Living With a Star TR&T
Abstracts of Selected Proposals
(NNH11ZDA001N-LWSTRT)

Below are the abstracts of proposals selected for funding for the Living With a Star TR&T program. Principal Investigator (PI) name, institution, and proposal title are also included. **129** proposals were received in response to this opportunity. On June 29 and October 10, 2012, a total of **31** proposals were selected for funding.

Joel Allred/NASA Goddard Space Flight Center
Computational and Observational Investigations into the Atmospheric Response to Flare Accelerated Particles

Flares dramatically enhance emission in numerous atomic lines and continua. If properly interpreted, this emission can reveal vital information about the Sun's atmospheric state during flares. However, due to the complexity of the radiative transfer in the Sun's atmosphere, extracting this information can be quite difficult. Here we propose to perform radiative hydrodynamic simulations of the response of the solar atmosphere to flare heating. The simulations model radiative transfer coupled with hydrodynamics and make predictions of how emission will increase during flares. We will correlate our predictions with data from the RHESSI and SDO space craft. We will use spectral fitting of RHESSI hard X-ray observations to deduce details of electron beams impacting on the chromosphere. A model of the electron beam deduced from RHESSI observations will be injected as a heating term into our code to simulate the radiative hydrodynamic response to flare heating. With this heating as input, the model will solve in detail the dynamics of the flaring atmosphere and can be used to predict emission, densities, velocities, temperatures, and emission measures as a function of time during the flare simulation. These will be compared with observations.

It is important to note that spectral fitting to RHESSI data provides information about the electron beam and the state of the plasma where the beam impacts i.e., primarily the chromosphere. The non-uniform ionization in the chromosphere produces a break in the X-ray energy spectrum. Several flares have been observed that have breaks in the X-ray spectrum that are consistent with partial ionization. We will investigate to what extent this break is caused by partial ionization in the chromosphere. To do this we will compare emission measure and ionization fractions obtained from the models with those obtained directly from spectral fitting. Since the model has as its input an electron beam obtained from the spectral fit, the comparison of the output of the model with the spectral fit essentially closes the "loop" between the two and provides checks on both the models and spectral fits.

Accelerated ions are known to be a source of flare heating in the lower solar atmosphere. We are enhancing our model to include the effects of ion beam heating. We will use this to investigate the origins of white light emission, sunquakes and the broad 511 keV emission line.

The positron-electron annihilation line at 511 keV has been observed in several flares to be unexpectedly broad. The line may be broadened by thermal mechanisms, but that would require a significant amount of material to be heated to ~0.5 MK. In addition, the material stays hot even after the impulsive has ended, suggesting an energy source separate from the impulsive flare heating. One possibility is low-energy ions (< 1 MeV). Our models are ideally suited to explore this issue. In this proposal, we will investigate low energy ion heating as a potential explanation of the broad 511 keV line.

Meg Austin/UCAR
Heliophysics: Integrating Knowledge Across Disciplines

One of the major challenges facing the Living With a Star Program (LWS) is the development of a research community that crosses traditional discipline boundaries to attack system-wide problems central to understanding and modeling the Sun-Solar System connection. The Visiting Scientist Programs office (VSP) of the University Corporation for Atmospheric Research (UCAR) has partnered with the university community to develop a focused Heliophysics Summer School (held yearly since 2007) and a successful postdoctoral fellowship program (since 2009) to address this challenge. This proposal seeks to establish a multi-year Cooperative Agreement with NASA for the continuation of VSP s successful efforts to facilitate the training and education of a new generation of heliophysicists and support interactions within the heliophysics community.

VSP s Mission: To help prepare the next generation of scientific leaders and workforce by supporting effective and collaborative fellowship, visitor, and workshop programs that meet emerging training and research needs.
In support of the NASA Heliophysics division s long-term goal of developing the scientific understanding needed for the United States to effectively address those aspects of the connected Sun-Earth system that may affect life and society, the Visiting Scientist Programs office helps Earth systems scientists develop a new research community and build productive, collaborative, working relationships.

To reach this goal, VSP:

- Organizes, hosts, and administers the annual Heliophysics Summer Schools to foster learning and development of Heliophysics as a broad, coherent discipline. This includes support in developing additional teaching tools that may include textbooks, problems sets, labs, and distance learning modules.
- Established and administers the Jack Eddy Postdoctoral Fellowship Program, which matches early career PhDs with hosting mentors in order to build a new generation of heliophysicsts.
- Hosts and administers the annual Space Weather Enterprise Forum and Space Weather Workshop to advance collaboration between industry, academia, and government, raising awareness and improving understanding of space weather.

- Proposes to develop and administer the Jack Eddy Summer Institute as part of the fellowship program. When the program has developed a critical mass of program graduates, a biennial workshop will provide ongoing opportunities for alumni to build their community. The young scientists will spend several days sharing and discussing the implications of their science on global policy and societal impacts. Experienced host scientists will also be invited to participate.

S. Irfan Azeem/ASTRA LLC
On the Global Dynamics of the Time-Dependent and Three Dimensional Ionospheric Response to Sudden Stratospheric Warming Events

Sudden Stratospheric Warming (SSW) events in the lower atmosphere polar regions represent a unique type of meteorological phenomena that exhibits significant dynamical coupling of the troposphere-stratosphere-mesosphere-ionosphere system. SSW events are caused by rapid changes in the mean stratospheric zonal flow accompanied by an enhancement in planetary wave activity, which as a result can produce large perturbations in the electrodynamics and electron density at ionospheric heights even at low-latitudes. It is now recognized that, for a better specification of the ionospheric variability, a better understanding of SSW events and the coupling with the upper atmosphere is needed. Much of our knowledge of the ionospheric variability during SSWs, however, has come from observation made independently and only at a few locations. Nevertheless, these observations have provided important basic information about the SSW effects in the ionosphere. A broader, more global, observational capability and more comprehensive analyses are required to unambiguously reveal the global response of the ionosphere to SSW events.
The overall goal of this proposal is to elucidate the global ionospheric signatures associated with SSW events in the Northern and Southern Hemisphere. To reach this goal, we will answer the following science questions:

a) What is the time-dependent three-dimensional (latitude, longitude, altitude) response of the ionosphere to SSW events and how does the ionosphere evolve through the SSW recovery phase?
b) How do the effects of SH SSW events on the equatorial and low-latitude ionosphere compare with those due to the NH SSWs?
c) What is the global structure of the lunar semi-diurnal perturbation in the ionosphere and to what extent is it modified by the SSWs?

To answer these questions we will use four-dimensional (latitude, longitude, height and time) images of the global distribution of the ionospheric electron density. These images will be obtained using a variety of data sources and the Ionospheric Data Assimilation Four-Dimensional (IDA4D) algorithm. An investigation of the variability in the electron density images and underlying electrodynamic processes taking place during the most recent SSW events will be aided by unique observations of equatorial electric fields made by the Ion Velocity Meter (IVM) instrument onboard the Communication/Navigation Outage Forecasting System (C/NOFS) satellite. The results of the proposed work will provide a comprehensive, global characterization of the ionospheric response to different types and magnitudes of SSW events. Our analysis will provide the time evolution of the ionospheric disturbances associated with SSW events. We anticipate that these results will contribute to test and validate numerical modeling and other theoretical efforts put forward by other members of the LWS Focus Team.

Jacob Bortnik/University of California Los Angeles
Quantifying the Effect of Wave-Driven electron Precipitation on Ionospheric Conductivities

Magnetospheric plasma waves are known to be of critical importance in controlling the structure and dynamics of the Earth s radiation belts, and are implicated in a host of other phenomena. For example, in a recent series of papers it was shown that lower-band chorus was the dominant driver of the pulsating aurora, and that the combination of scattering by lower-band and upper-band chorus was responsible for producing the diffuse aurora. It is these two auroral phenomena that produce significant precipitation into, and modification of the upper atmosphere and ionosphere, precipitating electrons in the range of a few 10 s of keV in the case of pulsating aurora, and 0.1-10 keV in the case of the diffuse aurora. The diffuse aurora in particular is known for providing the main source of energy into the nightside upper atmosphere, though it is generally not visible to the naked eye.

The electron precipitation into the upper atmosphere leads directly to changes in the ionospheric conductivity which, in turn, controls the intensity and distribution of the global electric fields that drive convection and transport in the plasmasheet. The feedback loop is completed in that the transport of electrons in the plasmasheet determines the distribution of the excited magnetospheric plasma waves and their downstream effects on radiation belt acceleration and loss. In this way, there is an intimate interplay of the plasmasheet and the radiation belts, mediated by magnetospheric plasma waves and their modification of ionospheric conductivities.

In this proposal, we will use the RAM code to model the kinetic drift of energetic particles in the plasmasheet, and dynamically calculate the growth rates of Very Low Frequency (VLF) waves throughout the inner magnetosphere. By mapping growth rates to wave saturation amplitudes (as has been done in previous work) and calculating the electron precipitation rates, we will be able to assess the change in the ionospheric conductivity driven by the waves, and in turn modify the electric field in the inner magnetosphere.

The results of this work will be directly applicable to the goals outlined in several documents such as the Sun-Earth Connections Roadmap Report, and Heliophysics Roadmap, and is aimed at addressing Focused Science Topic (b) of the LWS TR&T program, entitled: Interaction between the magnetotail and the inner magnetosphere and the impact of that interaction on the radiation belt environment .

Alan Burns/University Corporation for Atmospheric Research
The Effects of Sudden Stratospheric Warmings on the F2 Region

The lower and middle atmosphere can drive significant changes in the upper atmosphere. One example of this is the effects of sudden stratospheric warmings (SSWs) on the F2 region ionosphere (e.g., Liu and Roble, 2002; Gornachenko and Zhang, 2008). Understanding how and why these SSWs change the F2 region ionosphere will not only increase our understanding of their effects, but will also help us better understand the more general variations of F2 region ionosphere   an important element of space weather. We propose to undertake a comprehensive investigation using global space-based data from Constellation Observing System for Meteorology, Ionosphere, and Climate (COSMIC) Global Positioning System (GPS) occultation, Total Electron Content (TEC) data from the ground-based GPS network, ground-based ionosonde data, and results from the state-of-the-art General Circulation Models (The National Center for Atmospheric Research Thermosphere Ionosphere Mesosphere Electrodynamics General Circulation Model - NCAR TIME-GCM - and The Whole Atmosphere Community Climate Model - X   WACCM-X) to study the global development and evolution of stratospheric warming effects on the F2 ionosphere to address three key questions:

1) Are the apparent anomalies observed in the ionosphere during SSWs uniquely associated with these events?
2) How do the F2 region ionospheric effects of SSWs evolve in time?
3) Is the low-latitude dynamo the primary mechanism driving ionospheric changes during SSWs?

The proposed effort will directly address the NASA Living With a Star Targeted Research and Technology program (announcement NNH11ZDA001N-LWSTRT) in focused science topic (c) Atmosphere-Ionosphere Coupling During SSWs by helping in Understanding the forcing mechanisms for SSW events, including wave-wave interactions in the neutral atmosphere and neutral/plasma coupling which has the potential to significantly improve understanding of the drivers of ionospheric variability, and improve forecasting of ionospheric space weather . It also addresses NASA s strategic goal to Understand the Sun and its interactions with the Earth and the solar system , by analyzing how the ionosphere can be affected by the interaction between changes in the atmosphere below and forcing by solar-driven processes. The products of this study include: a greater understanding of the effects of stratospheric warmings on the ionosphere, a set of validated, gridded ionospheric data from the COSMIC mission that will be made available to the wider community and improved versions of the NCAR TIME-GCM and WACCM-X for future development as a community model.

Scot Elkington/University of Colorado at Boulder
Transport and Trapping of Energetic Plasmasheet Electrons in the Inner Magnetosphere

Energetic particles in the plasma sheet and near-Earth magnetotail can be transported sunward by large-scale magnetospheric convective processes, allowing some populations to be trapped inside the 'Alfven Layer' on close drift paths in the inner magnetosphere. These newly-trapped particles may contribute directly to the seed populations that are subsequently heated to ring current and radiation belt energies, and may also provide a source of free energy for the generation of electromagnetic waves that affect the dynamic variations of the outer radiation belts. In this effort, we propose a study of the dynamics of the Alfven layer and the characteristics and effects and contributions of energetic plasma sheet particles on trapped populations in the inner magnetosphere.

Specifically, the following questions are addressed: (1) What solar wind driving conditions and magnetospheric activity parameters dictate the position and morphology of the Alfven layer? (2) How do we characterize the transport-induced electron temperature anisotropies that provide the free energy for chorus and hiss wave activity in the inner magnetosphere? (3) What are the effects of transport, energization and trapping of plasma sheet source particles on the radiation belts, both in terms of direct adiabatic injection, and the the resulting effects of wave activity in the inner magnetosphere?

MHD/particle simulation, using both simplified solar wind conditions and case studies driven by observations from L1, will be combined with energetic particle and field observations from the inner magnetosphere and near-Earth tail to examine the physical processes involved in transporting, energizing, and trapping plasma sheet electrons in the outer zone radiation belts. The results will provide a deeper understanding of the mechanisms of coupling between the plasma sheet and inner magnetosphere, a model of the spectrum and dynamics of the seed populations that contribute to the ring current and radiation belts, and insight into the evolution and morphology of temperature anisotropies that can be used in models of inner magnetospheric wave activity.

Tim Fuller-Rowell/University of Colorado at Boulder
Workshop Support: International AGU Chapman Conference on Longitude and Hemispheric Dependence of Space Weather

Proposal Summary
This proposal request support for an International AGU Chapman Conference on:

Longitude and Hemispheric Dependence of Space Weather

The meeting will be held in Addis Ababa, Ethiopia, on November 12-16th, 2012.

The International AGU Chapman Conference will have three primary objectives:

- ❖ Determine the nature and cause of the longitudinal and hemispheric dependence of the ionosphere and thermosphere response to major solar events.
- ❖ Expand the study of space weather by examining the Earth system response during times when solar and geomagnetic activity are not so extreme; for instance plasma irregularities can occur on any night even when geomagnetic activity is benign, and can have a severe impact on satellite communication and GPS navigation.
- ❖ Quantify the impact of forcing from the lower atmosphere on space weather.
- ❖ The conference will have at least two broader objectives:
- ❖ Assemble an international group of heliophysics scientists to target current and needed observations at mid and low latitudes in the African longitude sector, a region that has yet to be explored in detail using ground-based instruments. In order to have a complete global understanding of space weather and advance the global modeling effort, deployment of ground-based instruments in Africa is essential. Therefore, strong interaction between scientists from instrument suppliers and host institutes is crucial in order to have successful instrument deployment and continuous data retrieval process.
- ❖ Enhance the space science education and research interest in the continent. The interaction between African and other international scientists will significantly spark interest in space science education and research throughout Africa. It will facilitate international collaborations, gain exposure in African universities, and encourage the next generation of African scientists to become inspired by space science. The conference will also provide ideal opportunities for African scientists and graduate students to communicate their scientific results to the international scientific community.
- ❖ The conference will focus on six main science themes, all of which strongly support the objectives of the NASA Living With a Star Program. These science themes are:
    - Hemispherical dependence of magnetospheric energy injection and the thermosphere-ionosphere response
    - Longitude and hemispheric dependence of storm-enhanced densities (SED)
    - Response of the thermosphere and ionosphere to X-Ray and EUV time-history during flares
    - Quiet-time longitude spatial structure in total electron content and electrodynamics
    - Temporal response to the lower-atmosphere disturbances
    - Ionospheric irregularities and scintillation

Larisa Goncharenko/MIT Haystack Observatory
Characterization of the Stratospheric, Lower Thermospheric, and Ionospheric Variability Related to the Sudden Stratospheric Warmings

We propose a research program that will analyze a variety of data with the goal of providing insight into possible causal mechanisms of stratosphere-ionosphere coupling during sudden stratospheric warming (SSW) events. The proposed study will focus on three key altitude regions at low and middle latitudes: 1) the stratosphere, where semidiurnal tides are generated through the absorption of solar UV by ozone molecules; 2) the lower thermosphere, where tides reach their largest amplitudes and drive the E-region dynamo; and 3) the ionosphere, where sudden stratospheric warming effects are the strongest at low and middle latitudes. Science focus questions on which we will reach closure are quantitative identification of key SSW temporal and spatial effects in 1) stratospheric planetary wave, wind, temperature, and ozone mass mixing ratio perturbations; 2) lower thermosphere tide and E region ionospheric modifications; and 3) ionospheric F region and TEC responses. We will use ECMWF (European Center for Medium Range Weather Forecast) and NASA MERRA (The Modern Era Retrospective-analysis for Research and Applications) reanalysis data to characterize variations in stratospheric parameters, including temperature, planetary wave activity, zonal and meridional wind, and ozone mass mixing ratio. Lower thermospheric data from incoherent scatter radars will be used to examine variations in tidal modes around stratospheric warming events, with the focus on inferring the temporal development of tidal components. GPS total electron content (TEC) measurements and incoherent scatter radar data will be used to identify and examine the ionospheric response to stratospheric warmings using observations of the ionospheric vertical drift, the density and height of the F2 region peak (NmF2 and hmF2), and the TEC. The results of this research will provide a unique and valuable set of observational truth and observational constraints for the team modeling effort.

Janet Green/National Oceanic and Atmospheric Administration
Understanding the Dynamics of the Radiation Belts

The goal of the proposed work is to determine if changes in particle drifts and the open closed boundary control whether the outer radiation belt flux is depleted or enhanced. More specifically, we propose to test the following hypotheses: 1) The outer electron radiation belt will be depleted due to direct transport out the magnetopause and enhanced outward radial diffusion if the open/closed boundary of radiation belt electrons intersects the magnetopause and 2) The outer electron radiation belt will be enhanced only when the last closed drift orbit of seed electrons is inside the magnetopause, allowing those electrons access to the inner magnetosphere from the tail. We do this using a four step method. First, we create a dataset of phase space density at fixed invariants with error estimates for the GOES and POES proton and electron data to determine how often decreases are just adiabatic. Next, we calculate proton and electron drift orbits in TS05 field with the Volland-Stern electric field model to find which particle energies and pitch angles should be lost to the magnetopause and compare to the GOES data set. Then, we use observed PSD radial gradients and ULF wave measurements from multiple GOES and POES satellites to determine whether outward radial diffusion and direct magnetopause loss can explain decreases. Lastly, we identify storms with small, medium and large PSD enhancements in the GOES dataset. We calculate the width of the forbidden region by tracing particles in the TS05 model with a Volland-Stern electric field and use a superposed epoch analysis to determine whether the width of the forbidden region dictates whether the radiation belts are enhanced. Ultimately, the impact of the proposed work is that it will clarify and possibly alter our understanding of both radiation belt loss and acceleration processes leading to more realistic modeling and predictive power for anticipating events with societal impacts. Additionally, the work will provide a new dataset of PSD as a function of the adiabatic invariants that can be used to complement the upcoming RBSP mission as well as future NASA missions.

Lucia Kleint/Bay Area Environment Research Institute
Bridging the Gap in Space, from the Ground: Dynamics and Magnetic Fields of Flares in the Photosphere and in the Chromosphere

Imaging instruments are required to capture flares and study the transport of mass, momentum and energy through the solar atmosphere. Of NASA's fleet of spacecraft, SDO provides full Sun magnetic and thermal data every few seconds at 1" resolution. The SDO/AIA UV (160nm) and EUV channels observe material above and at the base of the chromosphere, omitting several scale heights between the chromosphere and corona. From 2012, the UV slit spectrometer IRIS will partly plug this gap by making rapid rasters of chromospheric features. We propose to augment these capabilities using, in particular, the IBIS imaging spectropolarimeter at Sacramento Peak Observatory, and applying sophisticated spectral line inversion techniques to full Stokes photospheric and chromospheric data. Our goal is to investigate the 3D magnetic field configurations in the solar atmosphere necessary for flares to occur and their changes during and after flares.

Our proposed work is essential to this focused science topic, because our complementary observations have the proven capability to (1) capture flares efficiently; (2) measure both thermal and vector magnetic properties of photospheric and chromospheric plasma through the Zeeman effect, (3) study the role of particle beams through their imprint on linear polarization of chromospheric lines. The simultaneous use of space- and ground-based instruments will reveal crucial aspects of the physics of flare phenomena, unattainable otherwise, at a time when the solar activity is increasing. Our work will also help define the next generation of space-based instruments, such as will fly on SOLAR-C.

Alexander Kosovichev/Stanford University
Characterization of Sunquake Signatures in Terms of Energy and Momentum, and Their Relationship with the Flare Impulsive Phase

The sunquakes, observed in the form of expanding wave ripples, in the solar photosphere represent packets of acoustic waves that are excited by flare impacts and travel through the solar interior. The excitation impacts strongly correlate with the impulsive flare phase and are caused by the energy and momentum transport from the flare magnetic energy released sites. However, the exact mechanism of the energy and momentum transport are not known. Solving the problem of the sunquake mechanism will substantially improve our understanding of the flare energy release in the form of energetic particles, wave and mass motions, and radiation. We propose a comprehensive investigation of the sunquake properties and their relationship to the physical processes of the impulsive phase, using observational data from the SDO, RHESSI, Hinode, SOHO, GONG, and numerical modeling. The problem of the flare dynamics in the lower solar atmosphere is very complex and involves a wide range of topics from the particle acceleration in specific magnetic configurations, MHD instabilities and CME initiation to the impacts in the solar photosphere and helioseismic response.

Our main goal and contribution to the LWS TR&T Focused Topic Team "Flare Dynamics in the Lower Solar Atmosphere" will be analysis, characterization and interpretation of the photospheric and helioseismic response ("sunquakes") and associated localized impacts in terms of the energy and momentum transport, and relationship to the flare impulsive phase. The data analysis will be supported by 3D MHD simulations and comparison with X-ray and coronal data.

More specifically, we will contribute:
1) Data sets of the flare observations from SOHO/MDI and SDO/HMI, including dynamic and energetic characteristics of sunquakes (by two different techniques: time-distance analysis and holography), magnetic field characteristics, variations of magnetic field, Doppler shift, white-light emission, Stokes profiles and line profiles by implementing a special processing of the HMI level-1 data for M- and X-class flares and specific targets selected by the Focused Teams;

2) Simulation results of the energy and momentum impacts in the lower atmosphere for various theoretical models (including the thick-target model, localized heating, magnetic field variation (so-called "McClymont jerk"), CME eruptions and others) by using numerical simulations of two types: non-linear realistic 3D radiative MHD simulations, and 3D MHD simulations of the helioseismic response; these simulations will be coupled with computations of the HMI and MDI/GONG spectral lines, Stokes parameters and observables, and take into account instrumental characteristics;

3) Understanding of the physical mechanisms of the flare impacts, energy and momentum transport in the low chromosphere and photosphere, and "sunquakes" through comparison of the observational characteristics with the simulation models and with the characteristics of the X-ray emission and coronal dynamics, in close cooperation with other Focused Topic Teams.

Ruth Lieberman/GATS-Inc.
Mechanistic Studies of Stratosphere-Ionosphere Coupling During SSW Events

A number of recent studies indicate possible connections between midlatitude sudden stratospheric warming (SSW) events, and the F-region ionosphere. Nonlinear interactions between tides and the strong-amplitude planetary waves preceding SSWs have been proposed as a mechanism to facilitate their coupling. However, this hypothesis has remained unvalidated, in part because the evolution of tides during SSW events between the stratosphere and the F-region cannot be observed with the existing global satellite and radar networks. One way to circumvent this limitation is to use output from an assimilative model that includes the relevant physics that produces tides.

We propose to analyze a newly available hourly product of the NOGAPS-ALPHA forecast-assimilation system. This product will enable, for the first time, the identification of the tidal components in the middle and upper atmosphere that evolve concurrently with SSW events. The tidal components will be used as a bottom boundary condition for the NCAR TIEGCM, in order to track their effects on key thermospheric and ionospheric state variables, including tropical induced electric fields that are believed to be an important link in coupling the neutral thermosphere to the ionosphere. We will close the loop by comparing TIEGCM output with ionospheric radar data such as that from Jicamarca, and with several satellites datasets including TIMED, C/NOFS and CHAMP.

This proposal describes an end-to-end study spanning the middle atmosphere, thermosphere and ionosphere, that addresses Focused Science Topic (c): Atmosphere-Ionosphere Coupling During Stratospheric Sudden Warmings. This topic was formulated in support of Strategic Goal 4 articulated in NASA LWS TR \& T SC Report, 2010-2011: "Deliver understanding and predictive models of upper atmospheric and ionospheric responses to changes in solar electromagnetic radiation, and to coupling above and below".

Chang Liu/New Jersey Institute of Technology
Exploring the Physical Relationship Among Photospheric Magnetic Field Changes, Sunspot Motions, and Sunquakes During Solar Eruptions

Solar flares and coronal mass ejections (CMEs) are generally believed to be manifestations of a sudden and rapid release of the accumulated magnetic energy in the corona. The transients created in the tenuous low-beta corona are generally thought unlikely to alter the photospheric magnetic fields, which are line-tied to the dense high-beta photosphere. Only recently, a rapid back reaction on the photosphere due to the coronal magnetic field reconfiguration has been seriously considered from the theoretical point of view (e.g., Hudson et al. 2008; Fisher et al. 2012), with a prediction that the photospheric magnetic field would be oriented more horizontally resulting in a Lorentz force acting on the solar surface and interior. Such magnetic impulse is speculated to

cause sudden perturbation of sunspots and excitation of seismic waves. Thus the changes in the photospheric field and dynamics associated with flares/CMEs could serve as a direct observational probe of the energy transformations and momentum balance in the flare/CME process. Notably, a more inclined state of the photospheric magnetic field persisting after flares than before has been consistently found by our group in the past two decades.
The studies so far are, nevertheless, still very limitedmainly due to the quality and availability of ground-based vector magnetograms. The solar maximum 24 is approaching, and it is now possible to obtain the unprecedented high-quality and high-resolution vector magnetograms, line-of-sight Doppler images, and continuum and line intensity images of flaring active regions from the Solar Dynamics Observatory (SDO) and Hinode. These make it an opportune and timely moment to quantitatively address the physics behind the flare-related photospheric (and interior) phenomena including magnetic field changes, sunspot motions, and sunquakes. The scientific objectives of this study include three related components:

1. Using vector magnetograms fromSDO/HMI and Hinode supplemented by the archived and future data from BBSO, we will systematically study the temporal and spatial relationship between the changes of vectormagnetic fields and the related dynamics including signatures of flare energy release, the CME launch, and variation of sunspot white-light (especially penumbra) structure. We will explore the connection of the properties of the Lorentz-force change with the flare magnitude and CME energetics.
2. We will trace the sunspot motions throughout the eruption process, and study the correlation between it and the horizontal component of the Lorentz-force change, in the directions both parallel and perpendicular to the flaring magnetic polarity inversion line. As related, the evolution of the sunspot rotational motion across the flare time will be characterized based on the flow field derived using the differential affine velocity estimator for vector magnetograms (DAVE4VM).
3. Applying helioseismic techniques to the LOS velocity data cube, we will reveal the seismic transients due to the flare impact. We will then mainly concern ourselves with the question of whether the photospheric vector magnetic field changes and sunspot motions could be physically associated with sunquakes. The anisotropy of sunquake ripples will also be explored under this context.

The proposed research directly responds to the focused science topic “Flare Dynamics in the Lower Solar Atmosphere”. We will contribute to the focused team effort by analyzing high-quality vector magnetograms, velocity and intensity images, and multiwavelength (e.g., hard X-rays and white light) flare/CME data obtained with the state-of-the-art NASA missions (SDO, Hinode, and RHESSI). This will help to address the fundamental physics concerning the transport of energy and momentum into the interior from the solar atmosphere during flares/CMEs. Our team has profound expertise in the related data analysis as demonstrated in many publications.

John Lyon/Dartmouth College
Energy Transport from Tail to Ring Current via Fast, Low Entropy Flows

Recent theoretical research has indicated that it is very difficult to populate the ring current from the tail when the convection from the tail is laminar. This is because the general gradient of the flux tube entropy does not allow tail material to approach the Earth very closely. Observationally, the study of fast flows in the tail have indicated the extent that the general flow is both non-laminar and that the Earthward moving ``bursty bulk flows" have reduced entropy from their surroundings. These features have also been called flow channels and/or bubbles. The leading edge of these bubbles have a quick rise in magnetic field strength and velocity. There is a decrease in density behind the leading edge and, generally, a continuing increase in velocity.

This proposal seeks to probe through the use of computer simulation, how the tail dynamics, through the formation and propagation of bubbles, affects the inner magnetosphere. We can break this research down into four distinct, but related, questions:

1. How do bubbles form and how do they propagate? How do the plasma properties evolve as the bubble propagates toward the inner magnetosphere?
2. How is the bubble plasma processed into the ring current?
3. What is the effect of the ionosphere on the whole process?
4. What is the back reaction of the ring current upon the tail?

The computational tools will be based upon a coupled model combining a very high resolution global MHD code (LFM) and a ring current model incorporating the appropriate drift physics (RCM). Four different approaches to answering the science questions will be used. One will be to study isolated depleted flux tubes. Another will be global simulations using idealized solar wind conditions. Another will be to use realistic solar wind drivers. Finally, we will modify the plasma conditions entering the RCM domain to see how important the mesoscale structure of the tail convection is to ring current formation.

Proposed Contribution to the Focus Team Effort:

The proposed research is directly relevant to Focused Science Topic (b), the ``interaction between the magnetotail and the inner magnetosphere and the impact of that interaction on the radiation belt environment". The research will contribute to the focus team efforts both by providing global models to aid in analysis of observational studies and characterizing the physical processes that lead to the formation of the ring current. The project metrics will assess progress in (1.) completion of simulations of idealized cases and event studies and (2.) in understanding how plasma is energized and transported from the tail to the inner magnetosphere.

Petrus Martens/Montana State University
Solar Information Processing Workshop VI: Optimizing the Scientific Return from Petabytes of Data

The immense volume (>1 TB/day) of complex, multi-dimensional data delivered by the LWS mission Solar Dynamics Observatory (SDO) is now streaming into the solar and heliospheric community. Tools such as the Heliophysics Event Knowledgebase (HEK) and the Lockheed-Martin Solar and Astrophysics Laboratory (LMSAL) data cutout service make it simple for scientists to acquire the science data from SDO. Many other science data are available via the Virtual Solar Observatory (VSO).

The amount of science data available to the scientific user community has never been greater. However, with these large data volumes comes the significant challenge of optimizing the scientific return from these data. We propose a workshop to examine the challenge of how to extract the useful information from all the available science data. A solar information processing workshop is an ideal environment to discuss the challenges involved in a new era of data analysis where it is possible for a single scientist to examine terabytes of data and millions of events in search of scientifically useful information. We will address topics such as feature recognition and tracking, fusing of event information from multiple wavelengths, the three-dimensional reconstruction of the extended solar corona, and on data-mining techniques applied to solar physics databases such as the HEK. We will do this within the context of the Solar Image Processing Workshops, which will be re-named hence forward as the Solar Information Processing Workshops.

Solar Information Processing Workshop VI (SIPWVI), to be held on 13-16 August 2012 at Montana State University in Bozeman, MT, will follow the format of the previous solar image processing workshops with mornings given over to presentations to all participants of the workshop, and afternoons working groups focusing on specific topics targeted to the needs of the LWS program. Further, in response to previous attendees suggestions, we will also have a special problem-solving session where new challenges in solar information processing will be presented in order to generate fresh approaches. We request funding to support a workshop of 80-100 attendees, with full support for 15 US-based students and three invited speakers. As in previous years, we will publish the workshop results in a refereed journal. This workshop supports the Cross-Discipline Infrastructure Building Programs component of the LWS TR&T solicitation.

Astrid Maute/University Corporation for Atmospheric Research
Coupling of the Atmosphere and Ionosphere During Stratospheric Sudden Warming Events: Signals, Processes and Their Sensitivities

Stratospheric Sudden Warming (SSW) events give us the opportunity to study how strong disturbances in the stratosphere propagate upwards, change mesospheric and thermospheric dynamics, and affect the ionosphere. Although during the recent solar minimum clear ionospheric signals due to SSW events could be observed, it is still unclear what the major coupling processes of the atmosphere-ionosphere are.

The main science objective of this proposal is to understand what are the major processes which influence the ionosphere during SSW periods, and to elucidate their sensitivity with respect to geospace conditions. The NCAR-Thermosphere-Ionosphere-Mesopshere-Electrodynamic General Circulation Model (TIME-GCM) will be used to self-consistently simulate different SSW events. The Ionosphere-Plasmasphere-Electrodynamics (IPE) model will be driven by the TIME-GCM results to examine the importance of the major coupling mechanisms. We will focus on two mechanisms that have been proposed to explain effects observed in the F-region ionosphere: electrodynamic coupling via electric fields modulated by waves and tides mainly in the E region during the day and in the F region at night, and direct penetration of tidal disturbances to the upper thermosphere. We will quantify their relative importance during the evolution of SSW events with respect to latitude for both day and night time.

For space weather applications it is important to understand the influence of the solar cycle on the ionosphere during SSW events. Using realistic SSW events we will study the ionospheric SSW effects for different levels of solar activity, and examine if the major atmosphere-ionosphere coupling mechanisms are changing. Modeling results have shown that the geomagnetic disturbance signals in the ionosphere are stronger when planetary wave forcing is included at the lower boundary. Using numerical simulations we will investigate if there are positive feedback mechanisms between meteorological and geospace forcing. SSW events originate in the polar winter stratosphere due to strong planetary wave activity. The ionosphere at low and middle latitudes exhibits decreases in zonal mean NmF2 and hmF2 as seen by, e.g., COSMIC, with a 2-4 day delay from the stratospheric temperature maximum. We will quantify the simulated ionospheric SSW effects at all latitudes, compare with observations, and investigate possible mechanisms.

Ground magnetic perturbation observations have a long historical record and a wide-spread spatial distribution. Signatures of SSW are seen in the ground magnetic perturbations. At low latitude the magnetic perturbations can be used to quantify the strength of the equatorial electrojet. In the afternoon a counter-electrojet has been reported during SSW events. We will use the TIME-GCM to calculate ground magnetic perturbations and the current system. We will examine the effects of SSW events on the magnetic perturbations, and determine how ground magnetic perturbations can be used to study ionospheric SSW signals and the atmosphere-ionosphere coupling.

The proposal addresses NASA strategic goal 2 Expand scientific understanding of the Earth and the universe in which we live , specifically the objective Improve understanding of the fundamental physical processes of the space environment from the Sun to Earth& . Understanding the causes of ionospheric variability is important since these can lead to ionospheric irregularities and scintillations of communication and navigation systems. The outcome of this study will help guide improvements to space weather models by elucidating the importance of different coupling mechanisms. Model simulations and processed model data will be made available to the scientific community through this investigation, further extending its impact.

James McAteer/New Mexico State University
Student Support for the "Tracing the Connections in Solar Eruptive Events" Meeting, December 2012

Goal and Objectives
We propose to host to a workshop to assess, validate and compare existing observational, theoretical and modeling tools by comparing model predictions with a spectrum of different data sets, where possible for the same events. The goal of this workshop is to examine the connections amongst the phenomena that lead to solar eruptive events . This naturally leads to the 4 following science objectives: (i) addressing the theoretical and observational challenges in understanding the build up and energy release processes, taking into account new observational and theoretical results; (ii) the formulation of an enhanced understanding of computational challenges to address the vast data load currently available, and in connecting existing models to each other and to the new data; (iii) maximizing our science return from the multiple solar observatories by making new connections across the breadth of current instrumentation expertise; (iv) summarizing and projecting our ability to predict the occurrence of solar flares and CMEs, with emphasis on the all-clear prediction possibility. Addressing these objectives with a contingent of observers, theorists and modelers spanning the gamut of solar activity research will undoubtedly create new insights into the connections between the flare / CME process in the Sun and their effect in the heliosphere. It will identify the future challenges and requirements of these connected facets of heliophysics.

Request to NASA and Cost Effectiveness
From previous experience in organizing this series of workshops, we expect about 150-200 registered delegates. We are requesting funding to provide financial support for 20 students, at a cost value to NASA at almost dollar for dollar, to attend what he hope will prove to be another pivotal assembly of experts in the field.

Relevance to NASA
The Connections meeting addresses topics directly relevant to the Heliophysics strategic goal to Understand the Sun and its interactions with the Earth and the solar system under the NASA strategic plan (2010). Specifically in concentrating on the solar eruptive events this meeting is directly relevant to the sub-goal to Understand the physical processes of the space environment from the Sun to Earth, to other planets, and beyond to the interstellar medium. directly connects to the TR&T objectives of   data analysis, theory, and modeling, and the development of tools and methods (e.g., software for data handling) . It issue of connections focuses specifically on the LWS primary goal of to make progress in understanding this complex system, focusing on the most critical interconnections .

John McCormack/Naval Research Laboratory
Investigating the Temporal Evolution of Mesospheric Dynamics Before, During, and After Recent SSW Events Using a High-altitude Data Assimilation and Modeling System

This proposal addresses two key scientific questions: (1) How do the global-scale dynamics of the mesosphere and lower thermosphere (MLT) respond to recent stratospheric sudden warming (SSW) events? (2) What are the relevant multi-scale wave-wave interactions among Rossby waves, tides, and gravity waves that determine the ionospheric response to SSWs? The objective is to identify the physical mechanisms responsible for observed SSW-ionosphere correlations during three separate SSW events in the Northern Hemisphere winters of 2005-06, 2007-08, and 2008-09, when geomagnetic activity was extremely low.

To achieve this objective, the proposed investigation will combine and study observations-based meteorological products from a global high-altitude atmospheric data assimilation system (DAS) with model simulations from the latest version of the Whole Atmosphere Community Climate Model (WACCM). The DAS will be based on the existing high-altitude version of the Navy Operational Global Atmospheric Prediction System (NOGAPS), known as NOGAPS-ALPHA (Advanced Level Physics-High Altitude), which assimilates both operational tropospheric and stratospheric observations and research mesospheric and lower thermospheric (MLT) observations from NASA s TIMED (Thermosphere Ionosphere Mesosphere Energetics and Dynamics) and Aura satellites to produce global synoptic analyses of the atmospheric state (e.g., winds, temperature, and constituents) from the surface to ~90 km every 6 hours. WACCM is a state-of-the-art global coupled chemistry-climate model of the neutral atmosphere extending from 0-130 km.

NOGAPS-ALPHA global meteorological analyses will be used to diagnose the spatial and temporal evolution of the main dynamical drivers in the MLT (i.e., planetary waves, tides, and gravity waves) before, during, and after specific SSW events. WACCM simulations constrained by NOGAPS-ALPHA DAS fields will be conducted and used to determine the impact of SSW-related mesospheric variability on the neutral atmosphere up to 130 km, making it possible to recreate neutral atmospheric forcing for specific SSW periods up to the lower boundary of the ionosphere. The results of these simulations can be used as lower boundary conditions for ionospheric models to validate proposed SSW/ionosphere coupling mechanisms. In addition, ensembles of free-running (i.e., unconstrained) WACCM simulations will be performed to determine the sensitivity of the MLT dynamical response to the effects of both orographic and non-orographic gravity-wave drag.

The proposed investigation will provide the first definitive description and understanding of the complete chain of events linking large dynamical changes in the polar winter stratosphere during the SSWs of 2005-6, 2007-08, and 2008-09, to large observed changes in a variety of ionospheric properties. In addition to representing a fundamental advance in our scientific understanding of the dynamics of the global Earth system, this research will provide relevant quantitative information for improving and validating Earth system prediction models of the coupled atmosphere-ionosphere system.

Eli Mlawer/Atmospheric and Environmental Research, Inc.
Implementation and Validation of Solar Variability in Radiation Code RRTMG_SW

Multiple hypotheses exist to explain the observed impacts of the 11-year solar cycle on the climate of Earth. The top-down or downward control mechanism suggests that while the direct impacts of ultraviolet (UV) variability over the solar cycle are contained in the stratosphere, important dynamical processes translate these anomalies downward and hemispherically, altering winter weather and the positions of the jet stream and mid-latitude storm tracks. To accurately model this UV variability, radiation schemes in climate models must have sufficient spectral resolution to model both the absorption of radiation by gases and the wavelength dependence of the UV variability. However, the faster radiation codes currently used in general circulation models (GCMs) typically have fairly broad spectral bands and therefore cannot account for these processes.

In this project, we will establish the capability for accurately parameterizing solar variability into our fast radiative transfer model RRTMG_SW, the operational shortwave radiation code in numerous climate prediction models, including the upcoming version 5 of the Whole Atmosphere Community Climate Model (WACCM), which is a widely-used model for the study of solar cycle impacts on climate. We will introduce two well-regarded specifications of solar variability into RRTMG_SW, as well as allow the code to handle a user s arbitrary specification of the spectral variability of solar irradiance. These improvements will take advantage of the internal spectral resolution of RRTMG_SW, which is needed to accurately parameterize solar variability effects, in contrast to alternate approaches that merely scale individual spectral bands in the code. These changes will be validated against corresponding calculations by line-by-line radiative transfer models for a number of key test atmospheres. The improved model will be incorporated into version 5 of WACCM (WACCM5) and a series of simulations will be performed to quantify the degree to which model predictions improve when the radiative impacts of solar variability are properly accounted for and to enhance our understanding of the impacts of the intra-spectral solar variability on surface climate.

By improving the ability of RRTMG_SW to account for the radiative impact of solar variability, the proposed work will allow the improvement of our 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 time scales , a key strategic goal of the NASA Living With a Star (LWS) program. In addition, the planned radiation code improvements and subsequent WACCM5 modeling experiments will allow advancement of our understanding of the coupling of the upper and lower atmosphere and the processes responsible for transmitting solar variations to the Earth s surface where they can modulate global and regional climate. Furthermore, the radiation code development work proposed is directly targeted at evaluating the spectral detail necessary for proper treatment of the radiative and photochemical response to solar spectral variability.

Martin Mlynczak/NASA Langley Research Center
Solar Influence on Climate Inferred from the Radiant Energy Budget and Diabatic Circulation of the Middle Atmosphere

We propose to investigate the influence of solar variability on the climate of the atmosphere from the tropopause into the thermosphere. We will do this by computing time series of the radiant energy budget at high vertical and temporal resolution throughout this entire region of the atmosphere from ~ 15 km to ~105 km. All terms in the radiant energy budget will be rigorously derived from extant satellite observations dating from 1978 through at least the year 2013, a 35-year time span. This approach enables comprehensive examination of the effects of solar variability directly within the atmosphere - in the energy budget - where it is first manifest. The examination of satellite data starting in 1978 also enables the differentiation of the effects of increasing carbon dioxide (CO2) from those due to solar variability. Atmospheric CO2 has increased approximately 20% since 1978. We also propose to compute the diabatic circulation from the energy budget in order to diagnose the effects of changes to the energy budget on atmospheric dynamics.

The results of this work will be far-reaching. First, the long-term time series of radiant heating and cooling throughout the entire middle atmosphere will enable direct determination of the influence of the Sun on the climate of this region. Previous studies have examined solar influence on temperature and species. However, the variability in those parameters is a direct consequence of the effects of solar variability on the energy budget. The proposed work will identify the occurrence of solar variability at its origin within the atmosphere. Second, the computation of the diabatic circulation will enable a direct assessement of the role of solar variability plays in altering the dynamics of the middle atmosphere. This is essential to understanding how solar variability may be communicated down into the troposphere through changes in the dynamics of the middle atmosphere. Finally, we will generate millions of profiles of radiant heating and cooling of the middle atmosphere. These data will be made publicly available to directly test and assess the radiant and chemical physics of multidimensional models of the middle atmosphere. Validation of model energetics is an essential first step in assessing a model s predictive capability.

The proposed research will utilize multiple satellite datasets including the Limb Infrared Monitor of the Stratosphere (LIMS) instrument (1978-79); the Upper Atmosphere Research Satellite (1991-2000); the Thermosphere-Ionosphere-Mesosphere Energetics and Dynamics (TIMED) satellite (2001-present); the AURA satellite (2004 present); and the Solar Radiation and Climate Experiment (SORCE) satellite (2003-present).

Shin-ichi Ohtani/Johns Hopkins University Applied Physics Laboratory
Energization and Transport of O+ Ions in the Nightside Magnetosphere

The present study will address the LWS/TRT Focused Science Topic interaction between the plasma sheet and the inner magnetosphere focusing on the transport and energization of the O+ ions. The energy density of the O+ ions in the ring current can be comparable to that of the protons during magnetospheric storms. Therefore, through the magnetic deformation and the change of wave environments, the intensification of the O+ ring current makes a significant impact on the dynamics of the radiation belt. However, it still remains to be understood how the O+ ions are transported and energized on their way to the ring current.

In this project we will observationally address the following questions:
Q1. How often and under what conditions are earthward busty bulk flows (BBFs) in the plasma sheet followed by the intensification of the O+ ring current?
Q2. How do the O+ ions enhance in association with the BBFs and dipolarization? What features of the BBFs and dipolarization are essential for the O+ ion enhancement?
Q3. How do the characteristics of the O+ ions change in association with fast tailward flows with southward Bz?
Q4. How do the characteristics of the O+ ions in the nightside magnetosphere respond to the sudden enhancement of geoeffectiveness? How does it depend on the radial distance or on external and internal conditions?

In general, the earthward BBFs play a significant role in the transport of mass and energy in the plasma sheet. In Q1-Q3 we will observationally examine its role in the O+ dynamics. Q1 addresses the access of BBFs to the inner magnetosphere, for which the oxygen ENA enhancement serves as a global indicator. We will statistically examine entropy-related quantities of the BBF flux tube and will test how/if the intensification (or its absence) of the ring-current oxygen ENA emission depends on them. Q2 addresses the local O+ enhancement associated with BBFs in terms of the transport and energization of the O+ ions. We will compare the time sequences of the O+ enhancement with those of local quantities such as electric field and Bz. The regression analysis will also be performed. For Q3 we will conduct the same analysis as for Q2 but for fast tailward flows. Whereas such flows may be regarded as a counter part of earthward BBFs, the total magnetic field does not increase for tailward flows. The comparison of the results for Q2 and Q3 should tell us, for example, the importance of the drift betatron acceleration of O+ in the earthward BBFs. For Q4 we will examine how the O+ population builds up during magnetospheric storms. If the O+ ions are transported through the distant tail, the build-up should be quicker farther away from Earth. We will test such a hypothesis.

The Geotail data will be used as a primary data set for Q1-Q4. IMAGE/HENA data will be used for Q1 for examining the O+ ring current. We will also use RBSP-SPICE data for Q4, and possibly also for Q2, as optional tasks provided the data are obtained as planned.

Each of the proposed tasks is straightforward and does not require any major development of software. Geotail has been operation for 20 years, and because of its equatorial, rather than polar, orbit, Geotail/EPIC provides the largest ever data set of the O+ ion measurements in the near-Earth (9-31 Re) plasma sheet. The IMAGE/HENA data has also been proven in both quality and quantity. The project team members are familiar with both the target science and the data sets. Therefore this project is highly feasible.

This project is proposed as a contribution to the LWS/TRT Focused Science team. Whereas the target science, the O+ ion dynamics, may be unique, the project will share interests in basic physical processes such as the transport and energization of ions by BBFs. The outcome of this project should also be useful for validating modeling efforts and also for setting up boundary conditions.

David Ortland/NorthWest Research Associates
The Dynamical Effects of Sudden Stratospheric Warming Events on the Thermosphere

The dynamically active stratosphere during Northern Hemisphere winter sometimes undergoes dramatic changes, called stratospheric sudden warmings (SSW). During a SSW event, temperatures can increase dramatically over a period of days and the normally strong polar westerly winds may reverse to easterlies. These events also have impacts both above and below, causing dramatic cooling in the mesosphere of up to 20 K with associated transport and chemistry changes, and foretelling statistical shifts in surface weather patterns with enhanced skill at intraseasonal timescales. Recent modeling and observational evidence also suggests that SSW events can have an impact within the thermosphere. Our research will examine the dynamical connections that are in force during SSW events. These connections include anomalous mean meridional circulations set up by nonlinear interactions between waves and the mean flow, the filtering and refraction of various waves by anomalous flow conditions during an SSW, and the nonlinear interaction between tides and planetary waves that give rise to tide variability during the rapidly changing conditions when an SSW is under way.

We will specifically focus on the following goals:
1) Quantify how gravity wave filtering and forcing drives the evolution of the atmosphere up into the thermosphere during SSW;
2) Characterize nonmigrating tide variability arising from all sources and isolate the source due to interaction between the large migrating tides and planetary wave amplification.

Our study will employ a global mechanistic model that extends from the surface to 300 km. This model directly simulates all large scale wave dynamics, including tides, planetary waves and tropical waves, and it includes small-scale gravity waves via parameterization. All the wave-wave and wave mean flow interactions needed to describe the connections between the different layers of the atmosphere are present in our simulated SSW events. The model will be further constrained to various degrees by wind and temperature fields from the NASA reanalysis data, MERRA, up into the mid-stratosphere, but will be allowed to evolve freely above, up to the model top. We will also examine simulations of the Whole Atmosphere Community Climate Model (WACCM) run freely and in specified dynamics mode. Both model results will be validated by comparing the evolution during an SSW to the real atmosphere as observed in TIMED-SABER and AURA-MLS temperature measurements in the mesosphere and thermosphere.

Nature has provided a nice set of SSW experiments for our study in the last seven years of these data, with major warmings in 2006, 2009, and 2010. There is also a minor SSW in early 2012 that shows unusually dramatic effects at mesospheric heights apparently more similar to conditions during a major SSW. Since the evolution of an SSW in the upper atmosphere is quite sensitive to the gravity waves in the model, our goal will be to use these comparisons to constrain the gravity wave source spectra used as input to the gravity wave parameterization. We will also derive the short term variability of tides from the temperature data, and use the model simulations to determine the source of this variability. Through collaboration with NCAR, the results of this study will lead to improvements in the parameterized gravity waves in the WACCM.

Vahe Petrosian/Stanford University
Coupling of Particle Acceleration and Atmospheric Response Processes in Solar Flares: Combined Kinetic-fluid Modeling and Multiwavelength Observations

We propose to investigate the coupling between particle acceleration and the dynamic response of the lower solar atmosphere to the energy input during flares. We propose a combined kinetic-particle and hydrodynamic simulation, and analysis of observations from different wavelengths. This work directly addresses the ``Focused Science Topic (a) Flare Dynamics in the Lower Solar Atmosphere" in the 2011 LWS TR&T solicitation. We seek answers to the following Compelling Science Questions:
1. What is the fundamental mechanism that accelerate particles in solar flares?
2. How does the lower solar atmosphere, particularly the chromosphere, respond to the impulsive energy input?
3. How are the particle acceleration and atmospheric response coupled together and affect each other?

Answering these questions will enable us to constrain the acceleration mechanism, understand the process of evaporation and seismic wave generation. The major strengths of the proposed work lie in our expertise in particle acceleration and the unique contribution this will provide for the LWS focused science topic, and our past experience in the coupling between acceleration and hydrodynamic response.

Raymond Plumb/Massachusetts Institute of Technology
Communication of Solar Variability to the Earth's Surface via the Stratosphere

Of the several pathways that have been proposed by which solar variability can influence climate, the best documented, and arguably the most credible, is via its direct impact on the tropical upper stratosphere. Accordingly, the research in this proposal is aimed at the identification of mechanisms and pathways by which perturbations to the tropical upper stratosphere, induced by variations in solar UV output, modify the stratospheric circulation, and thence influence the troposphere, and surface climate. The emphasis is on the middle and high latitude stratospheric and tropospheric response to tropical anomalies induced by solar variability, in particular the impact on stratospheric sudden warmings, since prior work indicates that it is these events that are sensitive to tropical perturbations, and that it is during such events that linkage with the troposphere is strongest. The approach to be taken is experimentation with a global dynamical model of the troposphere-stratosphere-mesosphere system with simplified physics, used as a mechanistic tool to classify the response of the deep atmosphere to range of upper stratospheric perturbations, under a range of meteorological conditions (in particular, different planetary wave regimes, and different phases of quasi-biennial oscillation in the tropical stratosphere). Emphasis will be on the climate response, i.e., the long-term response to sustained solar-induced anomalies, rather than short-term responses, under perpetual solstice conditions and under a full seasonal cycle.

Andrei Runov/University of California Los Angeles
Energetic Particle Acceleration and Transport towards the Inner Magnetosphere via Transient Dipolarizations

The main objective of this proposal is to understand the physical connections between energetic particle populations observed in the vicinity of dipolarization fronts in the near-Earth plasma sheet and those observed in the dipole-dominated inner magnetosphere. Taking advantage of unprecedented multi-point observations by THEMIS, we propose to study the spectral properties, spatial distribution, occurrence rates and spatial and temporal scales of the injections. Typical observed spectra will be used as input parameters for particle-tracing under a transient electric field to calculate the particle paths and spectra in the inner magnetosphere under a variety of conditions and ascertain the importance of such injections. Case studies with three to five THEMIS spacecraft (as well as RBSP, when available) will be used for direct comparisons with the model results. This comparison will make it possible to adjust model parameters, leading to better understanding of the underlying physical processes and driver properties, such as

the scale size and duration of the impulse. The proposed study will contribute towards the resolution of an outstanding science question in space physics:
How do the impulsive plasma energization and transport contribute to build up the inner magnetosphere energetic particle populations?
Specifically, we will address the following science questions:
i) What are the temporal, spatial and spectral properties of particles energized on dipolarization fronts?
ii) How do these particles penetrate into the inner magnetosphere? and
iii) How do the particle spectral properties change during transport toward and in the inner magnetosphere?
The proposed study will also result in a set of deliverables for the Focus Team: characteristic particle spectra during transient dipolarizations, spatial and temporal scales of flux changes, and predicted particle spectra and phase space density in the inner magnetosphere. These are valuable as initial conditions and parameters for a variety of models expected to be available to the Focus Team and for the interpretation of RBSP observations.
This proposal is directly relevant to NASA's Living With a Star Targeted Research and Technology Focused Science Topic (b): ``Interaction between the magnetotail and the inner magnetosphere and the impact of that interaction on the radiation belt environment''

Alexander Ruzmaikin/Jet Propulsion Laboratory
Solar Influence on Climate Variability on Centennial Time Scales

We propose a study addressing the LWS Sun-Climate Theme strategic objective 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.   Our investigation is focused on the role of the solar Centennial Gleissberg Cycle (CGC) in producing global and regional climate change. The CGC is characterized by a 90-100 year variation in the amplitude of the 11-year cycle accompanied by a corresponding variation in the intensity of geomagnetic activity. The extreme sunspot and geomagnetic minima during the recent sunspot cycle 23/24 transition can be understood as part of a CGC series of minima that also occurred in the beginnings of 18th, 19th and 20th centuries. These minima have been associated with cold winters in the Northern Hemisphere and the CGC has now been identified as operating at least 80% of the time during the last 1,500 years. The low-frequency nature of the CGC enhances the influence of solar variability on climate due to the engagement of oceans. This study of solar influence on climate at time scale intermediate between decadal and millennia scales is now possible and timely due to availability of high-resolution climate records and the development of adaptive data analysis methods.

Objectives: We will carry out empirical studies of climate response to solar forcing on the centennial time scale using advance data analysis methods and compare our results with those expected on the basis of the mechanisms that have been suggested for solar influence on climate. The effect of the CGC forcing of climate is expected to be seen primarily in regional patterns rather than in global changes. To trace the solar connection we will relate selected climate change records with the century-long records of solar variability seen in sunspots, geomagnetic activity, solar irradiance reconstructions and a millennium long record of low-latitude auroras, the best available markers of solar variability on centennial time scale. We will carefully investigate the role of the centennial climate change during the 19th and 20th centuries for which we have detailed and abundant data sets. Climate change during the 20th century has been increasingly caused by anthropogenic (CO2) forcing but the 19th, 18th and earlier centuries were less affected by it and solar forcing should be dominating. A comparison of these century-long climate histories can lead to improved understanding of the difference of climate responses to solar and to anthropogenic forcing. Well-dated volcanic contributions produce short-term effects and will easily be taken into account. The CGC response at earlier times and in specific Earth s regions will also be investigated.

Expected Significance: The regional and global effects of the CGC have received little attention until now. The investigation of CGC role in climate change is expected to validate and to expand our understanding of mechanisms of solar influence on climate. The major mechanisms include the solar effects on the annular modes coupled with the stratosphere-troposphere interaction, the solar irradiance effect on tropical oceans, and the influence of cosmic ray modulation of clouds. The CGC is expected to produce much stronger effects on climate relative to the decadal solar cycle because due to the thermal inertia of the ocean the whole atmosphere-ocean climate system is fully engaged. We expect strong regional effects. A comparison of the climate changes during the most recent CGC (1910 through 2010) and earlier CGCs will permit better estimates of the relative contribution of solar versus anthropogenic forcing.

The proposal team is confident it will achieve the objectives quoted above due to a long-term expertise in working with long-term solar, geomagnetic and climate data with an excellent record of publications in this field.

Raymond Shaw/Michigan Technological University
Investigating the Effect of Solar Activity During a Grand Minimum on Clouds

There is widespread, suggestive evidence for a correlation between solar activity and Earth's climate, and a variety of linkages have been proposed. The link addressed in this proposal connects galactic cosmic radiation flux, which is modulated by the solar wind and solar magnetic field, and cloud properties, which directly influence the Earth's albedo. The galactic cosmic radiation (GCR) flux to the Earth's atmosphere is a primary form of ionization, and these ions subsequently drift in the large-scale planetary electric field to form unipolar charge accumulations at cloud boundaries. We propose a laboratory and modeling study of the effect of cloud droplet charging on the formation of precipitation in stratocumulus clouds, and, in turn, on the large-scale dynamical structure and radiative properties of the clouds. The objectives of the proposed work are:

1. Characterization and quantification of collision-coalescence kernels for charged cloud drops based on laboratory experiments and direct numerical simulation (J. Lu, R. Shaw). These experiments and simulations, which provide a detailed, particle-by-particle view of a cloud, will result in a kinetic theory describing the Coulomb interaction of cloud droplets in turbulence, in the presence of gravity.

2. Exploration and quantification of the sensitivity of drizzle formation to cloud drop charging using a detailed, cloud microphysical box model (G. Feingold, J. Kazil, J. Lu, R. Shaw). This will lead to development of a cloud-to-drizzle “autoconversion” algorithm accounting for droplet charge, suitable for use in cloud-resolving simulations.

3. Characterization of cloud drop charging in stratocumulus clouds, and of its effect on precipitation and cloud radiative properties using the WRF/Chem model in Large Eddy Simulation mode (J. Kazil, G. Feingold). The simulations will use solar activity levels and the resulting GCR ionization rates for the minimum and maximum of the decadal solar cycle, as well as for the conditions of a Grand Solar Minimum, with much enhanced GCR ionization.

One outcome of the work will be the development of an autoconversion algorithm that will connect the cloud-resolving simulations to larger scales, and lay the groundwork to investigations of the phenomenon in climate models. Although not explicitly proposed as part of this work, it is anticipated that this will enable using future implementations of whole-atmosphere models (e.g. WACCM), which will describe the global atmospheric electric circuit and its response to solar disturbances of the ionosphere, as input for cloud-resolved models.

In the proposed work, we will build on existing experimental and modeling tools to achieve the proposed objectives. A laboratory environment for the investigation of the effect of charge on the collision-coalescence of cloud droplets has been developed and used in the group of R. Shaw. In this system, where droplet size, droplet charge, and turbulence intensity can be externally controlled, cloud droplets are tracked in three dimensions using a digital holographic method. The experiments are complemented by a direct numerical simulation of turbulence, seeded with charged droplets. The resulting, modified collision rates will enable quantifying the effect of solar variability on cloud properties in Large Eddy Simulations of marine boundary layer clouds. The model that will be used for these simulation is WRF/Chem, in which a detailed representation of chemical, aerosol, and cloud processes, as well as of atmospheric ionization by GCR at different solar activity levels, has already been implemented to investigate marine stratocumulus.

The proposed work will provide a quantifiable connection between solar activity and cloud properties. This is a necessary step in quantifying perturbations to Earth's radiative forcing by the decadal solar cycle, as well as by longer-term variations in solar activity (e.g., due to a Grand Solar Minimum).

Elsayed Talaat/Johns Hopkins University Applied Physics Laboratory
Diagnostic Investigation of Middle Atmosphere Climate Sensitivity

The middle atmosphere and lower thermosphere (MALT) region is highly variable and has a complex system of drivers. Its physical and dynamical variability is induced almost equally by the variable solar radiation from above and transient weather and climate processes from below. Though the MALT responses to solar variations have been well investigated, relatively little has been done on the long-term variation and its spatial structure induced by the anthropogenic secular trend. Recently, it has become increasingly recognized that one needs to understand and predict climate change from a global perspective including the MALT due to altitude amplification of the anthropogenic radiative forcing.

One difficulty in understanding and projecting the future climate changes comes from inability of identifying and isolating the signals from the external forcing and from different feedback processes in the middle atmosphere climate system. The recently developed climate feedback-response analysis method (CFRAM) provides a framework for estimating the external forcing and various climate feedbacks for the coupled tropospheric atmospheric-oceanic system. We propose to extend the CFRAM for climate feedback studies in the MALT using both the TIMED measurements and outputs of specially designed modeling experiments with the high-altitude GEOS-5 climate model. The extension of CFRAM in the MALT is based on the JHU/APL middle atmosphere radiation module. We propose to apply the extended CFRAM to infer and isolate different mechanisms in the MALT responsible for the interannual variability associated with solar cycle forcing and secular trend associated with anthropogenic radiative forcing. The key scientific questions to be addressed are:

1. How much is the temperature change in the stratosphere and mesosphere due to solar cycle variation, how much due to the human-induced changes in CO2 and O3?
2. What are the differences in the spatial patterns of temperature changes in the MALT induced by the short-term solar, interannual natural variability, and long-term trends in the CO2 and O3 concentrations?
3. How do we quantify the contributions to the differences in the spatial patterns of temperature variations/changes due to differences in the external forcing (natural or anthropogenic), in various climate feedbacks?

Frank Toffoletto/Rice University
RCM-E Investigation of Magnetospheric Bubbles and their Effects on Inner Magnetosphere Particles and Fields

The primary objective of our proposed project is to achieve quantitative understanding of plasma-sheet/ring-current coupling, with an extended simulation domain covering the magnetic field transition region between 6.6 and 12 RE. Our current understanding of this region is much less advanced than of the main ring current region inside 6.6 RE and this project particularly focuses on that poorly understood, but crucial, region and its effects on the main ring current. The central theme of our proposed study is that bubbles (i.e., reduced entropy flux tubes) play a critical role in the earthward transport of plasmasheet plasma and the structure of the ring current.

This proposal is targeted at the LWS focus science Topic: (b) Interaction between the magnetotail and the inner magnetosphere and the impact of that interaction on the radiation belt environment and, as is noted in the LWS TR&T amendment: Therefore, understanding how plasma is energized and transported inward to the inner magnetosphere is one of the missing links in our ability to predict near-Earth space weather. In addition, our proposed work addresses all 3 goals: Improvement in our understanding of plasma transport process; Development of detailed descriptions of the nonlinear interaction between low-energy plasma transport, the ring current and its impact on the outer radiation belt; Continued improvement of coupled numerical models of the inner and outer magnetosphere.

To accomplish our objective, we propose using the RCM-E with global MHD/RCM, utilizing the RCM-E s capabilities for high resolution and low numerical diffusion in the inner magnetosphere, but employing a coupled MHD/RCM code to represent the effect of solar-wind/magnetosphere coupling, including a time-variable standoff distance. We will also add to the RCM-E the capability for controlled dissipative violation of the adiabatic drift condition on closed field lines, a process that plays a key role in some substorm models. This research project is designed to make optimal use of RBSP and THEMIS data. Simulation results will be extensively compared with observations ranging from RBSP, THEMIS and geosynchronous spacecraft in the near-equatorial magnetosphere to magnetic fields, auroral emissions, and ionospheric electric fields measured from the ground. Moderate and major magnetic storms will be simulated, including at least one steady magnetospheric convection event and one sawtooth event. An entropy analysis will be performed for each event, to determine quantitatively what part of the simulated storm-time ring current comes from bubbles and what part comes from acceleration of previously trapped particles and from convection outside bubbles. The model should produce the best available quantitative calculation of storm-time electric and magnetic field configurations on time scales of minutes to hours, and it can also provide magnetic fields and high-L and low-energy boundary conditions for radiation belt models.

Haimin Wang/New Jersey Institute of Technology
Study of Flare Footpoint Emissions Using Advanced Observing Tools

Observations of flares at sub-arcsecond resolution with sub-second cadence in lower solar atmosphere have been very rare, but are crucial in understanding the initiation and energy release process of solar eruptions. Recent completion of the 1.6-m New Solar Telescope (NST) at Big Bear, the 1.5-m German GREGOR solar telescope on Tenerife

(Canary Islands), and the Yunnan 1-m Telescope in China, in combination with a fleet of advanced space-borne instruments, RHESSI, Hinode, and Solar Dynamic Observatory (SDO), will enable a detailed study of flare dynamics at unprecedented resolution, cadence and wavelength coverage. Combining observations of three observatories in this project will maximize the chance to obtain suitable data sets. We will concentrate on the following two interrelated topics, for which high-cadence and high-resolution observations are highly desirable, to address some of the most important questions regarding the physics of flare footpoint emissions.

1. We will investigate the nature of flare elementary bursts, i.e. burst in the time scale around or below 1 second. We have previously successfully obtained high-quality photospheric/chromospheric flare observations with the Dunn Solar Telescope (DST) at the National Solar Observatory/Sacramento Peak (NSO/SP). The 1.6-m NST, 1.5-m GREGOR, and Yunnan 1-m Telescope are capable of advancing such observations. RHESSI data analysis with newly developed demodulation tool is complementary to optical observations. The observations will allow us to study the detailed evolutional properties of flare footpoints and their relation to photospheric magnetic fields. In particular, we recently found that the conjugate footpoints may move inward in the early phase of flares before the well-known separating motion. We will investigate possible relationship between this physical phenomenon and the implosion mechanism as proposed by Hudson (2000).

2. Using multi-wavelength visible and infrared continuum observations, we will systematically study the structure of white-light flares (WLFs). Among the most notable results in our previous studies have shown that the time profiles and the spatial characteristics of core and halo in WLFs behave quite differently. This is presumably due to different heating mechanisms such as direct heating and backwarming radiation. New observations are planned in multiple wavelengths to assess the viability of heating mechanisms in the core and halo. We will also explore the usage of imaging spectroscopy to further diagnosis the properties of flare kernel emissions.

The proposed research will extensively use data from space missions, RHESSI, SDO, and Hinode. It is in direct response to the solicitation of the Living with a Star (LWS) Focus Science Team addressing the "Flare Dynamics in Lower Atmosphere". It is closely relevant to one type of research in NRA: "Analysis of Footpoint Emissions to Understand Energy Transport of Flares".

Qian Wu/NCAR
What Can the Data and Model Tell Us About the Stratospheric Warming Effect on the Ionosphere?

The key objective of the project is to understand how the stratospheric warming events can affect the ionosphere. Since the stratospheric warming events alter the tides and planetary waves, they are the focus of the study. The goal is to understand why these waves change with the stratospheric warming and how they propagate upward and affect the ionosphere.

We plan to do the study by using a NASA satellite mesospheric data-driven thermosphere ionosphere community model from NCAR. Because the data contains the changes related to the stratospheric warming changes, it can provide a true description of the mesosphere for ionosphere simulation. We will use ground-based data to study fast variations in the mesosphere and ionosphere to validate the simulation results.

The space weather phenomena in the upper atmosphere and ionosphere can cause anomalous satellite drag, GPS position error, radio blackouts, and radar clutter. In order to mitigate space weather s impact on life and society, NASA Living With a Star program supports research to deliver understanding and predictive models of upper atmospheric and ionospheric responses to changes in solar electromagnetic radiation and to coupling above and below. This proposal addresses the impact on the ionosphere by the stratosphere from below, which is not well understood now. A better understanding of this impact will eventually lead to ionosphere predictive capability in the future. The proposed effort will improve a widely used community model TIEGCM by adding a new data driven capability. Considering that NASA CCMC (Community Coordinated Modeling Center) provides TIEGCM model runs, more improvements to the model will certainly benefit a large number of community users.