2014 LWS Meeting
Abstracts – Oral Presentations
(by day/session, as of October 29, 2014)

Monday, Nov. 3

Plenary Session 1a. *Magnetic Energy and Field from Solar Interior to Corona and Heliosphere*

Energy Transport in the Transition Region and Lower Solar Corona
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Hinode and IRIS observations, especially when combined with high resolution ground based data, are giving unprecedented clues as to the transport of energy from the photosphere through the chromosphere and transition region into the lower solar corona. Real progress on finding the sources of outer atmosphere heating can be made when these observations are combined with state of the art numerical simulations. In this talk we will discuss several exciting developments relevant to the understanding of energy transport in these regions of the atmosphere, including UFS-loops, RBEs/spicules type II, pervasive twist in small scale structures, evidence for Alfvenic waves, and flux emergence.

Radial Extent of Preferential Ion Heating in the Corona and Solar Wind
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The physical mechanism responsible for the high temperatures of the solar corona and the solar wind is capable of heating different ion species unequally, resulting in temperatures that are proportional to mass, or even supra-mass proportional. Spectroscopic measurements of coronal ions indicate that these uneven temperatures emerge within tenths of solar radii from the surface of the Sun. It is possible that preferential heating occurs closer to the surface of the Sun, but only at these heights are Coulomb collision rates sufficiently low that different temperatures can persist long enough to be observed. Solar wind ions in interplanetary space are also often seen to have unequal temperatures, but are these differences due to ongoing preferential heating or a signature of a process that occurred much closer to the Sun? This presentation will demonstrate a new technique that uses interplanetary solar wind observations from the Wind spacecraft and a model for the effects of Coulomb collisions to solve for the typical outer boundary of preferential ion heating. We will compare our results with theoretical models of solar wind heating, and make predictions for the upcoming Solar Probe Plus and Solar Orbiter missions to the inner heliosphere.

Magnetic Energy Storage, Release and Conversion in Solar Flares
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Energy release by magnetic reconnection has been hypothesized to drive numerous energetic phenomena in the Sun's corona including flares, coronal mass ejections and bright points. Prior to its release, energy is stored in the magnetic field as it slowly evolves subject to constraints on the topology of magnetic field lines. While this energy is stored in the large-scale coronal field, its release can be initiated by an electric field localized to very small scales provided it eliminates one of the topological constraints. Energy release initiated through local topological change is the essence of magnetic reconnection. It will be shown how observations of large-scale evolution of the Sun's photospheric field can be used to estimate the magnetic energy stored in the coronal field. It is then demonstrated how magnetic energy is converted into heat following small scale topological change. This is a transient, three-dimensional variant of the classic Petschek model whereby rotational discontinuities convert magnetic energy into kinetic energy of bulk flows whose collision creates slow magnetosonic shocks converting bulk kinetic energy into heat. The release of stored magnetic energy also reduces and redistributed large-scale coronal currents. This sudden change in current is accommodated in the global field by a fast magnetosonic front initiated at the reconnection site. We use a simple model to determine what fraction of the released energy takes this form.

Dynamic Models of the Corona Confronted to Observations

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Over recent years 3D MHD models allowed the reproduction of realistically-looking coronae. The models do provide not only the temperature, density, velocity and magnetic structure, but also allow to synthesize coronal emission – to be compared to observations of the real Sun. Confronted to numerous observational results, such as Emission measure, Doppler shifts, or the variability of individual structures these models gave many good matches. Ultimately, these comparisons provide a crucial test, if the spatial and temporal distribution of the energy input into the corona as resulting from the models is realistic, at least on the scales resolved by current models and observations. New observations with HiC and IRIS add new observational constrains that provide challenges for future models.

The Heating of the Solar Atmosphere: From the bottom up?

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The heating of the solar atmosphere remains a mystery. Over the past several decades, scientists have examined the observational properties of structures in the solar atmosphere, notably their temperature, density, lifetime, and geometry, to determine the location, frequency, and duration of heating. In this talk, I will review these observational results, focusing on the wealth of information stored in the light curve of structures in different spectral lines or channels available in the Solar Dynamic Observatory's Atmospheric Imaging Assembly, Hinode's X-ray Telescope and Extreme-ultraviolet Imaging Spectrometer, and the Interface Region Imaging Spectrograph. I will discuss some recent results from combined data sets that support the heating of the solar atmosphere may be dominated by low, near-constant heating events.

Plenary Session 1b. *Reconnection and Magnetic Instabilities in Geospace, Heliosphere, and Solar Atmosphere*

Dynamical Petscheck Reconnection

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Magnetic reconnection is the major mechanism for explosive energy liberation in the various plasmas. However, the mechanism of fast reconnection in high magnetic Reynolds number (S) plasmas is still unclear. While Petscheck (1964) proposed the fast reconnection model driven by slow mode shock, the previous studies suggested that the Petscheck-type reconnection is not stable in uniform resistivity and some anomalous resistivity or non-MHD effects are needed for fast reconnection.

In this paper, we developed the high-resolution magnetohydrodynamics (MHD) simulation of magnetic reconnection for the high-S (S~10^4-10^6) regime aiming at revealing the acceleration mechanism of magnetic reconnection in the MHD regime of uniform resistivity. As a result, we found that a new type of fast reconnection appears after the secondary tearing mode instability grows. When the width of magnetic island formed by the secondary tearing mode instability becomes large enough, the electric current sheets between some particular magnetic islands bifurcate to V-shape current layers. The reconnection at the apex of bifurcated current layers is preferentially accelerated, because the bifurcated current layers create slow mode shocks. The slow mode shocks are repeatedly created and dissolved corresponding to the formation and transportation of plasmoids. These results indicate that, even though resistivity is uniform, when the magnetic Reynolds number is high enough, the multiple X-line reconnection of Sweet-Parker current sheets (plasmoid reconnection) is switched to a new regime called "dynamical Petschek reconnection".

Magnetic Evolution, Reconnection and Particle Acceleration in Solar Flares: Insights from RHESSI

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The Ramaty High Energy Solar Spectroscopic Imager (RHESSI) observes solar flares in X-rays and gamma rays at photon energies above a few keV. It observes radiation from the hottest flare plasma and from accelerated electrons and ions. Thus, it observes processes closely associated with the release of magnetic energy. I will review how RHESSI observations have advanced our understanding of magnetic evolution, reconnection, and particle acceleration in flares. I will also briefly address the importance of thorough diagnostics of ~10 – 50 MK plasma to understanding particle acceleration in flares.

Magnetic Reconnection, Buoyancy and Flapping Motions in Magnetotail Explosions: Theory, observations and 3D full-particle simulations

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Magnetotails accumulate energy of the solar wind-magnetosphere interaction and then explosively release it. The most plausible mechanism of explosions is reconnection of magnetic field lines that are almost antiparallel in the tails. However, tail configurations, which have a potential for spontaneous reconnection, also facilitate interchange motions of sharply curved flux tubes. The magnetic tension in those tubes creates an effective gravity force, and a Rayleigh-Taylor-type instability becomes possible when sufficient magnetic flux is accumulated in the tail. Multi-spacecraft observations of Earth's magnetotail show signatures of both reconnection and interchange motions. They also reveal strong north-south oscillations of the tail plasma sheet making it similar to a flapping flag, with an important and puzzling distinction from the latter in that the magnetotail flapping waves propagate almost normal to the Sun-Earth direction. Understanding roles of these different plasma motions in magnetotail explosions requires three-dimensional plasma simulations taking into account kinetic effects of particle motion. Simulations show, that hat sufficiently far from the planet explosive processes in the tail are dominated by reconnection motions. These motions occur in the form of spontaneously generated dipolarization fronts accompanied by changes in magnetic topology which extend in the dawn-dusk direction over the size of the simulation box, suggesting that reconnection onset causes a macro-scale reconfiguration of the real magnetotail. Buoyancy and flapping motions significantly disturb the primary dipolarization front but neither destroy it nor change the near-2D picture of the front evolution critically. Consistent with recent multi-probe observations, dipolarization fronts are also found to be the main regions of energy conversion in the magnetotail.

The Impacts ULF Waves on the Dynamics of the Earth's Van Allen Belts

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We review the impacts ultra-low frequency (ULF) wave power on the dynamics of ultra-relativistic electrons in the Van Allen belts. We place emphasis on the significance of using properly characterised time-series of ULF waves for properly estimating their impacts for both acceleration and loss. Specifically we compare results derived from observed wave power with those from more standard approaches using statistical characterisations based on geomagnetic indices such as Kp, revealing the importance of properly characterising the waves through the course of the main and recovery phases of geomagnetic storm-time Van Allen radiation belt dynamics. We find using the observed ULF wave power presents a remarkable explanation for the overall dynamics of the belts in terms of the impacts of inward and outward radial diffusion in association with plasmasheet sources and magnetopause shadowing. At ultra-relativistic energies the resulting dynamics demonstrate a remarkable simplicity which is controlled by the ULF wave power. Especially at ultra-relativistic energies, ULF wave power can explain all of the morphologies of the Van Allen belts at in the form of either one, two or three belts.

Poster Session – P1/P2 (Poster abstracts are on separate download)

Featuring Plenary Sessions 2a, 2b, and Hinode/IRIS Splinter Sessions

Splinter Session S-1 (4b). *Heliophysics and Space Weather in the Coming Decade*

Living With a Star: Science That Matters to People – Past Accomplishments and Future Promise

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A hundred years ago, the sun-Earth connection (the field of LWS research and space weather impacts) was of interest to only a small number of scientists. Solar activity had little effect on daily life. Today, a single strong solar flare could bring civilization to its knees. Modern society has come to depend on technologies sensitive to solar radiation and geomagnetic storms. Particularly vulnerable are intercontinental power grids, interplanetary robotic and human exploration, satellite operations and communications, and GPS navigation. These technologies are woven into the fabric of daily life, from health care and finance to basic utilities. Both short- and long-term forecasting models are urgently needed to mitigate the effects of solar storms and to anticipate their collective impact on aviation, astronaut safety, terrestrial climate and others. Even during a relatively weak solar maximum, the potential consequences that such events can have on society are too important to ignore. The challenges associated with space weather affect all developed and developing countries. Work on space weather specification, modeling, and forecasting has great societal benefit: It is basic research with a high public purpose and the stated goal of LWS is to achieve the Sun-Earth, Sun-Planet system understanding. LWS science through the Targeted Research &Technology program tackles large-scale problems that cross discipline and technique (data analysis, theory, modeling, etc.) boundaries and identifies how the new understanding will have a direct impact on life and society. In this talk I will summarize some of the key accomplishments of this program and discuss the future possibilities.

The Solar Probe Plus Mission and our Understanding of the Solar Wind and Heliosphere

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Solar Probe Plus (SPP), one of the most challenging missions to understand the origins of the Heliosphere, will carry a payload consisting of plasma and energetic particle detectors, electromagnetic field antennas and magnetometers, and a white light imager, to the unexplored regions extending from 70 to less than 9 solar radii (0.3 to 0.05 AU) from the photosphere of the Sun. Solar Probe Plus's goals are to understand the extended heating of the solar corona and acceleration of the solar wind, the origins of solar wind structures including high and low speed streams, and the origins of energetic particle acceleration in Coronal Mass Ejections and CMEs. In addition, combined measurements from the white light imager and the EM field antennas will allow the first direct measurements of dust deep in the inner solar system. This presentation will provide a broad context for the mission objectives and measurements and illustrate the likely progress SPP will bring to the understanding of the Heliosphere, stellar winds, and the fundamental physics of particle acceleration, reconnection, collisionless shocks and turbulence in space and astrophysical plasmas.

Geoscience Current and Future Space Weather Plans

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Space weather is the state of the plasma, radiation, and magnetic environment in space driven by changes originating at the Sun and carried through interplanetary space by the solar wind. Space weather can cause large variations in Earth's upper atmosphere and ionosphere, and in Earth's radiation belts, and can prevent the reliable operation of technologies in space as well as on the ground. *With the launch of the Van Allen Probes in August 2012, Geoscience gained another important mission to help predict space weather impacts. The Van Allen Probes have a near real time space weather broadcast picked up by ground stations around the world. Other upcoming NASA missions will add to the observations: the Magnetospheric Multicale Mission (MMS) launching in 2015 and the Ionosperic Connection Explorer (ICON) and* Global-scale Observations of the Limb and Disk (GOLD) mission*, launching in 2017/18.* Today the Community Coordinated Modeling Center (CCMC) supports over 20 space weather models. These are the latest, most robust models enabling space weather prediction, and are used by NOAA's Space Weather Prediction Center (SWPC), the U.S. official source for space weather forecasts. This paper will highlight the observations and models currently in use, and discuss possibilities for the future.

How the Statistical Analysis of Magnetic Structures Will Help Us Usher a New Generation of Solar Cycle Predictions

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Due to its clear modulation of solar activity, the solar cycle is the main driver behind changes in the heliospheric environment, and the Earth's magnetosphere and atmosphere. For this reason, long-term prediction of activity levels has been one of the main practical goals of solar physics. During the last three solar cycles, there have been many attempts to predict the amplitude of the solar cycle with different degrees of success. One of the clear lessons, learned from the last round of cycle amplitude predictions, is the confirmation that the polar magnetic fields are the best cycle amplitude precursor (once solar minimum has been reached). With this in mind, it is clear that the scope of solar cycle predictions has to expand beyond simply predicting amplitude, in order to improve their timeliness, usefulness, and accuracy.

Ultimately, both the causal propagation of the solar cycle, and the modulation of solar activity and heliospheric conditions, are tied to the emergence and decay of bipolar magnetic regions (BMRs) on the photosphere. For this reason, it is necessary to gain an intimate understanding of their properties and how are they connected to the evolution of the cycle itself. Here we show the results of analyzing data taken by 10 different observatories, discuss what they teach us about the systematic evolution of BMR tilt and flux, and demonstrate how this can be used to improve solar cycle prediction.

Challenges in Modeling of Extreme Space Weather Events

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Extreme space weather events are known to cause adverse impacts on critical modern day technological infrastructure such as high-voltage electric power transmission grids. First principles physics-based 3-D global MHD models play a major role in simulating the large-scale dynamics of magnetospheric systems and represent a very important component of attempts to understand the response of the magnetosphere-ionosphere system to varying solar wind conditions. Understanding of coupled magnetosphere-ionosphere dynamics during extreme solar wind driving is still a major challenge mainly because of a lack of data during time intervals when the magnetosphere is being strongly driven. In this presentation, we will highlight some of the on-going efforts to model extreme space weather events. Additionally, we will present results from current research efforts and discuss the major challenges encountered during these studies. Furthermore, we show how complete or good quality solar wind measurements from NASA's STEREO mission can complement current modeling efforts and provide vital information for the study on the Earth's response to extreme space weather.

Splinter Session S-2 (1a). *Magnetic Energy and Field from Solar Interior to Corona*

Hi-C Observations of Penumbral Bright Dots: Comparison with the IRIS Results

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We observed bright dots (BDs) in a sunspot penumbra by using data acquired by the High Resolution Coronal Imager (Hi-C). The sizes of these BDs are on the order of 1 arcsecond (1") and are therefore hard to identify using the Atmospheric Imaging Assembly's (AIA) 0.6" per pixel resolution. These BDs become readily apparent with Hi-C's 0.1" per pixel resolution. Tian et al. (2014) found penumbral BDs in the transition region (TR) by using the Interface Region Imaging Spectrograph (IRIS). However, only a few of their dots could be associated with any enhanced brightness in AIA channels. In this work, we examine the characteristics of the penumbral BDs observed by Hi-C in a sunspot penumbra, including their sizes, lifetimes, speeds, and intensity. There are fewer Hi-C BDs in the penumbra than seen by IRIS, though different sunspots were studied and Hi-C had a short observation time. We use 193 A Hi-C data from July 11, 2012 which observed from ~18:52:00 UT--18:56:00 UT and supplement it with data from AIA's 193 A passband to see the complete lifetime of the dots that were born before and/or lasted longer than Hi-C's 5-minute observation period. We use additional AIA passbands and compare the light curves of the BDs at different temperatures to test whether the Hi-C BDs are TR BDs. We find that most Hi-C BDs show clear movement, and of those that do, they move in a radial direction, toward or away from the sunspot umbra, sometimes doing both. BDs interact with other BDs, combining to fade away or brighten. The BDs that do not interact with other BDs tend to move less and last longer. We examine the properties of the Hi-C BDs and compare them with the IRIS BDs. Our BDs are similar to the exceptional values of the IRIS BDs: they move slower on average and their sizes and lifetimes are on the higher end of the distribution of IRIS BDs. We infer that our penumbral BDs are some of the larger BDs observed by IRIS.

Modeling of the Coronal Magnetic Field and Plasma Heating: New frontiers in the SDO epoch

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Data provided by AIA and HMI instruments onboard the Solar Dynamics Observatory can be used for the comprehensive modeling and assessment of important properties of the solar corona above active regions to provide insight into how magnetic energy is stored and released to produce both flares and quiescent emissions.

In our field modeling, coronal loops observed by AIA in the extreme ultraviolet are used combined with HMI magnetograms to shape the non-potential magnetic field. The resulting model field is demonstrated to reproduce key features of the field of the specific active region modeled, such as the shape of the field bundles, the presence of twisted field in the region's core, and the free magnetic energy that suffices to power the explosive event observed in this region around the time of the modeling effort.

We proceed to test concepts for coronal heating by modeling the emission over the active region and comparing these to observations made in AIA's coronal channels. We use the non-potential model field as foundation for the emission modeling. We avoid simplifications that have had to be made in earlier work, and discuss how such simplifications influence the appearance of the model corona. In our search for the parameters ruling the coronal heating mechanisms, we make no prior assumptions about the shapes of flux tubes, their expansion, the field strength along them, or the shape of their cross-section, but take these from the model magnetic field. We discuss which of the existing heating models best fit the observations.

Transition-Region/Coronal Signatures of Penumbral Microjets: Hi-C, SDO/AIA and Hinode (SOT/FG) Observations

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Penumbral microjets are bright, transient features seen in the chromosphere of sunspot penumbrae. Katsuaka et al. (2007) noted their ubiquity and characterized them using the Ca II H-line filter on Hinode's Solar Optical Telescope (SOT). The jets are 1000--4000 km in length, 300--400 km in width, and last less than one minute. It was proposed that these penumbral microjets could contribute to the transition-region and coronal heating above sunspots. We examine whether these microjets appear in the transition-region (TR) and/or corona or produce brightenings there.

The chosen sunspot is one observed by Hi-C on July 11, 2012 at ~-145",-300". First, we identify penumbral microjets with the SOT's Ca II H-line filter. We then examine the sunspot in the same field of view and at the same time (from ~ 18:50:00 UT to 20:00:00 UT) in other wavelengths. We use the High Resolution Coronal Imager Telescope (Hi-C) at 193Å and the 1600Å, 304Å, 171Å, 193Å, and 94Å passbands of the Atmospheric Imaging Assembly (AIA) on board the Solar Dynamics Observatory (SDO). We find many Ca II jets and examine whether they have any discernible signature in the other passbands, but find none, except for a few exceptionally strong jets that have longer lifetimes and bigger sizes and occur at only a few locations in the penumbra. We conclude that the normal (smaller) microjets are not heated to transition-region/coronal temperatures, but the larger jets are.

NuSTAR's First Solar Observations: Search for a high energy X-ray component to the "non-flaring" Sun

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We present spectroscopy of the Sun with the NuSTAR hard X-ray (HXR) telescope, searching for high temperature and non-thermal emission in the "non-flaring" Sun. A substantial amount of flare energy goes into accelerating electrons. HXR observations are a crucial tool for understanding this non-thermal emission and the energy release in flares. RHESSI is able to study this emission over many orders of magnitude (active region flares from X-class to A-class microflares), but it cannot detect the emission from smaller events. Such "nanoflares" have been postulated as a possible source of coronal heating and their existence and relationship to larger flares is still uncertain. In order to detect these events in HXRs, instruments more sensitive than RHESSI are required. Launched in 2012, the astrophysics mission NuSTAR uses focusing optics to directly image X-rays between ~2-80 keV. Although not optimized for solar observations, NuSTAR's highly sensitive imaging spectroscopy will be used to search for the faintest X-ray emission from the Sun. These solar observations will begin in September 2014. Here we present the first results of our search for transient brightenings in active and quiet Sun regions with NuSTAR.

A Revolution in DEM Analysis with Application to Nanoflare Heating

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Differential emission measure analysis is a technique commonly used with instruments that observe multiple spectral bands (e.g., SDO/AIA, Hinode/XRT and EIS) to solve for the temperature and emission measure of multithermal, optically thin coronal plasma along a line of sight. However, the inversion is ill-posed and frequently under-determined. Until now, all DEM methods have only attempted to solve single solution shapes (albeit with Monte Carlo sampling of the uncertainties sometimes) that reasonably satisfy constraints of positivity, regularization, fit to the data, and/or speed of calculation. A novel method is presented for the under-determined problem that identifies all of the global best-fit, positive solutions at a useful speed. We apply the method to investigate nanoflare heating to illustrate the range of high-temperature emission measure slopes that are compatible with the data.

Deciphering Solar Magnetic Activity: On the Relationship Between the Sunspot Cycle and the Evolution of Small Magnetic Features

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Sunspots are a canonical marker of the Sun's internal magnetic field which flips polarity every 22 years. The principal variation of sunspots, an ~11-year variation in number, modulates the amount of magnetic field that pierces the solar surface and drives significant variations in our Star's radiative, particulate and eruptive output over that period. This paper presents observations from the Solar and Heliospheric Observatory and Solar Dynamics Observatory indicating that the 11-year sunspot variation is intrinsically tied to the spatio-temporal overlap of the activity bands belonging to the 22-year magnetic activity cycle. Using a systematic analysis of ubiquitous coronal brightpoints, and the magnetic scale on which they appear to form, we show that the landmarks of sunspot cycle 23 can be explained by considering the evolution and interaction of the overlapping activity bands of the longer scale variability.

Splinter Session S-3 (2b). *From the Sun to Earth: Turbulence and wave-particle interactions at the Sun, at the Earth, and in the solar wind*

White-Light Emission and Related Particle Acceleration Phenomena – Conditions that Enhance White-Light Emission in Solar Flares

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"White-light (WL) flares" occur in association with strong solar flares like the Carrington event. It is thought that WL emission is related to strong particle acceleration, which might be connected to CMEs and SEPs as the original source. However, these relationships have not been studied well due to the small number and difficulty of obtaining WL observations. Moreover, there is still a problem concerning how the energy of non-thermal electrons (the origin of WL emission) propagates and produces WL emission.

To understand the conditions that produce enhancements of WL in solar flares, we performed a statistical analysis of the Hinode/SOT WL data. We found data for more than 30 flare events that were observed with

Hinode/SOT and RHESSI among all the X- and M-class flares that have occurred since 2011. Less than the half of the events have WL emission, and more than half don't have any WL emission in the SOT FOV. We compared several parameters of these two groups, and found that the precipitation of large amounts of accelerated electrons into a compact area within a short time plays a key role in generating a WL event.

The Hinode satellite also can observe the chromospheric response seen in EUV observations. During the X1.8-class flare on 2012 October 23, Hinode/EIS was scanning over the flaring active region, and observed strong red and blue shifts over the WL kernel. Using these data we also found that density changes in the chromosphere play a key role in producing WL emission.

Investigating Prominence Turbulence with Hinode SOT Dopplergrams

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The motions of plasma in quiescent prominences, as revealed by Hinode observations, display highly complex flows across a wide range of spatial and temporal scales. Using H-α dopplergrams from Hinode SOT, we investigate the spatial and temporal fluctuations of the line-of-sight velocity of a prominence observed on 2008-09-29 to determine its turbulent characteristics. Analysis of the velocity increments reveals hints of both the Kolmogorov ($r^{2/3}$) and the Kraichnan-Iroshinikov ($r^{1/2}$) scaling for magnetohydrodynamic turbulence. The results from this analysis will be of great importance for determining the spatial and temporal scales over which energy is injected into the prominence, transported through the prominence and dissipated in the prominence.

Ion Kinetics in the Solar Wind Generation Region

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The fast solar wind is generated in coronal holes by strong ion heating perpendicular to the large-scale magnetic field. The solar wind flow away from the Sun then results primarily from the mirror force acting on these anisotropic ion distributions in the decreasing coronal hole magnetic field. Solar wind behavior cannot be reliably modeled until the responsible heating mechanism is identified and understood. Fluid models do not provide sufficiently detailed information, so kinetic treatments are required. We have been investigating the radial evolution of the proton and minor ion distributions in a solar coronal hole by numerically solving the collisionless kinetic guiding-center equation including the large-scale forces due to gravity, charge-separation electric field, Alfvén wave pressure, and mirroring of the particles. We also include the kinetic scattering due to the resonant cyclotron wave-particle interaction, which will efficiently organize the ion distributions whenever velocity-space gradients appear along the quasilinear resonant surfaces. Turbulent heating and the large-scale forces will continually create these gradients, and the distributions evolve under the combination of these processes. We find that the resulting proton distributions become asymmetric along the radial direction, with different characteristic features in the sunward and anti-sunward portions of the distribution in the plasma frame. We will present results of these calculations and discuss further implications of this kinetic picture.

Kinetic Scale Turbulence in the Solar Wind: A review of current challenges

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The solar wind has been observed to be a turbulent plasma for many decades. It provides a unique environment in which spacecraft can directly measure the turbulent fluctuations at the small scales on which the turbulence is dissipated, providing the detail necessary to identify the nature of these small-scale fluctuations, information critical for unraveling the physical mechanisms by which the turbulence is dissipated. The underlying question of the nature of the fluctuations is still under debate. Indeed, the steepening of the observed power spectra, although originally attributed to ion cyclotron damping, is now believed to be due to the dispersive nature of the fluctuations, with two leading interpretations in terms of Kinetic Alfven Wave Turbulence and/or Whistler Wave Turbulence. Several recent studies have focused on developing various tests to distinguish between both wave modes. Other possible contributions to the spectrum at these scales include current sheets and/or kinetic instabilities, although their effect remains to be fully investigated.

We present here a review of the recent ground-breaking observations in the dissipation range of solar wind turbulence. We discuss the different available interpretations and their impact on the heating of the solar wind plasma. We will also discuss the recent "Turbulent Dissipation Challenge", a community driven effort to address these issues via coordinated numerical simulations, in close connection to observations.

Simultaneous ULF Waves, Whistler-mode Chorus and Pulsating Aurora Observed by the Van Allen Probes and Ground-based Imagers

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Theory and observations have linked equatorial VLF waves with pulsating aurora for decades, invoking the process of pitch-angle scattering of 10's keV electrons in the equatorial magnetosphere. Recent satellite studies have strengthened this argument, by showing strong correlation between pulsating auroral patches and (1) lower-band chorus observed by THEMIS and (2) 30-100 keV electron precipitation in the vicinity of geosynchronous orbit observed by GOES. Additionally, a link has been made between Pc4-5 compressional pulsations and modulation of whistler-mode chorus using THEMIS. Here we present simultaneous in-situ observations of structured chorus waves and an apparent poloidal field line resonance, from Van Allen Probes, along with ground-based observations of pulsating aurora. We demonstrate the possible scenario being one of ULF pulsations modulating chorus waves, and thus providing the driver for pulsating particle precipitation into the Earth's atmosphere. We also show, for the first time, a particular 3-Hz modulation of individual chorus elements concurrent with pulsating aurora. Such modulation has been noticed in camera data of pulsating aurora for decades.

Splinter Session S-4 (4b). *Space Weather Impacts using HSO Measurements (focus on observations)*

NOAA Space Weather Operations: Current operational models and future needs for space weather modeling

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The NOAA Space Weather Prediction Center has the mission of helping to protect society from the impacts of space weather on technological systems. This involves both specification and forecasting of a number of environmental parameters and span the space from Sun to Earth. The timescales of interest cover the full range from seconds to decades. In this presentation, we will review the specification and forecast models currently in operations. We will discuss the models that are under development and in prototype or test-mode at SWPC. And finally, we will highlight some of the current un-met customer needs and how these translate into modeling challenges that operational space weather forecasting presents to the research community.

The Discriminant Analysis Flare Forecasting System ("DAFFS")

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Forecasting solar flares is a challenge from various scientific perspectives; major solar flares are inherently rare events, and all observations available with which to evaluate the flare-readiness of the Sun are remote, with inferences about the physical state rather than direct measurements. We report on the efforts to improve flare forecasts, using data from the Helioseismic and Magnetic Imager on the Solar Dynamics Observatory to characterize the photospheric vector magnetic field, the sub-surface helioseismic activity, and

the coronal magnetic connectivity. We employ Discriminant Analysis as the statistical method by which historical data are evaluated and new forecasts are produced. The performance of the Discriminant Analysis Flare Forecasting System ("DAFFS") is evaluated against that of the NOAA Space Weather Prediction Center using standard skill scores.

This work is supported by NASA/LWS and the NOAA SBIR program.

Testing the Reliability of Far-side Active Region Predictions from Helioseismology using STEREO Far-side

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We test the reliability of helioseismic far-side active region predictions, made using Dopplergrams from both the Helioseismic and Magnetic Imager (HMI) aboard the Solar Dynamics Observatory (SDO) and the Global Oscillation Network Group (GONG), by comparison with far-side observation of solar activity from the Solar TERrestrial Relations Observatory (STEREO). Both GONG and HMI produce seismic Carrington maps showing strong magnetic field regions, labeling predictions of far-side active regions that have a probability ≥ 70%. By visual comparison of these prediction maps with STEREO extreme ultraviolet (EUV) Carrington maps, we determine whether or not solar activity, as evidenced as brightness in EUV, is observed at the predicted locations. We analyzed 9 months of data from 2011 and 2012. For both GONG and HMI, we find that for approximately 90% of the active region predictions, activity/brightness is observed in EUV at the predicted location. We also investigated the success of GONG and HMI at predicting large active regions before they appear at the east limb as viewed from Earth. Of the 27 identified large east-limb active regions in the 9 months of data analyzed, GONG predicted 15 (55%) at least once within the week prior to Earth-side appearance and HMI predicted 13 (48%). Based on the STEREO far-side EUV observations, we suggest that 9 of the 27 active regions were probably too weak to be predicted while on the far side. Overall, we conclude that HMI and GONG have comparable reliability using the current data processing procedures.

Global MHD Simulation of the Coronal Mass Ejection on 2011 March 7: From Chromosphere to 1 AU

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Performing realistic simulations of solar eruptions and validating those simulations with observations are important goals in order to achieve accurate space weather forecasts. Here, we perform a global MHD simulation of the fast CME that occurred on 2011 March 7. The simulation is made using the newly developed Alfven Wave Solar Model (AWSoM) in Space Weather Modeling Framework (SWMF), which describes the background solar wind starting from the upper chromosphere to 1 AU. Physical processes included in the model are multi-species thermodynamics, electron heat conduction (both collisional and collisionless formulations), optically thin radiative cooling, and Alfven-wave pressure that accelerates the solar wind. The Alfven-wave description is physically consistent, including non-WKB reflection and physics-based apportioning of turbulent dissipative heating to both electrons and protons. We initiate the CME by using the Gibson-Low analytical flux rope model and follow its evolution for days, in which time it propagates beyond 1 AU. A comprehensive validation study is performed using observations from SDO, SOHO, STEREOA/B, and OMNI. Our results show that the new model can reproduce many of the observed features near the Sun (e.g., CME-driven EUV waves, deflection of the flux rope from the coronal hole, “double-front” in the white light images) and in the heliosphere (e.g., CME-CIR interaction, shock properties at 1 AU). The CME-driven shock arrival time is within 1 hour of the observed arrival time, and nearly all the in-situ parameters are correctly simulated, which suggests the global MHD model as a powerful tool for the space weather forecasting.

Forecasting the Impact of Equinoctial High-Speed Stream Structures on Thermospheric Responses and an Extension to Solstitial Events

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We examine thermospheric neutral density response to 172 solar wind high-speed streams (HSSs) and the associated stream interfaces during the equinox seasons of 2002-2008. We find responses to two drivers: 1) the equinoctial Russell-McPherron (R-M) effect, which allows the azimuthal component of the interplanetary magnetic field (IMF) to project onto Earth's vertical dipole component; and 2) coronal streamer structures, extensions of the Sun's meso-scale magnetic field into space. Events for which the IMF projection is antiparallel to the dipole field are classified as "Effective-E"; otherwise they are "Ineffective-I". Effective orientations enhance energy deposition and subsequently thermospheric density variations. The IMF polarities preceding and following stream interfaces at Earth produce events that are: Effective-Effective-EE; Ineffective-Ineffective-II; Ineffective-Effective-IE; and Effective-Ineffective-EI. These categories are additionally organized according to their coronal source structure: helmet streamers (HS-EI and HS-IE) and pseudo-streamers (PS-EE and PS-II). The response to HS-IE structures is smoothly varying and long-lived, while the response to PS-EE structures is erratic, short-lived, and modulated by thermospheric preconditioning. We find significant distinguishable responses to these drivers in four geomagnetically sensitive observations: low-energy particle precipitation, proxied Joule heating, nitric oxide flux, and neutral density. Distinct signatures exist in neutral density response that can be anticipated days in advance based on knowledge of on-disk coronal holes. Further, we show that the HS-IE events produce the largest neutral density disturbances.

We extend this work to include 66 solstitial HSSs during 2002-2008. Though the R-M effect no longer dictates response, we find distinct signatures according to coronal streamer structure categorization.

Splinter Session S-5. *Hinode/IRIS: Flares (outside the context of CMEs)*

Probing Energy Release & Transport in Flares – New insights from IRIS and EIS

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While there is broad agreement that the primary energy release site in flares in solar flares is situated in the corona, there remain many open questions relating to the coupling between different atmospheric regimes and the mechanisms by which the flare energy is transported, including the relative roles of non-thermal particles and kinetic and MHD perturbations. On 29 March 2014 an unprecedented number of different solar instruments, including IRIS and EIS, simultaneously observed an X-class flare, presenting us with a unique opportunity to probe the mechanisms of energy transport from the corona to the lower atmosphere in this event. We focus in particular on the new spectroscopic information from IRIS and EIS and its interpretation in the context of existing models for flare energy transport.

Testing the Standard Flare Model with Hinode/EIS, RHESSI, and SDO/AIA Data

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Hinode/EIS and RHESSI observed an M3.5 flare on 25 September 2011. At the time of the X-ray burst recorded by RHESSI at energies between 3 and ~100 keV, EIS was scanning the footpoint regions of the flare and detected the dynamics of the footpoint regions in spectral lines of O VI, Fe X, Fe XII, Fe XIV, Fe XV, Fe XVI, Fe XXIII and Fe XXIV. Large evaporation outflows in Fe XXIII and Fe XXIV on the order of several hundred km/s were measured, as well as outflows and downflows in the cooler lines. Thermal electron

densities are determined from the intensity ratio of two Fe XIV lines. The EIS slit is spatially coincident with strong emission in the RHESSI hard X-ray images. The RHESSI X-ray spectra provide measures of the energy in the hot thermal plasma at ~20 MK and the total energy in the nonthermal electrons generating the hard X-rays. In addition, there was a spectacular surge-like event associated with the flare that is well observed by SDO/AIA. By a fortunate coincidence EIS continued its raster scan spatially over the surge region as it was occurring and therefore temperatures and dynamical properties of the surge plasma have been determined from the EIS spectra. The flare temperatures, densities, and dynamics resulting from an electron beam interacting in the chromosphere thick target are modeled using the 1D HYDRAD code. Results from the flare, surge, and modeling are given in this paper. This work is supported by a NASA Hinode grant.

First High-resolution Spectroscopic Observations by IRIS of a Fast Prominence Eruption Associated with a CME on 2014-May-09

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Spectroscopic observations of prominence eruptions and associated coronal mass ejections (CMEs) are rare but can provide valuable plasma and energy diagnostics. We report the first result of such joint IRIS-Hinode observations of a spectacular prominence eruption occurring on 2014-May-09. IRIS detected a maximum redshift of 450 km/s, which, combined with the plane-of-sky speed of 800 km/s, gives a large velocity vector of 920 km/s at 30-deg from the sky plane. This direction agrees with the source location at 30-deg behind the limb indicated by STEREO-A. There are two branches of redshifts separated by 200 km/s appearing in all strong lines including Mg II k/h, C II, and Si IV, indicating a hollow, rather than solid, cone in the velocity space of ejected material. Opposite blue- and redshifts on the two sides of the prominence exhibit corkscrew variations both in space and time, suggestive of unwinding rotation of a left-handed helical flux rope. Some erupted material returns as nearly streamline flows, exhibiting distinctly narrow line widths (~10 km/s), about 50% of those of the nearby coronal rain at the apexes of coronal loops where the rain material is initially formed out of cooling condensation. We estimate the mass and kinetic energy of the ejected and returning material and compare them with those of the associated CME. We will discuss the implications of these observations for CME initiation mechanisms.

IRIS Observations of Solar Flares in Comparison with Hybrid Particle and Radiative Transfer Hydrodynamic Simulations

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We have recently developed a hybrid model that combines the Fokker-Planck Flare code (Petrosian et al. 2001; Petrosian & Liu 2004) with the RADYN radiative hydrodynamic code (Carlsson et al. 1992, 1996; Allred et al. 2005). This allows a self-consistent simulation of intimately coupled physical processes including particle acceleration and transport and the atmospheric response to energy deposition. Among flares well-observed by IRIS, we selected the 18 April 2014 M7.3 flare to perform data-driven simulations. One of the interesting features found is the blueshift at the cool O I line (logT=3.8) in contrast with redshifts at warmer lines, Mg II k/h (logT= 4.0), C II (logT= 4.3), and Si V (logT= 4.8), which is not expected in the standard picture of chromospheric evaporation. We use simultaneous RHESSI hard X-ray observations to constrain model parameters for the Fokker-Planck code, allowing us to model the multi-wavelength emission of the flare in a realistic manner and to compare it directly with IRIS observations. We discuss the implications of such comparisons for flare dynamics in the lower atmosphere and particle acceleration mechanisms.

IRIS Observations of Magnetic Reconnection and Chromospheric Evaporation in a Solar Flare

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NASA's IRIS mission has observed signatures of the Fe XXI 1354 line in tens of solar flares. In many of them, large blue shifts were identified, supporting the scenario of chromospheric evaporation in postflare loops. In the standard CSHKP flare model, the postflare loops are a natural consequence of magnetic reconnection occurring at the flare site. The CSHKP model also predicts downflow (and upflow) plasma having a speed close to the Alfven speed. Yet, to date
there were no observations of fast moving downflow plasma in flares. Here, we report the first detection of large red shift (~200 km/s along line of sight) of the Fe XXI line with IRIS. Combined imaging and spectroscopic observations of IRIS, together with SDO/AIA and RHESSI observations, reveal that the redshifted Fe XXI feature co-located with the loop-top hard X-Ray source and above the retracting loops. We interpret this large redshift as signature of downward moving reconnection outflow/retracting loops. Possible flux rope eruption and reconnection inflows are also observed. Furthermore, we found that the entire Fe XXI line is blueshifted by ~250 km/s at the loop footpoints. Cool lines of Si IV, O IV, C II and Mg II all show obvious redshift at the same locations, consistent with the scenario of chromospheric evaporation. The map of electron temperature reconstructed from SDO/AIA observations shows that the locations of ~10MK temperature generally coincide with the observed Fe XXI feature very well. Hard X-rays up to ~100keV were found from RHESSI observations, indicating an efficient electron acceleration process in this event.

IRIS Observations of Plasma Heating and Dynamics in a Well-Observed M-Class Flare

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On 2014 February 13, IRIS observed an M1.8 flare with FUV and NUV spectrograph raster scans repeated every 43 seconds. The flare was also well covered with IRIS slit-jaw imagery, AIA imagery, and RHESSI imaging spectroscopy. Of particular interest are the dynamics and plasma characteristics of the flare footpoints, the flare loops, and the partially erupting filament, and how they relate to the sites of magnetic reconnection and particle acceleration. An initial analysis shows high (10^{13} cm^{-3}) density downward moving 10^5 K plasma near a HXR footpoints, upward moving 10^7 K plasma originating near the same location, and high rotational velocities in the partially erupting and untwisting filament above the hot flare loops.

Tuesday, Nov. 4

Splinter Session S-6 (2a). *Onset and Coronal Evolution of CMEs*

On the Initiation of Coronal Mass Ejections, Their Evolution, and Propagation into the Heliosphere: Recent progress and outstanding questions

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With the combination of remote and in situ observations from SDO, STEREO, SOHO, and ACE, we now observe with unprecedented detail almost every aspect of CME initiation and evolution: from the magnetic topology and configuration of the CME source region, to plasma and temperature structure of the prominence and cavity system, to the dynamics of the eruptive flare ribbons and arcade loops during impulsive rapid energy release and gradual post-flare relaxation phases of the eruption, through the CME/ICME coronal and heliospheric propagation, and finally to the direct measurement of the ICME magnetic field and plasma signatures at 1 AU. We are truly entering a period of comprehensive Sun-to-Earth System science that requires an integrated modeling, data analysis, and numerical simulation approach. We will discuss recent advances in the MHD modeling of CME initiation and our efforts to relate these to observational signatures as well as utilizing insight gained from simulation results to help interpret and simplify complex eruption scenarios.

Observational Signatures of CME Initiation and Eruption: Does Flux Rope Exist Prior to the Eruption?

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We present detailed observational studies of two contrasting eruptive events, one resulting in a CME and the other a failed eruption. We argue that a magnetic flux rope (MFR) has already formed before the eruption. The magnetic flux rope revealed itself as a hot EUV channel (~10 MK) in SDO/AIA 131 A passband. It initially appeared as a sigmoidal structure with two ends rooted in the photosphere, minutes before the onset of the accompanying flare. The hot channel was not visible earlier in time, probably due to its low temperature before it was activated. The rise of the central portion of the sigmoid led to the formation of a semi-circular-shaped flux rope. The flux rope then entered into the impulsive acceleration phase accompanied at the same time by the flare energy release. Similar evolution was observed in the case of failed eruption, except that the impulsive acceleration was quickly quenched by the overlying magnetic field. Morphological, kinematic and thermal evolutions of these events will be presented. The theoretical implications will be discussed.

Measuring Coronal Energy and Helicity Buildup with SDO/HMI

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Solar eruptions are driven by energy and helicity transported through the photosphere and into the corona. However, the mechanism by which energy and helicity emerge from the solar interior to form the observed coronal structures is poorly understood. SDO/HMI data are the first space-based full-disk vector field observations of the Sun with a near 100% duty cycle and, therefore, represent an unprecedented opportunity to quantify the energy end helicity fluxes through the photosphere. However, because of the SDO satellite's highly inclined geostationary orbit, the relative velocity of the instrument varies by ±3~km/s which introduces major orbital artifacts. We have developed a procedure for mitigating these artifacts and have applied this analysis to AR11084 to produce a cleaned data set. Our analysis procedure is described, in detail, and the results for AR11084 presented. We have also recast the Berger and Field (1984) helicity transport equation in manifestly gauge invariant form and derived the terms quantifying the injection of helicity into the corona by the emergence of closed field, versus helicity injection by the stressing of pre-emerged flux. The plasma velocity fields in the photosphere, necessary for computing energy and helicity fluxes are determined using an upgraded version of DAVE4VM that incorporates the spherical geometry of the solar images. We find that the bulk of the helicity into the corona is injected by twisting motions, and we discuss the implications of our results for understanding solar activity and especially for data-driven modeling of solar eruptions.

This work was supported, in part, by NASA.

Flux Ropes: Observations of their evolution prior to eruption

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After years of study there is now strong support that many coronal mass ejections are caused by the eruption of a magnetic flux rope from the solar atmosphere. This talk will look at the formation and evolution of these twisted magnetic field configurations in a selection of active and quiet sun regions, using a range of imaging and spectroscopic techniques. Convergence of opposite polarity magnetic fragments along a polarity inversion line, and their subsequent magnetic reconnection, supports the formation of flux ropes in a manner following the model of van Ballegooijen and Martens (1989). Following this, the observations suggest that flux ropes may evolve their specific magnetic configuration and that they may only be stable on the Sun for a few hours before they erupt as a CME, in line with the latest theoretical and modelling expectations.

Direct Observations of Reconnection Outflow and CME Triggering in a Small Solar Eruption Observed with IRIS, AIA and XRT

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On May 1, 2014 at about 01:35 UT a small prominence eruption occurred at the limb of the Sun. Before the eruption, tendrils of coronal rain forming a dome shape above the prominence are seen in AIA 304 A and the IRIS 1330 A slit jaw imager. The eruption resembles a classic breakout reconnection scenario, but close inspection of the pre-eruption images indicates that tether cutting may also play a role. As the eruption occurs, effects of reconnection between the CME magnetic field and the overlying magnetic field are observed. At the IRIS slit, non-thermal widths of up to 50 km/s are seen in the Si IV 1393 A line, along with large red-shifts indicating line-of-sight velocities up to 200 km/s. Bright material is seen flowing away from the reconnection site in the AIA 171 A images. The plane-of-sky velocity of this plasma is found to be about 300 km/s. Taken together with the IRIS line-of-sight velocities, these measurements give a total speed of approximately 360 km/s, indicating that this plasma is probably due to the reconnection outflow. Temperature measurements derived from the AIA filters show a localized heating at the site of the reconnection, and later observations from XRT show a bright, hot loop extending to the south of the eruption.
This work is supported by under contracts 8100002705 and SP02H1701R from Lockheed-Martin to SAO, contract NNM07AB07C from NASA to SAO and grant number NNX12AI30G from NASA to SAO.

Using Deflections to Constrain the Mass of CMEs: The 12 December 2008 Case

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Decades of observations show that CMEs can deflect from a purely radial trajectory yet no consensus exists as to the cause of these deflections. Observations typically show that the majority of the deflection motion occurs in the corona at distances where the magnetic energy dominates. In Kay et al. (2013) and Kay et al. (2014) we present ForeCAT, a model for CME deflections based on the magnetic forces (magnetic tension and magnetic pressure gradients). Kay et al. (2014) introduced an improved three-dimensional version of ForeCAT. We compare ForeCAT predictions to the observed deflection of the 2008 December 12 CME and find that ForeCAT can accurately reproduce the observations. From the observations, we are able to constrain all of the ForeCAT input parameters except the CME mass and the drag coefficient that affects the CME motion. By minimizing the reduced chi-squared, $\chi 2$, between the ForeCAT results and the observations we can determine the values of these two parameters. Varying the mass between 1e14 and 2e15 g and drag coefficients between 1 and 5 produces $\chi 2$ between 0.90 and 21.4. Restricting $\chi 2 \approx 1$ yields an acceptable mass range between 7.5e14 and 1e15 g and the drag coefficient between 2.7 and 3.2. By comparing ForeCAT results from an artificially scaled magnetic field background, we are able to constrain the rate at which the quiet sun magnetic field falls to be similar to the Potential Field Source Surface model.

Splinter Session S-7 (1b). *Reconnection and Magnetic Instabilities in Geospace and Heliosphere*

Reconnection during CME Propagation and Interaction

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Coronal mass ejections (CMEs) interact with the solar wind, interplanetary magnetic field (IMF) and other CMEs as they propagate in the inner heliosphere. Although white-light imaging provides some insight about the evolution of the CMEs, most information is gained by performing numerical simulations and studying in situ measurements. Here, we present results of recent MHD simulations of the reconnection of a CME with the IMF and with another CME as they propagate as well as some evidence of this type of processes from in situ measurements at 1 AU.

The Role of Interchange Reconnection in CMEs/Eruptive Flares

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Magnetic reconnection in the solar atmosphere is generally accepted to be the underlying driver of most solar explosive phenomena. Therefore, the topology of the coronal magnetic field is central to understanding the onset and development of major eruptions, such as CMEs/eruptive flares, and to determining the resulting space weather. Of particular importance to space weather and to LWS are the impulsive Solar Energetic Particles (SEP) that are associated with eruptive events. These impulsive SEPs are believed to be accelerated by the flare reconnection of the standard eruptive flare model. A long-standing problem, however, is that such particles should remain trapped in the closed corona and the ejected plasmoid; whereas, flare-accelerated particles frequently reach the Earth long before the CME does. We present a model that can account for the injection of flare-accelerated particles onto open magnetic flux tubes connecting to the Earth. This work uses high-resolution 3D MHD numerical simulations performed with the Adaptively Refined MHD Solver (ARMS). Our model is based on the well-known breakout topology, which has a coronal null point and a multi-flux system for the coronal magnetic field. The model includes an isothermal solar wind with open-flux regions. Depending on the location of the open flux with respect to the null point, we find that interchange reconnection between the open flux and the CME flux can have major effects on the development of the eruption. In particular, interchange reconnection can allow energetic particles to escape. We discuss the implications of our work for LWS observations.

Modeling Substorms in the Magnetotail

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We investigate the onset and consequences of reconnection in the magnetotail, related to substorms and bursty plasma flows, and discuss possible applications solar flares. Equilibrium theory demonstrates that modest perturbations of the magnetotail under mass and entropy conservation can cause the formation of thin current sheets and ultimately a loss of equilibrium. Using 2-D PIC simulations we identify the conditions that lead to the onset of collisionless tearing instability under such deformations. The subsequent dynamic evolution is modeled by 3D MHD simulations, showing the growth of reconnection with the formation of flow bursts and collapsing fields. The electric field associated with the collapsing field is the main mechanism of production of energetic particles, accelerating electrons via betatron and Fermi mechanisms, as demonstrated by test particle tracing in the dynamic MHD fields. Energy flow investigations in both PIC and MHD simulations show the relevance of compressibility, enthalpy, and Poynting flux.

EUV and Radio Observations of an Eruptive Magnetic Flux Rope and Fast CME

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Magnetic flux ropes (MFRs) are believed to be at the heart of solar coronal mass ejections (CMEs). However, observational evidence of eruptive, fast-CME-leading filament-MFR systems has been elusive for those originating from active region. Using multi-passband EUV observations from SDO/AIA on 3 March 2012, we present direct evidence of an eruptive MFR in the low corona that exhibits a hot envelope and a cooler core; the latter is likely the upper part of a filament that undergoes a partial eruption, which is later observed in the upper corona as the coiled kernel of a fast, white-light CME. This MFR-like structure exists more than one hour prior to its eruption, and displays successive stages of dynamical evolution, in which both ideal and non-ideal physical processes may be involved. The timing of the MFR kinematics is well correlated with the energy release of the associated long-duration C1.9 flare. We suggest that the long-duration flare is the result of prolonged energy release associated with the vertical current sheet induced by the erupting MFR and fast CME. The Janky Very Large Array (VLA) was used to obtain dynamic imaging spectroscopic observations of the same event from 1-2 GHz with a spatial resolution of approximately 15", a time resolution of 50 ms, and a spectral resolution of 1 MHz. We present VLA observations of radio bursts associated with energy release resulting from the launch of the fast CME.

End-toEnd Modeling of Space Weather Events with the Space Weather Modeling Framework

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The Space Weather Modeling Framework (SWMF) has two validated space weather simulation configurations: the Alfvén Wave Solar Model (AWSOM) and the Magnetosphere with Ring Current and Ionospheric Electrodynamics (MARCIE). MARCIE has recently been selected by NOAA's Space Weather Prediction Center (SWPC) for transitioning to operations.

This talk will describe the basic physics of AWSOM and MARCIE and show validation studies for both model setups. We will also discuss some new scientific results obtained with these models. The talk will conclude with a description of future work and plans for the further developments of SWMF.

Integrating Kinetic Effects in Fluid Models for Magnetic Reconnection

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The integration of kinetic effects in global fluid models is a grand challenge in space plasma physics, and has implication for our ability to model space weather in collisionless plasma environments such as the Earth's magnetosphere. We propose an extensible multi-fluid moment model, with focus on the physics of magnetic reconnection. This model evolves the full Maxwell equations, and simultaneously moments of the Vlasov-Maxwell equation for each species in the plasma. Effects like the Hall effect, the electron inertia, and the pressure gradient are self-consistently embedded in the resulting multi-fluid moment equations, without the need to explicitly solving a generalized Ohm's law. Two limits of the multi-fluid moment model are discussed, namely, the five-moment limit that evolves a scalar pressures for each species, and the ten-moment limit that evolves the full anisotropic, non-gyrotropic pressure tensor. Particularly, the five-moment model reduces to the widely used Hall Magnetohydrodynamics model under the assumptions of vanishing electron inertia, infinite speed of light, and quasi-neutrality. In this presentation, we compare ten-moment and fully kinetic Particle-In-Cell simulations of a large scale Harris sheet reconnection problem, where the ten-moment equations are closed with a local linear collisionless approximation for the heat flux. The ten-moment simulation gives reasonable agreement with the Particle-In-Cell results, regarding the electron flows, the polarities and magnitudes of elements of the electron pressure tensor, and the decomposition of the generalized Ohm's law. Possible ways to improve the simple closure towards a non-local, fully three-dimensional description are also discussed.

Splinter Session S-8 (4a). *Solar Origins of Variability in the Space Environment*

Solar Subsurface Characteristics and Solar Activity

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We study the evolution and properties of the solar magnetic field by investigating the linkage of flows in the upper solar convection zone with magnetic fields in the solar photosphere. We derive solar subsurface flows from GONG and SDO/HMI Dopplergrams using the ring-diagram analysis. We derive photospheric and subphotospheric flows in active regions to validate the subsurface dynamics and plan to extend the analysis to explore precursors of solar activity. Helicity, a measure of topological complexity, plays an important role in a broad range of solar phenomena from the dynamo to flares and coronal mass ejections (CMEs). The kinetic helicity of subsurface flows can be used as a proxy of magnetic/current helicity. Flare-productive active regions are associated with subsurface flows with large values of kinetic helicity density. We will discuss recent results as well as data products that are available now or are under development.

Investigation of Surface Magnetic Flux Transport by use of Hinode/SOT and SDO/HMI

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Magento-convection on the solar surface is thought to play an important role in structuring large-scale magnetic field. One important issue is how magnetic flux is transported there. The transport is treated as a classical diffusion process for long time but the recent observational papers report the different characters from the diffusion. One of the critical properties to understand such large-scale description is square displacement of each patches. In the diffusion case, it is necessarily proportional to the elapsed time. But from the recent studies, the dependence obtained from the observation shows more steep dependence, i.e. super-diffusion scaling.

One problem to extend it to a larger-scale, i.e., global Sun, is the limitation of the observational period. So in this study we extend this kind of the investigations to a larger scale by use of satellite data, Hinode/SOT and SDO/HMI, and auto-tracking technique. It is critical to use longer observational data to see large-scale treatment. We want to note that this kind of study becomes possible because of the accumulation of the satellite data and development of auto-tracking technique which enables us to treat huge amount of the events. As a result of the analysis, we obtain super-diffusion scaling in the range smaller than network field and sub-diffusion scaling in the range larger than it. It can be interpreted as a result from network flow structures. In the presentation, we discuss the effect of these characters to the global-scale flux transport and also show some results from 3D MHD simulation.

Progress in Measuring Coronal Magnetic Fields and Energies

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Magnetic energies contained in solar active regions or dissipated in flares can now be calculated from coronal images (such as from AIA/SDO) and line-of-sight magneto grams (such as from HMI/SDO). The magneto gram provides a potential field solution, while automated tracing of coronal loops in different EUV wavelengths provide the misalignment angles between potential and non-potential field lines. We present an automated code that uses data from AIA and HMI to calculate the free energy and dissipated energy in solar flares, based on a nonlinear force-free field approximation in terms of vertical currents that produce helical twist of coronal loops. We study the time evolution of free energy and energy dissipation during some 200 solar flares and compare it with the global energetics of flare and CME energies. The occurrence frequency distributions of dissipated magnetic energies follow closely the predicted power law distribution functions of self-organized criticality models. The presented results provide for the first time statistics on magnetic energies dissipated in solar flares.

Multi-Instrument Differential Emission Measure (DEM) of the Solar Corona

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Thermal plasma in the solar corona, while often modeled as isothermal, is decidedly multi-thermal, ranging from ~1-2 MK in the quiescent corona to ~30-50 MK in intensely flaring loops. It is difficult to obtain a well-constrained differential emission measure (DEM) from a single instrument, whose wavelength coverage invariably provides sensitivity to only a limited range of plasma temperatures. Recently, we developed a new technique using combined extreme ultraviolet (EUV) and soft and hard X-ray (SXR, HXR) data from the EUV Variability Experiment (EVE) onboard the Solar Dynamics Observatory (SDO) and the Reuven Ramaty High Energy Solar Spectroscopic Imager (RHESSI), respectively, to obtain a self-consistent DEM that is strongly constrained across the full range of coronal plasma temperatures (<2 to 50 MK). An accurate, precise determination of the plasma temperature distribution enables not only studies of plasma heating and thermal plasma evolution, but can also provide strong constraints on the non-thermal accelerated electron population, including the low-energy cutoff which is typically determined only as a loose upper limit.

We adapt this new technique to combine EUV data from EVE with SXR data from the GOES X-ray Sensor (XRS) and the X123 -- a new SXR spectrometer flown on two recent SDO/EVE calibration sounding rockets and scheduled to fly on the Miniature X-ray Solar Spectrometer (MinXSS) NASA CubeSat -- to examine both the coronal DEM and composition during quiescent (non-flaring) times with varying activity levels; the X-ray data provide crucial constraints on the high-temperate extent of the DEM, the elemental abundances, and any potential non-thermal emission. The resultant DEM, with abundances, can also be used to predict the SXR emission in the poorly-observed ~1-5 nm wavelength band, knowledge crucial for understanding solar-driven dynamics in Earth's upper atmosphere (ionosphere, thermosphere, mesosphere). We compare these EVE+X123 results with those from a parallel technique to derive DEMs from imaging data from the Atmospheric Imaging Assembly (AIA) onboard SDO, and we discuss the implications for plasma heating, both during flares and in the quiescent corona. This research is supported by NASA contracts NAS5-98033 and NAS5-02140, and NASA Heliophysics Guest Investigator Grant NNX12AH48G.

Sub-daily EUV Irradiance Variations

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Observations from the Extreme Ultraviolet Variability Experiment (EVE) on the Solar Dynamics Observatory (SDO) have shown that the EUV irradiance varies quasi-periodically on timescales of less than a day (on the order of hours). I will show an overview of the observations and discuss the origin of these variations in relation to regions of enhanced EUV emission and non-flaring active regions.

Variations in the Properties of Solar Energetic Particle Events over Recent Solar Cycles

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We have carried out a survey of Solar Energetic Particle (SEP) events over 2 to 4 solar cycles using data from ACE, STEREO, GOES, SOHO, and other near-Earth spacecraft. The peak-intensity, fluence, spectral slope, and compositional signatures were compared for 72 solar proton events during cycle 24, including all those with >10 protons/cm2-sr-s at either GOES, STEREO-A, or STEREO-B. Compared to the first 5.7 years of cycles 22 and 23 the number of near-Earth GOES-class SEP events in cycle 24 is reduced by ~40%, and the total fluence of >10 MeV protons is lower by a factor of ~4. At >100 MeV the cycle 23 fluence is lower by a factor of >7 compared to cycles 22 and 23, reflecting a significant decrease in the number of very large SEP events during cycle 23. The fluences of heavy ions from He to Fe show even greater reductions in cycle 23. We discuss factors that may have limited the intensity, spectra, and composition of SEPs during cycle 23, including the interplanetary magnetic field and solar wind properties, CME and shock properties, and seed particle densities and abundances.

Splinter Session S-9 (3b). *Energy Flow in the Magnetosphere*

Understanding the Effects of Data-Driven Repetitive Chorus Elements on the Scattering Characteristics of Energetic Radiation Belt Electrons

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Whistler-mode chorus waves have been identified as a key element in driving radiation belt acceleration events, as well as precipitation in the form of relativistic electron microbursts. However, even though these chorus waves are often modeled as a uniform band of continuous low-amplitude, incoherent in quasilinear-theory based numerical simulations, they are in fact observed as a series of discrete, intense, narrowband rising or falling-tone elements. In this study we investigate the effects of this discreteness on the applicability of quasilinear theory to interactions between electrons and parallel propagating chorus waves in a dipole field using test particle simulations. We produce the most realistic description of a chorus element based on observed waves, including the effects of rising frequency, amplitude modulation (or subpackets) and finite amplitude, and run a large number of test particles through a repetitive sequence of such waves, noting the effects of nonlinear interactions versus strictly linear scattering. We present the results of our simulations and discuss the implications of chorus discreteness on the large-scale evolution of various electron populations.

<u>Formation of the "Seed" Population of 1-10 keV Electrons in the Outer Van Allen Radiation Belt by Time Domain electric Field Bursts</u>

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A huge number of different non-linear structures (double layers, electron holes, non-linear whistlers, etc.) have been observed by the electric field experiment on the Van Allen Probes in conjunction with relativistic electron acceleration in the Earth's outer radiation belt. These structures, found as short duration (~0.1 msec) quasi-periodic bursts of electric field in the high time resolution electric field waveform, have been called Time Domain Structures (TDS). They can quite effectively interact with radiation belt electrons. Due to the trapping of electrons into these non-linear structures, they are accelerated up to ~10 keV and their pitch angles are changed, especially for low energies (∼1 keV). Large amplitude electric field perturbations cause non-linear resonant trapping of electrons into the effective potential of the TDS and these electrons are then accelerated in the non-homogeneous magnetic field. These locally accelerated electrons create the "seed population" of several keV electrons that can be accelerated by coherent, large amplitude, upper band whistler waves to MeV energies in this two step acceleration process. All the elements of this chain acceleration mechanism have been observed by the Van Allen Probes.

<u>Nonlinear Electric Field Structures at Plasma Boundaries in the Inner Magnetosphere</u>

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Van Allen Probes observations demonstrate that kinetic-scale nonlinear electric field structures, including double layers and phase space holes, are frequently observed in the inner magnetosphere (< 6 Earth radii) over a range of radial distances and magnetic local times. These structures are often observed in association with earthward plasma flows or when the Van Allen Probes spacecraft encounter the earthward edge of the plasma sheet boundary layer. In both cases, large scale plasma flows within the terrestrial magnetosphere result in sharp boundaries between plasmas with disparate properties (e.g. temperature, density). Because kinetic-scale electric field structures can be formed by the relaxation of unstable plasma distributions, these electric field structures may be useful for identifying localized regions of active particle distribution homogenization (therefore regions of energy redistribution) at plasma boundaries in the inner magnetosphere.

<u>Mission View of Field Aligned Currents from NASA's ST5 Spacecraft</u>

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Magnetometer data from NASA's three-spacecraft Space Technology 5 (ST5) mission are available from March 27 – June 27, 2006. We transformed the data from the 300 km x 4500 km elliptical orbit frame into the Modified Apex Coordinate System for projection to a common reference altitude of 110 km. When projected as a keogram these magnetic perturbations reveal a pattern of long-lived magnetic "calms" interspersed among numerous variable-length episodic enhancements. The variations are directly related to changes in high-latitude field aligned current (FAC) systems caused by solar wind structuring. The most obvious association is with magnetosonic mach number (Mms) decreasing to values <5. Many of these occur with recurring high-speed streams, while a few appear with other recurrent features, and a transient in the solar wind. Evidence of equinoctal effects in the FAC response gives way to responses that appear closely linked to summer-enhanced conductance and variations in the radial component of the interplanetary magnetic field projected onto Earth's sunward-tilted dipole. Analysis from the entire mission suggests that FAC responses at high-speed stream interaction regions lead to previously unexplained, impulsive, thermospheric temperature enhancements, reported in the literature.

Poster Session – P1/P2 (Poster abstracts are on separate download)
Featuring Plenary Sessions 4a, 4b

Plenary Session 2a. *Evolving Coronal Mass Ejections from Corona, through the Heliosphere, into Geospace*

Modeling the Convection Zone-to-Corona System over Global Spatial Scales

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How magnetic energy and flux emerges from the turbulent convective interior of the Sun into the solar atmosphere is of great importance to a number of challenging problems in Heliophysics. With the wealth of data from missions such as SDO, Hinode, and IRIS, it is evident that the dynamic interaction of magnetic structures at the photosphere and in the solar atmosphere occurs over a vast range of spatial and temporal scales. Emerging active regions often develop magnetic connections to other regions of activity some distance away on the solar disk, and always emerge into a global coronal field whose structural complexity is a function of the solar cycle. Yet even small-scale dynamic interactions (e.g., processes at granular or supergranular scales in the photosphere) can trigger rapid changes in the large-scale coronal field sufficient to power eruptive events such as coronal mass ejections, or solar flares. The challenge of modeling this system in its entirety is that the magnetic field not only spans multiple scales, but also regions whose physical conditions vary dramatically. In this overview, we will summarize recent progress in the effort to dynamically model the upper convection zone-to-corona system over large spatial scales, and will present the latest results from a new, global radiative-MHD model of the upper convection zone-to-corona system, RADMHD2S. We will characterize the flux of electromagnetic energy into the solar atmosphere as flux systems of different scales dynamically interact, and discuss how physics-based models of the convection zone-to-corona system can be used to guide the development and testing of data-driven models of CME initiation and propagation.

Using Realistic MHD Models to Connect Observations of CMEs to Their Physical Underpinnings

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Understanding how coronal mass ejections (CMEs) form and evolve in the corona and heliosphere is a key research topic in heliophysics. While our observational capabilities and modeling techniques have grown considerably in the past few decades, it remains difficult to unambiguously connect some observed aspects of CMEs to their physical underpinnings. In this talk I will give an overview of present techniques and challenges in realistically modeling CMEs, with a particular focus on how including synthetic observables can help bridge the gap between theory and observations. One such example is the study of large-scale waves launched by CMEs in corona (visible in the EUV and white light), where using simulations as digital laboratories has aided in interpreting previously ambiguous observations. Other aspects, such as the interaction of a CME with the ambient corona (related to observations of coronal dimming), and the challenges in modeling extreme events will also be discussed.

<u>The Interaction of Solar Eruptions and Large-Scale Coronal Structures Revealed Through Modeling and Observational Analysis</u>

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We use numerical and observational approaches to explore how the interaction of a coronal mass ejection (CME) with preexisting structures in the solar atmosphere influences its evolution and space weather effects. We study two aspects of CME evolution: deflection of the CME's propagation direction, and expansion. First, we perform a statistical study of the influence of coronal holes on CME trajectories for more than 50 events during years 2010-2014. Second, we use a global solar wind model within the Space Weather Modeling Framework (SWMF) to study a CME's expansion. The interaction of the modeled CME with a nearby streamer results in non-uniform expansion. We calculate the pile-up of material along the front and sides of a CME due to the non-uniform expansion, and constrain the properties of the pile-up under a range of conditions. These plasma density structures prove to be important for space weather: using the global MHD simulation data as input to a proton acceleration and transport model (EPREM), we demonstrate that the compression regions efficiently accelerate protons to high energies, whereas other locations along the CME produce little proton acceleration. Looking toward the future, we show data-constrained simulations of CME initiation in the Alfven Wave Solar Model (AWSoM) within the SWMF, which employs a sophisticated treatment of the physics of coronal heating and solar wind acceleration. We discuss how this approach will improve our understanding of CMEs.

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<u>Modeling of Coronal Mass Ejections</u>

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In the last 15 years, there has been significant progress in the modeling of Coronal Mass Ejections. Three areas of research have been actively pursued – their initiation, their 3D morphology and their propagation through the interplanetary medium. An overview of the research in these areas will be presented, with particular attention on the 3D morphology. Some surprises have arisen. For example, detailed studies of the propagation of individual events show that there is significant interaction of the CME with the ambient solar wind. Another example is that rotation of a CME beyond 3 Rsun has been reported.

<u>Nonlinear Magnetosphere-Ionosphere Coupling in Near-Earth Space During an ICME-Driven Storm</u>

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Localized potential electric field modification is identified in the Van Allen Probes data during magnetic storm times, when significant energetic plasma (above a keV) is injected into the inner magnetosphere. This modification is from the closure of field-aligned currents through the ionosphere in a region of low

conductance just equatorward of the auroral oval. Observations from the Van Allen Probe instruments HOPE, EMFISIS, and EFW are presented for several magnetic storms, showing the relationship of the plasma pressure peak and the magnetic field distortion to the local electric field vector. An assessment of the intensity of the nonlinear feedback on the electric field is made by determining its deviation from the large-scale potential electric field, as observed by EFW outside of the pressure peak. The coupling that emerges is in agreement with numerical simulations of near-Earth space that predict strong perturbation of the local electric field near pressure peaks.

Plenary Session 2b. *Dynamics of Energetic Particles, Wave-Particle Interactions, Shocks, Turbulence*

Recent Results on Kinetic Simulations of Shocks and Turbulence

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In this talk, we review the latest results that point to new and deeper relationships between the three fundamental processes of reconnection, turbulence and shocks in collisionless plasmas. The role of wave-particle interactions in these processes is discussed. We present results from three types of 3D kinetic simulations: decaying turbulence, global simulations of the magnetosphere, and reconnection of large scale current sheets.

Multi-Spacecraft View of Solar Energetic Particle Events in Solar Cycle 24

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The fleet of spacecraft distributed through the inner heliosphere during solar cycle 24 offers us the opportunity to (i) analyze solar energetic particle (SEP) events from multiple vantage points, and (ii) assemble longitudinal distributions of SEP intensities. Particles from individual SEP events have been observed to extend over broad ranges of longitude, in some cases nearing a 360° span. Fits to the longitudinal distributions of SEP intensities give both an approximate picture of the longitudinal broadening of the SEP events and an insight into the mechanisms responsible for spreading SEPs in the inner heliosphere. One of the mechanisms proposed to explain the wide spread of SEP events invokes particle injection from inherently broad particle sources associated with CME-driven shocks. The extent of the pressure waves traveling in the lower corona and associated with the onset of CMEs has been suggested as an indication of the longitudinal spreading of the SEP events. We will discuss whether the extension of these waves provides a good proxy for the longitudinal span of SEP events.

Collisionless Shock Waves and Wave-Particle Interactions

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Collisionless shock waves are a topic of great interest in multiple fields of study from lab plasmas to astrophysics. Shock waves are arise when a nonlinearly steepening wave manages to form a stable discontinuity through the irreversible transformation of the free energy, or energy dissipation, available in the change in bulk flow kinetic energy across the shock to some other form (e.g., heat). In a regular fluid (e.g., Earth's atmosphere), shock initiation can occur because binary particle collisions provide sufficient energy dissipation to balance nonlinear wave steepening. Ever since the prediction of collisionless shocks nearly 60 years ago, the debate surrounding possible energy dissipation mechanisms has been a subject of great debate. The energy dissipation mechanisms proposed are: (1) quasi-static field effects [e.g., cross-shock potential]; (2) particle reflection; (3) dispersive radiation; and (4) wave-particle interactions. However, recent results show that the first three mechanisms are all part of pathways that ultimately end with this "black box" mechanism I refer to as "wave-particle interactions." Therefore, in this talk I will focus on wave-particle interactions and present recent results showing that they are capable to regulating the macroscopic structure of collisionless shock waves.

Wednesday, Nov. 5

Splinter Session S-11 (3a). *Chromosphere: Dynamics, heating and ion-neutral effects*

The Role of the Chromosphere in the Energization of the Corona

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We present results on the effect of the partially ionized chromosphere on the transfer of magnetic field and energy into the corona during the birth and evolution of solar active regions. Using numerical MHD simulations which include the effects of partial ionization, namely ion-neutral collisions and Pedersen dissipation, we investigate how the magnetic flux and energy emerges from beneath the surface to energize the corona, and how these chromospheric partial ionization effects modulate these processes. Of particular interest is the nature of the electric currents and the force-free nature of the magnetic field.

This work is funded by NASA's living with a star (LWS) targeted research and technology (TR&T) program, and by the Office of Naval Research (NRL).

Observation of Velocity Differences between Neutral Atoms and Ions in Solar Chromosphere

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Solar chromospheric plasma is collisional partially ionized plasma. If the velocity of neutral is different from that of ion, the multi-fluid effects may affect the dissipation of high-frequency waves and physics of reconnection, and break ideal MHD approximation on the dynamics of chromospheric plasma. When neutral atoms move across the magnetic field, electric field act on the neutral atoms. In order to diagnose the electric field, we observed the full Stokes spectra of the Paschen series of neutral hydrogen in chromospheric jets that took place at the solar limb on May 5, 2012, and we derived upper limits of electric field felt by neutral hydrogen. Because the velocity of neutral atoms of hydrogen moving across the magnetic field derived from these upper limits of the electric field is far below the bulk velocity of the plasma perpendicular to the magnetic field as measured by the Doppler shift, we conclude that the neutral atoms must be highly frozen to the magnetic field in the surge. On the other hand, we observed spectra of prominence in H alpha (neutral hydrogen), He D3 (neutral helium), Ca 8542Å (ionized Calcium) simultaneously with a cadence of 0.5 seconds for several hours by using Horizontal spectrograph of Domeless Solar Telescope at Hida observatory. Velocity differences between neutral atoms and ionized Calcium are significantly larger than the measurement error of Doppler velocity.

On the IRIS Signature of Ellerman Bombs

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Ellerman bombs, transient brightenings that have traditionally been observed in the wings of the Balmer Halpha line, are a ubiquitous phenomenon in the lower atmosphere of active regions with considerable flux emergence. These explosive events have sub-arcsecond fine structure, evolve on short timescales and their energy estimates tend to fall in the nanoflare ballpark. Using SST/CRISP Halpha data as well as SDO/AIA 1600Å and 1700Å images to confidently pinpoint Ellerman bomb locations, we investigate their signature in observations from the Interface Region Imaging Spectrograph (IRIS). Although not all Ellerman bombs observed in Halpha result in a perceivable IRIS signal, we do observe coinciding brightenings in both the 2796Å and 1400Å slit-jaw images, with a clear response in the Mg II h & k and both Si IV (1394Å and 1403Å) lines in those cases. We here present an analysis of their time evolution and spectral signature, deriving properties such as densities, velocity shifts and temperatures, and discuss how these fit in the current Ellerman bomb picture.

Asymmetric Magnetic Reconnection in Partially Ionized Chromospheric Plasmas

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Magnetic reconnection is a ubiquitous process in the solar chromosphere. Realistic models of chromospheric reconnection must take into account that the plasma is partially ionized. Asymmetric reconnection in the chromosphere may occur when newly emerged flux interacts with pre-existing, overlying flux. We present simulations of asymmetric reconnection in weakly ionized, reacting plasmas where the magnetic field strengths, densities, temperatures, and ionization fractions differ in each upstream region. The simulations show considerable thinning of the current sheet, asymmetric decoupling of ions and neutrals in the inflow regions, and plasmoid formation late in time. We will discuss these simulations in the context of newly available observations from the Interface Region Imaging Spectrograph (IRIS) and present opportunities for validation against laboratory reconnection experiments.

Torsional Motions and Heating in the Disk Counterparts of Spicules

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Slitjaw images from the Interface Region Imaging Spectrograph (IRIS) reveal the ubiquitous presence of small-scale jets in network regions. Coordinated observations with IRIS and the Swedish Solar Telescope in La Palma show that many of these jets can be associated with so-called Rapid Blue- or Red-shifted Excursions (RBE or RREs) which are the disk-counterparts of type II spicules. We have a large number of RBEs and RREs in our coordinated observations that are covered by the IRIS slit. For these events, we find clear spectral signatures in the Mg II h en k spectral lines. Furthermore, we find associated signatures in the C II 1336 and Si IV 1394/1403 lines. This supports earlier observations that showed that type II spicules are heated to at least transition region temperatures. The combined IRIS and SST observations show that torsional motions on very small (subarcsecond) spatial scales are an important component in the dynamics of spicules.

Formation of the O I 135.56 nm and the C I 135.58 nm Lines

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The O I 135.56 nm and C I 135.58 nm lines are covered by NASA/SMEX mission Interface Region Imaging Spectrograph (IRIS) and their behaviour has also been reported during solar flare in 1970s (Cheng et al. (1980)). The formation of these two lines is therefore interesting because they can potentially become powerful tools that probe the solar chromosphere. In this work we study the 3D-RMHD atmosphere performed by the Bifrost code (Gudiksen et al., 2011) and the RH1.5D code (Uitenbroek, 2001) to carry out the full radiative transfer. We found that the O I 135.56 nm line forms optically thin while the C I 135.58 nm line forms optically thick at mid-chromosphere (1.2Mm ~ 1.6Mm). The O I line itself can already provide interesting information: the doppler shift of its maximum emission is sensitive to the velocity field at the line-forming region, therefore can be useful as a good velocity diagnostic; and its line-width will serve as the constraint of the line-broadening due to the velocity field, as the O I line appears to be the thinnest emission line in the IRIS window; the intensity of it maximum emission can also provide the information of the electron density at its forming region. By using the O I and the C I line together, one can get the velocity gradient diagnostic as they forms at slightly different height. From their line ratio it is also possible to get a hint of the formation height of the lines.

References:

Cheng, C. C., Feldman, U., & Doschek, G. A. 1980, A&A, 86, 377
Gudiksen, B. V., Carlsson, M., Hansteen, V. H., et al. 2011, A&A, 531, A154
Uitenbroek, H. 2001, ApJ, 557, 389

Splinter Session S-12 (1b). *Reconnection and Magnetic Instabilities in Solar Atmosphere*

Magnetic Reconnection in Emerging Active Regions

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Solar active regions (ARs), in particular newly emerging ARs, exhibit magnetic reconnections of many scales from catastrophic activity phenomena such as solar flares and CMEs to arcsec-sized brightening features known as Ellerman bombs. This is because the developing ARs harbor a wide variety of magnetic processes including flux emergence and cancellation. Numerical and observational studies have shown that the small-scale, low-atmospheric reconnection in the sheared magnetic structure in an AR may lead to the triggering of large-scale flare reconnection, resulting in the ejection of a magnetic flux rope. On the other hand, utilizing the Hinode, IRIS and SDO data, we found that the small-scale reconnections repeatedly launch the collimated plasma flows (cool jets) above a newly emerging AR. In this talk, I will report on our recent results of numerical and observational studies on the emerging ARs and reconnection events, and discuss what we can learn from the comparison between the simulations and the observations.

Correlated Quasi-periodic Fast-mode Magnetosonic Wave Trains and Flare Pulsations: Implications for Pulsed Magnetic Reconnection in the Solar Corona

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Quasi-periodic fast propagating wave trains (QFPs; Liu et al. 2011, 2012 ApJ) are a new observational phenomenon recently discovered in extreme ultraviolet (EUV) by SDO/AIA. They are fast-mode magnetosonic waves, usually originate from flares, and propagate at typically 500-2200 km/s within funnel-shaped waveguides. QFPs share some common frequencies usually in the 20-400 sec range with quasi-periodic pulsations in radio to hard X-ray emissions of the accompanying flares. This suggests a common physical origin, e.g., repeated energy-release episodes caused by pulsed magnetic reconnection. QFPs can thus serve as a new diagnostic tool to probe flare energy release and magnetic reconnection processes. We will present recent observational and numerical results of QFPs and compare them with flare pulsations, with special attention paid to possible modulations of the reconnection process by MHD waves and/or instabilities (e.g., Ofman & Sui 2006 ApJL). Observational examples include the 2010-Aug-01 C3.2 flare/CME event with correlated QFPs (Liu et al. 2011 ApJL) and zebra-shaped radio bursts (Karlicky 2014 A&A). We will also present an initial survey of QFP-correlated flare pulsations in IRIS data in search of a possibly alternative, subsurface origin of their periodicities.

IRIS Sub-Arcsecond Scale Observations of an Explosive Event

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We present a study of an explosive event witnessed by strong non-Gaussian profiles with blue- and red-shifted emission of up to 150 km/s registered in the transition region Si IV 1402.8 A, and the chromospheric Mg II K 2796.4 A and C II 1334.5 A lines observed by the Interface Region Imaging Spectrograph (IRIS) at unprecedented spatial and spectral resolution. The analysis of the lines' wing and line-centre emission reveals plasma up- and down-flows that are a signature of plasma jet-like ejections followed by retraction. We also analyse the evolution of the feature in the IRIS 1330 A slit-jaw and various AIA channels' images. The slit-jaw 1330 A images reveal for the first time that explosive events' strong non-Gaussian profiles are associated with a compact bright-point-like structure of ~1.5" where continuously small-scale (as low as 120 km long) plasma ejections take place. The explosive event is detected in the higher temperature channels of AIA 171 A,

193 A and 131 A suggesting that it reaches a higher temperature, which is found to be logT = 5.36 K derived using the emission measure loci method. Brightenings observed in the AIA channels with durations 90 -120 seconds are most probably caused by the small-scale jets seen in the IRIS slit-jaw 1330 A images. We found that magnetic convergence or emergence in the region of the explosive event is followed by magnetic-flux cancellation at a rate of about 5x10^14 Mx/s. The potential magnetic field extrapolation permitting to follow the field connectivity evolution reveals that significant reconnection associated with the explosive event must take place with time.

What Can We Learn from MHD Simulations and Observations about the Initial Phase of Solar Eruptions?

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Ideal MHD flux rope instabilities and magnetic (flare) reconnection are believed to be the two main driving mechanisms of solar eruptions, being responsible for the rapid acceleration of the ejecta in such events. However, their onset thresholds and specific trigger mechanisms, as well as their respective contributions to the acceleration, are not well understood from theory, and cannot be inferred unambiguously from observations at present. These limitations greatly hamper our ability to predict the onset and early evolution of individual eruptions. In this talk, I will briefly discuss to what extent MHD simulations and their comparison to observations can be utilized to improve our understanding of the initial phase of solar eruptions.

Miniature Filament Eruptions and their Reconnections in X-Ray Jets: Evidence for a new paradigm

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We investigate the onset of ~10 random X-ray jets observed by Hinode/XRT. Each jet was near the limb in a polar coronal hole, and showed a ``bright point'' in an edge of the base of the jet, as is typical for previously-observed X-ray jets. We examined SDO/AIA EUV images of each of the jets over multiple AIA channels, including 304 Ang, which detects chromospheric emissions, and 171, 193, and 211 Ang, which detect cooler-coronal emissions. We find the jets to result from eruptions of miniature (size <~10 arcsec) filaments from the bases of the jets. Much of the erupting-filament material forms a chromospheric-temperature jet. In the cool-coronal channels, often the filament appears in absorption and the jet in emission. The jet bright point forms at the location from which the miniature filament is ejected, analogous to the formation of a standard solar flare in the wake of the eruption of a typical larger-scale chromospheric filament. Thus these X-ray jets and their bright points are made by miniature filament eruptions. They are evidently produced the same way as an on-disk coronal jet we observed in Adams et al. (2014); that on-disk jet had no obvious emerging magnetic field in its base. We conclude that, for many jets, the standard idea of X-ray jets forming from reconnection between emerging flux and pre-existing coronal field is incorrect. ACS and RLM were supported by funding from NASA/LWS, Hinode, and ISSI.

A Study of Eruptions Detected by the LMSAL Eruption Patrol

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Observations of the solar atmosphere reveal a wide range of real and apparent motions, from small scale jets and spicules to global-scale coronal mass ejections. Identifying and characterizing these motions are essential to advance our understanding the drivers of space weather. Both automated and visual identifications are used in identifying CMEs. To date, the precursors to these — eruptions near the solar surface — have been identified primarily by visual inspection. Here we report on an analysis of the eruptions detected by the Eruption Patrol, a data mining module designed to automatically identify eruptions from data collected by Solar Dynamics Observatory's Atmospheric Imaging Assembly (SDO/AIA). We describe the module and use it both to explore relations with other solar events recorded in the Heliophysics Event Knowledgebase and to identify and access data collected by the Interface Region Imaging Spectrograph (IRIS) for further analysis.

Splinter Session S-13 (4a). ***Effects of Solar Variability at Earth***

Solar Variability Impacts on Thermosphere-Ionosphere Weather and Climate

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The effects of solar ultraviolet irradiance and geomagnetic storms on upper atmosphere of the Earth increase with increasing altitude, and become dramatic above about 100 km. Problems associated with tracking and predicting the trajectories of the thousands of objects currently in Earth orbit have received recent attention, especially with regard to the drag force applied by thermospheric atoms and molecules. In order to calculate and predict thermospheric density and composition, numerical models are employed, using solar irradiance and magnetospheric currents, together with lower atmosphere processes, to create a dynamical description of the coupled thermosphere and ionosphere. In addition to the challenges associated with applying realistic external inputs, the upper atmosphere is evolving, due to changes in thermodynamics associated with anthropogenic increases in radiatively active gases. Understanding these long-term changes is, in turn, complicated by recent developments in the solar cycle, with the last solar minimum particularly long and quiet, and the current cycle very weak. This presentation will give an overview of these developments, present some modeling and measurement results, and discuss new opportunities for global observations of the thermosphere and ionosphere.

How Consistent are the Solar Absolute Irradiance Changes for the Two Latest Solar Cycle Minima with the SOHO/EIT and SDO/AIA Image Spatial Spectra and with the CODE TEC Sectorial Harmonic Spectra Changes

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The Solar Cycle minimum in 2008-09 showed a decrease compared to the minimum of 1996 in the absolute solar EUV irradiance measured by SOHO/SEM first-order (26 to 34 nm) channels, in the Mg II core-to-wing solar index, and in TSI. This decrease was also detected in the changes of thermosphere neutral gas densities as modeled and measured using satellite drag data. Some other measurements, for example the f10.7 proxy and TEC global data did not show such a decrease. We use SOHO/EIT and SDO/AIA solar image spatial spectra and CODE TEC sectorial harmonic spectra to verify whether such changes of the absolute solar irradiance are consistent with changes of the spatial structure of the Sun's He-II network layer and with the changes of the Earth's day-side ionosphere TEC detected using CODE sectorial harmonic spectra.

Solar Flare Effects in the Thermosphere and the Ionosphere

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Solar flares produce a large and rapid increases of solar irradiance in the X-ray and Extreme Ultra-Violet (EUV) ranges. This rapid increase of X-ray and EUV radiance instantly enhances ionization in the upper atmosphere and causes sudden ionospheric disturbances that affects radio communications and navigation systems. In the magnetic equator region, solar flares can cause prolonged F2-region disturbance and TEC enhancement. On the other hand, the enhanced ionization results in sudden heating that increases thermosphere neutral density. Through modeling and observational studies, we examine these solar flare effects and how flare characteristics influence these effects. In addition, we will present new results using SDO/EVE measurements.

Progress in Resolving X-Class Flare E-Region Issues

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Four X-class flares are observed by SDO-EVE in early May 2013 all within a three day period. The ionospheric E-region impact of all four flares were also observed by the Poker Flat Incoherent Scatter Radar (PFISR). During this extended three day period the PFISR observations also provide a non-flare baseline of the E-regions response to the quiet solar irradiance. Thus there is sufficient ionospheric information to provide ground-truth for ionospheric E-region modeling. We will report to the status of modeling the quiet time contrasted to the flare periods. In so doing we will identify key issues associated with modeling of the ionization especially the Auger process as well as handling the secondary ionization processes associated with energetic photo electrons. These results will be put in context of today's best practices for modeling ionospheric E-region impacts of X-class flares.

Influence of Solar Flare Irradiance on Nitric Oxide in the Lower Thermosphere and Ionosphere

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Most of the energy in solar flare irradiance lies at solar soft X-ray wavelengths below 7 nm and especially below 2 nm. This energy is deposited in the altitude region near 110 km where Nitric Oxide (NO) peaks in concentration. NO is crucial to the structure of the lower thermosphere and ionosphere as it is a key source radiative of cooling and leads to the production of NO+, the terminal ion in many processes. The production of NO is driven by ionization of N2 and so solar flares photons efficiently lead to the production of NO. The integrated solar irradiance below 7 nm has been measured at high time cadence since the launch of the Solar Dynamics Observatory (SDO) by its EUV Variability Experiment (EVE). We use 1D and 3D models of the upper atmosphere driven by EVE observations updated at each time step to examine the spatial and temporal distribution of NO produced in response to a solar flare. We show that there is strong variation with altitude in both the magnitude and the time scale of the response. In addition, the small flares that EVE observes on many days induce horizontal variability that is significant and unseen in models that are not driven with solar irradiance updated in time steps on the scale of minutes to an hour. Model results are validated through comparisons to observations of both NO abundance and radiance.

Contribution of Solar Irradiance to Ionospheric and Odd Nitrogen Chemistry

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It is well known that nitric oxide (NO) production and loss in the lower thermosphere are each controlled by the solar ionizing irradiance. Less clear is how much each wavelength contributes to which process. While it is generally agreed that the soft x-rays lead to production and Ly-beta and Ly-alpha lead to loss, a more quantitative assessment of the relative contributions from these and the other EUV wavelengths is needed.

Answering this question requires connecting the NO chemical sources (N(2D), N2(A)) and sinks (N(4S), O2+) with their origins in the solar spectrum. Such precursor minor species ultimately derive from the irradiance and are created via chemical cascade from higher energy ions like N2+ and O+. Thus each species in this chemical chain must be traced back to its origins in the solar spectrum.

Furthermore, the chemical cascade itself is primarily initiated by fast photoelectrons. The multitude of processes governing their path to thermalization (e.g. inelastic collisions, secondary production) precludes a simple determination of which photoelectron energies are controlled by which solar wavelengths. However, at altitudes where the equilibrium assumption is appropriate (lower E-region) untangling these contributions is straightforward.

In summary this talk will quantify the contribution of each wavelength of the solar ionizing irradiance to the net NO production and loss. This claim is evaluated for quiet and flare conditions. Uncertainties in the photoelectron spectrum from recent laboratory results on the electron impact cross sections and quantum chemical results for the chemical cascade are assessed.

Exploring Extreme Solar Proton Events, Their Possible Atmospheric Impacts, and Potential Paleoclimate Signatures

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Satellite measurements and global modeling efforts have established the significant impact of solar energetic particles on the chemistry and dynamics of Earth's upper atmosphere. However, determining the magnitude and frequency of solar energetic particle events throughout Earth's history remains elusive. The analysis of paleoclimate archives of cosmogenic signatures in tree rings and ice cores holds much promise, but distinguishing solar influences from atmospheric effects is challenging. We present a series of WACCM (CESM) modeling experiments that consider the potential impact of extreme solar proton events (SPEs) on the atmosphere, including events much stronger than the SPEs observed to date. Comparisons between model simulations of recent SPEs and surface snow observations at Greenland fail to support the use of nitrate spikes in ice cores to identify individual SPE events, motivating the search for alternate proxies. We examine the largest SPE measured by satellite (October 1989) and calculate its possible atmospheric impact had it occurred during ideal polar meteorological conditions. Using preliminary results from coupled EPREM-WACCM model simulations, we study the effect that the July 2012 SPE would have on the atmosphere if its maximum intensity reached Earth. We also conduct simulations based on estimates of SPE energies needed to explain the 14C tree ring enhancements of AD 774 to 775 and place results in the context of limits of solar flares in sun-like stars, contributing toward efforts to detect solar footprints in paleoclimate archives amid variability attributable to the Earth system.

Splinter Session S-14 (2b). *Shocks, Waves, and turbulence: Heliospheric particle acceleration mechanisms*

Particle Acceleration at Shocks at 1 AU and Beyond

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This talk will focus on observations of energetic ion and electron distributions at shock waves in the helioradial range from 1 to ~100 AU. We are most are familiar with particle acceleration at CME-associated shocks near 1 AU. However, during particularly active periods around solar maximum, two or more strong solar wind disturbances can coalesce to form merged or global merged interaction regions that drive global-scale shocks into the outer heliosphere, to the termination shock, and beyond. These shocks continue to accelerate particles for many months as they propagate outward. We will use measurements made mainly by the Voyager 1 and 2 spacecraft to characterize how shock-accelerated particle intensities and angular distributions evolve with helioradial distance and with solar cycle. We will also compare accelerated particle populations at measured at traveling heliospheric shocks with those measured at the termination shock.

Van Allen Probe Observations of Electric Fields and Their Role in the Dynamics of the Inner Magnetosphere of the Earth and Energetic Particle Acceleration

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The Electric Fields and Waves Instrument on the two Van Allen Probe Spacecraft provide measurements in the inner magnetosphere of the Earth of the large scale convection electric field, electric fields associated with explosive energy release in the tail, large scale waves driven by both internal free energy sources and solar wind conditions, and interplanetary shock impacts. The role of these electric fields in the dynamics of the inner magnetosphere and in the acceleration of energetic particles measured by the complement of energetic particle instruments on Van Allen Probes will be discussed.

Understanding Earth's Radiation Belt Electron Dynamics and its Relation to Solar Wind Conditions

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The highly dynamical evolution of the Earth's outer radiation belt electron fluxes is due to a competition between various loss and acceleration processes. Identifying which process is dominant under various solar wind conditions is critical to understand the influence of solar activity on the Earth's radiation belts. In this study, we focus on analyzing a few interesting events observed by the Van Allen Probes, including a few very rapid electron acceleration events up to multi-MeV energies within ~12 hours, and a gradual electron transport event where the peak in electron fluxes slowly moves inwards closer to the Earth. Using the UCLA 3D particle diffusion code, we simulate the evolution of the electron phase space density by including the most important physical processes, such as electron energy diffusion and pitch angle scattering caused by whistler-mode chorus waves and plasmaspheric hiss and radial diffusion driven by ULF waves, to quantify the role of each physical process in each type of event. We further discuss the preferential solar wind conditions that lead to the rapid electron acceleration up to multi-MeV and the gradual electron radial transport towards the Earth.

BARREL Observations of a Solar Storm: The Flare, The SEP, and the CME arrival at Earth

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The Balloon Array for Radiation belt Relativistic Electron Losses (BARREL) mission of opportunity working in tandem with the Van Allen Probes was designed to study the loss of radiation belt electrons to the ionosphere and upper atmosphere. However BARREL is able to see x-rays from a multitude of sources. During the second campaign the Sun produced a X-class flare observed by BARREL, followed by x-rays, gamma-rays, and direct injection of protons from the solar energetic particle (SEP) event associated with the same solar active region as the X-class flare, also observed by BARREL. Two days later the coronal mass ejection (CME) originating from the solar active region hit the Earth while BARREL was in a conjunction with the Van Allen Probes and GOES. The solar interplanetary magnetic field (IMF) Bz was not ideally situated to cause a geomagnetic storm, but the compression led to the formation of drift echoes, ultra low frequency (ULF) waves, electromagnetic ion cyclotron (EMIC) waves, and very low frequency (VLF) whistler mode waves all near the noon-dusk sector. The combination of these waves and the enhancement of the local particle population led to precipitation of electrons remotely observed by BARREL. This is a unique event as BARREL saw portions of the entire solar storm process.

The Energetics of a Global Shock Wave in the Low Solar Corona

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As the most energetic eruptions in the solar system, a coronal mass ejection (CME) can produce shock waves at both its front and sides as it erupts from the Sun into the heliosphere. However, the amount of energy produced in these eruptions, and the proportion of energy required to produce the wave, is not well characterised. Here we use observations of a solar eruption from 2014 February 25 to estimate the energy budget of an erupting CME and the globally-propagating "EIT wave" produced by the rapid expansion of the CME flanks in the low solar corona. The "EIT wave" is shown using a combination of radio spectra and extreme ultraviolet images to be a shock front with a Mach number greater than one. Its initial energy is then calculated using the Sedov-Taylor blast wave approximation, which provides an excellent approximation for a shock front propagating through a region of variable density. This approach provides an initial energy estimate of ~6×10^{31} ergs to produce the "EIT wave", which is comparable to the energy of a flare. The kinetic energy of the associated CME is shown to be ~2.5×10^{32} ergs, indicating that the "EIT wave" had approximately 10% the energy of the associated CME. These results suggest that the energy of the "EIT wave" is significant and must be considered when estimating the total energy budget of a solar eruption.

Poster Session – P3/P4 (Poster abstracts are on separate download)

Featuring Plenary Sessions 1a, 1b

Splinter Session S-15. *Hinode/IRIS: Spectroscopic Mass and Energy Transfer between the Chromosphere and Corona*

IRIS-Hinode Collaborative Observations of Oscillating Prominences and Discovery of Resonant Absorption

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Coronal heating and the acceleration of the solar wind are unsolved problems in solar physics. The propagation of Alfven waves along magnetic field lines is one of the candidate mechanisms for carrying energy to large distances from the surface and heat the coronal plasma. Although such waves are actually damped in short spatial and temporal scales in observations, it is still unclear whether any significant dissipation occurs, or whether most of the energy is merely converted from one wave mode to another.

Here we report prominence observations coordinated with IRIS, Hinode/SOT, and SDO/AIA to find evidence and clues of dissipation. In the high-spatial, temporal, and spectral observation, we found temperature increase in oscillating small-scale structures and a characteristic phase difference between the transverse motions of the threads and the line-of-sight velocities.

These observational features support a scenario in which resonant absorption takes place on the surface of oscillating prominence flux tubes in the corona. In this particular model, the transverse shear motions from the dipole flow are enhanced by the azimuthal flows in the resonant layer, a process that can lead to the Kelvin-Helmholtz instability. This mechanism deforms the tube's boundaries and generates thin current sheets and turbulence, leading to dissipation of the wave energy into heat. This observation identifies the locations and form of energy dissipation to propose the existence of numerous thin current sheets with enhanced turbulent regions on the oscillating threads.

The Multi-Thermal and Multi-Strand Nature of Coronal Rain

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New IRIS observations in upper chromospheric and TR lines show abundance of coronal rain in active regions. The wide range of spectral lines in which it is observed, through co-observations in cool chromospheric lines with SOT and SST, and in coronal and TR lines with SDO, show clearly that coronal rain has a broad multi-thermal character. Prevalence of fine structure is found to increase at higher resolution with no clear change of trend, suggesting a tip of the iceberg scenario. A possible correlation with temperature is also found, strengthening the picture in which cool and dense cores are surrounded by a diffuse halo of warmer material. Whether such inhomogeneity extrapolates to the magnetic field, as expected from the Bennett pinch effect, is discussed. Furthermore, SST reveals highly coherent fine structure at the smallest scales in the transverse direction to the magnetic field, suggesting influence from the MHD thermal mode on the blob morphology. All these features agree well with the thermal instability scenario. A statistical analysis of the line widths in the rain provides estimates of the non-thermal line broadening and temperature. Mainly, we find Gaussian-like distributions of non-thermal line broadening with a peak at 7 km/s and a small upper tail spanning up to 25 km/s, with a small tendency to increase with height.

Using IRIS to Constrain Flare Loop Properties in Simulations of Impulsive Conduction-Driven Evaporation

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During a flare, magnetic reconnection in the corona creates closed coronal loops which are then free to contract under tension. The energy released during this process is converted to shocks and thermal conduction fronts, which transport thermal energy down the loop into the chromospheric footpoint plasma. The heated plasma then flows upward to fill the coronal loop in a process referred to as chromospheric evaporation. This process is thought to depend on the properties of the energy release, the state of the pre-flare corona, and the magnetic geometry of the footpoints. In this study, we analyze an M7.3 flare which occurred on 2014-April-18, which was observed by the Interface Region Imaging Spectrograph (IRIS) in a sit-and-stare operation with 9-second cadence. The slit pointing for this flare was ideally located over both footpoint and coronal portions of flaring loops, capturing spectral data for the Si IV, O IV, and Fe XXI emission lines. The high cadence allows for detailed analysis of the time-evolution of the Doppler velocity shifts for these lines within both footpoint and coronal regions during the impulsive phase of the flare. We then utilize a simplified 1-D hydrodynamic code, which we have developed specifically to simulate impulsive shock-induced chromospheric evaporation, to calculate synthetic Doppler shift profiles for the lines of interest. Finally, we compare the synthetic Doppler profiles from multiple simulations to the observed data to place constraints on the flare loop properties described above.

Challenging the FIP Bias Paradigm?

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Plasma composition is a critical plasma parameter linking coronal source regions to solar wind streams. We typically characterize plasma composition using first ionization potential (FIP) bias which is the ratio of elemental abundance in the upper atmosphere to that in the photosphere. Though the in situ determination of plasma composition is well established, the solar side has not significantly evolved since the seminal Skylab results. Using spectroheliograph observations from Skylab, Widing & Feldman (2001) demonstrated plasma trapped in coronal loops in newly emerged active regions (ARs) has photospheric composition (FIP bias ~ 1) and from thereon the AR plasma becomes enriched at an almost constant rate per day so that after 2-3 days coronal and slow solar wind abundances are reached (FIP bias ~3-4).

Hinode/EIS has provided a new opportunity to re-examine the evolution of plasma composition in ARs at the highest temporal and spatial resolutions. Using Hinode/EIS large field-of-view, high resolution composition ratio maps of a large, decaying AR (NOAA 11389), we found the evolution of composition to be counter to the prevailing paradigm that plasma enrichment in ARs is linearly related to AR age. Even in an aging AR, FIP bias is modulated by small-scale flux emergence. This result has possible implications for what is observed in the slow solar wind.

Investigating the Nature of Running Sunspot Waves with the Interface Region Imaging Spectrograph

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We present simultaneous, high-resolution, NUV and FUV observations of running waves and umbral flashes in sunspots from the Interface Region Imaging Spectrograph (IRIS). We analyze intensity variations in slit-jaw images to investigate the relationship between running waves in the 1400 Å (Si IV, transition region) passband and umbral flashes in the 2796 Å (Mg II, chromosphere) passband. Using global wavelet analysis, we find that the dominant wave periods increase from approximately 180 s in the umbra to about 300 s in the penumbra in both passbands, experiencing a sharp increase near the umbra-penumbra boundary. This coincides extremely well with the radially increasing inclination of magnetic field lines observed with SDO/HMI, suggesting that the oscillations/waves are likely propagating vertically along the inclined field lines. Furthermore, apparent velocities in both passbands decrease from about 12 km s-1 at the sunspot center to about 3.5 km s-1 in the penumbra which is predicted by the same inclined field geometry. Finally, we find that umbral flashes lead running waves in both the spatial and time domains. The former result is attributable to the inclined field geometry; however, the geometry does not predict the radially increasing time lag which is likely due to the opacity disparity between the emission lines that dominate the two passbands. These results suggest that the apparent trans-sunspot propagation of running waves is not real, but is rather a signature of upward-propagating (slow) magneto-acoustic modes triggered by photospheric p-mode oscillations and tied to field lines of radially increasing inclination.

Evidence of Non-Thermal Particles in Coronal Loops Heated Impulsively by Nanoflares

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The variability of emission of the "moss", i.e., the upper transition region (TR) layer of high pressure loops in active regions provides stringent constraints on the characteristics of heating events. The Interface Region Imaging Spectrograph (IRIS), launched in June 2013, provides imaging and spectral observations at high spatial (0.166 arcsec/pix), and temporal (down to ~1s) resolution at FUV and NUV wavelengths, and together with the high spatial and temporal resolution observations of SDO/AIA, can provide important insights into the coronal heating mechanisms. We present here an analysis of the temporal variability properties of moss regions at the footpoints of hot active region core loops undergoing heating, as observed by IRIS and AIA, covering emission from the corona to the transition region and the chromosphere. We model the observations using dynamic loop models (the Palermo-Harvard code, and RADYN, which also includes the effects of non-thermal particles) and discuss the implications on energy transport mechanisms (thermal conduction vs beams of non-thermal particles).

Plenary Session 3a. *Ion-Neutral Interactions within Earth's Atmosphere and the Solar Atmosphere*

Heating Requirements of the Solar Chromosphere

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The chromosphere is arguably the most difficult and least understood domain of solar physics. All at once it represents the transition from optically thick to thin radiation escape, from gas-pressure domination to magnetic-pressure domination, from neutral to ionised state, from MHD to plasma physics, and from near-equilibrium ("LTE") to non-equilibrium conditions.

The heating requirements of the solar chromosphere are not easily determined since the radiative cooling is dominated by optically thick spectral lines that form far from equilibrium. Energy estimates are therefore

very model dependent. 1D semi-empirical model atmospheres indicate that to maintain the quiet, average solar chromosphere, the required energy input is in the range 2-12 kW/m^2 but these models neglect many important aspects like the dynamics of the chromosphere, non-equilibrium ionization effects and spatial structuring.

In this talk, we will present 3D "realistic" radiation-MHD simulations spanning the solar atmosphere from the convection zone to the corona, and synthetic observations calculated from the simulations. We will especially focus on what the comparison between the synthetic observations and new observations from the IRIS satellite tell us about the heating requirements of the solar chromosphere.

Numerical Simulations of Ion-Neutral Interaction Effects in the Solar Chromosphere

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IRIS was launched in 2013 to study the chromosphere and transition region which is crucial for understanding how these regions modulate the flow of mass and energy into the upper atmosphere. The complexity of the chromosphere and transition region results from the various regime changes that take place across them these layers. Some of these regime changes are as follows: Hydrogen goes from predominantly neutral to predominantly ionized; the plasma behavior changes from collisional to collision-less; it goes from gas-pressure dominated to magnetically driven, the radiation goes from optically think to optically thin, etc. Consequently, the interpretation of chromospheric observations in general and those from IRIS, in particular, is a challenging task. It is thus crucial to combine IRIS observations with advanced radiative-MHD numerical modeling. Because the photosphere, chromosphere and transition region are partially ionized, the interaction between ionized and neutral particles has important consequences on the magneto-thermodynamics of these regions. We implemented the effects of partial ionization in terms of a generalized Ohm's law in the Bifrost code (Gudiksen et al. 2011) which solves the full MHD equations with non-grey and non-LTE radiative transfer and thermal conduction along magnetic field lines. I will describe the relevance of partial ionization effects in the modeled radiative-MHD atmosphere.

How Does the Sun Drive the Dynamics of the Earth's Thermosphere and Ionosphere

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Radiation from the Sun drives a strong circulation in the Earth's upper atmosphere. Because of the solar zenith angle and rotation of the Earth and changes of solar radiation over a solar cycle, the thermospheric temperature, winds and composition have significant diurnal, seasonal and solar cycle variations. Solar radiation also produces ionization in the upper atmosphere to form the ionosphere. The nonlinear dynamical interaction between the thermosphere and ionosphere results in a coupled dynamical system that varies with different spatial and temporal scales. The variation of this system is further influenced by the transient events happening on the Sun and in the solar wind, such as solar flares, coronal mass ejections and corotation interaction regions. In this talk, we will describe the basic state of the Earth's thermosphere and ionosphere and the dynamical processes that lead to this state. We will further demonstrate, through data and modeling, the changes of these dynamics by energy and momentum deposition during geomagnetic storms.

Observing Earth's Response to Solar Variability with the GOLD Mission

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The Global-scale Observations of the Limb and Disk (GOLD) mission of opportunity will provide unprecedented imaging of the Earth's space environment and its response to forcing from the Sun and the lower atmosphere. The mission, which NASA selected in April 2013, will fly a far ultraviolet imaging spectrograph that is scheduled for a 2017 launch into a geostationary (GEO) orbit on a commercial communications satellite. From this vantage point, most of a hemisphere will be imaged. Fundamental space weather parameters that will be derived from the images include composition (O/N_2) and temperature (simultaneously) of the thermosphere as well as nighttime ionospheric densities. These images allow changes in time to be distinguished from changes in location because the same locations will be imaged at a thirty-minute cadence, and they will provide context for other measurements from low Earth orbit or the ground. The resulting information is essential for understanding of the Sun's effects on Earth and to advancing our physical understanding of coupling between the space environment and the Earth's atmosphere. GOLD will advance our understanding of how the Earth responds to solar variability and how that variability may affect space based systems.

Plenary Session 3b. ***Heliosphere-Magnetosphere Interactions from Bowshock to Geotail***

An Overview of Transient Ion Foreshock Phenomena and their Impacts on Earth's Magnetosphere

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Ion and electron foreshocks form upstream of the quasi-parallel portion of bow shocks in space plasmas. A significant fraction of incident particles can be accelerated and reflected at a bow shock, resulting in their counter-streaming along field lines and interacting with the incident plasma. Earth's bow shock provides a natural laboratory to study the complex interactions between the incident solar wind and the counter-streaming foreshock populations and compare in situ observations to global simulations of the system. Such simulations and observations have revealed the ion foreshock to be a complex environment characterized by strong wave activity and suprathermal particles and punctuated frequently by large-scale transient disturbances, which we refer to here as transient ion foreshock phenomena (TIFP). A veritable "zoo" of TIFP have been identified, including strong large-amplitude magnetic structures, foreshock cations and cavities, hot flow anomalies, and the recently discovered foreshock bubbles, and several of these features have also been observed at other planetary systems in the heliosphere. As observed at Earth, these TIFP often involve significant pressure variations compared to the pristine upstream solar wind, and it has been established that these pressure variations can penetrate through the magnetosheath resulting in significant magnetopause deformations. Here, we provide an overview of the latest understanding of various TIFP, including how they form, their unique and common characteristics, and the latest estimates of their occurrence rates. We discuss the difficulty in distinguishing between different types of TIFP using single-point satellite observations and stress the importance of multi-point analysis for TIFP identification. We next outline the latest results showing how TIFP impact Earth's magnetosphere. Due to their frequency, we argue that TIFP are an important mode of energy transfer from the solar wind into Earth's magnetosphere. We finish with a brief discussion of outstanding questions concerning TIFP and the importance of the ion foreshock for driving activity in Earth's magnetosphere.

Ion and Electron Bulk Heating in Magnetic Reconnection: Dependence on the Inflow Alfven Speed and Magnetic Shear Angle

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Based on observations of reconnection at Earth's magnetopause we found that the amount of ion and electron heating are correlated with the Alfvén speed based on the reconnecting magnetic field and the plasma number density measured in the reconnection inflow regions. Our empirical finding may explain the relatively weak ion and electron heating in solar wind reconnection exhausts at 1 AU and strong heating to keV (~10^7-10^8 K) energies common in Earth's magnetotail exhausts. The finding could potentially be used to evaluate the role of reconnection in plasma bulk heating in laboratory, solar and astrophysical contexts. For example, in the solar coronal region where the local Alfven speed is ~2200 km/s (based on B ~ 100 Gauss, N~ 10^{10} cm^{-3}), the electrons could be heated up to 10^7 K (or ~1 keV) by reconnection.

Energy Transfer from the Heliosphere and the Dynamics of the Van Allen Radiation Belts

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The Van Allen radiation belts are composed of energetic protons and electrons trapped in electromagnetic drifts encircling Earth. The so-called "outer zone" radiation belts, a population found primarily at radial distances of 3-7 Re, exhibit significant temporal and spatial variability, with particle fluxes observed to vary over orders of magnitude on time scales ranging from minutes to periods commensurate with the solar cycle. A central focus of radiation belt research is concerned with understanding the direct and indirect transmission of energy from the heliospheric environment to the individual particles comprising the belts. In this work we review the various mechanisms by which energy is thought to be transferred from the solar wind to the radiation belts, and discuss recent advances in modeling and new observations from the NASA Van Allen Probes mission providing insight into the structure and dynamics of the belts.

The Complex Structure and Dynamics of the Inner Magnetosphere as Revealed by the Van Allen Probes Mission

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The Van Allen Probes mission (RBSP) was launched just over two years ago with the goal of understanding the complex, coupled dynamics of the Heliosphere-Magnetosphere system. The mission science objectives focus on the processes that control acceleration, transport, and loss of particles in the inner magnetosphere.

The Energetic particle, Composition, and Thermal plasma (RBSP-ECT) suite measures the structure and dynamics of the plasmasphere, plasma sheet, ring current, and radiation belt environments over a broad range of energies. Now, the Van Allen Probes has completed it's 2-year prime mission - in which the orbit apogee precessed through all local times - and the satellites have begun their second swing through the night side of the inner magnetosphere. During that time the Van Allen Probes have developed the most complete statistical picture to date, of the inner magnetospheric environment including the plasma conditions, the composition of plasmas and energetic particles in the inner magnetosphere, and the spatial-temporal-energetic structure of the radiation belts.

While the prime mission phase has seen very low solar activity and very few large storms, the Van Allen Probes mission has observed a surprising diversity of activity and dynamics. We have seen that the "classical" two-belt structure is often an incomplete or inaccurate picture. In addition to the occasional presence of multiple belts, at high energies the inner belt has been essentially absent. In contrast we find low energy electron enhancements are frequently observed in the slot region and inner belt region. Both statistically and for individual events the distribution of plasmas, plasma composition, and energetic particles is highly dependent on energy as well as on solar wind driving and geomagnetic activity. In this talk we will review the mission observations to date. We will explore the energy and activity-dependence at different energies for different species. And we will discuss some of the new observations that challenge our conventional wisdom regarding the inner magnetosphere.

Thursday, Nov. 6

Plenary Session 4a. *Origins of Solar Magnetic Fields, Variability, and Effects at Earth*

Helioseismic Studies of Solar Dynamics

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Understanding the origins of solar magnetism and its cyclic behaviour requires understanding the interplay between solar plasma flows and magnetic fields. Helioseismology provides us with a view into the otherwise invisible solar interior, enabling us to study the dynamical processes in the solar convection zone. Recent progresses in the helioseismic studies of solar dynamics are reviewed.

Empirical, Semi-Empirical, and Physical Models of Solar Irradiance Variability

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The solar irradiance at soft X-ray, EUV, and UV wavelengths plays a central role in determining the state of the Earth's upper atmosphere. The accurate specification and forecasting of the solar irradiance and its variability at these wavelengths is critical to problems ranging from modeling stratospheric ozone to predicting collisions between orbital debris and operational satellites. In this talk we review three approaches to irradiance modeling: empirical - the regression of observations with proxies for solar irradiance, semi-empirical - coupling computed radiance spectra with solar images, and physical - first principles calculations of the density and temperature structure of the solar atmosphere. We discuss the advantages and limitations of each approach. We also show how each approach can be tied to measurements of solar magnetic fields, which are ultimately responsible for driving almost all aspects of solar variability. Finally, we describe the future breakthroughs that are needed to improve our understanding of the sun's radiative output.

Toward Connecting the Sun-to-Earth Picture: What we can do today

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Current modeling capabilities allow us to integrate what we have learned into a broader picture of our local space environment's relationship with the Sun. In particular we describe how one simulation of the interplanetary medium and heliospheric disturbances -ENLIL- has been used as a tool to physically tie together multipoint observations of the Sun, solar wind structure and energetic particle events, and to understand how the evolving solar behavior affects what we experience on Earth. We also consider possible future developments and challenges for this type of endeavor and others like it.

Global Variability of the Outer Radiation Belt: Highlights from Van Allen Probes

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Charged particles can be trapped in the near-Earth space where the planetary magnetic field is approximately dipolar. Trapped electrons accelerated to relativistic energies are (on average) organized in two populations, the inner and the outer belts, separated by a slot region. During increased solar activity the state of the outer belt can highly dynamic: electron intensities can vary by orders of magnitude on the timescales from minutes to days. Understanding dynamic processes in the outer belt is essential for developing our understanding of general energization and transport processes which operate across the universe. Recent measurements from the twin-spacecraft Van Allen Probes mission showed that geomagnetic storms can produce deep depletions of electron intensities across the entire extent of the belt, followed by rapid rebuilding of electron intensities to the levels exceeding their pre-storm values. In this talk we review how our understanding of global variability of the outer belt has evolved with development of better physical models and new multi-spacecraft observational capabilities. We mainly focus on the properties of radial transport and electron acceleration, including recently results on non-diffusive transport and drift orbit bifurcations, and observations and analysis of rapid storm-time dropouts of electrons from the outer belt.

Solar Influences on the Earth's Atmosphere

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This talk will provide a brief overview of solar influences on the Earth's atmosphere, focusing on the effects of impulsive solar events (ISEs) and, more generally, energetic particle precipitation (EPP). Solar energy input is a critical driver of the Earth's climate system, yet the climatic perturbations from solar and geomagnetic variability are poorly understood. The basic mechanisms by which EPP and ISEs are thought to impact the atmosphere will be reviewed. This will include the initial impacts on the ionosphere and upper neutral atmosphere as well as the consequent production of chemically reactive constituents and changes in temperatures and possibly circulation. Empirical evidence for solar variability influences on the atmosphere will be summarized, and will be compared to recent model calculations. Key outstanding questions in the field will be highlighted, and a new NASA Living With a Star focused science team project to address some of these questions, "Response of the Atmosphere to Impulsive Solar Events" (RAISE), will be described.

Plenary Session 4b. *Modeling and Forecasting Space Climate and Space Weather Events*

NASA Heliophysics System Observatory (HSO)

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The goal of NASA's Heliophysics Division is to develop an understanding of the Sun and its interactions with the Earth and the solar system, including space weather. Heliophysics encompasses science that improves our understanding of fundamental physical processes throughout the solar system, and enables us to understand how the Sun, as the major driver of the energy throughout the solar system, impacts our technological society. Heliophysics incorporates studies of the interconnected elements in a single system that produces dynamic space weather and that evolves in response to solar, planetary, and interstellar conditions. The recent launches of Van Allen Probes and the Small Explorer, IRIS, along with the and upcoming launch of the major strategic mission– MMS – and the distributed systems observatory they create in combination, are significant assets allowing our scientific community to achieve major advances in understanding and predicting the space environment.

The heliophysics NRC decadal survey, Solar and Space Physics: A Science for a Technological Society (NRC, 2013), articulates the scientific challenges for this field of study and recommends advances culminating in the achievement of a predictive capability to aid human endeavors on Earth and in space.

The programs, initiatives, and investments in the field outlined in the Survey and codified in the Heliophysics community roadmap are designed to make fundamental advances in current scientific knowledge of the governing processes of the space environment—from the interior of the Sun, to the atmosphere of Earth, to the local interstellar medium. To meet national and societal space weather needs, NASA coordinates its space weather activities with several interagency and international partners.

Panel Discussion: ***Using HSO to Improve Data-Driven Modeling in Heliophysics***

Poster Session – P3/P4 (Poster abstracts are on separate download)
Featuring Plenary Sessions 3a, 3b

Splinter Session S-16 (1a). *Magnetic Energy and Field in the Heliosphere*

Equilibria, Current Sheet Formation and Heating of the Magnetically Confined Corona

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Parker model for coronal heating is investigated within the framework of reduced magnetohydrodynamics (RMHD) in cartesian geometry. Equilibria and nonlinear dynamics are studied numerically giving a new relation for the minimal twist required for dynamics to occur and current sheets to form. These equilibria are shown not to be linearly unstable. Beyond the critical twist nonlinear dynamics lead to current sheets formation, whose thickness is tracked with the analiticity strip method and shown to decrease down to dissipative length-scales on fast ideal Alfvenic timescales. The impact on the heating of solar and stellar coronae will be discussed.

Magnetic Nature of Prominences and CMEs at Different Scales Throughout the Cycle

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Solar magnetic fields tend to twist as they emerge from the photosphere and evolve dynamically in the corona. Described in terms of magnetic helicity or field chirality (handedness) the field structures have a tendency for left-handed (right-handed) to dominate in the northern (southern) hemisphere. Photospheric, chromospheric, coronal and heliospheric forms of magnetic field twist are causally linked forming a highly interconnected system evolving dynamically in space and time. This system may include photospheric vortices, active regions, filament channels and filaments, coronal arcades, CMEs and ICMEs.

I will discuss the formation and evolution of the magnetic systems of filament channels, filaments and CMEs and one of the main characteristics of such systems – the magnetic twist (helicity). How does the magnetic helicity of pre-eruptive and eruptive systems evolve through the different phases of the solar cycle? The answer to this question will help to understand global magnetic field evolution and therefore space climate and weather through the varying cycles.

On Remotely Measuring the Interplanetary Magnetic Field

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Measuring the interstellar magnetic field remotely as it traverses interplanetary space provides significant advancement in our ability to predict the impact of space weather on Earth and at other magnetized bodies. In this talk we present an observational concept for remotely measuring the interplanetary magnetic field and the associated supporting research that is needed for this concept to be realized.

The Heliomagnetic Field 1835-2014

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The is now a broad consensus that it is possible to infer the magnitude [at Earth] of the Heliospheric Magnetic Field, B, from the geomagnetic record extending back to the earliest systematic observations by C.F.Gauss in the 1830s. Several methods by different groups have converged to a well-constrained series of B with estimated errors less than 10%.

Magnetic Flux Density in the Inner and Outer Heliosphere

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The flux density (the normalized radial component) of the heliospheric magnetic field (HMF) has recently been estimated in different methods. Using the modulus of the radial HMF component when calculating the average flux makes the flux values increase with distance, a situation now called the flux excess problem. This is mainly due to the field fluctuations whose relative significance increases for weak fields of the far heliosphere. The flux excess problem can be largely avoided by assuming that the HMF is oriented along the Parker spiral and by removing the perpendicular fluctuations. Thereafter the fluxes observed by different probes at different radial or latitudinal locations are in a good agreement. Naturally, fluctuations along the spiral remain but have only a minor effect on flux variation. We also study the fluctuations in more detail and find that the dominant period of fluctuations varies with solar cycle phase and is different in fast and slow solar wind.

Splinter Session S-17 (2a). *Evolution of Coronal Mass Ejections through the Heliosphere into Geospace*

Propagation and Evolution of Coronal Mass Ejections in the Heliosphere; the STEREO-era

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Since its launch in 2007, data from the STEREO mission has vastly improved our understanding of the propagation and evolution of coronal mass ejections (CMEs) in the heliosphere. The ability to continuously track CMEs from Sun to Earth from multiple viewpoints has been the primary source of these advances. In this talk, I will review the advancements made in the STEREO era connecting solar observations with those made in situ. As well as, outline some issues we still face in understanding the Sun-Earth system.

Earth-Affecting Coronal Mass Ejections

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Coronal mass ejections (CMEs) are the most energetic phenomenon in the heliosphere occurring a few per day during solar maxima and one every other day during solar minima. However, only a small fraction of the CMEs affect Earth by producing geomagnetic storms and solar energetic particles (SEPs). The internal structure of CMEs is important for producing geomagnetic storms because it determine where the southward component of the CME magnetic field. On the other hand, SEPs depend on the outer structure of CMEs, viz., the shock. The coronal and interplanetary environment into which a CME is launched can significantly affect the ability of CMEs in causing these space weather events. This paper discusses various ways in which CME/shock propagation is modified and how the modification affects the Earth impact.

Recent Results on the Longitudinal Distribution of Solar Energetic Particles in the Heliosphere

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With the combined observations from near-Earth spacecraft and the twin STEREO spacecraft, the properties of solar energetic particle (SEP) events can be studied in detail simultaneously from multiple longitudinal locations. These measurements have revealed unexpected characteristics including fast particle intensity rise times from remote sources and broad longitudinal spreading from localized solar sources. With these multi-spacecraft observations it is possible to test theories on the longitudinal dependence of SEP heavy ion composition and how it relates to the properties of the coronal mass ejection and the magnetic connection to each observer. This presentation will review these recent results and discuss their implications for particle acceleration and transport in the inner heliosphere and for space weather predictive capabilities.

Gamma-rays, EUV Wave (Shock), and SEPs Associated with the M1.5 Behind-the-limb Flare on 2013-Oct-11

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On 2013-Oct-11 Fermi detected its first behind-the-limb flare, an M1.5 flare about 10-deg behind the solar limb emitting gamma-rays up to 3 GeV for ~30 minutes. The gamma-ray spectra can be adequately described by a power law with a high-energy cutoff, or as a result of the decay of pions produced by accelerated protons and heavy ions. RHESSI detected hard X-rays produced by electrons well above the limb from the top of the flare loop whose footpoints were occulted. SDO/AIA observed a global extreme-ultraviolet (EUV) wave, likely the low-corona counterpart of a shock (associated with a type II radio burst) which was driven by a fast (~1200 km/s) coronal mass ejection (CME). Both STEREO spacecraft detected energetic electrons, protons, and heavy ions. This rich data set of multi-wavelength observations provides a unique, new opportunity to investigate the relative importance of particle acceleration in the flare vs. CME-driven shock. Our calculation suggests two equal possibilities for the origin of the detected gamma-rays, which can originate from behind the limb and penetrate the solar interior at a grazing angle, or some ions, e.g., accelerated in large loops or at the CME-driven shock, could land on the front side of the Sun and produce gamma-rays there. We discuss the implications of these results for constraining particle acceleration mechanisms in solar eruptions.

Tracking a coronal mass ejection and co-rotating interaction region as they travel from the Sun passing Venus, Earth, Mars and Saturn

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During 2010, there was a good alignment in the inner solar system between Venus, STEREO-B, Mars and Saturn. This has allowed the excellent opportunity to study the propagation of a CME and a closely occurring CIR from the Sun right through to the outer solar system. The CME erupted from the Sun at 01:30 UT on 20 June 2010 with a speed of ~600 km/s, observed from STEREO-B, SDO and LASCO. It arrived at Venus over 2 days later, which was about 3.5 days after a CIR is also detected by Venus Express. This CIR is also observed at STEREO-B and Mars, prior to the arrival of the CME. The CME is not directed towards the Earth, but the CIR is detected here less than 2 days after its arrival at Mars. Around a month later, a strong compression of the Saturn magnetosphere is observed by Cassini, which corresponds to this CIR impacting the planet. At this point it is determined that the CME and CIR have merged into a single solar transient. These transients are also modelled using the ENLIL with cone model. The arrival time of the CME at Venus, STEREO-B and Mars is predicted to within 20 hours of its actual detection, but the predictions for the arrival of the CIR showed greater differences from the observations, all being over 1.5 days early. Much better predictions of the CIR arrival times were found by extrapolating the travel time between different locations using the arrival times and speeds detected by STEREO-B and ACE. We discuss the implications of these results for understanding the propagation of solar transients.

The Internal Structure of ICME Ion Properties, Its Magnetic Structure and Associated Solar Eruption Sources

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A common feature in most solar flare-CME models is the formation of a post-CME current sheet (CS) between the outgoing CME and the post-flare loops at the eruption site. Continuous reconnection inside the post-CME CS presumably heats and accelerates particles that stream upwards to be trapped within the structured magnetic fields of the CME and carried into the heliosphere. Since the ionization states of heavy

ions become frozen-in within a few solar radii, the ion properties inside the interplanetary coronal mass ejections (ICMEs) should bear direct signatures of magnetic reconnection in the coronal environment. In this presentation, we investigate the relationship of the internal structure and variations of ion properties inside ICMEs with its magnetic field structure and the associated solar eruption sources.

Splinter Session S-18 (1a). *Magnetic Energy and Field in the Heliosphere (Part II)*

Magnetic Field Lines and Coronal Loops – A Difficult Relation

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In a 3D MHD model of an emerging active region we study the relation of the magnetic field to coronal loops. At any given time, loops seen in synthesized coronal extreme UV (EUV) emission follow field lines. However, the temporal evolution of magnetic field and EUV loops is different. While the field lines are expanding during flux emergence, the EUV loops are almost stationary-- the field lines move through the loops! This can be compared to a traffic jam: while all cars move, the construction site causing the jam, and thus the high car density remains at the same location. The cars would be the markers of the structure (i.e. fieldlines), while that traffic jam is the pattern we see (i.e. loops in AIA). We find that the coronal loops form due to increased Poynting flux at the outer edge of the sunspots which is caused by magnetic elements moving into the sunspots. Because fieldlines move through these regions of enhanced Poynting flux, the heating on each fieldline changes in time. In the end this is the reason why the fieldlines seem to move through the loops seen in EUV emission.

First Use of Synoptic Vector Magnetograms for Global Nonlinear Force-Free Coronal Magnetic Field Models

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The magnetic field permeating the solar atmosphere is generally thought to provide the energy for much of the activity seen in the solar corona, such as flares, coronal mass ejections (CMEs), etc. To overcome the unavailability of coronal magnetic field measurements, photospheric magnetic field vector data can be used to reconstruct the coronal field. Currently, there are several modelling techniques being used to calculate three-dimensional field lines into the solar atmosphere. For the first time, synoptic maps of a photospheric-vector magnetic field synthesized from the vector spectro-magnetograph (VSM) on Synoptic Optical Long-term Investigations of the Sun (SOLIS) are used to model the coronal magnetic field and estimate free magnetic energy in the global scale. The free energy (i.e., the energy in excess of the potential field energy) is one of the main indicators used in space weather forecasts to predict the eruptivity of active regions. We solve the nonlinear force-free field equations using an optimization principle in spherical geometry. The resulting three-dimensional magnetic fields are used to estimate the magnetic free energy content for the global solar corona. For two Carrington rotations 2121 and 2124, we found that the global nonlinear force-free field (NLFFF) magnetic energy densities are about 15% higher than their respective potentials. Most of this free energies are located above active regions. In the study, we found that spatially, the low-lying, current-carrying core field demonstrates strong concentration of free energy in the AR core, from the photosphere to the lower corona (about 70Mm).

Thermal Diagnostics with SDO/AIA: Applying a Validated Method to Studying Eruptive Active Regions

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The ability to track the thermal evolution of plasma in the Sun's corona is essential for understanding how stored free magnetic energy is converted into thermal energy during eruptive events. We present a new method for performing differential emission measure (DEM) inversions using AIA imaging data. This method has been validated against a diverse set of thermal models of varying complexity and realism. These include (1) idealized gaussian DEM distributions, (2) 3D models of Active Region 11158 comprising quasi-steady loop atmospheres in a non-linear force-free field, and (3) thermodynamic models from a fully-compressible, 3D MHD simulation of AR corona formation following magnetic flux emergence. We then present results from the application of the validated method to studying observed ARs. Finally, we show that synthetic Hinode/XRT images from inversions using AIA data have good match with actual observed images in a broad range of XRT channels.

Joint SDO/AIA and IRIS Observations of Propagating Coronal Disturbances

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Propagating disturbances have been observed frequently in long coronal loops at the edges of active regions. In this study, we analyse AIA imaging observations in different wavelengths and both IRIS Slit-Jaw images and spectral data. Careful alignment and comparing the timing of events in the different wavelengths allows us to track the evolution of these disturbances as they propagate through the atmosphere. Within a spatio-temporal resolution element, the data show a complex and challenging interplay of signatures of shocks, twist, flows and waves.

Flare Clustering

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Since the mid 70's the statistics of flares has been intensively examined because of the clues that they might provide on flare origins or for flare prediction. The scientific debate has continued for more than 40 years in spite of the fact that most papers relay entirely or in part on the x-ray flare data generated by the GOES satellites. Here we report on clustering of flares during cycle 23, which spanned 1997 to 2008. In the maximum of cycle 23, 2000 to 2003, 18.6% of the flares, in a GOES data set containing all flares from C5.0 through X, occurred in clusters that lasted more than a solar disk passage, 13 days (G13_Clusters), and one lasted more than 3 disk passages, 42.6 days. The mean rate of flaring in G13_Clusters was 4.46 flares/day, while outside them the flare rate was i.16 flare/day. G13_Clusters only occurred in solar maximum. These observations indicate; 1) G13_Clusters are created from more than a single active region; 2) There is a global effect because of the much higher sustained rate of flaring in the G13_Cluster periods; 3) If subsequence cycles are similar to cycle 23 it may be possible to predict long periods of enhanced flare rates. The details vary but the same clustering phenomena occurs for GOES data sets with lower thresholds above C1.

Overview of the HMI Coronal Observations

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The Heliospheric and Magnetic Imager (HMI) on board SDO, it turns out, can observe flare sources in an annular domain above the limb, ie in the low corona (Martinez Oliveros et al., ApJ, 780, L28, 2014). We have found that we can make effective use of the Stokes polarimetry of these sources (Saint-Hilaire et al., ApJ, 786, 219, 2014). In this presentation we review the morphology of these sources, which are common in major flares that occur near the limb. The most easily interpretable sources in this database can be identified with loop prominence systems (flare loops). We also give an overview of their properties in the context of EUV images from AIA, spectra from EVE, and soft X-ray and microwave observations.

Splinter Session S-19 (3a). *The Ionosphere: Dynamics, energetics and ion-neutral effects*

Plasma-Neutral Coupling in the Solar Chromosphere and Ionosphere/Thermosphere

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The physics of plasma-neutral coupling adds another layer of complexity to problems that previously have been addressed by assuming a fully-ionized plasma or some other single-fluid approximation. Plasma-neutral interactions modulate momentum and energy exchange among the neutral gas, electrons, and ions, and between the ionized plasma and electromagnetic fields. Plasma-neutral coupling is important in both the solar chromosphere and terrestrial ionosphere/thermosphere.

The solar chromosphere is the highly dynamic, complex region above the relatively cool visible surface of the Sun and beneath the very hot corona. It is characterized by several transitions that occur with increasing altitude: e.g. from predominantly neutral to ionized hydrogen. The chromosphere modulates the flow of mass and energy into the corona.

The ionosphere/thermosphere is a similarly transitional region in the Earth's upper atmosphere, in which the gas is ionized to varying degrees by incident solar radiation. It encompasses the same physical transitions as those occurring in the chromosphere.

In this review, we highlight the commonalities and differences between the chromosphere and I/T in order to develop cross-disciplinary collaboration between the two communities, which typically use different approaches to the same fundamental physics. We conclude with thoughts about current challenges to our understanding of plasma-neutral coupling on the Sun and at the Earth.

This work was funded by NASA's "Living with a Star" TR&T program via the "Plasma-Neutral Coupling" Focused Science Team.

Search for the Drivers of Ionospheric Variability

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Conditions in the ionosphere are more variable than our current knowledge of the key drivers would suggest. Such variability presents difficulties to efforts to predict global ionospheric conditions even 24 hours out, even in the absence of strong solar wind/magnetospheric drivers. In this presentation, examples of the wide range of conditions are discussed, along with the potential explanations for the effects. Further, we describe the approach of NASA's Ionospheric Connection Explorer to resolving the questions regarding this variability.

Atmospheric Wave Impacts on the Ionosphere via Multiple Coupling Pathways

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Wave-like patterns in the density and velocity of the ionosphere that look like and are correlated with the presence of atmospheric waves have been reported in a wide range of observations. Such features offer an opportunity to test our understanding of ion-neutral coupling as there are multiple pathways through which waves in the atmosphere can modify the ionosphere. A serendipitous case study using ground- and space-based observations in which the coupling pathways could be identified will be discussed. The way in which the upcoming ICON and GOLD mission will enable new explorations of these mechanisms will be discussed.

Impact of Tsunami-Generated Gravity Waves on the Ionosphere

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The NRL first-principles ionosphere model SAMI3 is used to study the ionospheric effects associated with tsunami-driven gravity waves. It is shown that gravity-wave induced variations in the neutral wind lead to plasma velocity variations both perpendicular and parallel to the geomagnetic field. Moreover, the electric field induced by the neutral wind perturbations can map to the conjugate hemisphere. Thus, electron density variations can be generated in both hemispheres which impact the total electron content (TEC) and 6300A airglow emission. It is found that the TEC exhibits variations +/- 0.15 TECU and the 6300A airglow emission variation is up to +/- 2.5% relative to the unperturbed background airglow. These results are consistent with observational data.

Research supported by NRL Base Funds, NASA LWS program, and ONR BRC program.

How the Thermosphere Shapes the Quiet-Time Plasmasphere

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The Naval Research Laboratory SAMI3 (Sami3 is Also a Model of the Ionosphere) code[1] is used to model observed plasmasphere dynamics for 2001 February 1--5, a period of quiet time refilling[2]. The SAMI3 model is driven at high latitudes by the magnetospheric potential calculated by the Weimer05 empirical model, using the observed solar wind. At mid-to-low latitudes, the self-consistent dynamo potential is included, driven by specified winds. During this quiet period we find that the shape of the plasmasphere, at any given time, varies significantly with the wind model even as a similar degree of model-data agreement is recovered for each of the three wind models used. Diurnal oscillations in the model electron density, a result of a non-round plasmasphere measured at a fixed local time, are consistent with the degree of variation seen in the measured densities. In all three cases, SAMI3 compares favorably to electron density measured in situ by the IMAGE spacecraft. Results with no winds or with specific wind effects excluded show that wind-driven ExB drifts shape the plasmasphere, relative to a round plasmasphere with no winds, and reduce the refilling rate, relative to the higher refilling rate found without winds.

Research supported by NRL base funds and the NASA LWS program.

[1] Huba, J. and J. Krall, "Modeling the plasmasphere with SAMI3", *Geophys. Res. Lett.,* 40, 6-10, doi: 10.1029/2012GL054300, 2013.

[2] Krall, J., J. D. Huba, R. E. Denton, G. Crowley, and T.-W. Wu, "The effect of the thermosphere on quiet-time plasmasphere morphology", *J. Geophys. Res. Space Physics,* 119, 5032-5048, doi: 10.1002/2014JA019850, 2014.

The Disappearance of the Post-Midnight High Energy Ion Plasmasphere

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The Van Allen Probes Helium Oxygen Proton Electron (HOPE) instrument measures a high energy tail of the thermal plasmasphere that has strong MLT dependence in the near Earth space. In our study, we statistically analyze a 16 month period of HOPE data, looking at quiet times with a Kp index of less than 3. The high energy plasmasphere tail is the upper 5% of plasmasphere energies, consisting of ions between 1 - 10 eV. We calculated plasma densities over this energy range and see that there is strong depletion in O+ and H+ from 1-4 MLT and a similar but less dramatic density decline in He+. Our results are compared with the Van Allen Probes Electric Fields and Waves (EFW) instrument space craft potential to rule out spacecraft charging. We conclude that the post-midnight ion disappearance is due to diurnal ionospheric temperature variation and charge exchange processes.

Splinter Session S-20. *Hinode/IRIS: Origins of the Solar Wind*

Prevalence of Micro-jets from the Network Structures of the Solar Transition Region and Chromosphere

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IRIS observations in the 1330Å, 1400Å and 2796Å passbands have revealed numerous small-scale jet-like features with speeds of ~80-250 km/s from the chromospheric network. These network jets occur in both the quiet Sun and coronal holes. Their widths are often ~300 km or less. Many of these jets show up as elongated features with enhanced line width in maps obtained with transition region (TR) lines, suggesting that these jets reach at least TR temperatures and they constitute an important element of TR structures. The ubiquitous presence of these high-reaching (often >10 Mm) jets also suggests that they may play a crucial role in the mass and energy budgets of the corona and solar wind. The generation of these jets in the network and the accompanying Alfven waves is also consistent with the "magnetic furnace model" of solar wind proposed by Axford & McKenzie (1992). The large speeds (greater than sound speed) suggest that the Lorentz force (perhaps related to reconnection) must play an important role in the generation and propagation of the network jets. We believe that many network jets are the on-disk counterparts and TR manifestation of type-II spicules.

A Search for the Origin of the Slow Solar Wind using Full Sun Spectroscopic Observations from Hinode

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Fast and slow winds flow from the Sun, fill the entire solar system with hot gas, and affect the Earth's near space environment. The fast wind originates from the Sun's polar regions, but the source regions of the slow wind have long been debated. Using new measurements from the Hinode satellite, we have identified the most likely sources by constructing a map of the whole Sun that shows areas where plasma with the same chemical composition as the slow wind is flowing out from the solar atmosphere on open magnetic field lines. This comprehensive observation and analysis allows us to account for most of the mass flux observed at Earth. For these observations, taken near solar maximum, we find that the most significant sources of the slow solar wind are outflows from the edges of sunspots.

Elemental Abundances of Plume and Interplume Regions: Identifying the coronal source of the fast solar wind

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Plumes are relatively bright, narrow structures in coronal holes that extend along open magnetic field lines far out into the corona. It is not known whether the plume or interplume regions are the preferred channel for supplying material into the fast solar wind from coronal holes. Elemental composition is one way to identify the source region of solar wind observed in-situ. Extensive coronal measurements show abundances anomalies in the solar corona, in which elements with a low first ionization potential (FIP) < 10 eV are enhanced relative to the high FIP elements. In-situ measurements show that the composition of the fast solar wind is nearly photospheric. Remote sensing spectroscopic measurements show that interplume regions also have a photospheric composition. In contrast, the elemental composition of plume material is still unclear, in particular whether or not they are subject to the FIP effect. In this work, we measured the FIP bias, i.e. the ratio of coronal to photospheric abundances, in both interplumes and plumes using Hinode/EIS data. Using spectral line intensities and Differential Emission Measure analysis, we access the chemical composition of plumes and interplumes over one week in March, 2007. Previous measurements in active regions indicate that the magnitude of the FIP bias seems to depend on the plasma confinement time. We analyzed the evolution in time of the plume FIP bias, and then compared our results with the age and lifetime of the plume.

Determination of the Abundances of Polar Jets using Hinode/EIS and an Investigation of the Relationship with the Fast Solar Wind

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With X-ray observations, we can find many jets caused by reconnection in the Sun's polar region, and they are thought be a fast solar wind source. The ejected plasma along the jets can contribute mass to the solar wind. From the in-situ measurements in the magnetosphere, it has been found that the fast solar wind has photospheric abundances while the slow solar wind has coronal abundances. Therefore, we investigated the abundances of polar jets to determine whether they are the same as that of the fast solar wind. For this study, we selected jets in the polar region observed by Hinode/EIS and XRT simultaneously on 2007 November 3. We calculated the FIP bias factor from the ratio of the intensity between high (S) and low (Si, Fe) FIP elements using the EIS spectra. The values of the FIP bias factors for the polar jets are around 0.7~1.0, which indicates that they have photospheric abundances similar to the fast solar wind. The results are consistent with the reconnection jet model where photospheric plasma is rapidly ejected into the fast wind.

Determining the Location of Open Magnetic Field Areas in Active Regions and their Potential as Sources of the Slow Solar Wind

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Discovery of persistent plasma upflows from active region (AR) peripheries by the Hinode X-ray Telescope (XRT) and EUV Imaging Spectrometer (EIS) instruments attracted considerable attention since the flows could contribute ~ 25% of the slow solar wind if they reached the heliosphere. However, strong evidence for arrival of AR plasma in the slow solar wind measured by the ACE spacecraft has been established for only two AR complexes observed in December, 2007 and January, 2008. The present work seeks to enlarge the scope of these results by examining upflows from seven ARs observed in 2011 and 2012. These ARs were located over a range of latitudes, have a range of ages and were found with different neighbours e.g. other ARs, coronal holes. For each of the ARs examined, between one and four associated peripheral upflow regions were identified. Hinode/EIS was used to delineate the upflow regions, measure the flow velocities and establish the First Ionisation Potential (FIP)-bias of the upflowing plasma. For each of the observed ARs a potential field source surface (PFSS) model was constructed to determine the magnetic topology of the global field at times when the upflows were observed. In the presentation, the relationship of FIP-bias to the topology will be assessed and the presence of closed or open field regions and the role of separatrix surfaces will be examined for all of the upflow regions. Possible upflow contributions to the slow solar wind will be reviewed and future directions for AR upflow work will be discussed.

Strong Blue Asymmetries in IRIS Line Profiles: Identifying Heliospheric Tributaries

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We identify strongly blue-shifted asymmetries in the FUV and NUV line spectra of the magnetized chromosphere and transition region as observed by IRIS. We demonstrate the spatial and temporal dependence of these asymmetries in addition to their characteristic appearance in the optically thick MgII and optically thin Si IV lines. These asymmetries unequivocally correspond to (Type II) spicules and associated phenomena observed by IRIS and Hinode. Further, on many occasions, these asymmetries have coronal counterpart emission that are readily observed by Hinode and SDO/AIA and are tributaries to the outer solar atmosphere. These complex spectra at the root of the heliosphere require high-level data analysis, and possibly point to a much more complex magneto-thermal interface to the corona and helisophere than we might have thought before the launch of IRIS. We discuss points of exploration for any Hinode follow-on mission.