SH43B-03 1410h

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

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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

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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

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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

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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

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The high solar activity during the last weeks of October and beginning of November 2003, including X-class flares and fast coronal mass ejections, provides a great opportunity to study their effects on the upper atmosphere. Some of the CME's were geomagnetically effective, some were not. The variable energy inputs during these series of solar and geomagnetically disturbed times would affect important chemical reactions involving energetically-important minor species such as O and NO throughout the high-latitude mesosphere and lower thermosphere. For example, increased NO cooling in the thermosphere provides a cooling mechanism which effectively compensates the energy deposited from the enhanced particle and electrodynamic inputs. In addition, the transport of these important minor species in latitude and altitude alters the global thermal structure and composition, and ultimately result in changes in the circulation pattern that further provides feedback to various time-varying atmospheric effects. The disturbed wind patterns can also affect the large- and small-scale variations of ionospheric density, including those in the Appleton anomaly. The accompanying energetic solar protons could also rain down over the polar cap and produce changes of NO, H2O, ozone, and plasma concentrations in the lower mesosphere. There were a suite of spaceborne and groundbased instruments operating during the Oct/Nov 2003 storm periods, including those onboard the Thermosphere, Ionosphere, Mesosphere, Energetics and Dynamics (TIMED) spacecraft. The availability of sophisticated multi-dimensional general circulation models, such as the Thermosphere-Ionosphere-Mesosphere-Electrodynamics General Circulation Model(TIME-GCM), have provided valuable insight for the interpretation of the observed phenomena. In this paper we will present a selective set of observations highlighting the Earth's global response to these large solar and geomagnetic disturbances and discuss these observations in conjunction with TIME-GCM simulations.

SH44A-02 1545h

Observations of the Ionospheric and Thermospheric Response During the October and November 2003 Storms

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The Global Ultraviolet Imager (GUVI) on the NASA TIMED satellite obtained unique and important measurements of the thermospheric and ionospheric composition and auroral inputs during these storms. The energy inputs were extraordinarily high - well over 150 ergs/cm2/s. This energy input into the high latitude E-region led to large-scale changes in the structure and composition of the neutral atmosphere. We will show movies of these changes in composition and show how this compares to the average and to the modeled disturbed conditions. GUVI also obtained unique ionospheric observations: these allow us to look at the coupling between the neutral atmosphere and the ionosphere. For example, the wind fields redistribute ionization in the equatorial ionosphere - GUVI can see this response and model data comparisons illuminate our ability to determine the inputs that drive the models. Furthermore there was a very unusual and shortlived enhancement of the ionosphere during the peak of the storm that has not been seen before. The two year lifetime of the TIMED mission enables us to compare the 2002 to 2003 observations and this comparison makes it clear that while some of the effects observed during the storm period are seasonal and local time driven, there are others that would have had a significant societal impact and exhibit clear departures from the mean behavior.

SH44A-03 1600h

Modeling the Thermosphere/Ionosphere Response to Large Solar Flares and Geomagnetic Storms

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During October-November 2003, a series of large coronal mass ejections and solar flares caused significant changes in the terrestrial upper atmosphere and ionosphere. We have simulated these effects using the NCAR Thermosphere-Ionosphere-Electrodynamics General Circulation Model (TIE-GCM). Solar photon inputs to the model were obtained from solar irradiance instruments on the TIMED and SORCE satellites, and auroral forcing obtained using the AMIE procedure. This study enables quantification of the relative importance of photon and auroral forcing of ionosphere/thermosphere density and temperature. Ion density enhancements and airglow intensities derived from the model results can be compared to observations to investigate the simulation fidelity during these extraordinary events.

SH44A-04 1615h

Neutral Middle Atmospheric Influences by the Extremely Large October 2003 Solar Proton Event

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The huge coronal mass ejection (CME) on October 28, 2003 caused an extremely large solar proton event (SPE) at the Earth, which impacted the middle atmospheric polar cap regions. The highly energetic protons produce ionizations, excitations, dissociations, and dissociative ionizations of the background constituents, which lead to the production of HOx (H, OH, HO2) and NOy (N, NO, NO2, NO3, N2O5, HNO3, HO2NO2, ClONO2, BrONO2). The total production of middle atmospheric NOy molecules by individual SPEs can be used to compare their sizes. Using this scale, the extremely large October 2003 SPE was the fourth largest in the past 40 years and the second largest of solar cycle 23. Only the October 1989, August 1972, and July 2000 SPEs were larger. The Goddard Space Flight Center (GSFC) Two-dimensional (2D) Model was used in computing the influence of this gigantic SPE. The NOy amount was increased by over two orders of magnitude in the mesosphere in both the GSFC 2D Model computations and Upper Atmosphere Research Satellite (UARS) Halogen Occultation Experiment (HALOE) measurements as a result of this noteworthy SPE. The model also calculated polar middle mesospheric ozone decreases of over 70% during the SPE. Other atmospheric impacts from both model predictions and measurements as a result of this major SPE will be discussed in this paper.

SH44A-05 1630h

Global Thermosphere-Ionosphere Response to the October-November 2003 Storms

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The period of post-solar maximum geomagnetic storms in October and November 2003 were some of the largest storms ever recorded. The thermospheric and ionospheric responses are simulated using the NCAR TIMEGCM. The model shows large areas of O/N2 depletion spreading from high latitudes, and corresponding reductions in the ionospheric electron density. Similar depletions were observed by several instruments. The model is used as a framework to interpret some of the effects observed by the GUVI instrument on the TIMED satellite.

SH44A-06 1645h

Explosive Redistribution of Earth's Thermal Plasma Environment during Major Geomagnetic Storms

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Disturbance electric fields during the major geomagnetic storms of October and November 2003 resulted in the large-scale perturbation and global redistribution of Earth's thermal plasma environment. The solar-produced plasmas of the low-latitude ionosphere and plasmasphere erupted poleward in response to storm-time penetrating electric fields, producing greatly-enhanced plasma concentrations in the outer plasmasphere. Sub-auroral electric fields associated with the storm-enhanced ring current stripped away these outer-plasmasphere regions and carried them sunward as intense plumes of storm-enhanced density (SED), or plasmasphere drainage plumes. These, in turn, were convected rapidly through the dayside cusp and back across polar latitudes forming dense tongues of ionization (TOI). We use global ground-based imagery of total electron content (TEC) derived from GPS observations to map the intensity and evolution of these features. Polar-projection snapshots and movies of

TEC reveal rapid transport of the low-latitude plasma to the cusp, across the polar cap, and its deposition around the nightside auroral oval. Incoherent scatter radars at Sondrestrom and EISCAT Svalbard provide vertical profiles through the TOI at polar latitudes, while radars at Millstone Hill and EISCAT Tromso detail the plasma characteristics at its source and at midnight-sector auroral latitudes. F-region TEC (below 1000 km altitude) observed with the Sondrestrom radar was > 120 TECu within the polar TOI, while TEC over the continental USA approached 300 TECu. During the November event, spatial gradients in TEC exceeded 100 TECu per degree of latitude over the northeast USA. No polar cap absorption event accompanied the Nov 2003 storm, and the SuperDARN radars provided full convection patterns over the northern polar latitudes. The continuous streams of thermal plasma TEC observed with the GPS mapping closely follow the convection streamlines simultaneously determined from the SuperDARN observations. GPS TEC observations now extend to high southern latitudes and we determine that the SED plumes and polar TOI imaged in the north appear simultaneously in the conjugate hemisphere.

SH51A CC: 220 C-E Friday 0830h

Violent Sun-Earth Connection Events of October-November 2003 I Posters

(joint with SA, SM)

Presiding: **T H Zurbuchen,** University of Michigan**; Q Zong,** Boston University

SH51A-01 0830h POSTER

Photospheric field variations during the Oct. 28 and 29 solar events

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Solar photospheric magnetic field variations around the Oct. 28th and 29th, 2003 large flares and CMEs are investigated. The essential data for the study are the high cadence MDI full disk line of sight magnetograms. Abrupt and permanent changes of the field strength occur at the times of both X-flares (Oct. 28, 10:30UT and Oct. 29, 20:45UT). GONG+ magnetograms are used to provide a possible confirmation of the observed field changes. Velocity fields in the CME related active region and their evolution around the time of the events are obtained using the Local Correlation Tracking (LCT) technique on the MDI magnetograms. Some Mees/IVM vector magnetic field data analysis results may also likely be available.This level of observation of major active region fields spawning superstorm conditions is unprecedented.

SH51A-02 0830h POSTER

Evolution of the Coronal Magnetic Structures traced by X-ray and Radio Emitting Electrons during the Flare of 3 November 2003

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During their transit on the solar disk AR 0488 and AR0486 produced 12 X-class flares. Two of these flares (28 October 2003 and 3 November 2003) were observed at both X-ray/gamma-ray wavelengths by the RHESSI experiment and by the Nancay Radioheliograph. We shall present here results for the 3 November 2003 event which was observed and imaged up to several 100 keV by RHESSI and which produced at radio wavelengths a type II burst with an unusually high starting frequency and a long duration continuum extending from the low corona to the interplanetary medium. The combined analysis of RHESSI sources at energies above a few hundred keV and of metric/decimetric sources observed by the NRH shows a spatial extension of both X-ray and radio sources traced by energetic electrons between the impulsive part of the event and the late energetic X-ray phase associated with the radio continuum. This spatial extension will be discussed in the context of the shock-associated type II burst and of the CME onset. Analysis of radio and X-ray spectra will be tentatively done to investigate the nature of the radio continuum.

SH51A-03 0830h POSTER

UVCS Observations of CMEs from October-November 2003 Flares

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UVCS observed the CMEs associated with several of the powerful flares in late October and early November of 2003. While some of the observations were compromised by high particle background, useful observations of at least six events were obtained. In general, these events resemble the CMEs associated with X-class flares observed in 2002, in that low ionization spectral lines that dominate most UV spectra of CMEs are nearly absent. On the other hand, the [Fe XVIII] line formed at 65 MK is rarely seen in CMEs, but it is detected in many of these events. We discuss whether this means that no cool prominence material is ejected, or that the prominence material is heated so strongly that all the plasma reaches a high ionization state.

SH51A-04 0830h POSTER

Solar Flares in the UV from SORCE SOLSTICE

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The SOLar-STellar Irradiance Comparison Experiment (SOLSTICE) on the SOlar Radiation Climate Experiment (SORCE) measures the solar irradiance from 115-300 nm. During the solar storms of October and November of 2003, we observed large increases in the emission lines from many transition region species during several flare events. The greatest impact of a flare on the solar UV spectrum is in the brief impulsive phase. In the timespan of just a few minutes, the strength of an emission feature can rise by a factor of 10 and then subside back to its quiescent level over the course of an hour or more. The SOLSTICE observing technique scans the solar spectrum at a variety of rates, some scans taking 30 minutes to complete while others measure the entire wavelength range in a few minutes. Each flare reported here occurred while SOLSTICE was sampling a different piece of the spectrum. The combined information from all the observed flares provides new insight concerning the spectral signature of a flare as a function of both time and wavelength.

SH51A-05 0830h POSTER

The Role of a Nearby Emerging Active Region in the Events of October 2003

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On Oct 28, there was a large and complex magnetic region (10486) in the southern hemisphere. An X17 flare took place and a very high speed CME was launched and a Solar Energetic Particle (SEP) event took place. This was the first of the series of flare/CME/SEP events that occurred over the next few days. Series like this are typical of the major proton events that threaten damage to spacecraft systems and manned missions. Why did this active region produce a series of such fast CMEs? The release of this CME was preceded by a most remarkable flux emergence event. In the northern solar hemisphere, at approximately the same longitude as region 10486 a new major flux region began to emerge rapidly. When the new region(10488)began to emerge there were no obvious coronal structures connecting it with 10486 but the 10488 flux soon began to interact with the 10486 flux and a connecting structure could be seen in the EIT 195A. Connections between the two magnetic regions changed over the next 31 hours and Multiple connections could be seen just before the X17 flare and CME occurred. The connections seemed to be severed at the time of this CME but reformed later. We will discuss the series of connections and disconnections between the fluxes from 86 and 10488 in the context of the causes of ultra-high-speed CMEs.

SH51A-06 0830h POSTER

Sun-Earth Propagation Time of the October - November 2003 Shocks

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We computed the radial and expansion speed profiles of the CMEs that resulted in shocks detected at 1 AU, in order to evaluate the empirical shock arrival (ESA) model. The CMEs were observed by the Large Angle and Spectrometric Coronagraph (LASCO) on board SOHO during October - November 2003 period. The shocks were detected by CELIAS/MTOF Proton Monitor on board SOHO and ACE spacecraft. The basic input to the ESA model is the CME speed. For limb events, we assume axial symmetry in order to obtain the most probable CME speed in the Sun-Earth direction. We apply the ESA model to obtain the travel times of shocks driven by Earth-directed and limb CMEs which had in situ observations at 1AU. For most cases the difference between the predicted and observed shock arrival times is negligible. We discuss these differences and their possible causes. Work supported by NASA/LWS and NSF/SHINE programs

SH51A-07 0830h POSTER

CME Cannibalism and Long-wavelength Radio Emission During the October-November 2003 Storms

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A spectacular interaction between two fast coronal mass ejections (CMEs) was observed by the Large Angle and Spectrometric Coronagraph (LASCO) on board SOHO on November 4, 2003. The interaction resulted in a broadband radio enhancement in the dynamic spectrum of the Radio and Plasma Waves (WAVES) experiment on board Wind. The radio enhancement occurred when the second CME moving with a speed of 2700 km/s caught up with a slower CME ($\sim$ 600 km/s) and its dense core at a distance of 18 solar radii from the Sun. Direction finding from WAVES observations matched with the white-light location of the interaction region. The radio enhancement was brighter than the associated type II burst. We also show from the observed flux radio density and white-light source extent that the radio emission is nonthermal. The radio emission due to the colliding CMEs was also observed