SPA-Magnetospheric Physics

SM11A MCC: 2006 Monday 0800h

Sun-Earth Connections: Linked Models I *(joint with SA, SH, NG)*

Presiding: **R Clauer,** University of Michigan**; J W Freeman,** Rice University

SM11A-01 0800h

Linked space physics models for operational ionospheric forecasting

W. Kent Tobiska[1] (310-573-1485; ktobiska@spacenvironment.net); Dave Bouwer[1] (dbouwer@spacenvironment.net); Jeff Forbes[2] (forbes@colorado.edu); Rudy Frahm[3] (rfrahm@swri.edu); C.D. Fry[4] (gfry@expi.com); Maura Hagan[5] (hagan@ucar.edu); George Hajj[11] (george.hajj@jpl.nasa.gov); Tung-Shin Hsu[7] (thsu@igpp.ucla.edu); Delores Knipp[8] (Delores.Knipp@usafa.af.mil); Anthony Mannucci[6] (anthony.j.mannucci@jpl.nasa.gov); Vladimir Papitashvili[9] (vpapita@geo-mag.net); Xiaoqing Pi[11] (Xiaoqing.Pi@jpl.nasa.gov); Jim Sharber[3] (jsharber@swri.edu); Mark Storz[10] (mark.storz@peterson.af.mil); Chunming Wang[11] (cwang@math.usc.edu); Brian Wilson[6] (Brian.Wilson@jpl.nasa.gov)

[1]SET, Space Environment Technologies 1676 Palisades Dr., Pacific Palisades, CA 90272, United States

[2]Univ. of Colorado, Dept of Aerospace Eng. Sciences 429 UCB University of Colorado, Boulder, CO 80309, United States

[3]SwRI, SouthWest Research Institute PO Drawer 28510, San Antonio, TX 78228, United States

[4]EXPI, EXPI Suite 37-105 6275 University Dr. NW, Huntsville, AL 35806, United States

[5]NCAR, NCAR PO Box 3000, Boulder, CO 80307, United States

[6]JPL, Jet Propulsion Laboratory MS 238-600 4800 Oak Grove Dr., Pasadena, CA 91109, United States

[7]IGPP/UCLA, IGPP University of California 405 Hilgard Ave., Los Angeles, CA 90095, United States

[8]USAFA, Suite 2A25 Fairchild Hall US AF Academy, US AF Academy, CO 80840, United States

[9]GS, Geomagnetic Services 8315 N. Brook Lane, Bethesda, MD 20814, United States

[10]ASAC, AFSPC/XPYE, Peterson AFB, CO 80914, United States

[11]USC, Dept. of Mathematics Denney Research Bldg 346 University of Southern California, Los Angeles, CA 90089, United States

The shorter-term variable impact of the Sun's photons, solar wind particles, and interplanetary magnetic field upon the Earth's environment that can adversely affect technological systems is colloquially known as space weather. It includes, for example, the effects of solar coronal mass ejections, solar flares and irradiances, solar and galactic energetic particles, as well as the solar wind, all of which affect Earth's magnetospheric particles and fields, geomagnetic and electrodynamical conditions, radiation belts, aurorae, ionosphere, and the neutral thermosphere and mesosphere. These combined effects create risks to space and ground systems from electric field disturbances, irregularities, and scintillation, for example, where these ionospheric perturbations are a direct result of space weather. A major challenge exists to improve our understanding of ionospheric space weather processes and then translate that knowledge into operational systems. Ionospheric perturbed conditions can be recognized and specified in real-time or predicted through linkages of models and data streams. Linked systems must be based upon multi-spectral observations of the Sun, solar wind measurements by satellites between the Earth and Sun, as well as by measurements from radar and GPS/TEC networks. Models of the solar wind, solar irradiances, the neutral thermosphere, thermospheric winds, joule heating, particle precipitation, substorms, the electric field, and the ionosphere provide climatological best estimates of non-measured current and forecast parameters. We report on a team effort that is developing a prototype operational ionospheric forecast system to detect and predict the conditions leading to dynamic ionospheric changes. The system will provide global-to-local specifications of recent history, current epoch, and 72-hour forecast ionospheric and neutral density profiles, TEC, plasma drifts, neutral winds, and temperatures. Geophysical changes will be captured and/or predicted (modeled) at their relevant time scales ranging from 10-minute to hourly cadences. 4-D ionospheric densities are being specified using data assimilation techniques, coupled with physics-based and empirical models for thermospheric, solar, electric field, particle, and magnetic field parameters that maximize accuracy in locales and regions at the current epoch, maintain global self-consistency, and improve reliable forecasts. We report on a system architecture underlying the linkage of models and data streams that is operationally reliable and robust to serve commercial space weather needs.

SM11A-02 0815h INVITED

Initial results from the coupled LFM-TING model

Michael Wiltberger[1] ((303)497-1530; wiltbemj@ucar.edu)

Wenbin Wang[1] (wbwang@ucar.edu)

Alan Burns[1] (aburns@ucar.edu)

John G Lyon[2] (lyon@tinman.dartmouth.edu)

Stan Solomon[1] (stans@ucar.edu)

[1]NCAR/HAO, 3450 Mitchell Lane, Boulder, CO 80301, United States

[2]Dartmouth College Department of Physics and Astronomy, 6127 Wilder Laboratory, Hanover, NH 03755, United States

The Lyon-Fedder-Mobarry global MHD code has been successfully used to model the coupled solar wind - magnetosphere - ionosphere system. The simulation uses the ideal MHD equations to model the interaction between the magnetospheric plasma and the solar wind. The magnetosphere - ionosphere interaction is modeled through a simple 2D electrostatic approximation for the conservation of current flowing between the magnetosphere and ionosphere. The Thermosphere - Ionosphere Nested Grid (TING) model is a three dimensional code designed to simulate the thermosphere - ionosphere system by solving the momentum, thermodynamic energy equations for the global thermosphere and ionosphere. TING uses magnetospheric indices to determine the magnetospheric input into the ionosphere. We begin this paper with a presentation of the coupling methodology and then present the results from a series of calibration studies conducted to determine the optimal parameters for coupling these models. The first study used an isolated substorm which occurred on May 20, 1996 as the basis of comparisons between in situ observations made by DMSP satellites and the results from AMIE studies. In addition, we present the results from a series of idealized solar wind conditions which explore the coupling under various IMF clock angles, levels of geomagnetic activity, and dipole tilt angles. These results show that the core coupling of the LFM to TING has been successful and is now ready for detailed analysis and tuning of the coupling parameters.

SM11A-03 0835h

Incorporating Vector Magnetic Field Measurements into MHD Models of the Solar Atmosphere

William P Abbett (510-642-6880; abbett@ssl.berkeley.edu)

Space Sciences Laboratory, University of California, Berkeley, CA 94720-7450, United States

We report on our efforts to incorporate high cadence vector magnetic field measurements of the CME and flare producing active region NOAA 8210 (observed from April 28 to May 2 1998) into the photospheric boundary layers of our 3D MHD models of the solar atmosphere. We find that it is is essential to be able to specify an initial model atmosphere that is both consistent with soft X-ray observations of the corona and with observed vector magnetic field measurements at the photosphere. Further, MHD codes require that certain components of the flowfield be specified at the lower boundary in such a way as to self-consistently update the model photosphere between each successive magnetogram. We will present the results of our application of several techniques to infer the velocity field of magnetized plasma in the photosphere using a time-series of IVM vector magnetograms of NOAA 8210, and will present the results from our latest attempt to model this complex active region.

SM11A-04 0850h

CISM: Modeling the Sun-Earth Connection

W. Jeffrey Hughes[1] (617 353 2471; hughes@bu.edu)

The CISM Team[1] (617 358 3241; cism@bu.edu)

[1]Center for Integrated Spaceweather Modeling, Boston University, 725 Commonwealth Avenue, Boston, MA 02215, United States

The Center for Integrated SpaceWeather Modeling (CISM), an NSF Science and Technology Center that is a consortium of ten institutions headed by Boston University, has as its primary goal the development of a series of ever improving versions of a comprehensive physics-based simulation model that describes the space environment from the Sun to the Earth. CISM will do this by coupling existing models of components of the system. In this paper we review our progress to date and summarize our plans. We discuss results of initial coupling of MHD models of the corona and solar wind, and of a global magnetospheric MHD model with a global ionosphere/thermosphere model, a radiation belt model, and a ring current particle model. Coupling the SAIC coronal MHD model and the U Colorado/SEC solar wind MHD codes allows us to track CMEs from the base of the corona to 1 AU. The results show how shocks form and develop in the heliosphere, and how the CME flattens into a pancake shape by the time it reaches earth. Coupling the Lyon/Fedder/Mobarry global MHD model with the Rice Convection Model and the NCAR TIE-GCM/TING model allows full dynamic coupling between the magnetosphere, the ionosphere/thermosphere, and the hot plasma in the inner magnetosphere. Including the Dartmouth radiation belt model shows how the radiation belts evolve in a realistic magnetosphere.

SM11A-05 0905h

Solar-Atmospheric Coupling by Electrons: Mesospheric, Stratospheric, and Tropospheric Effects

Linwood B Callis[1] (1-757-539-7915; lbos2@aol.com)

Eugene Rozanov[2] (+41 81 417 5135; e.rozanov@pmodwrc,ch)

Michael E Schlesinger[3] (1-217-333-2192; schlesin@atmos.uiuc.edu)

Fanglin Yang[4] (1-301-614-6213; fyang@climate.gsfc.nasa.gov)

[1]Atmospheric Effects, 613 W. Riverview Dr., Suffolk, VA 23434, United States

[2]PMOD/WRC and IACETH, Dorfstrasse 33, Davos Dorf CH-7260, Switzerland

[3]University of Illinois at Urbana-Champaign , 105 S. Gregory St., Urbana, IL 61801, United States

[4]NASA Goddard Space Flight Center, Code 913, Greenbelt, MD 20771, United States

Published analyses of observational data have shown: (1) that energetic (1 keV $<$ E $<$ 1 MeV) electron precipitation (EEP) fluxes are highly correlated with the high speed solar-wind streams during the 11-year and 22-year solar cycles; (2) that high levels of odd nitrogen are formed during the precipitation of these electrons into the atmosphere; and (3) that during periods of advective descent, a portion of this odd nitrogen is transported from the mesosphere and lower thermosphere into the stratosphere. It has been suggested that this additional source of odd nitrogen is important to stratospheric ozone and temperatures, and hence may have an impact on the phase and amplitude of the long planetary waves extending into the troposphere. 2-D model simulations in comparison with observations have provided support for this linkage between the Sun and the atmosphere of the Earth. In the present paper we will: (1) review the evidence for this coupling; (2) display the observed and calculated effects of EEP in the mesosphere and stratosphere; and (3) present preliminary results, derived with the fully coupled 3-D UIUC climate/chemistry model, extending from the surface to approximately 98 km, that illustrate the effects of the coupling in the lower stratosphere and troposphere. We suggest that this coupling may help to reconcile the discrepancy between the observed and calculated atmospheric effects apparently related to the 11-year solar cycle variations. Unresolved problems relative to the linkage and the 3-D simulation will be discussed.

SM11A-06 0920h

Time Dependent Radial Diffusion Modeling of Relativistic Electrons Including Realistic Loss Rates

Yuriy Shprits[1] (310 794-9273; yshprits@atmos.ucla.edu)

Richard Thorne[1] (310 825-5974)

[1]UCLA, Department of Atmospheric Sciences, 7127 Math Sciences, Room 7984, Los Angeles, CA 90095, United States

A second order semi-implicit code is used to model radial diffusion of relativistic electrons in the outer radiation belt with electron lifetime as a specified parameter. To isolate the controlling effect of electron lifetime we make a number of assumptions: dipole field model, constant boundary conditions, and idealized variations of the Kp index. Phase space density and 1.0 MeV electron fluxes are computed for both constant lifetime and Kp dependent values. We demonstrate that knowledge of lifetimes is crucial for both idealized steady-state and time dependent cases. Comparison of steady-state and time dependent profiles shows that steady state is never attained during a storm, and radial diffusion should be modeled with a time dependent code. Comparison of our results and data suggest that lifetimes are on the order of days, much shorter than that of expected plasmaspheric losses. Results and possible limitations of the model are discussed.

SM11A-07 0935h INVITED

The Education Program of the Center for Integrated Space Weather Modeling

Ramon E Lopez (relopez@utep.edu)

Dept. of Physics, University of Texas at El Paso, El Paso, TX 79968, United States

The Center for Integrated Space Weather Modeling (CISM) is a Science and Technology Center (STC) funded by National Science Foundation whose goal is to produce space weather models that extend from the Sun to the Earth. Like all STCs, CISM has an extensive education program that ranges from precollege to graduate education. A key educational goal is to communicate the idea of a coupled space weather system involving the Sun, interplanetary space, the magnetosphere, and the ionosphere. In this talk I will review the set of CISM education activities and discuss the implications for space science education in general.

SM11B MCC: 3009 Monday 0800h

Solar Wind-Magnetosphere Coupling: Comparative Magnetospheres I *(joint with P, SH)*

Presiding: **J Saur,** Applied Physics Laboratory, Johns Hopkins University**;** **C Paranicas,** Applied Physics Laboratory, Johns Hopkins University

SM11B-01 0800h

Ionospheric Effects on the Paleomagnetosphere

Bertalan Zieger[1] (b.zieger@iu-bremen.de)

Joachim Vogt[1] (j.vogt@iu-bremen.de)

Aaron James Ridley[2] (ridley@umich.edu)

Karl-Heinz Glassmeier[3] (kh.glassmeier@tu-bs.de)

[1]International University Bremen, Campus Ring 8, Bremen D-28759, Germany

[2]The University of Michigan, 1411B Space Research Building, Ann Arbor, MI 48109-2143, United States

[3]Institut fuer Geophysik und Meteorologie, Mendelssohnstr. 3, Braunschweig D-38106, Germany

Paleomagnetic studies indicate that the strength of the Earth's internal magnetic field has varied over the range 0.1 to 3 of the present value. Consequently the paleomagnetosphere, which results from the coupled interaction of the solar wind, the Earth's internal magnetic field and the conductive paleoionosphere, must have undergone severe changes, especially during the so-called polarity transition epochs, when the Earth's internal dipole moment reversed. Different transition scenarios can be conceived, none of which is excluded in the present state of our knowledge: The dipole moment could decay to zero and quickly build up again in the opposite direction; or a much reduced dipole moment could turn around, staying close to the equatorial plain for a significant time; or the dipole moment could completely vanish and higher order multipoles could dominate during the transition epoch. In a paleomagnetosphere with reduced internal magnetic field the ionospheric conductivity is expected to be higher, which implies stronger ionosphere-magnetosphere coupling, i.e. stronger ionospheric and field aligned magnetospheric currents. Although several scaling relations have been found to scale different parameters of a dipolar paleomagnetosphere to the dipole moment, no theoretical scaling relations exist for the magnetospheric-ionospheric current systems that control the inner magnetospheric convection. In the first part of this paper, we present some theoretical considerations and new scaling relations related to the current systems in the paleomagnetosphere. In the second part, we test the effect of different ionospheric boundary conditions and conductivity models on different types of paleomagnetospheres by means of the Michigan BATS-R-US MHD code. Namely, we study the inner magnetospheric plasma convection patterns and the equivalent ionospheric electric potential patterns. In general, we conclude that the ionosphere plays a more important role in the paleomagnetosphere during polarity transition epochs.

SM11B-02 0815h

Magnetic Reconnection and Magnetospheric Dynamics as a Function of Dipole Tilt and the IMF By Component

Kyung Sun Park[1] (sun@stelab.nagoya-u.ac.jp)

Tatsuki Ogino[1] (ogino@stelab.nagoya-u.ac.jp)

Raymond J Walker[2] (rwalker@igpp.ucla.edu)

[1]Solar-Terrestrial Environment Laboratory, Nagoya University, 3-13 Honohara, Toyokawa 442-8507, Japan

[2]Institute of Geophysics and Planetary Physics, University of California, 6843 Slichter Hall, Los Angeles, CA 90095-1567, United States

Magnetospheric dynamics are controlled by magnetic reconnection between the geomagnetic field and the interplanetary magnetic field (IMF). Dayside magnetic reconnection is often described by two different models: antiparallel merging which occurs preferentially where the magnetosheath magnetic field is antiparallel to the Earth's magnetic field and subsolar point merging which is sometimes called component merging. Observationally it is not clear which of these two models better describes the reconnection process at the magnetopause. Observations of flux transfer events (FTEs) at the dayside magnetopause are usually explained by subsolar merging, while observations of ionospheric convection are usually explained by antiparallel merging. In global magnetohydrodynamic (MHD) simulations antiparallel merging frequently dominates. A study of magnetopause reconnection as a function of IMF By and dipole tilt should help us determine which model best describes dayside merging. We have studied magnetic reconnection and magnetospheric dynamics by using a full 3-D MHD simulation for finite dipole tilt, IMF By and Bz components. We find that antiparallel reconnection is dominant at the dayside magnetopause during intervals with southward IMF, a finite IMF By component and finite dipole tilt. Under these conditions reconnection near the magnetic equator and noon-midnight meridian is suppressed because of increased magnetosheath flow. For IMF $By > 0$ and finite tilt the reconnection site splits as it moves from the subsolar point. The reconnection sites separate into northern dusk and southern dawn parts for $By > 0$, and the sites shift sunward in the summer hemisphere and tailward in winter hemisphere for finite tilt. There are observable changes in the ionospheric configuration that can help us determine if the antiparallel reconnection pattern in the simulation is correct. The convective flow in the ionospheric throat region where the flow changes from sunward to tailward becomes more dawnward/duskward in the summer hemisphere and more poleward in the winter hemisphere.

SM11B-03 0830h

3-D, MHD Studies of the Effects of the Crustal Magnetic Field and Corona on the Solar Wind Interaction with Mars.

Andrew F. Nagy[1] (734-764-6592; anagy@umich.edu)

Yingjuan Ma[1] (734-647-3485; yingjuan@umich.edu)

Igor V. Sokolov[1] (734-647-4705; igorsok@umich.edu)

[1]U. of Michigan, Department of Atmospheric, Oceanic and Space Sci., Ann Arbor, MI 48109, United States

We present the most recent results from our continuing studies of the interaction of the solar wind with Mars. In our 3D multi-species MHD model, the Martian ionosphere is assumed to consist of $O2+$, $O+$ and $CO2+$ ions, while the solar wind is represented by protons. Chemical reactions involving these ions, such as photoionization, charge exchange and recombination are included in the model self-consistently. The effects of the crustal magnetic field and the hot oxygen and thermal hydrogen corona are evaluated by using a spherical co-ordinate system, which allows an altitude resolution of 10 km within the ionospheric region.

SM11B-04 0845h

Localized and Continuous Nature of the Ionospheric Plasma Cloud Ejection: Solar Wind-Venus Global Hybrid Simulation Perspective.

Naoki Terada[1] (+81-533-89-5517; teradan@stelab.nagoya-u.ac.jp)

Hiroyuki Shinagawa[1] (sinagawa@stelab.nagoya-u.ac.jp)

Shinobu Machida[2] (machida@kugi.kyoto-u.ac.jp)

[1]Solar-Terrestrial Environment Laboratory, Nagoya University, Honohara 3-13, Toyokawa, Aichi 442-8507, Japan

[2]Department of Geophysics, Kyoto University, Kitashirakawa Oiwake-cho, Sakyo-ku, Kyoto 606-8502, Japan

Plasma cloud ejection, the signatures of which were often detected just above the Venusian ionopause by the Pioneer Venus Orbiter, is investigated using a comprehensive global hybrid (particle ion/massless fluid electron) simulation model of the solar wind-Venus interaction with a planetary ionosphere included. The model reveals that the ejection region of plasma clouds is not smoothly distributed as that is expected from previous local simulations of the Kelvin-Helmholtz (K-H) instability, but instead is rather localized and travels tailward as time goes on. The tailward traveling of the ejection region is accompanied by the co-moving of the background field structure, and the ejected clouds carry farther away from the ionopause than those in the local K-H simulation. These results suggest that the ejection may not be controlled by the local Kelvin-Helmholtz process but affected by the other processes related to the global stream around the planet.

SM11B-05 0900h

Transport of Angular Momentum in the Magnetosphere of Jupiter

Vytenis M Vasyliūnas (vasyliunas@linmpi.mpg.de)

Max-Planck-Institut für Aeronomie, Max-Planck-Str. 2, Katlenburg-Lindau 37191, Germany

The subcorotation of plasma in the Jovian magnetosphere is attracting renewed interest. In Hill's classical theory, as plasma injected deep within the magnetosphere is transported outward, corotation can only be maintained as long as Birkeland currents supply sufficient angular momentum from the ionosphere and atmosphere. These Birkeland currents are now widely viewed as primarily responsible for the main auroral emissions at Jupiter. Mathematical models for calculating the radial profiles of mean angular velocity and associated Birkeland currents have been developed by Hill, Cowley and coworkers, and others. In all these models, angular momentum is assumed to be simply convected outward by a (zonally averaged) mean flow. The dependence of angular velocity on radial distance is then determined (given a model of the magnetic field and of the ionospheric conductance) by a first-order differential equation (Hill-Pontius equation), subject to the single boundary condition of corotation at the inner boundary. In the region where the magnetic field lines are closed, however, there can be no mean MHD outflow, and the outward transport must be described as a diffusion process, averaging over inward and outward flows. Here I apply the mathematical description of diffusion, familiar from mass transport, to angular momentum transport. The Hill-Pontius equation generalizes to a differential equation of second order (thus requiring an additional boundary condition), which in the limit of long acceleration time reduces to a diffusion equation for flux tube content of angular momentum, of the same form and with the same diffusion coefficient as the equation for flux tube mass content. Physical implications and simple examples of solutions will be discussed.

SM11B-06 0915h

Influence of Magnetospheric Electrons on Titan's Interaction With Saturnian Magnetospheric Plasma

Heiko Backes[1] (++49-221-470-2840; backes@geo.uni-koeln.de)

Fritz M. Neubauer[1] (++49-221-470-2310; neubauer@geo.uni-koeln.de)

[1]Institut für Geophysik und Meteorologie, Albertus-Magnus-Platz Universität zu Köln, Cologne 50923, Germany

On its orbit around Saturn Titan interacts with the magnetospheric plasma that is more or less corotating with Saturn. Titan's dense neutral atmosphere (and ionosphere) and the trans-alfvénic plasma environment form a challenging constellation from a plasma physical point of view. The approaching Cassini spacecraft