- Support the development of certain strategic capabilities that have broad potential use for science and application;
- Support model testing and validation when they are useful for comparison and when data become available;
- Support tools and data environment development relevant to LWS goals and objectives; and
- Support both small and large research proposals.

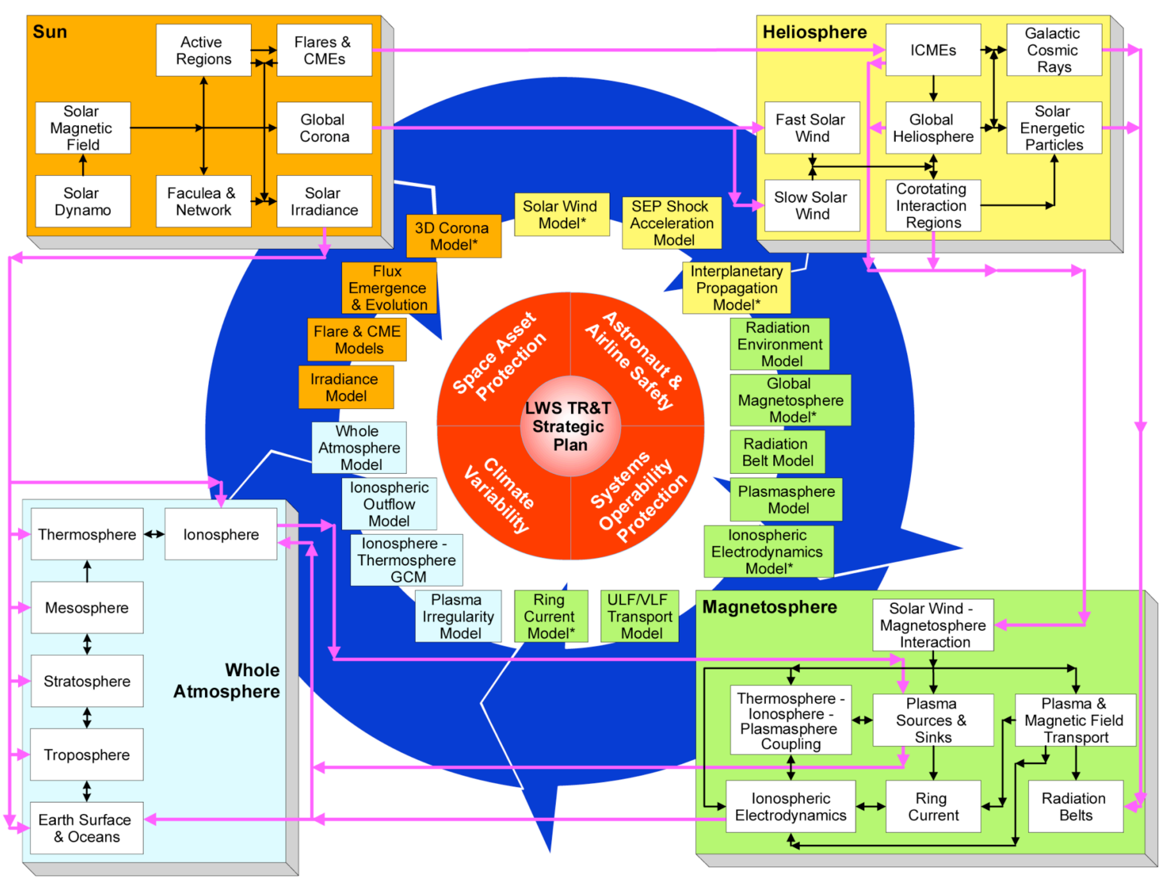

Fig. 1: Summary of the strategic goals and proposed strategic capabilities of the LWS TR&T program. Asterisks denote capabilities that were competed in 2005/06.

Based on the guiding principles specified by the Science Definition Team, the TSC recommends the following strategic goals for the next decade.

- Energetic particles from solar storms and galactic cosmic rays pose major radiation hazards for space assets and astronauts. Passengers and crew on polar flights are also endangered by penetrating particle radiation. In support of NASA's Vision for Space Exploration (VSE) objectives, the TR&T needs to deliver the understanding and modeling required for useful prediction of Solar Energetic Particles (SEP) events and Galactic Cosmic Rays (GCR) variability at the Earth, Moon, Mars and throughout the solar system;
- One of the major challenges facing humanity is global climate change. In order to determine effective mitigation policies, natural and anthropogenic causes must be distinguished; the TR&T needs to deliver the understanding of how variations in solar radiation and particles contribute to global and regional climate variability;
- Communication, navigation and other national infrastructures are increasingly dependent on satellites orbiting Earth. With increasing miniaturization these systems are ever more sensitive to the near-Earth space environment. To protect these assets, the TR&T needs to deliver the understanding and modeling required for effective forecasting/specification of inner magnetospheric radiation and plasma;

- The upper atmosphere and ionosphere is central to a host of space weather effects, ranging from anomalous satellite drag, GPS position error, radio blackouts, radar clutter and geomagnetically induced currents (GIC). In order to mitigate space weather's impact on life and society NASA's LWS/TR&T in conjunction with other national agencies such as NSF and DoD needs to deliver understanding and predictive models of upper atmospheric and ionospheric coupling above and below.

These strategic goals will guide the selection of focused science topics for FY07 and beyond, as well as the selection of strategic capabilities. Figure 1. captures the complexity and high level of interconnections between the main elements and it summarizes our system-level understanding of the LWS components and their top level interactions. The primary goal of the LWS program is to make progress in understanding this complex system, focusing on the most critical interconnections.

3 RECOMMENDED FY07 FOCUSED SCIENCE TOPICS

Below are nine recommended focused science topics in no priority order. Additional topics are listed in the Appendix.

3.1 Determine the Conditions Leading to CME/Eruptive Flare Onset

3.1.1 Target Description

Although there has been significant progress in recent years on theories for explosive eruptions, many important questions remain unanswered and require observational resolution. For example, the pre-eruption magnetic topology is still an issue of intense debate. It is not clear what role flux emergence and/or flux cancellation plays in coronal mass ejection (CME) onset. The role of helicity is far from understood. Furthermore, the roles of magnetic shear and magnetic complexity are unresolved. All these issues need to be clarified if LWS is to enable the development of a capability for predicting CME initiation. Given that Solar-B, STEREO, and SDO will be delivering revolutionary new observations of the photospheric magnetic and velocity fields and of the coronal structures that give rise to CMEs, it is now timely to mount a coordinated attack on the problem of identifying definitively the conditions leading to explosive eruptions.

3.1.2 Goals and Measures of Success

The goal of this Focused Science Topic is to quantify accurately the timing and magnitude of developments in the photosphere and corona that lead to CME/Eruptive Flares. The prime measure of success for this work would be a substantial improvement in our ability to determine where and when solar eruptions are likely to occur.

3.1.3 Types of investigations

It is expected that the focus team will include, but certainly not be limited to, the following types of investigations: observational and theoretical/modeling investigations relating to understanding the solar subsurface and atmospheric conditions that give rise to the regions responsible for CME/Eruptive Flares; observational and theoretical/modeling investigations relating to understanding the pre-eruption magnetic and plasma structure; observational and theoretical/modeling investigations relating to understanding the trigger mechanism(s) for initiating the eruption.

3.2 Predict the Emergence of Solar Active Regions Before They are Visible

3.2.1 Target Description:

A major roadblock for predictive models of space-weather effects has been our inability to forecast the emergence and evolution of large active regions on the Sun. Recent developments in the field of helioseismology show promise for the detection of active regions that emerge and grow on the far side of the Sun, and for the detection of pre-emergence signatures on the front side that may be measurable with several different techniques. This research area has obvious importance for improved space-weather modeling, predictions of the structure of the corona and the heliosphere. Research in this area will greatly enhance the usefulness of the SOLAR-B and SDO missions.

3.2.2 Goals and Measures of Success:

The goal of this Focused Science Topic is to develop, test, and refine techniques for the detection of active regions before they are visible, the exploration of techniques to determine whether pre-emergent or newly emerged active regions will grow and become flare-productive, and to explore how such knowledge could be incorporated into downstream predictive models of the outer corona and heliosphere. The prime measure of success for this work will be to demonstrate a statistically significant ability to predict the location of new active regions before they are visible on the surface of the Sun, and also their evolution.

3.2.3 Types of investigations:

It is expected that the focus team will include, but not be limited to, the following types of investigations: The improvement of helioseismic techniques for far side imaging of active regions; the refinement and testing of helioseismic techniques for detecting active regions on the front side of the Sun before they are visible on the surface, and for detecting signatures of developing flare-productive active regions; collaborative research between helioseismologists and solar interior modelers on the behavior of magnetic fields and flows expected in pre-emergent and growing active regions; and the development of techniques to quantitatively assess the predicted impact of a specific newly emerged active region on the global structure of the corona and heliosphere.

3.3 Origin and Evolution of the Suprathermal Seed Population and its Effects on Large Gradual SEP Events

3.3.1 Target Description

Understanding the acceleration of large gradual event solar energetic particles at CME-driven shocks near the Sun and in interplanetary space is a critical unsolved problem for NASA's LWS TR&T program. Recent observations (e.g., the acceleration of ^{3}He ions) indicate that CME-driven coronal and interplanetary shocks routinely accelerate ions out of a dynamic suprathermal ion population rather than from the ambient corona or the thermal solar wind. However, many key properties (e.g., origin) of the suprathermal seed population are not well understood. Furthermore, it is not clear how exactly the variability in the suprathermal population affects key properties of large SEP events. To understand and predict solar particle radiation associated with large SEP events near the Earth and throughout the heliosphere requires a cross-disciplinary approach from the solar and heliospheric communities. Specifically, it is necessary to combine coronal spectroscopic measurements with those obtained by *in situ* solar wind, suprathermal, and energetic particle instruments, model the origin and evolution of the suprathermal ions, and relate its intrinsic variability to that seen in large SEP events.

3.3.2 Goals and measures of success

The goal of this topic is to combine theoretical studies, numerical simulations, and remote or *in situ* observations to understand how evolving suprathermal seed populations are linked to the solar corona and the solar wind and fed into the acceleration process during large gradual SEP events. The measure of success and the criterion for proposal selection, is the potential impact of the work in improving current understanding of the origin and evolution of the suprathermal population, and how this variability affects the properties of large SEP events.

3.3.3 Types of solicited investigations

Proposals that contribute to our fundamental understanding of the suprathermal seed population in the solar corona and in the interplanetary medium using either observations or theoretical analysis are encouraged. Observational studies that seek to identify and quantify the relative contributions from various sources are encouraged. Analytical and numerical studies that model the origin and the spatial and temporal evolution of the suprathermal ions are highly relevant. Proposals that seek to characterize the effects of variations in the suprathermal ion population on key properties e.g., peak particle intensities, ion composition, and spectral variability, of large gradual SEP events near the Sun and throughout the heliosphere are also encouraged. Analytical and numerical models that address the preferential injection and subsequent acceleration of suprathermal ions into the shock acceleration mechanisms are also relevant. Proposals that combine existing datasets with relevant datasets from upcoming missions like STEREO, SDO, and Solar-B are also encouraged.

3.4 Understand how Flares Accelerate Particles near the Sun (i.e., through Shocks and/or Reconnection) and how they Contribute to Large SEP Events

3.4.1 Target Description

Recent studies have shown that energetic particles accelerated during solar flares could make direct and significant contributions above tens of MeV during some large SEP events observed at Earth. However, the basic mechanisms by which particles are accelerated to such high energies in flares are not well understood. This makes it difficult to assess the relative contribution of flares to any given large SEP event. To understand and predict solar particle radiation near the Earth and in the heliosphere requires a cross-disciplinary approach from the solar and heliospheric communities. Specifically, it is necessary to utilize remote and *in situ* observations of solar flares and SEP events to test and improve existing analytic and numerical models of particle acceleration in solar flares.

3.4.2 Goals and measures of success

The goal of this topic is to combine theoretical studies, numerical simulations, and remote and *in situ* observations to understand the basic mechanisms by which particles are accelerated to >50 MeV energy in solar flares. The measure of success, and the criterion for proposal selection, is the potential impact of the work in quantifying the limits of various particle mechanisms (e.g, magnetic reconnection, parallel electric-fields, shocks, second-order Fermi acceleration, etc.,), and in determining if the flare-accelerated ions could also make direct and significant contributions to the large gradual SEP events observed at Earth.

3.4.3 Types of solicited investigations

Proposals that contribute to our fundamental understanding of the energization and escape of particles accelerated during solar flares using either observations or theoretical analysis are encouraged. Observational studies that seek to characterize the solar origin and key properties (e.g., ion composition, electron association, electromagnetic emission) of SEP events at Earth using remote and *in situ* measurements are also relevant. Analytical and numerical models that seek to predict the energy extent, the observed ion composition i.e., the enhancements in ^{3}He, heavy and ultra-heavy ions, and the associated spectral forms, are also encouraged. Proposals that seek to quantitatively test the predictions of various numerical and analytical models and determine the relative contributions of flare-accelerated ions to large gradual SEP events are highly relevant. Proposals that combine existing datasets or numerical models with relevant datasets from upcoming missions like STEREO, SDO, and Solar-B are also encouraged.

3.5 Solar Origins of Irradiance Variations

3.5.1 Target description

Solar irradiance is the dominant driver of Earth climate. The variations in this fundamental parameter which are best known are the cyclic changes in total solar irradiance (TSI). In recent years continuous records of fluctuations in spectral irradiance have also been acquired. These data are now being incorporated in Earth-atmosphere models that include the absorption of different wavelengths of solar irradiation in different atmospheric layers and their coupling to fundamental modes of atmospheric oscillation. The variable solar soft X-ray, EUV, and coronal X-ray emissions play a dominant role in controlling the thermodynamics, chemistry, and ionization state of the terrestrial upper atmosphere, and are largely responsible for the most severe space weather impacts affecting telecommunications and satellite drag.

Progress in nowcasting and forecasting the solar spectrum depends critically on the availability of realistic, physics-based models of the solar activity affecting irradiance. Both total and spectral irradiance variations have been associated with manifestations of solar activity since the availability of the first space-borne measurements of these parameters, but less has been done to understand the physical processes by which solar activity causes these variations. Improved understanding of the detailed properties of solar active regions and solar impulsive events will allow the construction of models that describe the spectrum of the radiation emitted from the Sun under different conditions, and thus indicate where in the terrestrial atmosphere the radiant energies will be deposited.

3.5.2 Goals and Measures of Success

The goals of this Focused Science Topic are to understand how spectral irradiance variations from the Sun are produced and, in particular, to understand the physical processes causing variations in the solar spectral emissions. The prime measure of success for this work would be a substantial improvement in our ability to reproduce multi-spectral observations of active regions using physics-based models.

3.5.3 Types of Investigations

It is expected that the focus team will include investigations to model active regions based on first principles; predict the dependence of solar spectral irradiance on key physical parameters such as magnetic topology, field strength, loop length, and velocity patterns; and give a relationship between active region evolution and changes in the solar radiation spectrum.

3.6 Mechanisms by which Variations in Solar Spectral Irradiance Affect Climate

3.6.1 Target description

Determine the influence of solar spectral irradiance and its variability on different regions of the atmosphere and the mechanisms by which these can affect climate in the troposphere and at the Earth's surface.

Eleven-year and longer variability found in regional and global climate data are often attributed to the cyclic changes of about 0.1% that are well-known features of the total solar irradiation, or to presumed variations of longer term and possibly greater amplitude in the same parameter. In contrast, solar activity-related variations in some of the spectral components of TSI are far greater than those found in the total amount, ranging from about 1% in the near ultraviolet (which accounts for almost 10% of the TSI) to changes of 10% in the EUV (where less than 0.1% of the total irradiation is found.) Because short wavelength solar radiation is responsible for much of the basic thermal and chemical structure of the entire middle atmosphere, variations in different parts of this spectral region could through various couplings and interactions exert considerable impact on the course of weather and climate. The availability of ongoing, calibrated measurements of spectral and total irradiance from dedicated spacecraft like the SORCE mission, launched in 2003, provide new opportunities to examine the specific mechanisms through which solar spectral irradiance and its variation could directly or indirectly impact weather and climate, and help establish the relative importance of these effects in the context of other climate forcing mechanisms.

3.6.2 Goals and measures of success

Success in this endeavor will be measured by

the ability to quantify the direct or indirect effects of the proposed mechanism or mechanisms on different climate parameters, both globally and in terms of specific regional impacts;

a quantitative assessment of the ability of the proposed mechanism to replicate relevant features in global and regional climate data; and

a demonstration of its relative importance in the broader context of other known climate forcing mechanisms. The over-riding objective is an evaluation of the relative impacts of specific mechanisms on regional and global climate change.

3.6.3 Types of investigations

Submitted proposals are expected to focus on a specific mechanism or class of mechanisms for which a quantitative evaluation is currently possible, based upon available spectral irradiance and climatological data and current theoretical understanding. Proposals should involve working collaborations between solar and atmospheric scientists, and rest heavily on the application of modern climatological data analysis and modeling techniques. Envisioned participants might include solar scientists familiar with irradiance measurements and their interpretation; atmospheric chemists and dynamicists; climatologists; and modelers of the coupled atmosphere and of the coupled climate system. Activities would ideally include multivariate analyses of climate data; sophisticated analytical modeling of the proposed mechanism or mechanisms; a comparison with other solar or non-solar climate forcing mechanisms; and their possible interactions with internal oscillations of the atmosphere and with other climate forcing mechanisms.

3.7 Effects of Ionospheric-Magnetospheric Plasma Redistribution on Storms

3.7.1 Target description

Large-scale redistribution and restructuring of the ionosphere by storm-induced electric fields promotes massive ion flows into the magnetosphere. An enhanced polar wind, heavy-ion accelerations from the low-altitude cusp and auroral regions, and convective entrainment of an eroding plasmasphere are all consequences of large-scale ionospheric changes that are especially prevalent during intense storms. Magnetospherically entrained ionospheric ions populate the plasmasheet and ring current, modify magnetospheric convection and current systems, and, thereby, couple back into ionospheric plasma electrodynamics. Quantitative understanding of the effects of stormtime ionospheric restructuring on the magnetosphere, and how this feedback evolves with time, is needed to develop forecast-quality models of near-earth space weather.

3.7.2 Goals and measures of success

The goal for this topic is to establish how the magnetospheric uptake of ionospheric plasma during storms changes as a result of plasma restructuring, and how this uptake influences the dynamics and coupling of the magnetosphere and ionosphere, with emphasis on the plasma and geomagnetic field conditions of the inner magnetosphere and the evolution of the ionospheric conductance, temperature and densities. Measures of success include the identification of principal mechanistic features and quantitative assessment of their impacts over the range of stormtime conditions and solar wind and IMF drivers.

3.7.3 Types of Solicited Investigations

Team efforts optimally would encompass complementary theoretical analysis, observational and empirical approaches, both ground-based and *in situ*, and large-scale modeling of the ionosphere and magnetosphere. Nonexclusive topics of interest include: specification and forecasting of plasmasheet and ring current ion composition, energy, and distribution for stormtime solar, ionospheric, and magnetospheric conditions; distribution and rate of magnetospheric intake of ionospheric and plasmaspheric ions during storm conditions; impacts of stormtime ionospheric plasma redistribution on magnetosphere-ionosphere coupling; and energization, transport and loss of ionospheric ions in the magnetosphere.

3.8 Location and Rate of Magnetic Reconnection on Earth's Magnetopause

3.8.1 Target description

The magnetosphere/ionosphere system is driven dynamically by the solar wind, with magnetic reconnection on the magnetopause as the primary mechanism facilitating the energy exchange. Reconnection drives the overall transport in the magnetosphere and, therefore, must be modeled accurately to establish the outer boundary condition for the inner magnetosphere and ionosphere. Understanding the location and the rate of reconnection is fundamental to understanding how geospace responds to solar wind driving, which is critical to modeling many of the processes that control space weather, including plasma convection, particle acceleration, Joule heating, ionospheric ion outflow, plasmaspheric dynamics, and disturbances within the high- and low-latitude ionosphere. Predicting the dynamics of the magnetosphere/ionosphere system requires knowledge of not only the incident plasma and field conditions and the local process operating over the magnetopause, but also how the ionosphere and magnetosphere respond and subsequently modify the large-scale magnetospheric configuration.

3.8.2 Goals and measures of success

The ultimate objective of this targeted research area is a global model of the solar wind-magnetosphere-ionosphere interaction capable of accurately predicting the distribution and rate of magnetic reconnection as a function of the upstream solar wind conditions. Toward this goal, steps that could be taken include characterizing the location and rate of reconnection in existing global models and comparing results of global models with *in situ* satellite measurements, ionospheric and plasmaspheric images, and measures of ionospheric electrodynamics, including convection, cross polar cap potential, currents, Joule dissipation, etc.

3.8.3 Types of solicited investigations

Progress on this topic will require the coordination of research involving global models of the solar wind-magnetosphere-ionosphere system, local models of reconnection, satellite observations, and ground-based measurements. The team that is formed from the successful proposals should be able to quantitatively compare the location and rate of reconnection predicted by the models with observations and investigate methods for improving the accuracy of the global models.

3.9 Investigate the Global Distribution, Sources and Effects of Large Electron Density Gradients at Middle and Low Latitudes

3.9.1 Target Description

Large electron density gradients in the middle and low latitude ionosphere have a major impact on a variety of technological systems, including navigation, communications and radar. Recent methods for imaging ionospheric electron density structure using ground-based and space-borne instruments are providing a new observational context for measurements that capture these gradients. Understanding the physical causes of large gradients often requires a "systems-level perspective" of the coupled Sun-Earth system, involving solar-wind, magnetospheric, ionospheric and thermospheric processes. The interaction of these various physical systems to create the ionospheric features of such major societal impact represents an important frontier of scientific knowledge, and will require imaginative new methods, models, and combinations of data to understand and predict. The focus of this topic is middle to low latitudes regions (broadly defined) where technological systems are concentrated.

3.9.2 Goals and Measures of Success

The goal of soliciting these investigations is to produce an improved scientific understanding and characterization of large electron density gradients in the Earth's middle and low latitude ionosphere, leading to improved models that can generate predictions of societal value. We expect to produce a better characterization of the temporal and spatial scales, magnitudes, and global distribution of large gradients, under what conditions they form, and the physical understanding necessary to model such features as a function of the geophysical conditions that create them. Improved prediction capability should be established.

3.9.3 Types of Solicited Investigations

Proposals that address this topic are expected to exploit observational, theoretical and modeling approaches that improve characterization and scientific understanding of large electron density gradients in the middle and low latitude ionosphere. The research objectives can address one or more of the following areas: 1) improved characterization of the global distribution, dynamics and lifetimes of large gradient features; 2) theoretical analyses that elucidate how they are generated and related to conditions in the broader geophysical environment; 3) model development of appropriate spatial and temporal resolution to simulate the relevant physical processes; and 4) establishing new empirical or theoretical relationships that will lead to improved modeling and prediction. It is expected that a significant number of submitted proposals will deal with cross-disciplinary topics involving observations and modeling of solar wind, magnetospheric, ionospheric and thermospheric coupled processes.

4 RECOMMENDED FY07 STRATEGIC CAPABILITIES

Below we list the recommended strategic capabilities in no priority order.

4.1 Empirical Model for Causally Driven Ionospheric Outflows

4.1.1 Capability Description

This strategic goal is development of a reference empirical model that provides the composition, number flux and density or velocity of ionospheric ion outflows as a function of electromagnetic and particle inputs and source region properties.

4.1.2 LWS Strategic Need

Stormtime outflows of high-latitude ionospheric plasma modify the states of the ionosphere and the magnetosphere. Plasma of ionospheric origin, especially O^+, dominates the stormtime ring current, and influences the magnetic field of the inner magnetosphere and the distribution and energy of radiation belt particles. Characterization of the outflows can be viewed empirically in terms of cause and response. The magnetosphere supplies electromagnetic power and precipitating particles to an ionospheric source region that responds with massive outflows into the magnetosphere. The flux, energy and other properties of the outflow depend on the properties of both the magnetospheric driver and the ionospheric source population. Development of an empirical model for causally driven outflows is needed to advance, constrain and validate global, physics-based models of the coupled magnetosphere-ionosphere-thermosphere system. This strategic capability also anticipates a future need to interpret measurements from the IT Storm Probes and GEC satellites of disturbances of the ionospheric plasma in terms of causal magnetospheric drivers.

4.1.3 Expected features

- Specification of O^+ and H^+ outflow flux for given causal inputs, e.g., Poynting flux, electron precipitation flux or energy, ionospheric Joule heating rate, ionospheric source density and altitude;
- Identification of regional variations in outflow properties, e.g., association with cusp, mantle, polar cap, polar cap boundary, auroral, and region 1/2 field-aligned currents;
- Based on *in situ* data for particles and electromagnetic fields;
- Includes capability to interface with existing global MHD, GCM and polar outflow models;
- Provides error bars on predicted relationships or other measures of reliability.

4.1.4 Desirable features

- Ability to update model with future data sources, e.g., from future satellite missions;
- Characterization of ion pitch-angle and energy distributions of the outflows;
- Specification of He^+ outflow flux;
- Characterization of the altitude dependence of outflow properties;
- Provision of synoptic overlays of predicted outflows on global satellite images and maps of other relevant variables, e.g., convection, TEC, field-aligned currents.

4.2 Solar Spectral Irradiance Model

4.2.1 Capability Description

Estimate the solar spectral irradiance from 1 to 2500 nm based on solar imagery or wavelength proxies. This empirical model may be the primary means of estimating the solar spectrum at wavelengths longer than the SDO's 125 nm spectral irradiance measurements following the completion of the current SORCE mission.

4.2.2 LWS Strategic Need

The sensitivity of the Earth's atmosphere to incident solar irradiance is highly wavelength dependent, allowing variations in solar radiation to affect different layers in the Earth's atmosphere. With the recent mission launches of TIMED (2001) and SORCE (2003), whole atmosphere modelers now have daily solar spectral irradiance observations spanning 1 nm to 2700 nm, and these newly available data are beginning to be used in models of atmospheric energy transport. Correlating these new spectral irradiance data with readily observable manifestations of solar magnetic activity will:

- identify portions of irradiance fluctuations which are attributable to different manifestations of solar magnetic activity; and
- allow estimates to be made of solar spectral irradiance based on ground- or space-based solar images.

This model may be the only means of spanning expected upcoming gaps in spectral irradiance observations after the conclusion of the SORCE mission, when measured spectral irradiances will be limited to wavelengths shorter than 127 nm, which is the long-wavelength limit of the EVE experiment on SDO. Such models may facilitate simpler future instruments if measurements at select wavelengths can be identified that allow accurate estimates of full spectral irradiances.

4.2.3 Expected Features

- Correlates measurements of solar spectral irradiances with solar features and magnetic activity;
- Uses existing spectrally continuous solar irradiance data from the last few years of spacecraft measurements;
- Spans the spectral range available from current spacecraft instruments (1 to 2500 nm);
- Uses existing ground- or space-based solar images for feature identification;
- Estimates solar spectral irradiances in absence of temporally nearby irradiance data (i.e. without relying on extrapolation over time);
- Estimates irradiances through times of extreme solar activity as well as during times of minimal activity.

4.3 3D Model of an Active Region Coronal Magnetic Field

4.3.1 Capability Description

A quantitative 3D model for the slowly evolving magnetic field of a complex active region.

4.3.2 LWS Strategic Need

A primary objective of LWS is to enable the development of physics-based modeling of the Sun-Heliosphere and Sun-Earth systems. Since the energy source for the most destructive space weather throughout the solar system is the magnetic field of a complex active region, a clear prerequisite for LWS to meet its objective is a robust model for this field. An accurate physics-based model for the 3D structure and slow evolution of the field and, especially, its free energy, is essential if we are to understand and predict the onset and development of CME/Eruptive Flares. An active region field model is also essential for understanding and predicting the solar UV/XUV emission that drive Earth's upper atmosphere. Furthermore, a robust model for the active region field would be an invaluable research tool for advancing our basic understanding of the photosphere – corona – heliosphere coupling. Given that

Solar-B and SDO will be delivering revolutionary new observations of the photospheric fields and of coronal structure, and given that a great deal of work has been performed by a number of groups on magnetic field extrapolation, it is now timely to develop a next-generation community tool that can meet the needs of LWS.

4.3.3 Essential Features

- Use vector magnetic field data of the kind expected from Solar-B and SDO/HMI as input;
- Find physically consistent flow fields/electric fields from vector magnetograms for time dependent (quasi-steady) magnetic field evolution, including flux emergence/cancellation and apparent shearing motions;
- Determine the 3D vector magnetic field and electric currents of a complete active region over as large a scale as possible;
- Include the capability to interface with global coronal-heliospheric field models;
- Provides user-friendly interfaces and graphical interface for runs on demand by the general research community, including capability for zooming in on small portions of the simulation domain, and ability to analyze magnetic topology;
- Provide the flexibility for quick-turn-around runs;
- Working version to be delivered to CCMC within 3 years, final production version within five years.

4.3.4 Desirable Features

- Includes the ability to incorporate, as input, magnetic field observations from different heights in the solar atmosphere;
- Includes the ability to incorporate, as input, photospheric velocity field data;
- Includes the ability to incorporate, as input, coronal imaging data;
- Allows for a variety of user-selectable field-determination methods.

4.4 Helioseismic Imaging of Emergence and Evolution of Active Regions

4.4.1 Capability Description

Comprehensive helioseismic data models, analysis procedures and tools for mapping magnetic and thermal structures and plasma flows associated with active regions in the solar interior and on the far-side of the Sun for understanding and predicting emergence and evolution of active regions, and their heliospheric effects.

4.4.2 LWS Strategic Need

For an integrated, system-wide picture of heliophysics science, and long-term space-weather forecasts, it is crucial to understand and predict when and where active region emerge and how they evolve. In particular, it is important to predict the growth and magnetic complexity of active regions. This information can be provided by local helioseismology methods, by analyzing 3D maps of subphotospheric structures and flows. Information about flow patterns and emerging structures in the sub-photosphere provides essential input for modeling evolution of coronal magnetic structures and CME initiation. The LWS program needs robust and efficient data analysis tools and models for understanding and monitoring the solar activity in the solar interior and on the far side of the Sun. This capability is particularly important and timely for the upcoming Solar-B and SDO space missions which will provide unique opportunities for understanding the intrinsic mechanisms of solar activity and sources of irradiance variations, and will substantially advance short- and long-term forecasts of solar storm, SEP events, and irradiance changes.

4.4.3 Expected Features

- Provides common infrastructure and components for various data sources, models and analysis procedures (such as ring-diagram analysis, acoustic holography, and time-distance helioseismology).
- Substantially improves the spatial and temporal resolution of the subsurface and far-side maps, and extends the helioseismic imaging to greater depths in the interior.
- Develops comprehensive oscillation data models including turbulence, magnetic fields, physics of wave excitation and damping.
- Includes large-scale realistic numerical MHD simulations of solar oscillations, convection, magnetic elements and sunspots, critically important for testing the helioseismology analysis procedures and for verifying the inferences.
- Delivers fast, near-real time, data processing procedures and codes, interactive data analysis, inversion and visualization tools.

5 LWS POSTDOC COMPETITION

The TSC recommends the creation of a new and prestigious LWS Postdoc competition as a visible commitment of the LWS program (potentially as a separate NRA) to support researchers who intend to work in this field and have recently received their Ph.D. degree. The program would allow successful candidates to request limited support for LWS research activities of their own devising.

5.1.1 PI Eligibility

The researcher to be supported must have received his/her Ph.D. in a relevant discipline within the past 3 years or expect to be in a postdoctoral research position by the time the award is made. Candidates may submit no more than one proposal in response to this program solicitation in any given year. He/she should appear on the proposal as the sole Principal Investigator provided his or her institution allows this. If the institution does not allow postdoctoral researchers to act as PIs on research grants, then the researcher's advisor at the institution may appear as the sole PI, and the candidate should be listed by name in the Senior Personnel section of the budget.

5.1.2 Description

An important goal of the LWS program is to foster the development of a new generation of researchers involved in the theory, modeling, and data analysis necessary to enable an integrated, system-wide picture of Heliophysics science with societal relevance.

The anticipated typical award is about $100,000 per year. Awards will be limited to a maximum duration of three years. The project description may be brief and must not exceed 5 pages. The project description need only include a synopsis of the type of LWS-related research that is to be carried out. The postdoctoral researcher's biographical sketch must be included in the biographical sketch section of the proposal.

In addition to the standard items required in a LWS proposal, a letter indicating the host institution's interest in pursuing this project must also be included, along with two letters of recommendation, an abstract of the candidate's doctoral thesis, and a transcript of the candidate's graduate course work.

The LWS postdoctoral research awards will provide a stipend of $50,000 per year for the postdoctoral researcher, plus appropriate amounts for benefits, travel, publishing expenses, and indirect costs. This does not preclude the receipt of additional support from other sources. However, awards made under this Program Solicitation may provide salary or stipend support for only the postdoctoral researcher.

Reviewers will be asked to comment on the relevance of the proposed research to the LWS program objectives. They will also be asked to comment on the qualifications of the researcher based on the letters of recommendation, transcript of course work, and the quality of the researcher's previously published work.