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Helicity-driven sigmoid evolution and its role in CME initiation

Recent observations of rotating sunspots in TRACE white light images and their apparent association with soft X-ray sigmoids have led to the intriguing possibility that observations of sunspot rotation serve to identify the driver for sigmoid formation, evolution and their potential eruption. A number of rotating sunspot events have now been observed, many associated with some of the largest solar flares and CMEs of this solar cycle. We propose to explore the energization of the corona resulting from the observed rotational motions of the sunspots. In particular we will focus on the relationship between the sunspot rotation and the evolution of sigmoid structures with the objective to determine the key physical conditions that govern whether a sigmoid will destabilize and produce a CME. The role of the coronal helicity injection implicit in the sunspot rotation will be explored as the 'proximate cause' for the sigmoid evolution. This study will lead to a better understanding of the physics that determines the conditions for sigmoid eruption and, consequently, may lead to a useful forecasting tool for predicting geo-effective events.

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LWS02-0096-0020

Energy Scaling of Flare Phenomena During the Solar Cycle

Quantifying and physical modeling of the energy scaling of flare-related phenomena on all scales is important to arrive at a better understanding of the solar variability and solar-terrestrial interactions. We propose to investigate the statistics of geometric and physical parameters that control the energy scaling of solar flare phenomena during the solar cycle (from nanoflares to CMEs). Since the volume represents the most decisive parameter for the energy estimate of a flare process, we pursue a new and more sensible approach to measure first the fractal geometry (using Yohkoh, TRACE, SoHO/MDI, and EIT images), to quantify the accurate scaling laws between observed length scales, projected areas, and volumes. Combined with the measurements of other physical parameters, such as time scales, densities, temperatures, and magnetic field strengths, we develop then physical models of the scaling laws between observed parameters. The frequency distributions and correlations between different solar activity indicators in different wavelengths can den be quantified from first principles, permitting us to use one solar activity indicator as a proxy for another and to predict the energy content of various solar flare-associated phenomena in an early-warning phase.

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LWS02-0054-0033

Stratospheric Modulation of Terrestrial Climate during the Solar Cycle

We propose a diagnostic investigation of the physical mechanisms linking the solar cycle to terrestrial climate variability. It is well known that UV variations associated with the solar cycle modulate the upper stratospheric circulation. The solar cycle is also observed to be related to annular atmospheric variability in the lower stratosphere and troposphere. The physical mechanisms for the latter linkages remain elusive, however. Recent studies postulate both indirect and direct dynamical mechanisms in which the stratosphere can modulate tropospheric climate (Shindell et al. 1999, Black 2002). We hypothesize that the stratosphere provides the "missing" dynamic link between the solar cycle and terrestrial climate variability. The modulation of terrestrial climate by the solar cycle will be examined by comparatively testing the ideas put forward in the two studies mentioned above. Our primary objectives include (1) characterizing the typical stratospheric and tropospheric dynamic structures associated with the solar cycle and (2) diagnosing the mechanistic interaction among these structures, focusing particularly on the downward influence of stratospheric circulation anomalies. These objectives will be pursued with a combination of (a) quantitative diagnostic analyses of space-based and ground-based observations of the Earth System and NASA/GISS GCM output and (b) diagnostic modeling analyses. The indirect mechanism will be tested by assessing Eliassen-Palm fluxes, refractive indices, and forcings of the Transformed Eulerian-mean circulation. The direct mechanism will be studied by applying potential vorticity inversion methods and diagnostic downward control principles. The proposed research is aimed to provide an improved scientific understanding of the physical mechanisms linking the Sun-Earth system. In doing so, the project will address some of the primary research objectives of NASA, the Space Science and Earth Science Enterprises, the OSS Sun-Earth Connection Theme, and the Living With a Star Research Program. The results will likely provide useful information for assessing the potential for future predictive efforts and helping focus the needs of future NASA space missions. Black, R.X., 2002: Stratospheric forcing of surface climate in the Arctic Oscillation. *J. Climate*, 15, 268-277. Shindell, D. T., D. Rind, N. Balachandran, J. Lean, and P. Lonergan, 1999: Solar cycle variability, ozone, and climate. *Science*, 284, 305-308.

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LWS02-0000-0025

Physics of Coronal Wave Fronts: Coronal Pulse Waves as a Predictive Tool for CME Properties

We propose to study coronal pulse wave fronts as a diagnostic tool to characterize solar coronal mass ejection (CME) events. Such waves ("EIT waves", "Moreton waves", and "SXT waves") are frequently observed in conjunction with CME onset, but so far are poorly understood. By systematically comparing existing CME catalogs with archival data from several instruments, we will identify the currently debated relationship between wave fronts and the CMEs that give rise to them. Further, we will develop tools to semi-automatically identify, extract, and summarize physical wave parameters from existing high cadence TRACE observations that include pulse wave fronts; these data are a good proxy for the prototype operational data from SDO. By quantitatively relating these wave parameters to conditions and effectiveness of past CMEs (including confounding variables), we will develop an empirical predictive tool for rapidly estimating kinetic energy and geoeffectiveness of future CMEs, potentially greatly improving operational space weather forecasts from near-Earth telescopes. This work, while directed toward development of a space-weather predictive tool, has other important consequences for solar physics. Wave observations provide a unique window into the kinetic energy release profile of CME liftoff events, helping to constrain models of CME onset; measurements of wave propagation yield a powerful probe of the plasma through which they propagate; and wave energy dissipation and scattering, which are directly observable in these large-scale mixed-mode waves, are important to the physics of coronal heating.

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LWS02-0000-0043

Solar EUV Variability Modeling with CHIANTI

A principal component of NASA's LWS program is to understand the mechanisms of solar EUV variability and its effect on the Earth. NASA recently selected the EVE investigation to observe and model solar variability within the SDO program. The EVE investigation makes use of the NRLEUV physics-based model for solar EUV variability studies. This model is in turn largely based on the CHIANTI database for astrophysical spectroscopy. CHIANTI currently incorporates essentially all publicly available excitation and radiative rates for modeling the necessary solar EUV optically-thin emission lines. However, the ability to model the solar spectrum accurately is limited by at least two factors that we will attempt to correct with the work proposed here. First, atomic data for a number of strong lines, particularly at X-ray wavelengths, need to be incorporated into CHIANTI. Second, the differential emission measures derived from lines of different iso-electronic sequences often do not agree to within unexpectedly large factors. This can almost certainly be traced to errors in the ionization equilibria used to model solar spectral line intensities. We will review the available ionization and recombination rates, including the latest calculations and measurements. Of particular importance is the inclusion of the density sensitivity of dielectronic recombination which is not included in recent calculations of ionization balance. These rates can be reduced by a factor of about 10 at coronal densities as compared with the low electron density rates commonly used. We will calculate new ionization equilibria based on the best currently available atomic data and determine their ability to improve solar EUV variability modeling.

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LWS02-0066-0107

Ionospheric response to short term variations in the solar flux

The proposed comparison of the electron density data with solar soft x-ray fluxes will provide quantitative measures of the dependence of the electron density, TEC and hmF2 on the solar measurements for a variety of time scales. While the solar flux is responsible for the ionization rate, it is also responsible for changes in other parameters which affect the observed electron density data. More specifically, while the ion production rates, neutral densities and winds all depend on the solar fluxes, the neutral parameters and ion production have different time dependencies on the solar flux. Ions are produced by the current solar flux. In contrast, there is a time lag of ~ 1 day between changes in the solar fluxes and neutral densities at F region altitudes. Analysis of the time dependencies is needed for the future use of solar soft x-ray fluxes. This information is needed for incorporating short wavelength solar flux measurements, rather than F10.7, into model calculations.

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LWS02-0000-0084

Refining and understanding the auroral electrojet indices

The rationale for the proposed research is based on the current understanding of the energy flow from the Sun via the solar wind through the magnetopause and into the upper atmosphere. Only a few percent of the kinetic energy available in the solar wind impinging on the dayside magnetopause is extracted by the magnetosphere yet this is the driver of the dynamic and steady state plasma processes in the earth's magnetosphere and ionosphere. After intermediate storage in the tail the primary sinks for this energy are the ring current and the ionosphere, where energy is dissipated in the form of Joule heating and particle heating. During substorms the ring current does not intensify and hence the ionosphere is the dominant energy sink. All of these sinks result in the creation of electric currents, the cross tail current, ring current in the heart of the magnetosphere, and ionospheric currents in the high latitude region. For many decades the latter two currents have been studied via the magnetic fields that the currents create, as measured by ground-based magnetometers. In the mid-1960s Sugiura and coworkers created magnetic indices in attempts to provide quantitative monitoring of the dominant current system, Dst for the ring current [Sugiura, 1964] and the auroral electrojet indices [Davis and Sugiura, 1966] for the horizontal ionospheric currents. Through their extensive use these indices play an important role in statistical studies as well as case studies of the complex solar wind-magnetosphere-ionosphere system. We show that a refinement and better understanding of the auroral electrojets and their indices is important for a number of scientific and practical reasons.

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LWS02-0000-0132

Pacific centers of action: linkage between the solar cycle and regional climate variations

Recent work carried out at Stony Brook University has presented evidence that the atmospheric Centers of Action in the North Pacific, the Aleutian Low and the Hawaiian High pressure systems shift their geographical positions significantly between solar minimum and maximum conditions, and also, that such changes in the Centers of Action are correlated significantly with the interannual variations of winter temperature and precipitation in several regions in North America and Asia. The goal of this project is to further understand this sun-climate link and to study the hypothesis that regional climate changes caused by the Pacific Centers of Action act to amplify the relatively small solar forcing to produce large perturbations in regions of North America and Asia. We propose to use an integrated approach of data analysis from satellites, NCEP reanalyses and GCM simulations with solar cycle forcing. The specific tasks detailed in the proposal are: i) integrated analysis of satellite measurements, operational reanalysis products, and conventional meteorological measurements to study the temporal and spatial structures of the sun-Centers of Action-regional climate relationship; ii) hypothesis study of the mechanism of the sun-climate relationship through amplification feedback processes of the atmospheric action centers.

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LWS02-0000-0103

Solar Wind Structure from Measured Boundary Conditions

We propose a focused investigation of existing spectral and magnetic observations from SOHO to quantitatively deduce the physical properties of observed outflows (velocity, mass flux, surface area) in both polar and equatorial coronal holes. These quantitative observations of velocity, mass flux and field geometry will be used as boundary conditions for a solar wind model which will be compared with direct heliospheric observations, and which could potentially be used to predict strength and location of solar wind velocity structure such as co-rotating interacting regions. Comparison of our solar wind model to heliospheric observations will help empirically determine the relationship and coupling between heliospheric boundaries (between fast and slow solar wind), surface velocity structures and magnetic field geometry. This will enable us to develop and put constraints on potential predictive capability, assessing the potential of this technique as an improved tool to predict solar wind and heliospheric conditions from future Dopplergrams, spectral images and magnetograms. This work builds upon previous work (NASA SEC GI Grant NAG511594 "Structure and Dynamics of the TR and Corona") by quantitatively applying the observed coronal hole outflow velocity structure to a solar wind model, and comparing it with direct heliospheric in-situ observations to understand and potentially predict heliospheric conditions and related non-CME geomagnetic events.

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LWS02-0000-0075

The Collaborative Sun-Earth Connector

The success of the LWS program demands that scientists be able to navigate through a complex, distributed data system to find the data they need; efficiently cull through possibly peta-bytes of data to acquire the relevant information; and assimilate data from multiple instruments and missions reactively or proactively via intelligent interpretation, comparison and fusion. A working environment and data assimilation infrastructure that presents the LWS components as an integrated, robust system is essential to keeping the focus on the science rather than on data management - and this system must be operational when SDO is launched in 2007. We propose to develop a test-bed, distributed data system that can meet this goal. The Collaborative Sun-Earth Connector (CoSEC) will merge the successful components of current state-of-the-art prototype systems, including the "Problem-Solving Environment for Living with a Star" (PSELWS), the "European Grid of Solar Observations" (EGSO) and the "Virtual Solar Observatory (VSO), as well as on-going development of SolarSoft applications. PSELWS will provide the basic system architecture; ESGO and VSO will provide integration into the grid infrastructure -- with its security and resource-allocation capabilities -- and unified data descriptions. The CoSEC system will be populated with application services to support space weather prediction, space climate characterization and Solar-B and STEREO data analysis operations. A flare forecasting application will build upon these services to assess the performance of CoSEC and to form the foundation of a distributed, empirical tool for space weather forecasting -- the first space weather "killer-app". At the end of this three-year project, the CoSEC test-bed will have laid the groundwork for implementing a complete LWS/SDO data system.

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LWS02-0018-0006

Modeling the Long-Term Variations of Energetic Trapped Protons

We propose to develop methods to model the secular, seasonal, and solar cycle variations of the energetic protons in the Inner Zone. The effort will involve merging data from the low altitude POES and SAMPEX spacecraft as well as from CRRES to develop a data base of proton data covering more than two solar cycles and energies from 1 to 500 MeV. Each of these spacecraft has unique advantages and disadvantages. CRRES provides good energy resolution and covers essentially the entire radiation belt region, but the data extend only up to 100 MeV. SAMPEX provides data out to 500 MeV, but only at low altitude. POES has relatively poor energy resolution, but provides data covering more than two solar cycles. The spacecraft data will be augmented with simulations performed using the Salammbô code in order to extend the spatial region of validity of the low altitude SAMPEX and POES data. In addition, we will develop a statistical model which for the first time will allow spacecraft designers to predict proton fluxes as a function of confidence level for any time period of interest. This trapped proton model will allow the design of more capable and robust spacecraft, and will also provide valuable insight into the source, transport, and loss mechanisms operating in the radiation belts. This project is a collaboration of researchers from the U.S. and Europe and thus provides the maximum return for NASA funding.

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LWS02-0000-0071

Heliospheric Disturbance Propagation from Remote Sensing Observations - Data Analysis and Modeling

Earth, immersed in the Sun's atmosphere and bombarded by solar high-energy particles, reacts to these inputs in a variety of ways. We now know that the largest solar coronal disturbances, called coronal mass ejections or CMEs, are the cause of major geomagnetic storms, which can create hazardous conditions affecting satellites and astronauts in orbit, communications, and even ground-based systems. At UCSD we have been at the forefront of remote sensing studies of the origins and propagation of CMEs, and their effects on geospace. We have developed a tomographic technique to track these disturbances outward from the Sun. We are also involved in the construction of the Solar Mass Ejection Imager (SMEI) to be launched in February 2003. At present there is no effective way to track interplanetary disturbances crossing the large gulf between the solar corona and Earth. If successful, SMEI will revolutionize the way we are able to measure heliospheric features and forecast their arrival at Earth by measuring CMEs from near the Sun until they strike Earth 2-3 days later. To understand and forecast how solar transients are produced and propagate, we need to study the origins, interplanetary propagation and signatures of CMEs, and to develop techniques to measure and model heliospheric plasma and their interactions from a global perspective. To accomplish these objectives we propose to: 1) Develop our heliospheric tomography programs for use in extrapolating magnetic field data outward from the solar surface; and 2) Incorporate existing 3D-MHD programs into our tomography technique. 3) Develop SMEI analysis techniques that use the 0.1% differential photometric precision required for tomographic analysis so that other groups can use these data. Our proposed program is relevant to NASA's Sun-Earth Connection Theme and the techniques developed will be pertinent to future NASA space missions such as STEREO, Solar Dynamics Observatory, Telemachus and ESA's Solar Orbiter.

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LWS02-0000-0125

Development of high time resolution sensors for the detection of pulsed electron beams employed to measure electromagnetic fields.

Electric fields are important agents of charged particle dynamics and acceleration in space. They influence many ionospheric, magnetospheric and heliospheric plasma processes. Yet, due to the difficulties inherent to classical electric field measurement techniques for spaceborne platforms, electric fields are still not well enough understood. New techniques like electron drift instruments (EDI) have been developed and successfully applied to overcome these shortcomings. More recently, multi-beam electron drift instruments (MEDI) have been proposed and studied to greatly enhance the capabilities of electron drift measurements while simultaneously significantly reducing the resource requirements compared to current EDI technology. We propose to study the sensor component of such a MEDI instrument. In departure from presently used devices, these instruments will use CDMA-style encoded electron beams emitted from spacecraft to determine the ambient electric fields and magnetic field gradients by measuring the travel time of electrons returning to the spacecraft with nanosecond accuracy. The technological requirements for this type of instrument suggest the use of avalanche photodiodes (APD) as detector technology for MEDI. We propose to study the feasibility of using APD sensors for this application. We will describe the technological framework under which their deployment will be possible, address issues relevant to operating under the influence of solar UV photons, and investigate any design requirements resulting from the use of APD sensors for the other components of a MEDI instrument.

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LWS02-0007-0011

The geoeffectiveness of solar cycle 23 as inferred from a physics-based storm model

The energization of the ring current and its subsequent decay is the central aspect of geomagnetic activity. However, what mechanisms are responsible for energizing particles and for causing their loss, and how the relative importance of these mechanisms depends on the field and flow parameters in the near-Earth interplanetary (IP) medium as it varies over the solar cycle, are issues not well understood. In this proposal we aim at investigating these issues for solar cycle 23 using the continuous coverage of IP parameters provided by NASA's ACE and Wind satellites. By selecting a representative variety of temporal profiles of IP parameters during geomagnetic storms of $Dst < -80$ nT (i.e., moderate to major storms), we shall determine how the following phenomena known to be important in generating strong ring currents, are related to solar cycle phase: a) the spatial and temporal variability of the convection electric field; b) enhanced ionospheric outflows and nightside plasma sheet densities; c) saturation of the polar cap potential with the interplanetary electric field, and d) the strength of the ring current as a reflection of the changing activity in this solar cycle. For this task we shall employ our physics-based numerical code driven by models of the convection electric field tailored to the temporal profiles of IP parameters. A particular focus of this effort will be to extend our model to address the behavior of electrons of both non-relativistic and relativistic energies during storms, and the IP drivers/internal mechanisms which determine this behavior. The proposed work furthers the objectives of NASA's Living with a Star (LWS) program by a) addressing the energy flow through the solar wind - magnetosphere - ionosphere system during stormtime, since we include an electric field based on IP parameters, b) seeking to forecast strong ring currents through an investigation encompassing the whole range of solar activity seen in this cycle, and c) providing information on radiation belt electron dynamics, which can be used to reduce hazards to humans and technological systems during storms.

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LWS02-0000-0101

Empirical Low Energy Ion Flux Model for the Terrestrial Magnetosphere

This proposal addresses the Living With a Star (LWS) Targeted Research and Technology Program's Aeronautics and Space Transportation Strategic Enterprise. The purpose of this work is to develop an empirical low energy ion model of the Earth's magnetosphere incorporating ion flux observations from multiple satellites in a statistical flux model. Activities described in this proposal will exploit data from present space missions (Geotail, Polar) for the purpose of characterizing surface dose radiation environments and producing models that aid in design of more reliable subsystems for space transportation systems. Our goal is to develop an improved predictive tool for magnetospheric ion flux environments over a range of energies from 50 keV through 1 MeV for varying geomagnetic disturbance levels in the geospace environment. This model will provide an improved predictive tool that can be used to mitigate harmful effects on human technologies. A secondary objective of the proposal supports the LWS Characterization of Space Climate objective by enabling cost-effective design of scientific spacecraft and subsystems by providing design tools to minimize space environmental effects and damage. Finally, the proposed technique to incorporate ion flux observations from multiple spacecraft in a single statistical flux model yields a simple and cost-effective technique for assimilating data from networks of research spacecraft.

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LWS02-0037-0019

Seismic Study of the Solar Subsurface based on Robust Time-Distance Inferences

I propose a 3 year program to develop, refine and strengthen the analysis methods needed to provide robust and reliable diagnostic methodology for the solar sub-surface using time-distance analysis. I propose to continue and expand the work done in time-distance analysis at the Smithsonian Astrophysical Observatory (SAO). The proposed work will focus on both data analysis -i.e. the computation of time anomalies- and on inversion techniques for structure and dynamics, in quiet and active regions. The focus of the work proposed at SAO will be aimed at the error analysis and the trade-off between precision and resolution. Error estimates for time anomalies are a key ingredient to adequately scale the inverse problem as well as to properly assess the uncertainty and the resolution of inversion inferences. Surprisingly most results in time-distances have ignored this key aspect of the analysis. Additional work in inverse techniques is also proposed. On one hand, additional simulations can and will help us establish the observational precision and resolution needed to extract credible information. On the other, there is a need to continue developing the forward model, especially in terms of adequate kernels. Finally, in order to invert velocity flows that are consistent with basic physical principles we must find an effective way to include a mass conservation constraint. Our current implementation is only a first step in that direction. I thus propose to contribute to the development of a robust Time-Distance data analysis and inversion methodology. It will allow us to better characterize the actual diagnostic potential of the method and to better understand the bias in the inferred solutions introduced by the topology of the associated annihilator, while addressing the issue of trade-off between resolution (in time and space) and error magnification. Such development of time-distance analysis techniques is a key element to ensure the full scientific return of the Helioseismic and Magnetic Imager that will fly on board the Solar Dynamics Observatory, a key mission of the Living with a Star initiative.

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LWS02-0000-0093

Injection of Magnetic Helicity into the Corona

Coronal mass ejections (CMEs) -- the major source of geomagnetic disturbances -- carry magnetic flux and helicity from the sun into interplanetary space. The magnetic helicity quantifies how the magnetic field is distorted and stressed beyond its lowest energy state. Such stressed states are associated with solar flares, filament eruptions and CME onsets. Thus, it is important to examine solar observations for the sources of this helicity. Recent studies show that emergence of subsurface helical fields into active regions is the most important source of coronal helicity. We will use new methods to analyze high-resolution solar vector magnetograms and find the places and rates of helicity transfer into the corona. We will analyze the magnetograms already obtained with the Imaging Vector Magnetograph to follow the flow of helicity over time scales of minutes to days. We will compare this flow to CME activity and to helicity measurements in magnetic clouds. We will try to determine which signatures of the magnetic helicity developments in active regions might be useful for forecasting CMEs. During the proposed three-year effort, we will also analyze new data, to be obtained in cooperation with the Institute for Astronomy in Hawaii during campaigns supporting the RHESSI mission.

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LWS02-0000-0069

Energetic Particle Acceleration at CME-driven Shocks

We propose a three year program to analyze the energetic particle signatures produced by interplanetary shocks driven by coronal mass ejections (CMEs) at their arrival at 1 AU. We will use data from the magnetometers and solar wind experiments on board the Advanced Composition Explorer (ACE) and the Interplanetary Monitoring Platform (IMP-8) to determine the physical characteristics of such shocks (i.e., strength, normal vector orientation, Mach Number, magnetic compression ratio, and speed). In order to determine the effects that shocks have on energetic particle population, we will use energetic particle data from the Charged Particle Measurements Experiment (CPME) and Energetic Particle Experiment (EPE) on board IMP-8, the Energetic Proton Alpha Monitor (EPAM) and Ultra Low Energy Isotope Spectrometer (ULEIS) on board ACE, and the Energetic Particle Sensor (EPS) on board the Geostationary Operational Environmental Satellites (GOES). The large angular coverage and high-time resolution of ACE/EPAM will allow us to study the anisotropy flow of energetic ions in both the upstream and downstream regions of the shocks. The high-time resolution of the magnetometer on ACE will allow us to determine the level and frequencies of hydromagnetic wave turbulence associated with the shocks or generated by the energetic particles. The high sensitivity of ACE/ULEIS will allow us to determine the elemental abundances of the energetic particle enhancements observed in association with the shocks. We will correlate shock characteristics with the energetic particle effects. We will perform detail analyses of the most intense events and distinguish those events consistent with predictions of the current shock acceleration theories and those events in which additional mechanisms play important roles, such as trapping of particles around the shock, and/or contribution of additional sources of particles. We will also use an existing simulation model to understand the effects that the shock structure, the upstream medium and seed particle population have on the formation of ESP events. We will determine (1) the acceleration mechanisms working at the CME-driven shocks; (2) the seed particle population of the ESP events; (3) the energy gained by this seed particle population; (4) the effects of magnetic structures formed in the upstream and downstream regions of the shocks; and (5) the origin, characteristics, and effects of the hydromagnetic wave turbulence associated with the shocks.

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LWS02-0000-0012

Characterizing Solar Farside Images for Space Weather Applications with Near-Real-Time GONG+ Data

We propose to 1) develop near-real-time compression and transmission of the images needed for farside imaging from the six GONG instruments around the world; merge the data to a uniform time series; and produce and distribute in a timely manner farside proxy images on a regular basis. In order to enhance the space weather predictive capabilities of the farside images, we propose to 2) compare full-disk photospheric and chromospheric magnetograms with holographic images of the nearside and farside of the Sun derived from helioseismic data to quantitatively determine the characteristics (distribution, strength, complexity) of active region magnetic fields associated with seismic signatures, and the relationship between changes in the seismic signatures and the evolution of the magnetic field.

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LWS02-0000-0049

Dynamics of Radiation Belt Electrons Associated with Solar Wind Variations

The objective of the proposed work is to enhance our understanding of the physical mechanisms governing the variation of relativistic electrons in the inner magnetosphere. Outer radiation belt electrons vary on solar cycle, semiannual, and solar rotation time scales, and with geomagnetic storms. The basis of this proposal is the recent achievement of exciting new results in predicting the MeV electron flux at geosynchronous orbit 1-2 days in advance [Li et al., 2001a] based on measured solar wind parameters. This work provides a resolution to several long-standing mysteries of the variations of the MeV electron fluxes around geosynchronous orbit. The results have also raised new questions. For example, while the variation of MeV electrons at geosynchronous orbit can be attributed mostly to the variation of solar wind velocity itself, the variation of MeV electrons deeper inside the magnetosphere ($L < 5$) is highly correlated with the Dst index, a measure of magnetic activity and storms [Li et al., 2001b], which itself is mostly dependent on the B_z magnetic component of the interplanetary magnetic field (IMF). What is the physical basis behind the different behaviors of MeV electrons in different regions? In particular, can our MeV electron prediction model (after modification) also make quantitative prediction of MeV electron flux inside geosynchronous orbit, even down to the International Space Station orbit? These are some of the questions to be addressed in the proposal. We propose to first make a better prediction of the electrons throughout the outer radiation belt based on trial-and-error, then to interpret it in terms of physical understanding. This method has been proved to be successful at the outer edge of the outer radiation belt and shall lead to a better understanding of the physical mechanisms governing the variations of relativistic electrons in the inner magnetosphere. [Li et al., 2001a] Li, X., M. Temerin, D. N. Baker, G. D. Reeves, and D. Larson, Quantitative Prediction of Radiation Belt Electrons at Geostationary Orbit Based on Solar Wind Measurements, *Geophys. Res. Lett.*, vol. 28, 1887, 2001a. Li et al., 2001b] Li, X., D. N. Baker, S. G. Kanekal, M. Looper, and M. Temerin, Long Term Measurements of Radiation Belts by SAMPEX and Their Variations, *Geophys. Res. Lett.*, vol. 28, 3827, 2001b.

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LWS02-0000-0053

Progenitors to Geoeffective Coronal Mass Ejections: Filaments and Sigmoids

Coronal mass ejections -- particularly those with flux rope structures -- have the potential to trigger geomagnetic storms, depending on the properties of the flux ropes. Because of the increasing importance of geoeffectiveness, it is desirable to be able to predict coronal mass ejections, and to predict how geoeffective they may be. Analyses of coronal sigmoids (e.g., Canfield et al. 1999, Leamon et al. 2002) have indicated sigmoid eruptions are important drivers of space weather. Chromospheric filaments and sigmoids both have been modeled with flux rope structure; however Leamon et al. (2002) suggested that magnetic clouds associated with filament eruptions are different from magnetic clouds associated with erupting sigmoids. If the potential for geoeffectiveness depends on the details of the pre-eruption magnetic structures, can the characteristics of magnetic clouds at 1 au be related statistically to measurements made via remote sensing, e.g. via X-ray coronal imagery and/or photospheric magnetography? This investigation will address this question, by combining data from solar observatories like Yohkoh/SXT, SoHO/MDI with near-Earth monitors like ACE, WIND, etc., to explore possible systematic differences between filaments and sigmoids and the magnetic clouds which are associated with them.

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LWS02-0000-0031

Observational Constraints in the Solar Wind Acceleration Region: The HERSCHEL Investigation (Helium Resonance Scattering in the Corona and Heliosphere)

Proposal Objectives: The proposed HERSCHEL (HELIum Resonance Scatter in the Corona and HELiosphere) program will: investigate the slow and fast solar wind, determine the helium distribution and abundance in the corona, and test solar wind acceleration models; by obtaining simultaneous observations of the electron, proton and helium solar coronae. The HERSCHEL will establish proof-of-principle for the Ultra-Violet Coronagraph, which is in the ESA Solar Orbiter Mission baseline. The NRL Solar Physics Branch is joining with the Italian UVC Consortium to address the objectives of the International Living With a Star program with this combination of NASA suborbital program and ESA Solar Orbiter flight opportunities. Indeed, while the Solar Orbiter flight is still many years away, the 3 year program being proposed here is essential in order to prove the validity of this exciting new concept before the Solar Orbiter instrument selection is finalized. Research Plan: This proposal will fund a three-year effort to design, fabricate, test, launch and analyze data from novel instrumentation on a suborbital rocket. The work will be performed at NRL and a number of institutions in Italy. The current EIT CalRoc payload will be used as the basis for the electronic and on-disk imaging components of the HERSCHEL sounding rocket payload. The UVCI hardware for the sounding rocket will be fabricated by the Italian UVCI consortium. NRL will assist in the coronagraph design, integrate and test the payload, lead the launch operations, and share in the analysis and publication of the data. Relevance to NASA LWS Programs: This proposal aims to develop instrumentation that for the first time will directly image and characterize on a global coronal scale the two most abundant elements, hydrogen and helium. This will directly address three outstanding questions in the Sun-Earth Connection theme: 1) Origin of the slow solar wind, 2) Acceleration mechanism of the fast solar wind, and 3) Variation of Helium abundance in coronal structures. The characterization of the ambient solar wind is essential, as it directly effects transient and recurring space weather and influences the heliospheric passage and near-Earth impact of CMEs and SEPs. Lastly, by establishing proof of concept for the Solar Orbiter UVC, this mission fits the goals of the International Living With a Star (ILWS) program.

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LWS02-0000-0026

Efficiency of Energy Transfer from the Solar Wind, Storage in the Magnetosphere and Release into Earth's Atmosphere

A key component of the Living With a Star (LWS) Targeted Research and Technology (TR&T) program is the quantification of the physics, dynamics and behavior of the Sun-Earth system over the 11-year solar cycle. The interaction of the solar wind with Earth's magnetosphere can result in the storage of large amounts of energy in the magnetospheric system. The subsequent release of this energy results in the energization of particles trapped in the magnetosphere and the acceleration into Earth's atmosphere causing the aurora. In addition, the ionosphere in the auroral zone is modified by the precipitating particles causing large variations in the height integrated conductivities and the flow of currents in the region. The rate of energy storage in the magnetosphere is related to the rate of merging of magnetic flux on the dayside of Earth. It has been known for three decades that the addition of energy to the magnetospheric system is controlled by the north/south direction of the magnetic field in the solar wind impacting Earth's magnetosphere near local noon. What is not yet well understood, however, is the efficiency of this process. In particular, what fraction of the solar wind energy flux impacting the dayside magnetosphere is converted to energy stored in Earth's magnetotail? What fraction of this stored energy is eventually deposited into the auroral ionosphere? And are there solar cycle variations? The Polar spacecraft was launched near solar minimum in February 1996 and has continued operation through today in the post-solar maximum period. Global auroral image data covering this time period from the Visible Imaging System (VIS) of the Polar spacecraft will be used to determine the instantaneous open polar cap magnetic flux. The time rate of change of this magnetic flux is the net result of magnetic merging in the solar wind-magnetosphere interaction region and of reconnection in the distant magnetic tail. During periods of low auroral activity in the nightside, the nighttime reconnection rate will be small and the change in the total open magnetic flux of the polar cap will be a direct measure of the rate of merging on the dayside. The Polar/VIS observations of total open magnetic flux of the polar cap in combination with static and dynamic pressures of the solar wind can be used to estimate the energy stored in the flaring magnetotail lobes. The HF radars of the Super Dual Auroral Radar Network (SuperDARN) have been operating for the same period with additional radars becoming operational with time. SuperDARN data will be used to determine in detail the geomagnetic flux transferred into and out of the polar cap. The SuperDARN data combined with the height integrated auroral conductivities derived from the Polar/VIS auroral images will be used to derive the joule heating dissipation in the auroral ionosphere. The solar wind parameters required for this study will be taken from publicly available key parameter data sets of the ACE, Wind, IMP#64979;8 and Geotail spacecraft. The goal of this study is to investigate the relationship between solar wind parameters, storage of energy in the magnetosphere, and the eventual release of this energy into Earth's atmosphere. The completion of this study will result in the production of a set of parameters to allow spacecraft operators with access to an upstream solar wind monitor such as ACE or Wind to make accurate short-term predictions (of the order of 1-hour) on the effects of the solar wind on the Earth magnetosphere system.

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LWS02-0026-0042

Storm-time ring current: Development of a new storm index and its prediction from solar wind and IMF parameters

Space weather is an essential component of the "Living with a Star (LWS)" Program, and the magnetospheric storm is the main target of space weather because of its hazardous nature. The physics and prediction of magnetospheric storms have been conventionally addressed in terms of the Dst index, which is ideally regarded as a measure of the ring current intensity. However, there is a growing conjecture that a considerable fraction (~25%) of storm-time Dst can be actually attributed to the tail current. Furthermore, the substorm-associated variations of the tail current and the ring current have opposite effects on Dst, and the former overcompensates the latter. Thus the conventional Dst index is misleading with regard to not only the intensity of the ring current but also the timings of the ring current development and decay. The present project seeks to develop (1) a new index for the intensity of the ring current and (2) a basic scheme to predict this new index from solar wind and IMF measurements. For (1), first Dst (Sym-H will be actually used) will be decomposed into the trend and auto regression (AR) components; the AR component represents substorm-association variations. Then the project will derive an empirical formula to convert the AR component to the actual change of the ring current intensity by examining the associated change of global energetic neutral atom (ENA) fluxes measured by the IMAGE/HENA instrument. The new ring current index can be obtained by adding this converted AR component back to the trend component. The developed procedure calculates the ring current index based solely on Dst. The procedure will be applied to storm events in the last 18 years. Then the project seeks to examine the predictability of this new ring current index from solar wind and IMF measurements. The prediction scheme developed should be more adequate for predicting the intensification and decay of the ring current during magnetospheric storms. The project will also examine the asymmetry of the ring current by comparing the AR component with the Asy-H index. The successful achievement of this project will provide an important component for space weather and therefore for the LWS program.

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LWS02-0016-0092

Long-Term Solar Irradiance Variations Over Solar Cycles 21 to 23

In response to NRA 02-OSS-01, this proposal is submitted to the Living with a Star Targeted Research and Technology Program. The main goal of the proposed research is to study the long-term changes observed in total solar and UV irradiances over three consecutive solar cycles and their relations to solar magnetic field variations. The proposed research is divided into three major research tasks. (1) We will analyze the total solar irradiance and the Mg II h & k core-to-wing ratio (Mg c/w) composites. In particular, we will compare the SOHO/VIRGO total irradiance and the UARS/SUSIM Mg c/w data, which are used in the irradiance composites for solar cycle 23, with additional total and UV irradiance measurements. The main goal of this research task is to clarify whether the high irradiance values during the maximum of solar cycle 23 reflect real solar effects, rather than unidentified instrumental effects. (2) We will compare the spatially resolved sunspot and faculae data derived from the SOHO/MDI and Kitt Peak magnetic field observations for solar cycle 23 and will estimate their contribution to total and UV irradiance variations. As part of this research effort, we will also compare the MDI and Kitt Peak labeled images used for identifying sunspots and faculae in order to develop a more homogeneous image processing and classification system. (3) We will study the relation between the long-term variations of solar irradiance and the averaged absolute values of the magnetic field strength derived from the Kitt Peak measurements over solar cycles 21 to 23. Using advanced statistical techniques, we will estimate the contribution of magnetic fields to the observed irradiance variations as a function of the solar cycle and from one cycle to another one. The proposed research falls into LWS's "basic research" category. Specifically, it addresses one of LWS's major tasks: how solar irradiance variations are related to solar magnetic activity and what is their potential effect on climate. The proposed research is related to the "Helioseismic and Magnetic Imager" (HMI) experiment and it will provide analysis tools (both image processing and time series analysis techniques) to examine the HMI photometric and magnetic field measurements. The proposed research is a three-year effort. The science team of the proposed research consists of Dr. Judit M. Pap (Principal Investigator, Goddard Earth Sciences and Technology Center, University of Maryland Baltimore County), Dr. Richard Bogart (Co-Investigator, Stanford University), Dr. Michael Turmon (Co-Investigator, Jet Propulsion Laboratory), Dr. Harrison Jones (Collaborator, Goddard Space Flight Center Southwest Station at Kitt Peak), Dr. Claus Frohlich (Collaborator, Physikalisch-Meteorologisches Observatorium Davos, World Radiation Center), and Dr. Linton Floyd (Collaborator, Interferometrics Inc./Naval Research Laboratory).

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LWS02-0072-0002

On the Physics of Strong Magnetic Storms

The objective of the Sun Earth Connection (SEC) Living with a Star (LWS) program is to develop the scientific understanding of the solar terrestrial environment. A critical element in achieving this objective is the development of models that are physics based. The Lyon-Fedder-Mobarry (LFM) model, with its complement of subsidiary modules, diagnostics and visualization components has been an important contributor in understanding and modeling the magnetosphere-ionosphere system in ISTP. In assessing the performance of LFM against the ISTP database we found that the model performed well against data collected under weak and moderate solar wind conditions when v is smaller than 5 mV/m. However, there were significant discrepancies between the ground based measurements and the LFM model for larger values of the solar wind electric field. It is the objective of the proposal to study the importance of an upgraded physics based LFM ionospheric module that includes anomalous heating due to electrojet instabilities, effects of neutrals on ion heating due to interaction between the magnetosphere and ionosphere-thermosphere system, and altitude dependent precipitation, in the understanding the phenomenology of super-storms.

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LWS02-0000-0097

Oxygen Profiling Infrared Experiment (OPIE)

The Oxygen Profiling Imaging Experiment (OPIE) would combine a specially designed telescope with recently developed detector and cooler technologies to create a far-infrared detector to study the atomic oxygen altitude profile of the Earth. A spectral line of O-I at 63~\micron\ is the target of OPIE. The planned gallium-doped germanium (Ge:Ga) detector is small and may require cooling by liquid helium. Temperatures of the telescope and other parts of the satellite viewed by the detector would be reduced by passive radiative coolers. OPIE would address a problem that underlies many of the goals of the Living With a Star Program: The response of the Earth's atmosphere to variations in the solar EUV radiation and changes in magnetospheric conditions. By providing near-continuous observations of the atomic oxygen altitude profile in the lower thermosphere, the state of the terrestrial thermosphere will be determined. By measuring thermal radiation, OPIE can also see the diurnal variations. Once a regular series of data is available, assimilated data sets can be created to provide a global picture of the lower thermosphere. This proposal would support the optical design of the dual-function telescope, the thermal design, power restrictions, and orbital sampling of OPIE. Light from the desired altitude region must be spectrally filtered into a narrow spectral region and focused onto the detector surface, something that has had limited success in the past. Thermal control is a critical aspect of OPIE as we would like to fly it close to the Earth.

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LWS02-0000-0081

The Study of the Changing Solar Interior Using Global and Local Helioseismology

The research we are proposing has the main goal of improving our knowledge of the temporal changes which are occurring in the structure and dynamical motions of the solar interior. Recently, several hints of possible temporal changes that have occurred during the current solar cycle have been obtained through the application of helioseismic techniques to observations made with the Michelson Doppler Imager Experiment onboard the SOHO spacecraft. These hints have included the discovery of the so-called Solar Subsurface Weather (SSW), and the confirmation of the existence of the so-called torsional oscillations in the sub-photospheric layers. The discovery of the SSW has included a reversal in the meridional circulation beneath the solar surface in the northern hemisphere during the years 1998 through 2001. We first plan to verify that these same features can be seen in co-temporaneous ground-based observations taken at the Mt. Wilson Observatory 60-Foot Solar Tower since the SOHO launch and we then propose to search for changes in both the meridional flow and in the torsional oscillations during Solar Cycle 22 using earlier MWO observations since our 60-Foot Tower data observations are the only suitable data available during that solar cycle. We also propose to improve the radial resolution of the measurements of the shallow sub-surface layers by incorporating measurements of the frequency-splitting coefficients of the high-degree p-mode oscillations now that we have been able to remove the contamination introduced into those measurements by solar differential rotation. Since the high-degree p-modes are largely confined to the shallow sub-photospheric layers, including their frequency splittings should allow us to improve upon the depth resolution available from the use of the intermediate-degree f-mode splittings alone. We also propose to invert the high-degree frequency splittings in order to provide an independent verification of the zonal velocities which are measured by the ring-diagram methodology.

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LWS02-0024-0021

Building a Space Physics Virtual Observatory for Global and Local Sun-Earth Connection Studies

We propose to use existing and rapidly developing tools for browsing, analysis, retrieval of space physics data to produce a "virtual observatory" that will enable a much deeper understanding of multispacecraft and ground-based time series and images from the Sun, the heliosphere, the magnetosphere, and the ionosphere-thermosphere-mesosphere. The core visualization software for time series is reaching a mature stage, but we need to integrate external data bases with our current tools, as well as to add capabilities such as viewing related solar, auroral, and other images. Initially we will provide a simple means for accessing the online holdings at the National Space Science Data Center but we plan to include as many relevant data providers as possible. We also propose to provide tools for viewing models and simulations along with measured data. Our ultimate system will allow a user to gather and browse data from disparate sources, view them in place on the spacecraft orbits, view time-series graphs of selected quantities, produce animations and record them, and download "value-added" data at desired resolutions. This project is relevant to NASA and this NRA both in the short and long term through the provision of a continually upgraded set of tools for the LWS/SEC community.

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LWS02-0082-0127

A Neutron Spectrometer for Solar Sentinel

We propose to develop a solar neutron spectrometer/telescope for deployment on a Solar Sentinel. Measuring neutrons below 10 MeV from solar activity requires a platform much closer to the Sun than 1 AU. These neutrons carry information about the spectrum and composition of energetic particle populations on the Sun. To effectively use these neutrons, one must measure them rather than simply detect them. To that end, we propose to develop an instrument that performs the necessary spectroscopy to remove the neutron spectrum velocity dispersion. It also is designed to image a neutron source as a means to minimize the count rate from directions other than the Sun.

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LWS02-0039-0129

Determining the Source of High Energy Electrons in the Inner Magnetosphere

A research program is proposed to understand the global process of electron transport and acceleration from the solar wind to the inner magnetosphere. After being launched in the upstream region, electron particle trajectories will be followed in a global magnetohydrodynamic (MHD) simulation of the solar wind and Earth's magnetosphere for geomagnetic storm-like conditions to understand the complete process of transport and heating that leads to high energy relativistic electrons in the vicinity of geosynchronous orbit. The primary goals of this research will be to understand the physical mechanisms that lead to the formation of relativistic electrons starting from the solar wind, and to determine what controls the response of relativistic electrons in the near-Earth region for geomagnetic storms. Of particular interest will be to determine the origin and flux of "seed" electrons in the near-Earth region at an equatorial radial distance of about 10 RE, which is where many inner magnetospheric models begin their calculations. The approach will be to run a global MHD simulation for different upstream solar wind driving conditions and follow electrons from the solar wind as they circulate in the Earth's magnetosphere. The upstream solar wind conditions to be run include high-speed solar wind flows and/or high density, for different interplanetary magnetic field orientations. Electron flux maps at different locations will be calculated, in particular at the seed electron location and near geosynchronous orbit. By running several cases with different upstream driving parameters, particular solar wind and/or magnetospheric conditions that lead to more strongly geo-effective storms will be determined along with a physical understanding as to why such conditions occur. The global model proposed here will help to understand the acceleration, global distribution and variability of electrons in the inner magnetosphere. This represents a step forward in the predictive capability of hazardous near-Earth conditions due to high-energy relativistic electrons that can lead to satellite damage.

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LWS02-0000-0109

Microphysics of Plasma Processes Dissipating Inertial Alfvén Waves

It is now commonly believed that Inertial Alfvén waves (IAWs) with short transverse scale lengths play a crucial role in transporting electromagnetic (EM) energy from the outer magnetosphere to the topside auroral ionosphere. However, the mechanisms for the dissipation of this energy remain largely illusive. Very intense IAWs have been measured by Freja and FAST satellites and have been called solitary kinetic Alfvén waves (SAWs). The SAWs are typically characterized by (1) intense transverse electric and magnetic fields obeying the linear Alfvén wave relation (LAWR); (2) intense field-aligned currents; (3) relatively large parallel electric fields, greatly exceeding the parallel field given by the LAWR; (4) transversely energized ions and bursts of parallel energized electrons; and (5) intimately co-located intense density depletions. These observations reveal that the SAWs are a product of nonlinearly evolved wave structures. A quantitative understanding of their dissipation requires an in-depth understanding of the wave-driven nonlinear processes. In view of the great significance of Alfvénic wave energy in the energetics of the M-I coupling along the high-latitude magnetic field lines, we have proposed to study the dissipative processes for the inertial Alfvén waves. The study will be facilitated by parallel PIC codes. Among the dissipative processes to be studied include (i) instabilities (ion-acoustic, ion-cyclotron, Buneman, etc.) driven by the Alfvén wave parallel current, (ii) interplay between the wave current and the density depletions naturally occurring as a part of the ambient plasma turbulence, forming a large number of weak double layers, (iii) cavitation by large amplitude waves, (iv) interplay between the wave current and the wave-generated cavities forming strong double layers and thereby generating burst of energetic electrons and ions, and (v) establish the link between Alfvén waves and the ubiquitously present electron holes in space plasmas. A better understanding of the dissipative processes will lead to a quantitative determination of dissipation rate of Alfvén waves. Since the Alfvénic wave energy is a major component of the energy budget in Sun-Earth connection, such rates are crucially important for physics-based rigorous space-weather modeling, which is an important element of the LWS program.

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LWS02-0058-0117

Global MHD Simulation Study of Polar Cap Energy Deposition

The objective of this research program is to study deposition of energy into the polar cap ionosphere. Deposition from both Joule heating and auroral precipitation will be considered. The flow of energy from the solar wind to the polar caps will be mapped through the magnetosphere, and its dependence on solar wind parameters will be determined. This research is important because the rate of energy deposition can exceed many hundreds of gigawatts during geomagnetic storms. The scale height of the atmosphere can be affected which causes perturbations in spacecraft orbits. Variations in the neutral winds occur and the effects propagate to mid and low latitudes. The research strategy is to use global MHD simulations of the magnetosphere to study polar cap heating. The simulation effort will consist of two types of studies. The first set of studies will be to simulate real events. We will choose interesting periods for study, i.e., times of disturbance when good estimates of the energy input to the polar caps can be made from observations. We will require that the data be sufficiently comprehensive to perform the simulations and to verify the results. The data sets will include solar wind data to be used as the input conditions for the simulation code, and magnetospheric and ionospheric data to be used for verification of the simulation results. The second type of effort will be model numerical studies where, for example, the solar wind data or solar flux are modified in one or more parameters. We will survey the energy deposition as a function of solar wind ram pressure, IMF strength and direction. The dipole tilt of the Earth will be varied to assess seasonal deposition effects. By changing the solar flux, solar cycle dependences can be studied. This research directly supports NASA's Living with a Star (LWS) objective of determining energy transfer from its generation by solar activity to its deposition in the upper atmosphere, namely, the critical link from the solar wind through the Earth's magnetosphere into the ionosphere. It specifically addresses the first of the five objectives of the LWS program, "Scientific Understanding."

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LWS02-0092-0106

GPS Occultation Sensor Contributions to Ionospheric Space Weather Specification and Prediction

Through analysis of data from a new type of space-based ionospheric sensor, this proposal seeks to address aspects of three Space Weather effects that can potentially impact society. First, we will characterize the global morphology, strength and occurrence of small ionospheric irregularities capable of distorting electromagnetic signals. Second, we will validate key aspects of first-principles models' projections of ionospheric daily and storm-time. Both ionospheric irregularities and variability can impact communications and navigation (e.g., GPS) systems. Finally, we will develop a method to improve specification of highly energetic particles in the Earth's radiation belts that can be responsible for damage to satellite components. Attainment of these goals is made possible by the advent of the GPS occultation sensor, which is capable of measuring electron densities over the full range of ionospheric altitudes from the D-region (60-90 km), through the E-region (90-150 km), and up to the F-region (150-800 km). Over the last few years several GPS occultation sensors have been flown, generally with the primary objective of making lower atmospheric observations. However, some ionospheric observations have been made as well. The launch of the Ionospheric Occultation Experiment (IOX) in late 2001 marked the first flight of an occultation mission focused on ionospheric remote sensing. The proposed study will utilize IOX and other occultation sensor observations of D-, E-, and F-region densities and density fluctuations to address the above three objectives through statistical evaluations and model/data comparisons. Ancillary data from NASA's TIMED and SAMPEX satellites will also be used. Successful completion of the proposed work will enable development of better environmental models, improve understanding of Space Weather phenomena, and validate the utility of GPS occultation sensors as a part of future LWS space missions.

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LWS02-0055-0030

Do we need a multi-spacecraft cluster at L1 for space weather monitoring?

NOAA has been using L1 solar wind observations from ACE with considerable success to forecast geo-effective events with an approximately 45-minute warning time. However, there is still a significant level of false alarms and some potentially dangerous events are missed all together. This proposal aims to determine the expected level of increase in forecast accuracy based on multiple solar wind input using already available data from ACE, WIND, IMP 8, Geotail, Interball and Cluster. The first portion of this study will determine the most effective way to combine multi-spacecraft solar wind observations of the triggers of the most geo-effective events. Once the optimal data assimilation method is determined, the increase in geomagnetic activity forecast accuracy would be quantified based on magnetospheric and ground magnetic field data observed by POLAR and the Dst and UCLA magnetometer networks. The benefits of advanced on-board processing of event fronts will be evaluated along with long-term, solar cycle variations in the forecast accuracy. Thus this work will directly contribute towards the development of knowledge of advanced warning capabilities of the most geo-effective events that could place spacecraft and space faring humans at jeopardy, one of the main goals of the NASA LWS program.

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LWS02-0063-0055

Storm time ULF waves in the inner magnetosphere

ULF waves in the Pc3-5 band (period = 10-600 s) play a fundamental role in the acceleration and transport of energetic particles in the magnetosphere during geomagnetic storms. When disturbances in the solar wind hit the magnetosphere they propagate through the magnetosphere as MHD ULF waves. The electric field associated with the waves then interacts with the pre-existing particle populations. Some of these particles are accelerated and transported. The importance of understanding these processes in the context of the Living With a Star Program is obvious since elevated flux of energetic particles is hazardous to human activity in space and to operation of spacecraft. Previous studies of storm time ULF waves were done primarily using data from geostationary satellites ground magnetometers. We will use electromagnetic fields measured by the elliptically orbiting CRRES spacecraft to investigate the spatial and temporal development of storm time ULF waves. Ground magnetometer data will be also used to investigate the spatial extent of the waves.

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LWS02-0000-0094

Solar-Induced Variations in Polar Mesospheric Clouds

Solar-Induced Variations in Polar Mesospheric Clouds Polar Mesospheric Clouds (PMC) are located near the high-latitude summertime mesopause near 83 km in a region which is susceptible to both anthropogenic influences from below, and to external influences from above. Their ground-based manifestation, noctilucent clouds (NLC), has been observed for over a century. Yet, we are far from understanding the relationship of atmospheric forcing and mesospheric cloud response, particularly on time scales of a year or more. It is evident that PMC/NLC activity exhibits a ten-to-eleven year periodicity, most likely a result of the 11-year variation in ultraviolet solar irradiance and its effect on the ambient water vapor at 83 km. However up to now, there have been no attempts to model this interaction, nor to explain why solar minimum surprisingly precedes maximum PMC/NLC activity by 2-3 years. We first propose an analysis of four extensive PMC data sets to establish a unified database for long-term PMC variability, from seasonal to decadal time scales. Secondly, we propose to model the influences of atmospheric transport, temperature, water vapor and nucleating particles on PMC occurrence and brightness. Two models will be used. The first simulates the two-dimensional atmospheric transport on seasonal to decadal time scales. The second describes the one-dimensional behavior of ice particle properties in supersaturated conditions. Our aim is to create a self-consistent two-dimensional model of the atmosphere forced by seasonal and solar cycle variations, which includes PMC properties that will be constrained by the satellite data. In this way we will establish a theoretical basis for long-term variability near the summer mesopause. variability, from seasonal to decadal time scales. Secondly, we propose to model the influences of atmospheric transport, temperature, water vapor and nucleating particles on PMC occurrence and brightness. This is done through the use of two self-consistent models, one simulating the atmosphere, the second describing the ice particle properties in supersaturated conditions. Our aim is to create a model of PMC physical and optical properties, forced by atmospheric variations and constrained by the available satellite data. models, one simulating the atmosphere, the second describing the ice particle properties in supersaturated conditions. Our aim is to create a model of PMC physical and optical properties, forced by atmospheric variations and constrained by the available satellite data.

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LWS02-0000-0124

Spectral Characterization of the Hot Plasma Population at Geosynchronous Orbit Over an Entire Solar Cycle

The geosynchronous orbital slot is heavily populated with commercial, military, and other governmental satellites. Unfortunately, the space environment at geosynchronous orbit is highly variable and often far from benign. One major environmental hazard in this region of the magnetosphere is surface charging, which occurs when satellites are immersed in the hot plasma originating in the tail plasma sheet. Recent work shows the importance of the shape of the ambient ion and electron energy distributions for determining the occurrence and amount of surface charging. Mitigating the effects of such charging (through design or through operational action plans) requires a good understanding of the extent of the hazard, i.e., a statistical characterization of the charging environment that captures the spectral properties that are directly related to surface charging. We propose to use the comprehensive and unique database of plasma measurements obtained over the last 12 years by Los Alamos Magnetospheric Plasma Analyzers on several geosynchronous satellites to perform such a statistical characterization. Guided by recent detailed charging analyses based on MPA data, we will perform multiple-population functional fits to MPA observations, and we will compute charging-relevant parameters based on actual distributions. The spectral properties and charging parameters will be analyzed statistically, as a function of orbital position, magnetospheric activity, phase of the solar cycle, etc. This will provide a statistical characterization that should be directly useful for the design of more reliable spacecraft systems. Identification of the multiple populations will enable a statistical assessment of the role of the different source/delivery processes that ultimately produce the charging environment. Finally, we will explore the use of novel feature-identification techniques to characterize the energy-time-domain signatures at multiple satellites to obtain statistical information about the delivery and acceleration of the plasma into the near-earth region.

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LWS02-0077-0015

Assessing Interactions Between Solar Subsurface Weather and Magnetism

The Helioseismic and Magnetic Imager (HMI) instrument to be flown on the Solar Dynamics Observatory (SDO) will enable continuous mapping of the vector magnetic fields in the atmosphere coupled with seismic measurement of complex large-scale flows over a range of depths below the solar surface using local helioseismic ring-diagram and time-distance methods. Such remarkable weather-like horizontal flows, now called Solar Subsurface Weather (SSW), were first revealed using SOI-MDI data from SOHO. SSW involves intricate flow patterns that can change from one day to the next, accompanied by more gradually evolving features such as banded zonal flows and meridional circulation cells. The SSW flows are of particular significance since they appear to interact and influence the magnetic fields visible at the surface, with active regions appearing as zones of convergent flow and possible subduction. Such subsurface flows can mechanically twist and displace field lines, possibly leading to unstable magnetic configurations that may flare or erupt as coronal mass ejections (CMEs). Preliminary helioseismic probing has revealed that at least one recent active region complex possessed strong inflowing streams just below the surface and prominent diverging flows at greater depths during an extended interval of flaring and CMEs. It is highly likely that such flows and magnetic fields are broadly linked in their evolution. In getting ready for the major data streams from HMI on SDO, we propose to investigate interactions between SSW and magnetism through two major tasks: (A) characterization of the flows associated with SSW in the vicinity of active regions using ring-diagram analyses applied to existing and future SOI-MDI data, (B) verification of these ring-diagram flow deductions through careful testing and detailed comparison with inferences drawn using time-distance analyses. These elements should provide the means to design optimal helioseismic analysis strategies for studying SSW in near real time in the vicinity of active complexes. Upon completion of these tasks, the HMI project should be able to implement these strategies into the data analysis pipelines in the two years prior to launch. This would ensure that the interaction of SSW flows with magnetic complexes can be studied in detail from the outset of the SDO mission.

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LWS02-0000-0137

Mt. Wilson Solar Photographic Archive Digitization Project

The Mt. Wilson Solar Photographic Archive Digitization Project (Mt. Wilson SPADIP) will make available to the scientific community in digital form a selection of the solar images in the archives of the Carnegie Observatories. These images date from 1894 and include many which can be judged to be of superb quality by modern standards. The digitization will use commercial scanning technology with a prepress scanner having 16-bit precision and up to 3000 by 3000 dots per inch spatial resolution. These images will permit a variety of retrospective analyses of the state of solar magnetism and provide a temporal baseline of about 100 years for many solar properties. The 20th Century was a period of increased anthropogenic production of greenhouse gases which might contribute to global climate change. The sun could also be a factor in global climate change and the data provided by this digitization will allow the scientific community to freely examine some properties of solar magnetism over the 20th century. This project will take place at UCLA under the direction of P.I. Roger K. Ulrich. The observing personnel of the synoptic program at the 150-foot solar tower telescope on Mt. Wilson will participate in the project and help interpret the observing and photographic log books which give technical details concerning the photographic procedures. The digitized images will be made freely available through world-wide web procedures implemented at UCLA and through other virtual solar observatory data archives as they are implemented. Raw images as well as images subjected to partial processing will be included. The total number of images available is approximately 150,000. These include a significant fraction of duplicate exposures taken at closely spaced times. The 5-year project described here will digitize and make available on-line approximately 30,000 of the images concentrating on those of the best quality taken in the light of the Calcium K line and in broadband light. The full time period will be covered uniformly by the selected images. The primary scientific output will come from the utilization of the data by the general scientific community. Many of these results will take a form that cannot be anticipated. In addition three specific topics are recognized:² The group at UCLA will carry out two analyses:- The strength of the widely distributed weak solar magnetic fields will be studied through examination of the brightness of the Calcium K line emission over regions of the solar surface not directly associated with sunspots.- The rate of solar rotation over the whole solar surface will be determined as a function of time using the day-to-day motions of features on the Calcium K images.² A separately funded effort by a group under the direction of J. Pap at Goddard Space Flight Center in Maryland will carry out the following analysis:- The time dependence of sunspot and plage areas using the broadband images will be determined and the influence of these variations on the Total Solar Irradiance (TSI, sometimes known as the solar "Constant") will be estimated in order to reconstruct an improved history of the solar output of energy. The analyses to be carried out at UCLA are presented in detail in this proposal. The digitization effort at UCLA includes a routine component of mounting the photographic material in the scanner, recording log-book information and carrying out the actual scans. Although care will be required in handling the photographic material, this task is suited for well supervised, non-specialist, undergraduate students. The opportunity to participate in the study of century-old images of the sun will be used to bring a sense of excitement about solar physics to young students at UCLA.

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The acceleration and propagation of energetic particles at the Sun and in the inner heliosphere

Our proposed studies focus on understanding the solar and interplanetary components of solar energetic particle (SEP) events, the effects of the interplanetary medium on SEP events, and whether it is possible to develop a semi-empirical model to predict the properties of shocks at the Earth based on SEP events. Particular emphasis will be placed on trying to determine whether flares play any role in major particle events, in view of our recent work on the relationship of SEP events and a specific class of type III radio bursts which suggests that the current understanding in terms of only one acceleration mechanism (shock acceleration) is inadequate. We will characterize the particle compositions early in a large number of well-connected events, compare these with the compositions of impulsive events, and assess whether they are dependent on the characteristics of the associated "flare" phenomena. We will also use an existing extensive database of interplanetary shocks and particle events, and their solar associations, during the last 35 years that we have developed to understand the large-scale structure of interplanetary shocks, and the implications for particle acceleration. This database will be made available to the community as part of the project. Our studies will use extensive observations from the current solar cycle and from previous cycles, in particular from cycle 21 when multiple spacecraft were present in the inner heliosphere.

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LWS02-0000-0064

Coupled Model of Storm-Time Effects on the Low- and Mid -Latitude Ionosphere

The proposed research centers on self-consistently calculating the storm-time variations of the low- and mid-latitude ionosphere. This will be accomplished by coupling SAMI3, the new NRL model of the low- and mid-latitude ionosphere, and the Rice Convection Model of inner magnetosphere electrodynamics. At present, SAMI3 relies on an input electric field model, while the RCM uses an input ionospheric conductance model. When coupled, SAMI3 will provide conductance values to the RCM, while the RCM will provide electric fields to SAMI3. We propose to answer the following scientific questions: -- How do magnetospherically driven electric fields that penetrate into the low- and mid-latitude ionosphere evolve as a function of longitude and latitude during magnetic storms? -- What is the response of the ionosphere to penetrating electric fields as a function of geophysical parameters (e.g., geomagnetic conditions, solar EUV, longitude, latitude, etc.)? -- Will the output from the coupled codes, when applied to major storm events like the Bastille Day 2000 storm, agree with the observed dramatic prompt-penetration electric fields and density disturbances? In the later phases of the research, realistic wind fields will be input to the coupled codes in order to investigate the effects of disturbance neutral winds on electric fields and ionospheric structure. For simulated events, we will investigate the effect of the model electric field on the linear growth rate of the generalized Rayleigh-Taylor instability, which is believed to trigger spread F. The proposed research program directly addresses a major objective of NASA's Living with a Star (LWS) program: to determine the mid- and low-latitude ionospheric response to geomagnetic storms. Ionospheric variability can adversely affect navigation, communications, and radar systems. At present, ionospheric behavior during geomagnetic storms is not well enough understood to meet LWS requirements. The self-consistent coupling of the RCM and SAMI3 will provide a basis for qualitatively and quantitatively understanding this complex phenomenon on a global scale.

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Structure and Dynamics of the Near-Earth Large Scale Electric Field During Major Geomagnetic Storms

The main objective of this study is to provide the first measurements of large-scale electric fields at all local times in the inner magnetosphere during the main and recovery phases of geomagnetic storms. In addition, this study will discover the ways in which variations in solar wind driving impact the inner-magnetospheric convection pattern and electric field. This study will compare the electric field measurements to measurements of the ring current and plasma sheet populations in order to understand the processes by which the particles are energized and by which they modify the electric fields. The last main objective is to discover the systematic variations in inner-magnetospheric electric fields with increasing solar wind driving by creating average electric field vector maps covering all local times under various geomagnetic activity conditions. We propose to analyze data from the electric field instruments on the Polar and CRRES spacecraft. We will produce radial profiles of the vector electric field at all local times during the main and recovery phases of major storms, calculate potential drops associated with these electric fields, and infer convection patterns. We will compare these radial profiles to standard models. We will also compare these radial electric field profiles to simultaneous solar wind measurements obtained from the ACE and Wind key parameter data. In addition, we will make direct comparisons between the radial profile of the electric fields and the particles in the plasma sheet and ring current, as measured by instruments on Polar. Finally, we will produce average electric field maps in the equatorial plane under varying solar wind conditions, to put the storm-time measurements in context and to look for any systematic development of the electric field with increasing activity. This work is of direct relevance to the Living With a Star Science Advisory Team "Dynamics of the Near-Earth Radiation Environment" Problem Area. An objective associated with this problem area is to "Discover the processes that accelerate, transport, and distribute energetic particles during geomagnetic storms". This proposal will analyze the significance of one of these processes, the large-scale slowly-varying electric field. By providing a deeper understanding of the electric field and its effect on ring current particles we will be advancing the predictive ability of current and future models.

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Investigations of Interplanetary Propagation of High-Energy Radiation from Poorly Connected CME Events

We will investigate the propagation of solar energetic particles in the 3-dimensional heliospheric magnetic fields. We will study solar energetic particles from large gradual CME events, which are particularly dangerous to astronauts working in space. This data analysis project will be combined with our effort using new theoretic tools recently developed by the Principal Investigator that allow us to calculate particle propagation in a realistic 3-dimensional magnetic field of the heliosphere, including all the particle propagation effects such as pitch-angle scattering, focusing, cross-field diffusion, convection, drift, and particle energy change. Specific tasks of this investigation are: (1) develop theoretic tools based on the transport equations to incorporate realistic spiral (Parker, and random walking or Fisk) magnetic fields and a propagating shock and derive a new type of Fokker-Planck equation for the anisotropic distribution function that includes the effects of particle propagation across the magnetic field, convection and adiabatic energy loss, (2) with the newly enhanced theoretic tools, we will run various models suggested by researchers in the community and (3) analyze solar particle events and compare observations with our model calculations. By investigating the behaviors of solar energetic particles at various locations in the heliosphere, such as the time intensity profile, spectrum, anisotropy and elemental composition, and using them to constrain our models and parameters, we hope to increase our understanding of the interactions of particles, magnetic fields and plasma in the heliosphere. The goal of this investigation is to gain understanding of how solar energetic particles arrive at Earth from events that seem to have poor magnetic connections. The soft ware we gain from this study will become an important asset for the interpretation of observations from the up-coming NASA STEREO mission. The knowledge from this investigation will form basis for future tools to forecast near-earth space radiation environment.