THE ACCELERATION OF IONS IN THE INNER PLASMA SHEET DURING A MAGNETOSPHERIC SUBSTORM

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During a magnetospheric substorm on March 1, 2008 the five THEMIS spacecraft were radially aligned in the plasma sheet just duskward of midnight, while the Cluster spacecraft were at perigee approximately 5Re above the auroral zone. The Cluster observations clearly show the presence of Velocity Dispersed Ion Structures (VDIS) as well as considerable ionospheric outflow. THEMIS P1 and P2 located at 23Re and 16Re in the tail observed evidence of reconnection prior to substorm onset [*Runov et al.,* 2008]. Shortly after onset THEMIS P3 and P4 located in the inner plasma sheet at 9.6Re and 8Re respectively observed large increases in energetic ions at energies as large as 500keV. We will present results from a study using large scale kinetic (LSK) simulations to investigate the source of the VDIS and the consequences in the plasma sheet of the ion outflow observed by Cluster. First we modeled the magnetospheric configuration by using our global magnetohydrodynamic (MHD) simulation code [El Alaoui et al., this meeting] then we launched both solar wind and ionospheric ions into the electric and magnetic fields from the MHD simulation. In the MHD simulation like the observations the substorm is driven by reconnection between 15Re and 20Re in the near-Earth tail. Ions from both the solar wind and ionosphere were accelerated by non-adiabatic motion in the induced electric fields resulting from the reconnection. These accelerated ions populated the inner plasma sheet and are consistent with the P3 and P4 observations.

RESPONSE OF THE DAYSIDE MAGNETOSPHERE TO AN ABRUPT CHANGE IN THE IMF DIRECTION: CLUSTER OBSERVATIONS AND GLOBAL SIMULATIONS

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Recent analysis of Cluster measurements on September 23, 2004 has shown for the first time the immediate effect of an IMF rotation on cusp particle precipitation observed by polar orbiting spacecraft [Escoubet et al., 2008]. During the event the four satellites crossed the polar cusp within 2-16 minutes of each other while the IMF rotated from a southward to a northward direction. The first two spacecraft observed typical IMF-southward ion dispersions, while the last one observed both an IMF-southward-like dispersion in the boundary layer and an IMF-northward dispersion in the cusp. We present the results of a global magnetohydrodynamic (MHD) / large- scale particle (LSK) simulation study of that event. First, we show that ion dispersions derived from large samples of ion trajectories calculated using the time-dependent electric and magnetic fields from the MHD simulation compare very well with the ion dispersions measured by Cluster during the event. We then examine the impact of the solar wind discontinuity on the topology of large-scale merging at the dayside magnetopause and discuss how these changes affect particle precipitation in the cusp.

A COMPARISON BETWEEN STANDARD AND CONSTRAINED MINIMUM VARIANCE ANALYSIS AT THE MAGNETOPAUSE WITH CLUSTER

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In order to compare the standard minimum variance analysis of the magnetic field (MVAB) with the constrained MVAB, where the average normal magnetic field is forced to zero, we investigated three Cluster magnetopause (MP) crossing events. In the first event the MP surface has a non-planar geometry, in the second event the MP behaves like a rotational discontinuity, while for the third event additional information on the MP normal can be obtained from the orientation of the adjacent boundary layer. The results provided by the two flavors of MVAB were further compared with those obtained from a multi-spacecraft method which is based on the times when each satellite detects the discontinuity. We found that the constrained MVAB provides more reliable MP normals, even for the second event when, by definition, the normal magnetic field cannot be zero. These results are explained in terms of the (often present) small scale magnetic fluctuations, that can severely reduce the accuracy of the magnetic variance computation for the standard MVAB, but have a smaller effect on the constrained MVAB.

A RE-ANALYSIS OF THE RELATIVE IMPORTANCE OF HALL AND FLUCTUATION-DRIVEN E-FIELDS DURING A SUBSTORM EXPANSION PHASE OBSERVED BY CLUSTER ON 22 AUG 2001

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Cluster observations of a breakdown of the ion "frozen-in" condition were reported by Lui et al. [JGR, 2007] who claimed that the quasi-DC electric field arising from correlated field fluctuations (<dEdn>) is larger than the Hall field (JxB/en) during the event in question, leading to the conclusion that anomalous resistivity plays a more significant role in substorm electrodynamics than do Hall terms. These Cluster observations were re-examined in the light of data from the THEMIS mission where Hall electrodynamics were found to dominate on the relevant spatial scales.

In this re-examination we find the following: 1) <dEdn> is smaller than stated in Lui et al. [2007], leading to a significant over-estimate of the electrodynamic impact of fluctuations; 2) the form used to compute the fluctuation-driven E-field is incorrect for situations with significant background flows and Hall currents; 3) the ion flow velocity is significantly underestimated due to the high energy of the plasma sheet relative to the plasma detector's range; 4) re-evaluation of the Hall term suggests that it is adequate, within measurement errors, to explain non-zero values of (E + VixB).

These issues with both the form of quasi-linear electrodynamical theory and the difficulties in making the measurements required to compare its predictions against observations are generic, and these issues will be summarized as well.

CHARGED PARTICLE ENERGIZATION BY CYCLOTRON RESONANT ACCELERATION IN THE MAGNETOSPHERIC CUSP

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New evidence reveals that the charged particles can be energized locally and efficiently in the magnetospheric cusp. The power spectral density of the cusp magnetic fluctuations shows increases by up to four orders of magnitude in comparison to an adjacent region. Large fluctuations of the cusp electric fields have been observed with amplitudes of up to 350 mV/m. The measured left-hand

polarization of the cusp electric field at ion gyro-frequencies indicates that the cyclotron resonant acceleration mechanism is working in this region. The cyclotron resonant acceleration can energize ions from keV to MeV in seconds. These new results represent a fundamental advance in scientific understanding of the dynamic processes in geospace.

MAGNETOSPHERIC CAVITY MODES DRIVEN BY SOLAR WIND DYNAMIC PRESSURE FLUCTUATIONS: INITIAL RESULTS FROM GLOBAL MHD SIMULATIONS

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We present initial results from Lyon-Fedder-Mobarry (LFM) global, three-dimensional MHD simulations of the solar wind-magnetosphere interaction. These simulations are driven with idealized solar wind input conditions, where we introduce monochromatic and broadband ULF fluctuations in the upstream solar wind dynamic pressure. These idealized solar wind input conditions allow us to study only the effect of a fluctuating solar wind dynamic pressure while holding all of the other solar wind driving parameters constant. We present a limited set of results from five LFM simulations: four driven by monochromatic upstream dynamic pressure fluctuations and one by quasi-broadband upstream dynamic pressure fluctuations. We show that these upstream solar wind dynamic pressure fluctuations directly drive dayside magnetospheric ULF pulsations, in a manner similar to that suggested by Kepko and Spence [2003]. Moreover, we show that when the frequency of the upstream dynamic pressure fluctuations matches one of the natural frequencies of the magnetosphere, magnetospheric cavity modes are excited near the noon meridian. Our simulations also suggest that only even mode number cavity modes are possible within the dayside magnetosphere. Finally, we discuss how satellite constellations may be used to directly observe magnetospheric cavity modes, which have thus far proved elusive in observations.

DIRECTIVITY ANALYSIS DURING CLUSTER TILT CAMPAIGN: 3D VIEWS ON RADIO WAVES

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Radio wave direction finding using the spinning dipole technique has been performed since many years. This technique is based on simple assumptions concerning the wave properties, yields ray path orientation in the spin plane. All published studies about remote sensing radio wave sources from one or several observatories result in 2D views of source positions, since the spin planes are in all cases parallel to each other, with spin axis generally directed along Z axis of the GSE frame. The tilt manoeuvre operated recently on one of the four CLUSTER spacecraft, while configured in a multiscale constellation, provides new information about propagation of radio waves observed. During a one month campaign, the spin axis of one of the spacecraft pair at ~50 km separation has been tilted by an amount of about 45°. We show that, by combining information from the two satellites, it is possible to test the validity of hypothesis considered in the direction finding method and to derive safely ray path direction in 3D. We present event cases of radio wave observations (NTC waves and '2 fp' radiation) from the multiscale Cluster constellation placed in the outer flanks of magnetosphere (magnetosheath and foreshock).

MAGNETOSPHERIC IMPLICATIONS OF ONSET AND BREAKUP

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Between 06:04 and 06:08 UT on March 5, 2008, an auroral onset and breakup occurred near magnetic zenith at Gillam, Canada. Unusually comprehensive observations of the auroral evolution were collected by a combination of instruments including a multi-spectral All-Sky Imager (ASI), Meridian Scanning Photometer (MSP), white-light ASI, and a narrow field of view white-light imager, all at Gillam, as well as the nearby CGSM wide-beam riometers. The multi-spectral ASI and MSP data show unambiguously that this onset occurred near the transition between tail-like and dipolar field lines. As well, the onset aurora exhibits essentially all of the onset auroral features displayed in numerous similar events as described in detail by Voronkov et al. [2000, 2003], Lyons et al. [2002], Liang et al. [2008], Liu et al. [2008], and Donovan et al., [2006, 2007, 2008]. In this presentation, we focus on the multi-wavelength optical observations in an attempt to elucidate the magnetotail counterparts to both the initial brightening and ultimate saturation (which we call "breakup") of this arc.

ON THE SCALING OF THE SUBSOLAR MAGNETOPAUSE PARALLEL ELECTRIC FIELD: RESISTIVE MHD THEORY

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Recently, Cassak and Shay [Phys. Plasmas, 14, 2007] applied two-dimensional MHD conservation laws to derive an analytic expression for the reconnection rate at Earth's dayside magnetopause. Borovsky [JGR, in press, 2008] used the Cassak-Shay formula as a starting point to derive a first principles solar wind-magnetosphere coupling function. Based on 3D MHD numerical experiments (using the BATSRUS global MHD code), Borovsky argued that dayside reconnection is not driven by the solar wind. Rather, the reconnection rate is determined by the local plasma densities and magnetic field magnitudes on the two sides of the magnetopause current sheet, consistent with the Cassak-Shay formula. However, due to the three-dimensional nature of the subsolar magnetopause flow, the relevance of the Cassak-Shay formula to dayside magnetopause reconnection is questionable. In this talk, we revisit the problem of determining the subsolar magnetopause reconnection electric field in the context of the resistive MHD equations. We derive an analytic expression for the parallel electric field at Earth's subsolar magnetopause, demonstrating that neither the popular Sonnerup-Gonzalez expression [Sonnerup, B. U. O., JGR, 79, 1974; Gonzalez, W. D. and F. S. Mozer, JGR, 79, 1974] nor the Cassak-Shay formula is relevant in 3D resistive MHD. In particular, our expression predicts that if the plasma resistivity is constant, the subsolar parallel electric field should scale like the fourth root of the resistivity. In contrast, the Cassak-Shay formula predicts a square root scaling when the resistivity is constant. In principle, THEMIS could be used to address this question by determining the amount of magnetic flux pileup upstream of the magnetopause current sheet under various conditions.

STATISTICAL STUDY OF NEAR-EARTH DIPOLARIZATIONS WITH THEMIS SPACECRAFT

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Properties of near-Earth (6-12 Re) dipolarizations and their spatial relationship with substorm current wedge (SCW) are addressed by making use of THEMIS and ground observations. SCW locations were reconstructed from mid-latitude magnetic field measurements. We have found that dipolarizations

are observed inside SCW longitudinal sector demonstrating their collocation in space. The comparison of THEMIS measurements just prior and after dipolarization has showed that plasma pressure increased in the course dipolarization. Attempts to estimate plasma tube entropy attracting models of magnetic field gave mixed results, possibly reflecting complicated structure of dipolarization region.

CONJUGATE RESPONSE OF THE DAYSIDE MAGNETOPAUSE AND DAWN/DUSK FLANKS USING CLUSTER-THEMIS CONJUNCTIONS AND COORDINATED GROUND BASED OBSERVATIONS

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We report the planned activities of a science working team recently sponsored by the International Space Science Institute in Berne. The nature of the interaction of the solar wind and associated magnetic field benefits from simultaneous coverage over a range of different magnetopause sites. Cluster-THEMIS conjunctions allow exploration of the conjugate response of the dayside magnetopause and dawn/dusk flanks through such coverage of the magnetopause. During the April to July 2007 epoch, the array of four Cluster spacecraft were separated at large distances (10,000 km), traversing the dawnside magnetopause at high and low latitudes. In conjunction with this coverage, the five THEMIS spacecraft were placed initially into a 'string of pearls' configuration, all lying on the same equatorial orbit and traversing the low latitude, dusk-side magnetosphere and flank magnetopause. In addition, the Double star, TC-1 spacecraft lies in an equatorial orbit between the local times of the THEMIS and Cluster orbits, near local noon. This combination of 10 spacecraft provides an opportunity to simultaneously monitor the dawn/dusk magnetopause behavior across the whole range of local times, simultaneously, and to probe IMF and solar wind controlled asymmetries. The distribution and grouping of spacecraft also allow multi-scale analysis of local phenomena operating on both flanks of the magnetopause, such as Kelvin-Helmholtz waves and formation of the plasma sheet; boundary layer extent to be monitored, and simultaneous dawn-dusk tracking of the signatures of sporadic reconnection.

THEMIS BURST MODE OBSERVATIONS OF RECONNECTION AND FLUX ROPES IN THE MAGNETOTAIL CURRENT SHEET: SITES OF ENERGETIC ELECTRON PRODUCTION

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THEMIS burst mode observations of reconnection and flux ropes (secondary islands) in the magnetotail, recorded on 26 February 2008 (11 – 12UT) are presented and analyzed. The burst mode observations show in new detail the substructure of the reconnection generated secondary island, including large electric field fluctuations and density variations. The
3D structure of the thermal electron distributions are discussed in the context of guide field reconnection. We also examine the distribution of energetic electrons through this event; although a number of theories and observations have been presented exploring the role magnetic reconnection plays in producing energetic electrons, the relative importance of these different theories is still unclear. The data are used to explore the relative importance of the different models.

OBSERVATIONS OF TURBULENCE GENERATED BY MAGNETIC RECONNECTION

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Spacecraft observations of turbulence within a magnetic reconnection (guide field ~ 0) ion diffusion region are presented. In the inertial subrange, electric and magnetic fluctuations both followed a -5/3 power law; at higher frequencies, the spectral indices were -1 and -8/3 respectively. The dispersion relation was found to be consistent with fast mode/whistler waves rather than kinetic Alfvén/ion cyclotron waves. Lower hybrid waves, which could be enhanced by whistler mode conversion, were observed but the associated anomalous resistivity was not found to significantly modify the reconnection rate.

MAGNETOTAIL CURRENT SHEET EVOLUTION DURING A SUBSTORM

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A magnetospheric substorm occurred on March 1, 2008 while the THEMIS spacecraft were in conjunction in the late evening magnetotail. This arrangement provided a suberb data set with which to investigate meso-scale structures in the plasma sheet. We have used a global magnetohydrodynamic simulation to investigate the structure and dynamics of the near-Earth tail current sheet during this substorm. Ground auroral observations have been used to identify an initial intensification of the substorm at 0148UT followed by the main onset at 0155UT [*Runov et al.,* 2008]. Earthward and tailward flows as well as flux ropes were found in both the observations and simulations. We will use our simulation results combined with the observations to investigate the global convection systems and current sheet structure during this event. We will show how meso-scale structures in the MHD simulations and observations fit into the context of the overall tail dynamics.

WHISPER/CLUSTER OBSERVATION OF (N+1/2) FCE EQUATORIAL EMISSIONS IN THE PLASMASPHERE REGION: SPECTRAL PROPERTIES AND STATISTICS

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Intense electrostatic emissions with frequencies between harmonics of the electron gyro frequency,

often referred to as (n+1/2) fce emissions, are routinely observed by the WHISPER instrument on board CLUSTER spacecraft in the plasmasphere region at magnetic equator crossing. WHISPER spectral analysis, added to multipoint CLUSTER capabilities, allows the frequency and intensity characterization of the emissions with a good resolution in frequency, space and time. This points out in particular the fine frequency structure of the emissions inside harmonic bands. Nonlinear wave decay, a possible explanation of this fine structure, is investigated via the study of observed low frequency waves. We present also a statistical study of (n+1/2) fce, using a data set covering the three years interval 2002-2004. Confinement to geomagnetic equator and MLT dependence are shown. Dependence of the intensity of the emissions to the MLT sector and to the closeness of observation with plasmapause boundary is revealed. This leads to an estimation of the occurrence and position of most intense emissions, i.e. at levels above the reference level quoted by several authors as meaningful for strong pitch angle diffusion of 100 eV to keV electrons, leading to their subsequent precipitation into the auroral ionosphere.

COLD PLASMA FLOW IN THE MAGNETOTAIL REVEALED BY CLUSTER EFW AND EDI

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Cold ionospheric ions (energy below a few tens of eV) in the tenuous magnetotail lobes are difficult to measure by particle detectors due to the high spacecraft potential (tens of volts). Consequently, few studies exist of plasma flows like the polar wind above a few thousand km altitude. By combining Cluster EDI and EFW data we can study the formation of a wake behind the Cluster satellites, to show the existence of cold plasma flows and to determine their flow velocity. Combining with plasma density from the spacecraft potential, we also get the ion flux. The database thus obtained vastly exceeds any previous study of cold magnetotail ions. We present maps of the cold ion density, velocity and flux in the tail lobes, showing that the cold plasma flows observed at a few thousands of km altitude continue at least as far as the Cluster apogee around 20 RE.

FTE DYNAMICS AND EFFECTS ON LOCAL AND REMOTE REGIONS NEAR THE DAYSIDE MAGNETOPAUSE RECONNECTION LAYER

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THEMIS observed several near-simultaneous bipolar signatures on 8 June 2007 during an outbound postnoon magnetopause (MP) crossing in its string-of-pearl configuration. We interpret each as a flux transfer event (FTE). Whether observed in the magnetosheath or in the dayside magnetosphere, each FTE is unambiguously linked to the MP layer and the northward reconnection exhausts for the steady southward IMF conditions. TH-C observed a bifurcated MP current as it traversed the active MP layer. This MP crossing was unique in that it lacked a clear FTE signature. A high-resolution MHD simulation (0.0626 RE) suggests that the bifurcation is generated temporarily in the wake of a passing FTE. The same MHD simulation suggests that all of the simultaneously observed FTEs can be explained in

terms of a single flux rope within the active MP layer and its remote effects on the dayside magnetosphere and the magnetosheath adjacent to the MP. Cold ions in the dayside magnetosphere with characteristic time-of-flight energy dispersions are likely one such remote effect of the passing FTEs in the nearby MP layer as indicated by the generation of a standing wave train in the normal component of the simulated plasma velocity (VN) and corroborated by the observed VN.

EVOLUTION OF ION DISPERSIONS OBSERVED BY CLUSTER IN THE POLAR CUSP

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On 23 September 2004 the 4 Cluster spacecraft were crossing the mid-altitude polar cusp within 2-16 minute from each other. The first two spacecraft, separated by about 1min 20s observed a typical IMF Bz-South ion dispersion, where the energy of the ions decreases as latitude increases. The dispersion was not smooth but presented discontinuities that were the same on the two spacecraft. Preliminary investigations showed that these discontinuities could be either explained as temporal or spatial structures. Another example of cusp crossing will be shown where the discontinuities and dispersions are very different on three Cluster spacecraft. The first spacecraft detected a step in the ion dispersion, the second a few minutes later a smooth dispersion and finally the last one showed a gap in the dispersion. It will be shown that the varying IMF conditions could be the source of these changes.

TWO-STAGE OSCILLATORY RESPONSE OF THE MAGNETOPAUSE TO A CURRENT/VORTEX SHEET FOLLOWED BY NORTHWARD IMF: CLUSTER OBSERVATIONS

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We discuss the motion and structure of the magnetopause/boundary layer observed by Cluster in response to a joint tangential discontinuity/vortex sheet (TD/VS) observed by the ACE spacecraft on December 7, 2000. The observations are then supplemented by theory. Sharp polarity reversals in the east-west components of the field and flow occurred at the discontinuity. These rotations were followed by a period of strongly northward IMF. These two factors elicited a two-stage response at the magnetopause, as observed by Cluster situated in the boundary layer at the duskside terminator. First, the magnetopause suffered a large deformation from its equilibrium position, with large-amplitude oscillations of about 3 min period being set up. These are argued to be mainly the result of tangential stresses associated with change in the east-west component of the flow, the contribution of dynamic pressure changes being small in comparison. This strengthens recent

evidence of the importance to magnetospheric dynamics of changes in azimuthal solar wind flow. The TD/VS impact caused a global response seen by ground magnetometers in an MLT range spanning at least 12 hours. The response monitored on ground magnetometersis similar to that brought about by magnetopause motions driven by dynamic pressure changes. Second, Cluster recorded higher frequency waves (about 79 s). Two clear phases could be distinguished from the spectral power density, which decreased by a factor of three in the second phase. Applying compressible, linearized MHD theory, we show that these perturbations are consistent with surface waves originating from the Kelvin-Helmholtz instability. Varying the local magnetic shear at the Cluster locale, as suggested by the temporal profile of the IMF clock angle, we find that locally stability was reinstated, so that the reduced power in the second phase is argued to be due residual KH activity arriving from locations farther to the dayside.

SIMULTANEOUS OBSERVATIONS OF FLUX TRANSFER EVENTS BY THEMIS, CLUSTER AND SUPERDARN

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We present simultaneous observations of flux transfer events (FTEs) made by the THEMIS and Cluster spacecraft on the 3rd May 2007, along with supporting observations of fast ionospheric flows made by the SuperDARN radar network. The THEMIS spacecraft were in a string-of-pearls formation approximately 20,000 km long, and crossed the post-noon magnetopause at low latitudes between 12:00 UT (TH-C) and 14:30 UT (TH-E). The Cluster spacecraft were in a triangular formation tangential to the magnetopause with a maximum separation of ~9,000 km, and were situated in the magnetosheath at high latitudes in the southern hemisphere, approaching the magnetopause which was crossed at about 16:00 UT. THEMIS observed 'standard' polarity FTEs between 11:00 and 15:00 UT, whilst Cluster observed 'reverse' polarity FTEs mainly between 13:00 and 14:00 UT. The two sets of FTEs are consistent with being generated at the same small region of a subsolar reconnection line. Fast poleward flows were observed in the 12:00 MLT sector, near the magnetic footprints of both Cluster and THEMIS, between 13:00 and 14:00 UT. However, there was no clear pulsing of the flow as might be expected at the ionospheric footprints of flux transfer events.

EVOLUTION OF KELVIN-HELMHOLTZ ACTIVITY ON THE DUSK FLANK MAGNETOPAUSE

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Our purpose is to characterize the evolution of the magnetopause Kelvin-Helmholtz (KH) wave activity with changes in thickness of the adjacent boundary layer, geomagnetic latitude and interplanetary magnetic field (IMF) orientation. As the IMF turns northward, wave activity may be generated at the dayside before propagating down the tail, where the boundary layer is expected to support longer wavelengths. We use two-point observations on the dusk magnetopause at low latitudes, from Geotail on the dayside and Cluster tailward of the dusk terminator. We quantify the wavelength, power, wave front steepness and propagation direction at Cluster. An estimate of the LLBL thickness is obtained by correlating normal distances to the magnetopause with a systematic relationship found between the electron number density and temperature; the correlation factor is used to infer the temporal evolution of the thickness of the locally sampled layer. We find that wavelengths are

controlled by the IMF clock angle, as expected when generated by the KH mechanism at the dayside, although amplitudes, wave front steepness and propagation directions are more closely correlated with the layer thickness. A survey of parameter space provides evidence of the contribution of the KH mechanism to the widening of the electron LLBL.

THEMIS ORBIT UPDATES PRIOR TO THE SECOND YEAR TAIL SEASON

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After more than 1.5 years in orbit the THEMIS constellation is well on track and all probes have collected a wealth of unprecedented science data. As the second series of major conjunctions is about to start soon, we will give an overview of the next tail and dayside seasons. Their goals are to enhance the quantity of the data for statistical studies and to complement the analyses of the current disruption and reconnection (tail) and of magnetopause and magnetosheath processes (dayside).

We will detail the variations of the P5 orbit with regard to the inner probe conjunctions and the increase of the neutral sheet conjunctions of the outer probes in the tail, which are at the center of the orbit design until October 2009. For this last year of the nominal THEMIS mission, we provide the season timelines, illustrate conjunctions along the orbits and with ground stations, and summarize end of mission estimates. Implementation of these goals will support effective data collection and analysis, and enhance collaborative studies with CLUSTER and other magnetospheric projects.

In order to support long term planning of coordinated science investigations with CLUSTER and ground networks other than the THEMIS GBOs we will further give an estimate of the orbit evolution beyond 2009.

PLASMASPHERIC PLUMES OBSERVED BY THE CLUSTER AND IMAGE SPACECRAFT

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Global IMAGE/EUV observations have revealed complex changes in plasmaspheric structures as the plasmasphere responds to geomagnetic activity while remaining under varying degrees of influence by co- rotation, depending on the radial distance. The complex plasmaspheric dynamics, with different scales of variability, is clearly far from being well understood. There is now renewed interest in the plasmasphere due to its apparent connections with the development of the ring current and radiation belt, and loss of ionospheric plasmas. Early in the mission, the Cluster spacecraft only crossed the plasmapause (L ~ 4) occasionally and made measurements of the outer plasmasphere and plasmaspheric drainage plumes. The study by Darrouzet et al. [2006] provided detailed analyses of in situ Cluster observations and IMAGE EUV observations of three plasmaspheric plumes detected in April - June, 2002. Within the next couple of years, Cluster orbit will change, causing perigee to migrate to lower altitudes, and thus providing excellent opportunities to obtain more detailed measurements of the plasmasphere. In this paper, we report our analyses of the earlier Cluster-IMAGE events by incorporating the different perspectives provided by the IMAGE Radio Plasma Imager (RPI) observations. We will discuss our new understanding of the structure and dynamics of the Cluster-IMAGE events.

TIMING AND LOCALIZATION OF NEAR-EARTH TAIL AND IONOSPHERIC SIGNATURES DURING A SUBSTORM ONSET

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On 16 February 2008, the THEMIS spacecraft (probes) bracketed the near-Earth signatures of a substorm onset, as identified in the THEMIS ground-based observatories. The main onset was associated with the formation and tailward release of a plasmoid (a proto-plasmoid) at XGSM = -18.3 RE, and a dipolarization at the inner edge of the plasma sheet at XGSM = -11.0 RE. The time history and geometry of the event in the tail is consistent with magnetic reconnection as the cause of the substorm expansion onset process. Two activations of the plasma sheet, evidenced by tailward streaming of energetic ions and southward or bipolar signatures of the magnetic field preceded the main substorm. The first activation was associated with an intensification of a streamer, while the second with the onset of ULF pulsations at mid- and low latitude stations. We conclude that near-Earth plasma sheet activity that may also be due to reconnection and may be related to non-substorm arc intensifications can precede substorm onset by several minutes. In particular, streamers do not appear to result in substorm initiation even though they may occur in close temporal and spatial proximity to the substorm arc.

WHAT EVERYONE SHOULD KNOW ABOUT INNER MAGNETOSPHERIC PHYSICS

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The radiation belts, ring current, plasmasphere, and ionosphere are linked together by various currents and fields, and comprise a system of complex, ever-changing, and self-modifying magnetized plasmas. The past several years have witnessed a surge in understanding about this system, thanks to exciting new observations from ground-based observatories, GPS, and imagers that have helped to put decades of local measurements into a larger context, and tie these measurements together with a coherent story. I will attempt to describe the state of the art of inner magnetospheric physics, and how Cluster and THEMIS can advance our understanding even further. Hopefully this will provide a helpful overview to guide the inner magnetospheric session of the workshop.

USING THE FOUR CLUSTER SPACECRAFT TO EXPLORE MAGNETOFLUID TURBULENCE

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We use the velocity moments computed from the four PEACE thermal electron plasma experiments on the Cluster mission to determine compressibility and vorticity in the magnetosheath and plasma. Assuming that the four spacecraft are not co-planar and that there is only a linear variation of the plasma variables across the volume defined by the four satellites, one can estimate the divergence and curl of the fluid velocity. Once the vorticity has been computed, it is possible to estimate directly the Taylor microscale and to find regions of enhanced dissipation in the magnetofluid. We will show results from data that were obtained in the solar wind magnetosheath and plasma sheet. In the latter two regions the background flow is usually less than the Alfvén speed so that the Taylor frozen-in-flow approximation cannot be used. This four spacecraft approach is the only viable method for obtaining the wave number properties of the ambient fluctuations.

THEMIS OBSERVATIONS OF EXTREME MAGNETOPAUSE MOTION CAUSED BY A HOT FLOW ANOMALY

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On October 30, 2007, the five THEMIS spacecraft observed the cause and consequence of extreme motion of the dawn flank magnetopause, with a normal magnetopause speed reaching 800 km/s, and displacing the magnetopause outward by at least 4.8 RE in 71 seconds. While the THEMIS-A, C, D, and E observations allowed the determination of the velocity, size, and shape of a large bulge moving tailward along the magnetopause at a speed of 355 km/s, THEMIS B observed a hot flow anomaly (HFA) upstream of the bow shock at the same time, indicating that the pressure perturbation generated by the HFA is responsible for the fast compression and expansion of the magnetosphere. No pressure perturbation was detected by ACE and Geotail in the pristine solar wind. This event demonstrates that kinetic (non-MHD) effects at the bow shock can have global consequences on the magnetosphere.

MULTIPLE ENERGY DISSIPATION SITES DURING SUBSTORM? A CASE STUDY ON THE MARCH 1ST, 2008 EVENT OBSERVED BY THEMIS AND GOES SPACECRAFT AND FROM THE GROUND

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We present a multi-spacecraft study of a substorm event which occurred during an active period around 01:45~02:05 UT on March 1st, 2008. Four THEMIS (E, D, C and B) and the GOES-12 satellites were aligned along the X-direction in the pre-midnight magnetotail at geocentric distances ranging from 6 and 23 Re. The susbtorm developed through two successive events observed by the most distant probe, th-C and th-B located downtail at 17 and 23 Re respectively. At these locations, both events exhibited similar feature, i.e., tailward flows associated with strong magnetic disturbances. In the near-Earth tail, no significant changes were observed during the first event. Conversely, the second tailward flow event was associated with magnetic turbulence, particle acceleration and plasma flow observed by the satellites located in the near-Earth tail. The timing analysis of this is difficult to conciliate with a history implying a single source but rather suggests multiple energy dissipation sites. This interpretation seems to be supported by optical aurora observations which exhibited a complex pattern including multiple structures.

IMPLICATION FOR PLASMA VORTEX DURING DIPOLARIZATION IN THE NEAR-EARTH MAGNETOTAIL

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The present study examines plasma flow patterns during dipolarization of the magnetic field, utilizing multi-point observations by the THEMIS spacecraft. The five satellites were situated in the near- Earth magnetotail on the dawn side (X = -5 to -9 RE, Y = 0 to -6 RE), separated within 2 RE distance. On 12 December 2007, the THEMIS five spacecraft observed magnetic field fluctuations including dipolarization at 0300 - 0330 UT. THEMIS and ground magnetometers saw at least three activations during the interval. During two of the activations, tailward flow was observed by a THEMIS probe simultaneously with the earthward flow that was observed by another THEMIS probe. The innermost probe at the radial distance of ~6 RE observed no clear flow during the activations. The observations imply that plasma vortex was formed near the inner edge of dipolarization regions. We also discuss likely signatures of the field-aligned currents that may be generated by the vortex, using magnetic field fluctuations on the ground as well as at THEMIS.

FLOW, PI2 AND AURORAL ASSOCIATIONS OBSERVED BY THEMIS

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Pi2 pulsations (T = 40-150s) are irregular magnetic field oscillations typically associated with transient reconfigurations of the nightsidemagnetosphere. A subset of Pi2 are observed at low-latitude and are typically believed to be manifestations of a plasmaspheric cavity-mode or, more recently, directly associated with periodic midtail plasma flow oscillations. In this paper we present events observed by multiple THEMIS spacecraft and geosynchronous satellites and analyze the events in the context of the different models of Pi2 generation. We further analyze the relative timing of these Pi2 with respect to auroral brightening, mid-latitude, transient response Pi2 and substorm current wedge formation.

MICROPHYSICS OF MAGNETIC RECONNECTION

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Magnetic reconnection leads to global changes of magnetic field topology and transfers energy stored in the magnetic filed to kinetic and thermal energy of plasma. Despite of the global character of the reconnection many important processes are happening at spatial scales comparable to ion scales and smaller. We present observations of microphysical phenomena related to magnetic reconnection in the magnetotail and at the magnetopause. In particular we concentrate on observations of electromagnetic fields of lower hybrid drift waves, Langmuir and electrostatic solitary waves in a vicinity of reconnection site, separatrix and jet braking region. We discuss possible relation of the observed phenomena to particle heating and acceleration.

DETERMINING THE RECONNECTION LOCATION AND THE RECONNECTED FLUX - APPLICATION TO THEMIS OBSERVATIONS

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A method based on an analytical time–dependent reconnection model is used to determine the location of the reconnection site and the amount of reconnected magnetic flux transported in the course of two substorms on February 2, 2008 at about 0200 UT and 0815 UT. During these events, THEMIS-B (P1) detected two tailward propagating TCRs associated with typical variations in Bz and Bx. We find the reconnection site to be located at about -16 RE for the event at 0200 UT and -17.5 RE for the event at 0815 UT, respectively. These locations are consistent with simple timing considerations with respect to disturbances detected by the inner THEMIS spacecraft. The amount of reconnected flux can be found to be in the order of 108 nT ·m for both events. The calculations for the reconnection site's location are done by using two approaches, i.e., by using the Bz and the Bx signal, respectively, yielding consistent results. The reconnected flux can be determined using Bz and vz, respectively. Also these results are in good agreement. A comparison between the disturbances detected by P1 and the modeled variations show that our model describes disturbances in the magnetic field and the background plasma very well.

O+ ACCESS TO THE PLASMASHEET DURING GEOMAGNETIC STORMS

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We present results of a study of ionospheric ion access to the plasma sheet during storms using CLUSTER ion composition data from the CIS instrument. Our earlier work on O+ in the plasma sheet has shown that O+ is significantly enhanced during a storm main phase. In studying the detailed timing of when the first indications of enhanced O+ are observed we find two types of events. In one type, the O+ increases simultaneously when a sudden increase in the dynamic pressure occurs, indicating a local acceleration of a cold population. In the other type, there is a 3-5 hour delay between the pressure increase and the observation of O+ in the plasma sheet, and a substorm occurs before the O+ is observed. However, the O+ increase is often well after the substorm onset. When the O+ is observed in the plasma sheet, O+ lobe beams are also observed, and the beams are contiguous across the plasma sheet boundary. We conclude that a major source for the O+ in the plasma sheet is the enhanced ion outflow from the cusp. This O+ is convected to the lobe, and then enters the plasma sheet when the lobe field lines reconnect.

ADJUSTED MAGNETIC FIELD MODELS AND MAPPING

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We test a few modifications to adjust a standard T96 magnetic field model to fit spacecraft magnetic observations at any particular time in order to reproduce small time - scale variations of magnetic fields during substorms. These modifications include different input data (magnetic field observations, pressure observations, lobe field estimations), different variable parameters and different currents systems. Particularly, we found that the magnetospheric tail tilt from sun-earth direction due tonon-radial solar wind flow (which is typically

ignored in case studies) strongly influence the data interpretation and mapping.

The adjusted models are used to study spacecraft mapping with respect to the observed auroral features (breakup) both in ionosphere and in magnetospheric neutral sheet. We discuss the differences in mapping resulting from different modifications, and possible sequences of magnetospheric configuration. We also compare the positions of observed and modeled isotropic boundaries. The possibility of a thin current sheet appearance in a process of a substorm is considered in the latest version of adjusted models, and we discuss the possible effect on mapping results as well.

THREE-DIMENSIONAL SIGNATURES OF INTERMITTENT MAGNETIC RECONNECTION IN GLOBAL SIMULATIONS OF DAYSIDE MAGNETOSPHERE DYNAMICS

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We performed high-resolution global MHD simulations of THEMIS dayside crossings events in May – June 2007. We found that magnetopause surface is not in steady-state even during extended periods of steady solar wind conditions. The so-called tilted reconnection lines become unstable due to formation of pressure bubbles, strong core field flux tubes, vortices, and traveling magnetic field cavities. The topology of FTEs differ from that in two dimension cartoons representing obliquely oriented quasi-2D flux rope. The structure of FTE is changing at spatial scales of 1 -2 Re. Closely located space probes can observe completely different signatures. Branches of bended flux rope can move in opposite directions. THEMIS and Cluster observations are consistent with signatures predicted by simulations.

USING THE THEMIS ENERGETIC PARTICLE DATA

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The THEMIS SST instrument measures energetic particles greater than 30 keV. This portion of the particle distribution can often provide a significant contribution to total particle distribution and should generally be included in moment calculations. In this presentation we discuss the importance of this data set as well as the pitfalls of using it. We will discuss the instrument calibration and its evolution in time as well as techniques to handle the sunlight contamination.

WHISTLER WAVE EMISSIONS OBSERVED BY CLUSTER AND THEMIS DURING SUBSTORMS

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The polar orbit with an apogee around 20 Re of the Cluster mission provided lots of current sheet

crossings in the region of the expected reconnection site. In 2003 the average distance between Cluster satellites was only about 200 km so less than the local ion inertial length (c/ωpi) or than the ion Larmor radius. Intense and short lasting (< 4 sec) quasi-parallel whistler wave emissions were recorded associated with the existence of very thin current sheets (< c/ωpi) as expected in the collisionless Hall reconnection model. More recently, the THEMIS mission finished its first substorm season in April 2008. Its equatorial orbit with various probe apogees from 10 Re to 30 Re is complementary of the Cluster polar orbit. THEMIS observations show that quasi-parallel whistler wave emissions are also detected in the near-Earth tail (7-10 Re) around local substorm onset. After summarizing these observations of whistler wave emissions during substorm from both missions we will discuss possible mechanisms of generation and implications for the substorm process.

CLUSTER OBSERVATION OF A REFORMING OBLIQUE SHOCK

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Quasi-parallel and quasi-perpendicular collisionless shocks are distinguished by significantly different morphologies and dissipative processes. Quasi-parallel shocks are thick in terms of any characteristic ion-scale and display a rich and unsteady substructure, while quasi-perpendicular shocks appear much thinner and until recently did not offer much observational evidence of a possible intrinsically non-stationary behavior. On 16 March 2005, the Cluster spacecrafts crossed a shock almost at the transition between the quasi-perpendicular and quasi-parallel regimes preceded by an upstream low-frequency (~ 0.02 Hz in the spacecraft frame) wavetrain observed for more than 10 min. At roughly a wavelength away from the main shock ramp a feature is found to steepen and grow to shock-like amplitudes, offering insight into a reformation mechanism of oblique shocks.

COLD DENSE MAGNETOPAUSE BOUNDARY LAYER UNDER NORTHWARD IMF: RESULTS FROM THEMIS AND MHD SIMULATIONS

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A layer of nearly stagnant cold dense plasma is observed by THEMIS spacecraft on a closed field region immediately inside the dayside magnetopause near the low latitude boundary layer on 3 June 2007. Using the OpenGGCM global MHD magnetosphere numerical model, we successfully reproduce this observed cold dense plasma layer in the simulation. The simulation results show that reconnection first occurs poleward of the cusp in the northern hemisphere, creating new open field lines extending southward and forming an open field layer; then subsequently occurs in the other hemisphere, creating new closed field lines that capture the magnetosheath plasma and form the dayside cold dense plasma layer. In this event, the open layer and the skin of the cold dense plasma layer have a southward tangential flow while the inner part of the cold dense plasma layer has a more stagnant and more turbulent flow.

O+ ION TRANSPORT FROM THE CUSP TO THE PLASMASHEET

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We present results of a statistical study of the occurrence of O+ beams based on five years of CLUSTER CODIF data. Using an automated procedure to identify when O+ beams are observed, we have developed a data base that gives the occurrence of the O+ beams, their flux, and energy as a function of position for geomagnetically quiet

and storm times. The data set clearly shows the transport of the O+ from the cusp, over the polar cap, and into the tail lobes. The highest percentage of beams are observed during storm main phase, and they are most likely to reach the ~20 Re plasma sheet during this time, where they can enter the plasma sheet through reconnection. The energy of the beams increases from the cusp to the plasma sheet. Finally, the ion beams from the northern cusp are transported to the tail predominantly towards dawn, while the southern beams are transported predominantly towards dusk. Further work will look for the dependence of the transport on solar wind and IMF conditions.

DETERMINATION OF THE SUBSTORM INITIATION REGION FROM A MAJOR CONJUNCTION INTERVAL OF THEMIS SATELLITES

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We investigate in detail the time history of substorm disturbances in the magnetotail observed during a major tail conjunction of THEMIS satellites. During this interval, all THEMIS satellites were closely aligned along the tail axis near midnight and were bracketed in local time by GOES 11 and 12. The radial distance covered ranges from the geosynchronous altitude to ~30 RE in the tail. This interval consists of three activations detected by the THEMIS satellites with good ground all-sky-camera observations of auroral activity. The first activation is a small substorm with spatially limited disturbance in the tail. The onset arc was equatorward of an undisturbed arc. The second activation is a moderate size substorm with the onset arc also being equatorward of an undisturbed arc. The third activation is an intensification of the substorm with its onset indicated by the second activation. The active auroral arc for this intensification was near the poleward boundary of the auroral oval. Analysis of these observations indicates that (1) the first activation is a small substorm initiated by current disruption in the near-Earth plasma sheet and does not involve magnetic reconnection of open magnetic field lines, and (2) the second and third activations are part of a moderate size substorm initiated also in the near-Earth plasma sheet, with a subsequent substorm intensification involving activity initiated tailward of ~30 RE.

THEMIS OBSERVATION OF A SUBSTORM EVENT ON 4:35, FEB 22, 2008

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We report on THEMIS observations during a substorm between 0430~0450 UT on Feb 22, 2008. The spacecraft were aligned along the tail from X=-5 RE to -25 RE GSM. The most distant probe P1 (X=-24.5 RE) detected two successive tailward moving structures with different particle arrival times for different energies. P2 (X=-18 RE), P3 (X=-11 RE), P4 (X=-10.5 RE) and P5 (X=-6 RE) all captured the signatures related to the earthward movement of the structure. THEMIS ground stations and all-sky

imagers also captured Pi2 pulsations and aurora sudden brightening. We perform a detailed analysis of spacecraft and ground-based data and reconstruct the time line of this substorm event. The earliest sign of substorm onset was the Pi2 onset at 04:36:10UT observed by the Gillam ground magnetometer. However, a North-South magnetic bipolar perturbation (interpreted as the result of reconnection onset) was captured by P1 at 04:35:16UT and correspondent magnetic perturbation was also captured by P2 at 04:35:14UT. Aurora onset was seen at or before 04:36:18UT, the same time as the high-latitude Pi2 onset. The flow onset at P3 and P4 are ~04:36:03UT, after the onset time of P1 and P2 but before the ground signature onset. While the dipolarization time on P3 and P4 are ~04:36:50UT, later than the ground signature onset time. The magnetic perturbation at P5 was also after the ground signature onset. Reconnection in the tail preceded ground onset by 60~80 seconds, and also preceded near-Earth dipolarization (current disruption) by ~2 minutes. The time line of this event is more consistent with reconnection model of substorm onset.

CHARACTERIZATION OF ULF PULSATIONS IN THE INNER MAGNETOSPHERE BY THEMIS

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We will present a case study of the characterization of ULF pulsations on 09/04/2007, when THEMIS was going through the inner magnetosphere in the dawn sector. After crossing the plasmapause, clear ULF fluctuations were observed by THEMIS-D, initially at ~25 mHz, gradually dropping to ~4 mHz near the magnetopause. By plotting the poloidal versus the toroidal components of the electric field data, it is suggested that the polarizations are primarily radial between r = 4 and 6 R_E, mostly azimuthal from ~6 R_E to ~8 R_E, and turn to radial again at ~9R_E, near the region where THEMIS-D crosses the magnetopause. These observations of polarization signatures are compared to the model estimated polarizations of field line resonances simulated by Rankin et al. (2006) and Kabin et al. (2007). The observed pulsations are found to have similar spatial characteristics; the differences between model and observed polarizations are discussed. Statistical studies of the polarizations of ULF pulsations will also be presented, based on the spin-fit electric field data of a large number of orbits from July 2007 to June 2008, with full local time coverage. Preliminary analysis indicates that the polarizations are more radial in dawn/dusk sectors and more azimuthal in noon/midnight sectors.

FIELD-ALIGNED CURRENT SYSTEMS AND MOMENTUM TRANSFER IN THE HIGH- LATITUDE BOUNDARY LAYER

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Recently we have discovered a class of events in which momentum transfer from the solar wind to the magnetosphere is maintained on "old" (i.e., previously reconnected) open field lines during intervals when the interplanetary magnetic field has a strong Y component. This momentum is carried into the high-latitude boundary layer via Alfvén waves and flux transfer events, and thence to the ionosphere via a pair of field-aligned currents located poleward of the auroral Birkeland current system. In this paper we examine the global nature of this phenomenon through observations with Cluster, FAST, DMSP, and ground-based measurements.

A POSSIBLE ALTERNATIVE INTERPRETATION OF THE SUBSTORM EVENT PUBLISHED IN THE SCIENCE MAGAZINE

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The THEMIS mission aims to examine the validity of the outside-in model invoking magnetic reconnection and the inside-out model invoking current disruption for accurate description on the chronology of substorm onset phenomena. Angelopoulos et al. [2008] reported a substorm event on 2008 February 26 that indicates tail reconnection triggering substorm onset. We present additional observations for this event to show that the case at best is ambiguous in differentiating the two possibilities. We also point out some aspects of the reported observations that are inconsistent with the outside-in model.

ALFVÉN WAVE PROPAGATION AND THE TIMING OF SUBSTORM EVENTS

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A major goal of the THEMIS mission is to establish causal relationships between events occurring in various regions of the magnetotail during substorms. Achievement of this goal requires an understanding of convection and wave time scales in this region. The propagation of fast and shear Alfvén waves in the tail is complicated by their coupling at gradients in the Alfvén speed, which are ubiquitous in the tail. In particular, fast mode waves in the plasma sheet can couple with shear waves on the plasma sheet boundary layer, leading to higher propagation speeds than would be expected from wave speeds in the plasma sheet itself. Application of these ideas to the 26 Feb 2008 event discussed by Angelopoulos et al. (Science, 2008) and possibly other events will be considered.

RADIATION BELT AND INNER MAGNETOSPHERE SCIENCE WITH THEMIS AND CLUSTER

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THEMIS probe passes through the electron radiation belts enable high cadence cuts of phase space density as a function of L to be provided by the collective satellite constellation. These high cadence cuts will enable an examination of the evolution of PSD profile response to VLF and ULF wave fields in the magnetosphere, the waves being monitored locally at the probe or provided by ground arrays and partner satellites. Similarly, ground measurements of energetic particle precipitation magnetically conjugate to the probes may also allow innovative studies of radiation belt particle loss due to wave scattering into the atmosphere. Significantly, the combination simultaneous plasmasheet and inner magnetosphere monitoring by Cluster and THEMIS, respectively, is unprecedented enabling an examination of the plasmasheet source for inner magnetosphere particle populations. Contemporaneous monitoring in the solar wind, sheath, at the magnetopause, and internal to the magnetosphere also offers the capability to diagnose ULF wave excitation, whilst electron flux modulations potentially offer a "smoking gun" for periods of intense ULF wave-MeV electron coupling. The combined THEMIS-Cluster constellation offers an important opportunity to further examine radiation belt dynamics in advance of the launch of the NASA RBSP and Canadian ORBITALS radiation belt missions.

Angelopoulos, V., et al. (2008), Tail reconnection triggering substorm onset, Science.

CLUSTER OBSERVATIONS OF CONCENTRATED LOAD AND GENERATOR REGIONS IN THE PLASMA SHEET

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Although the plasma sheet behaves, on average, as a load, a close examination of E.J (with E the electric field and J the current density) reveals that this load is rather structured. A thorough inspection of the Cluster plasma sheet data from 2001, at 16-20 terrestrial radii, resulted in a set of concentrated load regions (CLRs, E.J>0), and a smaller, but still significant set of concentrated generator regions (CGRs, E.J<0). As expected, in CLRs the energy conversion is more intense, and the dominant contribution to E.J is provided by EyJy. The weaker correlation between E.J and EyJy, together with a preferred location towards the plasma sheet boundary layer, indicate the more fluctuating character of the CGRs. Both the CLRs and the CGRs are typically associated with bursty bulk flows, on average faster and hotter for CLRs, consistent with the source/sink of bulk kinetic and thermal energy in CLRs/CGRs. Other systematic differences between CLRs and CGRs will be also discussed. The possible extension of the investigation to the three-satellite THEMIS data from the current disruption region, in collaboration with ground and/or low altitude observations, will be addressed as well.

A CLUSTER LOOK AT PLASMASPHERIC NOTCHES

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Notches are one of the largest density features in the exterior boundary of the plasmasphere. They are characterized by deep density depletions that extend mostly radially inward to L=2 or less and up to 3 hours MLT in size. Significant advances in our understanding of this phenomenon have been achieved thanks to the IMAGE satellite and its extreme ultraviolet (EUV) imager. However, interior notch densities often fall under the EUV noise level. A case study of the four Cluster satellites flying through a notch captured by IMAGE for hours before the crossing will be presented, enabling in-situ density estimations and showing whistler-mode waves amplification within. A possible role of these waves in the radiation belts dynamics will be discussed.

STORM-TIME ELECTRIC FIELDS IN THE INNER MAGNETOSPHERE MEASURED BY CLUSTER

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We analyze storm-time electric fields in the inner magnetosphere measured by Cluster with a database longer than 5 years. Superposed epoch analysis with an epoch at Dst minimum is performed. Statistical analysis is useful for Cluster data analysis because electric fields in the inner magnetosphere are measured only during a fraction of orbital periods (several hours within 57 hours). Dependences of electric fields on epoch-time, L value, and magnetic local time are examined. This type of study is useful to reveal storm-time electrodynamics such as ionospheric shielding and subauroral phenomena and eventually to improve our empirical modeling.

CLUSTER OBSERVATIONS OF FAST SHOCKS IN THE MAGNETOSHEATH LAUNCHED AS A TANGENTIAL DISCONTINUITY WITH A PRESSURE INCREASE CROSSED THE BOW SHOCK

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The interaction of a tangential discontinuity (TD) and accompanying dynamic pressure increase with the Earth's bow shock launches a fast shock that travels ahead of the TD in the magnetosheath and caries a significant portion of the pressure change. In this event study we use observations from the Cluster spacecraft and MHD simulations to identify the fast shock and its properties and to track the TD in the magnetosheath. Velocities of the fast shock and the TD were determined by triangulation using the four, distant, Cluster spacecraft. The fast shock is a planar structure, traveling nearly perpendicular to B at the magnetosonic speed in the plasma rest frame. Changes in density and |B| are correlated, with about a 20% increase in each. A current was observed tangential to the plane of the fast shock, and the positive E • J there provided an electromagnetic energy source for the observed heating of the ions. The fast shock is generated by the pressure change and determines the timing of the initial response of the magnetopause to that change. Velocities of a fast rarefaction wave, reflected from the magnetopause, and an additional slow mode structure were determined by triangulation.

MEASURING THE DEVIATIONS FROM THE FROZEN-IN CONDITION DURING SUBSTORM DIPOLARIZATIONS

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THEMIS electric and magnetic field measurements are combined with ion flows determined from the plasma and energetic particle instruments to investigate deviations from the ion "frozen-in" condition (E + VixB = 0) during geomagnetic substorms. It is found that the vast majority of ion flows during inner-magnetospheric dipolarizations can be classified as "frozen-in" within measurement uncertainties. In an unanticipated result, the largest deviations from frozen-in are found at the end of the substorm growth phase as the plasmasheet thins, rather than during the dipolarization process. Plasmasheet thinning results in an increased current density which manifests itself as an increasing ion flow in the duskward direction. This duskward flow is the result of the ion pressure gradient and has no associated electric field. Applying these measurements to the generalized Ohms Law, it appear that the non-zero "VixB" term that we measure during growth phase is just that portion of the Hall term, JxB/ne, which results from ion motion in the cross tail current. Deviations from the frozen-in condition are also found for brief periods during the dipolarization process, with the largest deviations generally associated with ion pressure gradients, and therefore likely due to similar diamagnetic currents.

OVERVIEW OF SPDF DATA AND SERVICES SUPPORTING THEMIS AND CLUSTER ANALYSIS

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The Space Physics Data Facility (SPDF, http://spdf.gsfc.nasa.gov) multi-mission active archive serves extensive holdings of current THEMIS and Cluster data and orbits, in a unique combined context with most other active heliophysics missions. Services of special relevance include CDAWeb graphics, listings and file downloads; SSCWeb orbit plots, listings, and conjunction queries; and a Java-based 3-D interactive animated orbit viewer. SPDF data and orbit are accessible both through standard browser

pages and via callable APIs for easy incorporation into other clients and applications. SPDF also supports and distributes the CDF format and software, a data standard used by THEMIS, Cluster and many other missions. In our presentation and associated demonstrations, we will illustrate the extent of the data now served and the capabilities of our various services, as well as discussing our future direction and evolving role in the international heliophysics data environment.

DISRUPTION OF THE INNER EDGE OF THE TAIL CURRENT BY EARTHWARD FLOW BURSTS

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Turbulence in the equatorial magnetic field 8 and 12 Re behind the Earth near midnight is known to be associated with the onset of the substorm expansion phase. It has been suggested by many researchers that this turbulence is some intrinsic instability of the inner edge of the tail current sheet. They postulate that convection and current sheet thinning during the substorm growth phase produce conditions allowing instability to develop. An alternate hypothesis is that the turbulence is created by the arrival of a fast plasma flow from the midtail region produced by magnetic reconnection. We use observations from five THEMIS spacecraft during a major conjunction on February 26, 2008 to study possible causes of this turbulence. For two events that occurred during extremely weak electrojet activity we show that the turbulence begins after the arrival of a fast flow. Furthermore, Pi 2 activity at the foot points of the spacecraft is delayed relative to the arrival of the flow and the onset of turbulence. In a separate paper by members of the THEMIS team it is demonstrated that these flows are produced by X-lines Earthward of 23 Re. We support this conclusion with data from several other events observed during THEMIS conjunctions.

ONSET SIGNATURES AND SUBSTORM TIMING FROM THE THEMIS SATELLITE AND GROUND BASED OBSERVATIONS

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The NASA Time History of Events and Macroscale Interactions during Substorms (THEMIS) project is intended to investigate the major instability leading to the substorm energy release into the auroral atmosphere. In this paper we review the ground based signatures of the substorm onset from the THEMIS ground based all-sky imagers and magnetometers and examine their timing related to the occurrence of substorm signatures at the THEMIS satellites. The array of stations consists of 20 all-sky imagers and 30 plus magnetometers deployed in the North American continent from Alaska to Labrador. Each ground based observatory contains a white light imager taking auroral images at a 3 second repetition rate and a magnetometer that records the 3 axis variation of the magnetic field at 2 Hz frequency. The unprecedented time and spatial resolution combined with large area coverage allowed us to define the various substorm pre-

cursor signatures leading to the onset of the major auroral energy release and the poleward and equatorward expansion of the aurora. These signatures are discussed in terms of three substorm examples that occurred in the time period between 06 and 09 UT on the 2nd of February 2008 while the THEMIS satellites B, D, E and A were located in the tail of the magnetosphere at approximately 29.6,11, 11 and ~8Re down-tail distance (GSM) respectively. Although the satellites were outside of the plasma sheet they observed clear magnetic signatures associated with each substorm event. Assuming that these magnetic signatures propagated out from a single initiation point along the –X GSM axis the location of the onset points and the associated time of onset was derived for each substorm.

BEHIND THE SCENES LOOK AT THE VIRTUAL MAGNETOSPHERIC OBSERVATORY

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The Virtual Magnetospheric Observatory (VMO; http://vmo.nasa.gov) is one of the discipline-specific Virtual Observatories (VxOs) that aim to absolve scientists of the mundane aspects of finding research-relevant data by developing a distributed data environment with a search engine operating on SPASE metadata. The data search feature is the most prominent function of the VMO as we will demonstrate here but we will is also discuss a number of other important tasks performed 'behind the scenes' that enhance the utility and accuracy of returned results. For example, complete and comprehensive metadata both enable data searching and provide users with detailed description of found products. Data producers (e.g., the THEMIS team) provide the VMO with a guidance on data quality so the best data products from each experiment are given preference. The VMO also daily checks for new or modified data files and updates its repository index accordingly. Therefore, data obtained through the VMO are the best and most up-to-date according to the VMO and data producer teams.

ARE SHOCK NORMAL FLUCTUATIONS ACCOUNT FOR FAB THERMAL ENERGY?

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Although foreshock Field-aligned Beams (FABs) have been studied extensively, a comprehensive production mechanism model that accounts for their physical properties has yet to be fully developed. Recent Cluster-CIS observations have recently revealed that FAB velocity reduced distribution functions are organized into two categories: those with a nearly Maxwellian profile and those exhibiting enhanced high energy tails. In this presentation, we will emphasize on the parallel reduced distribution function and address the question of how its width (or temperature) is produced. Assuming that the ions are produced in a reflection mechanism, we examine the impact of a randomly variable shock normal direction on their velocity distribution. The resulting probability distribution function shows features that are similar with those associated with the FABs. A quantitative agreement with the observations is best reached for amplitude fluctuations in order of few degrees in the shock normal direction. This preliminary study hints to the impact of shock nonstationarity on the shape of the FAB distribution functions.

REMOTE SENSING OF LOCAL STRUCTURE OF THE QUASI-PERPENDICULAR EARTH'S BOW SHOCK BY USING FIELD-ALIGNED BEAMS

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An important population of reflected ions that originates at the Earth's quasi-perpendicular bow shock is field-aligned beams (FABs). The bulk velocity of these FABs depends significantly on the so-called shock normal angle, which is the angle between shock normal and upstream interplanetary magnetic field (IMF). This dependency may therefore be taken as an indicator of the local structure of the shock. Applying the direct reflection model to Cluster measurements, we have developed a method that uses proton FABs in the foreshock region for remote sensing of the local shock structure. The multi-spacecraft mission Cluster II also provides multi-point measurements to study the shock dynamics in detail. After combining FABs and multi-spacecraft timing analysis, a comparison of a surface wave model with the observations shows good agreement.

TERRESTRIAL AKR CHARACTERISTICS DETERMINED FROM CLUSTER: IMPLICATIONS FOR JOVIAN PLANETS AND STELLAR CMI SOURCES

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We investigate how recent studies of electron-cyclotron maser (ECM) growths rates for shell distributions (Mutel et al. 2007) and Cluster-based determination of terrestrial AKR angular beaming patterns (Mutel et al. 2008) may be applied to studies of ECM emission from the magnetospheres of the Jovian planets and from certain cool M-dwarf stars. We discuss how both similarities and differences in the plasma environment in these systems compared with the Earth will influence the CMI emission, especially the expected angular beaming. For that case of Jupiter's DAM, we suggest that previous interpretations of a loss-cone mechanism to explain the non-zero angle of the k-vector from the B-field normal direction are difficult to reconcile with the much larger growth rates expected from a shell distribution. By analogy with the Earth, we suggest that refraction may play an important role and could account for the non-perpendicular k-vector orientation. For some cool M-dwarfs, we may be detecting ECM emission from both hemispheres at the same time, similar to what Cassini sees at Saturn.

CLUSTER MULTI-POINT OBSERVATIONS OF NEAR-EARTH CURRENT SHEET DISTURBANCES ASSOCIATED WITH DIPOLORARIZATIONS DURING THE SUBSTORM ONSET

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Dipolarization is one of the key signatures indicating enhanced magnetic flux transported from the tail and/or change in the local/global configuration of the tail current sheet. On October 27, 2007, 9 UT, Cluster crossed the night-side plasma sheet closer to the Earth, at X =9 RE. Several sequences of Earthward evolution of the dipolarization (Bz enhancement) were observed associated with fast plasma jets or enhancements in flux-transport rate accompanied by electrojet enhancements preceding the substorm major expansion phase onset. The first dipolarization was accompanied by current sheet oscillations and a significant current density increase. Using

multipoint observations, characteristics of the current sheet fluctuations associated with dipolarization are examined and compared with the parameters obtained from current sheet models. Possible evolution of the near-Earth current sheet leading to the substorm major onset is discussed.

FAST FLOW SIGNATURES DURING MULTIPLE ACTIVATION OF FEB. 16, 0220 UT 2008 SUBSTORM

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We examine the relationships between magnetic field and plasma disturbances in the midtail and in the inner magnetosphere and auroral signatures during a small substorm with AE reaching ~250nT with two auroral activation with poleward/equatoward expansion starting around 0220 UT and 0243 UT on 16 Feb 2008 when THEMIS 5 spacecraft were distributed in the premidnight to midnight (22-24 MLT) region between 8 and 18 RE downtail. We compare and contrast the radial and azimuthal evolution of these two events by comparing the satellite and ground-based signatures. The magnetic field together with the electron beam and ion flow signatures of the most tailward spacecraft THC (P2) at X=-18 RE suggest that the reconnection region was on the Earthward side of THC (P2) during the first activation and on the tailward side for the second activation. THB (P1) at X=-15 RE and Y=10RE in the lobe observed positive Bz enhancement for both activations. These midtail observations suggest that the reconnection region was activated separately at different radial distances for these two events (The first event being closer to the Earth) and include transient temporal structures. The auroral signatures are localized for the first event, whereas wider local time and latitude region are involved for the second activations. Both of the two activations are accompanied by dipolarization and flow enhancements at THD (P3) and THE (P4) spacecraft in the premidnight and THA(P5) near midnight at downtail distances between 8 and 9 RE. Auroral streamers were detected for both events near the conjugate local time region of THD (P3) and THD (P4). Yet, the flow and field disturbances are quite different between these two activations. We suggest that this difference arises due to the different stage of the fast flows interacting with the ambient field with different configuration of the tail.

THEMIS: STRUCTURE AND THICKNESS OF THE LLBL

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Low latitude boundary layer (LLBL) can be found at low latitudes on magnetospheric flanks but it covers the whole dayside magnetosphere and thus mediates the transfer of the plasma of solar wind origin across the magnetopause. In spite of its crucial role in the solar wind - magnetosphere coupling, basic LLBL parameters and their relations to upstream conditions are still under debate. The main problem is that this region is highly structured and dynamic and single spacecraft observations cannot resolve spatial and temporal effects. We analyze multipoint observations of the LLBL (THEMIS, Cluster, Interball) with motivation to determine its structure and thickness during different upstream conditions. Simultaneous measurements of the magnetic field and plasma parameters in several points of the LLBL and monitoring of the solar wind and the adjacent magnetosheath allow us to determine the LLBL thickness as a function of the IMF orientation as well as its structure under various conditions. The results suggest that lobe reconnection is a dominant

source of the LLBL plasma but other mechanisms are required to explain its spatial profile. For this investigation, the electron and ion n-T plots are applied.

AN OVERVIEW OF ION FORESHOCK PROCESSES

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The ion foreshock region is populated with beams of ions, moving away from the bow shock, whose interaction with the solar wind results in generation of a variety of ULF waves. The nonlinear evolution of these waves leads to a turbulent plasma whose properties are considerably different from the pristine solar wind. Spacecraft observations and local kinetic simulations in the past couple of decades, have shed light on many fundamental microphysical processes occurring in the foreshock region. The major outstanding questions regarding the ion foreshock are its global structure and morphology as a function of solar wind conditions and how this region impacts the plasma and field conditions in the magnetosheath and magnetospheric processes. Multi-spacecraft missions such as Cluster and THEMIS and global hybrid (kinetic ions, fluid electrons) simulations are providing new insights into this complex region of space. In this talk, recent results from global hybrid simulations of the ion foreshock and comparisons with spacecraft observations are reviewed.

CLUSTER AND THEMIS OBSERVATIONS RELATED TO AURORAL ACTIVATIONS

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We investigate the relation between dynamics in near-Earth (4-6 Re) convection flows and auroral activations, including single arc brightenings and onsets of substorm expansions, using Cluster-THEMIS (THEMIS space probes or ground stations) conjunctions. In the cases that we studied, Cluster EDI monitored nightside convection flows at radial distances around 4-6 Re, and THEMIS space probes (when available) were located in the equatorial magnetosphere at radial distances ranging from 6 to 30 Re. We found that reversals or dropouts of convection flows measured by EDI tend to coincide with auroral activations, and occur after onsets of the first high-speed flow burst and current disruption signatures observed by THEMIS. THEMIS results alone are consistent with the outside-in scenario for substorm triggers, but flow directions are inconsistent with the Near-Earth-Neutral-Line model. Our Cluster-THEMIS conjunction results suggest that convection flow reversals correspond to onset of dipolarizations of the tail magnetic field.

OBSERVATIONS OF SUBSTORM TRIGGERING

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Observations of the trigger region are difficult because we don¹t know exactly where the auroral onset region maps to in the thin current sheet. Moreover, the probability that a satellite will traverse the trigger region in the thin current sheet at the time when a substorm is triggered is very small. However, the occasional encounters of the trigger region serendipitously by Cluster indicate the trigger mechanism operates in high beta plasma on spatial and time scales of an ion Larmor radius and period. The mechanism generates an electromagnetic pulse that is left hand circularly (elliptically) polarized whose phase speed in the plasma frame is V_ph ~V_A. Ion distributions include beams and electron distributions have a "flat-top" shape. Intense electromagnetic waves are also observed. The trigger region subsequently propagates with V_A and spreads to other regions. What mechanism can produce these features is still not known.

TRANSPORT OF TRANSIENT SOLAR WIND PARTICLES IN EARTH'S CUSPS

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An important problem in space physics still not understood well is how the solar wind enters the Earth's magnetosphere. We report observations of transient solar wind particles produced by solar disturbances in the Earth's mid-altitude (~5 RE geocentric) cusps with densities nearly equal to those in the magnetosheath. That these are magnetosheath particles is established by showing they have the same “flattop” electron distributions as magnetosheath electrons behind the bow shock. The transient ions are moving parallel to the magnetic field (B) toward Earth and often coexist with ionospheric particles that are flowing out. The accompanying waves include electromagnetic and broadband electrostatic noise emissions and Bernstein mode waves. Phase space distributions show a mixture of hot and cold electrons and multiple ion species including field-aligned ionospheric O+ beams. These particles are detected during quiet and disturbed solar wind conditions and for diverse IMF conditions.

COMPARISON OF CURRENT SHEET PROFILES OBSERVED BY CLUSTER WITH MODEL PREDICTIONS

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Cluster observations revealed a variety of cross-current sheet current density profiles, including embedded, asymmetric, bifurcated forms. Profiles of thin horizontal single-peaked sheets are consistent with predictions of the thin anisotropic current sheet model with multicomponent plasmas. For strongly tilted sheets, in accordance with the simple models of slip-type plasma sheet deformation (vertical differential displacement of neighboring flux tubes), Jy current density component remains equal to that in the undisturbed horizontal sheet, but significant varying embedded Jz component appears, which is controlled by the local sheet tilt.

THEMIS BURST MODE OBSERVATIONS OF KINETIC SIGNATURES OF MAGNETOPAUSE RECONNECTION

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The THEMIS burst mode triggers successfully captured a large number of magnetopause and bow shock crossings. High-resolution burst-mode data provided unprecedented details of electromagnetic fields and particle distributions across the magnetopause reconnection layer. Tens of full 3-D ion and electron distributions are typically sampled within each reconnection layer crossing which often reveals the presence of multiple interpenetrating ion populations. The implications for ion and electron heating by reconnection will also be discussed.

THEMIS MULTI-SPACECRAFT OBSERVATIONS OF SOLAR WIND AND MAGNETOSHEATH RECONNECTION

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We present the result of a survey of THEMIS observations of reconnection in current sheets embedded in the solar wind and magnetosheath

flows. The alignment of the 5 THEMIS spacecraft along the Sun-Earth line in July and August 2008 allows the study of the evolution of solar wind current sheets as they convect across the bow shock. In this presentation we focus of the effect of the bow shock on reconnecting and non-reconnecting solar wind current sheets. In one event in July 2008, reconnection occurred in the solar wind current sheet but appeared to cease downstream of the bow shock. Such events should shed light on the conditions for the onset (or cessation) of reconnection.

STANDING ALFVÉN WAVES AT THE MAGNETOPAUSE

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The dependence of the average location of the magnetopause on different solar wind conditions can be considered to be well known. Its oscillatory motion around this location, however, is still subject to current research. Making use of the unique "pearls on a string" configuration of the five THEMIS spacecraft during its coast phase we were able to perform a statistical analysis of this motion. We find prominent frequencies of the magnetopause oscillations to coincide with stable and recurring "magic" frequencies observed in ground based and ionospheric measurements of ULF geomagnetic pulsations and attribute them to standing Alfvén waves at the magnetopause. Consequently, we present theory and experimental evidence for the idea that the magnetopause has to be regarded a membrane under tension capable of supporting surface eigenmode oscillations.

MULTIPOINT MEASUREMENTS OF SUBSTORM TIMING AND ACTIVATIONS

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Substorm timing and activations are studied based on Double Star TC1/Cluster/Polar/IMAGE/LANL satellites and ground-based Pi2 measurements. Substorm expansion onset is found to begin in the near-Earth tail around X = -(8-9) Re, then progresses both earthward and tailward. About 8-10 minutes before aurora breakup, Cluster measured an earthward flow associated with plasma sheet thinning. A couple of minutes after the breakup, TC1 first detects plasma sheet expansion and then LANL satellites near the midnight measure energetic electron injections, or vise versus. About 20 minutes (or more) later, Cluster and Polar observe plasma sheet expansion successively. Of interest are also the following findings. Auroral bulge is found to quickly broaden and expand poleward when the open magnetic flux of the polar cap is rapidly dissipated, indicating the role of tail lobe reconnection of open field lines in the development of the expansion phase. Meanwhile, poleward expansion of auroral bulges and tailward progression of substorm expansion are shown to be closely related. An initial dipolarization in the near-Earth eventually evolve to enable disruption of the cross-tail current in a wide range of the magnetotail, until the open magnetic flux of the polar cap reaches its minimum. It then believed that both “outside-in” and “inside-out” scenarios work during the expansion phase of fully developed substorms.

CLUSTER-DOUBLE COORDINATED OBSERVATIONS OF MAGNETIC RECONNECTION AT THE DAYSIDE MAGNETOPAUSE

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During January to April, the apogees of Cluster and Double Star/TC-1 are both in the dayside solar wind. Conjunctions between Cluster at the high-latitude magnetopause (MP) and TC-1 at the low-latitude MP provide a unique opportunity for coordinated study of magnetic reconnection at the dayside MP. It has been demonstrated that dayside low-latitude MP is the predominant location of component reconnection when the IMF By10; while in high-latitudes anti-parallel and component MR can both occur. Detailed studies show that anti-parallel and component MR both appear at the MP under the same IMF condition, forming a global pattern of the X-line across the MP. This implies that reconnection at high-latitudes and low-latitudes might be globally related, supporting the 3D SEPARATOR MODEL of MP reconnection. The ¡°anti-parallel¡± and ¡°component¡± features might just be the local manifestation of the global process of reconnection at the dayside MP. Typical case and statistical studies are both presented in the talk, followed by a short discussion.

POLAR-CAP-LATITUDE CLUSTER CONTRIBUTION TO THE THEMIS SUBSTORM TIME HISTORY

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We report on Cluster as a high-latitude, polar cap monitor during substorm activity. Convection dropouts associated with dipolarization of the magnetic field at polar latitudes have been reported in the past. Studying these types of events during the THEMIS era introduces more information for the substorm time history. We present case events where Cluster traverses the polar cap/lobe fieldlines as substorm activity is measured by THEMIS. Substorm signatures at Cluster include convection dropouts/reversals, dipolarization of the magnetic field, and oxygen beams. Multi-point analysis at Cluster is used to determine the spatio-temporal dynamics of the substorm-related dipolarization front. The timing of Cluster observations relative to substorm signatures measured by THEMIS is discussed.

CONSTRAINING THE SUBSTORM PROBLEM FROM THE GROUND

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We present optical and magnetic observations that provide a clear and strong constraint on the substorm problem. We show that the onset of long-period Pi1/short-period Pi2 ULF waves commence at an epicentre in the ionosphere. This epicentre is co-located with the region where spatially-localised, latitudinally narrow small-scale undulations develop on a faint isolated arc several degrees equatorward of the pre-existing discrete auroral arcs, with an optical oscillation periodicity in the same Pi1 frequency band. The pre-onset poleward discrete arc system remains spatially and temporally distinct from, and quasi-stable and unaffected by, the rapid dynamics of the new more

equatorward auroral activity described in this paper during the first the 2-3 minutes following onset. These optical and magnetic manifestations of expansion phase onset initiation may represent a characteristic ionospheric signature of a near-Earth plasmasheet instability. An alternate scenario is that reconnection in a severely stretched geometry produces these signatures, but in that case the stability of the more poleward arc system mapping to the plasmasheet must be explained. Regardless, the combination of high cadence and spatial resolution magnetic and optical measurements such as those outlined here provide a remarkably tight constraint on the mechanisms responsible for the initiation of substorm onset.

SUBSTORM EXPANSION PHASE ONSET TIMING USING ULF WAVE TECHNIQUES

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With the successful launch of the THEMIS spacecraft, the expansion of the CARISMA magnetometer array, and the deployment and operation of the THEMIS GBOs and EPOs and the GIMA array, there is exceptional ground magnetic coverage over the North American sector. We have developed an advanced wavelet-based technique to determine the first onset of ULF wave activity during expansion phase onset in both ground and in-situ magnetometers. In this talk we outline the characteristics of both Pi1 and Pi2 pulsations in the nightside ionosphere and magnetosphere during substorms using this technique. We find that long-period Pi1 pulsations are the first ULF wave signals of substorm onset seen in the ionosphere. We validate Pi1 timing against the large-scale IMAGE FUV and smaller-scale THEMIS ASI auroral observations. We find clear, coherent and repeatable characteristics of these ULF waves on the ground indicating a localized onset epicenter. We further compare the relative location of the Pi1 epicenter to the subsequent location of the substorm current wedge. We are currently using these techniques to produce a substorm onset database during the THEMIS era for use by the scientific community.

WHAT CAN WE LEARN FROM GLOBAL SIMULATIONS OF SUBSTORM EVENTS?

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We will present examples of global OpenGGCM simulations of several substorms observed by THEMIS, such as the March 23, 2007, February 26, 2008, and March 24, 2007 events. We show that the simulations reproduce several essential features of substorms such as the westward traveling surge (WTS), dipolarization, and fast flows. While such comparisons serve to show that the simulations capture the essential physics of substorms we analyze the simulation results further to investigate the relation of Pi2s to fast flows and the relation of reconnection to the WTS.

SIMULATIONS OF THEMIS FEBRUARY-MARCH 2008 MAGNETOTAIL EVENTS USING GLOBAL MHD CODES AT CCMC

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We will present results of simulations of THEMIS February-March 2008 magnetotail events using global MHD codes residing at CCMC. On-line

mapping tool from THEMIS locations to ionosphere and equatorial plane will be demonstrated. The role of inner magnetosphere in magnetotail dynamics will be discussed.

THE MICROPHYSICS OF THE DIPOLARIZATION REGION IN THE NEAR-EARTH MAGNETOTAIL: CLUSTER MULTI-POINT OBSERVATIONS

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The dipolarization region in the near-Earth magnetotail is a key region associated with magnetic field reconfiguration and electromagnetic energy conversion/dissipation. While these processes affect large volumes of space, most of the underlying physics occurs at scales comparable with the ion scale and below. It is therefore important to study in detail the microphysics of the dipolarization region. Here we present Cluster high-resolution measurements of electromagnetic fields and particles during a sequence of dipolarizations occurring on October 27, 2007 when Cluster crossed the plasma sheet around X~ -10 RE. The spacecraft separation ranged from ~ 50 km to ~ 10000 km thus allowing to study the microphysics of the dipolarization region at scales from electron to fluid. The observations indicate that dipolarizations (Bz enhancement) occur in turbulent regions where earthward fast flows brake. These regions are comprised of thin current filaments associated with strong electric fields and waves and accelerated energetic electrons. We analyze in detail several of these current filaments and discuss their role for local conversion/dissipation of energy and acceleration of energetic electrons. We also discuss the possible role of microphysical processes within the dipolarization region for large-scale substorm features.

RELATION BETWEEN ELECTROMAGNETIC WAVES AND ELECTRON HEATING INSIDE A FTE

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On May 20th, 2007, the 5 THEMIS spacecraft passed by a FTE, in the post-noon sector. Spacecraft configuration was interesting since the satellites bracketed the FTE structure (Thb, Thc on the magnetospheric side, Tha, The on the magnetosheath side, Thd close to the magnetopause current layer).

The spacecraft in the magnetosphere observe a typical FTE signature, namely (i) a bipolar magnetic field signature normal to the nominal magnetopause, (ii) a crater-like variation in the magnetic field strength, (iii) enhanced densities, and (iv) enhanced ion flow velocities. Densities and ion velocities in the core region of the FTE are comparable to those in the magnetosheath, but electrons are apparently heated/accelerated well above magnetosheath values. This heating/acceleration coincides with enhanced magnetic components of ULF waves.

These observations suggest that electromagnetic waves interact with electrons, inside the FTE, on

the magnetospheric side, and in a broader region, in the current layer and magnetosheath side. Yet waves observed around a few Hz are L-H polarized, and are therefore expected to have Vphi//~Va<<Ve. Thus they are unlikely to interact with the bulk of the electrons (Ve is the electron thermal velocity). However these waves have frequencies well above the proton gyrofrequency in the spacecraft frame, which is not consistent with a LH mode, we therefore conclude that the Doppler shift is larger than the frequency in the plasma frame. Then we suggest that the observed waves are RH polarized in the plasma frame, and that they heat the electrons, thanks to the large omega/kparallel, obtained for K//<<Kperp.

MULTI-POINT SPACE AND GROUND-BASED OBSERVATIONS AT SUBSTORM ONSET

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Analysis of in-situ and ground-based observations is performed to establish the precise timing of observed signatures during two successive auroral activations between 0130 and 0205 UT on March 1, 2008. The first, minor, activation was interpreted as a pseudo-breakup, while the second, major one, was classified as a substorm. Timing of observations aboard four of the THEMIS probes situated in the plasma sheet in the tail-aligned conjunction indicates initial activity at about X=-15 RE. Magnetic field variations, tailward fast flows, and signatures in particle distributions observed by two THEMIS probes in the mid-tail plasma sheet suggest magnetic reconnection as the source of the activation. The substorm onset, detected 6 min after the pseudo-breakup, was found to be associated with the rapid decrease of the magnetic field strength, dipolarization, increase of plasma density and pressure, i.e., signatures of the cross-tail current collapse (disruption), observed in the near-Earth plasma sheet at X>-10 RE. Signatures of an upward field-aligned current were detected by the two near-Earth THEMIS probes and by the geosynchronous satellite (GOES 10) between the pseudo-breakup and the major onset. To explain the observed signatures, a scenario based on the model of the near-Earth breakup triggered by the Earthward fast flow generated in the course of reconnection is proposed.

MAGNETOPAUSE AND BOW SHOCK LOCATIONS: THEMIS OBSERVATIONS

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The prediction of the bow shock and magnetopause locations is a proof of our understanding of the processes governing the solar wind-magnetosphere interaction. However, the models describing the location of these boundaries as a function of upstream parameters are based on a statistical processing of crossings observed by a single spacecraft. This approach implicitly assumes that the downstream parameters are proportional to their upstream values.

We have analyzed a few intervals of simultaneous observations of the bow shock and magnetopause crossings at several well-separated points. Our results based predominantly on THEMIS observations are supported with solar wind monitoring and suggest that a small-scale deformation of the bow shock front due to magnetosheath fluctuations is often the most probable cause of bow shock displacements. Since the low-frequency magnetosheath variations exhibit largest amplitudes, a bow shock displacement over a large distance can be observed. Moreover, we have found several events when a spacecraft observed series of bow shock - magnetopause - bow shock

crossings in less than 10 minutes. We are discussing possible sources of these events.

MIRROR AND WEIBEL INSTABILITIES: SIMILARITY AND NONLINEAR DYNAMICS

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A commonality in nonlinear saturation mechanisms of Mirror and Weibel instabilities near threshold is demonstrated. In both cases the major contribution is provided by modification of the velocity distribution function in the vicinity of small parallel particle velocities (ions in Mirror case and electrons in Weibel). The final relaxation scenario is based on almost resonant particle interaction with Mirror/ Weibel modes. This scenario differs from that in quasilinear plateau formation (or equivalent trapping effects). The analogy between nonlinear regimes of those instabilities developing far from thresholds becomes muted. The saturated plasma state can be considered as a magnetic counterpart to electrostatic BGK modes. Our analytical model is verified by relevant numerical simulations. Test particle and PIC simulations indeed show that it is a modification of distribution function at small parallel velocities that results in fading away of free energy driving Mirror/Weibel modes. The multipoint measurements in space plasma are used to validate a proposed scenario.

DIAGNOSIS OF MAGNETIC STRUCTURES AND INTERMITTENCY IN SPACE PLASMA TURBULENCE USING THE METHDO OF SURROGATE DATA

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Several observations in space plasmas have reported the presence of coherent structures at different plasma scales. Structure formation is believed to be a direct consequence of nonlinear interactions between the plasma modes, which depend strongly on phase synchronization of those modes. Despite this important role of the phases in turbulence, very limited work has been however devoted to study the phases as a potential tracer of nonlinearities in comparison with the wealth of literature on power spectra of turbulence where phases are totally missed.

We present a method based on surrogate data to systematically detect coherent structures in turbulent signals. The new method has been applied successfully to magnetosheath turbulence (Sahraoui, Phys. Rev. E, 2008, in press), where the relationship between the identified phase coherence and intermittency (usually evidenced as non gaussian tails of the PDFs) as well as the energy cascade has been studied. Here we review the main results obtained in that study and show further applications to small scale solar wind turbulence. Implications of the results on theoretical modeling of space turbulence (applicability of weak/wave turbulence, its validity limits and its connection to intermittency) will be discussed.

ALFVÉNIC INTERACTIONS AND SUBSTORM ONSET

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Substorm onset is a result of Alfvénic interactions in the global current system including the tail current sheets as well as the auroral field-aligned current system. Thus, any substorm model that emphasizes only localized processes, whether the breakdown of the frozen-in condition at about 25 Re or the disruption of current at about 10 Re, is necessarily incomplete. A comprehensive nonlocal dynamical theory is needed to understand the onset and evolution of substorms.

During the growth phase, the solar wind-magnetosphere interaction stresses the tail current sheet, leaving it susceptible to the breakdown of the frozen-in condition. Changes in solar wind parameters or tail plasma flows can generate fast mode wave packets that interact with the stressed current sheet and cause the breakdown of the frozen-in condition in multiple active localized regions throughout the tail current sheet. In the

auroral acceleration region, the nonlinear interaction between the incident Alfvén wave packets from the generator and reflected Alfvén wave packets from the ionosphere can cause auroral intensification and lead to the subsequent auroral development seen in the expansion phase. The observational consequences of this alternative Alfvénic interaction theory on substorm triggering and timing will be compared with the CD and NENL models.

MHD-BASED RECONSTRUCTION OF A RECONNECTION EVENT SEEN BY CLUSTER AT THE MAGNETOPAUSE

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A recently developed method for reconstructing 2D time-independent field/plasma structures in space directly from the ideal MHD equations is reviewed briefly and is then applied to a reconnection event seen by Cluster at the magnetopause. The chief advantage of the new method over earlier Grad-Shafranov (GS) based methods is that it allows reconstruction to be performed in the frame of reference moving with the reconnection site (the X-line), rather than in the deHoffmann-Teller frame required in GS reconstruction, in which the X-line is in rapid motion. Results from our application are presented in the form of maps of magnetic field and flow field, as well as of the electric field, the current field, and various plasma parameters. The maps include the reconnection site itself, at which location ideal MHD breaks down and numerical diffusion takes over. Away from this region, ideal MHD is justified because entropy increase across discontinuities as well as plasma mixing on reconnected field lines appear fairly unimportant in the event studied. Reconstruction based on ideal as well as resistive Hall MHD is also possible. We discuss this important next step and how it will allow the physics in the ion diffusion region to be realistically incorporated.

FAST-THEMIS OBSERVATIONS IN THE DAYSIDE CUSP-CLEFT REGION

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We present initial results from a survey of FAST and THEMIS observations in the dayside cusp-cleft region. For example, on September 26, 2007 FAST observes ions in the cusp with reverse energy dispersion, i.e., decreasing from high to low energies as the spacecraft moves from high to low latitude. This signature appears to persist for several hours, as FAST observes the signature on 3 consecutive passes through the dayside cusp region. The THEMIS-C spacecraft also observes energy-dispersed ions, with higher energies being observed at larger radial distances. At FAST altitudes the signature could be attributed to reverse convection, but for the near- equatorial THEMIS-C spacecraft high latitude reconnection driving sunward convection would tend to result in higher energies being observed at smaller radial distances than the lower energy ions. Reconciling these observations will benefit from modeling with global MHD simulations.

MAGNETOPAUSE BOUNDARY LAYERS I HAVE KNOWN, MISSED, LOST, LOVED AND IN SOME CASES COME TO HATE

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We present examples of multi-mission conjunctions and highlight their potential in studying boundary layer formation and evolution. We extend previous studies using Cluster, Double Star and Geotail data to include recent conjunctions with these spacecraft and THEMIS. This work is being (and also has been) carried out under the auspices of the International Space Science Institute (ISSI) via working groups on 'Comparative Cluster- Double Star measurements of the dayside magnetosphere', 'Comparative Cluster- Double Star measurements of the magnetotail', and 'Conjugate response of the

dayside magnetopause and dawn/dusk flanks using Cluster-THEMIS conjunctions and Ground based observations.

RECONSTRUCTION OF A LARGE-SCALE RECONNECTION EXHAUST IN THE SOLAR WIND

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We have applied MHD-based reconstruction [Sonnerup and Teh, 2008] to a large-scale reconnection exhaust structure in the solar wind to recover its two-dimensional magnetic field and flow field configuration. The reconstruction is performed in the X-line frame, where the flow into, and the plasma jetting within, the exhaust region are clearly visible. The event was first identified by Phan et al. [2006] in the ACE, Cluster, and Wind data to show ongoing reconnection for over 2 hours at a long (390 Re) X-line. Our MHD reconstruction results show that (1) the X-line orientation was close to the bisector of the overall magnetic shear angle; (2) the X-line moved earthward, dawnward, and southward; (3) the reconnection electric field was small (~0.02 mV/m on average) and gradually decreased from the first crossing (ACE) to the last (Wind); (4) the plasma flowed into the exhaust region from its two sides. Time-dependence in the reconnection electric fields seen by ACE and Wind indicates local temporal variations in the field configuration. Overall, our results are consistent with those reported by Phan et al. [2006]. In addition, we provide analysis of many details from the three spacecraft crossings.

EVOLUTION OF COUNTER-STREAMING ELECTRON BEAMS OBSERVED IN A CURRENT SHEET OF THE EARTH'S MAGNETIC TAIL

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Cluster, THEMIS and Double Star observations of low energy (< 1 keV) counter-streaming electron beams and flattened electron distributions in thin current sheets are presented. These beams are embedded in fast flowing earthward and tailward plasmas in the plasma sheet and are often detected simultaneously with electrostatic and electromagnetic fluctuations. The counter-streaming beams have energies (E) ranging from 150 to 800 eV and temperatures (T) ~50 to 100 eV. For |B| ≥ 4-5 nT both E and T increase close to the neutral sheet. For lower |B|, counter-streaming beams and flattened distributions tend to weaken or even disappear. Our analysis indicates that the counter-streaming beams could evolve into flat top distributions via the interaction with electromagnetic waves.

ENERGETIC IONS IN THE CUSP AND DAYSIDE BOUNDARY LAYER

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The observation of energetic ions in the cusp region (CEP) and their possible origin is still a matter of controversy with possibly important implications for particle transport into and within the magnetosphere. The local acceleration model suggests that CEP ions with significant fluxes up to several hundred keV/e are created directly in the cusp. Alternatively, the distant origin model suggests that CEP ions are accelerated at the quasi-parallel bow shock, then transported downstream and enter the cusp along newly reconnected field lines. Composition and energy spectra of CEP ions resemble those of bow shock energetic diffuse ions and support this model.

We are investigating a Cluster cusp pass on Feb 14, 2003. Following the determination of the location of the reconnection site at the magnetopause, the IMF field lines are draped over the magnetopause and mapped back into the solar wind. This recently developed technique demonstrates the magnetic

connection between the cusp regions, the Earth's bow shock and the upstream region at the location of the quasi-parallel shock. 3D ion distributions from the Cluster/CIS instruments during the cusp pass show evidence of energetic ions streaming into the cusp from the bow shock region. These ions are also observed in the dayside magnetopause boundary layers, streaming from the quasi-parallel bow shock towards the cusp. This method allows us to use energetic ions as tracers for plasma transport into the magnetosphere and better understand the magnetic topology between the solar wind and the ionosphere.

MULTIPOINT OBSERVATIONS OF MAGNETOSPHERIC COMPRESSION-RELATED EMIC PC1 WAVES BY THEMIS AND CARISMA

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Electromagnetic ion cyclotron (EMIC) waves were observed simultaneously by the CARISMA network of ground-based magnetometers and THEMIS in the dayside magnetosphere. Following a long interval of sustained quiet geomagnetic conditions, EMIC wave activity was seen by CARISMA on the ground for several hours simultaneously with enhanced solar wind density and related magnetic compression seen at GOES 12 on 29th June 2007. During the EMIC event, the THEMIS C, D, and E satellites were outbound in a “string-of-pearls” configuration and all three spacecraft coherently registered the Pc 1 magnetic field fluctuations at L=5-6.5. THEMIS resolved some of the spatial-temporal characteristics of the EMIC waves and defined the radial extent of EMIC activity in the magnetosphere to be ~1.3 Re. The coherent EMIC waves were seen slightly further out in radial distance by each subsequent THEMIS satellite pass, but in each case were bounded at high-L by a decrease in density as monitored by spacecraft potential. The EMIC wave activity appears to be confined to a region of higher plasma density in the vicinity of the plasmapause, as verified by ground-based cross-phase analysis. Our observations suggest solar wind density enhancements may also excite radially localised EMIC waves close to, or perhaps just outside, the plasmapause.

CLUSTER, THEMIS AND THE VIRTUAL MAGNETOSPHERIC OBSERVATORY

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Founded in 2007 the Virtual Magnetospheric Observatory (VMO) provides one stop shopping for data and services useful in magnetospheric research. The VMO's purview includes ground and spacecraft observations. The data and services for using and analyzing these data are found at laboratories distributed around the world. The VMO is a federated system with operational units at UCLA and the Goddard Space Flight Center (GSFC). Information about data and services is described by using the Space Physics Archive Search and Extract (SPASE) metadata standard. The SPASE metadata are stored in distributed registries that can be maintained by the data provider. The VMO uses this information to enable broad search capabilities and its value-added services. Any data provider in the world can share data through the VMO. We have appointed a group of domain experts called “X-Men who are expert in both magnetospheric physics and data management and work closely with data providers to help them prepare the metadata and populate the registries. We also have developed a series of tools to populate and harvest information from the registries.

THEMIS spacecraft and ground magnetic data are currently available through the VMO and Cluster metadata are being prepared. In addition collaborative data from ground observatories and other spacecraft are available.

CLUSTER AND DOUBLE STAR MULTIPOINT OBSERVATIONS OF A PLASMA BUBBLE

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Depleted flux tubes, or plasma bubbles, are one possible explanation of bursty bulk flows, transient high speed flows thought to be responsible for a large proportion of flux transport in the magnetotail. Here we report observations of one such plasma bubble, made by the four Cluster spacecraft and Double Star TC-2 around 14:00UT on 21 September 2005, a period of southward, but By-dominated IMF. In particular the first direct observations of return flows around the edges of a plasma bubble, and the first observations of near-Earth plasma bubble features, consistent with MHD simulations are presented. The implications of the presence of a strong By in the IMF and magnetotail, and the consequent deformation of the ionospheric convection pattern, on the propagation of the plasma bubble and development of the associated current systems are discussed. You better come and listen to our talk.

THE COUPLING OF TAIL FAST FLOWS TO IONOSPHERIC FLOW SIGNATURES AND THEIR RELATIONSHIP TO SUBSTORM ONSET.

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Earthward convection of the tail plasma sheet is often organized in bursts of fast ion flows restricted in azimuthally narrow channels. It has been shown that Auroral Poleward Boundary Intensifications (PBIs) are often the ionospheric signature of such fast flow channels in the midtail. While PBIs can occur for all IMF orientations and solar wind conditions, they have a clear preference for southward IMF and their occurrence peaks within 1 hour after a substorm onset, with a secondary occurrence peak at 3 hrs after onset. Equatorward flow bursts have been observed in the ionosphere that are presumably the ionospheric mapping of the tail fast flow channels. We focus on identifying such ionospheric signatures and understanding the physics of this magnetosphere-ionosphere interaction via conjunctions of the THEMIS probes with the Sondrestrom radar. From a number of such conjunctions we find that the onset of a substorm that is soon followed by a PBI has a very distinct signature in the radar data. At onset and expansion the ionospheric flow turns strictly westward. During the PBI tail fast flows originate in the mid-tail and ionospheric flows turn equatorward. The generality and physical implications of this pattern are explored.

DYNAMIC MOTION OF BOW SHOCK AND MAGNETOPAUSE AND THE MAGNETOSPHERIC RESPONSE -THEMIS OBSERVATIONS

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We present an observational study of the dynamic motion of the bow shock and the magnetopause and suggest that the dynamic motion is due to the interaction of an interplanetary shock with the Earth's bow shock. THEMIS B spacecraft crossed the magnetopause, a discontinuity and the bow shock successively in 5 minutes during its outbound journey on July 10, 2007. Following THEMIS B, THEMIS C, D, E and A consecutively crossed the magnetopause and the discontinuity. Timing analysis shows that the magnetopause and the discontinuity were moving earthward with speeds of 40 km/s and 90 km/s respectively. The magnetopause accelerates as it moves earthward. By contrast, the discontinuity decelerates as it propagates towards the magnetopause. After the interaction, the transmitted interplanetary shock took the form of a discontinuity where total magnetic field and density increase and the temperature decreases. The rotation of the magnetic field across this discontinuity was similar to that of the interplanetary shock. The expected fast shock ahead of the discontinuity for shock-shock interaction was not observed. The expected fast shock ahead of the discontinuity for strong shock-shock interaction was not observed. Ground stations recorded compression over a wide range of MLT and latitudes.

FORMATION OF THE THIN CURRENT SHEET IN THE SUBSTORM LATE GROWTH PHASE: THEMIS OBSERVATIONS

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The formation of a thin current sheet prior to the expansion onset of a substorm event, which occurred on Feb 26, 2008, is studied in the near-Earth magnetotail based on THEMIS observations. During this time interval, the ion distributions showed mushroom-shaped structures with clear non-gyrotropic features, indicating that the ions were unmagnetized, which becomes possible only if the current sheet thickness is comparable to the thermal ion gyroradius. By comparing the observations with the Sitnov (2006) model, which is a generalization of the Harris (1962) model by considering the effect of the meandering ions in the thin current sheet, we reproduce the current sheet structure in the late growth phase of the substorm, and emphasize the key role of the ion kinetics in the evolution of the thin current sheet.

INITIATION OF BALLOONING INSTABILITY BY RECONNECTION IN THE NEAR-EARTH PLASMA SHEET

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In this work, an alternative scenario for the substorm onset process is proposed, based on ideal ballooning stability analysis of the near-Earth plasma sheet during the March 23, 2007 THEMIS substorm event. In this scenario, the ballooning instability is initiated by the magnetic reconnection in the near-Earth plasma sheet, which in turn directly contributes to the trigger of a full onset. Using the solar wind data from WIND satellite observation for the substorm event as an input at dayside, we reconstructed a sequence of global magnetospheric configurations around the substorm onset by means of OpenGGCM simulation. These simulations have reproduced most of the salient features, including the onset timing, observed in the THEMIS substorm event. The local ballooning instability criterion is evaluated for the near-Earth plasma sheet region when the configuration attains a quasi-static equilibrium condition. Our analysis of the evolution of the near-Earth magnetotail region during this substorm event reveals a correlation between the breaching of the ballooning stability condition and the substorm onset in both temporal and spatial domains. The analysis suggests that the Earthward bulk plasma flow induced by the reconnection event in the near-Earth plasma sheet, leads to the pressure build-up and creates a favorable condition for the initiation of the ballooning instability in that same region.

IONOSPHERIC OXYGEN IONS DOMINANT BURSTY BULK FLOWS: CLUSTER AND DOUBLE STAR OBSERVATION

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Two extreme oxygen-rich Bursty Bulk Flows (BBFs) with predominant ionospheric O+ ions have been observed on November 8, 2004 by the Cluster and Double Star spacecraft during a strong magnetic storm time period with Dst = -373 nT. The oxygen densities in two BBFs are found to be 3-5 times larger than the hydrogen densities and the oxygen thermal pressures in the BBFs are 8 times higher than the hydrogen thermal pressure. These BBFs are associated with nested magnetic structures, and are observed simultaneously by the CLUSTER and the DSP TC-1 spacecraft.

Thus, the flow braking region should be greatly pushed inside the usual pressure balance region (even inside the inner magnetosphere) since the BBF is dominated by oxygen ions. Results in this paper indicate that oxygen dominated BBFs can be formed during a strong magnetic storm time period. The observations made in this paper suggest that singly charged oxygen ions embedded in the BBFs could be carried into the ring current region by bursty flows during very intense magnetic storms.

How does the oxygen-dominant plasma affect the tail reconnection and BBF formation? Does the oxygen-dominant plasma change the reconnection rate significantly? How does single charged oxygen affect the scaling of reconnection? The detailed magnetotail physics during extreme cases like the observations in this paper with the ratio O+ remain unknown. It requires much more observations and working together among theoretic simulators and spacecraft data analyzers so as to completely answer those questions. Nevertheless, the observations in this paper provide some interesting factors to help us to understand more on the ionospheric oxygen effects on the magnetotail dynamics.