SH43A-02 1330h POSTER

The Carrington Storm of 1859 IMF, IEF, TPP, and Dst

George Siscoe (siscoe@bu.edu)

Center for Space Physics, Boston University 725 Commonwealth Ave, Boston, MA 02215, United States

From the shock transit time of the 1859 Carrington event, we use statistical relations to infer a shock speed, ICME speed, and maximum ICME field strength. Using average upstream solar wind and IMF conditions, we also infer the profiles of the ram pressure and IMF strength through the ICME-sheath. The Bombay magnetogram for the event gives the magnitude of the SSC and the duration of the transit time passed the earth of the ICME sheath. Since this event occurred during Solar Cycle 10, there is a statistical likelihood that the IMF in the ICME went from north to south as it passed the earth. We use these pieces of information, statistical relations and inferences to construct a probable scenario for the time sequence of solar wind and IMF parameters for the event. We feed this sequence of parameters into analytical models that convert upstream solar wind and IMF data into estimates of the position of the stagnation point, the value of the transpolar potential, and the profile of Dst. Some results: This was probably a two-phase Dst storm with the ICME-sheath driving the first phase and the trailing half of the ICME the second phase. The transpolar potential saturated at a value that probably exceeded 400 kV, and Dst probably reached -600 nT during both storm phases. The stagnation point probably moved to within 3 Re of the center of earth.

SH43A-03 1330h POSTER

How big was the Carrington 1859 Flare?

Edward W. Cliver[1] (781-377-3975; edward.cliver@hanscom.af.mil)

Leif Svalgaard[2] (713-682-5453; leif@leif.org)

Donald F. Neidig[3] (505-434-7019; donald.neidig@hanscom.af.mil)

[1]Air Force Research Laboratory, Space Vehicles Directorate, 29 Randolph Rd., Hanscom AFB, MA 01731-3010, United States

[2]Easy Tool Kit, Inc., 6927 Lawlor Ridge, Houston, TX 77005, United States

[3]Air Force Research Laboratory, Space Vehicles Directorate, 1 Coronal Loop, Sunspot, NM 88349, United States

The 1859 space weather event was distinguished by its great geomagnetic storm, widespread low-latitude aurora, and intense solar energetic particle event (inferred from the NO_3 concentration in polar ice cores). Arguably each of these three effects was the largest ever observed. What can we say about the size of the associated solar flare? We have two observations with which to make such an assessment: (1) Carrington's and Hodgson's report of the white-light flare and (2) the solar flare effect or magnetic crochet observed in the Kew and Greenwich magnetograms. Estimates of the area, duration, spectrum, and intensity of the white-light emission indicate a large ($\sim$2 x 10^{30} erg) but not unequalled event (the white-light emission of the 24 April 1984 >X13 flare contained $\sim$6 x 10^{30} erg). The magnetic crochet of 130 nT in the horizontal force, however, exceeds that for all >X10 soft X-ray flares observed from 1984-2002 (we are presently compiling magnetic data for the recent October-November 2003 activity for comparison with the 1859 event). Thus at this point, we can conservatively say that Carrington's flare likely had a soft X-ray classification >X10 and was at least comparable to the largest flares recorded during the spacecraft era.

SH43A-04 1330h POSTER

Magnetosphere-Ionosphere Coupling During Major Storms

William J Burke[1] (william.burke2@hanscom.af.mil)

Cheryl Y Huang[2] (781-377-1312; cheryl.huang@hanscom.af.mil)

[1]Space Vehicles Directorate, Air Force Research Laboratory, Hanscom AFB, MA 01731, United States

[2]Institute for Scientific Research, Boston College, 140 Commonwealth Avenue, Chestnut Hill, MA 02467, United States

We have investigated the response of the magnetosphere-ionosphere coupled system under extreme forcing during a number of superstorms when Dst was less than -250 nT. We find that (1) large penetration electric fields are generated which extend to the equatorial region causing ionospheric irregularities; (2) the cross-polar cap potential saturates at levels well below that predicted from the interplanetary electric field imposed on the Earth; (3) intense ionospheric field-aligned currents are observed intermittently during the main phases of the storms which have incommensurate ground magnetic signatures; (4) the magnetic field which maps to the ring current is inflated well beyond pre-storm distances. We will discuss these phenomena and their consequences for the global M-I system.

SH43A-05 1330h POSTER

Comparisons of magnetospheric simulations of the 1859 Carrington event with and without inner magnetospheric coupling

Darren De Zeeuw[1] (734-763-6224; darrens@umich.edu); Aaron Ridley[1] (ridley@umich.edu); Tamas Gombosi[1] (tamas@umich.edu); Richard Wolf[2] (rawolf@rice.edu); Stanislav Sazykin[2] (sazykin@rice.edu); Gabor Toth[1] (gtoth@umich.edu); Ovsei Volberg[1] (volov@umich.edu); Igor Sokolov[1] (igorsok@umich.edu); Chip Manchester[1] (chipm@umich.edu)

[1]Center for Space Environment Modeling, University of Michigan, 2455 Hayward St., Ann Arbor, MI 48109-2143, United States

[2]Rice University, Physics and Astronomy, MS108, Houston, TX 77251-1892, United States

The University of Michigan has recently completed a prototype space weather modeling framework (SWMF), including a global magnetospheric MHD model (BATSRUS), the Rice Convection Model (RCM), and a global ionosphere thermosphere model (GITM). The RCM provides high-energy particle physics within the inner magnetospheric region, which MHD is unable to model. These high-energy particles make up the ring current. This distribution of particles can dramatically alter the pressure distribution, and thus the global configuration, of the magnetosphere. It is therefore of interest to examine the results of simulations with and without the RCM to quantify the effects of the ring current on the global state of the magnetosphere. This is done for the 1859 Carrington event, in which the simulations of the magnetosphere without the ring current showed the magnetopause to be completely within geosynchronous orbit at all local times. We will show how the ring current changes the structure and location of the magnetopause, cusps, and ionospheric current system during this extremely disturbed period.

SH43A-06 1330h INVITED POSTER

Modeling the Carrington Event: sun-to-earth propagation of a very fast CME

Ward B Manchester[1] (734-647-3475; chipm@umich.edu); Aaron J Ridley[1] (ridley@umich.edu); Tamas Gombosi[1] (tamas@umich.edu); Darren De Zeeuw[1] (darrens@umich.edu); Igor V Sokolov[1] (igorsok@umich.edu); Gabor Toth[2] (gtoth@umich.edu)

[1]Center for Space Environment Modeling, University of Michigan, 2455 Hayward St., Ann Arbor, MI 48109, United States

[2]Dept. of Atomic Physics, Eotvos University, Pazmany setany 1/A, Budapest 1117, Hungary

We present a three-dimensional (3D) numerical ideal magnetohydrodynamics (MHD) model describing the time-dependent propagation of a CME from the solar corona to Earth in just 18 hours. The simulations are performed using the BATS-R-US (Block Adaptive Tree Solarwind Roe Upwind Scheme) code. We begin by developing a global steady-state model of the corona that possesses high-latitude coronal holes and a helmet streamer structure with a current sheet at the equator. The Archimedian spiral topology of the interplanetary magnetic field is reproduced along with fast and slow speed solar wind. Within this model system, we drive a CME to erupt by the introduction of a Gibson-Low magnetic flux rope that is embedded in the helmet streamer in an initial state of force imbalance. The flux rope rapidly expands driving a very fast CME with an initial speed of in excess of 4000 km/s and slowing to a speed of nearly 2000 km/s at Earth. We find our model predicts a thin sheath around the flux rope, passing the earth in only two hours. Shocked solar wind temperatures at 1 AU are in excess of 10 million degrees. Physics based AMR allows us to capture the structure of the CME focused on a particular Sun-Earth line with high spatial resolution given to the bow shock ahead of the flux rope.

SH43B CC: 518 A Thursday 1330h

Violent Sun-Earth Connection Events of October-November 2003: Ionosphere/Atmosphere I *(joint with SA, SM)*

Presiding: **S Basu,** Air Force Research Laboratory**; A D Richmond,** NCAR High Altitude Observatory

SH43B-01 1330h INVITED

Impacts to Electric Power Grid Infrastructures From the Violent Sun-Earth Connection Events of October-November 2003

John G. Kappenman (218-727-2666; jkappenma@aol.com)

Metatech Corp., 5 W. First St, Suite 301, Duluth, MN 55802, United States

The solar flare activity of October-November 2003 reached historic intensity levels and produced several large Earth-directed CME's that had the potential to cause historically large geomagnetic storms as well. These CME's did cause various geomagnetic storm indices, particularly the regional K and Planetary Kp index, to reach maximum levels for many hours. However, the resulting geomagnetic storms, while causing isolated and important disruptions to power grids, were not of historically large size when considering the rate-of-change of regional geomagnetic fields in many locations. Impacts to power grids are caused by large dB/dt variations in regional geomagnetic fields, in most cases the peak geomagnetic disturbance intensities (in nT/min) were only a fraction of what has occurred during historically large geomagnetic storm events. A review will be provided of the CME passages and features of the passage that drove resulting geomagnetic storm events and impacts to electric power grid infrastructures on October 29-30, 2003. A brief overview of the geomagnetic storm disturbance morphologies and intensities relative to other noteworthy storms will also be provided.

SH43B-02 1350h INVITED

IMAGE-FUV observations of the October-November 2003 flare and magnetic storm effects on Earth

Thomas Thomas Immel Immel[1] (510 6433504; immel@ssl.berkeley.edu); Nikolai Ostgaard[1] (nikost@ssl.berkeley.edu); Doug J. Strickland[2] (dstrick@cpi.com); Harald U. Frey[1] (hfrey@ssl.berkeley.edu); Stephen B. Mende[1] (mende@ssl.berkeley.edu); Gang Lu[3] (gang@hao.ucar.edu)

[1]Space Sciences Laboratory, University of California Berkeley, Berkeley, CA 94720, United States

[2]Computational Physics Inc., 8001 Braddock Road, Springfield, VA 22151, United States

[3]High Altitude Observatory, National Center for Atmospheric Research, Boulder, CO 80305, United States

The series of solar flares and coronal mass ejections that occurred between October 26 and November 4, 2003 had extraordinary effects on Earth's upper atmospheric and space environments. In several areas these effects can be quantified by space-based global imagers such as the Far Ultraviolet Imager on the NASA-IMAGE satellite. The immediate effects of the X-Ray and EUV components of the solar flares on terrestrial photoelectron fluxes are evident in the rapid, global variations in FUV brightness. IMAGE was favorably positioned in its 14-hour orbit to monitor the time variation of the photoelectron flux enhancement during four of the X-class flares, including the two greatest flares of the period, providing an indirect measure of the solar EUV irradiance enhancements. Also measured indirectly by the FUV geocoronal imager is the enhancement in the solar FUV HI Lyman alpha irradiance during each of the four flares. The October 28, 2003 flare produced an estimated 20% enhancement in the solar Lyman alpha irradiance at Earth, the largest increase ever observed. The global FUV imager also is able to determine the effects of the CME induced magnetic storms on thermospheric composition, with accurate global measurements of the FUV emissions of OI at 135.6 nm. A global survey of the O/N_2 ratios through the entire period of activity is therefore possible. Comparisons with TIMED-GUVI flare observations and NCAR TIMEGCM O/N_2 will be made for cross-validation purposes.

SH43B-03 1410h

The Extreme Solar Flares of October 28th and November 4th, 2003 and Resultant Extreme Ionospheric Effects

Bruce T Tsurutani[1] (Bruce.Tsurutani@jpl.nasa.gov); Darrel L Judge[2] (judge@usc.edu); Andrew R Jones[2] (arjones@usc.edu); Fernando L Guarnieri[1,2,3] (Fernando.Guarnieri@jpl.nasa.gov); Gicela A Zambon[2] (gicelazambon@hotmail.com); Pradip Gangopadhyay[2] (pradip@usc.edu); Matthew Harmon[2] (mharmon@usc.edu); Jeffrey Nuttall[2] (jnuttall@usc.edu); Donald E Shemansky[2] (dons@hippolyta.usc.edu); Anthony Mannucci[1] (Anthony.Mannucci@jpl.nasa.gov); Byron Iijima[1] (Byron.Iijima@jpl.nasa.gov); George Hajj[1] (George.Hajj@jpl.nasa.gov); Thomas N Woods[4] (tom.woods@lasp.colorado.edu); Linton Floyd[5] (floyd@louis14.nrl.navy.mil); Robert R Meier[6] (meier@uap2.nrl.navy.mil); Joseph Huba[7] (huba@ppdmail.nrl.navy.mil); Stan C Solomon[8] (stans@ucar.edu); Stephen Mende[9] (Mende@ssl.berkeley.edu); Thomas J Immel[9] (immel@ssl.berkeley.edu); Janet U Kozyra[10] (jukozyra@engin.umich.edu); Judit Pap[11] (papj@marta.gsfc.nasa.gov)

[1] Jet Propulsion Laboratory, 4800 Oak Grove Drive, Pasadena, CA 91109, United States

[2] University of Southern California, University of Southern California, Los Angeles, CA 90007, United States

[3] Instituto Nacional de Pesquisas Espaciais - INPE, Av. dos Astronautas, CP515, Sao Jose dos Campos, SP, Brazil

[4] LASP, University of Colorado, University of Colorado, Boulder, CO, United States

[5] Interferometrics, Inc, Interferometrics, Inc, Greenbelt, MD, Greenbelt, MD, United States

[6] E.O. Hulburt Center, Naval Research Laboratory, Naval Research Lab., Washington, DC 20375, United States

[7] Plasma Physics Division Naval Research Laboratory, Naval Research Lab., Washington, DC 20375, United States

[8] High Altitude Observatory, UCAR, High Altitude Observatory, UCAR - POB 3000, Boulder, CO 80307, United States

[9] Space Sciences Laboratory, Univ. California at Berkeley, Univ. California at Berkeley, Berkeley, CA, United States

[10] The University of Michigan, University of Michigan, Ann Harbor, MI 48109, United States

[11] Goddard Space Flight Center, Goddard Space Flight Center, Greenbelt, MD, United States

Some of the most intense solar flares in recorded history occurred at the end of 2003. The November 4th event is the largest on record (X28) and the October 28th flare was the fourth most intense (X17). These will be compared/contrasted to the July 14, 2000 Bastille Day (X6) event. We use SOHO EUV (SEM), GOES and TIMED x-ray data to characterize the flare spectral energy versus time. High time resolution, 1s ground base GPS data are used to examine the abrupt increase in path-integrated ionospheric total electron content (TEC). It will be shown that the dayside ionosphere responds dramatically to the x-ray, FUV and EUV input by an abrupt 20-25 percent increase in ionospheric electron densities. Polar and IMAGE UV spectra are used to quantify the dayglow enhancements. The TEC increases are nonlinearly related to the peak flare intensities. The reasons for this are not understood at this time. Ionospheric models using the flare input data will be used to compared against tomographic analyses of the GPS information.

SH43B-04 1425h

Saturation of the Polar Cap Potential Observed by DMSP During the October and November 2003 Superstorms

Marc Hairston[1] (972-883-2826; hairston@utdallas.edu)

Kelly Drake[1] (classiccat63@yahoo.com)

Rod Heelis[1] (heelis@utdallas.edu)

Ruth Skoug[2] (rskoug@lanl.gov)

Gang Lu[3] (ganglu@hao.ucar.edu)

[1] Center for Space Sciences-University of Texas at Dallas, PO Box 830688 FO22, Richardson, TX 75083-0688, United States

[2] Los Alamos National Laboratory, Group ISR-1, MS D466, Los Alamos, NM 87545, United States

[3] High Altitude Observatory-UCAR, 3450 Mitchell Lane, Boulder, CO 80301, United States

The superstorms of October and November 2003 provide an ideal case for observing the saturation of the polar cap potential and testing the Hill-Siscoe model of the behavior of this saturation. Our prior work showed that the reconnection electric field in the solar wind $E_{sw} \sin(\Theta/2)$) must be greater than about 8 mV/m before the saturation becomes clearly apparent. A search of the polar cap potentials observed by the DMSP-F13 spacecraft from 1998 through 2002 produced only 27 polar passes that occurred under these extreme solar wind conditions. The two superstorms of 2003 doubled this by adding another 29 polar passes to this dataset. In the earlier dataset there were only two polar passes which occurred while E_r ranged from 20 to 30 mV/m, but these storms added 18 more passes where E_r ranged from 20 up to 40 mV/m. We show evidence that saturation continues to manifest itself under these more extreme solar wind conditions. We contrast the polar cap potential response between the October storm (extreme speed, very low density, moderate IMF) and the November storm (nominal storm speed and density, extreme IMF). We test the Hill-Siscoe model of saturation by comparing the observed polar cap potentials with the model's predicted potentials using ionospheric conductivities derived from the AMIE procedure.

SH43B-05 1440h

Global Ionospheric and Magnetospheric Response to the October-November 2003 Geomagentic Storm

Gang Lu[1] (303-497-1554; ganglu@ucar.edu); Arthur Richmond[1] (richmond@ucar.edu); Fred Rich[2] (frederick.rich@hanscom.af.mil); Dave Evans[3] (David.S.Evans@noaa.gov); Marc Hairston[4] (hairston@utdallas.edu); Mike Ruohoniemi[5] (Mike.Ruohoniemi@jhuapl.edu); Thomas Immel[6] (immel@ssl.berkeley.edu); Ruth Skoug[7] (rskoug@lanl.gov)

[1] High Altitude Observatory, National Center for Atmospheric Research, 3450 Mitchell Lane, Boulder, CO 80307, United States

[2] AFRL/VSBXP, 29 Randolph Rd, Hanscom AFB, MA 01731-3010, United States

[3] SEC/NOAA, 325 Broadway, Boulder, CO 80305, United States

[4] Center for Space Sciences,, University of Texas at Dallas, Richardson, TX 75083, United States

[5] JHU/APL, Jones Hopkins Rd., Laurel, MD 20723, United States

[6] Space Sciences Laboratory,, University of California, Berkeley, CA 94720, United States

[7] Space and Atmospheric Sciences, Los Alamos National Laboratory, Los Alamos, NM 87545, United States

The October-November 2003 geomagnetic storm has been regarded as the third most powerful event on record. A set of comprehensive data has been collected both from space and from ground to study this event. The Assimilative Mapping of Ionospheric Electrodynamics (AMIE) procedure is used to derive the "snapshot" maps of the large-scale ionospheric electrodynamic fields. The preliminary analysis of the data has indicated dramatic variations in the ionospheric electrodynamic system during the passage of high-speed solar wind streams, with AE reaching up to 3500 nT and Dst dropping down to -450 nT. Energy deposition in terms of auroral precipitation and Joule heating will be estimated, and the variability of the energy inputs associated with geomagnetic activity as well as solar wind conditions will be examined. We also investigate the impact of solar and magnetospheric energy inputs to the upper atmosphere.

SH43B-06 1455h

Large-Scale TEC Variations of Low-Latitude Ionosphere Driven by the Solar Storm of October-November 2003

Chien-hung Lin[1,2] (303 497 1571; clin@ucar.edu); Jann-Yenq Liu[2,3] (jyliu@jupiter.ss.ncu.edu.tw); Arthur D. Richmond[1] (richmond.ucar.edu); Huey-Ching Yeh[2] (yeh@csrsddc.csrsr.ncu.edu.tw); Ho-Fang Tsai[4] (hftsai@nspo.org.tw); Shin-Yi Su[2,3] (sysu@jupiter.ss.ncu.edu.tw)

[1] High Altitude Observatory, NCAR, P. O. Box 3000, Boulder, CO 80307, United States

[2] Institute of Space Science, National Central University, Chung-Li 320, Taiwan

[3] Center for Space and Remote Sensing Research, National Central University, Chung-Li 320, Taiwan

[4] National Space Program Office, 8F, 9, Prosperity 1st Road, Science-Based Industrial Park, Hsin-Chu, Taiwan

Large-scale ionospheric total electron content (TEC) variations have been observed by using a chain of GPS receivers along the east Asia sector ($\sim 120^\circ$E) and a chain of receivers along the American sector ($\sim 70^\circ$W) during the October-November 2003 magnetic disturbance period. The day to day Latitude-Time-TEC (LTT) maps constructed from GPS receivers along the same longitudinal line show that the poleward boundaries of the equatorial anomaly in the east Asia can expand to $\pm 30^\circ$ magnetic latitude on Oct. 29th, followed by severe depletions in next two days. Meanwhile, the LTT maps observed in the American sector show strong equatorial anomaly expansions on both Oct. 29th and Oct. 30th. The poleward boundaries of the anomaly region can expand to $\pm 50^\circ$ magnetic latitude in this sector. Moreover, during the recovery phase of the storm, a TEC enhancement can be see in both sectors on Nov. 1st. The satellite in situ density and plasma drifts measurements obtained from the Republic of China Satellite-1 (ROCSAT-1) at 600 km height show that the equatorial anomaly expansions are caused by the strong upward plasma drift on Oct. 29th in the east Asia sector and on Oct. 29th and 30th in the American sector. Satellite data also shows that light ions are dominant in some area at night during the storm recovery phase. The component of the plasma drift parallel to the magnetic field measured by ROCSAT-1 is also used to explain this post storm light ion enrichment phenomenon.

SH44A CC: 518 A Thursday 1530h

Violent Sun-Earth Connection Events of October-November 2003: Ionosphere/Atmosphere II *(joint with SA, SM)*

Presiding: **L J Paxton,** Applied Physics Laboratory, Johns Hopkins University**; C Jackman,** NASA Goddard Space Flight Center

SH44A-01 1530h

Atmospheric Effects of the October-November 2003 Storms

Jeng-Hwa Yee[1] (240-228-6206; sam.yee@jhuapl.edu); Elsayed R Talaat[1] (240-228-3971; elsayed.talaat@jhuapl.edu); Janet U Kozyra[2] (jukozyra@engin.umich.edu); Larry J Paxton[1] (larry.paxton@jhuapl.edu); Andrew Christensen[3] (Andrew.B.Christensen@aero.org); James M Russell[4] (JAMES.RUSSELL@hamptonu.edu); Martin G Mlynczak[5] (m.g.mlynczak@nasa.gov); Stan Solomon[6] (stans@ucar.edu); Tim Killeen[6] (killeen@ucar.edu); Geoffrey Crowley[7] (crowley@picard.space.swri.edu); Roderick Heelis[8] (heelis@utdallas.edu); Charles H Jackman[9] (jackman@assess.gsfc.nasa.gov); Tom Woods[10] (tom.woods@lasp.colorado.edu); Ray Roble[6] (roble@ucar.edu); Qian Wu[6] (qwu@ucar.edu); Jeff Thayer[11] (jeff.thayer@sri.com); John Foster[12] (jcf@haystack.mit.edu); Chris Hackert[7] (CHackert@swri.org)

[1] The Johns Hopkins University Applied Physics Laboratory, 11100 Johns Hopkins Road, Laurel, MD 20723, United States

[2] University of Michigan Space Physics Research Lab, 2455 Hayward St, Ann Arbor, MI, United States

[3] Aerospace Corporation, PO Box 92957 M2/260, Los Angeles, CA, United States

[4] Hampton University, Ctr Atmospheric Sciences 23 Tyler St, Hampton, VA, United States

[5] NASA Langley Research Ctr, 21 Langley Blvd Rm 164 MS 420, Hampton, VA, United States

[6] National Center for Atmospheric Research High Altitude Observatory, 3450 Mitchell Ln, Boulder, CO, United States

[7] Southwest Research Institute, 6220 Culebra Rd, San Antonio, TX, United States

[8] University of Texas, Dallas, POB 830688 MS FO22, Richardson, TX, United States

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