervals of moderate to strong steady negative IMF Bz, the magnetosphere often enters a state in which quasi-periodic, large-amplitude oscillations are observed in the geosynchronous energetic particle fluxes. These oscillations have been termed ``sawtooth events'' because the trend in the flux measurements over many hours of time display a series of slow flux decreases followed by rapid increases which resemble the teeth of a saw blade. It has already been well established that the majority of such events are in fact quasi-period sequences of substorms that occur during enhanced ring current conditions. However, because the solar wind driving is often relatively steady during sawtooth events and because disturbances that may be present usually lack the characteristic sawtooth periodicity, there is still considerable debate as to whether or not the individual substorms are externally triggered by variations in the IMF/solar wind. We present observations which illustrate that individual teeth can be develop with or without an obvious external trigger. In addition, we find that there are usually more potential triggers than there are teeth. Thus, we propose that the periodicity results because the magnetosphere only becomes susceptible to (external or internal) triggering once it is driven beyond some stability threshold (or enters a ``meta-stable'' configuration).

Review of Kinetic Instabilities Associated with Substorms

Horton, W. (Institute for Fusion Studies, University of Texas at Austin,), J-H Kim, J. C. Perez, and H. V. Wong **[Invited Talk; Monday PM]**

Substorm dynamics models use a wide range of detailed plasma instabilities for different aspects of the complex substorm dynamics. We review the role of the kinetic theory of the drift ballooning interchange instability, kinetic models of the magnetic reconnection instability and the role of the kinetic fire hose instability in substorm dynamics. Following the bursty bulk flow model of Chen and Wolf and the Largrangian simulations of Ji and Wolf for the Earthward accelerated bubbles, we develop a nonlinear kinetic model of the driven fire hose instability that produces large amplitude magnetic fluctuations that are consistent with the Pi 2 precursors. We show nonlinear simulations of the kinetic version of the drift-ballooning interchange instability in the region L=4 to 10 RE and discuss the undulations observed in EUV on the IMAGE satellite. Finally, we give some simulations of a kinetically modified fluid version of the magnetic reconnection instability showing the formation of coherent current sheets structures and that are themselves unstable to current driven instabilities. The CD instabilities are briefly discussed.*S. Ji and R. A. Wolf*, JGR 108, 1191,2003. *W. Horton, R. S. Weigel, D. Vassiliadis, and I. Doxas*, Substorm Classification with the WINDMI Model, Nonlinear Processes in Geophysics, 1-9, 2003.*Lewis, W. S., J. L. Burch, J. Goldstein, W. Horton,J. C. Perez, H. U. Frey, and P. C. Anderson* (2005), Duskside auroral undulations observed by IMAGE, Geophys. Res. Lett., 32, L24103,doi:10.1029/2005GL.

Statistical Analysis of IMF Substorm Triggers Using Multi-Satellites Observations

*Hsu, Tung-Shin (IGPP/UCLA), and R. L. McPherron** **[Poster; Tuesday, Session 2]**

To understand the magnetospheric substorm it is necessary to determine whether substorm onset is always externally triggered by the interplanatery magnetic field (IMF) or whether substorm onset sometimes occurs spontaneously as a result of internal processes. Lyons [1995; 1996] argued that substorms must be triggered by external changes in the IMF and/or the solar wind. Specifically, Lyons [1996] argued that events without apparent triggers were likely to be a non-substorm disturbance such as a convection bay [Pytte et al., 1978]. The hypothesis that most or perhaps all substorms are triggered has initiated considerable interest in substorm triggering studies. Over the past decade, several studies have demonstrated that a majority of substorms (~60%) appear to be triggered by the IMF. However, 40% of all substorms appear to begin without obvious IMF perturbations. A recent study done by by Hsu and McPherron [2003] suggested that triggered substorms exhibit a larger response than non-triggered ones. This surprising result has been suggested to be a manifestation of undetected small scale structures in the IMF. Small structures are suggested to have weak driving fields of short duration and hence transfer less energy to the magnetosphere. To investigate this hypothesis, multi-satellite observations are required to eliminate the possibility of missing IMF trigger structures. In this study we will use multi-satellite observations to examine how frequently different IMF structure are observed at different locations in the solar wind. Two database are examined in this study. The data from 1977 to 1987 when at least two of the ISEE1, ISEE2, ISEE 3 and IMP8 spacecraft were in the solar wind will be used to examine the size and scale of the structures that trigger substorm onsets. Another database from the year 2001 when several satellites (POLAR, Cluster, GOES, LANL, Geotail, ACE) were in the solar wind and magnetosphere will be used to examine the magnetospheric respone to solar wind perturbations.

Geomagnetic field disturbances and solar wind effects during storm-time periodic substorms

Huang, Chaosong (MIT Haystack Observatory) **[Talk; Thursday AM]**

Substorms are often periodic with a relatively constant period of ~3 hours during magnetic storms. The geomagnetic field at low latitudes shows an increase after each onset of the periodic substorms. We have examined the cause of the geomagnetic field enhancements during southward IMF. The effect of the solar wind pressure on the low-latitude geomagnetic field appears to have an upper limit given by an empirical formula. At high latitudes, substorms and IMF southward turnings have much stronger effects on the polar cap index than solar wind pressure impulses. On average, the change of the polar cap index caused by substorms is four times larger than that caused by solar wind pressure impulses. The periodic variations in the polar cap index and low-latitude geomagnetic field during storm times are caused by periodic substorms rather than by a series of solar wind pressure impulses and cannot be used as an manifestation of solar wind effects. We have also examined the effect of IMF northward turings on periodic substorms. The period of storm-time substorms is always ~3 hours during continuously southward IMF and during rapidly fluctuating IMF, indicating that the onset of periodic substorms is not controlled by solar wind pressure impulses or by IMF northward turnings.

Monitoring the dayside and nightside reconnection rates during various auroral events using IMAGE-FUV and SuperDARN data.

Hubert, B. (Univ. of Liège), M. Palmroth, S. E. Milan, A. Grocott, P. Janhunen, K. Kauristie, S.W.H. Cowley, T. I. Pulkkinen and J.-C. Gérard **[Invited Talk; Thursday AM]**

The Imager for Magnetopause to Aurora Global Exploration (IMAGE) spacecraft was launched in 2000 with several imaging instruments onboard. The Far UltraViolet (FUV) experiment was devoted to the imaging of the N2 LBH (Wideband Imaging Camera – WIC-), OI 135.6 nm (Spectrographic Imager –SI13-) and Doppler-shifted Lyman alpha auroral emission (SI12). The Doppler-shifted Lyman-alpha emission is solely due to proton precipitation and is not contaminated by dayglow, allowing to monitor the auroral oval at dayside as well as at nightside. Remote sensing of the polar aurora can be advantageously completed by ground based data of the Super Dual Auroral Radar Network (SuperDARN) that monitors the ionospheric convection flow pattern in the polar region. In the present study, the SI12 images are used to determine the open/closed (o/c) field line boundary, and monitor its movement. The SuperDARN data are used to compute the electric field of the polar cap at the location of the o/c boundary. The total electric field is then computed along the boundary accounting for its movement applying Faraday's law, so that the dayside and nightside reconnection voltages can be retrieved. This procedure is applied to monitor the dayside and nightside reconnection voltages during several events. The phases of the substorm cycle can be identified: the growth phase characterised by intense dayside flux opening and occasionally pseudobreakups, the onset which is immediately followed by a maximum intensity of the flux closure rate, and the recovery phase during which the flux closure voltage slowly returns to undisturbed values, with occasional poleward boundary intensifications which appear along with a slight intensification of the closure voltage. The transient response to an interplanetary shock is also monitored and reveals a sharp intensification of the closure rate, despite a low open flux value for the studied case. A case of auroral streamer event has also been studied, presenting a remarkably large flux closure rate. This feature is related with a bursty enhancement of the ionospheric convection. Bursty bulk flow events can thus be associated as well with enhanced flux closure. The tool that we developed can also be used to study the relations between the topology of the magnetotail and the flux closure rate as well as to set up proxies relating the solar wind conditions with the dayside reconnection voltage. The monitoring of dayside and nightside reconnection rates can thus be considered as an investigation tool for nearly all types of auroral features.

Initial observations by the STEL all sky imager at Athabasca in Canada

Ieda, Aki (STEL, Nagoya university, Japan), K. Shiokawa, K. Sakaguchi, Y. Miyoshi, Y. Otsuka, T. Ogawa, K. Hosokawa, M. Connors, and E. Donovan **[Poster; Tuesday, Session 2]**

We have installed two all-sky imagers at Athabasca (62 AACGM-LAT) and at Resolute Bay (83 LAT) in Canada in 2005, whose summary plots are found at: http://stdb2.stelab.nagoya-u.ac.jp/canada/index.html. These two imagers will be in operation during the coming THEMIS mission. The THEMIS all-sky imagers are panchromatic with a high time resolution (5-sec). On the other hand, our STEL (Solar-Terrestrial Environment Laboratory, Japan) imagers are multi-spectral, including proton auroras and red lines, with lower time resolutions (currently 2-min), but are highly sensitive. In this meeting we will show initial observations at Athabasca beginning on September 3, 2005, including auroral signatures during the magnetic storm main phase on September 11. We appreciate discussions to optimize our imagers for the THEMIS mission. Our imager at Athabasca has 8 filters for different wavelength, including one for background subtraction. The time exposures are currently: OI (557.7nm, 5s), OI (630.0nm, 30s), Hbeta

(486.1nm, 40s), Na (589.3nm, 15s) for every 2min, and OH-bands (1s), OI (844.6nm, 25s), background (572.5nm, 15s) for every 10 min. We also plan to show initial observations from a meridian-scanning tilting photometer for proton auroras, and an induction magnetometer we installed at Athabasca.

NORSTAR and THEMIS

Jackel, Brian (University of Calgary), Eric Donovan, Trond Trondsen, Emma Spanswick, Mikko Syrjäsuo, Igor Voronkov, Noora Partamies, Thayyil Jayachandran, Leroy Cogger, Fokke Creutzberg, Don Wallis, David Knudsen, Hercules Olivier, and Zane Kryzanowsky **[Poster; Tuesday, Session 2]**

The NORSTAR array is one of the six observational components of the Canadian GeoSpace Monitoring Program. NORSTAR incorporates the former CANOPUS MSPs and riometers, and by 2007 a new array of as many as 12 full color and multi-spectral All Sky Imagers. The operational objective of NORSTAR is to characterise the auroral precipitation across the CGSM target region which is mainly northwestern Canada. Our scientific objectives mirror those of CGSM, with a current focus on the substorm related magnetospheric dynamics, and the origin of auroral structure and acceleration and scattering mechanisms. NORSTAR is part of the larger observational effort that comprises CGSM, and involves specification of auroral precipitation (NORSTAR), ionospheric currents (CARISMA and CANMOS), and ionospheric convection (SuperDARN and CADI) across much of Canada. In the substorm problem, for example, determining the interelaionship(s) between dipolarization, injection, current disruption, and fast flows is of crucial importance to the resolution of key questions related to the expansive phase onset. In this talk, we will provide a quick overview of the current status of NORSTAR. In the remainder of the presentation, we will focus on how NORSTAR riometer and MSP data can be used to simultaneously track the evolution of the dispersionless substorm injection and the dipolarization. We finsih with a statement about how CGSM as a whole can be used to simultaneously track the dipolarization, injection, current disruption, and substorm-associated fast flows. With this arsenal of tools, CGSM will be of central importance to the upcoming NASA THEMIS mission's ability to bring closure to it's primary science objective which is "what causes substorm expansive phase onset?"

Ground-based radar detection of the equatorward boundary of ion auroral oval in the dusk-midnight sector and its dynamical association with substorms

Jayachandran, P. T. (Physics Department, University of New Brunswick), J. W. MacDougall, and E. F. Donovan **[Poster; Monday, Session I]**

One of the important boundaries of the auroral region in the dusk-midnight sector is the equatorward boundary of the ion precipitation. In this region, on average, the ion precipitation region is equatorward of the electron precipitation region and carries most of the energy. There are several ground and satellite based measurement technique to detect this important boundary but many of these measurements lack the temporal and spatial resolution required to study the dynamical features of this boundary associated with substorms. In this talk a review of a new ground based radar technique to determine the boundary and its limitations are presented. The new radar method is used to study the substorm growth phase dynamics. It is found that on average, the boundary is located more equatorward during substorms than during no susbtorms. This implies that magnetotail stretching is a necessary condition for susbtorms. It is also found that statistically there is no difference in the location of the boundary for substorms and no substorms in the 18:00-19:00 hours magnetic local time sector. The equatorward expansion rate of the boundary shows clear distinction between substorms and no susbtorms: The equtaorward expansion rate of the

boundary is much lower during no susbtorms than during substorms. Implications of the results in substorm dynamics will also be presented.

Pi2 pulsation periodicity: Local field line resonances or variations in magnetotail flows?

Kale, A.(University of Alberta), I. R. Mann, and K. Murphy **[Poster; Tuesday, Session 2]**

Pi2 pulsations are a category of ULF waves with periods between 40-150 seconds observed by ground-based magnetometers predominantly during substorm onset. The origin of these pulsations has been attributed to the coupling of Alfvénic oscillations associated with the substorm current system, and fast-mode compressional waves moving radially inward from the tail, including plasmaspheric cavity modes at low-latitudes. It has recently been suggested that the frequencies of observed night side, low-latitude Pi2 pulsations or Pi2 waveforms on the flanks may be due to periodic variations in the sunward plasma flow from the tail such as during multiple bursty bulk flows (BBFs). Using favourable conjunctions of the Geotail satellite with the CARISMA ground-based magnetometers we will investigate the relationship between the frequency of Pi2 pulsations and periodicity in earthward plasma flows occurring during substorm onset. The natural resonant frequency of the field lines will be estimated to determine the relative contribution of directly-driven and resonant Alfvén waves in the auroral and sub-auroral zones across a range of longitude from midnight towards the flanks.

MIC-NEXL Model of Substorms

Kan, Joseph R. (University of Alaska Fairbanks), William Bristow, A. Ieda, and Y. Miyashita **[Poster; Monday, Session I]**

A new substorm model is proposed based on a comprehensive cause-and-effect sequence of processes, leading to NEXL formation to drive substorm expansion phase. This model combines the MI coupling process and the NEXL process, to be called MIC-NEXL model of substorms. The NEXL is responsible for driving tailward expansion of dipolarizing region to produce poleward expansion of auroral bulge in the midnight sector during the substorm expansion phase. Enhanced magnetospheric convection during the growth phase leads to brightening of auroral arcs near the equatorward edge of auroral oval in the midnight sector. Auroral enhanced conductance leads to southward polarization E-fields to drive westward electrojet of Cowling current. A positive feedback process, between the southward polarization E-field, the auroral enhanced conductance, intensifies the westward electrojet of Cowling current. Closure of intense westward electrojet disrupts the cross-tail current, leading to dipolarization earthward and NEXL (near-earth X-line) formation tailward of the current disruption region. The NEXL drives tailward expansion of dipolarizing region to launch poleward expansion of auroral activities during substorm expansion phase. A less intense current disruption cannot produce NEXL to drive poleward expansion of auroral activities, leading to pseudo breakups without substorms.

Ring Current Injection Conjecture: Ring Current Intensity Increases with X-Line Formed Closer to Earth in the Plasma Sheet

Kan, Joseph R. (University of Alaska Fairbanks), J. L. Burch, W. Sun, Y. Miyashita, and J. Goldstein **[Poster; Monday, Session I]**

A ring current injection conjecture is proposed to synthesize a comprehensive model for storm-substorm relations. The proposed conjecture consists of: (1) Ring current intensity increases with X-line formed closer to Earth in the plasma sheet. (2) Ring current intensifies by convection with or without substorms. A substorm is characterized by poleward expansion of auroral activities in the

midnight sector. In descending order of ring current intensity: (A) Sawtooth events during strong southward IMF, ring current intensifies jointly by convection and substorms powered by NEXL at X ~ -10 to -30 Re to produce ring current of major to super storms with Dst ~ -80 to -500 nT. (B) Intense SMC intervals during moderate southward IMF, ring current intensifies by steady convection driven by MTXL at X ~ -30 to -50 Re to produce moderate ring current with Dst ~ -30 to -80 nT. (C) During fluctuating IMF Bz intervals, ring current enhances by weak unsteady convection driven by mid-distant-tail X-line, M-DTXL at X~ -50 to -80 Re to produce weak ring current with Dst ~ -10 to -30 nT.

ICESTAR - A connection between IHY and IPY

Kauristie, Kirsti (Finnish Meteorological Institute), R.A. Harrison, R. Stamper, A. Weatherwax, V. Papitashvili, E.Donovan, and the ICESTAR and IHY Teams **[Poster; Thursday, Session 3]**

ICESTAR (Interhemispheric Conjugacy Effects in Solar-Terrestrial and Aeronomy Research) is a programme coordinating multinational research on Sun-Earth connections. ICESTAR is supported by SCAR (Scientific Committee on Antarctic Research) and concentrates on studies of magnetospheric and upper atmospheric responses to solar inputs, with emphases on the networking of ground-based instruments and the study of inter-hemispheric relationships. The ICESTAR team is fostering international collboration and open web-based access to the relevant data, and thus adheres to the overarching philosophies of the IHY. IHY and ICESTAR have submitted a proposal for a core project status to the Joint Committee of the International Polar Year (IPY). This initiative, "ICESTAR/IHY - Interhemispheric Conjugacy in Geospace Phenomena and their Heliospheric Drivers", includes altogether 24 research groups from more than twenty countries. Harvesting the unique opportunities of IPY will be an interesting and demanding task for the ICESTAR/IHY programme. In addition to far-reaching interdisciplinary scientific work IPY is looking forward to exciting new education and outreach activities and efficient utilization of the latest advancements in computer and communications technology. Preparatory work to meet these ambitious objectives has already started within the ICESTAR/IHY community. In the presentation we will review the most important scientific goals of the programme, discuss the main points of its implementation plan and describe some on-going activities to facilitate cooperative research.

Mesoscale observations of energy dissipation in the ionosphere during substorms

Kauristie, Kirsti (Finnish Meteorological Institute), Sanna Mäkinen, Noora Partamies, and Ritva Kuula **[Talk; Tuesday AM]**

With the combination of MIRACLE and EISCAT observations we study the mutual coupling of Joule heating and electron precipitation energy flux during substorms. EISCAT observations will be used to estimate the local Joule heating rate and as reference material for the precipitation flux estimates as deduced from ASC-images. The local observations will be compared with previously published proxies for global energy tranfer rates. The goal is to study whether there exists any general trends in the relative contributions of the two dissipation mechanisms according to substorm phases. We also would like to know how significant portion of the global energy dissipation the MIRACLE-EISCAT combination can cover when monitoring the different MLT-sectors.

Dayside electron precipitation following substorm onsets

Kavanagh, Andrew J. (Lancaster University), and Farideh Honary **[Poster; Monday, Session I]**

During substorms high energy electrons are injected from the magnetotail onto closed drift paths in the inner magnetosphere. Precipitation in the morning sector ionosphere is a consequence of wave-particle interactions as the electrons drift eastward. Statistical studies have shown that cosmic radio noise absorption, a proxy for electron precipitation, tends to maximise close to 9 MLT, tailing away after noon. The absorption structure contains traces of ULF wave, long quasi-periodicities and motion inconsistent with gradient drift. We present results from an epoch analysis study of morning-sector precipitation with data from the Imaging Riometer for Ionospheric Studies (IRIS) at Kilpisjärvi, Finland (L = 5.6 to 6.6). Each epoch is defined from a substorm onset as identified by Frey et al. (2004) in IMAGE FUV data. Difference in the structure following single and multiple substorms are highlighted, casting light on how the statistical distribution of absorption is dominated by the spread of substorm onset local times. We examine whether drift echoes play a part in the quasi-periodic nature of the precipitation and analyse the effect of solar wind parameters such as speed and pressure.

A new method of magnetic storm forecasting on the basis of solar wind data

Khabarova, O. (Space Research Institute, Moscow), V. Pilipenko M. J. Engebretson and E. A. Rudenchik **[Poster; Thursday, Session 3]**

None of the methods proposed so far for magnetic storm and substorm forecasting provides sufficient accuracy and proper timing. Therefore, the space weather community should try to implement the cybernetic principle – "to build a reliable system from non-reliable components", and combine various forecasting tools. We propose an additional forecasting technique based on the features of the solar wind plasma structure as observed by spacecraft upstream of Earth. We have analyzed a whole year of 1-min data during solar minimum (1995) and during solar maximum (2000) with 67 and 70 storms, respectively. For automated storm onset detection a 30-minute moving gradient of the SYM-H index exceeding a certain threshold value has been used. Correlation coefficients between various 1-min solar wind parameters show that solar wind dynamic pressure variations are mainly determined not by speed, but density. Magnetic storm commencements are mainly controlled by solar wind density jumps, whereas negative IMF is only a concomitant factor. It was found that a weak increase of density is observed before a magnetic storm commencement in nearly 80% of cases of high-speed streams. This tendency to weak density growth revealed itself, on average, 3 days before the main density jump. Both visual inspections and statistical analysis show also that solar wind density fluctuations with time scales ~2-250 min are observed before magnetic storms in ~80% of cases. The power of low-frequency solar wind density fluctuations, as estimated with the wavelet transform technique, starts to grow, on the average, ~2 days prior to storm commencement. The possible mechanisms of these phenomena are related, probably, to the stream instability of solar wind plasma, sector boundary oscillations, or even fluctuations in active solar regions. The combination of two factors: gradient level N > 3cm-3 per 10h and the growth of low-frequency solar wind density fluctuation power (with time scales from 10 min to 100 min) was considered as the alert parameter. Prognoses based on this parameter for 1995 and 2000 data give ~90% correct forecasts of magnetic storms, and ~12% false alarms. Thus, variations of the solar wind plasma are a largely underestimated factor in magnetic storm triggering and could be effectively used for space weather forecasting.

Ionospheric Input to the Magnetotail During Substorms

Kistler , L. M.(University of New Hampshire, Durham, NH, USA), C. G. Mouikis, X. Cao, H. U. Frey, B. Klecker, I. Dandouras, G. Parks, and R. Friedel **[Talk; Monday AM]**

We have used the CLUSTER ion composition data from the CIS instrument, to determine when ionospheric ions are a major contributor to the plasma sheet, and whether the source of these ions is direct input from the auroral regions. Our study uses ion composition data in the plasma sheet during substorms from four CLUSTER tail-seasons, 2001 - 2004. These apogee data are concentrated at about 19 Re. The data are divided into storm-time and non-storm-time substorms. By using four years of data, we are able to look at the local time dependence of the occurrence of O+ in the plasmasheet as a function of substorm phase. As expected we find significantly higher concentrations of O+ during storm-time substorms than during non-storm substorms. Initial results indicate that highest fluxes of O+ occur prior to substorm onset. The angular distributions and the energy dispersion of the O+ during storm-times is often consistent with an auroral source. The tail reconfiguration occurs almost simultaneously across the whole tail during the storm-time substorms. During the non-storm events, it starts closest to midnight, and then expands in local time. The O+ during storm-time substorms is observed across the whole tail, without a strong local time dependence, while during non-storm-time substorms, the O+ tends to peak close to midnight. Thus, the highest fluxes of O+ are observed in the MLT region where the tail reconfiguration at substorm onset begins, but whether there is a causal relationship is unclear.

Modeling the self-organized critical behavior of the plasma sheet reconnection dynamics

Klimas, Alex (NASA Goddard Space Flight Center), Vadim Uritsky, and Dan Baker **[Talk; Friday AM]**

Analyses of Polar UVI auroral image data that are reviewed in another presentation at this meeting (V. Uritsky, A. Klimas) show that bright night-side high-latitude UV emissions exhibit so many of the key properties of systems in self-organized criticality (SOC) that an alternate interpretation has become virtually impossible. It is now necessary to find and model the source of this behavior. We note that the most common models of self-organized criticality are numerical sandpiles. These are, at root, models that govern the transport of some quantity from a region where it is loaded to another where it is unloaded. Transport is enabled by the excitation of a local threshold instability; it is intermittent and bursty, and it exhibits a number of scale-free statistical properties. Searching for a system in the magnetosphere that is analogous and that, in addition, is known to produce auroral signatures, we focus on the reconnection dynamics of the plasma sheet. In our previous work, a driven reconnection model has been constructed and has been under study. The transport of electromagnetic (primarily magnetic) energy carried by the Poynting flux into the reconnection region of the model has been examined. All of the analysis techniques, and more, that have been applied to the auroral image data have also been applied to this Poynting flux. Here, we report new results showing that this model also exhibits so many of the key properties of systems in self-organized criticality that an alternate interpretation is implausible. Further, we find a strong correlation between these key properties of the model and those of the auroral UV emissions. We suggest that, in general, the driven reconnection model is an important step toward a realistic plasma physical model of self-organized criticality and we conclude, more specifically, that it is also a step in the right direction toward modeling the multiscale reconnection dynamics of the magnetotail.

Cluster plasma sheet observations and injections at geosynchronous orbit during corotating high speed streams.

Korth, Axel (Max-Planck-Institut für Sonnensystemforschung, Katlenburg-Lindau, Germany), M. Fränz, E. Echer, F. Guarnieri, R. Friedel, and H. Reme **[Poster; Thursday, Session 3]**

Corotating Interaction Regions (CIR's) are large scale structures in the heliosphere during the declining and minimum phase of the solar activity cycle. They are the result of the interaction of fast and slow solar wind. Streams of fast solar wind originating from coronal holes often recurred with a period of ~ 27 days, the solar rotation. These streams of fast solar wind and the interplanetary field will influence the dynamics of the Earth's magnetosphere. We will present magnetospheric conditions during high speed streams in September 2003 and will show Cluster ion data in the energy range from 30 eV to 500 keV and electrons from 30 keV to 300 keV in the plasma sheet of the magnetosphere at ~ 20 RE. The pressure change in the plasma sheet is correlated with injections at geosynchronous orbit. A cross-wavelet analysis between the interplanetary magnetic field IMF Bz and the sunward component Bx from Cluster in the plasma sheet show a high correlation at about two hours.

EISCAT radar and optical studies of black aurora: a signature of magnetospheric turbulence?

Kosch, M. J. (Communication Systems, Lancaster University, Lancaster, UK), B. Gustavsson, E. M. Blixt, T. Pedersen, A. Senior, A. J. Kavanagh, and J. Semeter. **[Talk; Monday PM]**

Black auroras are recognised as spatially well-defined regions within a uniform diffuse auroral background where the optical emission is significantly reduced, or possibly totally absent. Black auroras typically appear post-magnetic midnight and during the substorm recovery phase, but not exclusively so. Their horizontal size is typically 1x5 km, elongated in the east-west direction, and they move predominantly in an eastward direction with a speed of 1-4 km/s. There is no accepted theory for the phenomenon of black aurora, although they seem associated with substorms. We report on the first incoherent scatter radar observations of black aurora by EISCAT, coupled to white-light TV recordings of the phenomenon. From a 2002 observation, we show that non-sheared black auroras are most probably not associated with field-aligned currents. From 2002 and 2003 observations, we show that the apparent motion of the black aurora is most probably controlled by the drift of particles in the magnetosphere and not ExB drift in the ionosphere. The drift speed is therefore dependent on the energy of the precipitating particles forming the diffuse background. From 2005 bi-static observations, we attempt to confirm this by relating the height and propagation speed of the black aurora to precipitating particle energy within the surrounding background diffuse aurora. Hence, the mechanism for black aurora is most probably active within the magnetosphere and substorm associated plasma turbulence within the magnetosphere may account for the optical morphology of the black aurora, in particular the lack of pitch angle diffusion into the loss cone.

Scaling collapse and structure functions in TV data of substorm-time aurora

Kozelov, B.V (Polar Geophysical Institute, Apatity, Murmansk Region, Russia), and K. Rypdal **[Talk; Friday AM]**

We present a statistical study of scaling features of spatial and temporal variations of the optical auroral luminosity during expansion phase of substorm. The data of all-sky TV observations on Barentsburg observatory (Svalbard) and Kola Peninsula have been used. The generalized structure

functions (GSF) for the luminosity fluctuations have been calculated to determine the scaling properties of the higher order moments. Also we examine a shape of the probability density function (PDF) of the auroral fluctuations to find a scaling collapse in some range of spatial/temporal scales. We found that the observed PDFs have a non-Gaussian shape for auroral structures during expansion phase of substorm. The observed scaling features compare with the results previously obtained for aurora by fractal, avalanche and spreading analysis. Possible consequences for SOC and turbulence models of the substorm activity are discussed.

Scaling of electric field fluctuations associated with the aurora

Kozelov, B.V. (Polar Geophysical Institute, Apatity, Murmansk Region, Russia), and I. V. Golovchanskaya **[Poster; Thursday, Session 3]**

Intermittent fluctuations of the electric and magnetic fields across the polar caps are often observed by low-altitude satellites during positive Bz IMF . They are typically associated with so-called 'theta'-aurora and transpolar arcs. The interchange instability of the field-aligned currents was proposed to explain the observed turbulent nature of the fields in the region [Golovchanskaya and Maltsev, 2003]. Here, we present a statistical study of scaling features of the field fluctuations during several events when the theta-aurora was observed by DE-1 satellite. The generalized structure functions (GSF) for the electric field fluctuations have been calculated to determine the scaling properties of the higher order moments. It was found that the GSF usually has the power-law region corresponding to spatial scales from a limit of resolution (~4 km) up to 150-200 km. Also we found a scaling collapse of the probability density function (PDF) of the electric field fluctuations in the same range of spatial scales. The observed PDFs have a non-Gaussian form with long tails. Some dependencies of the PDF form on the solar wind characteristics are discussed. The observed scaling of the field fluctuations has been compared with the results of the same analysis applied to the TV observations of the theta-aurora.

Substorm on March 26, 2004 observed from the ground and from the space: case study

Kozelov, Boris V. (Polar Geophysical Institute, Apatity, Murmansk region, Russia), T. V. Kozelova, and L. P. Borovkov **[Poster; Tuesday, Session 2]**

The substorm event on March 26, 2004 with onset in 20:21UT is analyzed by data of ground-based and satellite observations. This event was well documented by coordinated optical ground-based observations in the Kola Peninsula, riometers and IMAGE magnetometers. The optical observations are allowed to estimate the characteristics of precipitated fluxes of protons and electrons. The expansion phase of the substorm had two steps. The particle injections were also observed by geosynchronous satellites. Dynamics of electrons and ions in the near-Earth magnetosphere during this event is discussed taking into account observed spatial-temporal manifestations in aurora: breakup arc, hydrogen band, WTS, N-S forms, ets.

Alternating bursts of low energy ions and electrons near the substorm onset

Kozelova, T.V. (Polar Geophysical Institute, Apatity, Murmansk Region, Russia), L. L. Lazutin, B. V. Kozelov, N. Meredith, M. A. Danielides **[Poster; Thursday, Session 3]**

The substorm associated behavior of the low energy particles (30 eV – 28.5 keV) near the Earthward edge of plasma sheet is examined using data from CRRES during the late growth and early expansion phases of a substorm on March 12, 1991 and their significance for the substorm onset mechanism is discussed. In this substorm the CRRES was located on L ~ 6.3 and ~ 20O westward the substorm onset and observed the sequence of the alternating bursts of the low energy

ions and electrons. The bursts of the 0.633 - 9.6 keV ions occurred 1-2 min before the (7.31 - 21.7 keV) electron bursts. The first ion burst happened 2 min before the substorm onset, at the moment of weak brightening of the most equatorial pre-breakup arc near the latitude ~62O. The alternation of the ion and electron bursts may be a signature of a drift-Alfvén ballooning on inner edge of the plasma sheet near substorm onset.

Observations of nightside magnetic reconnection during substorm growth and expansion phases

*Lam, Mai Mai (Physical Sciences Division, British Antarctic Survey), M. Pinnock, and E. F. Donovan** **[Poster; Tuesday, Session 2]**

The temporal and spatial variability of nightside magnetic reconnection is described using two-dimensional ionospheric measurements during the growth phase and early expansion phase of a single substorm. Two techniques (A and B) are used to address both the localized (across ~15 deg. longitude at ~23 magnetic local time (MLT)) and the large scale reconnection rate, using ionospheric data that provides the component of the electric field tangential to the polar cap boundary (PCB) in the stationary boundary frame. Technique A uses localized high resolution measurements derived from 630 nm all-sky imager data at Rankin Inlet and ionospheric convection vectors obtained from line-of-sight velocity data from the Kapuskasing and Saskatoon Super Dual Auroral Radar Network (SuperDARN) HF radars. Technique B uses lower resolution global measurements, obtained by combining Polar VIS imager data and a velocity field derived using SuperDARN global convection mapping. A third technique (C) estimates the nightside reconnection potential from the dayside reconnection potential and the variation in the polar cap area. Technique A reveals standing-wave-like variation of period ~16 min in the reconnection rate in the late growth phase (spatial non-continuity in the x-line). The localized measurements of the reconnection rate vary between 0 and 50 mV/m during both the growth and expansion phases. Technique B shows the expansion of the x-line towards the duskside during the first 15 min of the expansion phase, from a width of ~4 h of MLT to ~7 h MLT.

High energy ion bursts and their role in the substorm evalution

Lazutin, L. L. (Scobeltsyn Institute for Nuclear Physics of Moscow State University), T. V. Kozelova, and B. V. Kozelov **[Poster; Thursday, Session 3]**

Substorm expansion phase consists of a set of fast temporal and spatially localized activations. The most bright manifestations of substorms at the neargeostationary distances are the reconfiguration of the magnetic field and sudden increases of energetic particle fluxes (injections). In some cases the energetic particle injections are dispersionless suggesting that the observations were made inside the acceleration region. Using the data from the CRRES satellite we examine a characteristics and fine structure of ion flux increases near the moment of the local activation onset in the disturbed magnetosphere on r ~ 6 RE . We found the bursts of the energetic (50-300 keV) ions with the time duration ~ 10-200 s. It seems that such energetic ion enhancements are an important factor for the substorm onset. These ion bursts are beginning ~ 5-120 s before the local dipolarization and the energetic electron injection. The bursts are accompanied by an additional magnetic field depression and tailward magnetic field line stretching. Abrupt leading edge of ion bursts has a time duration from 1 to several seconds. The lack of the energy dispersion on leading edge of the ion burst is an argument for the local ion acceleration. Based on the energy dispersion of burst end, we estimate the azimuthal size of acceleration region to be ~700-1400 km (about the gyroradius of proton in the measured equatorial magnetic field) for the ion bursts with the time duration of 10-15 s. The ion bursts and fast noncoherent variations of the ion fluxes in different limited regions of the ion energy spectra are usual features of the disturbed magnetosphere. We

discuss a significance of these features of ion bursts to the proton acceleration and the substorm onset mechanism.

Small scale Cluster observations of current sheet disruptions during substorm

Le Contel, O. (CETP/IPSL, UVSQ-CNRS), F. Sahraoui, A. Roux, D. Fontaine, P. Robert, J.-A. Sauvaud, C. Owen, and A. Fazakerley **[Talk; Monday PM]**

During 2003, the distances between the Cluster satellites were about 200 km in the night side. Taking benefit of these short separations, we compute the electrical current density using the curlometer technique during two substorm events. We focus on periods of very small current sheet thickness (1000 km ~ proton Larmor radius). We analyse electromagnetic fluctuations inside the current sheet and show that low-frequency (~ 20 mHz) as well as high-frequency (>0.2 Hz) waves are associated with current sheet disruptions. In particular, we give evidence for a close association between particle acceleration, current disruption and large amplitude "high frequency" wave emission. Furthermore, we compliment the classical wave analysis by the k-filtering technique. The preliminary results of this recent study are presented as well as their further consequences.

Repetitive substorms caused by Alfvenic waves of the interplanetary magnetic field during high-speed solar wind streams

Lee, D.-Y. (Chungbuk National University), L. R. Lyons, K. C. Kim, J.-H. Baek, K.-H. Kim, H.-J. Kim, J. Weygand, Y.-J. Moon, K.-S. Cho, and Y.D. Park **[Talk; Thursday AM]**

Substorms sometimes occur repetitively with a period of ~1-4 hours. In this paper we examine repetitive substorms that we find during corotating high-speed stream associated with coronal holes. The solar wind speed increases to well above the average value within these streams, the streams typically lasting a few days. The high-speed streams are accompanied by large amplitude Alfvén waves of the interplanetary magnetic field (IMF) within the stream body. We find that repetitive substorms occur every ~1-4 hrs, regardless of the solar cycle phase, whenever the earth's magnetosphere is impinged by these high-speed streams. We suggest that these substorms are triggered primarily by repetitive northward turnings of the Alfvénic IMF, each northward turning preceded by weakly-to-moderately southward IMF, i.e., Bz ~ -4.3 nT on the average. We also demonstrate how and why it can be difficult to determine a precise trigger at times for some substorms. Lastly, we suggest that the repetitive substorms, which repetitively produce typical non-stormtime substorm-injections of energetic particles, are distinguished from sawtooth events that also produce injections quasi-periodically every ~1-4 hrs but are usually seen during storm times where the accompanied IMF is strongly southward.

The nature of Pi1B pulsations observed in space

Lessard, Marc (University of New Hampshire), Barrett Rogers, Hyomin Kim, Mark Engebretson, Allan Weatherwax, Jennifer Posch, and Melissa Geddes **[Talk; Wednesday AM]**

Ground-based observations have shown that Pi1B magnetic pulsations, characterized by broadband bursts in the ULF range (periods of 1 to 40 s), are well-correlated with substorm onsets. Recent work shows that these waves are also observed at geosynchronous orbit in conjunction with onset, where they are compressional in nature and that they can be observed by FAST, where they are transverse and appear to coincide with BBELF waves. These pulsations provide an onset signature with timing precision the order of a few seconds; ground stations that detect this signature need only be located within a couple of hours in MLT of the onset. Comparisons of onset times in

opposite hemispheres show, perhaps, seasonal effects and unexpected differences in arrival times. Although the origin of these waves remains a mystery, the fact that quite similar signatures are sometimes observed on the ground in the cusp region during periods of northward IMF, raises the question of whether they might be a consequence of reconnection. In this study, spectral properties associated with reconnection are investigated using results of two fluid numerical simulations of reconnection in simple geometries. The spectral analysis considers the variability in various quantities during the reconnection process, with the implicit assumption that the variability is emitted in the form of wave power that eventually is observed in space and on the ground. Preliminary results indicate that a pressure pulse moving away from the reconnection site at approximately the Alfven speed may produce a signature similar to that of Pi1B.

Convection vortices in pre- and post-midnight sector during magnetospheric substorms

Liang, Jun (Canadian Space Agency), G. J. Sofko, and E. F. Donovan **[Talk; Tuesday PM]**

Nightside tail reconnection and magnetic dipolarization associated with the substorm expansion are two key processes that reconfigure the nightside magnetosphere and modify the polar ionosphere plasma flow pattern. Nightside reconnection will excite a twin-vortex flow pattern with foci located at both ends of the merging gap, one in the premidnight and the other in the postmidnight sector [*Cowley and Lockwood*, 1992]. On the other hand, there are processes, e.g., the "field line slippage" [*Lui and Kamide*, 2003], that are directly associated with the dipolarization/current disruption during the substorm expansion phase and may lead to a pair of meridionally-aligned convection vortices near the midnight sector. In this study we investigate the nightside ionospheric plasma convection pattern during several substorm events and propose that the high-latitude convection vortices generated by nightside reconnection and dipolarization-associated processes tend to reinforce each other in the postmidnight sector but cancel each other in the premidnight sector, leading to an enhancement of the postmidnight counterclockwise vortex but to an attenuation or even an absence of the premidnight clockwise vortex during the substorm expansion phase. *Cowley, S. W. H. and M. Lockwood* (1992), Excitation and decay of solar wind-driven flows in the magnetosphere-ionosphere system, Ann. Geophys., 10, 103–115; *Lui, A. T. Y., and Y. Kamide* (2003), A fresh perspective of the substorm current system and its dynamo, Geophys. Res. Lett., 30(18), 1958, doi:10.1029/2003GL017835.

Substorm expansion as an avalanche phenomenon

Liu, William (Canadian Space Agency), Eric Donovan, Paul Charbonneau, and John Manuel **[Talk; Friday AM]**

The phenomenology of substorm shares some marked similarity with the avalanche of snow. There is a slow accumulation of potential energy. This initial buildup of energy is stable against an infinitesimal perturbation. Then, as the buildup continues, some small region may become unstable, and the release of the local energy perturbs the adjacent regions. If the global potential energy storage and the distribution thereof meet certain conditions, a chain reaction takes place, and the entire free energy in the system is released in a cascade. This behavior of self-organizing criticality has been studied in the context of magnetospheric substorms, but much of the work so far is more metaphorical than physically specific to the substorm process. In this paper, we propose an avalanche model encapsulating some key processes known to operate in a substorm. The model is intrinsically nonlinear and involves a basic level of cross-scale coupling. We describe the physical motivation for the model and how it might be used to test various substorm trigger mechanisms proposed to date.

Low frequency fluctuations of the plasma sheet – CLUSTER observations and models

Louarn, P. (CESR, France), G. Fruit, E.Budnik, J.A. Sauvaud, C. Jacquey, E. Lucek, and the CDPP, CIS, and FGM teams. **[Invited Talk; Monday PM]**

Using CLUSTER dataset, we analyse 'plasma sheet' low-frequency fluctuations and related phenomena. One of our objectives is to determine if some of the observed fluctuations may be interpretable in simple terms, i.e., as magnetohydrodynamic (MHD) eigenmodes of the sheet. To that purpose, the observations are compared with the results of a study of the MHD propagation in a Harris sheet. The theory shows that the eigenmodes have periods scaled by a characteristic time, τ, equal to the ratio between (1) the thickness of the sheet and (2) the sound speed. Using the 4 CLUSTER spacecraft, we estimate these quantities and determine the characteristic time. It is compared with the typical periods of the fluctuations deduced from a wavelet analysis of the magnetic field. Analysing the 2001-2004 'plasma sheet' periods of CLUSTER, we identify examples of oscillations that could well correspond to MHD eigenmodes. They are intense ($\Delta Bx \approx 10$ nT), have a rather short period (20-25 s), present both sausage and kink mode features and are observed during active periods, for example, in conjunction with substorm onsets. We discuss what are the plasma sheet characteristics that seem to favour their existence and their propagation, in particular, the fact that they are observed during low <Bz>periods. We then extend our analysis to fluctuations that seem hardly interpretable in the framework of this simple 1D MHD model and attempt to characterize them.

Relating Plasma Instabilities in the Magnetotail to Observables

Lui, A. T. Y. (The Johns Hopkins University Applied Physics Laboratory, Laurel, MD USA.) **[Invited Talk; Wednesday AM]**

Several plasma instabilities associated with strong current densities in the magnetotail have been considered in the literature. Most of them are directed to the substorm expansion onset problem. In this presentation, we examine some of these plasma instabilities to determine what observables, both in the magnetotail and on the ground, that may be related to the onset of these plasma instabilities, regardless of whether or not they are the principal process for the substorm expansion phase onset.

Expansion of substorm disturbances into the polar cap

Lukianova, R. (Arctic & Antarctic Research Institute) **[Poster; Tuesday, Session 2]**

Substorm disturbances on the ground are most prominent in the auroral oval. Previous investigations show that the similar signatures can also be observed deep in the polar cap. We selected events with very high-latitude expansion. Using ground-based magnetometers and riometers we examine the distinctive features of three types of events: isolated substorms, disturbances caused by high SW pressure front and quasi-periodic events associated with sawtooth particle injections into the inner magnetosphere. The interest is conditioned on the current debate of either sawtooth events are the result of strong but unsteady solar wind forcing of convection, or they are intrinsically internal response to strong steady solar wind forcing. We use the polar cap indices from both hemispheres to show what events are accompanied by strengthening of transpolar convection flow. To separate the effect of directly driven convection from contribution of substorm auroral electrojet and field-aligned currents of substorm current wedge, variations of total magnetic vector from stations located at nightside near the polar cap boundary are analyzed. Relevant examples of direct measurements of field-aligned currents by low-orbited satellite are presented along with the results of numerical modeling of ionospheric electric field. In particular, it is shown that if the SW pressure pulse occurs during southward IMF it causes much more strong disturbance

then if it occurs during northward IMF. It is also found that a specific riometer activity in deep polar cap is often accompanied the auroral zone activity. Such absorption events suggest that electrons with energies of several tens keV typical of closed field lines are precipitated in the polar cap. Abrupt enhancement of cosmic noise absorption is observed simultaneously with the strengthening of convection directly driven by SW pressure pulse. For substorm, the polar cap absorption event is seemed to occur when magnetic bay is in progress.

Relation of Substorm Disturbances Triggered by Abrupt Solar-Wind Changes to Physics of Plasma Sheet Transport

Lyons, Larry (Department of Atmospheric and Oceanic Sciences, University of California, Los Angeles, Los Angeles, USA), Dae-Young Lee, Chih-Ping Wang, and Steven Mende **[Invited Talk; Thursday AM]**

We will describe interplanetary magnetic field (IMF) and solar wind dynamic pressure P changes that lead to substorms and the significant differences in the features of substorms triggered by IMF and by P changes. We will also describe important interplay from simultaneous IMF and P changes that can prevent substorm triggering. This interplay leads to what we call "null events", since the IMF or P change alone would trigger a substorm but the effect of that change is nullified by a simultaneous change in the other quantity. We will then use the plasma sheet continuity equation to show how basic plasma sheet sources and losses account for: 1. The substorm growth phase build up of plasma energy and the Harang electric field reversal, 2. Steady magnetospheric convection events via the finite tail width giving particle flux and energy flux divergence that prevents excess build up of pressures, 3. Substorm onsets via IMF changes or P increases that substantially decrease the inner plasma source but not the loss, 4. Null events via competing effects of IMF and P changes that lead to an unchanged or increased plasma sheet source, 5. Pseudo-substorms via a nullifying IMF or P change that increases the plasma sheet source after onset, terminating substorm expansion before full development.

Radiation Belt Science in the THEMIS Era

Mann, Ian (Department of Physics, University of Alberta) **[Invited Talk; Wednesday AM]**

The outer zone electron radiation belt demonstrates variability on timescales from minutes to days, months and years. Current research efforts have focused on two competing acceleration processes, those which act on a VLF/ELF timescale and those which act on a ULF timescale, violating the first and third adiabatic invariants, respectively. These acceleration processes are balanced by dynamical losses, leading to either increases or decreases over pre-storm electron flux depending on conditions – the overall increases not being well-predicted by Dst, but being well-correlated with fast solar wind speed (Vsw). Recent research has highlighted the possibility that ULF wave fields can resonantly interact with electron drift, and since ULF waves are known to correlate with high solar wind speeds they offer an intermediary which can explain the Vsw electron flux dependence. In recent studies we have shown statistical evidence in support of inwards propagation of Vsw correlated flux enhancements (Mann et al., 2004); in addition ULF wave power penetrating to low-L has also been causally linked to slot filling events (Loto'aniu et al., 2006). Most recently, we have discovered time-domain signatures of ULF period modulations in MeV electron flux indicative of the action of ULF wave coherent acceleration and providing a "smoking gun" for a ULF wave-MeV electron interaction. The THEMIS satellites offer in-situ measurements of ULF and VLF waves, as well as profiles of MeV energy electron phase space density (PSD), and provide the capability to begin to study the evolution of the PSD profiles during multi-satellite perigee passes in response to local (VLF) heating and to ULF wave radial transport. They also offer the capability to examine the importance of MeV electron injection resulting from substorm fields (e.g., Ingraham et

al., 2001). We expect to begin to develop our capabilities for distinguishing between different acceleration/transport processes with the multiple THEMIS satellites, prior to the launch of the approved NASA Radiation Belt Storm Probes and the proposed CSA ORBITALS (www.orbitals.ca) missions to the Van Allen belts.

The Dayside Magnetosphere of Mercury

Massetti, Stefano (IFSI/CNR Roma Italy) **[Invited Talk; Friday PM]**

In view of the next space missions Messenger and BepiColombo, many efforts are in progress to derive an accurate description of Mercury's magnetosphere, in spite of the few data available from the Mariner 10 flybys. Although the magnetosphere of this planet can be roughly approximated by scaling the Earth's one (about 1:6.9), several differences are expected due to the lack of an ionosphere, and the likely absence of a stable ring current. Furthermore, at Mercury's orbit, the IMF BX component is expected to play a crucial role in the solar wind – magnetosphere coupling, causing the magnetosphere of the planet to be actually quite ``open'', even for IMF BZ > 0. Models indicate that a prominent feature is represented by the wide open area(s) on the Mercury's dayside magnetopause, due to the broad cusp regions, through which the magnetosheath plasma can enter and then circulate into the magnetosphere. Thanks to the acceleration gained by crossing the rotational discontinuity at the magnetopause, the ions injected along the reconnected field lines can reach energies up to tens of keV, depending on the value of the Alfvénic speed on both sides of the magnetopause. Finite gyro-radius effect and gradient drift cause the spreading of the initial distribution over a broad region. The absence of a dense atmosphere allows a large faction of the impinging plasma to reach the planet's surface, where it can contributes - via ion-sputtering - to the release processes of heavy atoms form the soil. Results obtained by modeling the Mercury's magnetosphere by means of an ad hoc modified Toffoletto-Hill (TH39) model, is presented. The analysis is focused on the dayside magnetospheric configurations, and on the plasma entry and circulation patterns.

Challenges of Multi-spacecraft Missions to End the Substorm Controversy

McPherron, Robert L. (IGPP, UCLA) **[Invited Talk; Wednesday AM]**

The concept of the magnetospheric substorm has had a contentious history. Even today after forty years of study there is no agreement on the location or cause of the substorm onset. Some even question whether there is a unique phenomenon that should have this name. There are a variety of reasons for the questions and our inability to answer them. First is the paucity of observations in space. The magnetosphere occupies an extremely large volume and at any one time there are only a few spacecraft present. The chances that a particular spacecraft will be in the right region to observe the onset are very low. A second reason is that the close coupling of various regions of the magnetosphere guarantees that different parts of the system become disturbed very quickly after the onset. Typical travel times for waves and plasma flows are at most a few minutes between the two regions suggested by many as the location of onset. Unfortunately the cadence of many important measurements such as satellite pictures of the aurora, ground magnetometer observations, Pi 2 pulsation onsets have been too low to determine accurately the time or location of onset so it is difficult to determine whether the event occurred first at some other location or first at the spacecraft. Also, when events are initially localized in space it is usually the case that the spacecraft will be outside the region of initiation and so will observe the onset with an unknown delay. The Themis mission is designed to solve these problems and determine where the substorm onset is located. It consists of five spacecraft in orbits with 1-day, 2-day, and 4-day periods. The spacecraft are controlled so that every four days their apogees are aligned. The plan is to catch a substorm onset in between the various spacecraft and to determine the direction in which the disturbance

propagates. In this way it will be determined whether the onset occurs at 10 Re or at 22 Re. Without doubt this is the proper approach to resolving the controversy. However, this mission too will be troubled with difficulties. These include: the short duration of satellite conjunctions; the short time the spacecraft will be in the midnight sector; the probability that geomagnetic activity will occur during a conjunction; the probability that the activity will be a substorm; the probability that the substorm will create flow channels that are aligned along the locus of satellite apogees. Other problems are related to the ground network designed to locate and time the substorm onset. Questions here include: is all equipment operational; are the seeing conditions good; does the substorm occur in the meridian of the spacecraft; does the meridian of onset map to the meridian of the spacecraft apogees? When all factors are taken into consideration the probability of observing the 'perfect event" in any year is very low. Despite these problems the mission is likely to capture a number of interesting events that will further the study of substorm if not entirely eliminate the controversy.

SuperDARN and IMAGE WIC Observations during intervals of Steady Magnetospheric Convection

McWilliams, K. A. (University of Saskatchewan), J. B. Pfeifer, R. L. McPherron,and H. U. Frey **[Poster; Monday, Session 1]**

Intervals of steady magnetospheric convection are, in general, characterized by active geomagnetic conditions, including active aurora in the substorm sector and strong convection, but without typical substorm signatures. It is hypothesized that magnetic flux transfer on the dayside and the nightside is relatively balanced when SMC occurs. Comparative analyses of the ionospheric convection from SuperDARN and the UV auroral images from IMAGE WIC will be presented. Statistical results and several case studies of interest will be discussed. The ever increasing coverage by SuperDARN makes it possible to determine global convection patterns with a higher degree of confidence than ever before. In some cases, nearly 1000 data points were available in successive scans to well constrain the determination of the northern polar cap convection pattern every two minutes. In these cases, nearly all local times contained radar measurements, which also increases the accuracy of the convection patterns. We will discuss the behaviour of the polar cap potential difference during the SMC intervals. Convection and aurora data will be compared, and these will be discussed in relation to the expected field-aligned currents flowing during intervals of SMC.

Alfven wave produced auroras during substorms

Mende, Stephen B. (Space Sciences Lab, University of California at Berkeley), H. U. Frey, and C. W. Carlson **[Talk; Friday AM]**

A survey of substorm onsets observations with IMAGE FUV and FAST satellite data provided about two dozen cases in which the onset events occurred in less than 1000 km separation from the FAST satellite. During these cases the satellite data showed the auroral conditions either just before or just after substorm onset in the vicinity of the onset region. Each FAST transit provides a snapshot of the spatial morphology of the precipitating particles and field aligned current profiles. In the FAST satellite data, Alfven wave dominated aurora can be recognized by the dominance of high fluxes of low energy electrons with beam like field aligned pitch angle distribution and accompanying strong wave activity. This can be distinguished from "inverted V" auroras produced by quasi static field aligned electric fields from their characteristic mono-energetic spectral signature. The wave accelerated electron auroras are produced by converting high intensity wave energy (Poynting) fluxes into electron energy and therefore the Alfven wave accelerated auroras are footprints of regions where large-scale magnetic reconfigurations take place. Alfvenic aurora is often located at the poleward edge of the substorm surge arc while equatorward of the surge there is a broader region of electron precipitation with embedded quasi-static "inverted V" electric fields.

Using the data set we will discuss frequently encountered situations where Alfven wave produced auroras occur very near to the substorm onset region during various phases of the substorm.

Global survey of the isotropic boundary during substorm expansive phase

Meurant, M. (Institute for Space Research, University of Calgary), E. F. Donovan, B. Hubert, C. Blockx, J.-C. Gerard, E. Spanswick, I. Voronkov, and T. S. Trondsen **[Talk; Tuesday AM]**

The Ion Isotropy Boundary (IB) is known to correlate well with the magnetic field inclination at geosynchronous orbit around 00 MLT and therefore provides a way to monitor the magnetotail stretching. Several ways to identify IB have been developed in the literature. Based on in situ spacecraft data, Sergeev and Gvozdevsky, 1995 have defined the IB position using NOAA data and Newell et al., 1996 defined a comparable boundary (the b2i boundary) based on Defense Meteorological Satellite Program (DMSP) data. From the ground, Donovan et al., 2002 used Meridian Scanning Photometers (MSP) to determine the "optical b2i" and Jayachandran et al., 2002 demonstrated the coincidence of the b2i and the equatorward boundary of the SuperDARN evening sector E-region scatter. In complement to these methods, an IB determination on a wide range of Magnetic Local Time (MLT) with a high temporal resolution is useful. In this way, Trondsen et al., 2003 investigate the ability of the IMAGE-FUV-SI12 imager to monitor IB by simultaneous comparison with MSP data during a 7 days period. Recently, Blockx et al., 2005 have shown the possibility of SI12 data for monitoring the magnetotail stretching during quiet periods. In this study, we focus our attention on the ability of SI12 to provide information on the tail stretching during active periods and more specifically during the substorm expansive phase. We base our investigation on more than 250 isolated substorms observed by IMAGE-SI12 between 2000 and 2002. Simultaneous comparison with GOES 8 and 10 allows us to estimate how strong is the relation between the IB position deduced from SI12 (SI12-IB) and the magnetic field stretching. Time evolution of the SI12-IB are also presented for different local times during events presenting different types of morphological evolutions.

Flux transport in the Dungey cycle: A survey of dayside and nightside reconnection rates

Milan, Steve (University of Leicester), Gabrielle Provan, and Benoit Hubert **[Invited Talk; Monday AM]**

Changes in the open flux content of the ionospheric polar cap, estimated from auroral, radar, and low-Earth orbit particle measurements, are used to determine dayside and nightside reconnection rates during 73 hours of observation spread over 9 intervals. We identify 25 episodes of nightside reconnection, and examine statistically the rates and durations of reconnection, as well as possible triggers for the onset of reconnection, such as changes in solar wind ram pressure or orientation of the interplanetary magnetic field. Approximately half of the events can possibly be identified with a trig-ger, the other half appearing spontaneous. On average 0.3 GWb of open flux are closed in each event, with average durations and reconnection rates being 70 min and 85 kV. We apply the observed time-series of reconnection rates and polar cap flux to a model of the flux profile of the magnetotail. It is demonstrated that the tail varies in length between a few 100s of RE and several 1000s of RE on time-scales of 10s of minutes.

The magnetotails of Mercury, Earth, Jupiter, and Saturn

Milan, Steve (University of Leicester) **[Talk; Friday PM]**

Magnetic flux conservation arguments allow the profile of flux within the magnetotail lobes to be

determined from a knowledge of the present size of the polar cap and the past history of dayside and nightside reconnection. Models are formulated for slowly (Earth, Mercury) and rapidly (Jupiter, Saturn) rotating planets. Significant dynamical differences exist between the two cases, and the implications for magnetotail structure are described. Where possible, the models are driven by realistic reconnection rates to determine the average lengths and variability of the tails of Mercury, Earth, Jupiter, and Saturn.

Substorm timing using Pi1B pulsations observed with CARISMA

Milling, D. K. (University of Alberta),and I. R. Mann **[Talk; Tuesday PM]**

Pi1B pulsations are impulsive ULF signals in the period range 1-40s typically observed in ground-based magnetometers at substorm onset. They offer a potentially more accurate estimate of substorm onset time than the longer period Pi2 (40-150s). We present magnetometer observations of Pi1B from the Canadian Array for Realtime Investigations of Magnetic Activity (CARISMA; formerly CANOPUS). The extensive latitudinal and longitudinal coverage of the array provides information on the source region and propagation characteristics of these pulsations. As CARISMA is located under the footprint of the THEMIS tail probe alignments we discuss the use of the Pi1B in ground-based timing of substorm onset to support THEMIS. THEMIS aims to achieve timing of current disruption and reconnection in space to within 10s. We comment on whether it is possible to achieve a similar timing accuracy for substorm onset on the ground using the Pi1B pulsation observations.

On the Role of O+ on Magnetic Reconnection in the Earth's Magnetotail

Mouikis, Christopher (University of New Hampshire), L. M. Kistler, M. Shay, B. Klecker, H. Reme, I. Dandouras, and E. Lucek **[Talk; Thursday PM]**

Recent observations from the CLUSTER mission have shown that during geomagnetically disturbed times, the O+ number density in the plasma sheet close to the reconnection X-line in the Earth's magnetotail can become comparable to, or even higher than, the corresponding H+ number density with the O+ ions carrying most of the particle pressure. The role of these O+ ions in the reconnection process has not being clearly identified in a self consistent way. How does it affect the formation of the ion diffusion region? What is its effect on the reconnection rate? Until now, there have been mainly theory/simulation attempts with no clear answer. In this study, we investigate the role of O+ on the magnetic reconnection process using plasma ion composition data from the CLUSTER mission. In particular, we identify the observational signatures of the coupling of the O+ ions in the reconnection system.

Fast flow, dipolarization, and substorm evolution: Cluster/Double Star multipoint observations

Nakamura, R. (IWF/OeAW, Graz, Austria), T. Takada, M. Volwerk, W. Baumjohann, T. L. Zhang, Y. Asano, A. Runov, Z. Voeroes, C. Carr, A. Balogh, E. Lucek, B. Klecker, H. Reme, and O. Amm **[Invited Talk; Monday AM]**

Fast flow and associated magnetic field disturbances are keys to understand the link between the midtail and the inner magnetosphere, where the essential energy conversion processes take place during substoms. With four-point observation Cluster allows to investigate spatial structure and associated signature of depolarization fronts as well as current sheet disturbances. With the launch of Double Star, simultaneous observations of the inner magnetosphere and the midtail took place in summer 2004 and 2005. Such a constellation of the spacecraft allows us further to study the flow and dipolarization disturbance both in the local and the larger context. That is, by applying multi-point analysis techniques, the direction and speed of the propagation is determined within Cluster

and can then be compared with the global propagation of the disturbances using Double Star as well as relevant ionospheric disturbances. In this talk we discuss how plasma sheet fast flow and dipolarization characteristics obtained from local as well as global multi-point observations can be understood in the context of the macroscopic evolution of the magnetosphere during substorms.

Simultaneous observations of ions of ionospheric origin over the ionosphere and in the plasma sheet at storm-time substorms

Nosé, M. (Kyoto University), T. Kunori, Y. Ono, S. Taguchi, K. Hosokawa, T. E. Moore, M. R. Collier, S. P. Christon, and R. W. McEntire **[Invited Talk; Thursday PM]**

We investigate variations of ion flux over the ionosphere and in the plasma sheet when storm-time substorms are initiated, using simultaneous observations of neutral atoms in the energy range of up to a few keV measured by the low-energy neutral atom (LENA) imager on board the Imager for Magnetopause-to-Aurora Global Exploration (IMAGE) satellite and energetic (9-210 keV/e) ion flux measured by the energetic particle and ion composition (EPIC) instrument on board the Geotail satellite. We studied some storm-time substorm events in which the IMAGE satellite was located near its apogee and the Geotail satellite was in the plasma sheet on the nightside. Low-energy neutral atoms traveling from the direction of the Earth can be created by outflowing ionospheric ions through charge exchange processes. The observed neutral atom flux enhancement in these events indicates an increase of low-energy ion flux over the ionosphere at substorm onset. In the plasma sheet, the flux of O+ and the flux ratio of O+/H+ are also enhanced at substorm onset and increased gradually with a timescale of <60 min, suggesting an additional supply of O+ ions from the ionosphere to the plasma sheet. We will discuss the role of substorms in the dynamics of O+ ions during magnetic storms.

Automated detection of Pi2 pulsations to monitor substorm signatures: Its application to real-time data and archived data

Nosé, M. (Kyoto University), T. Iyemori, M. Takeda, T. Kamei, F. Honary, S. Marple, J. Matzka, T. Ookawa, K. Takahashi, B. Toth, and G. Cifuentes-Nava **[Poster; Tuesday, Session 2]**

Pi2 pulsations are defined as geomagnetic field variations with a period range of 40-150 s and an irregular waveform. It is generally accepted that Pi2 pulsations appear clearly at mid- or low-latitude ground station on the nightside in a close connection with substorm onsets. Thus nowcasting of substorm onset becomes possible, if we monitor geomagnetic field variations and detect Pi2 pulsations in real-time. We have developed an algorithm to detect Pi2 pulsations with wavelet analysis, which is suitable for investigating waves that are limited in both time and frequency, such as Pi2 pulsations [Nosé et al., Earth Planet. Space, p. 773-783, 1998]. Using the geomagnetic field data from the Kakioka observatory, we have tested the algorithm and found that detection results by the algorithm on the nightside are fairly consistent with the detection results by visual inspection. Based on this successful test result the algorithm has been applied to real-time geomagnetic field data obtained at the Mineyama and Kakioka observatories in Japan, as well as the York SAMNET station in the U. K. since 1996. We started the Pi2 detection at Fürstenfeldbruck in Germany in July 2005, at APL (Applied Physics Laboratory) in the United States and Teoloyucan in Mexico in September 2005. Detection results are exchanged among these stations via the Internet and are available at our WWW site (http://swdcli40.kugi.kyoto-u.ac.jp/pi2/). The network of these 6 observatories will result in more reliable detection of Pi2 pulsations, because at least one station is located on the nightside at any given time. We plan to

apply this algorithm to archived data and create Pi2 database. Such database may be useful for substorm studies.

Outstanding Issues about Substorm Onset: Revisit to Fundamental Features

Ohtani, Shin (JHU/APL) **[Invited Talk; Monday AM]**

The initiation of substorm has been addressed in terms of two magnetospheric processes, that is, tail current disruption (TCD) and the formation of a near-Earth neutral line (NENL). Although causality between the two processes has been a focal issue of substorm study for quite some time, we still have two competing ideas. One idea considers TCD and near-Earth dipolarization as effects of the NENL formation (outside-in model), whereas the other idea proposes that TCD sets up a condition for the NENL formation (inside-out model). This presentation seeks to critically address these two ideas by revisiting fundamental substorm features such as auroral expansion, pseudobreakup, and northward IMF turning.

Effects of the Fast Plasmasheet Flow on the Geosynchronous Magnetic Configuration: Geotail and GOES Coordinated Study

Ohtani, S. (JHU/APL), H. J. Singer, and T. Mukai **[Poster; Monday, Session I]**

The present study statistically examines how (or if) the geosynchronous (GOES) magnetic field responds to fast earthward flow observed by the Geotail satellite in the plasmasheet. The change of the GOES H (north-south) component within 15 min of the detection of fast flows, del_H, is used as a primary measure of the geosynchronous response. It is found that following the detection of fast flows, the geosynchronous magnetic field rarely dipolarizes, but it often becomes more stretched, which is manifested by negative del_H. This H decrease is not accompanied by any correlated variation of the D (azimuthal) component, suggesting that the associated stretching is not an edge effect of the substorm current wedge formation but it can be attributed to the intensification of the local tail current. No systematic dependence of del_H on the satellite separation can be found. On the other hand, the geosynchronous magnetic field tends to dipolarize if it is already stretched significantly, although the associated changes in the H and V (radial) components are not much larger than those in events that are not preconditioned. The flow intensity does not seem to be a controlling factor, either. However, caution needs to be exercised because the present study is not able to address the azimuthal structure of the fast flow. It is concluded that in most events the fast plasma flow does not reach geosynchronous orbit and that the generation of the fast plasma flow in the plasmasheet is not sufficient for causing geosynchronous dipolarization.

Plasmasheet Expansion: Statistical Characteristics

Ohtani, S. (JHU/APL), and T. Mukai **[Poster; Tuesday, Session 2]**

The present study addresses the cause of the plasmasheet (PS) expansion by statistically comparing the characteristics of the lobe(LB)-to-PS and PS-to-LB crossings observed by the Geotail satellite. Whereas the flapping motion of the magnetotail causes both types of crossing, the PS expansion (thinning) can be associated only with the LB-to-PS (PS-to-LB) crossing. Thus, any systematic difference between the two types of crossing should reflect the difference between the PS expansion and thinning. Geotail observed more LB-to-PS crossings (744 events) than PS-to-LB crossings (640 events), and the preferred occurrence of the LB-to-PS crossing is more manifest closer to the Earth. It is found that at the PS-to-LB crossing the plasma moves in the same direction as the boundary motion. At the LB-to-PS crossing, in contrast, the plasma often moves in the opposite direction to the boundary motion, indicating that there is a finite electric field in the frame of the boundary motion associated with the PS expansion. The PS expansion is therefore considered

to be a manifestation of magnetic reconnection. That is, the PS expands because new PS flux tubes are added onto the pre-existing PS. In the course of the PS expansion the total pressure decreases, which may be interpreted in terms of the replacement of the pre-existing PS plasma with new low-pressure plasma originating from the tail lobe. The PS expansion is also characterized by relaxation (dipolarization) of the local magnetic field, which is a direct consequence of reconnection. Based on recent reports of the lack of a one-to-one correspondence between reconnection and substorm onset, it is suggested that the PS expansion cannot be uniquely associated with a specific substorm phase.

Conjugate imaging of substorms

Ostgaard, N. (Department of Physics and Technology, University of Bergen, Norway), S. B. Mende, H. U. Frey, J. B. Sigwarth, and A. Aasnes **[Invited Talk; Thursday PM]**

Simultanous imaging in the ultraviolet wavelengths by IMAGE and Polar, enable us to examine auroral features in the conjugate hemispheres. With an imaging cadence of 2 min and 1 min for IMAGE/FUV and Polar VIS Earth camera, respectively, we can study the substorm onset locations in the two hemispheres. When mapped onto apex magnetic coordinates our study shows that there exists a systematically displacement of substorm onset location in one hemisphere compared to the other. The relative displacement of onset locations in the conjugate hemispheres is found to be controlled primarily by the IMF clock-angle, with the dipole tilt angle as a possible secon order effect. Compared with some of the existing magnetic field models, the observed asymmetries are an order of magnitude larger than the model predictions. These results have been compared with the statistical distribution of substorm onsets in the southern and northern hemispheres for different clock angles. Based on 3000 substorm onsets in the Northern hemisphere and 1000 in the southern hemisphere observed over the entire IMAGE mission we find a remarkable support for our previous findings.

Time history effects at the magnetopause: Hysteresis in power input

*Palmroth, Minna (Finnish Meteorological Institute), Pekka Janhunen, and Tuija Pulkkinen** **[Poster; Monday, Session I]**

We examine the clock angle dependence of the solar wind power input into the magnetosphere using the Grand Unified Magnetosphere Ionosphere Coupling Simulation (GUMICS-4). We compute the power input through the magnetopause systematically in four events where the solar wind parameters are otherwise kept constant, but the interplanetary magnetic field (IMF) clock angle θ is rotated from 0 to 360 degrees. We find that when the clock angle rotates from north to south, the power input is well represented by $\sin^2(\theta/2)$. However, during the return rotation from south to north, the power input in the simulation remains enhanced longer than a $\sin^2(\theta/2)$ dependence would indicate. We suggest that the enhanced energy input during the return rotation may be a consequence of the nature of the reconnection process at the magnetopause.

Observing the MLT and L-shell dependence of ground magnetic signatures of the ionospheric Alfvén resonator

Parent, Adrienne (University of Alberta), and Ian R. Mann **[Poster; Thursday, Session 3]**

The ionospheric Alfvén resonator (IAR) is a resonant cavity that forms naturally in the upper ionosphere between two regions of large Alfvén velocity gradients. It is believed to be stimulated by the generation of shear Alfvén waves in the E-layer, which is in turn triggered by electromagnetic emissions from global and local thunderstorm activity and possibly by fluctuations in the E-region neutral wind. The effects of the IAR are manifested as distinct spectral features in

ground magnetometer data in the 0.1 to 10 Hz range. Many studies of ground magnetic signatures of the IAR have focussed on observations over time at a single site. In an attempt to better understand the global extent of the resonator, we present results of a preliminary study in which we have characterized IAR features across a collection of stations in the Canada-U.S. sector. We have quantified the evolution of IAR eigenfrequencies with respect to onset time and occurrence rate, as well as harmonic frequency values, spacing and intensities. The dependence of these properties on local time, L-shell, sunrise/sunset times and geomagnetic activity has been examined. Future work will involve analysis of IAR signatures over a longer time interval, in order to investigate dependency on seasonal variation, as well as examine the relationship (if any) between structured Pc1-2 pulsations and resonance features. Observational studies of resonant magnetic signatures are important in furthering our understanding of the ionospheric Alfvén resonator and its effect upon magnetosphere-ionosphere interactions.

Strong stretching in dusk sector: stormtime substorms and sawtooth events compared

Partamies, Noora (University of Calgary), Tuija I Pulkkinen, Eija I Tanskanen, Geoff D Reeves, Eric Donovan, Howard J Singer, and James A Slavin **[Poster; Tuesday, Session 2]**

We have analyzed electrojet activations during magnetic storms that occurred during the year 2004. The entire data set consists of about 130 activations, which include highly variable magnetospheric responses and solar wind conditions. Here we concentrate on a subset of events, where the magnetic field is highly stretched in the dusk sector (local time before 2200 MLT) geostationary orbit. While such strong stretching is typically found during sawtooth events, we demonstrate that it can also occur during other highly disturbed periods. We compare and contrast these events with the sawtooth events and with events where the field is highly stretched in the morning sector after 0200 MLT. Especially, we concentrate on the magnetosphere - ionosphere coupling: We examine the auroral-latitude current systems, the field-aligned currents coupling to the magnetosphere, and the auroral signatures during these events. Furthermore, we use the midlatitude magnetic variations to draw information about the inner-magnetosphere ring current and partial ring current evolution.

An attempt to locate substorm onsets using Pi1 signatures

Pilipenko, V. A. (Institute of the Physics of the Earth, Moscow), I. I. Tchebotareva, M. J. Engebretson, J. L. Posch, A. Rodger, and P. Ponomarenko **[Poster; Tuesday, Session 2]**

Pi1 observations, because of their higher frequency, hold the promise of providing better temporal resolution for accurate substorm onset timing, which continues to be a matter of considerable importance for evaluation of competing substorm mechanisms. In this presentation we show that Pi1 signatures detected by ground magnetometer arrays can be used also for the spatial location of substorm onsets. We have compared data from several Antarctic search-coil magnetometers with images of auroral activations from the FUV-WIC imager on the IMAGE satellite. To locate an ionospheric source of Pi 1 signatures we have applied the method of emission tomography that was previously used in seismology. The source image reconstruction algorithm uses scanning of the volume under investigation, whereas for each of the grid points a coherency measure for multi-channel data is calculated. For the source image reconstruction we have introduced a coherency measure, which may be coined the nonlinear semblance. Though the Antarctic stations are elongated in one direction, a pattern that is less than optimal for use with emission tomography methods, the results obtained seem to be very promising for the determination of substorm onset location using ground magnetometer data.

Effects of pressure gradients and convection on the inner plasma sheet

Prosolin, Victor (University of Calgary), Igor Voronkov, and Eric Donovan **[Poster; Monday, Session 1]**

We present a computer model that solves the system of nonlinear MHD equations in dipolar coordinates and is designed specifically to simulate the near-Earth plasma sheet region which has a near-dipolar field line topology. The objective of this work is a detailed study of the inner plasma sheet as a region of particular importance for auroral processes including the proton aurora and near-Earth breakup. Such factors affecting the stability of the inner plasma sheet as earthward plasma pressure gradients and different patterns of bulk plasma motion are considered. Modeling results show that pressure gradients lead to magnetic field line stretching and increased values of the ballooning instability growth rate which corresponds to an unstable state. Both earthward and tailward convection bursts form a local min-B region. However effects of tailward bursts are stronger. In general, convective motion under uniform electric field does not lead to the instability, but for the earthward velocity direction the system can reach a marginal state.

The role of random fluctuations in the magnetosphere-ionosphere system: a dynamic stochastic model for the AE-index variations

Pulkkinen, A. (NASA/GSFC), A. Klimas, D. Vassiliadis, and V. Uritsky **[Talk; Friday AM]**

Understanding the evolution of bursts of activity in the magnetosphere-ionosphere system has been one of the central challenges in space physics since, and even prior to the introduction of the term "substorm". An extensive amount of work has been put to the characterization of the average near-space plasma environment behavior during substorms and several more or less deterministic models have been introduced to explain the observations. However, although most of substorms seem to have some common characteristics (otherwise any classification would be completely meaningless), like intensification of auroral electric currents, dipolarization of the magnetotail and injections of plasma sheet charged particles, each substorm has its distinct features in terms of strong fluctuations around the average "typical" behavior. This highly complex nature of individual substorms suggests that stochastic processes may play a role, even a central one in the evolution of substorms. In this work, we develop a simple stochastic model for the AE-index variations to investigate the role of random fluctuations in the substorm phenomenon. We show that by the introduction of a stochastic component, we are able to capture some fundamental features of the AE-index variations. More specifically, complex variations associated with individual bursts are a central part of the model. It will be demonstrated that by analyzing the structure of the constructed stochastic model some presently open questions about substorm-related bursts of the AE-index can be addressed quantitatively. First and foremost, it will be shown that the stochastic fluctuations are a fundamental part of the AE-index evolution and cannot be neglected even when the average properties of the index are of interest.

Thin current sheets as part of the substorm process

Pulkkinen, T. I. (Los Alamos National Laboratory, Los Alamos, NM, USA) **[Invited Talk; Monday PM]**

It is well-known that during isolated substorms, the growth-phase-associated energy loading typically leads to the formation of a thin (ion gyroradius scale) current sheet in the inner magnetosphere. The inner edge of the thin current sheet is typically located between geostationary orbit and roughly 10 Re depending on the level of activity. It is generally assumed that an instability within this thin current sheet causes the global reconfiguration at substorm onset.

However, much less is known about thin current sheet dynamics and their role during stronger activity, be they multiple-onset substorms, sawtooth events, steady convection events, or other storm-time activations. This presentation focusses on recent observational and model results during a variety of magnetospheric configurations. It is demonstrated that the thin current sheets play an important role also during more complex activity.

Time history effects at the magnetopause: Implications to substorm processes

Pulkkinen, T. I. (Los Alamos National Laboratory, Los Alamos, NM, USA), M. Palmroth, E. I. Tanskanen, P. Janhunen, H. E. J. Koskinen, and T. V. Laitinen **[Poster; Monday, Session I]**

Two recent results from global MHD simulation GUMICS-4 show that: (1) The energy transfer rate from the solar wind into the magnetosphere is a function of also the past values of the IMF; and (2) The energy entering the magnetosphere is processed by the system without much delay. These two facts have important implications to the substorm process. We suggest that the total substorm dissipation is independent of the amount of growth-phase energy input into the magnetosphere. We demonstrate that the epsilon-parameter is a poor indicator of the time-evolution of the energy input to the system, as it does not correctly account for the energy input during the late phases of substorms. These results lead us to conclude that the flow of energy through the magnetosphere is quite directly driven. However, the growth phase is instrumental for creating the configuration change that allows the magnetotail instability to grow. Thus, the magnetotail stability requires preconditioning by the growth phase energy input, following the loading-unloading scenario.

Global ULF Wave Energy Transport in the Magnetosphere

Rae, I. J. (University of Alberta), I. R. Mann, E. F. Donovan, F. R. Fenrich, C. E. J. Watt, D. K. Milling, M. Lester, B. Lavraud, J. A. Wild, H. J. Singer, H. Rème, and A. Balogh. **[Talk; Tuesday PM]**

Transport of ULF wave energy via large-scale wave modes is extremely important in terms of solar wind-magnetosphere-ionosphere coupling. In this paper, we present a study in which we fully characterise and diagnose large-scale ULF wave dynamics on a near-global scale. We present a study using a favourable radial alignment of the Cluster, Polar and geosynchronous satellites in the dusk sector during a high solar wind speed interval. We infer that magnetopause undulations observed by Cluster drove compressional waves, perhaps in the form of Kelvin-Helmholtz unstable magnetospheric waveguide modes that propagate inward from the magnetopause. These compressional waves couple to resonant field lines close to location of Polar and geosynchronous orbit, and are observed as a field line resonance on the ground. Further we analyse the magnetopause boundary oscillations using the minimum variance technique to identify the planar nature of the boundary. Under favourable conditions, this experimental set-up can be augmented by the location of THEMIS spacecraft located in the solar wind, magnetosheath, magnetopause and inside the magnetosphere close to the mode-conversion region. This has important implications for the THEMIS mission; together with measurements from other satellites such as Cluster, Geotail and the geosynchronous satellite fleet, flank and dayside conjunctions of these satellites will be able to characterise the full radial nature of Global ULF wave events. This technique is valuable for the investigation of tail phenomena excited via the same K-H activity at the flanks, for example in the boundary layer model for magnetospheric substorms.

What causes substorm growth phase dropouts?

Reeves, G. D. (Los Alamos National Laboratory), Y. Chen, R. H. W. Friedel, T. I. Pulkkinen, and M. G. Henderson **[Talk; Tuesday PM]**

At geosynchronous orbit the substorm growth phase typically produces stretching of the night side geomagnetic field and an associated decrease in energetic particle fluxes. As the fluxes decrease the pitch angle distribution also changes. Field-aligned fluxes decrease more slowly and the pitch angle distribution evolves to a "cigar-like" distribution. At substorm injection the fluxes increase above their previous level and typically the pitch angle distribution is isotropic or "pancake". Growth phase dropouts and cigar-like distributions are observed for a wide range of substorm activity from pseudobreakups to storms. The typical signatures of growth phase were established as a predictive precursor for substorm onset in the 1970s. Around the same time an explanation for both the dropout and pitch angle evolution based on drift shell splitting and radial flux gradients was proposed. More recently alternative theories have been proposed based on de-energization of the trapped particle fluxes in the stretching tail field. We will show that the "classic" explanation remains a valid general framework for understanding the dynamics of the growth phase dropouts and that the more recent theoretical proposals are inconsistent with multi-spacecraft observations of the dropout. Additionally we will compare the growth phase dropout signatures for a range of geomagnetic activity to compare and contrast the physical processes associated with pseudobreakups, isolated substorms, activations, sawtooth events, and storm time substorms.

Auroral boundary observations by METEOR 3M auroral satellite

Riazantseva, M. O. (Skobeltsin Institute of Nuclear Physics, Moscow State University, Moscow, Russia), E. E. Antonova, B. V. Marjin, V. V. Hoteenkov, M. A. Saveliev, V. M. Feigin **[Poster; Thursday, Session 3]**

The results of the observations of auroral oval boundaries by satellite METEOR 3M are presented. The satellite was lunched 10.12.2002 on the orbit with height 1018 km and inclination 99.63 grad. The satellite is the multitask device producing the simultaneous observations of the Earth's resources, the control of the conditions in the near the Earth environment, meteorological and heliogeophysical parameters. The aims of the project are the prognosis of the solar flare activity, control and prognosis of the Earth's radiation and the conditions in the Earth's magnetic field, prognosis of the conditions of the radio wave spreading, diagnostic and the control of the conditions in the magnetosphere and ionosphere. The device MSGI-5EI is used for the analysis of the variations of the fluxes of auroral protons and electrons. MSGI-5EI measures the fluxes of protons and electrons with energies 0.1-10 keV in 50 energy channels and the integral flux of electrons with energies >40 keV. Determined by MSGI-5EI positions of auroral oval boundaries are compared with the predictions of OVATION model. It is shown that due to auroral substorm activity experimentally measured positions of auroral oval boundaries can differ from the positions predicted by OVATION model more then on 4 degrees.

Magnetospheric energy budget during huge geomagnetic activity

Rosenqvist, L. (Swedish Institute of Space Physics), S. Buchert, H. Opgenoorth, A. Vaivads, and G. Lu **[Poster; Thursday, Session 3]**

The Cluster spacecraft crossed the magnetopause at the duskward flank of the tail while the EISCAT radars and magnetometers observed the ionosphere during a sequence of intense substorm-like geomagnetic activity in October 2003. We attempt to estimate the local and global energy flow from the magnetosheath into the magnetotail and the ionosphere under these extreme conditions. We make for the first time direct observational estimates of the local solar wind power input using Cluster measurements. The global power input based on Cluster observations was found

to be between 12-30 TW at the onset of the substorm intensification. However, spacecraft observations and global modelling of the magnetotail suggest that the it is most probably closer to 12 TW. This is about three times lower than the predicted epsilon-parameter value (37 TW). Energy deposition in the ionosphere has been estimated locally with EISCAT and globally with the AMIE technique. The amount of the global solar wind power input (12 TW) that is dissipated via Joule heating in the ionosphere is found to be 38 %.The corresponding ratio based on empirical estimates is only 3 %. However, empirical proxies seem to underestimate the magnitude of the Joule heating rate as compared to AMIE estimates (~ a factor 5). In summary, the observational estimates provides a good balance between the energy input to the magnetosphere and deposition in the ionosphere. Empirical proxies seem to suffer from overestimations (epsilon-parameter) and underestimations (Joule heating proxies) when pushed to the extreme circumstances of this storm period.

Evolution of the Magnetospheric Substorm in the Framework of the Double Oval

Rostoke, Gordon r(Dept. of Physics University of Alberta) **[Talk; Tuesday AM]**

Originally, the development of substorms was studied in the context of an auroral oval that had no particular internal latitudinal structure. More recently, it has been recognized that auroral activations during substorms tend to develop near the poleward and equatorward edges of the oval. Expansion phase onsets, torch structures and pseudo-breakups develop on the equatorward branch of the oval, while poleward boundary intensifications (PBIs) occur in the evening sector on the high latitude branch of the oval. In this paper, I shall present in detail the development of one particular substorm and provide convincing evidence that poleward border activity maps to the interface region between the low latitude boundary layer and the central plasma sheet while the onset and initial development occur near the inner edge of the midnight sector plasma sheet. The results of this research suggest that the so-called westward traveling surge is not a property of the initial stages of substorm expansion phase development, but rather is related to the PBIs that develop on the high latitude branch of the evening sector auroral oval.

Role of instabilities at substoms

Roux, Alain (CETP/IPSL 10-12 ave. de l'Europe-78140-Velizy-France), Olivier Le Contel, D.Fontaine, P.Robert, P.Louarn, J.A.Sauvaud, and A.N.Fazakerley, **[Invited Talk; Monday AM]**

One of the most intriguing characteristics of substorms is the contrast between a slow growth phase, lasting typically half an hour, and a fast onset occurring in less than a minute. This sharp change in the behaviour of the plasmasheet has led to propose that substorm onset is due to the development of an instability in the plasma sheet. We briefly review potential candidates, discuss their theoretical background and describe their signatures in terms of waves emission that are expected to develop at substorm onset. In particular the direction of the k-vector is important; a radial modulation (Kx) is expected for tearing instability, while an azimuthal modulation (Ky) is expected for ballooning instability. Hence the determination of the direction of propagation is a critical issue. In an attempt to identify the signatures of instability(ies) at substorm we use Cluster multipoint observations. The large amplitude long period oscillations (typically 5-10mn) often observed while crossing the tail current sheet (CS) do not correspond to fast flows nor to substorm onset. On the other hand, when Cluster crosses an active thin tail CS (typically of the order of the ion Larmor radius or less) smaller period (1-2mn) quasi periodic fluctuations are observed, together with fast ion flows. These waves propagate azimuthally at a speed of the order of the ion drift velocity and can therefore be identified as ballooning modes. On the other hand we also observe higher frequency waves, with a broad spectrum (F~few Hz) that sometimes reach very large amplitudes,

and are well correlated with electron parallel acceleration. We show that the azimuthal modulation observed at, and after breakup, is not consistent with the development of a tearing instability, but could fit with the drift ballooning instability. Yet the characteristic time of the onset is so short that only an instability involving higher frequency waves has enough time to develop. We suggest that the observed "high frequency" modes, that develop over a short time interval, play the role of a substorm trigger.

Cluster observations during pseudo-breakups and substorms

Runov, A. (Space Research Institute, Graz, Austria), I. O. Voronkov, Y. Asano, W. Baumjohann, R. Nakamura, M. Volwerk, A. Balogh and H. Reme **[Invited Talk; Tuesday AM]**

We discuss Cluster observations of the magnetotail plasma sheet dynamics during a set of successive activations between 0300 and 0600 UT on September 15, 2001. Cluster was located near midnight meridian at about 19 RE downtail, with foot points on the CANOPUS network, staying in the plasma sheet during about 10 hours. Studying Cluster magnetometer and ion spectrometer data, we found that the activity in the plasma sheet starts after a ~2.5 hours long interval of Bz decrease; the pseudo-breakups, detected by CANOPUS, are associated with enhancements of tailward ion flow; and the substorm, following the pseudo-breakups, corresponds to a high-speed ion flow reversal from tailward to Earthward, with a quadrupolar magnetic field structure and intensive ion heating. Thus, the substorm is associated with magnetic reconnection in the near-Earth (X> -19 RE) plasma sheet. The current sheet thickness, estimated using four-point magnetic field measurements, gradually decreased prior to the flow reversal, achieving the minimum (less than 1000 km) at the onset of unloading. The excitation of quasi-harmonic waves with periods of 150 - 200 s, propagating duskward with velocities of 50 - 100 km/s, was detected by the Cluster magnetometers at the activity onset. Since IMF was mostly northward, the plasma sheet dynamics during this interval was internally triggered.

Substorm effect on ground observations of signatures of the ionospheric Alfven resonator

Semenova, N.V (Polar Geophysical Institute, Apatity, Russia), A.G. Yahnin **[Poster; Tuesday, Session 2]**

The spectral resonant structures (SRS) of the magnetic noise in the frequency range of 0.1-10 Hz are known as a phenomenon that anti-correlates with geomagnetic activity. In this report we discuss how SRS relate to substorms. It has been noted that in the auroral zone SRS disappear when such a signature of the substorm as PiB pulsations are observed. Evidently, this is due to close relationship between PiBs and dynamic, substorm auroras. The electron precipitation flux produces the ionosphere modification that leads to violation of conditions for ionospheric Alfven resonator (IAR) responsible for SRS. But, recent observations in Barentsburg, Svalbard, that is, poleward from the auroral zone, showed that SRS are rather often seen during PiBs. The interpretation of this fact is that SRS are due to IAR overhead, while PiBs observed at high latitudes are due to the ionospheric waveguide propagation from the remote source. This remote source co-locates with substorm auroras, which are situated well equatorward from Barentsburg. This interpretation is confirmed by the substorm-related aurora and electrojet observations.

Relationship of magnetic reconnection and injections/dipolarizations

Sergeev, V. (St.Petersburg State University), M. Kubyshkina, S. Apatenkov, A. Runov, W. Baumjohann, R. Nakamura, T. Zhang, H. Eichelberger, A. Fazakerley, C. Owen, J.-A.Sauvaud, P. Daly, J. B. Cao, H. Frey, E. Georgescu, K. H. Glassmeier, K.-H.

Fornacon, H. Singer, G. Reeves, E. Donovan, and I. Mann **[Invited Talk; Wednesday AM]**

Excellent constellation of spacecraft on September 26, 2005 (Cluster to probe reconnection at 15 Re, and TC-2 and geostationary spacecraft to probe the inner region in the same meridional plane) observed several activations (pseudobreakups and multiple substorm onsets) whose onset times and positions were controlled by auroral observations (IMAGE)and ground network. Identification of magnetic reconnection pulses and related structures has been done using the advantage of two-scale Cluster configuration. We discuss the time delays and possible causal relationships between the phenomena involved taking the advantage of carefully reconstructed (data tuned)magnetic configuration and controlled activity pattern. The event is also very interesting because the magnetic configuration was very stretched (due to enhanced SW flow pressure) allowing the reconnection to occur at r<15Re, in the absence of strong loading of SW energy into the magnetosphere and under the weak ground magnetic perturbations. Implications for future THEMIS investigations are also discussed.

Spatio-temporal dynamics of substorms during intense geospace storms

Sharma, Surja (University of Maryland, Department of Astronomy, College Park, Maryland, USA), and Jian Chen **[Poster; Monday, Session I]**

The global, regional and local features of substorms arise from the wide range of spatial and temporal scales of the plasma processes and cross--coupling among them. Integrating these into a comprehensive model has been the objective of many studies. The global features are in general captured by the geomagnetic indices and the regional and local features are measured by spacecraft-based imagers and ground-based instruments. The global features of the magnetosphere have been studied extensively using nonlinear dynamical techniques, such as phase space reconstruction from observational data. The time series data of the distributed observations are used to develop spatio-temporal dynamics of the magnetosphere using phase space reconstruction techniques. In this approach the solar wind - magnetosphere coupling is modeled as an input-output system with the solar wind variables as the input and the ground-based magnetic field variations as the magnetospheric response. The magnetic field perturbations at 57 ground stations during the year 2002 and the corresponding solar wind data are compiled for this study. The ground magnetometer data are from the three chains of stations: CANOPUS (13), IMAGE (26) and WDC (18). This new data set, with 1-minute resolution, is used to study the spatio-temporal structure, including the coupling between the high and mid-latitude regions. A technique that utilizes the daily rotation of the Earth as a longitudinal sampling process is used to construct a two dimensional representation of the high latitude magnetic perturbations both in magnetic latitude and magnetic local time. The reconstruction removes the typical day-night variations and can be used to predict the spatial structure of substorms during periods of strong solar wind – magnetosphere coupling.

Ground and satellite observations of substorm onset arcs

Shiokawa, Kazuo (Solar-Terrestrial Environment Laboratory, Nagoya University), K. Yago, K. Yumoto, K. Hayashi, D. G. Baishev and S. I. Solovyev, F. J. Rich, and S. B. Mende **[Talk; Wednesday AM]**

Auroral features and associated particles and fields are investigated for three auroral substorms (pseudo-breakups) observed at 19-20 MLT on December 30, 1994 and October 24 and 31, 2000. We identified the substorms using Pi 2 wave packets, positive/negative H variations at mid-/high-latitudes, and auroral brightenings in auroral images obtained by a ground all-sky camera and by the IMAGE FUV imager. The DMSP satellites crossed brightening arcs during the Pi 2 pulsations in the field-of-view of the ground camera at Fort Smith (67 MLAT), Canada (event 1) and Tixie (66

MLAT), Russia (events 2 and 3). The crossings were 1-2 hours duskside of the main onset local time. The brightening arcs were located at the equatorward boundary of the region 1 current and in the sunward convection region. The arcs corresponded to inverted-V accelerated electrons. From these observations, we suggest that the arc brightening occurs in the inner plasma sheet at the inner edge of the region 1 current source in the sunward convection region.

Decrease in Bz prior to the dipolarization in the near-Earth plasma sheet

Shiokawa, Kazuo (Solar-Terrestrial Environment Laboratory, Nagoya University), Yukinaga Miyashita, Iku Shinohara, and Ayako Matsuoka **[Poster; Tuesday, Session 2]**

We examine in detail the rapid decrease in Bz just before dipolarizations observed by the GEOTAIL satellite in the near-Earth plasma sheet at (Xgsm, Ygsm) = (-8.3 Re, -5.1 Re). The observations were made using high-time-resolution data from a fluxgate magnetometer (16-Hz sample), a search-coil magnetometer (128 Hz), and an electric field antenna (64 Hz). Two dipolarizations were observed during a short time interval of 2 min. The magnetic Bz component suddenly decreased 2-4 s prior to the dipolarization. Characteristic waves with frequencies of 5-20 Hz and amplitudes of 1-3 mV/m and 5-15 nT/s were observed in the electric and magnetic field data at the time of the sudden decreases in Bz. We discuss two possible causes of the sudden decreases in Bz prior to the dipolarizations: (1) passage of a field-aligned line current associated with the substorm current wedge, and (2) explosive growth phase and subsequent disruption of the tail current caused by the observed characteristic field oscillations.

Substorm Research: A Biography with a Moral

Siscoe, George (Boston University) **[Invited Talk; Monday AM]**

Forty-two years ago Akasofu's landmark paper "The Development of the Auroral Substorm" gave birth to substorm research. Like every new field it began its career exploring options to see where progress might lie. After four years, Akasofu could list ten generic substorm theories. Soon one dominated invoking a three-step, tail scenario in which magnetic flux in the tail increased (by dayside magnetic merging with convection to the tail) until the associated intensifying of the cross-tail current reached some threshold at which magnetic reconnection in the tail ensued leading to rapid deflation of tail flux. This idea engendered an explosion of research pursuing variations on the theme but still within the basic 'slow build-up, reconnection onset, rapid deflation' paradigm, which is known as the 'near-earth neutral line (NENL)' paradigm. Then an ostensibly alternative paradigm emerged, 'slow build-up, current disruption, rapid deflation,' which changed the dissipation mechanism responsible for the rapid deflation and relocated the site of dissipation closer to earth. A controversy between advocates of the two paradigms ensued characterized by a protracted period focused on determining where dissipation began, the answer presumably would settle the issue of which is the operative paradigm. This period of conflict, from which the field has yet to emerge, has been a period of stagnation. Stagnation means that the field has been pursuing the wrong questions. A simple antidote is deliberately to turn to pursue other questions, many of which have been suggested but largely ignored: theories that incorporate external triggering in a fundamental way; global instabilities; sawtooth events in the context of a region-1 dominated magnetosphere; comparative substorm studies. If either paradigm that now consumes the research energy and resources of the field is correct, all other questions will ultimately lead to it as part of the solution.

The Substorm – Reconnection Connection:

Slavin, James A. (NASA GSFC) **[Invited Talk; Monday AM]**

The connection between auroral substorms and reconnection-driven changes in the tail has been the subject of intense study for about 30 years. In the late 1960's and 1970's substorms were found to be closely associated with the build-up and subsequent release of energy stored in the lobes of the tail and the expansion phase onset was often seen lobe preceded by thinning of the plasma sheet and its embedded current sheet. The 1980's brought definitive observations of the ejection of plasmoids, and their associated traveling compression regions (TCRs), were obtained and shown to be an integral part of the substorm process. The 1990's began with the discovery of the short-duration, high-speed plasma sheet flows, termed bursty bulk flows (BBFs), that dominate the earthward transport of energy and magnetic flux in the tail during substorms and the decade ended with new understanding of how BBFs cause "dipolarization" of the near-tail magnetic field and its subsequent expansion in local time and down the tail. Thus far, the 00's have seen our first definitive observations of small flux ropes, and their associated TCRs, in the near-tail in close association with auroral substorms. This "filamentation" of the thinned cross-tail current sheet strongly suggests that, rather than being caused by the immediate formation of a single "near-Earth neutral line", the earthward flow of energy in the growth phase and early in expansion phase of substorms may be due to the integrated effect of simultaneous reconnection at multiple X-lines. Further progress in our understanding of the substorm-reconnection connection during the rest of this decade is expected to be driven by the multi-point measurements to be returned by NASA's soon-to-be-launched THEMIS mission.

Auroral Secondary Ions in the Inner Magnetosphere

Sofko, George J. (ISAS, Univ. of Saskatchewan), Maskaz Watanabe, and Robert Schwab **[Talk; Thursday PM]**

Primary auroral electron bombardment of the auroral zone ionosphere leads to a substantial population of low-energy secondary ions. These ions reach energies in the range of tens to hundreds of eV, after undergoing both parallel and transverse acceleration. The ion motion is a combination of bounce and ExB drift on streamlines originating in the storm/substorm sector. Three distinct populations of these ions exist - SAPS (Sub-Auroral Polarization Stream)ions and DAPS (Direct Auroral Postive Stream) ions drifting on streamlines in the afternoon convection cell and MAPS (Morning Auroral Positive Stream)ions on streamlines in the morning cell. Satellite observations will be presented to illustrate these ions. The possible effect of these ions on inner magnetosphere shielding will be discussed.

Ground Based Observations of Dispersionless Electron Injections

Spanswick, E. (University of Calgary), E. Donovan, R. Friedel, and A. Korth **[Talk; Tuesday PM]**

The phenomenology of the substorm injection has been thoroughly studied with geosynchronous particle observations. Ground-based riometer absorption has been shown to be a good proxy for the integrated high energy electron flux near the equatorial plane, provided specific conditions are met [Baker et al., JGR, 86, 2295, 1981]. In recent work, we have shown that it is possible to use riometer absorption to identify dispersionless electron injections. Using the 13 riometer NORSTAR array we can observe the injection region simultaneously over 4 hours of local time and up to 10 degrees of latitude. In this paper we explore the spatial and temporal characteristics of the electron injection region, both on an event-to-event basis and in a statistical sense.

The sub-storm as revealed by the EISCAT radars

Stromme, Anja (EISCAT Scientific Association) **[Poster; Tuesday, Session 2]**

Over the last two solar cycles, the EISCAT radars have contributed substantially to our understanding of the near Earth space environment. A recent trend has been towards more continuous operation, including a month long run in September 2005, during which the tri-static EISCAT UHF system in northern Scandinavia and the EISCAT Svalbard radar (ESR) outside Longyearbyen, Svalbard, ran continuously as part of a 30 day 'World Day'. During this period a series of sub-storms occurred. We present this unique data set showing the different phases of the sub-storms observed, including the full vector velocities of the flows in the auroral zone by the EISCAT UHF system, and additional multi-point measurements by the ESR located in the polar cusp and the polar cap. The mechanisms available to access and utilize the EISCAT data will also be coverered, as well as plans for further extended operations, particularly associated with the International Polar Year.

Automatic classification of auroral images in substorm studies

Syrjaesuo, M. (Institute for Space Research, University of Calgary), Eric Donovan **[Talk; Tuesday PM]**

Measurements of physical quanta such as ion temperature, particle density or solar wind speed are commonly studied in substorm research. These measurements are used quantitatively in developing and verifying our understanding of the physics of the magnetosphere and the ionosphere. Ground-based all-sky images, however, are treated completely differently: the appearance of aurora is typically described by using a few subjective qualifiers. A description of a substrom as recorded by an all-sky imager (ASI) usually starts with "equatorward drifting arcs" which then brighten and transform into "dynamic auroras". We do this regardless of the fact that different auroral types clearly indicate different physics. Obviously, this approach is not the optimal use of the soon to be hundreds of millions of auroral images that are captured annually. We are developing computer vision methods that provide quantitative measures of the shape and appearance of the aurora in ASI images. Using numbers instead of more or less ambiguous verbal description makes it possible to consider images equivalent to other measurements. This makes it possible to use them in, for example, verifying MDH models outputs, proper statistical and time-series studies, and data retrieval and mining. In this paper, we review the current state of these modern analysis methods and provide a few simple examples based on CANOPUS All-Sky Imager data. In this talk, we discuss image content analysis and how it can be used to produce time-series of quantitative descriptors of auroral images.

Characteristics of optical and CNA arcs observed before auroral breakup

*Tanaka, Y.-M. (National Institute of Information and Communications Technology, Japan), M. Kubota, M. Ishii, Y. Monzen, Y. Murayama, H. Mori, and D. Lummerzheim** **[Poster; Tuesday, Session 2]**

We report a substorm event observed at 1930-2130 MLT on March 8, 2005 using the all-sky imager, the 256-element imaging riometer, and the meridional scanning photometer at Poker Flat, Alaska (65.11N, 147. 42W). A remarkable feature of this event is an existence of two arcs of cosmic noise absorption (CNA) during the growth phase. The high-latitude and low-latitude arcs corresponded to a discrete arc and diffuse aurora seen in the optical emissions, respectively. The NOAA-17 satellite passed across these CNA arcs at about thirty minutes before the auroral breakup and measured the corresponding enhancements of precipitating electron flux. The main observational results are summarized as follows. (1) The electron energy spectra showed the Maxwellian-like distribution for the high-latitude arc and the power-law distribution for the low-

latitude arc. (2) The low-latitude CNA arc was associated with the precipitation at the isotropic boundary. (3) The auroral breakup started at the low-latitude arc. (4) At about ten minutes before the breakup, new optical discrete arc appeared at the location of the low-latitude CNA arc, while the low-latitude CNA arc faded. These results indicate that the latitude at which this substorm was initiated was close to the isotropic boundary, and that the energy spectra of precipitating electrons at this location changed gradually from ten minutes before the breakup.

Observational signatures of self-organized critical behavior of multiscale geomagnetic disturbances

Uritsky, Vadim M. (Department of Physics and Astronomy, University of Calgary, Calgary, Canada), and Alexander J. Klimas **[Talk; Monday AM]**

Earth's magnetosphere is a complex natural system whose dynamics encompasses an enormous range of spatial, temporal and energetic scales ranging from small-scale kinetic effects to the large-scale phenomena dominated by the overall geometry of the magnetosphere and global relaxation times. The intermediate range of scales between these two extremes is filled with a variety of nonlinear processes in the near-Earth plasma whose superposition makes the magnetospheric dynamics fairly complex and essentially unpredictable. Statistical-physical principles underlying scaling organization of the magnetospheric complexity is the main focus of our study. Based on the analysis of an extended set of high-resolution auroral images provided by the UVI instrument onboard the POLAR spacecraft, we demonstrate that the multiscale high-latitude geomagnetic disturbances represented by complex spatial redistribution of the electron fluxes are, in fact, scale-free as they obey a number of well-defined power-law relations in spatial and temporal domains of data analysis. In addition our earlier observations (PRE, 2003; JGR, 2002; GRL, 2003, 2004), we report new results highlighting the scale-invariant organization of the geomagnetic activity using the method of the finite-size scaling analysis. We also show that the scaling exponents describing the revealed power-law relations are remarkably stable with respect to changes both in the global magnetospheric field topology and the solar wind conditions, which implies the existence of a universal stabilizing mechanism controlling the cross-scale coupling effects at different stages of the magnetospheric substorm developments. According to out interpretation, the observed effects are a manifestation of a collective behavior of multiple bursty localized reconnections in the plasma sheet following the scenario of self-organized criticality (SOC). We show that the SOC hypotheses is fully consistent with the obtained set of scaling exponent governing the statistics of high-latitude perturbations as well as with some well-known features of the geomagnetic activity lying outside traditional substorm models.

Modeling Framework for ULF Wave-Particle Interactions

Usanova, Maria (University of Alberta), Richard D. Sydora, and Ian R. Mann **[Poster; Thursday, Session 3]**

In this study, the interaction of charged particles with ULF waves in the magnetosphere is investigated by means of test-particle simulations. The dynamics of charged particles is described in three-dimensional coordinate space with a background dipolar magnetic field. Model electromagnetic wave perturbations are used to simulate the effects on the full particle Lorentz motion. We focus on the ULF waves in the Pc1 and Pc5 frequency ranges. In particular, the effects of ion ExB drift leading to temperature anisotropy in the Pc5 range, and to resonance effects and pitch angle scattering of ring current ions and MeV energy electrons in Pc1 ULF waves are considered. These Pc1 pulsations have timescales associated with ring current keV ion gyration and MeV electron bounce periods, respectively. The results obtained can be used for the interpretation of ground-based and satellite observational data, in particular to look for evidence of resonant wave-particle interactions. In the future, we are also planning to apply a particle-in-cell method to

examine the formation of temperature anisotropy and EMIC wave growth in the framework of self-consistent simulations.

The substorm response of the high-latitude surface geomagnetic field to solar wind input parameters, as modeled from meridional array measurements

Vassiliadis, Dimitris (ST at NASA/GSFC), Antti Pulkkinen, Alexander Klimas **[Poster; Thursday, Session 3]**

Ground magnetic field measurements are one of the fundamental ways to remote sense and monitor substorm development. The response of the magnetic field during substorms, as opposed to other types of convection effects, has been investigated in terms of auroral electrojet indices [Bargatze et al., 1985; Vassiliadis et al., 1995] and specific components of the surface field [Valdivia et al., 1999; Vassiliadis et al., 2002]. We present the impulse response of the three dimensional surface magnetic field as obtained from a data-derived dynamic model based on 27 magnetometers of the IMAGE array. The near-meridional distribution of the magnetometers is used to obtain a tomographic profile of the disturbance. We discuss the field response during isolated substorms and the great storms of October-November 2003. We quantify the model prediction error as a function of geomagnetic coordinates and activity level.

Impossibility of Calculating Magnetic Field Change From Current Disruption

Vasyliunas, Vytenis M. (Max-Planck-Institut fuer Sonnensystemforschung) **[Talk; Tuesday PM]**

The picture of the substorm current wedge, formed by visualizing the cross-tail current as reduced or disrupted and thus diverted through the ionosphere, provides a compact summary of the magnetic field changes observed during substorms. There has long been a tendency, however, to view current disruption as an actual explanation, not just a convenient representation, of the magnetic field changes - to search for some model by which first to predict the current disruption and then, as a consequence, to calculate the magnetic field dipolarization from the Biot-Savart integral over the reduced current. Formally, the time derivative of the magnetic field can be expressed as the Biot-Savart integral over the time derivative of the current density, which in turn can be calculated in principle by summing all the forces (weighted by charge/mass) on all the charged particles.In the resulting expression, the integrand includes an electric field term which can be transformed (by means of an integration by parts) into curl E. Thus, the time derivative of B cannot be calculated directly from the Biot-Savart integral because one term in the integrand contains the time derivative itself, and the contribution of that term is very large when the electron inertial length is small in comparison to the spatial scale of the system; instead, the time derivative of B must be calculated by solving what is now an integral equation. In the limit of small electron inertial length, the solution reduces to the curl of all the terms other than E; this is identical to the method described by Vasyliunas (Ann. Geophys. 23, 1347-1354, 2005) for obtaining the time evolution of B - determined directly by plasma dynamics through the generalized Ohm's law and not by the changing current (which cannot be calculated except as the time derivative of curl B).

Electron precipitation power during substorm: DMSP F6 and F7 spacecraft observations

Vorobjev, V. G. (Polar Geophysical Institute, Apatity, Murmansk region, Russia), and O. I. Yagodkina **[Poster; Thursday, Session 3]**

Auroral boundary positions and average electron precipitation flux in different regions obtained from the observations of DMSP F6 and F7 spacecraft have been used to examine the electron precipitation power during all substorm phases. The power contribution was found for an average substorm of about 400 nT intensity in all 3-hour sectors of MLT and separately for three different auroral regions: diffuse auroral zone (DAZ), structured auroral oval precipitation (AOP) and soft diffuse precipitation (SDP) poleward of the AOP. It is shown that there is a significant increase in precipitation power both on the day and night sides of the Earth during the substorm growth phase from the quiet level of about 0.7 GW to 1.2 GW in the 09-12 MLT sector and from about 0.8 GW to 2.6 GW in the 21-24 MLT sector, respectively. On the dayside the greatest energy is allocated in the DAZ in the final stage of substorm recovery phase. In pre-noon the maximum makes about 1.8 GW. On the nightside the greatest precipitation power is registered in the AOP during the final stage of substorm expansive phase with the maximum of about 15 GW in the pre-midnight. The shape, not concerning the value, of precipitation power distribution versus MLT strongly depends on substorm phases. In the DAZ region the peak in precipitation power occurs in the 06-09 MLT sector. In the AOP region the electron precipitation is more powerful on the dayside than on the nightside, while the opposite is held in the SDP region. One hemisphere global precipitation power was found to be about 9 GW, 19 GW and 61 GW for the quiet level, in the final stage of substorm growth phase and at the end of substorm expansion correspondingly. Our database of DMSP F6 and F7 observations makes it possible to calculate the average precipitation power for all substorm phases and any substorm intensity as determined by the AL index. Thus, the quantitative estimates of global power at the end of substorm expansion phase were about 30 GW for AL=150 nT and 140 GW for AL=1000 nT.

Externally Triggered near-Earth Breakup.

Voronkov, I. O. (Department of Physics and Astronomy, University of Calgary, Calgary, Alberta, Canada) **[Poster; Monday, Session I]**

Computer modeling is performed in order to explore a hypothesis stating that the near-Earth breakup can be triggered by a pulse of convection traveling earthward from the more distant magnetotail. The following possible scenario for the interaction of the burst with the near-Earth edge of the plasma sheet (PS) is revealed. The near-dipolar magnetic field topology of the inner PS leads to the flow braking which in turn launches a wide spectrum of dispersive compressional waves propagating further Earthward. However owing to rather low magnitude of these harmonics, it is unlikely that they can bring the near-Earth PS into unstable state, as several recent models proposed. Thus, the central point of this suggested model is that strong topological variations of the magnetic field at the inner edge of the PS, required by the equilibrium conditions, play a role of the resonant cavity for selected compressional modes. Growing resonance modes provide a ponderomotive force pumping up corresponding nonlinear ballooning eigenmodes. The latter extract energy stored in the inner PS and produce vortical structures expanding tailward.

Features of magnetosphere-ionosphere coupling at breakups and onset inferred from in situ and ground-based multi-instrument alignment.

Voronkov, Igor (University of Calgary), A. Runov, A. Koustov, K. Kabin, M. Meurant, E. Donovan, C. Bryant,and E. Spanswick. **[Invited Talk; Tuesday AM]**

*This talk is meant to complement the accompanying paper by Runov et al. We consider a sequence of activations which include pseudo-breakups, breakups followed by local (or inner plasma sheet) substorms, and full substorm onset using a fortunate multi-instrument coverage at 0300-0700 UT on September 15, 2001. For this period of time, there was a radial alignment of GOES, POLAR (~9Re), and Cluster (~19Re) at the near-equatorial magnetotail in the pre- and

near-midnight sector mapped to the Canadian zone covered by the IMAGE field of view along with fully functional hi-resolution photometers, magnetometers, and SuperDARN. This allows reasonable timing and featuring of auroral breakup and substorm onset components as they are observed both in the magnetosphere and ionosphere. We concentrate on the following features: - The auroral breakup along with dipolarization and explosive Pi onset in association with large (up to 1000 km/s) tailward flows and strong bipolar variations in the central plasma sheet seen by Cluster at ~19 Re; - A bifurcated current sheet and mid-tail reconnection along with the large scale surge formation at full onset.

Equatorial distributions of the plasma sheet ions, their electric and magnetic drifts, and magnetic fields under different IMF Bz conditions

Wang, Chih-Ping (Dept. of Atmospheric and Oceanic Sciences, UCLA), Larry R. Lyons, James M. Weygand, Tsugunobu Nagai, and Richard W. McEntire* **[Poster; Thursday, Session 3]**

To understand the nightside plasma sheet structure under different IMF Bz conditions, we have investigated statistically the equatorial distributions of ions and magnetic fields from Geotail when the IMF has been continuously northward or southward for shorter or longer than 1 hr. A dawn-dusk density (temperature) asymmetry with higher density (temperature) on the dawn (dusk) side is seen in the near-Earth plasma sheet during northward IMF, resulting in roughly dawn-dusk symmetric pressure. As southward IMF proceeds, the density asymmetry weakens while the temperature asymmetry maintains, resulting in higher pressure on the dusk side. The plasma sheet is relatively colder and denser near the flanks than around midnight. The flux distributions show that the density asymmetry is due to ions < ~3 keV and the temperature asymmetry is due to ions above thermal energy. The perpendicular flow shows that ions divert around the Earth mainly through the dusk side in the inner plasma sheet due to westward diamagnetic drift. The magnetic fields indicate that field-lines are more stretched during southward IMF. Ion's electric and magnetic drift paths evaluated from the observations show that, for thermal energy ions, magnetic drift is as important as electric drift. Comparison of the distributions of the observed phase space density with the evaluated drift paths at different energies indicates that the electric and magnetic drift transport is responsible for the observed dawn-dusk asymmetries in the plasma sheet structure.

Multifractional Brownian Motion Models of Substorms

Wanliss, James (Embry-Riddle University), and Dario Cersosimo **[Poster; Monday, Session I]**

Many previous studies have considered the onset of substorms to be related to critical phase transitions. We investigate the statistical properties of high-latitude magnetometer data for differing geomagnetic activity. This is achieved by characterizing changes in the nonlinear statistics of the Earth's magnetic field, by means of the Hurst exponent, measured from a single ground-based magnetometer station. We find that the time-series behaviour can be described a multifractional Brownian motion, thus suggesting the required statistical structure of the mathematical models of magnetospheric activity. We also find that, in general, the average Hurst exponent for quiet magnetospheric intervals is smaller than that for more active intervals, consistent with the picture of phase transitions.

Image Analysis and Modelling of Substorm Onsets

Wanliss, James (Embry-Riddle University), and Gordon Rostoker **[Talk; Tuesday AM]**

We have used the IMAGE database of several thousand substorms to investigate, in a statistical

fashion, the source region of the auroral arc that brightens at the onset of expansive phase. This arc is usually identified as the ionospheric signature of the expansive phase onset that occurs in the magnetotail. This is an extension of a previous study [Wanliss, AG, 2005] where the substorm onsets were identified via ground-based magnetometer and photometer data from the CANOPUS array. Various Tsyganenko global magnetic field models were used to map magnetic field lines from the location of the onset arc out to its greatest radial distance in the magnetotail. For the individual cases the results that we have found therefore do not favor the near-earth neutral line model or the current disruption model, but the average onset location is consistent with theories that place the onset location nearer the ring current.

Substorm onset location and the Harang discontinuity

Weygand, J. M. (Institute of Geophysics and Planetary Physics, UCLA), O. Amm, R. L. McPherron, K. Kauristie, Anja Koistinen, and H. Frey **[Talk; Thursday AM]**

In this study we investigate the relation of the location of the auroral substorm onset to the Harang discontinuity. With a database of over 4300 onsets determined from auroral images, we will statistically examine the MLat and MLT location of the onset with respect to the location of the Harang discontinuity as determined with data from the IMAGE magnetometer network. We define the location of the Harang discontinuity as the transition from eastward to westward currents at the latitude of the main auroral electrojet flow. This work addresses the question of whether the substorm onset occurs within the ionospheric Harang discontinuity as proposed by Lyons et al. [2003]. We find for about 130 events over the IMAGE ground magnetometer array, about 75% occur within 6 degrees of latitude of the Harang discontinuity. The remaining 25% do not appear to be associated with a Harang discontinuity. Of those remaining onsets, 50% display an expansion and recovery phase as well as a sharp decrease in the AL index as expected for a typical substorm, while the remainder did not clearly resemble substorms.

Five plus four equals nine: combining the THEMIS and Cluster missions

Wild, J. A. (Department of Communication Systems, Lancaster University) **[Poster; Tuesday, Session 2]**

THEMIS represents the most ambitious coordinated multi-spacecraft and ground-based programme ever attempted and it is expected that this mission will dramatically increase our understanding of the substorm process. In the years leading up to the launch of the THEMIS probes, the four-spacecraft Cluster mission has defined the state of the art in the field of multi-spacecraft/ground-based investigations of the geospace environment. Hitherto unprecedented coordination of space- and ground-based experiments have yielded multi-point (in situ and remotely sensed) measurements of magnetospheric structure and dynamics. The overlap of the Cluster and THEMIS missions presents an excellent opportunity to move the multipoint measurement technique to the next stage. Since the apogees of the Cluster and THEMIS satellites' orbits are separated by nearly 12 hour of local time, the synergy of these two missions and ground-based experiments will allow the detailed simultaneous observation of solar wind-magnetosphere-ionosphere coupling on both the day- and night-side of the Earth. Several experimental scenarios will be presented.

Ion pressure profiles during substorm

Wing, Simon (The Johns Hopkins University Applied Physics Lab), Jesper W. Gjerloev and Robert A. Hoffman **[Poster; Thursday, Session 3]**

Over 200 substorm events were carefully selected from observations made by Polar UVI, VIS, and an ensemble of ground instruments. Four substorm phases were defined, namely, growth, expansion, early recovery, and late recovery. 2-D ion pressure, density, and temperature profiles

inferred from DMSP satellite observations were constructed for each of these four substorm phases. There are roughly 140 events for which there were simultaneous DMSP observations. The growth phase profiles show that the ion pressure is higher in the inner edge of the plasma sheet. The premidnight pressure enhancement can be attributed to the temperature enhancement while the postmidnight pressure enhancement can be attributed to the density enhancement. The temperature enhancement at premidnight has been previously reported and attributed to the curvature and gradient drift of the ions. The postmidnight density enhancement may result from the enhanced convection. The profiles show that the ion pressure near the midnight meridian in the midtail region increases right after the substorm onset, during the expansion phase. The pressure subsequently declines during the early recovery phase and declines further during the late recovery phase, but the late recovery pressure is still higher than that of the growth phase. This near midnight pressure enhancement during the expansion and recovery phases can be attributed to both temperature and density enhancements. The 2-D pressure, temperature, and density profiles provide observational constraints to the competing substorm theories.

Substorm aurora and processes in the near-Earth magnetotail

Yahnin, Alexander (Polar Geophysical Institute, Apatity, Russia) **[Invited Talk; Tuesday PM]**

Although the auroral substorm has been long regarded as a manifestation of the magnetospheric substorm, a direct relation of active auroras to certain magnetospheric processes is still debatable. To investigate the relationship, we combine the data of the UV imager onboard the Polar satellite with plasma and magnetic field measurements by the Geotail spacecraft in the near-Earth magnetotail. In this report the results of the performed investigation are briefly reviewed. In particular, the poleward edge of the auroral bulge, as determined from the images obtained at the LHBL passband, is found to be conjugated with the plasma sheet region where the oppositely directed (tailward and Earthward) fast plasma flows are generated during substorms, that is, with the reconnection site. This implies that the magnetic flux through the auroral bulge is equal to the flux dissipated in the magnetotail during the substorm expansion. We demonstrate that this flux is comparable with the magnetic flux accumulated in the magnetotail before the substorm onset. Also, the area of the auroral bulge is proportional to the total (magnetic plus plasma) pressure decrease observed in the magnetotail. These findings are consistent with the reconnection model of the substorm and evidence the loading-unloading concept of the substorm development. Additionally, our analysis indicates that the source region of the bi-directional fast flows (that is, reconnection site) coincides with the region of the cross-tail current reduction, and the tailward propagation (or re-appearance) of the fast flow source is associated with the tailward shift of the current disruption front.

Long-term variations of the precipitation boundary b2i

Yahnina, T.A.(Polar Geophysical Institute, Apatity, Russia), A.G. Yahnin, D.A. Yahnin, P.T. Newell, and T. Sotirelis **[Poster; Monday, Session 1]**

The stretching of magnetic field lines in the near-Earth magnetotail is characterized by the latitude of isotropy boundary (IB) of energetic protons. In the DMSP satellite particle data, the IB is represented by a specific boundary called b2i. We use b2i values obtained in 1984-2004 for investigation of the long-term evolution of the magnetotail stretching. We show that during two solar cycles the annual average b2i latitude has a pronounced variation, which is governed by interplanetary parameters. According to this variation, the near-Earth magnetotail is more stretched during periods of enhanced merging electric field, that is, around the solar activity maximum. This agrees with recent results by Nagai et al. (2005) who found that reconnection in the magnetotail develops closer to (further from) the Earth during interval 1999-2003 (1995-1998). Two distinct

minima in March and October are clearly seen in the annual behavior of the b2i latitude. It means the magnetosphere is more stretched in spring and autumn. In addition, we show that correlation of b2i and geomagnetic activity indices Kp, AE, and Dst is higher than the correlation between the indices and interplanetary parameters.

''Matreshka'' model of multilayered current sheet

Zelenyi, Lev (Space Research Institute, Moscow, Russia), Surja Sharma, Helmi Malova, V.Yu. Popov, Dominique Delcourt, and N. Yu. Ganushkina **[Poster; Thursday, Session 3]**

Current sheets are one of the key elements of the Earth's magnetosphere, determining both it's global magnetic topology and mesoscale processes of magnetic energy storage and subsequent fast release. An analytical self-consistent model of multicomponent thin current sheets, where the tension of magnetic field lines is balanced by particle inertia, and plasma consists of ions both solar wind and ionospheric origin, is presented. The influence of electron population is taken into account assuming Boltzman- like quasi-equilibrium distribution of the electrons component in the ambipolar self-consistent electrostatic field, which can lead to a specific singular-like peculiarities of the sharp peak in the electron current density in the center of the current sheet. We include the contribution of non-adiabatic O+ ions in our model as one of the terms in the Grad-Shafranov-like system of equations describing the quasi-equilibrium configuration. The contribution of the oxygen ions to the total cross-tail current should not exceed 28% for realistic conditions, but current "wings" carried by O+ ions produce very noticeable significant broadening of the current profile. The dependencies of these effects on e, p and O+ temperatures, fractional density of O+ ions and the curvature of magnetic field lines are analyzed. This model predicts a mismatch between the current profiles obtained from the particle distributions and the curlometer data from the multispacecraft measurement, arising from the dominance of the ion cross-tail current in the outer regions of the current sheet motion and curlometer currents measured in experiments which could be partially resolved by taking into account the dominance of ion cross-tail current at the periferical regions of the current sheet. This effect persists even for small O+/H+ relative density.

Dayside Convection Changes Observed by SuperDARN during Sawtooth Events

Zou, S. (University of California, Los Angeles), L.R. Lyons, A. Boudouridis,and J. M. Ruohoniemi **[Poster; Tuesday, Session 2]**

Sawtooth events are oscillations of energetic electron and proton fluxes measured by geosynchronous satellites during magnetic storms. Those oscillations that are manifestation of substorms are selected and analyzed. Whether the individual substorm is triggered externally by appropriate solar wind change or internally by some instability is highly debated. Solar wind dynamic pressure enhancements during strongly southward IMF and IMF changes which lead to a reduction of convection are two possible triggers of these substorms. Onsets of IMF initiated substorms have decreases in dayside convection flow speed, while substorms triggered by dynamic pressure enhancements have increases in dayside convection speed. On the other hand, any events not externally triggered would be expected not to be associated with a change in dayside convection. We examine the dayside convection change observed by SuperDARN to see whether it is consistent with the external trigger type determined by global auroral images from the Wideband Imaging Camera (WIC) on the IMAGE spacecraft, low-latitude ground magnetic field measurements, and geosynchronous energetic particles. Of three sawtooth events during 2000 and 2001, there are 15 individual teeth that are manifestation of substorms and have usable dayside convection measurements. It is found that 10 out of 15 of these teeth have dayside convection changes consistent with the type identified by using the other tools. Furthermore, since IMF

changes and solar wind dynamic pressure changes usually occur at the same time, SuperDARN observations may help to tell which component¡¯s change is more geoeffective.