AGU CHAPMAN CONFERENCE ON UNIVERSAL HELIOPHYSICAL PROCESSES (IHY)

SAVANNAH, GEORGIA, USA
10 - 14 NOVEMBER 2008

Conveners:

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Boston, Massachusetts, USA

Marina Galand
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Imperial College
London, England, UK

Program Committee:

Terry Forbes • University of New Hampshire
Joe Giacalone • University of Arizona
Wing Ip • National Central University
Chris Owen • University College London
George Siscoe • Boston University
Roger Smith • University of Alaska
Jan-Erik Wahlund • Swedish Institute of Space Physics
Gary Zank • University of California

Conference Objectives:

The conference title reflects the primary science theme of the 2007-2008 International Heliophysical Year (IHY), advancing our understanding of the fundamental heliophysical processes that govern the Sun, Earth, and heliosphere. The conference program will reflect the approach to research described in the 2004 report of the National Research Council (NRC), Plasma Physics of the Local Cosmos which is organized into five categories: creation and annihilation of magnetic fields, formation of structures and transients, plasma interactions, explosive energy conversion, and energetic particle acceleration. This approach seeks to find universal physical laws through comparative studies in the laboratory of the solar system.

http://www.agu.org/meetings/chapman/2008/gcall/

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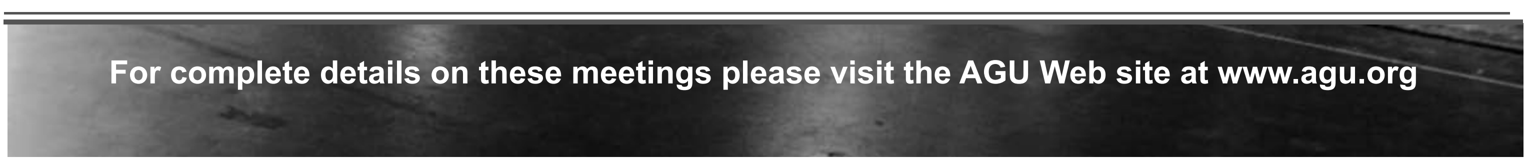

AGU Chapman Conference on Universal Heliophysical Processes (IHY)

Savannah, Georgia, USA
10–14 November 2008

Conveners

- Nancy Crooker, Boston University, Boston, Massachusetts, USA
- Marina Galand, Imperial College, London, England, UK

Program Committee

- Terry Forbes, University of New Hampshire, Durham, New Hampshire, USA
- Joe Giacalone, University of Arizona, Tucson, Arizona, USA
- Wing Ip, National Central University, Jhongli City, Taiwan
- Chris Owen, University College London, Surrey, England, UK
- George Siscoe, Boston University, Boston, Massachusetts, USA
- Roger Smith, University of Alaska, Fairbanks, Alaska, USA
- Jan-Erik Wahlund, Swedish Institute of Space Physics, Uppsala, Sweden
- Gary Zank, University of California, Riverside, Riverside, California, USA

Sponsor

U.S. National Science Foundation

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MEETING AT A GLANCE

Sunday, 9 November

18:30 – 20:00	Registration and Welcome Reception

Monday, 10 November

8:00 – 8:45	Registration
9:00 – 10:30	Oral Discussions
10:30 – 11:00	Morning Refreshments
11:00 – 12:30	Oral Discussions
12:30 – 14:00	Lunch (*on own*)
14:00 – 15:30	Oral Discussions
15:30 – 16:00	Afternoon Refreshments
16:00 – 17:00	Oral Discussions
17:00 – 18:30	Poster Viewings (*refreshments and cash bar*)

Tuesday, 11 November

7:30 – 8:15	Registration
8:30 – 10:30	Oral Discussions
10:30 – 11:00	Morning Refreshments
11:00 – 12:30	Oral Discussions
12:30 – 14:00	Lunch (*on own*)
14:00 – 15:00	Oral Discussions
15:00 – 15:30	Afternoon Refreshments
15:30 – 17:00	Oral Discussions
17:00 – 18:30	Poster Viewings (*refreshments and cash bar*)

Wednesday, 12 November

7:30 – 8:15	Registration
8:30 – 10:00	Oral Discussions
10:00 – 10:30	Morning Refreshments
10:30 – 12:00	Oral Discussions
12:00 – 13:00	Lunch (*on own*)
13:00 – 17:45	Excursion (*optional*)
19:00 – 21:00	Conference Banquet (*cash bar*)

Thursday, 13 November

8:00 – 8:45	Registration
9:00 – 10:30	Oral Discussions
10:30 – 11:00	Morning Refreshments
11:00 – 12:30	Oral Discussions
12:30 – 14:00	Lunch (*on own*)
14:00 – 15:00	Oral Discussions
15:00 – 15:30	Afternoon Refreshments
15:30 – 17:00	Oral Discussions
17:00 – 18:30	Poster Viewings (*refreshments and cash bar*)

Friday, 14 November

8:00 – 8:45	Registration
9:00 – 10:30	Oral Discussions
10:30 – 11:00	Morning Refreshments
11:00 – 13:00	Oral Discussions
13:00	Conference Adjourns

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SCIENTIFIC PROGRAM

Note: Oral Discussions will be held in the Trustees Room and Posters will be on display in the Living Room of the Mulberry Inn.

SUNDAY, 9 NOVEMBER 2008

18:30 – 20:00 Registration and Welcome Reception

MONDAY, 10 NOVEMBER 2008

8:00 Registration

Opening Session **Chair: Nancy Crooker**

9:00 Opening Remarks — Nancy Crooker and Marina Galand

9:10 *Universal Heliophysical Processes* — George Siscoe

9:40 *Universal Processes Involving Neutral Media* — Roger Smith

10:10 Discussion

10:30 Morning Refreshments The Living Room

Creation and Annihilation of Magnetic Fields **Chair: Jim Drake**

11:00 *Creation and Annihilation of Magnetic Fields* — Aad van Ballegooijen

11:30 *Comparative Aspects of Magnetic Reconnection in the Solar Wind and in Earth's Magnetosphere* — Jack Gosling

12:00 *Addressing Magnetic Reconnection on Multiple Scales: What Controls the Rate of Magnetic Reconnection in Astrophysical Plasmas?* — John Dorelli

12:30 Lunch (*on own*)

14:00 Discussion — Moderator: Jim Drake

15:30 Afternoon Refreshments The Living Room

16:00 Discussion

17:00 Poster Session (*refreshments and cash bar*)

18:30 Adjourn

TUESDAY, 11 NOVEMBER 2008

7:30 Registration

Formation of Structures and Transients **Chair: Tim Horbury**

8:30 *Universal Processes in Turbulence and Turbulent Transport* David Newman

9:00 *Commonalities between Turbulence, Flux-Tube Structure, and Current Sheets*
Joe Borovsky

9:30 *Comparative Shock Studies: From the Lower Corona to the Termination Shock*
Merav Opher

10:00 *Comparative Studies of Turbulent Relaxation and the Generation of Structure in Simulation and the Solar Wind* Bill Matthaeus

10:30 Morning Refreshments The Living Room

11:00 Discussion Moderator: Tim Horbury

12:30 Lunch (*on own*)

14:00 Discussion

15:00 Afternoon Refreshments The Living Room

Plasma Interactions **Chair: Marina Galand**

15:30 *Physical Processes Associated With Neutral Plasma Interactions in Planetary Atmospheres with a Significant Magnetic Field* Tim Fuller-Rowell

16:00 *Comparative Solar Wind - Planetary Magnetosphere - Ionosphere Interactions*
Michel Blanc

16:30 *Solar Wind or Planetary Magnetosphere Interactions with the Atmospheres of Unmagnetized Bodies* Janet Luhmann

17:00 Poster Session (*refreshments and cash bar*)

18:30 Adjourn

WEDNESDAY, 12 NOVEMBER 2008

7:30 Registration

Plasma Interactions (Continued) **Chair: Marina Galand**

8:30 Discussion Moderator: Jan-Erik Wahlund

10:00 Morning Refreshments The Living Room

10:30 Discussion Moderator: Wing Ip

12:00 Lunch (*on own*)

13:00 Excursion to Bonaventure Cemetery and Fort Pulaski

19:00 Conference Banquet Mulberry Inn Cafe

THURSDAY, 13 NOVEMBER 2008

8:00 Registration

Explosive Energy Conversion **Chair: Joachim Birn**

9:00 *Comparison of CME and Magnetospheric Substorm Initiation Mechanisms I* Terry Forbes

9:30 *On the Acceleration of Plasmoids in the Magnetotail and Its Relation to CME Acceleration* Michael Hesse

10:00 *Comparative Planetary Substorms* Emma Bunce

10:30 Morning Refreshments The Living Room

11:00 Discussion Moderator: Joachim Birn

12:30 Lunch (*on own*)

14:00 Discussion

15:00 Afternoon Refreshments The Living Room

Energetic Particle Acceleration and Plasma Heating Chair: Joe Giacalone

15:30 *Comparisons of Inner Radiation-Belt Formation in Planetary Magnetospheres*
Richard Horne

16:00 *The Universal Nature of Suprathermal Power Law Tails with Spectral Index of -5 on the Velocity Distributions Solar Wind and Pickup Ions* George Gloeckler

16:30 *Universal Aspects of Diffusive Shock Acceleration* Randy Jokipii

17:00 Poster Session (*refreshments and cash bar*)

18:30 Adjourn

FRIDAY, 14 NOVEMBER 2008

8:00 Registration

Energetic Particle Acceleration and Plasma Heating (Continued) Chair: Joe Giacalone

9:00 Discussion Moderator: Joe Giacalone
Invited Contributors, Marty Lee and Jakobus le Roux

10:30 Morning Refreshments The Living Room

11:00 Discussion

Concluding Session

12:00 *Discussion on Future Avenues of Research* Moderator: George Siscoe

13:00 Conference Adjourns

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POSTER SESSIONS

Posters will be on display in The Living Room. Posters are listed below in alphabetical order and will remain on display from Monday through Thursday afternoon, 18:30.

A01 Ågren, K., *The Structure of Titan's Deep Ionosphere*

A02 Al-Dayeh, M., *Spectral and Compositional Properties of the Quiet-Time Suprathermal Ion Population at 1 AU*

A03 Andersson, L., *Locations of non-Linear Processes in the Earth's Magnetosphere as Identified by Electron Phase Space Holes by the Themis Mission*

B04 Borovsky, J., *On the Axford Conjecture: What Controls the Reconnection Rate?*

C05 Cooper, J. F., *Impact of Universal Plasma and Energetic Particle Processes on Icy Bodies of the Kuiper Belt and the Oort Cloud*

D06 Das. I., *Presence of a Reverse Shock in the Evolution of a CME in the Lower Solar Corona*

E07 Evans, R., *Surface Alfvén Wave Damping in a 3D Simulation of the Solar Wind*

G08 Galand, M., *Comparative Planetary Auroralogy*

H09 Hill, M. E., *Interplanetary Suprathermal He+ and He++ Observations During Quiet Periods from 1.5 to 9 AU and Implications for Particle Acceleration*

K10 Korreck, K. E., *Solar Wind Particles from the Solar Corona to the Earth*

L11 Laming, J., *Electron Heating at Shock Waves by a Cosmic Ray Precursor*

O12 Owen, C. J., *Cross-Scale: An ESA Cosmic Vision Mission to Study Multi-Scale Coupling in Plasmas*

O13 Oz, E., *Laboratory Study of Solar Flare Dynamics in MRX*

R14 Romashets, E., *Magnetic Disturbances Within Solar Flux Ropes*

R15 Romashets, E., *Numerical Model for Electric Potential and Field-Aligned Current in Low Latitude Ionosphere*

T16 Thompson, B., *The Whole Heliosphere Interval: Campaign Summaries and Early Results*

W17 Wanliss, J. A., *Critical Behaviour in the Solar Wind and Magnetosphere over a Solar Cycle*

ABSTRACTS

Oral discussions: listed in order of daily presentation.

Monday, 10 November

Universal Heliophysical Processes

G. Siscoe (Center for Space Physics, Boston University, Boston, MA 02215, ph. 978 443 8559, fax 617 359 6463, e-mail siscoe@bu.edu)

We meet on the 50th year since the birth of space physics. A half century of space exploration has yielded a mass of data on nearly every object and region within 100 AU of the Sun. Facing this mass of data we are here to foster the effort to discern common processes that link phenomena that they reveal in different places and on different scales. The effort we are fostering was launched by the NRC report "Plasma Physics of the Local Cosmos," and it was carried forward significantly by the IHY program. The NRC report divided the phenomena to be linked by common processes into the five topics. These topics form the headings of the sessions of this conference. They identify activities and structures that distinguish the organization of magnetized plasmas on cosmic scales—plasmas organized under the long range forces of gravity and magnetism. The purpose of this talk is to review the NRC project, to illustrate it with examples of phenomena clearly linked over great ranges of scales, and to suggest with examples that comparative studies constitute a new approach that is well suited to address important problems in space physics.

Universal Processes Involving Neutral Media

R. Smith (Geophysical Institute, University of Alaska)

The International Heliophysical Year (IHY) aims to identify and study universal processes of importance to the physics of the heliosphere. Some processes are found in space plasmas, some in neutral media and some in both. All have important roles sustaining the mechanisms transporting energy, mass and momentum in the regimes of their operation. The varieties of regimes vary from those associated with the sun, the solar wind and planetary magnetospheres (generally plasmas) to those found in the atmospheres and condensed matter of planets. The purpose of this paper is to focus on some universal processes found in planetary atmospheres and ionospheres. One important process found in plasmas and neutral media is turbulence. At the planetary surface, atmospheric turbulence is the rate determining mechanism for hear transporting across the solid to gas boundary. In the upper atmosphere, turbulence enables the transport of heat and momentum where acoustic-gravity waves break and turbulent mixing gives way to gravitational layering. In both cases, small scale motions lead to large scale effects. Other examples include the coupling of neutral and ionized constituents through plasma drift driven by electric fields, the modulation of plasma processes in the magnetosphere by high-latitude ionospheric outflow and the destabilization of the equatorial ionosphere by vertical drift. All of these processes have at least partial dependence on the presence of neutral media.

Creation and Annihilation of Magnetic Fields

A. van Ballegooijen (Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, MS-15, Cambridge, MA 02138-0000; Ph.: 617 495-7183)

The magnetic fields that pervade the heliosphere are generated in the Sun through a variety of dynamo processes. These processes involve complex magnetic interactions between the solar interior and its atmosphere, leading to the creation and annihilation of strong "toroidal" magnetic fields inside the Sun. Bipolar active regions (ARs) emerging into the atmosphere alter the deep-seated magnetic fields, and play a key role in the solar cycle. According to the Babcock-Leighton (BL) model, the tilts of ARs are responsible for the cyclic

nature of the dynamo. Result from a BL model of the dynamo will be presented. The ARs also remove magnetic twist from the solar interior, which leads to eruptions in the form of flares and coronal mass ejections. As the ARs decay their magnetic flux and helicity are spread over the solar surface, creating large-scale helicity patterns that are important for understanding the Sun's open magnetic flux and its effects on the heliosphere. I conclude with a discussion of the universal processes involved in dynamo action.

Comparative Aspects of Magnetic Reconnection in the Solar Wind and in Earth's Magnetosphere

J. T. Gosling (Laboratory for Atmospheric and Space Physics, University of Colorado, 1234 Innovation Drive, Boulder, CO 80303; ph. 303-926-1795; fax 303-492-6444; e-mail: jack.gosling@lasp.colorado.edu)

Although the signatures of magnetic reconnection have been recognized and extensively studied at Earth's magnetopause and in Earth's magnetotail for more than 30 years, only recently have we learned how to recognize the unambiguous signature of reconnection in the solar wind: roughly Alfvénic accelerated plasma flow confined to a region where the magnetic field rotates and bounded on one side by correlated changes in velocity, /***V***/, and magnetic field, /***B***/, and by anti-correlated changes in /***V***/ and /***B***/ on the other. In many ways the solar wind is an ideal laboratory for studying the after-effects of reconnection because it contains a rich array of current sheets of varying thicknesses and spatial extents that are associated with a broad spectrum of field rotation angles. Moreover, the solar wind rapidly convects a reconnecting current sheet past a spacecraft, allowing separation of temporal and spatial effects, while multi-spacecraft observations reveal the relative stationarity and spatial extent of the reconnection process. This paper attempts to compare and contrast what has been learned about the overall reconnection process in general from studies of reconnection signatures in the quite different environments of the solar wind and Earth's magnetosphere.

Addressing Magnetic Reconnection on Multiple Scales: What Controls the Rate of Magnetic Reconnection in Astrophysical Plasmas?

J. C. Dorelli (Department of Physics, University of New Hampshire, Durham, NH 03824; ph. 603.862.0613; e-mail: john.dorelli@unh.edu)

Magnetic reconnection is often invoked to explain the rapid conversion of magnetic energy into plasma energy during explosive astrophysical events such as solar flares, coronal mass ejections and magnetic storms. Modeling large scale reconnection, however, is computationally challenging due to the enormous range of length scales involved. There is still no satisfactory solution to this multiple scales problem. For example, despite its well known flaws (e.g., its neglect of terms in the generalized Ohm's law which play an essential role in producing fast reconnection in collisionless plasmas) magnetohydrodynamics (MHD) is still the most common approach to modeling large scale systems such as the solar corona and Earth's magnetosphere. One way to bypass the multiple scales problem is to invoke the so-called "Axford Conjecture," which states that reconnection is completely controlled by the large scale dynamics, with microscopic processes (e.g., the geometries of the dissipation regions) adjusting to accommodate external boundary conditions. An alternative view is that microscopic processes influence the large scale dynamics such that the reconnection rate depends sensitively on kinetic scale lengths such as particle Larmor radii. In this talk, we review arguments for and against the Axford Conjecture. Addressing subsolar magnetopause reconnection as a special case, we demonstrate that solving the multiple scales problem involves an asymptotic matching of small scale physics to large scale physics, implying that both microscopic and macroscopic physics play essential roles in determining the reconnection rate. We conclude with a review of some open questions.

Tuesday, 11 November

Universal Processes in Turbulence and Turbulent Transport

D. Newman (Physics Department/Geophysical Institute, University of Alaska Fairbanks)

There are well known differences between the dynamics of turbulent plasmas which are magnetically confined and turbulent plasmas and neutral fluids which are gravitationally confined. Among other issues, these often involve the effective dimensionality of the system and the invariants of the turbulence. However here are also many similarities, particularly when the gravitational system is rotating. In this presentation, some of the similarities in the dynamics and turbulent transport properties will be discussed. We will discuss the interaction between the turbulence and sheared flows in the various systems as well as characteristics of the turbulent transport that can be thought of as "universal" because they transcend the details of the system. Finally, some comments will be made about the dynamical coupling between magnetically confined plasmas and neutral fluids.

Commonalities Between Turbulence, Flux-Tube Structure, and Current Sheets

J. Borovsky (Los Alamos National Laboratory 505-667-8368, e-mail: jborovsky@lanl.gov)

The global solar wind is born from a multitude of flux tubes of the magnetic carpet that reach out from the photosphere into the heliosphere. These magnetic-carpet flux tubes constantly undergo reconnection near the Sun as photospheric convection stirs the magnetic carpet. The question arises: Does the magnetic flux-tube pattern wash out as the solar-wind plasma convects away from the Sun, or does the pattern leave fossil structure in the solar-wind plasma? Far from the Sun, the solar-wind plasma is filled with structure. Some of the structure takes the form of discontinuities: distinct current sheets and changes in the plasma. Discontinuities could be a signature of the interface between fossil flux tubes. On the contrary, discontinuities could also be formed by the action of MHD turbulence. A picture of the solar wind plasma composed of fossil flux tubes plus MHD turbulence is presented, and the resulting outstanding issues to explore are discussed.

Comparative Shock Studies: From the Lower Corona to the Termination Shock

M. Opher (Department of Physics and Astronomy, George Mason University, Fairfax, VA 22030-4444; ph. 703-993-4571; fax 703-993-1269; e-mail: mopher@gmu.edu)

Shocks are present everywhere in the heliosphere, from close to the Sun to the outer edges of the solar system, the termination shock. Although our understanding of collisionless shocks has been advanced in recent years, we still lack a comprehensive study on how the evolution of shocks (and their characteristics) is affected by the environment in which they propagate. In particular, it is expected that the efficiency of the acceleration of particles will depend on the shock's geometry and strength, which will be a function of the shock's initial structure and the solar wind environment into which it propagates. From the in situ observations of the termination shock by Voyager 1 and 2, it became clear that shock properties are much more complex than previously expected. For example, the termination shock appears to be particle-mediated, and the temperature in the heliosheath is significantly lower than expected. A near-power-law spectral shape was not observed as expected for anomalous cosmic rays at the shock crossing. Observations with the Voyagers, SOHO, and STEREO indicate heliospheric asymmetries. In this talk, we will compare the shocks (and sheath) driven by Coronal Mass Ejections in the lower corona with the termination shock and heliosheath. We will focus on universal processes such as a) geometry of shocks and magnetic connection to the shock; b) flows; and c) magnetohydrodynamic instabilities, reviewing our recent works in this area (Opher et al. 2006; 2007, Liu et al. 2008a, 2008b, Loesch et al. 2008).

Comparative Studies of Turbulent Relaxation and the Generation of Structure in Simulation and the Solar Wind

W. H. Matthaeus (Bartol Research Institute and Dept. of Physics and Astronomy, University of Delaware (302-831-8111; email: whm.udel.edu) ; S. Servidio (Dpt. Of Physics and Astronomy, University of Delaware); Antonella Greco (Dipartimento di Fisica, Universita Della Calabria, Italy); P. Dmitruk (Dipartamento di Fisica, Cuidad Universitad di Buenos Aires)

Studies of model magnetic fields including turbulence show that flux tubes have a complex behavior in space, even using random phases. Dynamically generated intermittency, coherent structures, and reconnection give rise to even greater spatial complexity. A real-space picture of this is emerging: Recently, studies have shown that local relaxation processes in MHD turbulence to rapidly produce distinctive correlations of several types in spatial patches. These include correlations associated with Alfvenic fluctuations, Beltrami flows and force free fields. These arise even when global correlation is not present. We show that this implies the formation of coherent structures including current sheets at the borders between the quasi-relaxed cells or flux tubes. This provides a picture of the origin of spatial intermittency, and can also be associated with enhancement of dynamical processes including magnetic reconnection at these boundaries. When methods for identifying intermittency are applied to solar wind data, we find that statistically these select for “events” very similar to what is found using classical methods for identification of discontinuities. Furthermore, we find almost identical waiting time distributions and distribution of partial vector variances in simulations of intermittent MHD turbulence and in solar wind magnetic field observations. A taxonomy is suggested in which observed magnetic increment pdfs consist of contributions from sub-gaussian flux tube cores and super-gaussian current sheets at the boundaries. These results indicate that it is at least possible that a significant admixture of discontinuities in the solar wind are generated by in situ dynamical processes.

Physical Processes Associated With Neutral Plasma Interactions in Planetary Atmospheres With a Significant Magnetic Field

T. Fuller-Rowell (Space Weather Prediction Center, Boulder, CO 80305; ph. 303-497-5764; fax 303-497-3645; e-mail: tim.fuller-rowell@noaa.gov)

Planets with a significant magnetic field are shielded from the direct interaction of the solar wind velocity and magnetic field with their partially ionized upper atmospheres. The magnetic field, however, within the atmosphere does strongly impact the interaction between the neutral and ionized components. The neutral global circulation and wind patterns are forced by sources of heat and momentum and are strongly influenced by the velocity of the planetary rotation. The ionospheric plasma can be set into motion either by the solar wind-magnetospheric electromagnetic sources external to the planetary atmosphere, producing ion-drag, Joule heating, and auroral particle precipitation, or by the internal collisional interaction between the neutral atmosphere and ionosphere. Ion-neutral collisions are strongly height dependent due to the rapid decrease in neutral density with altitude, influencing not only the dynamic and heating response to the external forcing, but also the plasma response to the thermospheric dynamo processes.

Comparative Solar Wind - Planetary Magnetosphere - Ionosphere Interactions

M. Blanc (Ecole Polytechnique, Palaiseau, France; also at CESR, Toulouse, France; E-mail: michel.blanc@cesr.fr)

We present an overview of solar wind-magnetosphere-ionosphere interactions as they can be understood using a comparative approach linking different interaction regimes observed or conjectured at Earth, the giant planets, Ganymede and Mercury.

In all cases, the variety of interactions can be attributed to a relatively reduced set of parameters, such as the geometry of the dipole field with respect to the spin axis of the planet, its rotation rate, the intensity and radial distribution of internal plasma sources, the distance to the sun, the distribution of ionospheric conductances. For each case we describe the mechanisms involved in the coupling of the three key regions (transfer of plasma flow momentum, circulation of electric currents, acceleration of particles and generation of aurora, radio emissions and radiation belts).

Then we explore some "families" of planetary interactions with the solar wind, using the Earth case as a reference. The cases of Mercury and Ganymede, both still poorly known, are expected to illustrate an extreme situation when the ionosphere itself merely vanishes, and are particularly interesting to study possible direct surface-magnetosphere coupling effects.

The most documented three cases, however, are those of Earth, Jupiter and Saturn. We first discuss Earth and Jupiter as two sort of opposite cases: one with a strong internal plasma source and fast planetary rotation, in which planetary rotation effects likely dominate over solar wind control of the magnetosphere; one with relatively weak internal sources and a slow planetary rotation, in which solar wind control dominates. The Jupiter case is also the most interesting one in terms of the diversity of its auroral features, revealing at least three types of aurora generation mechanisms, in which only one involves an interaction with the solar wind. Using this categorization, we finally study the case of Saturn, which best illustrates the dynamics of a solar-wind driven magnetosphere and aurora at a fast rotating planet. Comparison of these three most studied magnetospheres is an ideal starting point to try and identify "universal" processes in solar wind-magnetosphere-ionosphere coupling.

Solar Wind or Planetary Magnetosphere Interactions with the Atmospheres of Unmagnetized Bodies

J. G. Luhmann (Space Sciences Laboratory, University of California, Berkeley, CA 94720; ph. 510-642-2545; fax 510-643-8302; e-mail: jgluhman@ssl.berkeley.edu)

Venus, Mars, and Titan represent our best probed and most analyzed examples of unmagnetized body/flowing plasma interactions in cases where a substantial atmosphere is present. Some common characteristics, even common to magnetosphere interactions, are expected and observed in the regions corresponding to the magnetosheaths and foreshocks of planetary magnetospheres in the solar wind. But details of these sheaths and shocks depend on the specifics of the interfaces between the planetary obstacles and their external plasma flows. At the same time, these interfaces depend on the details of the atmospheres and ionospheres, as well as on the external plasma and field conditions. The three interactions are to first order well-represented by MHD, but ion kinetic aspects play distinctive roles. This presentation summarizes the essential physical processes inferred from observations and models, and considers the consequences of general factors such as body size, proximity to the Sun, and proximity to another parent body.

Thursday, 13 November

Comparison of CME and Magnetospheric Substorm Initiation Mechanisms I

T. G. Forbes (Institute for the Study of Earth, Oceans, and Space, University of New Hampshire, Durham, NH 03824; ph. 603-862-3872; fax 603-862-1915; e-mail: terry.forbes@unh.edu)

The standard models for both CMEs and magnetospheric substorms involve a slow build-up of magnetic energy followed by its sudden release. In each case the model invokes a growth phase during which the magnetic energy is stored, a trigger mechanism that releases this stored energy, and a recovery phase during which the field relaxes to a relatively low energy state. Because of these shared principles, researchers working on these two phenomena often ask similar questions. For example, "How long must the growth phase be in order to store sufficient energy?," "What is the physics of the trigger mechanism?," and "What is the role of magnetic reconnection during each phase?". There are, however, some fundamental differences between models of CME initiation and substorm initiation that prevent a one-model-fits-all approach. The field configurations prior to onset are quite different as are the properties of the plasmas in which the two phenomena occur. A common puzzle regarding the initiation mechanism for both CMEs and substorms is the identity of the mechanism that triggers the sudden energy release. One possibility is the onset of an ideal-MHD instability or, more generally, a loss of an ideal-MHD equilibrium. A mechanism of this type would easily account for the fact that the phenomena typically occur on the Alfven timescale of their respective environments. Another possibility is the onset of a resistive instability that involves magnetic reconnection, for example, the tearing mode. Models of both types have recently been developed as well as hybrid models that involve ideal and resistive processes acting in tandem.

On the Acceleration of Plasmoids in the Magnetotail and its Relation to CME Acceleration

M. Hesse (Space Weather Laboratory, NASA Goddard Space Flight Center) Spiro Antiochos (Space Weather Laboratory, NASA Goddard Space Flight Center) Joachim Birn (Los Alamos National Laboratory)

The acceleration of magnetotail plasmoids continues to be a subject of great interest in magnetospheric physics. Accordingly, a number of observational and modeling studies have been conducted to address the issue. In addition to the “slingshot effect” of magnetic field lines draped about the plasmoid after its disconnection, other studies have concluded that most of the plasma acceleration occurs outside the plasmoid. The latter studies concluded that plasmoid momentum gain occurs when such previously accelerated plasma becomes entrained in reconnection magnetic flux. We present a review and analysis of plasmoid acceleration studies. In addition, we compare the results of these studies to the problem of CME acceleration, and we will identify similarities and differences.

Comparative Planetary Substorms

E. J. Bunce (Department of Physics and Astronomy, University of Leicester, Leicester, LE1 7RH, UK; ph. +44-116-252-3541; fax +44-116-252-2464; e-mail:emma.bunce@ion.le.ac.uk)

At Earth the substorm phenomenon has been extensively studied, yet the onset mechanism remains hotly debated. Most agree, however, that substorms involve the reconnection process and large-scale reconfiguration of the magnetotail. Similar effects have been observed within other magnetospheres e.g. at Mercury, Jupiter, and Saturn. Here we review such observations and focus on the recurring themes and differences arising from the various magnetospheric configurations.

Comparisons of Inner Radiation-Belt Formation in Planetary Magnetospheres

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The Earth's radiation belts were the first major discovery of the satellite era. They pose a major scientific problem to understand how electrons can be accelerated up to energies of several MeV from plasma sources originating in the ionosphere, or the solar wind. During the 1960s and 70s a consensus grew that the radiation belts are formed as a result of plasma entry into the magnetosphere followed by diffusion towards the planet which conserves the first two adiabatic invariants. This radial diffusion process accelerates electrons via Fermi and betatron acceleration and becomes very effective when strong Ultra low frequency waves are excited by the solar wind. Radial diffusion was subsequently applied to the formation of radiation belts at Jupiter and Saturn. However, in the late 1990s it was shown that resonant wave-particle interactions can also accelerate electrons up to radiation belt energies, and that this process could play a significant role during large geomagnetic storms and fast solar wind stream events. Recent multi-satellite data (2007) now show conclusive evidence in support of local acceleration by wave-particle interactions in the heart of the radiation belts, but it appears that inward radial diffusion and substorms still play an essential part in radiation belt formation. Here we review the process of radiation belt formation at the Earth, and emphasise the outstanding problems related to the acceleration, transport and loss of particles and their relation to the solar wind drivers. We show that acceleration by resonant wave-particle interactions could be important for Jupiter's radiation belts, and play an important role in the production of synchrotron radiation from Jupiter. We also discuss how resonant wave-particle interactions could be important for Saturn and the other magnetized planets.

The Universal Nature of Suprathermal Power Law Tails with Spectral Index of -5 on the Velocity Distributions Solar Wind and Pickup Ions

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Suprathermal power law tails with the unique spectral index of -5 (in the solar wind frame of reference) on the velocity distributions (or equivalently of -1.5 on differential intensity) of solar wind and pickup ions are commonly observed in the heliosphere as well as in the heliosheath. Here we summarize measurements of velocity distributions and differential energy spectra of protons and heavier ions in the heliosheath, as well as in the heliosphere during quiet times in the slow solar wind, in the super-quiet high-speed wind of polar coronal holes, in Corotating Ion Events and even during times dominated by turbulence associated with CMEs. The only condition that appears to be necessary for creation of these common power law tails is that the medium be spatially homogeneous. In all cases, these suprathermal tails gently roll over, with an e-folding energy depending on ambient solar wind conditions. The -5 spectra are explained assuming non-traditional stochastic acceleration in thermally isolated compressional turbulence (Fisk and Gloeckler, ApJ. Oct 4 2008). We apply these concepts to particle acceleration in the heliosheath and show that the un-modulated Anomalous Cosmic Ray spectra near the heliopause are consistent with being these same -5 power law tails with a gentle roll over at several hundred MeV/nucleon.

Universal Aspects of Diffusive Shock Acceleration

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Energetic particles (energies above thermal energies) are observed in the astrophysical universe wherever the ambient gas density is low enough for them to exist. Their observed intensity energy spectra are nearly always power laws in momentum with a spectral index within a narrow range of about 2-5, suggesting a universal acceleration mechanism which accelerates most of the energetic particles.

Stochastic acceleration mechanisms, such as the famous 2nd-order Fermi mechanism can give power laws only with parameter tuning, but even then, obtaining the correct power-law index requires more parameter tuning. This would make it difficult to explain the similar spectra in different places. Diffusive shock acceleration, on the other hand, does produce power laws in the observed range quite generally, shocks are frequent and the high particle energies are produced quickly. In its most simple form, the power-law index depends only on the ratio of downstream to upstream densities (or velocities). The density ratio is 4 for strong shocks and less than 4 for weaker shocks. Presumably strong shocks produce most of the particles and these produce a momentum power law with a spectral index somewhat greater than 2.

Diffusive shock acceleration has been sucessfully applied to many situations ranging from producing SEPs at the Sun and CMEs, co-rotating interaction regions, the heliospheric termination shock, supernova blast waves, astrophysical jets and galaxy clusters. Analysis of in situ observations in the heliosphere have provided convincing evidence for diffusive shock acceleration at propagating shocks. It is quite possible, then, that diffusive shock acceleration is the universal acceleration process which operates throughout the astrophysical universe. In each of the specific applications, a unique geometry and temporal dependence must be incorporated to obtain the energy range of accelerated particles, etc. These usually act to produce a high-energy cutoff to the power-law spectrum. In some cases, the acceleration appears to be so efficient that the accelerated particles have a sufficient energy density to modify the shock. Also, the energetic particles can produce upstream fluctuations and waves. Recently observations have also established that pre-existing large-scale upstream turbulence has important effects. All of these refinements affect the energy spectrum, but usually not enough to significantly remove the universal power law.

Posters: Listed in alphabetical order by last name of First Author.

The Structure of Titan's Deep Ionosphere

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The ionosphere of Titan is mainly created by photoionisation by solar EUV radiation and electron impact ionisation from Saturn's magnetospheric plasma. Over 40 Titan flybys have been conducted by the Cassini orbiter, showing that Titan's ionosphere exhibits a highly variable and complex structure. This study investigates the relative contribution of solar radiation versus magnetospheric input. We present results from several deep (< 1000 km) ionospheric passes, mainly based on data from the Radio and Plasma Wave Science (RPWS) and show that Titan's ionosphere largely varies with solar illumination conditions. In conclusion, we show that solar photons are the main ionisation source of Titan's dayside atmosphere. However, magnetospheric electron precipitation is also of high importance and its contribution, especially on the nightside, cannot be neglected.

Spectral and Compositional Properties of the Quiet-Time Suprathermal Ion Population at 1 AU

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We have surveyed the spectral and compositional properties of suprathermal heavy ions during quiet times from 1995 January 1 to 2007 December 31 using Wind/STEP and ACE/ULEIS at energies between 0.04 and 2.56 MeV nucleon-1. We find that: (1) Quiet-time Fe/O and C/O abundances are correlated with solar cycle activity, reflecting corresponding values measured in solar energetic particle (SEP) and interplanetary (IP) shock events during solar maximum, and those measured in the solar wind (SW) and corotating interaction regions (CIRs) during solar minimum conditions. (2) The 3He/4He ratio lies in the 3%-8% range during the quiet times of 1998-2004 with an average 3He abundance of ~27.4%. This ratio drops to 0.3%-1.2% during 2005-2007 and the 3He quiet-time abundance drops to ~5%. (3) All heavy ion species exhibit suprathermal tails between 0.04–0.32 MeV nucleon-1 with spectral indices ranging from ~1.27 to 2.29. These tails sometimes extend above ~2 MeV nucleon-1 with Fe spectra rolling over at lower energies than those of CNO. (4) The suprathermal tail spectral indices of heavier species (i.e., Fe) are harder than those of the lighter ones (i.e., CNO). These indices do not exhibit a clear solar cycle dependence and for ~50% of the time, they deviate significantly from the 1.5 value. These compositional observations provide evidence that even during the quietest times in interplanetary space, the suprathermal population (3He and C-through-Fe) consists of ions from different sources whose relative contributions vary with solar activity. The heavy ion energy spectra exhibit suprathermal tails with variable spectral indices that do not exhibit the spectral index of 1.5 predicted by some recent models.

Locations of non-Linear Processes in the Earth's Magnetosphere as Identified by Electron Phase Space Holes by the Themis Mission

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Electron phase-space holes are associated with thermalization of the electron beams and may be evidence of strongly non-linear processes. They have been observed in the auroral region, in the solar wind, at the bow shock, at the magnetopause and in the magnetotail. The THEMIS spacecraft have observed electron phase space holes with large potentials (>~1 keV) and high speeds. Such properties are identified for the first time outside the auroral region. The high speeds suggest that the electron phase space holes are caused by the electron two-stream instability. The environment in which theses large holes occur is analyzed and characterized using the observation from the magnetotail and the magnetopause. From the tail observations we find that the observed large electron phase space holes are associated with reconfiguration of the magnetotail and that the holes occur at the boundary between dense and tenuous plasmas.

On the Axford Conjecture: What Controls The Reconnection Rate?

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Using 2-D resistive-MHD computer simulations, the question of what controls the rate of reconnection is explored. For both driven and undriven reconnection, the reconnection rate is controlled by the local plasma parameters near the reconnection site; the Cassak-Shay formula holds. Using the 3-D MHD BATSRUS code with added resistivity, the reconnection rate at the dayside magnetosphere is specifically explored. We highlight 4 findings. (1) The dayside reconnection rate is controlled by the local plasma parameters of the magnetosheath and magnetosphere near the reconnection site; again the Cassak-Shay formula holds. (2) The solar-wind electric field does not determine the reconnection rate. (3) The dependence of the reconnection rate on the parameters of the magnetospheric plasma means the magnetosphere can exert some control over solar-wind/magnetosphere coupling. (4) There is no flux pileup at the nose of the magnetosphere to change the reconnection rate; the flow-around of the magnetosheath plasma relieves the tendency to pileup.

Impact of Universal Plasma and Energetic Particle Processes on Icy Bodies of the Kuiper Belt and the Oort Cloud

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Modeling of space plasma and energetic particle interactions with icy bodies of the outer solar system is simplified when there is commonality of the underlying source, acceleration, and transport processes in spatially distinct regions from the supersonic heliosphere through the heliosheath into the local interstellar medium (LISM). Current trends in the Voyager heliosheath measurements suggest strong commonality to processes in the LISM. The Fisk-Gloeckler "universal" spectrum at suprathermal energies apparently plays a strong role in coupling the plasma and high energy particle regimes in the spatial and energetic transitions from the outer heliosphere to the LISM. Dominant processes in consecutive energy regimes project to varying effects versus irradiation depth on exposed upper surfaces of airless small icy bodies and to upper atmospheres of larger bodies such as Titan and Pluto. Relative absence of the universal suprathermal spectrum in the mid-heliospheric region of the classical Kuiper Belt may profoundly affect surface color diversity of icy bodies in this region.

Presence of a Reverse Shock in the Evolution of a CME in the Lower Solar Corona

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We study the birth and the subsequent evolution of a reverse shock in the evolution of a CME in the lower corona. The CME has been simulated in the lower solar corona with Space Weather Modeling Framework (SWMF). To initiate the CME, we inserted a Titov-Demoulin (TD) flux rope in an active region of the Sun with magnetic field based on the MDI data for the solar surface during Carrington rotation 1922. The CME advances on top of a background solar wind created with the help of Wang-Sheeley-Arge (WSA) model. We'd explore the signature and characteristics of the reverse shock as the CME evolves through the lower corona. We also discuss the implication of the resulting acceleration of particles.

Surface Alfvén Wave Damping in a 3D Simulation of the Solar Wind

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It is known that a source of additional momentum is needed to drive the solar wind. Here we investigate the effect of surface Alfvén wave damping in solar minima and solar maxima conditions. The surface Alfvén wave damping length *L* depends on the superradial expansion factor *S* of magnetic field lines. We calculate *S* for Carrington Rotation 1912 with steady state solar background generated with the Space Weather Modeling Framework and compare with estimates by Dobrzycka et al. 1999 using SOHO observations. We estimate the surface Alfvén wave damping for active regions, quiet sun, and the border between open and closed magnetic field lines. We address how our results can be

incorporated in a MHD thermally driven-wind model.

Comparative Planetary Auroralogy

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We define 'Auroralogy' as a discipline of space science that study the physics of auroral processes and the origin and production mechanism of auroral emissions through the analysis of auroral emission observations and modeling. Though there is no unanimous definition of aurora - e.g., some restricting aurora to photo-emissions and others, to bodies with an intrinsic magnetosphere, most converge to the following basic definition: aurora is an electromagnetic emission induced by collisions between atmospheric species and energetic particles external to the "local atmosphere" of a Solar System body. Aurora is therefore restricted to bodies which have a significant atmosphere. Among those, aurora has been observed on all bodies having an intrinsic magnetosphere - i.e., Earth, Jupiter, Saturn, Uranus, Neptune, and Ganymede, and on bodies embedded in a plasma flow which impacts their upper atmosphere - i.e., Venus, Mars, comets, Jupiter’s moons Io and Europa. Auroras are produced over a wide spectral range, from high energy gamma-rays and X-ray to ultraviolet, visible, infrared, and radio wavelengths.

Auroras are the observable signatures of electrodynamical coupling between a planet’s magnetosphere – be intrinsic or induced – and its upper atmosphere. This bi-directional coupling is important in transferring energy from outside the upper atmosphere into the system, yielding auroral emissions. Aurora can be used as a "diagnostic tool" for learning about atmospheric composition, structure, dynamics, and temperature, energy budget, transport processes, plasma interactions, magnetospheric plasma properties, and magnetic configuration of a planet.

This poster makes a comparative study of auroral emissions at different Solar System bodies, summarizes their emitted power, special characteristics (spatial, temporal), and production processes in context of planetary auroralogy at different wavelengths.

Interplanetary Suprathermal He+ and He++ Observations During quiet periods from 1.5 to 9 AU and Implications for Particle Acceleration

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We study differential intensities of ~2–60 keV/nucleon He+ and He++ measured during the 1999-2004, 1.5-9 AU portion of Cassini’s interplanetary cruise to Saturn and find that the He+/He++ composition ratio increases with helioradius r as expected from the theoretical pickup ion and solar wind number densities. But surprisingly the absolute He+ intensity, counter to the predicted falling 1/r dependence, also increases or is nearly constant. A straightforward theory matches the higher-energy composition profiles well, as does a numerical model we use to treat the transport and acceleration more rigorously. We suggest that two acceleration processes are needed: the composition ratios are explainable by stochastic acceleration while another velocity-dependent mechanism, acting equally on He+ and He++, is required to explain the spatial profiles. The radial composition and intensity profiles are clear constraints that new theories must address.

Solar Wind Particles from the Solar Corona to the Earth

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Solar wind particles are accelerated and heated as they propagate from the solar corona to the earth. Using data from XRT and EIS on Hinode, ACE, and SOHO satellites, we follow the plasma characteristics such as density, flow speed, and composition from the solar corona to 1AU. XRT and EIS data are used to compare the initial conditions of these solar wind particles. Of special interest are minor ions such as oxygen and iron. ACE is used to characterize the plasma at 1AU. The solar wind will be examined after a set of flares as well as CMEs to distinguish a propagation time. The results give a sense of the changes the plasma undergoes as it moves through the heliosphere and where it deposits the energy.

Electron Heating at Shock Waves by a Cosmic Ray Precursor

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Recent observations of H alpha formed at shock waves associated with supernova remnants (SNRs), which allows a spectroscopic determination of the postshock electron temperature, have been interpreted in terms of electrons being heated ahead of the shock in an extended cosmic ray precursor. We discuss some implications of this idea, and its possible extension to solar wind shocks driven by coronal mass ejections (CMEs), which can reach similar speeds to those in SNRs. In particular, we highlight the potential for spectroscopic observations of the electron temperaure at shocks driven by CMEs, and the possibility of a prompt diagnostic of the shock accelerated solar energetic particle (SEP) hazard associated with a CME event.

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Cross-Scale: An ESA Cosmic Vision Mission to Study Multi-Scale Coupling in Plasmas

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Cross-Scale is a mission under study by the European Space Agency and is a candidate for the first launch slot for the agency's Cosmic Vision 2015-2025 program. It will provide critical new information of several universal collisionless plasma processes (shocks, magnetic reconnection and turbulence) by performing the first exploration and quantification of simultaneous multi-scale coupling across three critical scales: electron, ion, fluid. It will answer fundamental questions in collisionless plasmas, notably "How do shocks accelerate and heat particles?", "How does reconnection convert magnetic energy?" and "How does turbulence control transport in plasmas?" These universal processes will be unravelled by a fleet of 12 specialised spacecraft in near-Earth built by ESA and partner agencies (e.g., JAXA, NASA, CSA). This contribution will focus on the science questions and how this Cosmic Vision mission will answer them.

Laboratory Study of Solar Flare Dynamics in MRX

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Experimental studies of the dynamics of half-toroidal plasma arcs relevant to solar coronal activities have been carried out utilizing the existing MRX facility [1,2]. A set of electrodes are inserted in MRX to generate a variety of plasma flux loops which contain variable toroidal guide field. Three dimensional evolution of the simulated flares is monitored by an ultra fast framing camera. The time evolution of discharges with Argon, Helium and Hydrogen with currents of 5-15 kA show the stability condition for a line-tied plasma flux loop similar to those on the solar surface. With the initial data it is shown that the q value, which describes the rotational transform of field lines, is the key for characterizing the global stability. Our experimental results will contribute to the understanding of evolution of magnetic topology of the solar flare including concepts such as current sheets, stability of current carrying flares, and line-tying, which are vitally important for understanding the Solar/Heliospheric and Interplanetary Environment.[1] M. Yamada, H. Ji, S. Hsu, T. Carter, R. Kulsrud, N. Bretz, F. Jobes, Y. Ono, and F. Perkins. Study of driven magnetic reconnection in a laboratory plasma. Phys. Plasmas, 4:1936, 1997.[2] V.S. Titov and P. D´emoulin. Basic topology of twisted magnetic configurations in solar flares. Astron.and Astrophys., 351:707, 1999.

Magnetic Disturbances Within Solar Flux Ropes

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To treat local disturbances in a solar flux rope we consider the magnetic field in its interior as a superposition of two linear force-free magnetic field distributions, viz. a global one, which is locally similar to a part of the cylinder, and a local torus-shaped magnetic distribution. The symmetry axes of the toroid and that of the cylinder coincide. Both the large and small radii of the toroid are set equal to the cylinder's radius. As a result, depending on the field magnitude and the handedness, there is a local decrease or increase of the flux tube diameter. Different physical nature of processes caused by this inhomogeneity can lead to motions along the tube or to oscillations at a given point in the tube. We are going to use this approach for the interpretation of solar limb observations. The newly derived solution for a toroid with an aspect ratio close to unity is applied. Force-free toroidal distributions that are currently available in the literature (for example Miller and Turner, 1981) can only be applied to the case of small inverse aspect ratios.

Numerical Model for Electric Potential and Field-Aligned Current in Low Latitude Ionosphere

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A new model of ionosphere-magnetosphere coupling, developed on the basis of Prairie View Dynamo Code (PVDC), is presented. In the model, Tsyganenko magnetospheric field is used for ionospheric mapping with Euler potentials, and for finding boundary between open and closed field line ionosphere. When solving Poisson equation, the boundary values of electric potential at division line between open and closed ionosphere are taken from empirical Weimer's model. Thus the new model takes the variations in solar wind and interplanetary magnetic field, as well as the geomagnetic activity, into account. The new model shows good agreement with ionospheric radar data and with low altitude spacecraft field-aligned current (FAC) measurements. Original version of PVDC used International Geomagnetic Reference Field (IGRF) for the coupling, and thus is not related to solar wind interplanetary magnetic field (IMF) disturbances, as well as to geomagnetic activity. The results of previous version of PVDC are consistent with observations only in quiet times. In the future the new model can be used in study of instabilities and disturbances in the ionosphere through inclusion of density and velocity irregularities.

The Whole Heliosphere Interval: Campaign Summaries and Early Results

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The Whole Heliosphere Interval (WHI) is an internationally coordinated observing and modeling effort to characterize the 3-dimensional interconnected solar-heliospheric-planetary system - a.k.a. the "heliophysical" system. The heart of the WHI campaign is the study of the interconnected 3-D heliophysical domain, from the interior of the Sun, to the Earth, outer planets, and into interstellar space. WHI observing campaigns began with the 3-D solar structure from solar Carrington Rotation 2068, which ran from March 20 - April 16, 2008. Observations and models of the outer heliosphere and planetary impacts extended beyond those dates as necessary; for example, the solar wind transit time to outer planets can take months. WHI occurs during solar minimum, which optimizes our ability to characterize the 3-D heliosphere and trace the structure to the outer limits of the heliosphere. A summary of some of the key results from the WHI first workshop in August 2008 will be given.

Critical Behaviour in the Solar Wind and Magnetosphere over a Solar Cycle

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We have examined the burst lifetime distribution functions of solar wind VBs and e for 1995–2005 and compared them with the same for contemporaneous SYM-H. The analysis yields clear power-law exponents of the lifetime probability distributions. When we analyzed three years around solar minimum we found similar scaling behavior for all the variables, including SYM-H. However, for the three years around solar maximum the difference between solar wind and SYM-H scaling was very clear. The fact that power laws were consistently observed for different activity thresholds show that these features are robust and repeatable, although scaling can vary depending on solar cycle. During solar maximum it appears that the scaling properties of the low-latitude magnetosphere, whose output is recorded by SYM-H, are not purely a direct response to the scale-free properties of the solar wind but are due to inherent properties of the magnetosphere. Since SYM-H scaling is remarkably robust, irrespective of solar cycle, it could be that the solar wind never acts as a direct driver for the SYM-H scaling.

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