High energy particles generated during solar/interplanetary disturbances will pose a serious hazard to crew members traveling beyond low-Earth orbit. In order to provide warnings of dangerous radiation conditions, mission operators will need accurate forecasts of solar energetic particle (SEP) fluxes and fluences in interplanetary space. However, physics-based models for accelerating and propagating SEPs require specifications and predictions of the solar wind conditions and IMF configuration near the evolving interplanetary shock region, and along the IMF lines connecting the shock to the observation point. We are presently using the Hakamada-Akasofu-Fry kinematic solar wind model to predict, in real time, solar wind conditions in the inner heliosphere, including at the location of Mars. We are also conducting retrospective Mars space weather studies by simulating solar wind conditions during significant solar event periods and comparing modeling results with disturbance signatures observed at Mars. These signatures include enhancements in the energetic particle environment at Mars, and instrument anomalies on spacecraft orbiting Mars. We will present recent study results.

SA31A-06 0830h POSTER

The "Mars-Sun Connection" and the Impact of Solar Variability on Mars Weather and Climate

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We develop the scientific case to measure simultaneously the UV and near-UV solar irradiance incident on the Mars atmosphere and at the Martian surface, to explore the effects and influence of Solar variability and "Space Weather" on Mars weather and climate, its implications for life, and the implications for astronaut safety on future manned Mars missions. The UV flux at the Martian surface is expected to be highly variable, due to diurnal, daily, and seasonal variations in opacity of atmospheric dust and clouds, as well as diurnal and seasonal variations in ozone, water vapor and other absorbing species. This flux has been modeled (Kuhn and Atreya, 1979), but never measured directly from the Martian surface. By directly observing the UV and near UV solar irradiance both at the top of the atmosphere and at the Martian surface we will be able to directly constrain important model parameters necessary to understand the variations of atmospheric dynamics which drive both Mars weather and climate. Directly measuring the solar UV radiation incident upon the Mars atmosphere and at the Martian surface also has important implications for astronaut safety on future manned Mars missions. The flux at the surface of Mars at 250 nm is also believed to be approximately 3000 times greater than that on Earth. This presents potential hazards to future human explorers as well as challenges for future agriculture such as may be carried out in surface greenhouses to provide food for human colonists. A better understanding of the surface flux will aid in designing appropriate protection against these hazards.

SA31A-07 0830h POSTER

Concepts for a Mars Upper Atmosphere Orbiter Mission to Study Atmospheric Escape

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According to the recent decadal survey "New Frontiers in the Solar System: An Integrated Exploration Strategy" report by the National Academy of Sciences, a Mars Upper Atmosphere Orbiter (MUAO) mission is required to "provide quantitative information on the various atmospheric escape fluxes, thus quantifying current escape rates and providing a basis for backwards extrapolation in our attempt to understand the evolution of Mars' atmosphere." Mars' atmosphere may once have been thick, warm, and wet, but how did it evolve into the thin, dry atmosphere of today? Specifically, how much water was lost by escape to space versus sequestration in the surface? We are investigating several candidate MUAO missions and instrument suites that address these questions of Martian climate change. We report a preliminary list of science goals and needed measurements for a MUAO mission. Initial results from a design study of neutral mass spectrometer, plasma analyzer, and far-ultraviolet spectrometer instruments conducted by SwRI will be discussed, along with future prospects for a NASA Mars Scout size MUAO mission.

URL: http://swim.swri.edu/

SA31B CC: 519 A Wednesday 0830h

The Extended Ionosphere: A Unifying Approach to Magnetosphere-Ionosphere Coupling I

(joint with SM)

Presiding: **J Semeter,** SRI International**; J Horwitz,** University of Alabama in Huntsville

SA31B-01 0830h INVITED

Energetic (keV) Ionosphere-Origin Ions Found Between $R = 2$ and 23 R_E

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With the flight of ion composition instruments on the Polar satellite, beginning some eight years ago, adding to several earlier missions of varied orbits, we now have essentially contiguous altitude records of the outflow of energized ionospheric ions from $R = 2R_E$ (geocentric) to $R = 23R_E$, at least in the energy range from a few tens of eV/e to a few tens of keV/e. Magnetotail ion composition measurements in that energy range were first made more than 20 years ago during the ISEE mission (within 23 R_E) and are again being made with the Cluster satellites (within 20 R_E). According to the several years of ISEE measurements, the nearly omnipresent, singly charged oxygen ions, in particular, have a broad energy distribution within the tail plasma sheet, typically averaging about 3-5 keV. This may be contrasted with mean O^+ energies of only 0.2-0.4 keV observed in the ion outflow at $R \sim 2R_E$ by the Polar TIMAS instrument. The same instrument finds the O^+ mean energy to have increased to 1 keV or more by the time the ions have reached $R \sim 4 - 9R_E$, while the total rate of O^+ outflow (ions per second) above the nominal 15 eV minimum energy (plus spacecraft potential) has increased about fivefold. An important part of this progressive energization is transverse acceleration across the geomagnetic field lines. As will be shown, this process is sometimes resolved within the O^+ gyro period by the TIMAS instrument at these high altitudes. Early TIMAS results suggest that this kind of acceleration is intermittent and explosive and arguably caused by magnetic field-aligned space charge structures associated with earthward bursts of hot and filamentary magnetospheric plasma. The TIMAS data also imply that ionospheric ions are directly injected into the ring current region, but the very energetic O^+ ($\sim$100 keV) that is known to be a large component of the storm-time ring current has most likely arrived from the plasma sheet, undergoing adiabatic betatron and Fermi acceleration.

SA31B-02 0850h INVITED

Imaging Magnetospheric Perturbations of the Ionosphere/Plasmasphere System from the Ground and Space

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The thermal plasmas of the inner magnetosphere and ionosphere move across the magnetic field under the influence of electric fields. Irrespective of their source, these electric fields extend along magnetic field lines coupling the motion of thermal plasmas in the various altitude regimes. Modern remote-sensing techniques based both on the ground and in space are providing a new view of the large and meso-scale characteristics and dynamics of the plasmas of the extended ionosphere and their importance in understanding processes and effects observed throughout the coupled spheres of Earth's upper atmosphere. During strong geomagnetic storms, disturbance electric fields uplift and redistribute the thermal plasma of the low-latitude ionosphere and inner magnetosphere, producing a pronounced poleward shift of the equatorial anomalies (EA) and enhancements of plasma concentration (total electric content, TEC) in the post-noon plasmasphere. Strong SAPS (subauroral polarization stream) electric fields erode the plasmasphere boundary layer in the region of the dusk-sector bulge, producing plasmaspheric drainage plumes which carry the high-altitude material towards the dayside magnetopause. The near-Earth footprint of these flux tubes constitutes the mid-latitude streams of storm-enhanced density (SED) which produce considerable space weather effects across the North American continent. We use ground-based GPS propagation data to produce two-dimensional maps and movies of the evolution of these TEC features as they progress from equatorial regions to the polar caps. DMSP satellite overflights provide in-situ density and plasma flow/electric field observations, while the array of incoherent scatter radars probe the altitude distribution and characteristics of these dynamic thermal plasma features. IMAGE EUV and FUV observations reveal the space-based view of spatial extent and temporal evolution of these phenomena.

SA31B-03 0910h

Sub-Auroral Morning Proton Spots (SAMPS) as a Result of Plasmapause-Ring-Current Interaction

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The proton aurora imager SI-12 on the IMAGE spacecraft occasionally observed Sub-Auroral Morning Proton Spots (SAMPS) that rotate with 80-90 % of the Earth's corotation speed. Coincident particle measurements by DMSP confirm the source as pure high energy precipitating protons with energy likely above the detector limit of 30 keV. The spots appear after magnetic storms in the recovery phase and last for 1-4 hours in the magnetic local time region of 0600-1200 hours. IMAGE-EUV observations of the plasmasphere indicate a relationship with density gradients in the expanding plasmapause after magnetic storms. This is supported by nearby geosynchronous observations of increased cold plasma density. We interpret these spots as the result of the interaction of ring current protons with electromagnetic ion-cyclotron (EMIC) waves caused by the expansion and sub-rotation of the dense, cold plasmasphere ions. It is therefore a consequence of plasmasphere refilling after geomagnetic storms.

SA31B-04 0925h INVITED

Low Energy Neutral Outflow

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Analysis of ENA data from the LENA instrument on the IMAGE spacecraft shows that the terrestrial atmosphere is a copious emitter of low energy neutral atoms (10 - 300 eV) under all conditions. These emissions appear most intense when the spacecraft is close to the earth but as activity increases they can be seen at greater distances. The emissions correlate well with magnetic activity and increase at the same rate as the O^+ escape rate increases. Under extreme conditions such as the Bastille Day storm (July 14-16, 2000), the pattern of high latitude emissions matches what would be seen coming from an expanded and continuous, auroral oval source region. The ENA emissions coming from the winter hemisphere vary diurnally in intensity suggesting that under these conditions the dayside auroral oval/cusp region is the dominate source of the emissions. As activity increases, the altitude range of the auroral zone ENA emission region increases. This presentation will address the following three questions raised by this data. 1) Where do these neutral emissions come from? 2) What processes produce them? 3) What does this data tell us about ionosphere/magnetosphere coupling processes?

SA31B-05 0945h

Storm-Time Enhancements of Balmer-alpha Brightness at Arecibo: Transport of Atomic H or Low Latitude Aurora ?

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Two-fold enhancements of the atomic hydrogen Balmer-alpha airglow brightness are witnessed in the first 48 hours following the DST excursion demarking magnetic storm onset. The cause of these secular airglow brightness variations are alternately ascribed to enhancements of the atomic hydrogen column abundance due to global exospheric transport, or to collisional excitation of the Balmer-alpha emission by energetic neutral atoms generated in the ring current by proton recombination. These alternatives are evaluated by inspection of Balmer-alpha Doppler line profiles measured by the Arecibo Fabry-Perot interferometer during these post-storm brightness enhancements. The line profile analyses show no strong evidence for collisional excitation of those fine structure spectral components not present in the quiescent Balmer-alpha airglow feature pumped only by resonant-fluorescence of solar Lyman-beta photons. As such, the Arecibo data are consistent with global transport of neutral H to mid-latitudes following magnetic storms.

SA32A CC: 519 A Wednesday 1030h

The Extended Ionosphere: A Unifying Approach to Magnetosphere-Ionosphere Coupling II *(joint with SM)*

Presiding: **J Semeter,** SRI International**; R Schunk,** Utah State University

SA32A-01 1030h INVITED

3-D Dynamic Behavior of the Generalized Polar Wind With Low-Altitude Auroral Ion Energization

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The effects of low-altitude energization (LAE) of ions in the auroral region are investigated using a 3-D dynamic model. In this study, we simulate the behavior of a large number (~100 to 1000) of plasma-filled geomagnetic tubes. The model is composed of two components. The high-altitude component is based on a macroscopic particle-in-cell (mac-PIC) approach that extends from an altitude of 1200 km to several Earth radii. The lower boundary conditions of the mac-PIC model are provided by a 3-D fluid-like model (low-altitude component) that extends down to 100 km in altitude. The total number of simulation particles in the mac-PIC component is more than 10^8. The generalized polar wind is followed for about 12 hours with a time step of 2.5 seconds. The computing-intensive nature of the model requires utilization of super computers with ~100 to 1000 processors. A 3-D picture is assembled from the temporal evolution of the individual flux tubes by keeping track of their locations. The resulting 3-D dynamic picture is investigated with special emphasis on the role that the LAE plays. The main conclusions are: (1) In the absence of LAE, the dominant source of escaping O^+ occurs within the polar cap due to the influence of magnetospheric electrons; (2) Both upward and downward O^+ fluxes occur at low altitudes, while only upward O^+ fluxes occur at high altitudes; and (3) Downward O^+ fluxes occur essentially during the storm recovery phase, at the equatorward edge of the polar cap, within the dawn-noon sector.

SA32A-02 1050h

Observations of Ionospheric Outflows at low and Middle Altitudes

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Ionospheric outflows as observed at middle altitudes, such as those sampled by the FAST spacecraft, appear to be controlled by two energy inputs to the ionosphere: Poynting flux and soft electron precipitation. The former produces outflows because of ion heating in the ionosphere through collisional ion-neutral friction, the latter through electron heating. FAST observations alone can only partially address the relative importance of the two processes, since both Poynting flux and electron precipitation are often correlated. Observations of the lower altitude ionosphere, below 800 km, by radars such as the EISCAT Svalbard Radar (ESR), can resolve this ambiguity. The ESR provides observations of ion and electron temperatures as well as field-aligned ion flow velocities. Preliminary analysis indicates that electron temperatures are usually enhanced in regions of ionospheric outflows as observed by FAST. In addition there are indications that the ions are also heated. Furthermore, the ion heating is at times observed to extend to lower altitudes than the electron heating, with a corresponding structure in the upward flow velocities.

SA32A-03 1105h

Origin of type-2 thermal-ion upflows in the auroral ionosphere

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The origin of thermal ion outflows exceeding 1 km/s in the high latitude F region has been a subject of considerable debate. For cases with strong convection electric fields, the evaporation' of the ions due to frictional heating below 400-500 km has been shown to provide some satisfactory answers. By contrast, in the more frequent subclass of outflow events observed over auroral arcs, called type-2, there is no observational evidence for ion frictional heating. Instead, an electron temperature increase of up to 6000 K is observed over the outflow region. In this case, field-aligned electric fields have long been suspected to be involved, but this explanation did not seem to agree with expectations from the ion momentum balance. In the present work we introduce for the first time the electron energy balance in the analysis. We couple this equation with the ion momentum balance to study the salient features of the observations and conclude that type-2 ion outflows and the accompanying electron heating events are indeed consistent with the existence of a field-aligned electric field. However, for our explanation to work, we have to require that allowance be made for electron scattering by high frequency turbulence. This turbulence could be generated at first by the very fast response of the electrons themselves to a newly imposed field-aligned field. Their high frequencies would make it impossible for the ions to be affected by the waves. We have found the electron collision frequency associated with scattering from the waves to be rather modest, i.e., comparable to the ambient electron-ion collision frequency. The field-aligned electric field inferred from the observations is likewise of the same order of magnitude as the normal ambipolar field, at least for the case that we have studied in detail. We propose that the field-aligned electric field is maintained by the north-south motion of an east-west arc. The magnetic perturbation associated with the arc itself converts a small fraction of the perpendicular electric field into a field parallel to the total magnetic field, while the north-south motion ensures that the conversion never stops.

SA32A-04 1120h

Inductive Magnetosphere-Ionosphere Coupling

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A method for coupling a global magnetospheric MHD model to either an empirical ionospheric model or a dynamic ionospheric-thermospheric model is described for conditions in which inductive electric fields are important at low altitude. Existing coupling schemes based on quasistatic dynamics are valid for processes occurring on time scales of order 100 s or longer. The formulation developed here provides an efficient algorithm for extending the validity of the coupling model to faster magnetospheric processes, down to time scales of order 10 s, while retaining the physics of quasistatic coupling as the long time-scale limit. Both lumped and distributed formulations for the coupling-region fields are developed. The inclusion of magnetic induction gives rise to magnetic energy storage at low altitude. With additional extensions of the coupling model, this magnetic energy reservoir may provide a causal conduit for parameterizing ion heating processes leading to outflow.

URL: http://thayer.dartmouth.edu/spacescience/wl/pub/Lotko04.pdf

SA32A-05 1135h

Modeling the Continuous Ionosphere - Thermosphere - Magnetosphere System with the Integrated Space Weather Prediction Model (ISM)

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Historically, global models of the magnetosphere and ionosphere/thermosphere have operated in isolation, with each type of model treating the other region as a boundary condition. In recent years, existing stand-alone models have been linked together to create models that cover the entire ionosphere-thermosphere-magnetosphere (I-T-M) system. Unlike these models, the Integrated Space Weather Prediction Model (ISM) is a global first-principles two-material MHD model of the entire I-T-M system with no boundaries between the different regions. The two-material MHD equations, complete with the full Ohm's law including the Hall terms, provide self-consistent electromagnetic and material coupling throughout the ISM computational domain which extends from 40 earth radii (R_e) sunward of the earth to 300 R_e tailward, and down to a lower ionospheric boundary at approximately 100 km altitude. We describe the model and use currents, electric fields, and ion and neutral velocities to illustrate the I-T-M coupling that is inherent in ISM.

SA32A-06 1150h

What Governs Ion Outflow Composition?

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The variety of outflows in the polar ionosphere fall into two categories: bulk ion flows with energies up to a few eV, such as the polar wind and auroral bulk upflow, and energetic ion outflows such as upward ion beams and conics, in which a portion of the ion population is accelerated to much higher energies, and upwelling ions in the cleft, which have typical energies up to a few tens of eV and characteristic temperatures of a few eV. In general, the composition of each outflow population in