SM52B MCC: 133 Friday 1330h

Substorms and Storms I

Presiding: **W Horton,** University of Texas at Austin**; M R Lessard,** Dartmouth College

SM52B-01 1335h INVITED

Transient convection in the Earth's magnetosphere and the generation of Pi2 pulsations

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Pi2 pulsations (T 40-150 s) are irregular magnetic field oscillations observed to occur near substorm onset. In this talk we present the results of studies exploring the generation of Pi2 pulsations by transient magnetotail flow bursts. We find that waveforms of low-latitude Pi2 match the variations in flow velocity measured in the middle magnetotail with a 1-3 minute delay. This correlation had not been previously reported and identifies the intrinsic periodicity in flow bursts as the source of low-latitude Pi2. Pi2 generation is related to the types of impulses generated when a flow reaches the transition region between stretched tail and dipolar field lines. The field-aligned, Alfvnic component partially reflects at the ionosphere and leads to the generation of what we refer to as transient response (TR) Pi2. The periods of these Pi2 are intrinsic to the local flux tubes and are unrelated to the periodicity of flow enhancements. Transient currents caused by flow deceleration are also generated and we term the pulsations that result inertial current (IC) Pi2. An impulsive, cross-field, compressional wave is also produced by the braking of the flow. How this signal generates low-latitude Pi2 was unknown prior to this work. We offer compelling evidence that the impulsive signal travels sunward and perturbs field lines launching Alfvén waves towards the ionosphere. The Pi2 perturbations observed on the ground are directly-driven, and the waveforms of these waves match the flow variations.

SM52B-02 1355h

Characterizing the Periodicity of Bursty Bulk Flows

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Localized high-speed flows (> 400 km/s), called bursty bulk flows (BBFs), occur frequently in the inner central plasma sheet of Earths magnetotail. BBFs are observed to occur semi-periodically with a characteristic period of approximately 20 minutes. A large collection of BBF events from 1996 are identified using Geotail magnetic field and plasma data, at times when the spacecraft was located between 10 and 25 Earth radii in the anti-sunward direction. An ensemble BBF time series is constructed using a super-posed epoch analysis of the magnetic field and bulk plasma properties of the individual events. Epoch time is defined by the initial sharp increase in sunward velocity during a BBF, rather than at the time of the peak flow. The super-posed analysis interval spans one hour pre-epoch time to two hours post-epoch time. Fourier analysis of the post-epoch BBF interval reveals strong periodicities in plasma velocity, temperature, and magnetic field. Results of the analyses characterizing these periodicities, as well as representative case studies of BBF events, will be detailed.

SM52B-03 1410h

Double-Adiabatic-MHD Theory for Motion of a Thin Magnetic Filament and Possible Implications for Bursty Bulk Flows

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The plasma distribution function observed in a Bursty Bulk Flow (BBF) often exhibits one beam flowing through another, which raises the question of whether BBFs can reasonably be represented in terms of single-fluid magnetohydrodynamics, either in global MHD codes or in the thin-filament theory. Study of a simplified case suggests that double-adiabatic MHD is more realistic than ordinary MHD for situations with counter-streaming beams. Motivated by this result, we derive double-adiabatic MHD equations describing the motion of a thin filament through a medium. The dispersion relationships for linear waves are the same as in anisotropic MHD in an infinite homogenous medium and thus exhibit firehose and mirror instabilities, for transverse and longitudinal waves, respectively. We have developed a double-adiabatic MHD code to represent the motion of a thin filament moving through Earth's plasma sheet. An initial simulation shows the evolution of a double-adiabatic filament that starts out with lower gas pressure than nearby flux tubes. The near-equatorial part of the filament moves rapidly earthward, and a compressional shock wave propagates earthward along the filament. The near-equatorial region of the filament exhibits characteristics similar to a flow burst, while the behavior far from the equatorial plane resembles that of earthward-streaming plasma-sheet boundary layer. After the shock reflects from the earthward boundary of the simulation, the filament resembles a two-beam plasma-sheet boundary layer. The double-adiabatic filament tends to be firehose unstable, particularly after the shock wave reflects from the earthward boundary of the simulation.

SM52B-04 1425h

Coupling in the magnetotail between macroscale and mesoscale process during periods of magnetic activity: MHD simulations

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Global MHD simulations have proved very capable of representing the global interaction between the solar wind and the magnetosphere. Using the Lyon-Fedder-Mobarry model to simulate several storm and substorm events, we have noticed that the simulation often generates narrow flow channels in the magnetotail. These flow channels represent meso-scale dynamical features that may be related to the observered bursty bulk flows seen during substorms. During storm-like driving (magnetic cloud events) similar channels form in the magnetotail, even though the activity is directly-driven, as opposed to the loading-unloading process of substorm. In this paper we will examine various aspects of these flow channels during storm and substorm simulations and discuss how these features couple to the large-scale energy dissipation from the solar wind driver.

SM52B-05 1440h

On the three auroral electrojet system during substorms.

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The behavior of the auroral electrojet indices AU and AL during classical substorms is investigated by the use of global auroral images. A superposition of the 12 AE stations onto global auroral images and identification of the AL and AU contributing stations enable an understanding of the temporal as well as spatial behavior of the indices with respect to the substorm coordinate system and timeframe. Based on this simple technique it was found that at substorm onset the AL contributing station makes a characteristic jump from a location near the dawn terminator to the onset region and that it jumps back to the dawn sector in the early recovery phase. The observations indicate a local minimum in the westward electrojet intensity near midnight, which was confirmed in a case study. The defining AU station does not show any similar systematic behavior. We find that the observations can be explained by the two-component westward electrojet concept and the self-consistent substorm model by Gjerloev and Hoffman [JGR, 2000a&b, 2001, 2002]. These two westward electrojet components are found to be quasi-independent thus resulting in a three electrojet system during substorms.

SM52B-06 1455h

Observations of Dayside Convection Reduction Leading to Substorm Onset

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We have used SuperDARN radar measurements of ionospheric plasma flow on the dayside to evaluate the extent to which substorm onset is the result of interplanetary magnetic field (IMF) changes that lead to a reduction in the strength of magnetospheric convection and the timing of such convection changes relative to onset. By using direct observations of convection, we avoid the uncertainties in previous studies of substorm triggering arising from their use of IMF measurements from locations away from the magnetosphere. Our analysis of the dayside plasma flows indicates that the vast majority of well-defined substorm onsets are associated with a reduction in the strength of large-scale convection that is imparted to the magnetosphere from the solar wind. We also find that the convection reduction imparted to the magnetosphere initiates a few minutes prior to substorm onset. This is the same time relative to onset that, based on auroral observations, the nightside magnetosphere undergoes a transition to an unstable configuration. This suggests that the convection reduction is responsible for the transition to instability that leads to the substorm expansion phase. Our results are consistent with the idea that, under enhanced magnetospheric convection, energy builds up within the nightside magnetosphere and can reach a stable equilibrium where energy losses balance further energy input. If the energy accumulated on the nightside during a period of enhanced convection exceeds that of the equilibrium configuration after a reduction in the strength of convection, the nightside magnetosphere undergoes a transition to instability when the strength of convection is reduced and the excess energy is released as the substorm expansion phase. These results indicate that the question of how this instability arises and develops after a decrease in convection is a critical outstanding question for understanding the substorm expansion phase.

SM52B-07 1530h

Spatially Resolved Substorm Dynamical Model with Internal and External Substorm Triggers

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A spatially-resolved nonlinear dynamics model of the coupled solar wind driven magnetosphere-ionosphere system is developed for the purpose of determining the electrical power flow from the solar wind through the nightside magnetosphere into the ionosphere. The model is derived from Maxwell equations and nonlinear plasma dynamics and focuses on the key

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conservation laws of mass, charge and energy in the power transfer elements in this complex dynamical system. The models has numerous feedback and feedforward loops for six forms of the distributed energy storage in the M-I system. In contrast to neural networks, the model delineates physically realizable time ordered sequence of energetic events in substorm dynamics.

Three types of energy releases are observed in the substorm data and studied with the model. Type I events occur for solar wind conditions that lead to the creation of a near Earth neutral line (NENL) in the geomagnetic tail. Other solar wind conditions lead dominantly to the onset of convection in flux tubes with foot points in the auroral region that produced enhanced field aligned currents (FACs) closing in the ionosphere. These are the type II and type III events. In type II events a sudden northward turning of the IMF produces a transient mis-alignment of the pressure gradient with the gradient of the flux volumes as in the Lyons model. Large transient substorm current wedge and auroral region 1 sense currents are driven by the steep near-Earth pressure gradient in these events type II events. In type III events the slower evolving IMF field directly drives the nightside M-I system. This is the directly driven auroral substorm. We use physics-based filters to classify events in historical databases, and we use the 2-1/2D transport model to simulate the events for model solar wind inputs. The results of the research stress the need for more accurate determinations of the dayside magnetopause arrival times of structures in the solar wind required for space weather forecasting and the role of competing substorm triggering mechanisms.

SM52B-08 1545h

Is the Current Disruption Region the Genesis Region for the Substorm X-Line?

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The nominal location for the substorm near-Earth X-line (NEXL) has been found to be outside but near $20R_E$ in the tail. The modified Near-Earth Neutral Line (NENL) model postulates that braking of fast, earthward flows and pile up of magnetic flux accounts for the initiation of the substorm current wedge and dipolarization within $10R_E$, and its tailward expansion. Current disruption (CD) and CD-like magnetic activity accompanies dipolarization in the 8–$12R_E$ range and commences in close temporal proximity to auroral onset. We report here, based on Geotail observations, that 70% of CD-like activity in the 9 (perigee) to 12 R_E range of the pre-midnight and midnight plasma sheet begins in the absence of earthward flow. In only 20% of the cases does CD-like activity start coincident with arrival of earthward flow. Indeed, in a like number of cases, CD-like activity starts coincident with a clear signal (tailward Poynting flux) arriving from nearer Earth. When auroral coverage is adequate, we have shown that these substorms proceed in two stages, with reconnection occurring during the second stage. But this is not the entire story. We note three pieces of evidence that lead us to suggest that the CD region is the genesis region for the NEXL. (1) In 10% of CD-like events, magnetic fluctuations commence like typical CD events, but rather than dipolarizing, the magnetic field diminishes. Whereas the distribution for the typical CD signature shows a strong peak near $10R_E$, these hybrid events are more uniformly distributed between 9 and 19 R_E, and from 13–$19R_E$ represent 30% of all CD-like activity. (2) Signatures of a substorm NEXL earthward of Geotail can be found as near Earth as $13R_E$ on occasion. (3) A minimum in equatorial magnetic field strength is believed to evolve during the substorm growth phase near $10R_E$. *Hau and Wolf* [*JGR, 92*, 4745, 1987] discuss how, in the presence of resistivity, the B-minimum structure diffuses tailward, and the minimum deepens, until a NEXL forms. Collocation of CD with the growth-phase minimum in B and the subsequent emergence of reconnection (NEXL genesis) removes some of the major observational difficulties associated with both the Near-Earth Current Disruption and the modified NENL models. We discuss the advantages of such unification.

SM52B-09 1600h

Wind Observations Pertaining to Current Disruption and Ballooning Instability during Substorms

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In this paper, the drift ballooning instability as a possible substorm trigger mechanism is examined. Two features of the drift ballooning instability are the westward propagation of wave perturbations and the presence of a pressure gradient. Energetic ion (75 keV - MeV) and the magnetic field data from the Wind spacecraft observe time delays between earthward and tailward flux enhancements of ions at the onset of current disruption. We interpret the time delays as signatures of westward propagation, and estimate accordingly the propagation speeds to be several hundred kilometers per second. Clear signatures of westward propagation are present in most current disruption events observed $\sim$ 8-10 R_E. For events observed beyond 10 R_E, it is often difficult to identify time delays. This radial distance dependence suggests that the initially unstable region is within 10 R_E. For an event observed at ~ 8 R_E, anisotropy of ion fluxes observed between the duskward and dawnward directions persists until the time of the onset of the current disruption. The evolution of this anisotropy is consistent with a radial density gradient that is impulsively reduced during the abrupt magnetic fluctuations. The instability that triggers the current disruption, and hence the substorm, has to be able to relax the pressure gradient (which is proportional to the density gradient assuming an isothermal process). The impulsive reduction of the pressure gradient and the fact that its corresponding magnetic fluctuations have $\delta B/B$ exceeding 1 indicate that the process is nonlinear. We conclude that these observations support the drift ballooning instability as a possible mechanism to trigger substorms, but a nonlinear theory of the instability is called for.

URL: http://plasma4.physics.uiowa.edu:8080/~lijen/balloon.html

SM52B-10 1615h

AKR Disappearance During Magnetic Storms

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It is well known that auroral kilometric radiation (AKR) is intensified during substorm and has a good correlation with AE index. In the case of the magnetic storm, however, the AKR characteristics have not been investigated. In this paper, we report the unexpected behavior of the storm time AKR and related particle precipitation: (1) AKR often disappears in the initial and main phases of the magnetic storms in spite of the large enhancement of AE index, (2) At that time, the energy spectra of precipitating electrons do not show the signature of the field- aligned acceleration but the hot electron injection, (3) The radiation is activated strongly in the recovery phase, and (4) AKR disappearance phenomena tend to occur in larger storms. It can be suggested from these results that the field-aligned electric field which accelerates precipitating electrons and drives field-aligned currents is not formed in the initial and main phases of magnetic storms.

SM52B-11 1630h

Radial diffusion simulation of relativistic electron transport by ULF waves in the September 1998 magnetic storm

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Based on radiation belt diffusion theory, a 1-dimensional radial diffusion code has been developed to better understand relativistic electron transport during magnetic storms. We use radial diffusion coefficients as a function of ULF wave power at resonant electron drift frequencies and a time-dependent outer boundary location. The ULF wave power is obtained from global MHD simulations and the outer boundary location is based on drift shell tracing in the Tsyganenko 2001 magnetic field model. The Tsyganenko 2001 field model is also used for Roederer L* calculations. We have studied the September 1998 storm using this diffusion model, and results are compared with phase-space density radial profiles obtained from MHD test-particle simulations and with GOES satellite flux measurements.

SM52B-12 1645h

The Characteristics and Evolution of Chorus on the Ground and in Space During Geomagnetic Storms

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Whistler mode waves, predominantly in the form of ELF/VLF chorus, are known to be generated by electrons injected into the magnetosphere during geomagnetic storms. It has been suggested that this chorus may play a role in accelerating electrons to MeV energies. Ground observations provide a complementary perspective to those from satellite-borne receivers. This paper uses a decade (1992-2001) of nearly continuous (>95%) VLF/ELF observations from the VELOX instrument at Halley station, Antarctica (76S 27W, L=4.3). These comprise 1s resolution measurements of ELF/VLF wave power, arrival azimuth, polarisation and peak-mean-minimum ratios, in eight frequency bands from 500 Hz to 10 kHz. To provide a background reference, the mean wave power and standard deviation have been computed for each frequency, hour of local time, and month of the year. The variations in chorus activity during several storms, including the well-studied Bastille Day (14 July 2000) and 31 March 2001, have been compared with these reference levels. Chorus is often observed lasting many hours, beginning a day or so after the storm main phase, and reaching high intensities and also high VLF frequencies (up to ~5kHz); the latter implies a source region which has moved relatively close (L<4) to the Earth. Modulation on minute time scales can result from fluctuations in solar wind pressure and precipitation. During the initial phase of the storm, waves intensities may be suppressed by strong and sustained ionospheric absorption. A superposed epoch analysis using 300 storms with minimum Dst < -50 nT has been done to show the characteristic ground chorus storm response. The results are compared with electron flux and chorus observations made in space, and the predictions of chorus mediated acceleration theory.