Living With a Star Targeted Research and Technology
Abstracts of selected proposals.
(NNH09ZDA001N-LWSTRT)

Below are the abstracts of proposals selected for funding for the Living With a Star Targeted Research and Technology program. Principal Investigator (PI) name, institution, and proposal title are also included. 137 proposals were received in response to this opportunity, and 31 were selected for funding.

Plasmasphere/Ionosphere and Magnetosphere Panel

Pontus Brandt/The Johns Hopkins University Applied Physics Laboratory
LWS TR&T/FST: The Role of Currents and Conductance in Controlling Plasmasphere Dynamics

JUSTIFICATION: The objective of the LWS TR&T Focused Science Topic we are proposing to is to "Determine the Behavior of the Plasmasphere and its Influence on the Ionosphere and Magnetosphere". With this proposal we seek to understand how currents and ionospheric conductance work together to produce the large-scale electric fields of the ionosphere and magnetosphere that control plasmasphere dynamics. The pressure gradients in the storm-time ring current and near-Earth plasmasheet are in force balance with the region-2 current system. Its closure through the ionospheric conductance to the region-1 field-aligned current (FAC) system is associated with a complicated and globally varying electric potential pattern in the ionosphere that is mapped out along field lines to the magnetosphere to affect the transport and dynamics of the plasmasphere. Known examples include the over and under shielding effects from the ring current, and the stretched dusk side plasmaspheric plumes and undulations due to the enhanced electric field associated with the sub-auroral polarization streams (SAPS) in the ionospheric trough region.

OBJECTIVE: To determine how currents and ionospheric conductance control plasmasphere dynamics in the presence of varying convection.

METHODOLOGY:

1. Select IMAGE/EUV observations of the plasmasphere displaying dynamical behavior, such as onset of sunward convection surges, formation of tails, drainage plumes, shoulders and undulations. This will be done in conjunction with the FST team.

2. Determine spatial and temporal correlations with solar wind parameters, global ring current distribution, FAC patterns, auroral and sub-auroral conductance, and ionospheric flows, by using data from IMAGE/HENA, IMAGE/FUV, Iridium and ground radars.

3. Determine the physical mechanisms and their relative roles in controlling plasmasphere dynamics by modeling the plasmasphere, ring current and its coupling to the ionosphere using the Comprehensive Ring Current Model (CRCM) and the Dynamic Global Core Plasma Model (DGCPM), or any plasmasphere model from the FST Team other than DGCPM. The CRCM uses a self-consistent electric field to update the convection and can use data-derived conductances. The model will be validated against global measurements of the plasmasphere and ring current. In order to understand the relative roles of the physical mechanisms we will perform model experiments where either quantities are kept constant or turned off.

RELEVANCE TO FST: We determine the factors and mechanisms that control the dynamics of plasmasphere, and in particular how the ring current and its coupling to the ionosphere affect the plasmasphere. Understanding these controlling factors is required to achieve a predictive understanding of plasmasphere behavior.

CONTRIBUTIONS: We provide a quantitative view of how the plasmasphere evolves during the course of a geomagnetic storm and its relation to the solar wind, ring current, FACs and ionospheric conductance. The goal is to summarize the findings in statistical study, such as a superposed epoch analysis, but we recognize that this may be done at the FST Team level. In addition, we provide global plasmasphere, ring current proton and O+ distributions, auroral conductance and FAC patterns for the selected events.
We also provide validated model runs of selected events, where the dynamical electric field is one of the outputs of the model.

METRICS: The completion and quantification of relations between plasmaspheric dynamics and the factors above signify success of the observation study. The success of the modeling study is graded by how well the model can reproduce the results from the observational study and by how well we can determine, and thereby understand, the relative roles of the physical mechanisms controlling plasmasphere dynamics.

Vania Jordanova/Los Alamos National Laboratory
Modeling the Plasmasphere and its Influence on Plasma Waves and Ring Current Distributions in the Inner Magnetosphere

The behavior of the plasmasphere and the plasmapause is closely connected with the dynamics of energetic particles in the inner magnetosphere. During the main phase of geomagnetic storms and periods of enhanced convection the plasmasphere is eroded and forms dayside drainage plumes, while during storm recovery phases and reduced convection the plasmasphere refills with cold plasma from the ionosphere and expands. Various plasma waves are generated within regions of spatial overlap of anisotropic ring current source populations and cold plasma. These waves cause significant changes in radiation belt and ring current fluxes, which may lead to substantial damage of space-borne and ground-based technological systems, and endanger human activities. Predicting inner magnetosphere dynamics and protecting these assets are of great interest to the NASA LWS and the National Space Weather programs. The main scientific goal of this investigation is to provide better understanding and modeling capability of the plasmasphere, plasma waves, and energetic particle dynamics in the inner magnetosphere. These are key objectives of this LWS TR&T solicitation, Focused Science Topic (a). The methods include a combination of fundamental kinetic plasma theory, global numerical models, and ground-based and satellite data. Several physics-based models will be used to study the coupled plasmasphere-magnetosphere system. A fluid model will be used to simulate the behavior of the plasmasphere during magnetic storms, employing a self-consistently calculated convection electric field from the Space Weather Modeling Framework (SWMF). The concurrent injection of ring current particles into the inner magnetosphere and the excitation of electromagnetic ion cyclotron (EMIC) waves and chorus emissions will be simulated with a state of the art transport code (a ring current-atmosphere interaction model with self-consistent magnetic field, RAM-SCB) coupled with the plasmasphere model, and using the dynamic solar-wind driven outputs of the SWMF. Global maps of plasmaspheric density, plasmapause position, and plasma wave distributions in the equatorial plane will be obtained. The model predictions will be compared with in-situ data from LANL and THEMIS satellites and global images from IMAGE and TWINS. The acceleration and loss mechanisms for ring current ions and radiation belt electrons will be investigated to determine their applicability during various storm phases. The results will be published and made available for the upcoming LWS Radiation Belt Storm Probes (RBSP) mission that will be launched in 2012.

Jonathan Krall/Naval Research Laboratory
A First-Principles Model of the Plasmasphere

We propose a four-year program to develop a comprehensive first-principles physics model of the plasmasphere-ionosphere system. This will be accomplished by integrating the NRL ionosphere/plasmasphere code SAMI3, the Comprehensive Ring Current Model (CRCM) inner magnetosphere code, and the Lyon/Fedder/Mobarry (LFM) outer magnetosphere code. The primary coupling mechanism is electrodynamic: the electric field is determined by the ionospheric conductances and the Region 1 and 2 current systems. Ionosphere/magnetosphere coupling is essential in order to capture the influence of global electric and magnetic fields on plasmaspheric ion populations.

The important physics issues to be addressed are (1) the density, composition, and temperature of the plasmasphere, (2) plasmaspheric dynamics associated with stormtime erosion and refilling, and (3) the relationship of plasmasphere dynamics to ionosphere dynamics (e.g., SAPS/SED/drainage plumes). In particular, we intend to address the following outstanding science questions:

- How do ionosphere, ring current, and magnetosphere conditions affect the density, composition, temperature, and refilling rate of the plasmasphere?

- What is the influence of the plasmasphere on the magnetospheric ring current and on the TEC?

- What are the necessary conditions for the occurrence of a plasmaspheric plume and a sub-auroral polarization stream (SAPS), and how are they related to each other and to stormtime enhanced density (SED)?

- How closely does He+ track H+ in the plasmasphere during storms?

Over the course of this research, the proposed first-principles plasmasphere model will become an effective tool for data interpretation and for computing the 3D state of the plasmasphere. SAMI3 will therefore provide a significant alternative to the empirical models that are currently used. As part of the LWS Plasmasphere Team, we will provide model outputs for comparison to data. SAMI3 outputs can also be used in computations of phenomena that are beyond the scope of our proposed research, such as electromagnetic ion-cyclotron and whistler chorus waves.

The proposed study directly addresses key elements of the NASA Living with a Star Focused Science Topic "Determine the Behavior of the Plasmasphere and its Influence on the Ionosphere and Magnetosphere." Specifically the program will develop a "first-principles modeling of plasmaspheric density, composition, and temperature that include particle filling and depletion processes and electrodynamic coupling with the ionosphere" and will involve "observational and modeling studies of plasma convection, plasmapause layer dynamics, and plasmaspheric plume formation and transport." Moreover, the aims of this research directly address NASA near-and long-term goals, as outlined in the 2009 Living With a Star Announcement (ROSES 2009), the 2006 NASA Strategic Plan, and the Heliophysics Division Roadmap for Science and Technology: 2005-2035.

John Lyon/Dartmouth College
MHD Modeling of the Plasmasphere

The plasmasphere affects the propagation of pressure pulses, the timescale for magnetospheric reconfiguration, and the growth and propagation of electromagnetic ion cyclotron waves and whistler waves. Through its effect on these waves, it strongly affects the distribution of radiation belt electrons.

We propose to study the dynamics of the magnetosphere with a comprehensive model for the plasmasphere and the magnetosphere based on a global multi-fluid MHD simulation code. The major thrust of our investigation will be in the two areas: the dynamics of wave and impulse propagation in the magnetosphere under changing solar wind and ionospheric conditions and the development and evolution of plasmaspheric structure and its effects on the global magnetosphere-ionosphere system.

The key science questions to be addressed are:

1. How does the plasmasphere evolve, and how do the physical assumptions of the model affect the evolution?

2. How do plasmaspheric plumes develop and evolve?

3. What is the effect of the plasmasphere on ULF waves?

4. What is the effect of the plasmasphere on the propagation of interplanetary shock compressions through the magnetosphere?

The LFM global MHD code will be extended to carry an arbitrary number of ionic species which will, in addition to the usual plasma stresses, will react to gravity and the corotation centrifugal force. The global MHD code will be linked to the NCAR thermosphere-ionosphere model to provide realistic conductivities and wind driven stresses.

Mark Moldwin/University of Michigan
A 3D climate and weather global topside ionosphere and plasmasphere model

Key objective is to combine IMAGE EUV, GPS TEC, in situ, and ULF resonance data to make a 3D global topside ionosphere and plasmaphere empirical model that includes Ne, mass density, and information on composition. The model parameterization will include discrimination between the plasmasphere and trough.

We propose to develop a global space climate and weather model of the topside ionosphere and plasmasphere density using ground and space-based two-dimensional (latitude vs. altitude) tomographic imaging. The results of this model will be used to improve IRI modeling efforts and serve as a stand-alone empirical model helping to constrain such parameters of mass composition. Current global models provide monthly averages of ionospheric properties and do a poor job of modeling the topside ionosphere. Currently there are few mass density models and very limited composition modeling efforts. The new model will provide a topside ionospheric and plasmaspheric electron density as a function of local time, latitude (over both hemispheres), altitude and solar drivers. The data will be constructed using nearly a decade of data allowing the examination of long term “climate” solar driving dependences as well as regional “weather” information. This research goal directly addresses the NASA LWS TR&T Focused Science Topic “a” (Determine the Behavior of the Plasmasphere and its Influence on the Ionosphere and Magnetosphere). LEO satellites equipped with dualband GPS receivers (including C/NOFS and COSMIC) offer a breakthrough opportunity for remote sensing and monitoring of the topside ionosphere and plasmasphere. Tomographic imaging of LEO GPS TEC goes beyond two-dimensional TEC maps and allows the determination of topside ionosphere and plasmaspheric density altitude profiles, global coverage, and in combination with ground-based TEC tomography the ability to differentiate changes in F region density with topside ionospheric/plasmaspheric density variations.

In addition, we propose to combine simultaneous observations of the plasmaspheric mass density with the LEO-GPS TEC-inferred electron number density measurements to study the evolution of average mass density of the plasmasphere. The NSF MEASURE,SAMBA and McMac magnetometer arrays were designed to utilize the cross-phase technique to measure the ULF resonance frequency. The combination of TEC and ULFmass density observations will allow us to study the day-to-day variability of the ionosphere including composition of ionospheric and plasmaspheric densities.

Space Weather Impacts Panel

Mark Linton/Naval Research Laboratory
Modeling Dynamical Flux Emergence as the Driver of Coronal Mass Ejections

Coronal mass ejections (CMEs) are eruptions of solar plasma and magnetic field from the solar corona into interplanetary space. The collision of Earth-directed CMEs with the Earth's space environment is a primary source of magnetospheric substorm activity, which creates hazards for radio communications and Earth-orbiting spacecraft. There are a number of competing theoretical models for erupting CME magnetic structures, many of which rely on the emergence of magnetic fields from the solar convection zone into the corona to drive or destabilize the CME. However, rather than dynamically emerging this field, most rely on the specification of kinematic photospheric boundary conditions to mimic flux emergence. The goal of this proposal is to perform a fundamental test of whether CME initiation can be driven by self-consistent, dynamical flux emergence. We will primarily focus on the breakout CME model and the flux rope loss of equilibrium and torus instability models. We will study how flux emergence from the high beta convection zone into the low beta corona affects such CME-prone coronal fields. We will then develop a model for driving coronal simulations with observational data input at a high beta photospheric boundary. In collaboration with our Focused Science Topic teammates, we will simulate the evolution of CME producing regions, testing whether such data driven simulations can reproduce observed eruptions.

Our simulations will be run with the NRL-developed 3D magnetohydrodynamic code ARMS. This code has been used to study CME initiation via kinematic boundary driving, and to study dynamical flux emergence into a field free corona. For our proposed work we will combine these two simulation capabilities together to study the initiation of CME eruptions via flux emergence into a pre-existing coronal field. The simulation results will be compared against photospheric vector magnetic field observations of flux emergence, EUV and X-ray observations of coronal magnetic field structures, and coronagraph observations of CME eruptions. This program is aimed at improving our understanding of how CMEs are driven and destabilized, thus enhancing NASA's ability to develop predictive tools for CMEs and their space weather consequences.

Zoran Mikic/Predictive Science, Incorporated
Using a Sophisticated MHD Model to Improve Prediction of CME Initiation and Propagation

We propose to use a sophisticated magnetohydrodynamic (MHD) model to improve our understanding of CME initiation and propagation. Our proposed modeling will focus on performing detailed CME "event studies," in which we will use detailed observations as inputs to the model, including observed magnetic fields. From the model we will produce simulated outputs that can be directly compared with observations, including white-light images and EUV and X-ray emission, and the evolution of flare ribbons. The proposed work will improve our understanding of CME initiation, and the subsequent propagation of CMEs in the inner heliosphere, leading to improvements in space weather prediction.

At present, there are many theories of CME initiation. The proposed CME event studies are meant to identify which one (or more) of these theories captures the essential aspects of CME initiation, by using observations to discriminate between competing theories.

The following are selected guiding questions that will help us to improve CME prediction:

* Is there a relationship between the free energy in the magnetic field and the tendency of an active region to erupt?

* Can this relationship be exploited to predict when an eruption is imminent?

* Is there a characteristic signature in the magnetic field geometry/structure/topology that might be used to sense eruption?

* What are the fundamental ways in which active regions are energized?

* Can we quantify the trigger for eruption and use it as a predictor?

Our proposed project will utilize data from the upcoming SDO mission extensively, as well as data from Hinode, STEREO, and SOHO observations. The testing of models against these observations is a central task in our proposed effort. We will share our simulation results with the Focused Science Team members to maximize the progress of the team, and we will incorporate innovations from other team members into our model.

Alysha Reinard/CIRES
Using Helioseismology Measurements to Predict Active Region Flaring Probability

As our society becomes more technologically advanced, space weather is an increasing concern. Solar flares and CMEs affect satellite function, high frequency communication, power grids, as well as many applications related to GPS (deep-sea drilling and precision farming to name just two). Because of our increasing reliance on technology that is so susceptible to space weather effects, it is necessary to improve our ability to forecast when a solar event will occur and how large it will be.

One of the "holy grails" of space weather is the ability to forecast flares with useful accuracy and precision. Currently, the best methods are based on surface magnetic field measurements, and have a success rates ranging from 8-15% higher than always assuming no flare will occur (Barnes & Leka, 2008). We propose to use the properties of subsurface motions, detected through helioseismology methods, to understand and predict the onset of flares in active regions. Recent results indicate that helioseismology can be a useful tool to predict flare occurrence. Komm and Hill (2009) found that the combination of large flux and large vorticity in a given active region is highly correlated with the production of very large flares. Preliminary results from helicity measurements (Reinard et al., 2009) suggest that we can detect changes in helicity that predict the occurrence of a flare 1-3 days in advance. We will build on these results, improve our technique and quantify the predictive potential. We will then extend our analysis to a more detailed examination of how SVA measurements relate to other phenomena such as adjacent active regions (ARs) and Coronal Mass Ejections (CMEs). Once we have a firm understanding how SVA measurements relate to CME/flare onset we will conduct studies to gain a more complete understanding how subsurface motions lead to flare and/or CME production. Finally, we will test the method on new data and investigate the potential for a real-time warning system.

This proposal is highly relevant to NASA goals and to the scientific objectives of the focused topic (c): Predict the Onset and Space Weather Impacts of Fast CMEs/Eruptive Flares. The results from this study will increase our understanding of CME and flare initiation. The inclusion of the subsurface vorticity will result in improved flare forecasting, and this will increase the accuracy of space weather predictions with corresponding benefits to society in general. In addition, further study of the relationship between the subsurface vorticity, magnetic field evolution, and flare/CME activity will proved insight into the basic mechanisms of solar flares, sunspot structure, and astrophysical MHD.

Peter Schuck/Heliospheric Science Division
The Dynamics of Neutral-Line Flows During CMEs and Flares

We propose a four-year program to systematically characterize neutral-line (NL) flows associated with coronal mass ejection (CME) initiation and flares. The investigation will be accomplished with quantitative measurements of NL flows derived from our unique technology, the optical flow technique DAVE4VM, applied to space-based vector magnetograms from the Solar Dynamics Observatory (SDO) Helioseismic and Magnetic Imager (HMI). Vector magnetograms and accurate velocity maps of active region NL flows are arguably the most important new contributions that HMI will provide for the solar physics community because the photospheric magnetic fields and orientation, magnitude, and duration of NL flows are critical for testing current CME initiation theories and developing predictive models. We will survey NL flows of active regions, combined with the active region topology and the time variation of the unsigned vertical flux. We will analyze the results to test the predictions made by CME models for these three observables and incorporate new observables developed by the theoretical and simulation groups participating in the focused science team. We will collaborate with the other members of the focused science team by providing photospheric observables during eruptions for testing CME initiation theories and for driving lower photospheric boundary of simulations with the observed HMI vector magnetogram evolution and velocity fields derived from the DAVE4VM analysis. This critical component of the focused science team represents a suite of fundamental quantitative tests for CME models and theories. The close collaboration between observation, image processing, and theory simulation elements of the focused science team will produce rapid advancements in our understanding of the initiation and eruption of CMEs and flares and provide guidance for future NASA programs.

Plasma Neutral Gas Coupling Panel

Geoffrey Crowley/ASTRA
Plasma-Neutral Gas Coupling

We propose a four-year program to perform a comprehensive investigation of Plasma-Neutral gas Coupling in the thermosphere-ionosphere system. In this proposal, we explore several science topics that are intimately connected with ion-neutral coupling between the ionosphere and thermosphere. While these phenomena have all been observed, they are unexplained. We use a new coupled model to explore in detail the physics behind the phenomena. The work will involve the development of model postprocessors that will allow us to understand the detailed mechanisms that are at work, and their complex interactions. The lessons learned from this study are expected to have relevance to other plasma systems coupled via neutral-ionized interactions throughout the Heliosphere.

The proposed research addresses three critical scientific questions:
1) What are the physical mechanisms that generate the quiet time low latitude dynamo and PRE?
2) What is the effect of lower and middle atmosphere disturbances such as sudden stratospheric warmings' on the ionospheric electrodynamics?
3) What are the ion-neutral coupling processes that generate density depletions in the equatorial ionosphere?

The research will employ an improved first-principles numerical modeling capability of the ionosphere-thermosphere system that has been developed under other NASA funding. This new model has coupled the SAMI3 model of the ionosphere with the TIMEGCM model of the thermosphere. New model postprocessors will be developed, and used together with ground-based radar and C/NOFS satellite data to uncover the detailed mechanisms driving: (a) the ionospheric dynamo and PRE, (b) the effect of sudden stratospheric warmings on the ion-neutral coupling and resulting electrodynamics, and (c) the recently discovered the equatorial dawn density depletions. The data from the C/NOFS satellite, together with ground-based radars will be used to test and validate the findings from the model and the postprocessors.

The proposed study directly addresses key elements of the NASA Living with a Star Focused Science Topic Plasma-Neutral gas Coupling. Specifically the program will investigate the physical issues of plasma-neutral coupling in the ionosphere as we seek to resolve strategically important questions concerning the transition from a weakly ionized plasma with the linkage of the electromagnetic field, and our physical understanding of such systems in the Heliosphere. The aims of this research directly address NASA near- and long-term goals, as outlined in the 2009 Living With a Star Announcement (ROSES 2009), the 2006 NASA Strategic Plan, and the Heliophysics
Division Roadmap for Science and Technology: 2005-2035.

The proposed work brings together experts on thermosphere-ionosphere coupling from three different organizations (ASTRA, NRL, and UTD). It combines modeling and data analysis, and provides training for a new postdoc.

Holly Gilbert/ NASA Goddard Space Flight Center
Ion-Neutral Coupling in Solar Prominence Structure and Dynamics

The proposed work involves extending and testing previous work conducted by Gilbert et al. (2002, 2008) on cross-field diffusion of neutrals in prominences. Additional modeling of ion-neutral interactions in prominence plasma will be conducted, with the objective of understanding how ion-neutral coupling affects formation, structure, dynamics, longevity, and stability of prominences.

Gaining a better understanding of the ion-neutral coupling in prominences will enhance our more general understanding of ion-neutral coupling in a magnetized medium.

Philip Judge/National Center for Atmospheric Research
Thermal and Magnetic Models for Ion-Neutral Chromospheric Studies Based Upon Hinode, TRACE, SDO and Ground-Based Data

We propose a three-pronged attack on the solar chromosphere to begin meaningful quantitative studies of the macroscopic and microscopic effects of ion-neutral collisions. First, we will reduce existing spectropolarimetric data of magnetic features on the Sun carefully acquired by us using Hinode, TRACE, augmented with the IBIS ground-based instrument. Second, we will acquire new data augmented with SDO and the new FIRS instrument through new campaigns to take advantage of the rise of the next solar cycle and new instrumental capabilities. Third, we will build single fluid MHD models based upon the data using established inversion methods constrained with MHD models, within which parameters relevant to ion neutral dynamics can be accurately defined. We hope to work with other groups in the plasma-neutral FST team to study multi-fluid MHD models of several types of magnetic structure through the solar chromosphere.

Our proposed effort is central to a meaningful assessment of ion-neutral effects in the solar chromosphere. The datasets acquired and models developed will also help set a meaningful force-free boundary condition for the overlying corona. Both of these issues are critical to the LWS TR&T program.

James Leake/Naval Research Laboratory
Modeling Effects of Ion-Neutral Coupling on Reconnection and Flux Emergence in the Chromosphere

Objectives:
The chromosphere is a relatively poorly understood, partially ionized region of the solar atmosphere, but it is critical for understanding the corona as all solar magnetic field emerges from the convection zone through this region. Understanding reconnection events, such as spicules, chromospheric jets and Ellerman bombs, is now believed to be important for understanding chromospheric and coronal dynamics and heating. Some of these dynamic phenomena are closely related to the emergence of magnetic flux from beneath the solar surface. Our previous works are the only studies to date that have included some of the effects of ion-neutral coupling in the chromosphere in numerical models of flux emergence. However, ion-neutral coupling is believed to play a role in both reconnection and flux emergence in the chromosphere.

The goal of this proposal is to develop numerical models of these phenomena that self-consistently include the coupling of ionized and neutral plasma. We will identify the role of ion-neutral coupling on flux emergence and magnetic reconnection, and quantify its role in not only the dynamics and heating of the chromosphere but also on the state of the coronal magnetic field.

Methods:
Flux emergence, magnetic reconnection, and dynamics/heating in the solar chromosphere will be simulated in 2D, for the first time, using a two-fluid (plasma+neutrals) numerical model, HiFi. Single-fluid, 3D simulations including prominent ion-neutral effects will be conducted using the MHD code Lare3D. Simulation results of flux emergence and reconnection will be compared to both theoretical models and H-alpha, UV and EUV observations of the chromosphere.

Significance to NASA:
This program will develop first-principles, self-consistent models of chromospheric events such as Flux emergence, chromospheric jets, Ellerman bombs and Spicules that can be compared to current observations. These models will help the solar community understand the role of ion-neutral coupling in chromospheric heating, and on the state of the magnetic field in the chromosphere and corona. Through collaboration with the other Science Focus Teams, we will also improve understanding of the role of ion-neutral coupling in the ionosphere.

Jiuhou Lei/University of Colorado at Boulder
Investigation of Ion-neutral coupling processes in the equatorial F-region

The influence of the lower thermosphere through the E-region dynamo on the equatorial ionosphere anomaly (EIA) has been widely studied; however the direct coupling between the neutral gas and ionized plasma in the equatorial F-region has not been well addressed. Recent observations of thermosphere mass density have revealed new features of the equatorial thermosphere anomaly (ETA) which have not been investigated. We propose to investigate ion-neutral coupling processes in the equatorial F region. This proposed work will use thermosphere observations from CHAMP and GRACE satellites, ionospheric datasets from CHAMP and COSMIC satellites and ground-based GPS observations. These observations of the ionosphere and thermosphere are used to investigate the variations of equatorial anomalies in both the ETA and EIA, and their interactions. The similarities and differences between the ETA and the EIA will be established under various geophysical conditions, providing important insight to the physical connections of this ion-neutral coupling problem. Observations will be combined with a state-of-the-art self-consistent coupled thermosphere-ionosphere general circulation model, NCAR-TIMEGCM to understand the fundamental physical and chemical ion-neutral processes in the equatorial F region. Specifically, we will address the following outstanding scientific questions: (1) What are the main mechanism(s) for the ETA formation, and why do the locations of the crests in the ETA and the EIA differ in latitude? (2) What are the causes of the differences in longitudinal variations between the ETA and the EIA? (3) How does geomagnetic activity modulate the coupling between the ETA and the EIA? (4) Why are the variations in the ETA dependent on solar activity, and how does solar activity modulate the coupling between the ETA and the EIA? The proposed work directly addresses the NASA LWS TR&T strategic goal focused science topic:Plasma-Neutral Gas Coupling. In addition, the simultaneous measurements of the equatorial anomalies in the thermosphere and ionosphere can provide a new way, in which the state-of-the-art NCAR-TIMEGCM can be tested, validated, and improved; a critical effort towards the LWS TR&T's goal of bringing closure between observations and models.

Wenbin Wang/University Corporation for Atmospheric Research
Global Ionospheric Electric Field Variations in Response to Changes in Geophysical Conditions

We propose to undertake a comprehensive study of the variations of the penetration electric fields and the mechanisms causing these variations under various geophysical conditions. Ionospheric electric fields play a crucial role in ion-neutral coupling in the thermosphere and ionosphere system. They redistribute the ionospheric plasma through transport process, affecting not only global structures of the ionosphere, but also those of the thermosphere by the nonlinear, dynamical coupling between the ions and neutrals. Our understanding of the penetration electric fields and the total ionospheric electric fields is still very limited despite the studies done over the years. Furthermore, the variations of these fields in response to changing driving conditions, and the processes that lead to these variations have not been fully characterized. Thus, we propose to carry

out a comprehensive investigation of the behavior of ionospheric electric fields and their effects on thermospheric and ionospheric structures using combined model simulations and data analysis. The model we will use is a state-of-art Coupled Magnetosphere Ionosphere Thermosphere (CMIT) model. The data sets that will be used in this study include electric fields measured by the Jicamarca incoherent scattering radar and the ROCSAT-1 satellite, ionospheric total electron content (TEC) observed by GPS receivers, thermospheric mass density from the CHAMP satellite, and neutral composition obtained from the TIMED/GUVI observations. Four scientific investigations will be undertaken:
1) A study of the longitude variation of the penetration electric fields, the cause of this variation, and the dependence of this variation on solar cycle, season and other geophysical conditions using the CMIT model. The effect of ionospheric pre-conditioning on this variation will also be studied.
2) A study of the cause of the early morning eastward electric field at the geomagnetic equator, and its correlation with solar wind/IMF conditions.
3) An investigation of the effects of corotation interaction regions on the penetration electric fields and thermospheric and ionospheric structures, and the change of this effect with geophysical conditions.
4) A study of the behavior of penetration electric fields and the neutral wind dynamo during the main and recovery phases of storms. Emphasis will be on the changes of the penetration efficiency of high latitude electric fields during storms and the way ionospheric electric fields recover after storms.

The proposed work is directly relevant to the NASA-LWS objectives, in specific, to the NASA LWS Targeted Research and Technology Program Focused Science Topics 1.2.1 d: "plasma-neutral gas coupling". The proposed work will use both ground- and space based observations and a first-principles, self-consistent numerical model of the coupled magnetosphere, ionosphere and thermosphere to investigate the interactions between ionospheric plasma and neutral gas, and the responses of these interactions to changing geophysical conditions. The proposed study will advance our understanding of both the variations of penetration electric fields and the cause mechanisms of these variations, and thus our knowledge of the behavior of the T-I system under various geophysical conditions. The proposed work will help improve physics-based models of the coupled magnetosphere ionosphere and thermosphere system and thus our capability of space weather forecast.

Slow Solar Wind and SEP Transport Panel

Christina Cohen/California Institute of Technology
Using Impulsive SEP Events as Probes of Solar-Heliospheric Structures and the Coronal Origins of the Slow Solar Wind

In the quest to understand the origin of the slow solar wind and the evolution of the accompanying magnetic fields and plasma structure in the inner heliosphere, it is critical

to have tools which constrain and validate models as well as provide information regarding the source of magnetic fields. Observations of impulsive solar energetic particle (SEP) events are such a tool. Unlike the large SEP events created by shocks driven by coronal mass ejections (CMEs), these events are not accompanied by large scale changes in the heliospheric magnetic field. Additionally, these small events closely trace out the local magnetic field lines connecting the observer to the source region on the Sun. The fact that impulsive events are often observed within a slow solar wind stream [Kocharov et al., 2008], means that their source region may lie in close proximity to the origin of the slow solar wind. Thus, identifying and studying the source regions of the impulsive SEP events will yield important insights into the origin of the slow wind by providing multiday information on the magnetic connection point of the spacecraft to specific active regions on the Sun.
We propose to systematically examine the large and rich ACE dataset, specifically measurements from the ULEIS, EPAM, and SIS sensors, for impulsive SEP events and periods of 3He enrichments occurring within slow solar wind streams. Using a variety of solar observations and magnetic field mapping techniques we will identify the sources of these events. This analysis will then be extended to include data from the STEREO and SDO spacecraft which will permit us to monitor source regions of impulsive SEP events over significantly longer ranges of solar longitude (particularly when the two STEREO spacecraft are substantially distanced from ACE). Our intent is to work closely with other FST team members who will be modeling and observing the solar wind and heliospheric structures to provide concrete tests and constraints on the magnetic field topology and magnetic connection to solar source regions. Such collaborations will also benefit similar efforts in the future that will involve measurements from Solar Probe and Solar Orbiter.

Yuan-Kuen Ko/Naval Research Laboratory
Characterizing Relations Between Solar Energetic Particles and the Associated Slow Wind Source Regions

In a recent exploratory study, we have carefully analyzed 12 gradual solar energetic particle (SEP) events from 2004-2006. We have discovered that the SEP elemental composition at 5-10 MeV/nuc falls clearly into two classes depending on whether the associated solar wind (SW) source (and hence the solar footpoint of the magnetic field line connecting the Sun to Earth) is from an active region or from a coronal hole. The events we have analyzed so far show no correlation between the elemental compositions of SEPs and SW thermal particles. But our results interestingly hint at a correlation between the elemental compositions of SEPs and suprathermals, using finer time resolution and a much broader energy range than has been employed in previous studies. These new results pose interesting and important questions and suggest possible avenues toward better understanding both SEPs and the slow solar wind. We propose to expand this initial investigation by utilizing the vast database of SEP, SW, and solar observations accumulated in Cycle 23 and (when solar activity begins) in Cycle 24, to confirm, clarify, and extend the apparent relationships between the properties of SEPs and the associated SW source region. We will investigate if other features of the SEP variability, such as intensity, temporal structure, or spectral hardness, can be organized by the nature of the associated SW source region. We will also attempt to understand the physical basis of the empirical relationships that we uncover through application of state-of-the-art SEP acceleration and transport models, which include both fully self-consistent treatments of Alfven wave growth and the entire SEP pitch-angle distribution. Finally, we will examine whether our results on the connections between SEPs and SW source regions can be ``turned around'', so that observed SEP characteristics can be used to improve the accuracy of solar-wind traceback from 3D coronal-field models. Thus, we anticipate that the proposed work will contribute to our understanding of both the production and transport of SEPs as well as of the origin of the slow solar wind.

Mari Paz Miralles/Smithsonian Astrophysical Observatory
Characterizing the Origin and Nature of Slow Wind Sources During Solar Cycle 23 and 24

The slow wind is a sizeable component of the solar wind and plays a fundamental role in shaping the interplanetary environment. Yet, the slow wind has not been studied with the same detail as the fast solar wind because of its complexity, its variability, and the apparent multiple source regions. In particular, the source regions and the heating and acceleration mechanisms of the slow wind have not been identified. Understanding its origin and forecasting its variability are fundamental requirements for predicting the effects of the Sun on the heliosphere, Earth's upper atmosphere, and interplanetary space.

In the proposed investigation we will use data from Hinode, STEREO, and SOHO to characterize the sources of the slow wind during representative time periods of solar cycles 23 and 24. The main focuses of our investigation will be: 1) to identify tracers of the source regions of the slow wind; 2) to measure the overall physical properties of streamers as a function of time, latitude, and heliocentric distance using spectroscopic diagnostics from Hinode and SOHO spectrometers, and Hinode, STEREO, and SOHO imagers; 3) to investigate the heating and acceleration mechanisms of the slow wind by using the measured quantities to test theoretical models.

Given the strong dependence of the slow wind on the solar cycle, it is important to compare the properties of the slow wind during minimum periods where it represent less than 20% of the solar wind, to solar maximum periods where the slow wind dominates. In particular, the unusual conditions of the solar atmosphere during the current minimum of solar cycle 24 represent a unique opportunity to investigate the dependence of the slow wind on streamer parameters. The comparison of data from multiple spacecraft along 14 years of continuous observations encompassing the entire solar cycle 23 and the minimum of solar cycle 24 will provide for the first time an opportunity to map the slow wind evolution.

D. Aaron Roberts/NASA Goddard Space Flight Center
Multispacecraft Studies of the Origin and Evolution of the Slow Solar Wind with Predictions for Inner Heliosphere Probes

We propose to substantially extend previous studies of the slow solar wind and its comparison with the fast wind by performing multispacecraft and high-resolution studies of in situ measurements that allow for the clearer separation of spatial and temporal effects. This will greatly increase our ability to say what slow wind properties are due to initial conditions at or near the Sun as opposed to evolving with the wind, and to understand the detailed structure of often complex regions. The use of spacecraft at different solar distances, along with solar observations and (CCMC) models, examined in a variety of conditions, will lead to a greatly improved ability to predict the evolution of the solar wind properties. A representative observation as one starting point will be that slow solar wind has been measured to, at times, have temperature, fluctuation, composition, and other properties very like those in fast wind except for the speed. We will search for a comprehensive set of types of slow wind intervals and use the whole fleet of heliospheric spacecraft to determine, to the extent possible, the evolution of entropy, Alfven wave flux and spectra, pitch angle distributions, composition, and energetic particle populations, and use these to determine the types and unique properties of slow wind and to constrain the evolution of the wind. The roles of discontinuities, omnipresent but in varied ways, in the wind evolution will be elucidated. The investigation will involve many aspects that will have utility for the LWS Focus Group on the slow solar wind, including novel visualization and data mining methods, and the preparation of integrated datasets.

Thomas Zurbuchen/University of Michigan
The Wind from the Open-Closed Field Interaction Region

This proposal is focused on two fundamental challenges that have plagued our understanding of the origin of the slow solar wind: 1) The slow solar wind has a composition more similar to plasma of the closed corona, and different than the composition of coronal hole plasma. 2) The extent of the slow solar wind is between 20-30 deg from the current sheet.
Models describing the slow solar wind approximately fall into three categories. Slow solar wind could originate in a quasi-stationary fashion at the boundaries of open field rooted in coronal holes; slow solar wind could be the product of a dynamic instability of steamers; or, slow solar wind could be generated through interchange reconnection. In fact Fisk et al in several previous studies have provided a statistical description for interchange processes all around the solar corona.
Such models of the heliospheric magnetic field have been investigated in a previous LWS working group which has been tremendously successful. Out of this study resulted important conclusions about the slow solar wind and its physical properties: Antiochos et al. demonstrated the existence of open field corridors - small-scale extensions of open field into the topologically closed area of the corona. Recent simulations of the solar corona at unprecedented spatial resolution by the PSI group reveal that corridors and separators are ubiquitous in the streamer belt region. These structural features are natural

sites for the interchange reconnection proposed by Fisk et al. Their pervasive presence suggests that a dynamic description of the coronal streamer belt is necessary to understand the slow solar wind.
This proposal will focus on three specific questions related to the open field corridors and their relation to the generation of slow wind. 1) Is the angular extent and temporal behavior of the predicted slow-wind region consistent with data? 2) Does the predicted slow wind have the observed structure and dynamical properties of the slow wind? 3) Can this model be used to make observational predictions for Solar Probe and Solar Orbiter? This work will use a combination of theoretical, modeling and data analysis tools typical for a LWS topic area. Based on the tremendous success of the LWS team in "Heliospheric Magnetic Field", we will propose that the PI of this proposal be the lead of the entire study team to encourage integration of the selected studies.

Tools and Methods Panel

James Adams/National Space Science and Technology Center
Probabilistic Solar Energetic Particle Models

We propose to develop probabilistic solar energetic particle models for worst-case peak flux differential energy spectra and worst-case event-integrated fluence differential energy spectra for the elements with atomic numbers from 2 to 28. These models will complement the Emission of Solar Protons (ESP) models for protons and the Prediction of Solar particle Yields for CHaracterizing Integrated Circuits (PSYCHIC) Model for mission-integrated fluences of all elemental species. We also propose to update the ESP and PSYCHIC models, using all currently available data. In addition, we propose to include a procedure for extrapolating the worst-case spectra from 0.3 to ~100 AU so that they can be used for missions throughout the heliosphere.

Deliverables: We will deliver probabilistic solar energetic particle models that will accept as input the mission start date, and duration, the radial distance from the Sun and the required confidence level. The models will provide worst-case differential energy spectra for the elements hydrogen through nickel. The models will provide these spectra for the peak flux, the event-integrated fluence and the mission integrated fluence at the specified radial distance and confidence level.

Delivery Site: The Community Coordinated Modeling Center (http://ccmc.gsfc.nasa.gov/).

Schedule: 15 November, 2011

Josef Koller/Los Alamos National Laboratory
A New Drift Shell Integration Technique for Inner Magnetospheric Space Weather Models

The overarching goal of the proposed work is to deliver a new tool that will significantly advance our understanding of the physical processes responsible for the storm-time variations in the radiation belts. The key to the theoretical understanding and modeling of the radiation belts is detailed information about the Earth's magnetic field. The geomagnetic field is dynamic and is distorted by complex interactions with the solar wind. The magnetic drift invariant, known as L* (pronounced L-star) is used to model radiation belt dynamics. L* is directly related to the magnetic flux enclosed by a charged particle trajectory. Current applications and models either use a computationally intensive numerical integration to calculate L* or apply inadequate static models that are fast and easy to compute. Long computing times have been a long standing pitfall to accurate radiation belt research and the advancement of predictive models.

We propose to develop a new and faster tool that holds the potential to reveal underlying physical processes and mechanisms responsible for the storm-time variations in the radiation belts. Our tool will be using a novel approach of calculating adiabatic coordinates as an important stepping-stone towards answering the motivating science questions:

(1) What is the relative contribution of radial transport, localized acceleration, and loss process that cause the storm-time dynamics of radiation belt electrons?

(2) Do different types of solar wind events (high-speed streams, coronal mass ejections) lead to different dynamics and acceleration processes in the radiation belt environment during different phases of the solar cycle?

(3) Are the increased flux levels due to radial transport or a localized acceleration process and can they be linked to the different driving conditions in the solar wind?

In this project we will apply a neural network technique to calculate L* with a high degree of fidelity several orders of magnitude faster that with the standard integration technique. We have tested and validated a preliminary version of this tool, thus demonstrating its feasibility. This is a highly innovative approach that will enable the broad radiation belt research community to study a large amount of radiation belt data as a function of solar wind condition surpassing any degree of fidelity ever attempted before.

This work is both advantageous and timely for the LWS TR&T program goal of understanding the integral system linking the Sun to the Earth's magnetosphere. Specifically, our technique will be able to address the origin of radiation belt enhancements - a research task that will directly contribute to the NASA research objective of "developing the capability to predict the extreme and dynamic conditions in space in order to maximize the safety and productivity of human and robotic explorers".

In Summary:

Deliverable: the neural network as part of a software library including documentation

Delivery Site: Virtual Radiation Belt Observatory (ViRBO)

Schedule: three months before completion to allow for implementation support

Charles Lindsey/NorthWest Research Associates, Inc.
Fast Processing of Spherical Seismic Holography

We propose to provide

(Deliverable:) a software research utility that will run computations for helioseismic holography in a spherical environment. The code will take advantage of modern parallel-processing facilities to run the computations a hundred or more times faster than the serial codes that have been used for spherical holography heretofore. The primary object of the utility will be seismic diagnostics of flows in the deep convection zone. The utility will also include the facility for rapid computations of seismic images for the HMI far-side seismic monitor.

(Delivery Site:) The Joint Operations Science Center (JSOC) for the Solar Dynamics Observatory (SDO) at Stanford University, Stanford, California.

(Schedule:) The utility will be delivered in two instalments. The far-side imaging component will be delivered to the JSOC and implemented into the HMI far-side synoptic monitor at the beginning of the second year of the contract, on November 1, 2011. The near-side component will be delivered and implemented into the HMI data-analysis pipeline three months before the end of the second year of the contract, on August 1, 2012.

Rick Niciejewski/University of Michigan
TOOLS & METHODS: Mesosphere/lower thermosphere tidal strength product

Proposal title: Mesosphere/lower thermosphere tidal strength product

Key deliverables
1. Daily quantitative value of the amplitude and phase of the low latitude propagating diurnal tide in the mesosphere/lower thermosphere altitude range. This will be a zonally averaged product, essentially describing the Hough (1,1) diurnal tide.

2. Daily assessment of the strength of periodic waves in the mesosphere/lower thermosphere. This will be a zonally averaged product describing, but not limited to, the semi-diurnal tide, the two-day wave, and the two-day planetary wave.

Methods/techniques
The TIDI experiment aboard the TIMED satellite acquires a synoptic description of the global neutral wind pattern from pole to pole and throughout the mesosphere and lower thermosphere with nearly a 100% duty cycle on a daily basis. A dominant periodic signal is the propagating diurnal tide traditionally described by the Hough (1,1) function. At equinox and at low latitudes, the neutral wind and temperature respond almost exclusively in the MLT with a 24-hour periodicity. The strength of the diurnal tide is known to vary on a semi-annual basis and to exhibit inter-annual variations. It also

exhibits day-to-day changes in amplitude. Consequently, it has a variability that is difficult to capture with either first principle or empirical models. These models would be better served to adjust their behaviour given an observed tidal strength, much in the same fashion as thermosphere general circulation models employ published solar flux and geomagnetic activity indices.

Simple analysis techniques exist to extract the amplitude and phase of the diurnal tide from MLT observables, and which have been described in the literature. The University of Michigan is the point of contact for the TIDI MLT wind-measuring instrument and has the in-house capability to provide a daily diurnal tide index. Such an index may be retrieved on a daily basis in near real-time from TIDI and made deliverable to the LWS community via our mission site.

The analysis will also extract the power of other periodic features in the TIDI data. This approach requires an assessment of potential aliasing that may act to contaminate specific features such as the 2-day wave. The deliverable product will be a map of the power spectrum in terms of wavenumber and frequency (/day). The modeling community may use such a product to tune models on a daily basis rather than relying on empirical formulations or adjustable parameters.

We propose to develop the software tools that can identify tidal strength in the MLT region. The deliverable product will be a stand-alone index for the propagating diurnal tide and a web application for mapping other periodic features.

Perceived importance of the research problems and significance to NASA Heliophysics research focus areas

This proposed research is important to the Heliophysics Division of NASA via roadmap focus area 1: open the frontier to space environment prediction, which has the goal of understanding the fundamental physical processes of the space environment. The proposed work will lead to progress in LWS strategic goal #4, by providing a tool for predictive models to better deliver upper atmospheric response to changes in solar radiation and to coupling from above and below and to goal #2, understanding the degree variations in the solar radiative output have on climate.

DELIVERABLE: 1) tool to quantify MLT Hough (1,1) amplitude/phase on a daily frequency in the form of a daily index; 2) tool to portray spectral map in wavenumber/frequency of MLT periodic modes on a daily basis

DELIVERY SITE: mission site for TIDI: http://tidi.engin.umich.edu

SCHEDULE: first quarter of year 2) of proposal, estimated as spring 2011

Tools and Methods Workshop

Ana Cadavid/California State University
IAU Symposium 273 on the Physics of the Sun and Star Spots

A major goal of the "Living With A Star Targeted Research and Technology" (LWS) program is understanding and predicting the variations in solar radiative and particulate output over wide range of time scales. Although it is still not possible to explain all phenomena starting from first physical principles, it is very useful to find common threads connecting different phenomena. An example of relevance to the LWS initiatives are the class of models which use a classification of sunspot characteristics for flare prediction.

Despite more than three decades of vigorous observational and theoretical research on solar magnetic fields, the understanding of the mechanisms governing the origin and decay of sunspots is far from complete. Indeed, the delay of onset of the current solar activity cycle has come as a complete surprise to solar physicists. While sunspots are thoroughly studied objects, spots on other stars remain poorly understood. Combining the solar and stellar fields of research is mutually beneficial since solar investigations can gain insight from the long term evolution of stellar magnetism, and stellar research can gain insight into the roots of the spot phenomenon.

The astronomy group at California State University Northridge (CSUN) has been granted the opportunity to organize and host the International Astronomical (IAU) Symposium 273 on the Physics of the Sun and Star Spots, which will take place on August 23-26, 2010. The meeting will attempt to understand the long term behavior of the Sun by including knowledge about similar stars. At the same time, recent developments in the field of solar magnetism, which are vital to space weather prediction research, will be presented. Broadly, the conference aims to stimulate the cross fertilization of ideas both within established researchers and with students starting their careers. The contributions to the conference will be published in the form of proceedings.

Invited speakers will be selected by the scientific organizing committee from the pool of scientists working in the field of stellar and solar magnetism and activity around the world. The speaker roster will include both established and young researchers. Contributed talks will be given by graduate students and post-doctoral fellows. In all cases scientists from under represented groups will be actively recruited. This proposal requests travel funds to support students from USA.

Philip Judge/National Center for Atmospheric Research
The "Eddy Cross-Disciplinary Symposium on Sun-Climate Research"

In June 2009, the world lost a pioneer in sun-climate research, Dr. Jack Eddy. We propose a workshop centered on the LWS Sun-climate theme to celebrate the life, work, and cross-disciplinary approach of this remarkable man. We ask for funding to help bring significant numbers of students, from undergraduates to doctoral students, together with acknowledged experts and interested researchers, with several aims: We wish to stimulate talented students to enter the climate and solar research areas; we wish to assess the subject area some 34 years after Eddy's seminal paper on the "Maunder minimum", at a period when the Sun's behavior is somewhat unusual and political interest is intense; we want to highlight Jack's career as an outstanding example of cross-discliplinary research; last, but not least, we wish to celebrate the life of a remarkable man.

The meeting, if selected by NASA for support, will be scheduled sometime in 2010/2011 to optimize attendance by students and the Eddy family.

Alexander Kosovichev/Stanford University
LWS Workshops "Local Helioseismology: Data Analysis, Modeling and Comparisons"

We propose a series of 3 annual workshops in 2010-12 for discussing data analysis techniques and inferences of local helioseismology, helioseismic numerical simulations, their applications for verification and testing of the analysis methods, and comparisons of the techniques and results. Local helioseismology provides tools for imaging structures and mass flows below the solar surface, and becomes increasingly important for understanding the mechanisms of solar activity and developing physics-based forecasts of the solar cycle, emerging active regions and energy release events. However, local helioseismology diagnostics are very challenging, particularly, in regions of strong magnetic fields, because of the complexity of interactions of solar oscillations with the turbulent magnetized plasma of the convection zone and the solar atmosphere. Numerical simulations of solar MHD waves and turbulent dynamics give important insights into the complicated wave and turbulence physics, and also provide artificial data for verification and testing of helioseismology methods and results. Thus, we propose a series of the annual workshops to discuss and stimulate further development of local helioseismology methods, models, and numerical simulations. The workshops will provide a key support to the LWS TR&T helioseismology projects, for the space missions, SDO and Hinode, and ground-based helioseismology networks.

Sun Climate Theme Panel

Lon Hood/University of Arizona
Solar UV-Induced Responses of Stratospheric Ozone, Temperature, and Circulation on Decadal Time Scales

Objective: The objective of the proposed work is to more completely determine and interpret the observed solar cycle change in stratospheric ozone, temperature, and circulation as a function of altitude, latitude, longitude, season, and QBO phase.

Methods/Techniques: We will apply an improved multiple regression statistical model to evaluate the 11-year solar induced stratospheric response using a series of complementary and independent data sets. A primary initial task will be to evaluate whether the observed 11-year responses of ozone and temperature in the low-latitude lower stratosphere may be caused mainly by the troposphere-ocean amplification mechanism investigated recently by Meehl et al. [2009]. We will do this by determining more completely the dependence on latitude, longitude, season, and QBO phase of the lower stratospheric ozone and temperature responses and then evaluating whether these responses correlate significantly with observationally estimated and model-predicted sea surface temperature solar cycle variations in the Pacific sector. Second, we will analyze statistically a series of reanalysis and direct satellite remote sensing data sets for the purpose of determining more completely the zonal mean temperature, zonal wind, and planetary wave flux responses to 11-year solar forcing. Solar regression coefficients will be calculated in monthly and, in some cases, 10-day increments to allow detailed comparisons with recent model simulations. Third, we will evaluate the relative contributions of particle precipitation-induced odd nitrogen variability and solar UV variability in producing interannual ozone variations in the polar stratosphere as a function of altitude, season, and QBO phase.

Significance: As stated in the LWS TR&T Summary (Appendix B.6 of the ROSES-2009 NRA), ``NASA through the TR&T program and Earth Science Division in conjunction with other national agencies such as NOAA and NSF needs to deliver the understanding of how and to what degree variations in the solar radiative and particulate output contribute to changes in global and regional climate ..." The observed solar cycle variation of the stratosphere is a fundamental constraint on chemistry climate models that include stratospheric effects of solar ultraviolet and energetic particle inputs. The proposed work is intended to determine (to the extent allowed by the length and calibration of existing satellite data sets) the characteristics of the observed solar cycle variation so that current models can be quantitatively tested.

Cora Randall/University of Colorado
Atmospheric Coupling via Energetic Particle Precipitation

The goal of the work proposed here is to better understand the degree to which energetic particle precipitation (EPP) couples the upper and lower atmosphere, and the role of meteorology in this coupling. It is well known that EPP affects stratospheric NOx and O3, and that changes in O3 can influence atmospheric temperatures and circulation. Stratospheric processes can influence the troposphere, impacting weather and climate. Still unknown is the degree to which EPP might thus indirectly affect climate. In turn, tropospheric perturbations such as might originate from anthropogenic climate change can be communicated to the middle and upper atmosphere, thereby altering the atmospheric response to EPP through relevant meteorological pathways. Recent work has shown that meteorological conditions are fundamental to controlling the effects of EPP on the atmosphere. Indeed, depending on dynamical activity, EPP effects can be large even when geomagnetic activity is not elevated. Understanding the impact of EPP on the Earth's atmosphere and possibly climate thus requires that we explore the avenues through which the different regions of the atmosphere are coupled via EPP. To achieve the overall goal stated above, the objectives of the proposed work are to answer the following questions:

(1) To what extent has EPP affected atmospheric composition and temperature since 1979?
(2) By what mechanisms does meteorology influence the atmospheric response to EPP, and is there any feedback from EPP on these mechanisms?
(3) How does a changing climate affect the relevant meteorological mechanisms?

These questions will be answered with both satellite measurements and model simulations. The model is the NCAR Whole Atmosphere Community Climate Model (WACCM). Simulations with realistic EPP input specified from particle measurements will be compared to simulations without EPP to investigate EPP effects on atmospheric composition and temperature during the last three solar cycles. Model output will be evaluated by comparing to current and historical satellite observations. We also propose to analyze current satellite data to continue quantifying the flux into the stratosphere each year of NOx produced by EPP.

Demonstration of Relevance to NASA and LWS Objectives:
This proposal addresses the Living With A Star Sun-Climate Theme, for which the strategic objective is to "deliver the understanding of how and to what degree variations in the solar radiative and particulate output contribute to changes in global and regional climate over a wide range of time scales." By investigating the mechanisms by which different atmospheric regions are coupled under the influence of EPP, the work proposed directly addresses this objective. The Sun-Climate Theme places "particular emphasis...on coupling of the upper and lower atmosphere", which is the main topic of the work proposed here. The proposed work targets the processes by which EPP effects on the middle and upper atmosphere are communicated to other regions of the atmosphere, potentially altering the Earth's climate. The work proposed here also focuses on how the atmospheric response to precipitating particles is affected by climate change; this is also in line with the LWS Sun-Climate Theme, which "targets the pathways by which ongoing climate change influences the atmospheric response to solar forcing, both directly and via upward coupling".

Drew Shindell/NASA Goddard Institute for Space Studies
Global and Regional Climate Sensitivity to Solar Forcing in an Integrated Chemistry-Climate Atmosphere-Ocean Model Driven by SORCE Observations

We propose to examine the impact of solar irradiance variations on the Earth’s atmosphere and climate at multiple timescales. Using a state-of-the-art climate model driven by spectrally discriminated variations in solar output observed by satellite we will investigate the changes induced in atmospheric composition, circulation, and surface climate and compare against available observations. The model includes fully interactive chemistry operating seamlessly from the surface through the mesosphere in the new IPCC AR5 version of the GISS climate model (modelE). The flexible architecture of modelE allows us to easily run the identical atmospheric model with or without chemistry, and coupled to either a fully dynamic ocean, a slab ocean or using prescribed sea surface temperatures (SSTs). We propose to use this model to examine the climate response to solar variations on decadal to millennial timescales.

We will include extensive comparisons between observations and the simulated solar cycle response (with both a slab ocean and fixed SSTs) in the model driven by recent observations of solar irradiance variations as a function of wavelength from the SIM instrument on SORCE. Results to date indicate that modelE captures many aspects of the observed ozone response (including in the lower stratosphere), the poleward and downward propagation of zonal wind anomalies, and the spatial structure of long-term solar-induced surface climate changes. Sensitivity studies will test the importance of various processes, e.g. the tropospheric and stratospheric chemistry, or the model's vertical extent, in the cascade of solar effects from the upper atmosphere down to the surface. The simulations will also allow separation of the so-called "top-down" and "bottom-up" mechanisms of solar-climate interactions. The climate response will be compared with that reported in several observational analyses. Subsequently, we will use the evaluated model incorporating only those processes which are critical based on the solar cycle tests to simulate century-scale transients (e.g. to Maunder Minimum-type conditions) including a coupled ocean and compare with global and regional historical reconstructions. These latter simulations will be closely linked with GISS participation in the PMIP (Paleoclimate Model Intercomparison Project) simulations of the past millennium, but will add a distinct solar-climate analyses to that project which otherwise includes multiple forcings.

The proposal is highly relevant to the "Sun-Climate Theme" 1.2.2 of the solicitation and will address many of the potential research questions outlined in that section of the proposal call.

Ka-Kit Tung/University of Washington

Climate Response to Solar Forcing, Observational Analysis, Theory and Modeling

We study the effect of the variation of the spectral irradiance of the sun over the 11-year solar cycle on the terrestrial climate. On the forcing side, we will use the latest satellite data to quantify the spectral variations over a solar cycle. This will impact the radiative forcing for the climate system, especially on energy absorbed at different levels in the atmosphere and on the fraction of the top of the atmosphere radiation that reaches the surface land and ocean. On the response side, the observational analysis will focus on statistical methods that are capable of separating out the small solar signal from the climate noise and other components of climate signal, such as El Nino and Southern Oscillation(ENSO) and Quasi-Biennial Oscillation (QBO). Lack of rigorous statistical tests of the solar signal has in the past been a criticism of this Sun-Climate field. The observational analysis will concentrate on the global and, to some extent, the wide regional, response in temperature, zonal wind and circulation in the lower atmosphere, to yield a clearer picture of the spatial pattern of the climate response at the surface, with polar amplification of the warming during solar max. Methods used for data analysis include previously used methods :Empirical Mode Decomposition (EMD), Composite Mean Difference Projection (CMD Projection) and Linear Discriminant Analysis (LDA), and new methods in this application, such as Singular Spectrum Analysis (SSA). On the theory side, we attempt to quantify the effectiveness of various pathways through which solar forcing is transmitted from the upper atmosphere to the lower atmosphere. In the stratosphere, we seek to understand how the enhanced UV component of the solar radiation variability affects the distribution of ozone, and how that filters the amount of radiation reaching the troposphere. The long-wave downward radiation by a warmed stratosphere will also be taken into account. Possible effects of solar cycle heating in the stratosphere affecting the propagation of planetary waves will also be considered, although it is not clear at this time how much this mechanism can contribute to the surface warming on a global basis. These effects will be studied using a radiative transfer code and a 2.5-dimensional model with interactive radiation, chemistry and dynamical transport(involving the planetary waves) previously co-developed by the PI. The tropospheric research focuses on understanding how the net radiative forcing (RF) reaching the top of the troposphere (after stratosphere adjustment in ozone and temperature) forces directly and indirectly the surface temperature, with an aim to quantifying the climate-gain factor due to the feedback processes, such as water-vapor feedback, ice albedo feedback and cloud feedback. The time scale considered range from seasonal to 150 years, the length of the instrumented observational record. The proposed research attempts to address the objective of the solicitation to "deliver the understanding of how and to what degree variations in the solar radiative output contribute to changes in global and regional climate over a wide range of timescales."
