

SM51C-06 0945h

Anti-Parallel Merging vs. Component Dayside Reconnection: Role in Magnetospheric Dynamics

Masha M Kuznetsova¹ (301-286-9571; masha@elbrus.gsfc.nasa.gov); Michael Hesse¹ (301-286-8224; mhesse@lepvax.gsfc.nasa.gov); Lutz Rastaetter¹ (301-286-1085; lr@waipio.gsfc.nasa.gov); Marlo M Maddox¹ (301-286-5202; Marlo.Maddox@nasa.gov); Darren De Zeeuw² (734-763-6224; darrens@umich.edu); Tamas Gombosi² (734-764-7222; tamas@umich.edu)

¹NASA GSFC, Code 696, Greenbelt, MD 20771, United States

²University of Michigan, 2455 Hayward Str., Ann Arbor, MI 48109, United States

Magnetic reconnection is a key process in magnetospheric dynamics. In the presence of a nonzero IMF B_y component and of southward IMF B_z , magnetic neutral points are formed near the flanks of the magnetosphere. The relative role of almost anti-parallel merging near neutral points vs. component reconnection at the subsolar stagnation point is a matter of ongoing discussions. To address this problem we employ global MHD model BATSRUS with adaptive mesh refinement, which resides at CCMC. We perform simulations of magnetosphere dynamics after IMF turning from an initial northward orientation to IMF clock angles $90^\circ < \theta < 180^\circ$. We will pay special attention to the formation of multiple reconnection sites (almost anti-parallel and component). Prior to reconnection onset in the magnetotail, the rate of dayside reconnection can be estimated as the rate of the polar cap growth. We compare the contributions from all reconnection sites to the total newly reconnected magnetic flux. In addition to the role of local guide magnetic field the effects of local current sheet thickness and local flow pattern on the reconnection rate are investigated. We will pay special attention to the effects of spatial resolution and resistivity.

SM51D CC: 519 A Friday 0830h Inner Magnetosphere

Presiding: D M Ober, Mission Research Corporation; J L Roeder, Aerospace Corporation

SM51D-01 0830h

A Tale of Two Indices

James M Weygand¹ ((310) 825-1995; jweygand@igpp.ucla.edu)

R L McPherron¹ (rmcpherron@igpp.ucla.edu)

¹Institute of Geophysics and Planetary Physics, UCLA, PO Box 951567, Los Angeles, CA 90095-1567, United States

We have examined the ratio of the two indices SymH* and AsymH as a function of storm phase and solar wind VBz for about 160 storms. VBz was determined with solar wind data from the Wind and Ace spacecraft. Our initial results indicated that the ground disturbance is more symmetric during the main phase than it is in the recovery phase. Furthermore, these results showed that the ground disturbance grows more asymmetric starting about 5 hours into the recovery phase. These results disagree with previous reports [e.g. Sugiura and Chapman, 1960] and to theory which posits that the ring current is most asymmetric during the main phase and becomes increasingly symmetric during the recovery phase. These results held for weak storms, strong storms, and storms with a sudden commencement. In this report we show that the cause of this aberrant behavior is bias in both indices. We are able to reproduce the Sugiura and Chapman results by subtracting fixed offsets in both the AsymH and SymH* indices. The offset in SymH* is caused by the manner in which the baseline of quiet days is defined. The offset in AsymH is a consequence of its definition as the peak-to-peak amplitude of the local time profile of the disturbance variation in H. Our results raise serious questions above the value of these indices as measures of the partial and symmetric ring current.

URL: <http://www.igpp.ucla.edu/jweygand>

SM51D-02 0845h

Inner Magnetosphere Magnetic Field Evolution From a Simulated Storm-Time Plasma Distribution

Sorin Zaharia¹ (szaharia@lanl.gov); Vania Jordanova² (vania.jordanova@unh.edu); Michelle Thomsen¹ (mthomsen@lanl.gov); Joachim Birn¹ (jbirn@lanl.gov); C.Z. Cheng³ (fcheng@pppl.gov); Michael Denton¹ (mdenton@lanl.gov)

¹Los Alamos National Laboratory, P.O. Box 1663, Los Alamos, NM 87545, United States

²University of New Hampshire, 39 College Rd., Durham, NH 03824, United States

³Princeton Plasma Physics Lab, Princeton University, P.O. Box 451, Princeton, NJ 08543, United States

We model the magnetic field evolution in the near-Earth magnetosphere (2 to 6.6 RE) during the major magnetic storm of October 2001. The evolution is portrayed as a time series of still "snapshots" (one hour apart) in each of which the magnetic (Lorentz) force is equilibrated by plasma pressure gradient forces. Each "snapshot" is computed by employing our iterative 3-D equilibrium code, which is fed anisotropic pressure data in the equatorial plane that is an output from a kinetic ring current model (Jordanova et al., 1997). In the equilibrium code the parallel and perpendicular pressures are at each iteration extended along the magnetic field lines through considerations of energy and magnetic moment conservation. As computational boundary conditions for the 3-D equilibrium model we use inner and outer magnetic flux surfaces obtained from Tsyganenko's empirical model T01, parameterized with appropriate solar wind and DST values characterizing this particular storm event. We analyze the changes in the magnetic field configuration, plasma pressure and electric currents at each stage of the magnetic storm, focusing on how much the self-consistent magnetic field structure departs from both the dipolar and the T01 configurations during such a disturbed event. We find deep depressions in the magnetic field (compared to dipole) even very close to Earth at the peak of the storm, showing that during such disturbed times the dipole model is not appropriate even very close to Earth.

SM51D-03 0900h

Quasi-Periodic Energetic Particle Injections on the Dusk side during a Steady Magnetospheric Convection Event: A New Type of Onset

Michael G Henderson¹ (1-505-665-7425; mghenderson@lanl.gov)

Larry Kepko² (lkepko@bu.edu)

Harlan E Spence² (spence@bu.edu)

John B Sigwarth³ (john.b.sigwarth@nasa.gov)

Louis A. Frank⁴ (louis-frank@uiowa.edu)

¹Los Alamos National Laboratory, Mail Stop D466, Los Alamos, NM 87544, United States

²Boston University Department of Astronomy and Center for Space Physics, 725 Commonwealth Avenue, Boston, MA 02215, United States

³NASA Goddard Space Flight Center Electrodynamics Branch, Code 696, Building 21, Room 232, Greenbelt, MD 20771, United States

⁴The University of Iowa Department of Physics and Astronomy, 212 Van Allen Hall, Iowa City, IA 52242-1479, United States

Quasi-periodic energetic particle injections have been observed at geosynchronous orbit on the dusk side during a steady magnetospheric convection event. We examine high resolution auroral imager data and ground magnetometer data associated with these injections and conclude that they were not associated with classical substorm signatures. Based on an analysis of the data, it is proposed that these injections are caused by the explosive non-linear growth of a shear-flow ballooning instability in the region where sub-auroral polarization streams (SAPs) also occur. It is suggested that interchange will occur preferentially in the low-conductivity SAPs region since the magnetic Richardson number is lowest there and the 'line-tying' effect will also be least stabilizing there. We propose that the observed particle injection signatures and auroral morphology constitute a new type of explosive 'onset' that can occur during intervals of strong convection.

SM51D-04 0915h

The Magnetospheric Lobe at Geosynchronous Orbit: Where, When, and How?

Daniel M Ober¹ (dober@mrcnh.com)

M F Thomsen² (mthomsen@lanl.gov)

R M Skoug² (rskoug@lanl.gov)

C W Smith³ (chuck@bartol.udel.edu)

¹Mission Research Corporation, 589 West Hollis Street, Suite 201, Nashua, NH 03062-1323, United States

²Los Alamos National Lab, Space and Atmospheric Sciences (NIS-1), MS D466, Los Alamos, NM 87545, United States

³Bartol Research Institute, University of Delaware, Newark, DE 19716, United States

Typically geosynchronous orbit lies within the plasmasphere, plasma trough, and plasma sheet regions of the inner magnetosphere. During extreme solar wind conditions, however, the magnetosphere adjusts itself such that the magnetopause, bow shock, or even the open field lines of the magnetospheric lobes can extend into geosynchronous orbit. Polar-rain-type particles and the complete absence of all magnetospheric charged particle populations characterize these lobe events. Using an extensive set of observations from the Los Alamos MPA instruments along with the corresponding solar wind conditions observed by ACE we have identified the typical locations where the open field lines of the lobe are encountered at geosynchronous orbit and the unique set of solar wind driving conditions that lead to such encounters. Using this set of solar wind conditions the global configuration of the magnetosphere is modeled with the Integrated Space Weather Model (ISM), placing these data into context. The observations and simulation results are in good agreement. Events when multiple geosynchronous MPA observations are available further strengthen this agreement. Using this combined data analysis and modeling approach we explain how the magnetosphere becomes so distorted that the open field lines of the lobe are able to extend into geosynchronous orbit.

SM51D-05 0930h

The frequencies of the harmonics of standing Alfvén waves and their implication to plasma mass distribution along geomagnetic field lines: Statistical analysis of CRRES data

Kazuo Takahashi¹ (240-228-5782; kazue.takahashi@jhuapl.edu)

Richard E Denton² (603-646-2732; richard.denton@dartmouth.edu)

Roger E Anderson³ (319-335-1924; roger-r-anderson@uiowa.edu)

W Jeffrey Hughes⁴ (617-353-2471; hughes@bu.edu)

¹Johns Hopkins University Applied Physics Laboratory, 11100 Johns Hopkins Road, Laurel, MD 20723-6099, United States

²Dept Physics Astronomy, Dartmouth College, Hanover, NH 03755-3528, United States

³Department of Physics and Astronomy, University of Iowa, Iowa City, IA 52242, United States

⁴Department of Astronomy, Boston University, Boston, MA 02215, United States

The relationship among the frequencies of the harmonics of standing Alfvén waves depends on the variation of plasma mass density along the geomagnetic field line. This in turn means that observed standing wave frequencies may be used to infer the mass density variation, which is difficult to measure with particle instruments on spacecraft. Determination of the density variation is important in understanding mass transport processes in the ionosphere-magnetosphere system and also in improving magnetospheric diagnostic techniques using ULF waves. We investigate the frequencies of multi-harmonic toroidal standing Alfvén waves detected in the electric and magnetic fields measured by the Combined Release and Radiation Effects Satellite (CRRES). The data cover the entire CRRES mission period from July 1990 to October 1991. Using a semi-automated procedure we identify over 4000 samples of the fundamental toroidal frequency (f1), which are often accompanied by the second (f2) and third (f3) harmonics. Most (~3000) fundamental frequency samples are taken at dipole L shells from 4 to 8 and at magnetic local time (MLT) from 1200 to 1800, and we perform statistical analyses of the frequencies in this L-MLT domain. The most frequently observed ratios are f2/f1 ~ 2.5 and f3/f1 ~ 4.0 for 4 < L < 6 and f2/f1 ~ 2.8 and

$f3/f1 \sim 4.3$ for $6 < L < 7$. These observations are compared with the theoretical ratios obtained for the density variation of the form $\rho = \text{Req}LRe/R^\alpha$, where Req is the equatorial mass density, R is geocentric distance to the field line, and the power-law density index α is a free parameter. We find that $\alpha \sim 0.5$ fits the average observed frequency ratios at $4 < L < 6$, consistent with a diffusive equilibrium solution. No single value of α fits the average observed frequency ratios at $6 < L < 7$. In that case, theoretical solutions indicate that the mass density is locally peaked at the equator; that is, the mass density decreases as one moves off-equator, then increases again toward the ionosphere. Combined with the results of recent studies of electron density (which have not found such a peak in density at the magnetic equator), this indicates that heavy ions are preferentially concentrated at the magnetic equator.

SM51D-06 0945h

Magnetospheric toroidal Alfvén wave harmonics and the field line distribution of mass density

Richard E. Denton¹ (603-646-2732; Richard.denton@dartmouth.edu)

Kazuo Takahashi² (240-228-5782; kazue.takahashi@jhuapl.edu)

Roger R. Anderson³ (rra@space.physics.uiowa.edu)

Martin P. Wuest⁴ (Martin.Wuest@inficon.com)

¹Dartmouth College, Department of Physics and Astronomy, 6127 Wilder Lab, Hanover, NH 03755, United States

²Applied Physics Laboratory, The Johns Hopkins University, 11100 Johns Hopkins Rd., Laurel, MD 20723, United States

³University of Iowa, Department of Physics and Astronomy, 615 Van Allen Hall, Iowa City, IA 52242, United States

⁴Southwest Research Institute, Space Science Engineering Div, 6220 Culebra Rd, San Antonio, TX 78238, United States

Measurements of electric and magnetic field taken by instruments on the CRES spacecraft on July 29, 1991, reveal seven or eight toroidal Alfvén wave frequency bands. By using observations of the waves near the magnetic equator and the symmetry of the theoretical modes as a function of magnetic latitude, we can identify which theoretical Alfvén wave harmonic corresponds to a particular frequency band. This along with the L shell frequency dependence gives convincing evidence that we are in fact observing the toroidal Alfvén mode. Because the harmonics of the toroidal Alfvén wave have a different response to mass density at different points along a magnetic field line, the frequencies of these harmonics can be used to infer the distribution of mass density along the field line. While there is a significant uncertainty in the results due to the uncertainty in the observed frequencies, it is nevertheless true that both the solution based the peak (mean) frequencies and the majority of solutions using a Monte Carlo simulation of the effects of uncertainty in frequency show the same result, that there is a local maximum in mass density within about 30° of the magnetic equator. The same result is found for the wave event observed on August 28, 1990. These results imply that heavy ions are preferentially concentrated at the magnetic equator.

SM52A CC: 518 A Friday 1030h

Space Weather: Linking Research and User Needs II (joint with SA, SH)

Presiding: A Posner, Southwest Research Institute; **H J Singer**, NOAA Space Environment Center

SM52A-01 1030h INVITED

Predicting Extreme Events: the Halloween Storms of 2003

Joseph M Kunches (303-497-5275; joseph.kunches@noaa.gov)

NOAA Space Environment Center, 325 Broadway, Boulder, CO 80305-3337, United States

Space weather from October 19 through November 7, 2003, dubbed the "Halloween Storms," was, by any measure, spectacular. The solar flares, coronal mass ejections, energetic particles, geomagnetic, and ionospheric storms that occurred caused problems - and excitement - for forecasters, customers, and data providers. In addition, the print and electronic media were aggressive in acquiring information on what

was occurring. Forecasters were faced with the challenge of discerning what an extreme event must look like: how do you predict the events that almost never occur? What does that data have to look like? How do you convey the significance of the situation to the customers of those predictions, while knowing the odds are against you? Models are increasingly more valuable to forecasters, but are there limitations when the models are asked to predict the "outlier" events? Can forecasters believe the model output when those predictions are so far from what empirical evidence suggests? The customers must integrate these predictions in the context of other considerations that affect their system. Do they blindly react to the prediction or do they hedge? The customer reaction is often influenced by the reports they see and hear from the broadcast media. During the Halloween Storms, more than 300 media contacts, including live on-camera interviews, occurred at the NOAA Space Environment Center. What impact do these distractions have on maintaining a high level of operational integrity? The public interest in this activity was unprecedented. Finally, the system impacts of the Halloween Storms were many. As would be expected, the impacts were seen around the world. For providers of space weather services, each of these areas - the data, the models, the predictions, the users, the media, and the impacts - interleaved to form a service challenge of a very wide expanse. This talk will present representative examples of each of these areas during the Halloween Storms, and offer a glimpse to future space weather services needed for the strongest space weather events.

SM52A-02 1050h

October 29-31, 2003 Storm Effects on Ionospheric Currents and Geomagnetically Induced Currents

Donald W Danskin¹ (ddanskin@nrcan.gc.ca)

David H Boteler¹ (dboteler@nrcan.gc.ca)

Larisa Trichtchenko¹ (lrichtc@nrcan.gc.ca)

Lorne McKee¹ (lmckee@nrcan.gc.ca)

Gerritt Jansen van Beek¹ (gjansenv@nrcan.gc.ca)

¹Geomagnetic Laboratory, Natural Resources Canada 7 Observatory Cres., Ottawa, ON K1A 0Y3, Canada

A major solar storm in late October 2003 produced significant currents in the ionosphere. These currents resulted in geomagnetically induced currents (GIC) in several electrical power transmission systems. Using equivalent ionospheric currents determined from an international array of magnetometers, an enhanced understanding is obtained of how the two dimensional spatially extended currents vary over the Northern Hemisphere during this period. Also the temporal variation in the GIC and equivalent currents show several distinct responses to the conditions prevalent in the storm. For IMF Bz positive and strong B, significant amplitude pulsations in the GIC were observed.

SM52A-03 1105h INVITED

Research and User Needs Concerning Geomagnetically Induced Currents in the Ontario Power System

Luis Marti (1-416-345-5317; luis.marti@HydroOne.com)

Hydro One Networks Inc., 483 Bay St, TCT 15, Toronto, ON M5G 2P5, Canada

Hydro One (the Transmission and Distribution successor company of the old Ontario Hydro) has been interested in the effects of Geomagnetically Induced Currents (GIC) in Ontario's High Voltage transmission network for quite a number of years. Since the late 1990s, we have conducted impact studies looking at areas such as protection and control, impact on equipment, and system dynamics. Since 1998 Hydro One has taken operational measures to reduce the possible impact of solar magnetic events (in addition to those suggested by NPCC). Furthermore, Hydro One is in the process of completing a province-wide GIC measuring network to provide real-time data to circuit analysis software designed to estimate dc flows at any point in the HV transmission network. Alternatively, the same software will be able to use magnetic field measurements to complement and improve on the direct current measurements. The ultimate goal of this monitoring network and analysis software is to offer Hydro One's operating authority with the flexibility to make informed decisions during and prior to solar magnetic events. As we gain experience with the GIC detection network, we envision the capability to make planned selective operating decisions, as well as what-if studies to prevent equipment damage and service interruptions during severe solar magnetic events.

SM52A-04 1125h

Possibilities of the GIC modelling using geomagnetic data

Larisa Trichtchenko (613-837-9452; lrichtc@nrcan.gc.ca)

Geomagnetic Laboratory, NRCAN, 7 Observatory Crescent, Ottawa, ON K1A 0Y3, Canada

Forecast of GIC in power systems requires knowledge of all the steps from the origin of disturbances on the Sun, their propagation through the solar wind, interaction with the magnetosphere and ionosphere, to the production of local geomagnetic disturbances and associated geoelectric fields and resulting effects on power systems. In this paper we focus on the steps from geomagnetic disturbances to the power system on the ground. We make extensive use of GIC data from 3 recording sites in 3 different power systems to show the empirical relation between the global 3-hour index ap and measured peak GIC. Hourly ranges of the magnetic field variations and hourly peak dB/dt values from the magnetic observatories closest to the GIC recording sites serve as measures of local geomagnetic conditions. These were used to obtain the relation between local magnetic indices and hourly peak GIC. For more detailed modeling we use actual geomagnetic field variations (1-min data) and an earth model to calculate the electric fields in the area of the power system. Assuming a purely resistive model of the power network this should be directly proportional to the GIC in the network. Comparisons of the variations of 1-min electric field values to the measured 1-min GIC values has been done by using a linear regression analysis. Measured GIC data and geomagnetic field data served to determine an empirical frequency-domain transfer function. Application of this with magnetic field variations from a new time period to provide GIC values was used to test the consistency of this relationship. The comparisons using 1-hour and 3-hour indices show that local 1-hour magnetic indices (especially peak dB/dt) are better indices to use for correlations with peak GIC values. An examination of correlation coefficients between 1-min datasets shows a strong directional sensitivity. Each GIC measuring site in each system had a particular "preferred" direction for the electric or magnetic field that was most closely correlated with the GIC at that site. Hourly or 3-hourly indices and hourly or 3-hourly peak GIC values are better correlated than datasets of 1-min values produced by different models from geomagnetic or geoelectric fields and 1-min GIC data. This shows that it is much easier to predict the envelope of the GIC variations rather than the detailed GIC variations themselves.

SM52A-05 1140h

Indicator for the effects of geomagnetically induced currents on power transmission systems

Antti Aleksi Pulkkinen¹ (+358-9-19294694; antti.pulkkinen@fmi.fi)

Risto Pirjola¹ (+358-9-19294652; risto.pirjola@fmi.fi)

Ari Viljanen¹ (+358-9-19294668; ari.viljanen@fmi.fi)

¹Finnish Meteorological Institute, Vuorikatu 15 A, P.O. Box 503, Helsinki 00101, Finland

Geomagnetically induced currents (GIC) flowing in technological conductor systems on the ground are often considered as the end link of the space weather chain originating from the Sun. Despite the other systems affected, partly due to the magnitude of the semi-quantified economic impact, the effects of GIC on high-voltage power transmission systems have been of special interest both from the industrial and scientific viewpoint. In this paper we introduce a novel indicator tailored specifically to describe the effects of GIC on power transmission systems. The goal is to derive an indicator in which both geophysical and technological aspects of the phenomena are properly taken into account. Obviously, the same indicator or a similar approach can also be used for other systems experiencing impacts of GIC. The usage of the novel indicator is illustrated by applying it to the geomagnetic recordings of the October 2003 superstorm. It is shown that the indicator explains well the time of the GIC-related blackout experienced in southern Sweden in October 30.