Living With A Star Program
Abstracts of Awarded Proposals
NRA NNH04ZSS001N
April 2005

PI: Phillip Anderson/University of Texas at Dallas

Proposal Title: Effects of Hi- and Mid-Latitude Electric Fields on Thermospheric Composition and Winds

Abstract:
Ionospheric electric fields can have profound effects on the thermospheric composition and winds, particularly during geomagnetic activity. They influence numerous processes in the ionosphere/thermosphere (IT) system including plasma transport in the ionosphere, the ion drag force which affects neutral winds, and the Joule heating which drives much of the composition and structure of the IT system. They can extend to very low latitudes and can contribute substantially to the magnetospheric electric field structure, particularly during geomagnetic storms Modelers have begun to understand the importance of the subauroral electric field coupling to the thermosphere, the inner magnetosphere and the plasmasphere and efforts to incorporate recent results are currently underway. We propose to examine the effect of the subauroral electric fields on IT coupling by first developing an empirical model of the subauroral electric fields from data acquired by the low-Earth orbiting (LEO) Defense Meteorological Satellite Program (DMSP), Dynamics Explorer 2 (DE-2), and Atmosphere Explorer C (AE-C) spacecraft. The results will be incorporated into the Thermosphere Ionosphere Mesosphere Electrodynamics General Circulation Model (TIME-GCM) to examine the global effects of the subauroral electric fields on the thermospheric structure. The model outputs will be compared with model runs performed without the subauroral electric fields and with thermospheric composition data from the ultraviolet imagers on the Thermosphere Ionosphere Mesosphere Energetics and Dynamics (TIMED) and DMSP F16 spacecraft. We will also use event data from the AE-C and DE-2 spacecraft in conjunction with high resolution 2-D and 3-D nonhydrostatic models of the thermosphere to examine the small scale effects on the thermosphere of the subauroral electric fields. The DE–2 and AE-C satellites were the last satellites to carry instruments simultaneously measuring the in-situ thermospheric winds and composition as well as the 3-D ion drifts and ion composition. The data were largely ignored in the mid- and low-latitude regions and represent largely untapped databases from which to study thermosphere/ionosphere coupling in a region unfettered by direct auroral precipitation effects.

PI: Spiro Antiochos/Naval Research Laboratory

Proposal Title: Physics of the Sun-Heliosphere Magnetic Connection

Abstract:
The Naval Research Laboratory proposes a 3-year program of research on understanding the dynamic magnetic connections between the solar photosphere/corona and the

heliosphere -- a topic that has been identified as a focused science target by the NASA Living with a Star, Targeted Research and Technology (TR&T) program. Our research program is designed to mesh with that of a team of cross-discipline and cross-science-methodology researchers selected by the TR&T to address this science target. Our proposed program focuses on the following key questions: What is the dynamical topology of the solar corona's open-magnetic-flux regions? What is the role of magnetic reconnection in determining the dynamics? Answering these questions is essential for solving several outstanding problems in solar-heliospheric physics, including the origin of the slow solar wind, the rigid rotation of coronal holes, and the apparent contradiction between solar imaging and heliospheric in situ data. The work consists of a well-crafted balance of analytic theory, numerical simulation, and observational interpretation. It relies heavily on both the physical insights that we have developed from our numerous studies of solar-heliospheric activity, and from the unique state-of-art numerical technology that we have developed to model this activity. Both this physical insight and numerical technology should prove highly valuable to the TR&T team. The Principal Investigator of this program, Dr. S.K. Antiochos of the Space Science Division at the Naval Research Laboratory, is an expert in theoretical solar-heliospheric physics, and will be responsible for the coordination of theoretical analysis, numerical modeling, and observational data. His Co-Investigators --- Drs. C.R. DeVore, J.T. Karpen, and M.G. Linton --- have extensive experience in theory and numerical modeling of MHD processes in the Sun and the Heliosphere. The program will benefit from the high level of institutional support from NRL in terms of computer resources. http://solartheory.nrl.navy.mil/

PI: Thomas Berger/LMSAL

Proposal Title: Flux Transport Solar Cycle Simulations for Total and Spectral Solar Irradiance Modeling

Abstract:
A new method of calculating solar total and spectral irradiance using a flux transport solar cycle model is proposed. The flux transport model calculates the distribution of magnetic flux over a spherical model Sun with parameterized meridional circulation, differential rotation, and dispersion. The model can closely replicate existing magnetogram data through assimilations of SOHO/MDI data or it can simulate widely differing solar conditions from Maunder minimum conditions to hyperactive cycles. Total irradiance is calculated by using facular brightness levels from 3D compressible radiative magnetohydrodynamic numerical simluations in place of empirical contrast models. Spectral irradiance in the 1-300 Angstrom bandpass is calculated using a potential field source-surface and loop heating models to create simulated solar coronal conditions for any given magnetic configuration. The model is useful for parametric studies of varying solar cycle conditions on the Earth's climate and upper atmosphere. It will also be incorporated into the existing Lockheed Martin Space Weather Forecasting system.

PI: Anthony Chan/Rice University

Proposal Title: Radial Diffusion Coefficients for use in Radiation Belt Models

Abstract:
Understanding radial diffusion, particularly in the slot region and in the outer-zone, is a crucial element in the development of physics-based models of radiation belt electrons. The main objectives of this proposal are (1) to derive and numerically test radial diffusion coefficients in these regions, (2) to use observations and simulations to better quantify the ULF perturbations that drive the radial diffusion, and (3) to develop a software package of radial diffusion coefficients for use in radiation belt models. We propose to obtain quasilinear radial diffusion coefficients from recent analytic work by Brizard and Chan [Physics of Plasmas, 2001, 2004], and to perform simulations of test particles moving in analytic ULF wave fields to test these quasilinear coefficients numerically. Effects of non-axisymmetric magnetospheric magnetic fields and off-equatorial particle distributions will be considered. We also propose to carry out test-particle simulations of radiation belt electron motion in the electromagnetic fields of the Lyon-Fedder-Mobarry (LFM) global-MHD simulation code. These MHD-particle simulations would include effects of radial diffusion by MHD waves, convective transport by sudden compressions of the magnetosphere, and losses by magnetopause shadowing. We propose validation tests where MHD waves produced by the LFM code are compared with other calculations of magnetospheric MHD waves and with magnetometer measurements of ULF waves. Results will be used to evaluate how well the analytic quasilinear coefficients describe radial diffusion of radiation belt electrons, and to develop the code package of radial diffusion coefficients. We envision a hierarchy of diffusion coefficients, ranging from a simple power law dependence in L-shell, to more sophisticated coefficients which use a power spectral density calculated from global MHD simulations or from arrays of ground-based magnetometer data for a given set of solar wind inputs. The radial diffusion software package would be made available to the radiation belt community, for use in radiation belt models and for validation tests of those models. By providing a better quantitative understanding of radial diffusion and by developing software to implement the resulting radial diffusion coefficients, the proposed effort would contribute directly to the LWS TR\&T goal of ``developing and validating usable, quantitative models that describe the dynamic evolution of the radiation belt slot region and the adjacent outer zone flux peak."

PI: Craig DeForest/Southwest Research Institute

Proposal Title: Fluxon Modeling of CME Onset

Abstract:
We have developed a simulation framework ("fluxon modeling") that allows us to model 3-D plasma systems with high fidelity on a desktop workstation. We propose to continue developing the technique and to use it to determine the relative importance of three principal proposed mechanisms of CME onset: magnetic breakout, magnetic tether cutting, and plasma mass draining. Our fluxon modeling code eliminates numerical reconnection and scales efficiently to complex systems, allowing us to assess the contributions of reconnection, magnetic morphology, and plasma mass loading to CME onset. In addition to simple systems with prescribed boundary conditions, we will apply

the model to existing SOHO observations of actual CMEs to identify which mechanisms were responsible for those eruptions; and to determine the feasibility of predicting time, strength, and size of CME eruptions from magnetic and EUV imaging data. The proposed work is the natural continuation of a previous LWS TR&T project that funded the initial development of fluxons. In addition to enabling the present science investigation, fluxons are a key technology for several of the LWS goals, such as real-time space weather prediction. All software developed under this project will be documented and released freely to the community.

PI: Edward DeLuca/Smithsonian Astrophysical Observatory

Proposal Title: The Non-Potential Structure of Active Regions

Abstract:
Longitudinal and vector magnetic field measurements will be combined with coronal images to provide a three-dimensional look at magnetic structure and evolution of active regions. Using archival and new observations with TRACE, ASP and IVM we will apply recently developed magnetic field extrapolation codes and advanced image processing techniques to construct 3-D non-linear force free models of active regions that fit observed coronal structures. Filament channels and flux ropes will be included in such models and compared with observations. The topological properties of the coronal magnetic field are key to understanding the dynamics and stability of the plasma. Our approach offers a comprehensive solution to the active region topology problem with quantitative measurements of the "goodness of fit". Applications to currently available datasets will allow us to develop this technique before the launch of Solar-B and SDO.

PI: Mihir Desai/University of Maryland College Park

Proposal Title: Data Analysis and Modeling of Large Solar Energetic Particle Events of Cycle 23

Abstract:
Shock waves driven by coronal mass ejections are presently believed to be responsible for producing large gradual solar energetic particle events or SEPs that can pose significant radiation hazard for humans and technological systems near Earth. However, our present ability to accurately predict various properties of SEPs (e.g., peak intensities, energy spectra, and composition) is somewhat limited. Reliable prediction of these properties depends on developing a detailed understanding of particle acceleration at CME-driven shocks and their subsequent transport out to 1 AU, understanding and modeling the propagation of these shocks through the interplanetary medium, characterizing the ambient solar wind plasma, the magnetic field, and the interplanetary suprathermal ion population through which these CMEs propagate en route to Earth, and specifying key properties such as mass, momentum, and speed of the CMEs near the Sun. We propose a detailed experimental study combined with an extensive modeling effort focused toward understanding the event-to-event variability in the fluxes, spectra, and composition of various ion species during several large gradual SEP events of cycle 23. Specifically, we will survey the ACE/ULEIS and ACE/SIS heavy ion composition and

energy spectra over the 0.1-100 MeV/n. energy range in SEP events and characterize them in terms of properties of the associated CMEs, flares, IP shocks, and the local interplanetary magnetic field fluctuations. We will then use the observed properties of the CMEs, IP shocks, and turbulence as inputs to constrain both 1D and 2D time-dependent shock acceleration models and compare their predictions with the measured ion intensities, composition, and spectra. This study will clearly improve current understanding of the physical processes responsible for producing SEP events and will provide a sound framework for other CME and shock acceleration models. This proposal is directly related to the focused science topic (d) of the LWS TR&T Program – "to relate solar-energetic particles to their origin at the Sun and inner heliosphere," and therefore addresses a highly elusive problem for Space Weather.

PI: C DeVore/Naval Research Laboratory

Proposal Title: Dynamics and Topology of Coronal Mass Ejections

Abstract:
The Naval Research Laboratory proposes to apply physically robust theories of coronal mass ejection (CME) initiation and state-of-the-art numerical simulation techniques to understand the dynamics and magnetic topology of solar CMEs and their interplanetary counterparts (ICMEs). Previously, we have shown in spherically axisymmetric geometry that fast CMEs can be initiated by the onset of magnetic 'breakout' reconnection in multipolar coronal topologies. The ejecta exhibit the three-part density structure characteristic of many CMEs, and evolve into a force-free flux rope typical of the magnetic cloud subclass of ICMEs. We now propose to build upon these successes and to extend our understanding of breakout CMEs and ICMEs to more realistic, fully three-dimensional field configurations. Our research plan is to develop and analyze simulated breakout eruptions initially in global 3D topologies, and later in more concentrated and localized active-region topologies. Throughout these studies addressing CME initiation, we also will analyze the resultant model ICMEs for their plasma and magnetic signatures, and compare them with those observed. The initiation of CMEs in the corona, and the structure and connectivity of ICMEs in interplanetary space, are linked through the vital roles played by the dynamics of magnetic reconnection and the topology of the magnetic field. Our research effort seeks to develop new understanding of these important aspects of the CME/ICME connection.

PI: Mausumi Dikpati/National Center for Atmospheric Research

Proposal Title: Predicting Global-Scale Solar-Cycle Features using a Flux-transport Dynamo Model

Abstract:
Understanding solar cycle mechanisms and predicting the features of an upcoming cycle have become an increasingly necessary and challenging task for our technological society. In the past, the so-called "precursor method" predicted some cycles well, but not the current cycle 23, which has behaved anomalously (de Toma et al. 2004). Following the postulate of previous authors (Schatten et al. 1978) that there is "magnetic

persistence" or a memory of past magnetic fields in the Sun, and demonstrating the physical origins of such a memory in a flux-transport dynamo model of the solar cycle, we (Dikpati et al. 2004) recently built the first physical model for large-scale solar cycle prediction. Dikpati et al. (2004) have been able to show why solar cycle 23 behaved anomalously, and therefore why its features were not accurately predicted. By incorporating observed dynamical variations of the dynamo ingredients, namely the surface poloidal field source and the meridional circulation, we showed that a 10-20% weakening of the large-scale, surface poloidal field source in cycle 23 relative to the previous cycle 22 was the primary reason for a major delay in the polar reversal of cycle 23. Helioseismic observations indicate that the meridional flow decreased systematically during 1996-2002 and it remained slow until March 2004. We are now showing that this systematic decrease in the meridional flow speed caused the unusually slow rise of cycle 23. We are also making preliminary predictions (Dikpati et al. 2004b) that the onset of the upcoming cycle 24 should be delayed, starting late in 2007 or early in 2008. Here we propose research aimed at predicting the large-scale, mean solar cycle features, by further exploitation of our model using observed time-variations in various dynamo ingredients. We will focus on the solar cycle time-scale and predict the timings and amplitudes of upcoming cycles; the timing depends mostly on the meridional flow while the amplitude mostly on the Sun's memory effect. In order to do realistic predictions, we need to incorporate observations, namely the observational data from GONG, MWO, SOHO MDI and SDO HMI for the meridional flow and the NSO/Kitt Peak data for the surface source for weak magnetic fields that would determine the polar reversal and the amplitude of the future cycles. We will analyze the correlations between the dynamo-generated magnetic flux in the shear layer and the surface magnetic flux, spot area and spot number using data from wwwssl.msfc.nasa.gov/ssl/pad/solar/greenwch.htm -- such correlations should give us insight about the processes that determine the surface manifestations of the dynamo-generated flux. By analyzing the rise and fall patterns of each past cycle, we can construct, by using the Dikpati \& Charbonneau (1999) scaling law, a plausible meridional flow speed variation over the past 12 cycles. By postulating plausible relations between the differential rotation in the tachocline and the strength of the toroidal field induced and stored there, we will then attempt to simulate and explain Maunder minimum as well as Medieval maximum type behaviour. If successful, this effort could also help explain solar variability on a time-scale of centuries.

PI: Douglas Drob/US Naval Research Laboratory

Proposal Title: A Comprehensive Statistical Analysis of Thermospheric Neutral Wind Measurements; Building a Testing a New Reference Model

Abstract:
Based on the success and failures of the HWM-93 model, we propose to construct a new empirical wind reference model to answer several important science questions relating to the place of thermospheric winds in the broader LWS objectives. Our new model will also serve as the benchmark for future scientific investigations and numerical simulations of the thermosphere/ionosphere system.

PI: Scot Elkington/University of Colorado, Boulder

Proposal Title: Radial Diffusion Coefficients for use in Radiation Belt Models

Abstract:
Understanding radial diffusion, particularly in the slot region and in the outer-zone, is a crucial element in the development of physics-based models of radiation belt electrons. The main objectives of this proposal are (1) to derive and numerically test radial diffusion coefficients in these regions, (2) to use observations and simulations to better quantify the ULF perturbations that drive the radial diffusion, and (3) to develop a software package of radial diffusion coefficients for use in radiation belt models. We propose to obtain quasilinear radial diffusion coefficients from recent analytic work by Brizard and Chan [Physics of Plasmas, 2001, 2004], and to perform simulations of test particles moving in analytic ULF wave fields to test these quasilinear coefficients numerically. Effects of non-axisymmetric magnetospheric magnetic fields and off-equatorial particle distributions will be considered. We also propose to carry out test-particle simulations of radiation belt electron motion in the electromagnetic fields of the Lyon-Fedder-Mobarry (LFM) global-MHD simulation code. These MHD-particle simulations would include effects of radial diffusion by MHD waves, convective transport by sudden compressions of the magnetosphere, and losses by magnetopause shadowing. We propose validation tests where MHD waves produced by the LFM code are compared with other calculations of magnetospheric MHD waves and with magnetometer measurements of ULF waves. Results will be used to evaluate how well the analytic quasilinear coefficients describe radial diffusion of radiation belt electrons, and to develop the code package of radial diffusion coefficients. We envision a hierarchy of diffusion coefficients, ranging from a simple power law dependence in L-shell, to more sophisticated coefficients which use a power spectral density calculated from global MHD simulations or from arrays of ground-based magnetometer data for a given set of solar wind inputs. The radial diffusion software package would be made available to the radiation belt community, for use in radiation belt models and for validation tests of those models. By providing a better quantitative understanding of radial diffusion and by developing software to implement the resulting radial diffusion coefficients, the proposed effort would contribute directly to the LWS TR&T goal of "developing and validating usable, quantitative models that describe the dynamic evolution of the radiation belt slot region and the adjacent outer zone flux peak."

PI: Lennard Fisk/University of Michigan Ann Arbor

Proposal Title: Supporting Theoretical Studies of the Processes that Control the Topology and Evolution of the Open Magnetic Flux of the Sun

Abstract:
Project Summary This investigation will develop theories for the fundamental processes that control the evolution of the open magnetic flux of the Sun. The theories are intended to provide insights and inputs to numerical models that need to be developed for the dynamic behavior of the solar corona, its magnetic field, and the solar wind. This research thus needs to be conducted in close coordination with the investigations

developing these models through the Focus Team formed for LWS TR&T Program Objective T3e. The investigation will also conduct analysis of data sets we have access to, which can provide tests of models for the topology and evolution of the open magnetic flux. Such tests are important for both verifying the models and providing feedback to improve the theoretical concepts on which the models are based. This research also needs to be conducted through the Focus Team for Objective T3e. One of the most significant issues for understanding the coupling of the Sun and the heliosphere, and thus the formation of the heliosphere, is to determine the topology and evolution of the open magnetic flux of the Sun. The open flux controls the flow of the solar wind in the solar corona; the escape of energetic particles; the conditions through which Coronal Mass Ejections propagate and accelerate energetic particles; it is an integral component in the magnetic field reversal of the Sun. We have introduced a number of concepts that we consider are important for determining the topology and evolution of the open magnetic flux of the Sun. In particular, we have argued that open magnetic field lines can reconnect with closed magnetic loops, and that this represents a significant transport mechanism for the open flux that affects its distribution on the Sun and its evolution, and results in motions that alter the heliospheric magnetic field. We have and are proposing here to develop theoretical models to describe the transport of open flux by this mechanism, and the consequences. The results of these theoretical investigations should provide (i) insights into the likely distributions of open magnetic flux outside of coronal holes; (ii) the inner boundary conditions for the solar corona, such as the mass flux of the solar wind and the Poynting vector; and (iii) the deposition of energy into the corona to accelerate the solar wind. All these outputs are intended to be useful for developing full numerical models for the topology and evolution of the open magnetic flux of the Sun.

PI: Linton Floyd/Interferometrics, Inc.

Proposal Title: Solar UV Irradiance Variation during the Solar Cycle

Abstract:
Analysis of terrestrial climate data have shown effects of the solar activity cycle (e.g., Quasi Decadal Oscillation). Variations in the solar ultraviolet (UV) irradiance are one likely cause because of UV absorption in the Earth's various atmospheric layers. Recent climate simulations based on realistic models of atmopheric processes involving solar UV irradiance have shown that solar UV variation can cause significant terrestrial climate changes. Begun in 1978, space-based measurements of solar UV irradiance are often difficult to interpret because of uncertainties in the long-term responsivity calibration of the measuring instruments. Generally, the solar variations are large compared to these uncertainties for the shortest wavelengths (e.g. < 200 nm), but decline for longer wavelengths until ~300 nm where instrumental trends inevitably dominate. The goal of this research is to determine the solar cycle variation of the solar UV irradiance from the available data from several experiments. For each solar UV experiment and time period, the solar cycle variation will be determined. For wavelengths where the solar cycle can be observed directly, the solar cycle variation for rising or falling phases of the solar cycle will be directly calculated from the calibrated data. For longer wavelengths where instrumental trends dominate the solar variation, presence of the solar signal, as represented by the MgII core-to-wing ratio index and where possible the Photometric

Sunspot Index, will be detected and the solar cycle variation inferred. The results will be interpreted in the context of and will be compared with the results of state-of-the-art synthetic solar spectum models.

PI: Mei-Ching Fok/Goddard Space Flight Center

Proposal Title: A Physical Model of the Radiation Belt

Abstract:
While there are existing physical models that specify and forecast the terrestrial radiation belt environment, hardly any of them covers the entire radiation belt region and energy range. We propose to formulate a comprehensive physical model of the radiation belt electrons, encompassing both diffusive and convective effects. This model is a data-driven bounce averaged model, which solves the plasma distribution functions in the ranges of 2-10 earth radii and 10 keV to 4 MeV energy. The solar wind and IMF data are the only inputs of the model. The model will set a new standard for quantitative predictive capability, after refinement based on testing against representative event observations and calibration through comparison with diverse applicable data sets. The results will lead directly to a physics-based model that links the radiation belt response quantitatively to its energy sources and the mechanisms that accelerate charged particles into the energy range known to have harmful effects on humans and human systems in space. The model will be made available in the form of open source software tools that permit ready evaluation of radiation belt conditions for specific events, which will find applications to aerospace technology, biological and materials research, human exploration and development of space, and space science in the Sun-Earth connection theme.

PI: Rolando Garcia/NCAR

Proposal Title: Studies of the Atmospheric Impact of 11-Year Solar Variability Using the Whole Atmosphere Community Climate Model

Abstract:
NCAR's Whole Atmosphere Community Climate Model (WACCM) will be used to study the impact of 11-year solar variability form the troposphere to the lower thermosphere. The model domain extends from the ground to ~150 km, and includes fully interactive chemical, dynamical and radiative processes over this range of altitude. We propose a series of integrations over 8-10 simulated solar cycles to establish the statistical significance of the results, and help elucidate the physical mechanisms responsible for atmospheric variability on 11-year time scales; this approach is especially important in the troposphere and lower stratosphere, where solar signals are expected to be small. In addition to the model, we will use NASA satellite observations (UARS, TIMED, SNOE, etc.), plus ground-based observations, to specify the variability of solar irradiance and particle precipitation over the 11-year solar cycle, to validate model results, and to help elucidate the mechanisms whereby solar variability impacts the state of the atmosphere.

PI: Manolis Georgoulis/The Johns Hopkins University Applied Physics Laboratory

Proposal Title: The CME-ICME Connection: Understanding ICMEs from a Magnetic Analysis of their Solar Progenitors

Abstract:
In situ measurements of ICMEs at 1 AU and multi-wavelength observations of the solar corona have recently enabled a direct comparison between the properties of ICMEs and their origins, namely the initial CMEs and the source solar active regions. However, the first results of this comparison yield more questions than answers and the quantitative correspondence between CMEs and ICMEs remains unclear and problematic. Moreover, the actual mechanism, or combinations of mechanisms, that trigger CMEs continue to be unknown. As a CME initiation is almost certainly of magnetic origin, we propose to study photospheric and chromospheric, where available, vector magnetic field observations of CME-prolific active regions aiming to understand and quantitatively describe CMEs. Moreover, we propose to investigate for precursors of CMEs in the active region photosphere / chromosphere. In this effort we will employ two newly devised vector magnetogram analysis techniques: First, a technique to infer the flows of the magnetized plasma at the altitude of the magnetic field measurements. This allows an accurate calculation of the helicity variations that triggers CMEs in the solar atmosphere, due to helicity injection from the solar interior and helicity generation by photospheric shuffling. Second, a technique to estimate the total magnetic helicity budget of solar active regions by modeling their coronal magnetic fields. If a CME is launched the magnetic field lines open and the magnetic helicity content decreases in the calculation volume thus leading to an estimation of the magnetic energy, helicity, and the sense of twist of the departed CME to be directly compared with ICME observations. The required vector magnetograms will be provided by the archives of the Imaging Vector Magnetograph (IVM) of the University of Hawaii, while vector magnetograms from the Synoptic Optical Long-Term Investigation of the Sun (SOLIS) will be employed as soon as they become available. The proposed effort addresses the Focused Science Topics (e) and (f) of the LWS TR&T solicitation, namely "to determine the topology and evolution of the open magnetic field on the Sun connecting the photosphere through the corona to the heliosphere" and "to determine the solar origins of the plasma and magnetic flux observed in an ICME".

PI: Michael Henderson/Los Alamos National Laboratory

Proposal Title: LWS: Inferring Source Regions of Dispersed Injections from Polar and LANL GEO Particle Data

Abstract:
Although the injection of particles at geosynchronous orbit is one of the most well known and well documented signatures of magnetospheric substorms and their occurrence have become one of the most routinely used indicators of substorm onset, the physical mechanism responsible for the observed dispersion features is not yet completely understood. A number of different classes of models have been proposed over the years including: the injection boundary model, the time-dependent Alfven boundary model, the

convection surge model, and most recently the Earthward propagating magnetic field pulse type models. Despite the fact that the injection boundary model has been enormously successful in explaining and organizing the complicated dispersion patterns seen throughout the inner magnetosphere and demonstrates that an injection boundary like inner edge likely exists, the model is completely ad-hoc and does not explicitly invoke a physical mechanism for the particle energization. On the other hand, the propagating pulse type models do explicitly invoke a physical mechanism and have been shown to be capable of reproducing the observed dispersion over at least a limited range of energies. But, to date no attempt has been made to show that this type of model is capable of producing the complete dispersion signatures observed in the inner magnetosphere. We propose to make extensive use of LANL geosynchronous plasma and energetic particle data, together with Polar and Cluster energetic particle data in order to: (1) Test existing injection models using comprehensive, multi-point, pitch-angle-resolved observations of particle dispersion. (2) Determine the source locations for particles associated with injections. (3) Provide an empirical specification of particle source locations for input to The datasets that we will use in this proposal include in-situ data from POLAR CEPPAD/IPS, and the LANL GEO spacecraft.

PI: Bradley Hindman/University of Colorado, Boulder

Proposal Title: Tools Enabling Rapid Mapping of Solar Subsurface Weather with Time-Distance Tomography

Abstract:
The Helioseismic and Magnetic Imager (HMI) to be launched aboard the Solar Dynamics Observatory (SDO) will enable major new initiatives to study the complex coupling of turbulent convection and intricate magnetism within the sun's convection zone. HMI will provide continuous Doppler and magnetic imaging of the entire solar disk with fourfold better spatial resolution than is regularly available with any current ground- or space-based instruments. Helioseismology has revealed that strong winds and flow structures, called solar subsurface weather (SSW), are present beneath the solar surface. These flows clearly interact with magnetic active regions and are likely the signature of giant cells, the largest scales of solar convection which span the entire depth of the convection zone. We propose to develop new time-distance tomography procedures designed to explicitly resolve the role of giant cells in the evolving SSW. The primary goal of these tools will be to permit nearly real-time mapping of such flows and their interaction with photospheric magnetism on a continuous basis using HMI. Numerical simulations of solar convection indicate that giant cells can readily propagate and evolve in an intricate manner, often organizing into larger-scale patterns. Present helioseismic observations indicate that SSW interacts strongly with the magnetic fields that pierce the solar surface in the form of active regions, sunspots and plage. In particular, active regions usually appear as zones of convergence near the surface and often exhibit strong diverging flows at greater depths. It is likely that giant cells and larger-scale organizations of such convection may contribute to instabilities within the tachocline that yield the active regions, particularly in the case of active nests where new magnetic flux repeatedly emerges at the same location on the solar surface.

PI: Charles Jackman/Goddard Space Flight Center

Proposal Title: Solar Proton Events and their Atmospheric Dynamical Influence

Abstract:
This investigation will be directed towards two aspects of atmospheric dynamics and solar proton events. The first part will focus on the influence of solar proton events on atmospheric dynamics, including the temperature and wind changes caused by the events. Several very large solar proton events in the past thirty-five years have created significant perturbations in the polar mesosphere due to substantial ozone decreases and Joule heating over a couple of days. A few of these events also caused polar upper stratospheric ozone decreases of over 10% for a period of several weeks. The dynamical changes resulting from these short-term (days) and long-term (weeks) influences from solar protons will be investigated with two different models, the TIME-GCM (Thermosphere Ionosphere Mesosphere Electrodynamics - General Circulation Model) whose domain is from 30 to 500 km and the WACCM (Whole Atmosphere Community Climate Model) whose domain is from the ground to 140 km. The second part of the investigation will focus on the transport of the perturbed atmospheric constituents, caused by solar protons, for weeks to months past the events. The transport for the specific time periods of study will be generated from meteorological data sets and will be used in the GSFC Two-dimensional Photochemistry and Transport Model whose domain is from the ground up to 90 km. A third part of the investigation will focus on some of the uncertainties in the model computations that are particularly relevant to the solar proton-induced atmospheric perturbation. Model results from all parts of the investigation will be compared to satellite and ground-based measurements, whenever possible.

PI: Bernard Jackson/University of California San Diego

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

Abstract:
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 have also been involved in the construction of the Solar Mass Ejection Imager (SMEI) launched February 2003 that can can track interplanetary disturbances crossing the large gulf between the solar corona and Earth. 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 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 near real-time SMEI data analysis. 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 analyses. 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.

PI: Vinay Kashyap/Smithsonian Astrophysical Observatory

Proposal Title: Next Generation Tools for Diagnostics of Solar Coronal Structure

Abstract:
The aim of this proposal is to develop and make publicly available a set of robust IDL-based tools for investigation of the complete emission structure of the Sun from a wide variety of solar data sets but with emphasis on the new instrumentation on Solar-B and SDO. In particular, a major focus of our efforts will be towards robust investigation of temperature structure, including an extremely fast and efficient method for estimating Differential Emission Measures (DEMs). The proposed set of tools will allow scientists to investigate imaging and spectral data, understand the origins of observed flux in different bandpasses, interactively isolate coronal structures for analysis, derive DEMs for multi-bandpass image sets of up to 16 million pixels as a function of space and time and with the crucially important capability to estimate errors in the reconstructions, and to apply the same analyses seamlessly to observations with different instrumentation and different satellites. Visualization tools will be provided to show the evolution of DEMs in time and for construction of single temperature images from the DEMs. The tool set will build on and derive from the existing PINTofALE software developed for the analysis of high-resolution X-ray and EUV stellar spectra, such as those observed with the Chandra Mission. This will allow the users flexibility in their choice of atomic data and emission line codes, allow for easy modification of the assumptions that go into those codes, and incorporate the ability to take into account atomic data uncertainties. The combination will result in a very general software package for analysis of the solar outer atmosphere. The package will be fully-incorporated into SolarSoftWare.

PI: Jozsef Kota/The University of Arizona

Proposal Title: Energetic Particles and the Earth's Environment in Space

Abstract:
Energetic particles are one of the most-important elements of the Earth's environment in space. Large increases in the flux of energetic particles reaching the Earth may pose serious threat to technology such as satellites and other parts of the human environment in space. This proposal seeks three years of support for a program of detailed numerical modeling and theoretical studies to understand, model, and predict large solar particle events (SEPs). We propose to develop and apply tools to simulate the acceleration of energetic particles at CME (Coronal Mass Ejection) driven shocks and their subsequent

transport to the Earth in realistic CME models. We are already combining our SEP acceleration and transport codes to realistic CME simulations of other groups with encouraging results, and intend to continue and extend this work. Our code follows magnetic field lines as they evolve thus is suitable for handling the complex and time-varying configurations of realistic CMEs. We have the capability to work with other groups and incorporate their different CME models into our code. We intend to make our code accessible for the community. Theoretical studies will be continued to clarify the injection mechanism which is one of the most important processes in producing SEPs, and is still poorly understood. Also, we will study the role which cross-field diffusion plays in the process and incorporate it into our codes. Specifically we propose: - Full coupling between realistic CME simulation and our SEP codes. - Using CME simulations as input to our SEP code, implying partial, infrequent coupling with large time steps. - Study test cases to isolate and identify the role of different processes - Continue theoretical research addressing the injection problem, and explore the efficiency of quasi-perpendicular shocks. We shall use hybrid simulations and particle pushing techniques. - Address the role cross-field diffusion plays in the transport of SEP from the Sun to the Earth, and incorporate cross-field transport into our codes.

PI: Gang Li/University of California Riverside

Proposal Title: Particle Acceleration at CME-driven and Interplanetary Shock and Transport in Inner Heliosphere

Abstract:
Understanding the origin and acceleration of solar energetic particles and its interaction with interplanetary plasma is one of the outstanding problems in heliospheric physics and astrophysics. Over the past 30 years, an enormous amount of data on solar energetic particles events (SEPs) has been obtained. To fully appreciate these observational data, especially in-situ measurements by spacecraft such as ACE and WIND, a proper understanding of the properties of the turbulent interplanetary magnetic field and its role in the particle acceleration process, together with a realistic particle acceleration model, is necessary. In this proposal, we propose to perform the following studies, 1) We will investigate the generation and amplification of upstream turbulence (often in the form of Alfven waves) and its role in the particle acceleration process. We will re-examine the transmission of upstream turbulence to the downstream region at a CME-driven/ interplanetary shock. 2) We will continue the work of Li et al. [2004a] and investigate correlations between the upstream turbulence and particle spectra at the shock. Specific SEP events with clean turbulent magnetic field data and particle data will be identified, and the necessary data analysis on the turbulent magnetic field will be performed. 3) We will study particle acceleration at a perpendicular shock using a recently developed theory, known as non-linear guiding center theory (NLGC) [Matthaeus et al., 2003, Zank et al., 2004] and we will extend our existing particle acceleration model to incorporate quasi-perpendicular shocks. These goals are in excellent agreement with the objective T3d - Solar Energetic Particle, of the Living With a Star program. We believe our study will further help us understand basic questions such as the seed population of SEPs, the time scale for accelerating particles and the time intensity profile of energetic particle populations at L1.

PI: Michael Liemohn/University of Michigan

Proposal Title: Quantitative Assessment of Radiation Belt Driver Modeling: The Stormtime Ring Current and Plasmasphere

Abstract:

We propose to assess the physical processes responsible for the formation and dynamics of the outer zone radiation belt with an array of physics-based models. In particular, the ring current and the plasmasphere are two primary factors influencing the radiation belts. The dynamics of the radiation belts are highly dependent on the magnitude and morphology of the ring current through magnetic field perturbations and wave excitation. It is also highly dependent on the morphology and evolution of the plasmasphere, particularly the location of the plasmapause and the different plasma wave regimes inside and outside of this boundary. The Space Weather Modeling Framework (SWMF) will be employed to test various inner magnetospheric models for these two plasma populations. Because the SMWF allows for easy exchange of subroutines for a given science module (once implemented within the framework), several models each will be used for the plasmasphere and the ring current, resulting in model combi-nations of varying degrees of sophistication. Two magnetic storms will be considered: the CAWSES interval in March-April 2004 (high-speed stream and a small storm) and the Halloween superstorms of October-November, 2003 (with 3 Dst minima below -350 nT). Both of these intervals had post-storm enhancements of the outer zone fluxes, yet the storm sizes are very different. Several more storms will also be simulated in the second half of the project, as defined by the Focused Science Topic (FST) Team. All model results will be made available to the other funded researchers for use in their observational, theoretical, or numerical studies of the radiation belts. Extensive data-model comparisons of the plasmasphere, ring current, and near-Earth magnetic field will yield a quantitative accuracy-versus-sophistication assessment of the SWMF for these two events. The "best-fit" simulation will be used to calculate adiabatic invariants for several relativistic electron data sets throughout these storms. From this, fluxes can be converted to phase space densities and an assessment will be made of the formation and dynamics of the outer zone radiation belt. In particular, the question of an internal or external source will be examined, as well as the influence of the plasmasphere and ring current on inner magnetospheric relativistic electrons.

PI: Yuri Litvinenko/University of NH

Proposal Title: Particle Acceleration in Reconnecting Current Sheets in Solar Flares

Abstract:

A large fraction of solar flare energy is released in the form of nonthermal particles. This proposal requests funding for a three-year program of theoretical research on particle acceleration in flares and coronal mass ejections (CMEs). The modeling of particle acceleration by the direct electric field at magnetic reconnection sites in the solar corona and its observational consequences at the Earth is the focus of the proposed work. The major goal is to relate the observed properties of the high-energy particles and radiation

to the properties of an evolving magnetic field in solar active regions. This is a necessary step for the prediction of solar energetic particle events and, more generally, for the development of quantitative useful models of space weather. The proposed work is strongly motivated by new observations, primarily by the Ramaty High Energy Solar Spectroscopic Imager (RHESSI) that provided important information on the location, flux, and spectra of flare X-rays and gamma-rays, as well as the evolution of flare loops. The effects of the geometry of the coronal magnetic field on the process of particle acceleration will be investigated using an exact global solution for three-dimensional magnetic reconnection. The model for particle acceleration will be extended to include the effects of the Hall current at the reconnection site and a realistic time-dependent model for the magnetic field structure associated with an erupting filament or CME. The theoretical predictions will be compared with RHESSI data in order to relate the observed properties of solar energetic particles to the underlying process of magnetic energy release. Observational effects to be analyzed will include the correlation between the separation of flare loop footpoints and the total hard X-ray flux, the shape of hard X-ray light curves during the flare impulsive phase, and the soft-hard-soft pattern in the evolution of the flare hard X-ray spectra. A combination of numerical analysis and analytical modeling will provide testable quantitative predictions that can be effectively used for the interpretation of observations. The proposed work will provide a framework for modeling and predicting the active phenomena associated with solar energetic particles.

PI: Dirk Lummerzheim/University of Alaska Fairbanks

Proposal Title: Heating and Mixing of Thermospheric Constituents in Small Scale Aurora

Abstract:
The mechanisms for ion outflow from the auroral ionosphere into the magnetosphere are one of the fundamental open problems of space physics. It is widely accepted that this process is a multi-step process. In a first step ionospheric and thermospheric mechanisms provide an upwelling of oxygen and other heavy ions to higher than usual altitudes. These ions then constitute the seed population for active acceleration mechanisms such as localized electric fields or inertial forces. Both of these steps are currently not understood. Here it is proposed to study and quantify possible mechanisms which cause the ion upwelling. Similarly, observational evidence for unusually strong vertical neutral winds in the vicinity of aurora is plentiful. This wind contributes to thermospheric mixing and compositional changes. Wind velocities significantly exceed expectation, and modeling efforts to explain the structure and speed of vertical wind or the resulting compositional changes lack satisfactory conclusion. This problem fits well into the LWS focused science topic (T3.b) “to quantify the response of thermospheric density and composition to solar and high latitude forcing.” With this proposal we will investigate the coupled plasma and neutral dynamics in aurora to explain the generation, structure, and dynamics of vertical neutral wind and ion upwelling. Observations have shown strong upwelling of ionospheric ions, strong and localized vertical neutral winds, and changes to the atomic to neutral mixing ratio in aurora. Rather than considering each of these phenomena separately, we will look at the complete picture in a systematic manner. Structured aurora

leads to Joule heating in the lower ionosphere. This in turn drives neutral vertical wind. Auroral precipitation and field aligned currents cause electron heating, electron pressure gradients, and upwelling of ions through the resulting ambipolar electric field. Vertical neutral wind interacts with the plasma dynamics by ion drag and allows, or even forces, upwelling of ions. At the same time the neutral mixing ratio is transported upwards, causing atomic oxygen depletion in the aurora. We will use a 3-D three fluid code to simulate the ionospheric and thermospheric processes in aurora. This simulation code is well developed and runs with up to 1000x1000x1000 grid points on a parallel computer. We have used this code to study small-scale auroral processes in the past. We will conduct case studies using observations to specify the input and boundary conditions, and predict observable parameters. We will run the simulation in a parameter study where we look at individual processes separately and in combination. We will develop diagnostic tools for the simulation that allow us to produce parameters with the same spatial and temporal resolution as the instruments that are used for these observations. The results will clarify how different ionospheric conditions and different drivers impact the vertical motion of heavy ions. This is the source population for additional acceleration at higher altitudes. The upwelling and this additional acceleration together determine the ion-outflow from the ionosphere. In addition, the results will shed light on the neutral dynamics and composition changes in the auroral ionosphere. Theses changes are not well understood and are important for many dynamical and chemical processes in the upper atmosphere.

PI: J. Menietti/The University of Iowa

Proposal Title: Statistical Study of Stochastic, Chorus-driven Electron Acceleration During Geomagnetically Disturbed Periods

Abstract:
It has been previously shown [e.g., Tsurutani and Smith, 1974; Anderson and Maeda, 1977] that the injection of substorm electrons leads to the excitation of intense whistler mode chorus emissions in the vicinity of the geomagnetic equator outside of the plasmasphere. These waves, in turn, can accelerate the electrons in the Earth's outer radiation belt to relativistic (MeV) energies [Summers and Ma, [1998]; Meredith et al., 2003a] causing radiation damage to Earth-orbiting spacecraft, communication systems, and possibly even to humans. An important question to be resolved is the free energy source of chorus. It is generally believed that chorus is generated by a nonlinear process based on the electron cyclotron resonance of whistler-mode waves with energetic electrons in the outer radiation belt (e.g., Helliwell [1967]; Tsurutani and Smith [1974]; Nunn et al. [1997]). It is known that a two-temperature anisotropic Maxwellian particle distribution can be unstable to the whistler mode. Trakhtengerts [1999] has suggested that a "stepped" phase space distribution may trigger chorus as suggested by the recently discovered discrete, nonlinear fine sub-packet structures seen in the wideband waveforms and spectrograms [e.g., Santokik et al., 2003; 2004]. In this proposed study we will examine the particle and wave data for each of the chorus events observed by the Polar and Cluster satellites to date. We seek to extend the CRRES study of Meredith et al. [2003a] by examining the data from polar-orbiting spacecraft, essentially along L-shells, thus providing a latitudinal dependence of the data. We will also seek to identify the free-

energy source of the chorus emissions, to distinguish between competing generation mechanisms. This study provides an in-depth look at processes that are critical to the safety and operational functionality of Earth-orbiting spacecraft, communications systems, and conceivably to humans in orbit in the future. It is thus of particular interest to the Living With a Star Program sponsored by NASA. In accordance with NASA science objectives all of these studies directly attempt to enhance the scientific return of the Polar and Cluster missions, by studying the dynamical plasma and plasma wave processes operating in and near the plasmasphere of Earth. These efforts include data analysis and modeling studies relevant to the interpretation of the mission data. Goal I. OSS theme: Sun-Earth Connection; Science Objective: Understand the origins and societal impacts of variability in the Sun-Earth Connection; RFA: Specify and enable prediction of changes to the Earth's radiation environment, ionosphere, and upper atmosphere. Goal II. OSS theme: Sun-Earth Connection; Science Objective: Understanding the changing flow of energy and matter throughout the planetary environment; RFA: Understand the response of magnetospheres to the external and internal drivers.

PI: Zoran Mikic/Science Applications International Corp

Proposal Title: Relating Interplanetary Coronal Mass Ejections to their Source on the Sun

Abstract:
In situ magnetic field measurements of propagated interplanetary coronal mass ejections (ICMEs) provide an important constraint in verifying CME initiation models. This understanding can improve our ability to predict geomagnetic storms, since CMEs are an important driver of space weather. We propose to use numerical simulations of CME initiation and propagation to explicitly elucidate the relationship between CMEs and ICMEs, and to thereby link in situ measurements with their solar sources. The novel aspect of our investigation is to increase the realism of the models, particularly to include the important effects of a realistic background solar wind on CME propagation and distortion, and to use measured photospheric magnetic fields on an active-region scale, including their interaction with the surrounding large-scale magnetic field. We will explore leading candidates for CME initiation, including the flux cancellation model and the breakout model. We propose to work with selected team members to maximize the scientific return from the novel "Focused Science Topic" approach of this LWS program. Our proposed program will help to develop the foundation for the prediction of the geoeffective properties of ICMEs at Earth from solar and heliospheric observations, by providing a deeper understanding of the initiation and propagation of CMEs. Eventually, the numerical tools that will be developed in this investigation could be used for the development of a predictive capability. The proposed simulation capability will allow us to explore the magnetic cloud-active region relationship in more detail than has heretofore been possible. We will address the expansion of magnetic clouds in interplanetary space from their origin in the low corona, including the topology of the magnetic field lines that connect the magnetic cloud with the Sun and the outer heliosphere. We will study how magnetic reconnection transfers magnetic field and electric current from an active region and the overlying large-scale coronal field into the

magnetic cloud. We will also identify which characteristics of the magnetic field near the Sun determine the geoeffectiveness of ICMEs.

PI: Jeff Morrill/Naval Research Laboratory

Proposal Title: A Model of Long-Term Variability of Solar UV and EUV Irradiance

Abstract:
Studies of climate and ozone variability have shown the need for detailed knowledge of long-term solar UV/EUV spectral irradiance variability. The proposed research will derive estimates of the long-term solar UV and EUV spectral irradiance using Ca II K images and a solar irradiance model developed under an earlier NASA/LWS TR&T research grant. That model uses Ca II K images observed by Big Bear Solar Observatory and model results are currently being validated by comparison to observed full disk irradiance spectra from UARS. By using digitized versions of the Mt Wilson Observatory (MWO) Ca II K film archive and spectra measured from the SKYLAB film archive estimates of the solar UV irradiance spectrum can be derived over the wavelength range from ~ 120 to ~400nm. In addition, by using the calculated Mg II index as a proxy for shorter wavelength emissions we will provide irradiance values in the EUV. Use of the SKYLAB and MWO archives coupled with more recent photoelectric Ca II K observations will yield estimated UV/EUV spectra that will span the time period from 1915 through the present thus providing estimated values over nearly a century. These estimated spectra will be valuable as inputs to long-term models of climate and ozone variability as well as Martian photochemistry. Currently, a preliminary set of digitized versions of the MWO photographic solar images has been acquired from the National Geophysical Data Center. In addition, a more comprehensive analysis and improved digitization of the MWO photographic archive is presently underway as part of a NASA funded project. Once available, we will use these improved MWO images to generate the final set of estimated spectra. An initial component of this proposal will be to upgrade the current irradiance model to include wavelengths below 200nm and to validate model results with measured UV and EUV. Once completed, the resulting estimated spectra will be used to address unresolved questions surrounding current long-term reconstructions of solar variability.

PI: Terrence Nathan/University of California Davis

Proposal Title: Modeling the Climate System's Response to the 11-Year Solar Cycle

Abstract:
Observational and global modeling evidence both point to the stratosphere as the intermediary for communicating variations in solar irradiance to the troposphere. The observational evidence indicates that interactions between the quasi-biennial oscillation (QBO) and stratospheric ozone may provide a pathway for linking the 11-year solar cycle to long-term climate variability; the global modeling evidence shows that the solar cycle signal may be amplified by stratospheric ozone to affect the extratropical planetary waves. How the solar cycle modulates the interactions between the QBO, stratospheric ozone, and extratropical planetary waves remains largely unknown. This is due in part to

the inability of global climate models to produce a realistic QBO. In view of the importance of the QBO to the solar cycle problem and global climate, the proposed research will assimilate the QBO and its interactions with solar induced ozone perturbations into the Whole Atmosphere Community Climate Model (WACCM). This will permit us to address our central objective: to provide improved understanding and more accurate numerical simulations of atmospheric quasi-decadal variability associated with the 11-year solar cycle. In addressing this objective we shall employ a unified work flow that combines basic research, numerical modeling, and observational validation. The basic research will employ tropical and extratropical mechanistic models to help identify mechanisms that may provide a pathway for linking the solar cycle signal to variations in climate. Attention will be focused on developing a better understanding of how solar cycle induced variations in stratospheric ozone modulates the interactions between the QBO, stratospheric ozone and planetary waves. The numerical modeling will involve assimilating the QBO into the WACCM; the output will be analyzed with a suite of diagnostics; including Eliassen-Palm fluxes, refractive indices, and singular value decomposition. The modeling simulations will be validated by comparing the WACCM output with observations. The proposed research addresses the primary goal of NASA, the Office of Space Science, and the Living with a Star Program: to develop scientific understanding of the Sun-Earth system and its impact on terrestrial climate.

PI: Nariaki Nitta/Lockheed Martin Advanced Technology Center

Proposal Title: Solar Connection of Interplanetary Coronal Mass Ejections

Abstract:
We propose to identify and study solar sources of a few hundred interplanetary coronal mass ejections (ICMEs) identified in solar wind plasma and magnetic field data since 1996. We examine all the available EUV/X-ray full-disk images taken 30-120 hours before each ICME to isolate the particular coronal signatures that may be linked to the ICME. In the ideal case when only one fast and front-sided halo coronal mass ejection (CME) is observed in the time window, we concentrate on the few hours around the onset of the CME. ICMEs have several defining properties. One of them is the magnetic cloud, which can be modeled under the simplifying assumptions of force-free field and cylindrical geometry. Comparing the geometrical parameters from these models with solar observations, we explore the origin of flux ropes. Another ICME manifestation consists of compositional anomalies and high charge states, indicating high temperatures when the plasma is ejected with the CME. We analyze high temporal- and spatial-resolution EUV/X-ray images of solar eruptions associated with these ICMEs to understand when and where magnetic reconnection takes place during CME initiation. In order to understand why no ICMEs result from many front-sided halo CMEs, we compare LASCO and EUV/X-ray images to find any differences in the temporal or spatial behaviors of CMEs with and without ICMEs, and also study the effect of the CME's location within the large-scale magnetic field. A subset of ICMEs is directly responsible for geomagnetic storms. Our work complements several past and on-going projects that are targeted primarily to the prediction of geomagnetic storms on the basis of halo CMEs.

PI: T. O'Brien/The Aerospace Corporation

Proposal Title: Next Generation Specification of the Earth's Radiation Environment

Abstract:
We propose to develop a next generation comprehensive electron radiation belt specification model to supersede existing models like AE-8. The 2003 Science Definition Team report identifies this next generation specification as a top priority because the existing models are out of date, leading to incorrect and incomplete specifications. Incorrect specifications lead to a host of problems, including incorrect spacecraft design choices. Incomplete specifications limit the technical and scientific applications of the specification model. The primary objective of this upgrade will be to improve the quality of the outputs of the models by incorporating the enormous volume of radiation measurements obtained since the release of the current specifications. Additionally, we will enhance the capabilities of the model to: (1) provide 6-month resolution in solar cycle phase because the existing solar max/solar min delineation badly misrepresents the solar cycle variation of the radiation belts; (2) provide the ability to put error bars on the estimated mission dose and internal charging specifications through the provision of percentiles as well as mean fluxes--these error bars will curtail the multiple arbitrary fudge factors commonly added to the outputs of the specification models; (3) provide a specification of ring current ions (H+, O+, He+, He++ from 1 to 400 keV), which are not part of the existing specification models because such ions have only recently been recognized as a possible radiation hazard (e.g. solar array cover-glass darkening); (4) provide covariance matrices among the fiducial fluxes in the specification so that the specification can be used as an a priori model for data assimilation of in situ flux measurements and solar-wind driven forecasts and for inversion of ENA images. We will include data from a variety of sources in our next generation specification model, including Polar, SAMPEX, CRRES, SCATHA, GOES, POES, LANL GEO, LANL GPS, Cluster, and ISEE.

PI: Robert Pfaff/NASA/GSFC

Proposal Title: C/NOFS Data Dissemination and Processing Tools

Abstract:
Data processing tools and software will be prepared to disseminate the DC and AC electric field, magnetic field, Langmuir probe, and lightning detector data on the C/NOFS satellite to the space physics community.

PI: Victor Pizzo/NOAA/SEC

Proposal Title: Near-real-time Characterization of CMEs using Multi-view White Light Solar Observations

Abstract:
We propose to develop methods for utilizing multi-view white light observations of the solar corona to determine in near real time the gross properties of CMEs, such as the heliographic centerline, velocity, and geometric shape and extent. The results will address

both research and forecast needs within the space physics and space weather communities. While the study will make use of the prospective STEREO coronagraph data streams as model input, it will entail comprehensive forward modeling having broad applicability, including for future missions with out-of-the-ecliptic components. The best available descriptions of coronal backgrounds, Zodiacal light, and instrumental noise will be utilized in simulations of CME total intensity and polarization signals. The approach incorporates recent advances in two techniques, one using geometric triangulation upon the periphery of the CME, the other involving analysis of the polarized components of the white light emission. Both methods will be developed in conjunction to produce practical tools for tracking CMEs in the corona. The methods constructed in this work will complement tomographic and other approaches currently under study.

PI: Geoffrey Reeves/Los Alamos National Laboratory

Proposal Title: A Strengthened Numerical Foundation to Enable Integrated Ring Current and Radiation Belt Specification and Prediction

Abstract:
In an era of increasing reliance on space-based satellite assets, hazards associated with space weather and climate are becoming increasingly important. Modeling the coupled ring-current/radiation belt systems of the inner magnetosphere is one of the key ingredients for our understanding and possible forecasting of this region, leading to scientific insight that is beyond the scope of our current statistical-based models of both the geomagnetic fields and particle populations of this region. We propose here to radically extend and enhance our present modeling capabilities by adding additional physics modeling (cross-coupled diffusion) and by introducing fully self-consistent magnetic fields into an existing code. We expect this work to address the following scientific objectives, which directly relate to section 3.3.4 and 3.3.5 of the 2003 LWS TR&T Science Definition Team Report for the LWS Targeted Research and Technology [2003 LWS TR&T SDRT]: 1. Model and describe geomagnetically induced currents during disturbed times 2. Model the physical processes responsible for the acceleration, transport and loss of radiation belt particles throughout the inner magnetosphere 3. Provide a physics-based inner magnetospheric magnetic field model For this study we will build on the existing UNH-RAM code and significantly enhance its capability through new and novel numerical diffusion solvers and computation resources available at LANL. Self-consistency with the magnetic field description will be achieved by requiring force-balance with the calculated particle pressures. New insights on radiation belt dynamics will be achieved by a comprehensive inclusion of wave particle interactions and fully coupled energy, pitch angle and radial diffusion. We expect the work proposed here to lead to a more comprehensive and much more powerful numerical model, enabling a realistic approach to radiation belt evolution.

PI: Robert Richard/University of California, Los Angeles

Proposal Title: Predicting Energetic Ions in the Inner Magnetosphere

Abstract:

Energetic ions in the inner magnetosphere can be destructive to human technology. The modeling of these ions using basic physical principles is a major goal of the Living with a Star (LWS) program. A significant component of the energetic ion population can originate from solar energetic particles (SEPs) which can penetrate the magnetosphere. Because the number of energetic ions (greater than 100 keV) is much less than the number of thermal ions, they can be treated as test particles and can be followed in magnetic and electric field models. Ion acceleration at the bow shock and the magnetotail can also, at times, contribute to the energetic particle population of the inner magnetosphere. The goal of this proposal is to understand the population of the inner magnetosphere, particularly the slot region, by SEPs and accelerated solar wind ions. We will follow SEP test particles in the electric and magnetic fields from global magnetohydrodynamic (MHD) simulations of the magnetosphere. SEP test particles, based on measured upstream ion distributions will be launched in MHD simulations driven by solar wind measurements during the same interval. Even though SEPs can flood the inner magnetosphere the number entering that region compared to the number of particles upstream is small. To obtain penetration into the slot region between the inner and outer radiation belts (2-3 earth radii) will involve significant changes in this approach. Following ions backward in time can be used to identify regions accessible to energetic particles from the solar wind but does not yield their overall distribution. To obtain high-resolution maps of SEPs in the slot region, we propose to combine backwards and forward calculations. In addition we will also launch from "secondary sources", that is, distributions of particles will be launched within magnetospheric boundaries based on the distribution in location, energy and pitch angle of an initial run of test particles starting from the solar wind. This process will be repeated for particles penetrating into the inner magnetosphere to obtain significant penetration into the slot region. Because it is difficult to extend the MHD inner boundary closer than about 2 earth radii, the MHD result will be supplemented by an analytic inner region field model (a dipole plus a perturbation) based on the MHD results. We will also study additional acceleration of the ions that penetrate into the inner magnetosphere due to ULF waves. We will determine the sources of energetic ion in the inner magnetosphere and the relative contributions of SEPs and energized solar wind particles. We will determine the conditions under which ions enter the inner magnetosphere in large numbers and the detailed process by which they become trapped. We will determine the energization mechanisms acting on the ions. The goal is the develop a model that can predict fluxes of energetic ions in the inner magnetosphere based on upstream solar wind conditions based on physical principles. We will also investigate idealized storm time intervals to understand quantitatively the dependence of the process of injection into the inner magnetosphere on basic parameters. Finally we will use our results to construct a simple predictive model.

PI: Arthur Richmond/NCAR

Proposal Title: Quantifying the Effects of Magnetospheric Energy Inputs to the Thermosphere

Abstract:
The proposed work has four primary elements. (A) We will develop quantitative empirical models of the high-latitude forcing of the thermosphere, including auroral

particle precipitation, electric potential, mean-squared electric-field strength, Poynting flux, and probability distribution of Poynting flux, as functions of magnetic latitude, magnetic local time, season, interplanetary magnetic field, and magnetic activity, by analyzing satellite data and fitting the data to analytic functions of the independent variables. (B) We will evaluate the importance of the nonlinear thermospheric responses to small-scale high-latitude forcing, and develop parameterizations for global thermospheric general-circulation models to account for the effects of these sub-grid-scale nonlinear effects. (C) Through numerical simulations, forced by our empirical models and parameterizations, and through comparisons with observations and empirical thermospheric models, we will evaluate the influence of the high-latitude forcing on the global thermospheric temperature, density, and composition. (D) We will document our empirical models and parameterizations and make them publicly available to the scientific community. This proposal is a Living with a Star Targeted Investigation on Focused Science Topic b (To quantify the response of thermospheric density and composition to solar and high latitude forcing). It addresses NASA OSS RFAs I.SEC.1.b, I.SEC.1.c, and II.SEC.1.c. The investigators will actively participate in the science team that is to be formed for this Focused Science Topic, by providing the needed quantitative information about high-latitude forcing of thermospheric density and composition, by carrying out and analyzing thermospheric general-circulation model simulations that combine the high-latitude and solar forcing, and by comparing the model predictions with observations. As a supplement to this proposal, we are requesting support for a Postdoctoral Research Associate to participate in this research and contribute to the team activities on this Focused Science Topic. The descriptor for this proposal is T3b-C2.

PI: David Rust/Johns Hopkins University, Applied Physics Laboratory

Proposal Title: Probing Solar Open Magnetic Fields with Near-Relativistic Electron Beams in the Heliosphere

Abstract:
This proposed investigation utilizes a combination of heliospheric and solar data to identify a set of open solar magnetic fields for which both the solar and heliospheric locations are uniquely known. We will use solar imaging data to determine the origins of the beams of near-relativistic electrons recorded by the EPAM instrument aboard the ACE spacecraft. The beams come directly from the sun and act as probes of the solar and heliospheric magnetic fields. Detailed study of the solar regions at the inner terminus of the connecting magnetic fields will help resolve the presently incomplete understanding of the origins of energetic electrons in solar energetic particle (SEP) events. Delineation of the electron transport processes is one of the best ways to understand proton transport, which is of great interest to NASA because SEP protons can damage space systems, and in the worst of cases, they can sicken or kill astronauts working in space. We will use the electron and solar data to test existing models of magnetic field topology and to identify useful modifications of them. The primary goal of the investigation is to improve the quantitative agreement of magnetic models with the real heliosphere. A secondary goal is to prepare for the more rigorous tests of field connectivity that will be possible when the Solar Terrestrial Relations Observatory (STEREO) mission is operating.

PI: Philip Scherrer/Stanford University

Proposal Title: Methods and Tools for Studying Magnetic Field Structures and Dynamics Inside the Sun by Local Helioseismology

Abstract:
The goal of this proposal is to develop tools for investigation of magnetic field effects in the Sun's interior by methods of local helioseismology and, in particular, by time-distance helioseismology (or acoustic tomography). The key questions are: How strong is the magnetic field at different depth in the convection zone? What is the topology of the emerging magnetic structures? Where are the magnetic stresses and twists that cause flares and mass ejections generated? How does the magnetic field interact with convective flows, rotation and meridional circulation? What is the depth at which the internal flows control the surface magnetic field? Developing local helioseismology tools to answer these questions is absolutely essential for making further progress in our understanding the physics and dynamics of the solar activity and short- and long-term magnetic variability, solar cycle, and irradiance variations. The previous helioseismic diagnostics are focused on flows and a combined sound-speed signal caused by temperature variation and magnetic pressure. These methods are currently being developed and are at various stage of refinement. They have provided spectacular images of the sound-speed structures beneath sunspots, and emerging active regions. However, they also posed major questions: What are the relative contributions of magnetic field and temperature variations associated with the changes of the convective energy flux in these structures? How does the magnetic field affect helioseismic inferences? Currently, the magnetic field affects represent a central problem of helioseismology and the physics of the Sun's interior. Their investigation is very important to for developing MHD theories of sunspots and active regions, modeling magnetic configurations in the corona, and global dynamics of the heliosphere. We propose to make the next major step in developing local helioseismology methods and tools by studying explicitly magnetic effects for the whole helioseismic procedure, from measurements of the Doppler shift through helioseismic inversions. The proposed work is mainly focused on time-distance helioseismology which currently is the most advanced local helioseismology technique. However, the new methods and tools will be also applicable to other techniques, e.g. the ring-diagram analysis and holography, thus providing a major advancement in the field.

PI: Carolus Schrijver/Lockheed Martin Advanced Technology Center

Proposal Title: The Interaction Between Magnetic Fields and Large-Scale Flows, and its Effects on Modeling and Forecasting the Photospheric Magnetic Field

Abstract:
The LWS program aims to improve our understanding of the Sun-Earth connection to enable space-weather forecasting. Crucial to that effort is an understanding of the Sun's surface magnetic field which drives the corona and heliosphere. Active regions (ARs) and their decay products are important contributors to the coronal brightness and to the heliospheric field and plasma flows. Modeling the evolution and decay of the AR fields remains problematic, however: even though a diffusion model matches flux dispersal on

time scales of weeks to a few years, ARs are remarkably resistant to decay in their first few weeks. The relative coherence of ARs is likely caused by magneto-convective coupling. We propose a two-pronged approach to improve our understanding of AR decay: we plan (1) to use our existing surface-field dispersal model in comparison to observations to study how recently discovered inflows around ARs affect flux dispersal, and (2) to use numerical models of compressible magnetoconvection to study the cause of these inflows. The AR inflows likely impede flux dispersal and thus increase flux cancellation within ARs, thereby decreasing the flux escaping into the network. Such AR inflows, and the modulation of the meridional flow which converges onto the activity belts, have been mapped with SOHO/MDI. The AR inflows appear to strengthen with the magnetic flux within them, suggesting a non-linear coupling between flux dispersal and inflow strength. We propose to study AR decay by combining observations and models. First, we will measure the decay of sample ARs by comparing magnetogram sequences to simulations made with our surface-dispersal data-assimilation model which will be modified to incorporate AR inflows. In parallel, we will study the causes and effects of AR inflows using our numerical model for compressible magnetoconvection in a spherical segment by modifying it to allow for converging surface flows through, e.g., field-dependent cooling. Our project will improve our understanding of the evolution of the patterns in the solar magnetic field, and will help eliminate ad-hoc processes from current flux dispersal models. This will provide a better understanding of large-scale field that determines space weather. The required observations are available online, our model codes need but modest adaptation, and the team is familiar with both data and models; hence, the support requested here will be applied effectively to analysis and interpretation.

PI: Igor Sokolov/University of Michigan Ann Arbor

Proposal Title: Numerical Studies of the Solar Energetic Particle Acceleration Using a Dynamical Field-Line-Advection Model Coupled With a Realistic CME Model

Abstract:
Solar Energetic Particle (SEP) acceleration and transport is an issue of really vital importance, because SEPs produce radiation hazards. The manifold increase in the SEP fluxes after a Coronal Mass Ejection (CME) endangers human life and can destroy electronic devices on board manned or unmanned spacecraft that are not shielded by Earth's magnetic field. Despite some uncertainties, the available models for CME dynamics can reproduce some particular features in the CME observations, as well as the models for SEP acceleration can qualitatively explain some features in the SEP fluxes. Nevertheless, to construct a quantitative model which could explain and predict the fluxes observed in the Earth's proximity, a realistic model for CME dynamics, and a model for SEP acceleration, should be coupled together and combined with the model for dynamic interplanetary magnetic field and the solar wind to account for SEP transport from the Sun to the Earth. This project seeks funds to develop a global framework, including the MHD models of the Sun-heliosphere system, coupled with the realistic models for CME events, as well as the model describing the SEP acceleration and transport in a realistic magnetic field from the Sun to the Earth. Observational data from present (SOHO, ACE) and future (STEREO, SDO) NASA missions will be used to drive the models and to

validate them accordingly. These data-driven models will then be used as the framework to investigate the physical processes that are responsible for the SEP fluxes observed at 1 AU from the Sun. These studies will provide an improved understanding of the physical coupling between the Sun, heliosphere, magnetic field topology, CME dynamics, and SEP acceleration processes. They will also be important for the development of advanced prediction tools for Space Weather. To accomplish our scientific goals, we will use the state-of-the-art computational technology developed at the University of Michigan, namely the three-dimensional global MHD code BATS-R-US, as well as the FLAMPA code modeling SEP transport and acceleration. Both codes are integral parts of the Space Weather Modeling Framework (SWMF). These tools are the most suitable for our purposes because their inclusiveness, robustness, and adaptive grid capability will allow us to explore the physical coupling of the Sun-heliosphere system over a wide range of length scales, the SEP acceleration up to relativistic energies, and transport from the Sun to the Earth. The proposing team consists of six scientists from the University of Michigan, University of Arizona and the Naval Research Laboratory that have the necessary computational, analytical, and observational expertise needed for the success of the proposed studies. This project is expected to improve our scientific understanding of the basic physical processes of importance for Space Weather. Thus, we expect the outcome of the proposed investigations to be valuable to NASA, the Sun-Earth Connection Program in particular, and to have an impact on the solar, heliospheric, and SEP communities. This project is relevant to LWS TR&T Program Objective T3d and we will coordinate with the Focused Team to target this objective. The proposed studies address the following OSS Themes, Science Objectives and RFAs: Goal I, Sun-Earth connection, RFA 1(a); and Goal II, Sun-Earth connection, RFA 1(a), 2(a), 2(b).

PI: Stanley Solomon/UCAR/NCAR

Proposal Title: Quantification of the Thermospheric Density Response to Solar Forcing

Abstract:
The response of thermospheric densities to variable solar energy inputs in the ultraviolet and X-ray spectral regions will be studied using a general circulation model of the thermosphere-ionosphere system, and measurements of solar irradiance from several space-based instruments. Calculated densities at different geophysical conditions and locations, using measured solar irradiance as input to the model, will be compared to an extensive database of measured densities obtained from long-term changes of multiple satellite orbits due to atmospheric drag. The general circulation model physical processes and boundary conditions will be examined and adjusted to obtain agreement with the density measurements and with empirical models. Results of this research will be communicated at community model development workshops as well as in the journal literature. These studies will result in an improved understanding of short-term and solar cycle modulation of thermospheric density, and a more quantitative basis for long-term studies of possible secular change in the upper atmosphere due to cooling induced by anthropogenic gases.

PI: W Kent Tobiska/Space Environment Technologies

Proposal Title: Improvements in Solar Irradiances During Flare Periods for use in Thermospheric and Ionospheric Models

Abstract:
We propose a targeted and focused investigation that will provide substantial improvements in solar irradiances for use during flare periods in thermospheric and ionospheric research and operational models. Our proposed effort takes the next major step of a long-term project to improve solar soft X-ray (XUV) and extreme ultraviolet (EUV) irradiance specification, especially during solar flare periods. Our top research objective is to characterize solar XUV and EUV flare energy that is deposited into the terrestrial thermosphere and ionosphere with a spectral and temporal accuracy, precision, and validation not previously achieved. Secondly, we aim to predict the short-term evolution of solar flares that impact the coupled thermosphere and ionosphere systems. Thirdly, we will provide a research and operational tool that dramatically captures solar flare impacts for use by the research and operations communities. Four major tasks will be performed enabling us to accomplish these objectives. First, to obtain high time resolution irradiances in the XUV–EUV, we will use recently developed XUV flare indices that provide flare evolution detail over a few minutes. Next, these indices will be translated into electron effective temperatures and emission measures allowing increased XUV–EUV spectral resolution through the incorporation of the atomic physics databases of Chianti and APEC into the SOLAR2000 model. For a 0-6 hour prediction capability, we will improve an XUV–EUV flare evolution model using a flare index derivative. Finally, we will conduct a three part validation of our work using data and physics-based as well as empirical models. The improved spectral and temporal irradiances will be compared with TIMED SEE irradiance measurements. The new spectral, time-resolved, and predicted flare evolution XUV–EUV irradiances will be used in the physics-based 1DTD thermospheric density model with results compared to subsolar HASDM mass density data. We will also quantify the uncertainty and skill score in the flare evolution model's prediction capability through comparison with ionospheric TEC data during quiet and perturbed solar activity conditions and with SOHO SEM data. The SOLAR2000 Research Grade, Professional Grade, and Operational Grade models will be the tools that we provide to the research and operations community to capture the results of our 3-year performance period.

PI: Allan Tylka/US Naval Research Laboratory

Proposal Title: Development and Validation of a Realistic Model of the Acceleration and Transport of Solar Energetic Particles Produced by CME-Driven Shocks

Abstract:
We propose to develop and validate a realistic numerical model of solar energetic particle (SEP) production by CME-driven shocks. Specifically, we will: (1) generalize our present time-dependent non-linear model [Ng, Reames, & Tylka 2003] to include shock-drift and first-order Fermi acceleration at shocks of arbitrary obliquity on arbitrary evolving magnetic flux tubes; (2) combine the model with realistic, 3-D models of CMEs and coronal and heliospheric fields that are selected by the LWS TR&T Program for this purpose; (3) provide data analyses that will guide and constrain the model development;

(4) thoroughly validate the model by detailed comparisons with SEP measurements from the whole complement of energetic particle detectors on Wind, ACE, IMP8, SAMPEX, SOHO, and GOES and (in some events) ground-based neutron monitors; and (5) employ the model in testing new ideas on the origin of SEP variability, such as shock geometry, compound seed populations, and time-dependent acceleration. This proposal specifically addresses: (i) the acceleration time-scale; (ii) the location of the SEP acceleration region; (iii) particle distributions and their variability, both event-to-event and temporally within an event; and (iv) the intensity and spectra of ultra-heavy ions in gradual events. The results of this research will be a better understanding of the physics behind SEP variability, as well as numerical tools that can provide a basis for future predictive capabilities. These efforts directly support Goal II, SEC-Theme, RFA (2a).

PI: Bernard Vasquez/University of New Hampshire

Proposal Title: Simulation and Analytical Investigation of Waves Supported by Solar-Wind Tangential Discontinuities

Abstract:
In the solar wind, mulitple spacecraft have observed abrupt field rotations, called directional discontinuities. Surprisingly, single spacecraft misidentify many discontinuities as rotational ones with large finite normal magnetic field components. This suggests that the discontinuity is the result of the steepening of an Alfven wave. Timings from three or four spacecraft reveal that the discontinuity actually has a small magnetic field normal, more in agreement with a tangential discontinuity (TD) which has zero normal field component and can represent the boundary between magnetic flux tubes. The discrepancy at a single spacecraft is interpreted as a direct sign of the TDs supporting surface waves. Hollweg [1982] predicted the existence of linear noncompressive magnetohydrodynamic (MHD) surface wave solutions on solar-wind TDs where the magnetic field rotates across the layer. Because these waves are noncompressive, they would propagate undamped by collisionless resonant particle damping. Hollweg showed that such a wave on a TD causes the inferred normal component from a single spacecraft to appear large. Moreover, one class of these surface wave solutions travels near the average solar-wind magnetic field direction and could contributed to slab modes in the solar wind, which are an inferred population of solar-wind waves that propagate in this direction. Hollweg's analysis was limited to a cold plasma and linear MHD equations wherein the TDs are true discontinuities. In the solar wind, waves attain large relative amplitudes. We propose a three year investigation of the nonlinear behavior of finite amplitude surface waves, in a warm plasma, and on finite-width TDs. We plan to conduct numerical hybrid simulations with particle ions and fluid electrons of the surface waves on TDs. This work will be complemented with further analysis of MHD equations. We intend to determine whether or not nonlinear surface waves on TDs evolve to noncompressive waves which can travel far into the solar wind without collisionless damping. We will also examine how to identify discontinuities in the presence of waves, which is important in open magnetic field regions where waves from the Sun are very commonly present. The proper identification of a directional discontinuity as either rotational or tangential is often the difference between a type of wave structure or an actual boundary in the solar magnetic fields. We will also explore

the possibility that some surface waves contribute to solar-wind slab modes.

PI: Marco Velli/NASA JPL

Proposal Title: Towards a Global 3D MHD Solar Wind Model with Realistic Energy Flux: Tracing the Turbulent Energy Flow from the Photosphere to the Corona and Beyond

Abstract:
One of the key unsolved problems in our understanding how the solar corona and its embedded magnetic structure expands into interplanetary space is the role of waves and turbulence in the heating of the corona and accelerating the solar wind. We plan here to develop and use a combination of novel numerical techniques and analytical approximations to investigate the following fundamental questions: • How is the spectrum of outwardly propagating turbulence observed in high speed solar wind streams generated, and is it the remnant of a basal flux heating the corona? • What are the spectral characteristics and energy dissipation rates of waves and turbulence from the photosphere to the corona? and use the results as an input, using a tested global 3D MHD code BATS-R-US, to • Construct a global 3D solar wind model with a realistic flux of turbulent energy. In previous work, many aspects of the above questions have been addressed by different researchers. In particular, linear, wkb analyses, and/or phenomenological nonlinear terms have been used to study the propagation of waves from the photosphere into the corona, using a variety of geometries for the magnetic field. The physics of this problem is complicated by the strong gradients in temperature and magnetic field across the transition region and the consequent coupling of the various wave modes. Here we will investigate the propagation of waves through the lower regions of solar atmosphere (from the photosphere, through the transition region and into the corona) using models of increasing complexity: from semi-analytical models, to shell-type models for nonlinear interactions, to direct numerical simulations. We plan to develop a new type of compressible MHD code coupling shock capturing schemes (Shu, 1997) to high order compact finite difference schemes (Lele, 1992, Pirozzoli, 2002), in order to follow the transport of a turbulence made up of Alfvén, fast and slow modes in 2 and 3 D while retaining shock capturing capability. We will obtain profiles of turbulent energy dissipation with height in the solar atmosphere in regions of different magnetic topology. We will then adapt an existing compressible 3D MHD code (BATS-R-US) to construct a global 3D solar wind model using results from the previous investigation to obtain a correct heating/turbulent pressure contribution to the global momentum equation as a function of height and magnetic field line topology. This research will be used as an input to a 3D MHD Global Modeling of the Sun-Earth Connection as a more realistic input driving the solar wind. It relates directly to one of the Focused Science Topics of the LWS TR&T program (e). In keeping with the goals of the LWS TR&T program, this research will increase our scientific understanding of the basic physical processes underlying the Sun-Earth connection and addresses all three SEC roadmap primary objectives. The team assembled, consisting of scientists from JPL and the University of Florence, has the necessary numerical, analytic and observational experience needed for the proposed work.

PI: Yi-Ming Wang/Naval Research Laboratory

Proposal Title: Understanding and Modeling the Evolution of the Sun's Open Magnetic Flux

Abstract:
RELEVANCE AND OBJECTIVES: This proposal directly addresses LWS TR&T Focused Science Topic (e) (``To determine the topology and evolution of the open magnetic field of the Sun connecting the photosphere through the corona to the heliosphere''). Our main goal will be to use our extensive observational and modeling background in this area to achieve a better understanding of the Sun's open flux, in collaboration with the other team members. We propose to focus on the following four objectives: (1) To identify and understand the sources of the Sun's open flux, and to develop further and test a model relating the observed photospheric field to the total open flux and radial IMF strength. (2) To simulate and understand the variation of the open flux over the solar cycle, and to investigate the role of stochastic processes (as opposed to organized "active longitudes") in producing the observed fluctuations on timescales of the order of a year. (3) To simulate the evolution of the Sun's open and closed flux from the Maunder Minimum to the present, in order to determine the secular variation (between cycle minima) of the open flux, of the total photospheric flux, and of the total solar irradiance. (4) To elucidate the role of interchange reconnection in the evolution of the open flux, to determine quantitatively the relative rates of interchange and opening-up/closing-down of flux, and to compare the predictions with observations. APPROACH: (1) Open field regions will be identified by applying a source surface extrapolation to the observed photospheric field. Far from the Sun (where the heliospheric current sheet dominates and the source surface model breaks down), the radial IMF strength will be taken to be proportional to the total open flux. (2) Building on our earlier modeling, the solar cycle evolution of the photospheric field will be simulated using a transport code that includes the effects of emerging flux (in the form of longitudinally randomized magnetic bipoles), differential rotation, supergranular diffusion, and meridional flow. The open flux will again be derived from the photospheric field using a source surface/current sheet model. (3) In our multi-cycle simulations, the flux emergence rates and latitudes will be constrained using sunspot data, while the poleward flow speeds will be allowed to vary from cycle to cycle, subject to the condition that the Sun's dipole moment continue to reverse its polarity. We will also examine the effect of locating the source surface closer to the Sun when the photospheric field is very weak. The long-term predictions will be compared with cosmogenic isotope data and geomagnetic activity records. (4) The rate of interchange reconnection will be estimated for a large variety of nonaxisymmetric, differentially rotating photospheric configurations, using a newly developed parameter that measures changes in the distribution of open flux between successive potential states. The predictions will be compared with SOHO/LASCO observations of streamer blobs and coronal inflows.

PI: Vasyl Yurchyshyn/New Jersey Institute of Technology

Proposal Title: Understanding Magnetic Complexity in Active Regions from Structure

Functions of Observed Magnetic Fields

Abstract:
OBJECTIVE. Non-stationary explosive events in the solar atmosphere, such as solar flares and coronal mass ejections (CMEs), may cause significant changes in the earth magnetic and ionospheric environment and thus affect human life. The origin of those events is concealed in the variability of solar magnetic fields, in particular, magnetic fields of active regions. Understanding how magnetic fields evolve and produce these events is of great importance for both fundamental solar physics research and practical applications such as space weather forecasting. APPROACH. We propose to study physical properties of ever evolving solar magnetic fields by using a cross disciplinary approach. We will apply method of structure functions, that is widely used to study non-linear processes in the solar wind, to photospheric magnetograms. The research is based on our previous results obtained for a limited number of active regions. Earlier we found that high statistical moments of structure functions calculated from the photospheric magnetograms describe the complexity of the magnetic field and they are related to the level of flare productivity of a given active region. This novel method of structure functions allowed us to detect such variations in the complexity of photospheric magnetic fields that could not be sensed by traditional methods where only low order statistical moments are analyzed. PLAN and DELIVERABLES. (1) We will carry out a broad statistical study of different active regions observed with high time resolution near the center of the solar disk in order to: i) confirm the reliability of our previous conclusions on a larger data set; ii) create a more complete picture of how the derived parameters reflect both the state of evolution of the magnetic field and flare productivity of an active region. (2) We will analyze the basic properties of structure functions for many flare-productive active regions, determined prior the flare onset. Then we will conduct a correlative study of these properties with the parameters of the associated flares. We expect the following deliverables of the research: i) results of data analysis -- specifications of the solar magnetic fields which will be used as input/restrictions for modeling; ii) diagnosis and analysis tools for the future studies and iii) online spaceweather related data products. RELEVANCE. The main question we are going to address is how the parameters, describing the complexity of an active region magnetic field, are correlated to the state of evolution of an active region and to the level of flare productivity. Thus, this study will have a noticeable impact not only on the research on solar flares their precursors but also on the demands of space weather. The results of this study will provide an important knowledge and analysis tools for future missions within LWS program such as Solar Dynamic Observatory (SDO) and the development of online data bases.

PI: Xiaoyan Zhou/Jet Propulsion Laboratory

Proposal Title: Dependence of Magnetic Storm Intensity on Interplanetary Electric Field Variability

Abstract:
Recent studies have shown that magnetic storms are relatively weak when the solar wind dawn-dusk electric field (Ey) is smooth and accordingly there is a lack of substorm

expansion phases over long intervals (5 to 7 hours) during the ring current intensification. It is, therefore, speculated that the magnetic storm intensity is controlled not only by the intensity, but also by the variability of the interplanetary electric field. This proposed investigation addresses this issue by calculating the two types of current systems in disturbed polar regions (i.e., DP1 and DP2 current systems). Two scenarios of frequent or rare occurrence of substorm expansion phases are suggested to explain the model-predicted overestimation and underestimation of storm intensity. To test these scenarios we would study two categories of magnetic storms in the epoch from 1996 to 2003, specifically, those occurring during intervals of highly variable Ey and those induced by interplanetary magnetic clouds. We specifically choose this time interval to cover a solar minimum and a solar maximum. We would compare the two categories of storms on their intensities and the occurrence of substorm expansion phases (i.e., when the DP1 current system is dominant) and ionospheric/magnetospheric convections (i.e., when the DP2 current system is dominant). We would use Wind and ACE data for interplanetary events, Polar and IMAGE auroral images for the identification of substorm expansion phases, SuperDARN and DMSP IDM data for analyzing the polar cap potential drop and the magnetospheric/ionospheric convection, and the ground-based magnetograms for the calculation of DP1 and DP2 components. When necessary, other available data sets will be studied as well. The expected results of the proposed study include: 1) the answer of how the magnetic storm intensity would change when the dominant current system is different in terms of style (DP1 or DP2) and intensity; 2) the correlation between the solar wind controller and the DP1/DP2 current system, and therefore, the correlation between the storm intensity and solar wind conditions; 3) an elucidation the storm-substorm relationship from the point of view of the Ey controller; 4) suggestions on how to reduce the overestimation of the Dst index, and suggestions for how to increase the underestimation of the Dst index, respectively. This study will not only maximize the utilization of currently operating Sun-Earth Connection missions, but will also significantly improve our scientific understanding of the solar wind-magnetosphere-ionosphere interaction upon which space weather prediction tools and thermosphere-ionosphere models are developed. This effort, therefore, addresses important objectives of the NASA-LWS TR&T program and its mission exploration,i.e., "to address those aspects of the connected Sun-Earth system that affect life and society".

PI: Richard Canfield/Montana State University

Proposal Title: Topological Studies of Photospheric, Coronal, and Interplanetary Magnetic Fields

Abstract:
The overall goal of this research is to understand why certain coronal magnetic field topologies erupt to produce interplanetary magnetic clouds. We determine the topology of coronal magnetic fields from photospheric vector magnetograms to address this goal. Recent results strongly point to reconnection of active regions with their surroundings as a basic physical process in such eruptions. We focus on eruptions that involve active regions because they represent a major fraction of the most geoeffective events. We will enlarge our present preliminary database of eruptive events for which we have unambiguous solar and interplanetary associations. The unique nature of our database is

that it enables: (1) determination of the topological parameters of coronal active region magnetic fields derived from nonlinear force-free coronal magnetic field reconstructions based directly on observed photospheric vector magnetograms of active regions; (2) values of the topological parameters of magnetic clouds created in eruptions associated with the same active regions. It is well known that magnetic helicity is well conserved in magnetic reconnection in the solar corona. We therefore propose to apply helicity conservation and the concepts of self and mutual helicity to the coronal magnetic field reconstructions to better understand the role of coronal topology in the genesis of magnetic clouds. Our present understanding of the tendency of any given coronal magnetic field topology to erupt is inadequate for predictive purposes. The magnetic field topology connecting the photosphere to the corona is a specific research topic of high current interest to the LWS TR\&T program. The proposed research promotes training of graduate and undergraduate students with expertise on this topic, and is an archetype for the first LWS mission, the Solar Dynamics Observatory. We expect that the proposed research will yield improved physical understanding and a better physics-based ability to predict space weather.