

**NASA LIVING WITH A STAR (LWS)  
TARGETED RESEARCH AND TECHNOLOGY (TR&T)  
STEERING COMMITTEE REPORT FOR 2007-08**

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This report describes potential topics for the FY08 NASA LWS TR&T program announcement as recommended by the current TR&T Steering Committee (TSC). The TSC held a Town Hall Session at the Fall 2007 AGU Meeting, several teleconferences and a committee meeting, (March 3-4, 2008 in Rosslyn, VA) that led to these recommendations. In addition to the Steering Committee members listed above, Lika Guhathakurta (LWS Program Scientist) and Mona Kessel (LWS Deputy Program Scientists) participated in all of these discussions. On several occasions Chris St. Cyr (NASA/GSFC), Paul Bellaire (NSF), Steve Guetersloh (NASA/JSC) and Masha Kuznetsova (CCMC/GSFC) were also present and added their perspectives.

The TSC was charged to address three main topics:

- The extent to which the current LWS TR&T Program is following the distinctive philosophy, goals and content set out for it,
- Desirable focused science topics for FY09
- Potential strategic capabilities for FY09.
- Any changes in management practices that could further strengthen the LWS TR&T program

## **1 STRATEGIC PLAN FOR THE LWS TR&T PROGRAM**

The strategic plan for the LWS TR&T program is based on the LWS TR&T Science Definition Team report of November 2003 ([http://lwstrt.gsfc.nasa.gov/TRT\\_SDT\\_Report.pdf](http://lwstrt.gsfc.nasa.gov/TRT_SDT_Report.pdf)). The main points of this report were:

- LWS is a systematic, goal-oriented research program targeting those aspects of the Sun-Earth system that affect life and society.
- The TR&T component of LWS is to provide the theory, modeling, and data analysis necessary to enable an integrated, system-wide approach to LWS science and applications.
- The vision for TR&T depends on the successful implementation of an approach that:
  - Encourages and enables teamwork toward solving specific LWS science and applications problems through the creation of Focused Science Topic working groups;
  - Supports data analysis and the development of theories and models in TR&T target areas that have potential societal benefits;
  - Requires deliverables with clear relevance to the program's goals;
  - Gives particular emphasis to cross-disciplinary research;

- Supports synergistic activities such as workshops and summer schools to facilitate cross-disciplinary activities and to foster an infrastructure for mentoring and developing careers in LWS science areas;
- Supports the development of selected Strategic Capabilities that lead directly to LWS science applications;
- Supports model testing and validation using available data and
- Supports the development of tools and data environments that better enable the achievement of LWS goals and objectives.

Based on the guiding principles specified by the Science Definition Team, the TSC considered and adopted the previously defined LWS TR&T strategic goals for the next decade:

**Strategic Goal 1. *Deliver the understanding and modeling required for useful prediction of the variable solar particulate and radiative environment at the Earth, Moon, Mars and throughout the solar system*** (Solar Storms)

Rationale: Solar energetic particles and galactic cosmic rays pose major radiation hazards for space hardware and astronauts. Penetrating particle radiation adversely affects aircraft avionics and potentially the health of airline crews and passengers on polar flights. Communication and navigation systems are directly affected by major and sometimes sudden increases in the solar particle and XUV output leading to re-routed polar flights, GPS outages, and spacecraft anomalies. This goal supports NASA's Vision for Space Exploration and the elements of our national communication, navigation, and transportation infrastructure whose operations are impacted.

**Strategic Goal 2. *Develop a fuller understanding of how and to what degree variations in the Sun's radiative and particulate outputs will in conjunction with other forcing factors affect regional and global climate in the present century*** (Sun-Climate)

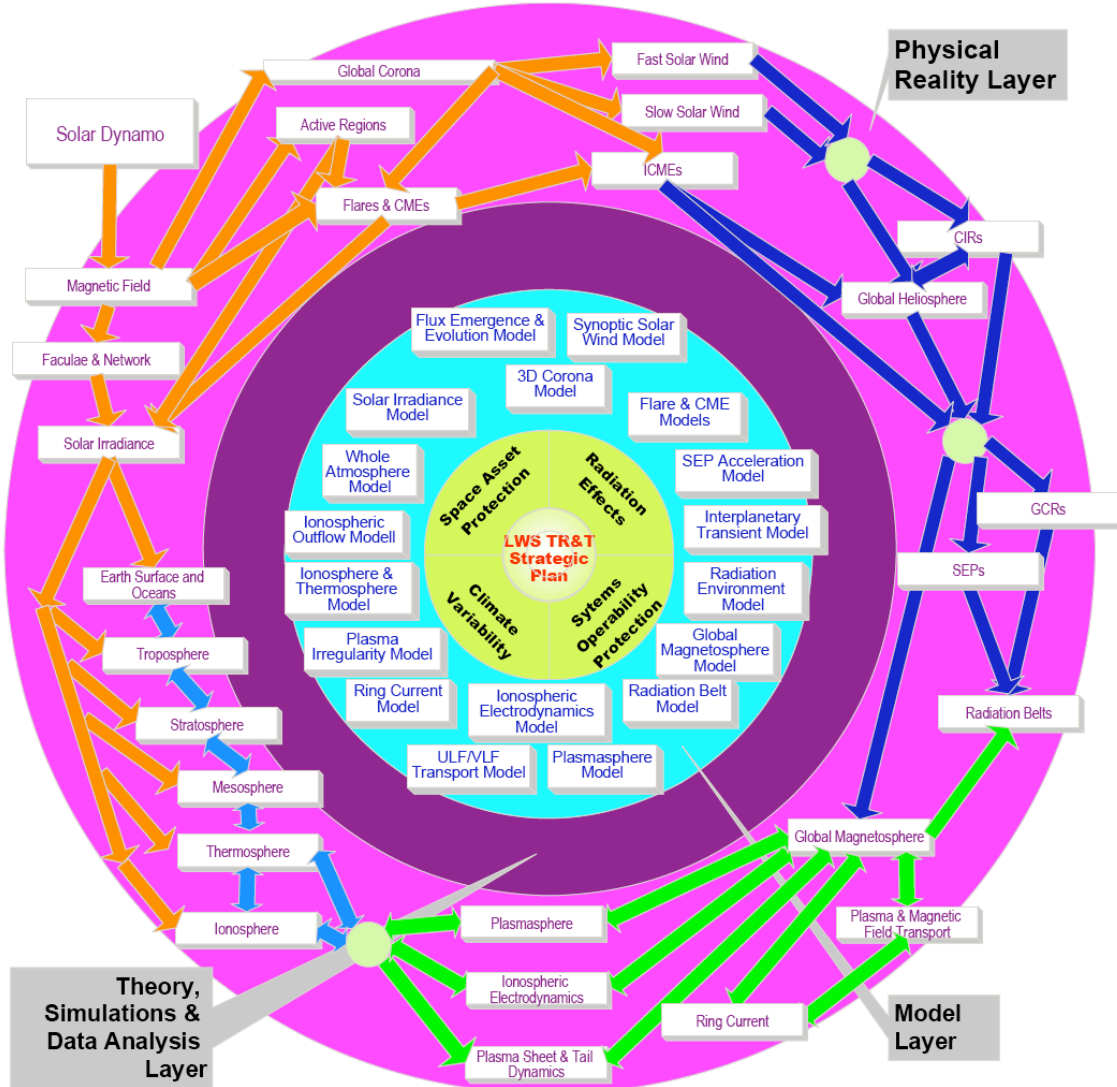
Rationale: One of the major challenges we face today is global climate change, which is driven in part by the variable Sun. The influences of the Sun and its 11-year cycle are readily apparent in global and regional averages of air and sea temperatures. What is yet uncertain is the degree to which solar variability has affected the climate of the Earth on longer time scales of decades, as well as the physical mechanisms that could explain the reported evidence. In particular, this goal addresses the role(s) that the Sun has played in climate during the documented global warming of the last 100 years, and the extent to which variations in solar inputs may enhance or diminish the projected heating due to enhanced greenhouse gases in the atmosphere.

**Strategic Goal 3. *Deliver the understanding and modeling required for effective forecasting/specification of magnetospheric radiation and plasma environments*** (Near-Earth Radiation)

Rationale: National infrastructures are increasingly dependent on satellites orbiting Earth. With advances in miniaturization these systems are becoming more sensitive to variations in their space environment. This goal aims to inform the space technology developers and to protect these assets through improved characterization of magnetospheric particle populations and electric and magnetic fields through their full range of variations. A part of this endeavor is an understanding of the physical processes responsible for these variations and especially for their extremes.

Strategic Goal 4. *Deliver understanding and predictive models of upper atmospheric and ionospheric responses to changes in solar electromagnetic radiation, and to coupling above and below* (Ionosphere-Thermosphere)

Rationale: The upper atmosphere and ionosphere is central to a number of space weather effects, including anomalous satellite drag, GPS position errors, radio blackouts, radar clutter and geomagnetically induced currents (GIC). Models of this region are becoming increasingly detailed and realistic to the point where they can provide guidance in both orbit and operations planning and designing affected systems. Moreover, this region of the space environment is amenable to data assimilation into models, allowing active forecasting.



The figure reproduced above, from the previous TSC report, captures the complexity of the high level interconnections among the main LWS TR&T science and applications components, and summarizes their relationships. In addition to the individual goals mentioned above, the LWS program seeks to make progress in understanding this complex system, focusing on the most critical couplings. As in the past, the strategic goals guided the current TSC's recommendations for new focused science topics for FY09, as well as the choice of strategic capabilities targets.

2004	2005	2006	2007
Determine the solar origins of the plasma and magnetic flux observed in an ICME	Shock acceleration of SEPs by interplanetary CMEs	Predict emergence of solar active regions before they are visible	Exploring the magnetic connection between the photosphere and low corona
Determine the topology and evolution of the open magnetic field of the Sun connecting the photosphere through the corona to the heliosphere	Mechanism for solar wind heating and acceleration	Understand how flares accelerate particles near the Sun (i.e., through shocks and/or reconnection) and how they contribute to large SEP events	Prediction of the Interplanetary Magnetic Field Vector Bz at L1
Relate solar-energetic particles to their origin at the sun and inner heliosphere	Solar wind plasma entry and transport in the magnetosphere	Effects of ionospheric-magnetospheric plasma redistribution on storms	Toward combined models of acceleration, loss and transport of energetic electrons and protons in the magnetosphere
Determine the mechanisms responsible for the formation and loss of new radiation belts in the slot region in response to geo-effective solar wind structures	Storm effects on global electrodynamics and middle and low latitude ionosphere	Investigate the global distribution, sources and effects of large electron density gradients at middle and low latitudes	Determine the sources of daily variability in the thermosphere and ionosphere
Quantify the response of thermospheric density and composition to solar and high latitude forcing	Atmospheric abundance of greenhouse gases and dynamics of the upper atmosphere	Solar origins of irradiance variations	Solar Modulation of the galactic cosmic rays and the production of cosmogenic isotope archives of long-term solar activity, used to interpret past climate changes
Quantify the sensitivity of regional and global climate to solar forcing in the full context of the interactive climate system			Extreme Space Weather Events in the Solar System

Previously selected focus topics, summarized in the accompanying Table, addressed the LWS components and interconnections indicated in the figure by the encircled items. It can be seen that on average, there is broad coverage of topics across heliophysics subfields, although not every subfield is a principal contributor to a selected topic every year. The same is true this year. Recommended new topics are chosen primarily on the basis of timeliness and critical knowledge gaps, but also take into account ongoing LWS TR&T efforts. The same can be said about the selection of new investigations under the Strategic Capabilities category. In addition, special attention was paid this year to the specificity of the Focused Science Topics. This was done for the purpose of both better concentrating effort and ultimately determining whether (or not) a desired goal has been reached.

## 2 TYPES OF INVESTIGATIONS

### Focused Science Topics

The Focused Science Topic option presents proposers with an opportunity to work as contributors to a team effort on a targeted subject with the aim of achieving a higher level of progress or closure toward an LWS goal. Focused Science Topic proposals can be submitted by any Principal Investigator and their CoInvestigators and/or collaborators to address one of the

selected topics described in the annual program announcement of opportunity. While the primary evaluation criteria remain unchanged (see the NASA Guidebook for Proposers), the criterion for relevance includes relevance to one of the Focused Science Topics as an essential requirement for selection within this component. Once selected, these investigators will form a team in order to coordinate their research projects, defining a plan to structure their work into an integrated research program. These proposals, therefore, must address how the investigation would fit within the larger framework of a team effort, but are not for the entire team effort. Potential activities with other proposing groups competing for membership on the same Focused Science Topic team may be mentioned in a proposal, however each proposal must be independent and is judged on its own merit and relevance. In general, the selection of the team makeup remains at the discretion of the program selecting official(s) who base their decision on peer review, program priorities, and the Focused Science Topic questions. The duration of a typical Focused Science Team effort is 4 years. Members of Teams whose investigation periods are ending may submit new proposals in response to the LWS TR&T program announcement, but their proposals must address one of the new Science Focus Topics. Follow-on efforts can be submitted under the Strategic Capability category (if appropriate for the selected areas called out in the announcement) or to the Tools or Independent Research categories, where they compete on an equal footing with new proposals.

Based in part on the peer review, one of the PIs will be identified and asked to serve as the Team Coordinator for the Focused Science Topic for which he/she proposed. These Team Coordinators will take the lead role in organizing their teams, setting up appropriate meetings and interactions, and generally ensuring the success of the project as a whole. The Team Coordinators will also serve as the lead liaison with the LWS Project Office at NASA's Goddard Space Flight Center (GSFC) and LWS Program Office at NASA Headquarters, which together will monitor and assist the progress of each team. The Team Coordinator will receive supplemental funding as necessary to support costs associated with these duties. Proposers are encouraged to propose to act as a Team Coordinator and if they do so, should include a brief section in their proposal describing how they would lead the team effort. Up to one extra page in the proposal is allowed for this proposed effort. All proposers for Focused Science Topics should include sufficient travel funds in their proposed budgets to cover two team meetings per year to be held on the U.S. coast furthest from their home institutions.

### Strategic Capabilities

Strategic Capabilities are up to 5-year efforts that address a small set of mature subject areas and deliverables identified in the call for proposals. These may follow from earlier Focused Science Topics or be separately identified, but in both cases are open to all competitors. Previous Strategic Capabilities have included:

2005:

- A Comprehensive Magnetosphere-Ionosphere Model
- Time-dependent 3D Model for the Corona and Ambient Solar Wind
- Earth-Moon-Mars Radiation Model

2006:

- 3D Model of an Active Region Coronal Magnetic Field

Typically one or two PI-led Strategic Capability proposals are selected per year. These efforts require defining milestones, and reporting and documenting results beyond what is required in traditional research investigations because of their ‘project’ nature. Proposers must address how they plan to manage their effort and fulfill these requirements as well as to deliver the end-product specified in the announcement of opportunity. Past Strategic Capability efforts have generally included critical-mass teams under each PI-led effort. Their budgets are thus typically larger than those for the Focused Science Topic investigation proposals. Proposers should also indicate their visions for how the “end products” of Strategic Capability developments will be maintained and, if appropriate, upgraded after their program funding ends.

#### Independent Research

Independent research proposals are the most unrestricted category of the LWS TR&T program. These individual PI-led investigations may be in any area of relevance to the LWS TR&T Strategic Goals (see earlier discussions), and are not necessarily related to the selected Focused Science Topics or Strategic Capability areas. This component allows flexibility for cutting edge ideas that may be too narrowly focused or not yet mature enough to form a focus team. A few independent research proposals might be selected that emphasize ideas or approaches directed at advancing a particular topic for eventual qualification as a Focused Science Topic. The proposer must specify how their work is critically important for reaching LWS TR&T program goals. Following selection, interactions with related Focused Science Teams are encouraged where appropriate.

#### Tools

The Tools and Methods component supports efforts that, by themselves, may not deliver significant new science understanding, but instead deliver tools and/or methods that enable needed science and/or applications advances toward the LWS Strategic Goals. Examples include the development of empirical methods or analysis techniques, such as local helioseismology, that can be used to forecast solar, interplanetary, and geospace activity, and the development of software tools that can identify, retrieve, assimilate, and/or portray data from different sources in order to meet LWS research and forecasting objectives.

A deliverable product(s) must be specified along with a delivery date. The deliverable product can be, for example, a stand-alone code or a web application, and must be delivered to an LWS approved repository/server such as the CCMC or an existing VxO. The delivery date must be during the final year of work with enough time left to support appropriate documentation and transfer to the CCMC/VxOs to insure longevity and to enable its independent use by the scientific community. All tools whose development is supported by LWS TR&T Program are expected to be linked to the LWS TR&T web site (<http://lws-trt.gsfc.nasa.gov>) by the end of the funded period.

#### Workshops and Summer Schools

One of the major challenges facing the LWS program is the development of a research community that can cross traditional boundaries and address the system-wide problems that are central to understanding and modeling the Sun-Solar System connection. In order to meet this challenge, proposals to this LWS TR&T program may include one or more of these infrastructure-building elements: cross-disciplinary workshops and summer schools. Workshops and summer schools represent a means by which small groups of experts can be brought together

to make progress on an LWS TR&T subtopic, and by which newer members of the LWS research workforce can be both inspired and educated in the discipline. Proposals must specify how the workshop or summer school benefits the program and the LWS community. Discussion of such plans with an LWS Program official is encouraged prior to submitting a proposal in this category. Workshops that leverage funding from other institutions or agencies are strongly encouraged.

Some workshop areas of special interest for the LWS program that would be appropriate and widely applicable concern data assimilation and ensemble forecasting, for example. Prospective proposers of summer schools should be aware that there is a general graduate-student-level LWS Summer School currently being funded (see <http://www.vsp.ucar.edu/HeliophysicsSummerSchool/>).

#### Postdocs

The LWS Program now solicits proposals for Postdoctoral Researcher awards. This opportunity is for new investigators completing their PhD studies in the timeframe of the next LWS program year. See Section 6 for a complete description of this program.

### 3 RECOMMENDED FY09 FOCUSED SCIENCE TOPICS

The recommended Focused Science Topics listed here are based on a combination of community and Program management input, together with deliberations by the TSC on what are timely areas of endeavor with potentially high value for the LWS TR&T goals. They are organized by the Strategic Goal they most directly address. Note that a topic's presence is to be regarded only as an outcome of the TSC analysis, and does not guarantee it will be adopted by the LWS program officials for the upcoming announcement of opportunity. Prospective proposers are advised to consult the program announcement for the official subset of 2009 Focused Science Topics, which are likely to number no more than ~5.

#### 3.1 Focused science topics for Strategic Goal 1 (Solar storms)

##### 3.1.1 Predict the Initiation of CMEs

###### Target Description:

Predicting the occurrence of CMEs is key to having advanced knowledge of the major space weather storms. This capability can also lead to the physical insight needed to ultimately model realistic events and their propagation to Earth. Although the physical processes involved in CME initiation are still subjects of active heliophysics research, this Focused Science Topic challenges proposers to identify innovative ways to estimate the likelihood of CME initiation, to test their strategies, and to identify measurements and tools needed to put their approaches into practice.

###### Goals and Measures of Success:

The goal of this Focused Science Topic is to develop and test methods of estimating the likelihood of CMEs. The prime measures of success will be a substantial improvement in our ability



to determine when and where solar eruptions occur, together with increased understanding that can be applied to forecast tools and realistic event simulations.

Examples of appropriate investigations (but not limited to):

- 1) Investigations characterizing pre-eruptive states and trigger mechanisms
- 2) Development of procedures that integrate observations with physical models of potential CME launch regions to predict the properties of significant events
- 3) Development of global data-driven models of the eruptive corona

### *3.1.2 Determine the solar and heliospheric conditions that can be used to make reliable "all-clear" forecasts*

Target Description:

While forecasting disturbed space weather conditions is a primary target of the LWS TR&T program, it is equally important for forecasters to not issue significant numbers of false alarms. Spacecraft operators and space station workers seek to conduct critical communications and other activities such as EVAs when they are confident that the space environment will provide minimal interference or hazard. This Focused Science Topic is aimed at defining the criteria for forecasting 'all clear' conditions, during which the likelihood of deleterious effects of space weather is minimal.

Goals and Measures of Success:

An all clear forecast can be viewed as the probability that an event or condition will not occur over periods of hours to days with predetermined reliability standards. Solar flares, Coronal Mass Ejections (CMEs), and solar energetic particle (SEP) events are the sources of the most significant space weather events. Solar flares and CMEs not only result in SEP acceleration, but they also strongly modify conditions in the heliosphere by generating shock waves and creating strong, highly inclined interplanetary magnetic fields conducive to geomagnetic storms, SEP entry into geospace, and ionospheric disturbances. A successful investigation will provide an observation-based quantitative measure of the likelihood that disturbed space weather conditions will *not* occur at the Earth at a particular time in the future.

Examples of appropriate investigations:

- 1) Analyses of active region information from solar magnetograms (scalar and/or vector), leading to procedures for confirming eruptive and noneruptive states.
- 2) Analyses of photospheric, chromospheric, and coronal conditions surrounding significant eruptive events, and of contrasting noneruptive conditions.
- 3) Analyses of eruptive and noneruptive active regions to determine from historical examples how they each evolve.



- 4) Development and testing of schemes to determine if an expected flare and/or CME site has a high probability of affecting the Earth's space environment..

### *3.1.3 Measure the properties of the solar dynamo that affect solar irradiance and active region generation*

#### Target Description:

This task challenges proposers to characterize the properties of the solar dynamo that determine the strength of the solar activity cycle and its terrestrial consequences (e.g. through irradiance changes and geomagnetic effects). Recent advances in modeling promise to provide accurate forecasts of the strength and timing of solar cycles. Now Cycle 23, a longer than average and somewhat peculiar cycle, is ending, and the new Cycle 24, which has widely different predictions for its maximum activity level from different models, is beginning. In order to be useful for future cycle forecasting, models need to be constrained and related more closely to LWS impacts. Interpretation of available data from SOHO, GONG, SOLIS and other space- and ground-based sources, and the upcoming SDO mission toward this resolution is timely and may lead to new observational strategies as the solar activity level increases.

#### Goals and Measures of Success:

Successful investigations should help us to discriminate between and improve dynamo models. This requires improved measurements of critical subsurface flows, including the expected deep meridional flow, detection of the subsurface magnetic fields, and a determination of the influences of the solar polar properties on the dynamo. The connections between dynamo operation and the properties of the active regions that give rise to terrestrial effects also require clarification. Solar irradiance variations are determined by both sunspot and plage areas. What in the dynamo action determines this combination? Similarly, significant eruptive events can occur during both large and small activity cycles. An understanding of what aspect of dynamo action gives rise to eruptive regions is needed.

#### Examples of appropriate investigations:

- 1) Development of methods to discriminate between sub-surface magnetic fields and thermal structures.
- 2) Determination of the properties of the deep meridional return flow.
- 3) Analyses revealing how the magnetic and dynamic characteristics of the solar poles affect the dynamo and the solar activity cycle .
- 4) Use observations to discriminate between models that forecast the properties of Cycle 24.

### *3.1.4 Use Inner Heliospheric Observations to better constrain CME and SEP Event models*

#### Target Description:

The inner heliosphere remains a frontier that has been minimally explored. Thus far only the Helios mission and the Pioneer Venus Orbiter (PVO) have probed this region in any depth. Yet it is key to understanding what happens to ICMEs and their SEP-accelerating shocks in transit from the Sun to the Earth. Now Messenger and Venus Express are providing some new observations. In conjunction with STEREO, WIND, ACE and SOHO, these make a changing constellation of space weather measurements useful for investigating both the widths and the radial evolution of heliospheric space weather phenomena. Planning is also underway for Solar Orbiter/Sentinels and a Solar Probe mission will finally explore this inner frontier in more detail. These upcoming mission opportunities are best exploited if available measurements are used together with our increased understanding to obtain new insights.

#### Goals and Measures of Success.

The goal is to provide observational validation for inner heliosphere models, as well as updated information for new mission instrumentation and observational strategies. Measures of success for this Focused Science Topic include the ability to predict the evolution of shocks in the inner heliosphere that are inferred from remote sensing close to the Sun and in-situ measurements at Mercury's orbit and beyond. This will require the characterization of coronal and solar wind properties into ~5-10 Rs where ICME shocks are inferred to form. Observational and theoretical tests that resolve contested issues such as the importance of scattering in energetic particle transport, the mode(s) of acceleration at the shock, and the nature and origin of the heavy ion contributions to energetic particle populations are desirable consequences. Improved diagnostics of the physics of CME ejecta evolution and their solar wind interaction as they travel into the heliosphere, accelerating or decelerating and undergoing distortions as they travel, will aid future forecasting efforts and provide Sun-to-Earth event model constraints

#### Examples of appropriate investigations:

- 1) Retrospective analyses with modern tools and models of solar wind properties, CME/ICMEs and their SEP events observed during the Helios mission
- 2) Multispacecraft analyses of events detected at Messenger and Venus Express that use Sun-to-Earth event models
- 3) Analyses of 0.3-1.0 AU suprathermal ions from a SEP event seed particle perspective.

### *3.2 Focused science topics for Strategic Goal 2 (Sun-Climate)*

### *3.2.1 Determine the possible role of energetic solar and magnetospheric particles as significant agents of climatic change.*

#### Target Description:

It is well known that the fluxes of energetic charged particles precipitating in the Earth's upper atmosphere, from solar and interplanetary sources to magnetospheric populations such as the plasma sheet, ring current and radiation belts, are controlled by solar activity and the interplanetary conditions near the Earth. However, because the total energy transmitted by these agents is a minor fraction of the electromagnetic radiation received from the Sun, observational evidence of their possible impact on the Earth's climate has generally been disputed or ignored. This Focused Science Topic seeks to resolve the longstanding question of whether solar or magnetospheric particles impacting the Earth's upper atmosphere are significant agents of change in the lower atmosphere. In particular, mechanisms through which they can modify weather and climate need to be identified, or ruled out.

#### Goals and Measures of Success

The goal is an objective interdisciplinary analysis of observational evidence and physical and chemical mechanisms through which incoming particles of solar or magnetospheric origin could alter the course of weather and climate in the stratosphere and troposphere. The measure of success is the degree to which the investigations definitively clarify the extent of their effects relative to human-induced changes and the more direct effects of solar radiative changes.

#### Examples of appropriate investigations:

- 1) Comprehensive (re)examinations of the evidence to identify the least ambiguous examples and/or to rule out proposed evidence that is invalid or inconclusive
- 2) Numerical experiments with coupled upper/lower atmosphere models involving direct chemical and dynamical couplings (e.g. via ozone abundance alteration)
- 3) Experiments and/or calculations to determine the effects of particle-induced atmospheric chemistry and ionization changes in the middle and lower atmosphere.

### *3.2.2 Identify regional aspects of solar induced variability and modulation of climate*

#### Target Description:

The climate change research community is now challenged to determine how regions are connected to the larger, hemispheric or global climate and how different forcing factors affect local variability. Overall or large-area trends can be misleading when dealing with the richness of regional climate variations. Despite being comparatively small, solar variations offer one of the few options to identify idiosyncracies of regional climate response. Climatically relevant solar activity changes occur in quasi-periodic fashion over multiple time scales, in particular the decadal and centennial-scale. These solar forcings leave characteristic imprints that may help

identify the locales where influences on climate can be most clearly distinguished, aiding both general climate as well as Sun-climate research.

Goals and Measures of Success:

The goal of this Focused Science Topic is to sort out the regional aspects of solar forcings in climate, in order to better interpret both the observations and the physical responses involved. In contrast to the previous Focused Science Topic (3.2.1), this challenge is specific to the detailed interpretation of the climatological evidence. Whereas 3.2.1 is geared toward identifying potential impacts of non-radiative solar inputs, the measure of success in this case is a more thorough understanding of what a particular type of evidence, obtained locally, implies. The desired outcome includes the identification of regions and effects that can be exploited in future observational and modeling studies, and in forecasting.

Examples of appropriate investigations:

- 1) Intercompare solar forcing effects in climate models with different limitations and complexities (e.g. global vs. regional models, models with and without upper atmosphere coupling, etc.).
- 2) Identify how the interactions of climate signals from different forcings may lead to signal obscuration or amplification on regional scales.
- 3) Determine the site-specific manifestations of the solar forcing signal in various regional climate systems

### *3.2.3. Determine the possible role of galactic cosmic ray particles as a source for cloud condensation nuclei in the troposphere and lower stratosphere.*

Target Description:

It has been shown that the galactic cosmic rays (GCRs) reaching Earth, as measured by their by-product neutrons that reach ground level, vary by about 20% over the course of the solar cycle, with an inverse correlation to sunspot activity. Other by-products of these GCRs include the creation of ions in the lower atmosphere, specifically in the troposphere and lower stratosphere. It has been postulated that these ions could act as condensation nuclei, which, through subsequent coalescent stages, could lead to additional cloud condensation nuclei and therefore a change in the solar cycle dependence of the overall cloud coverage of the planet. Even if a substantial amount of such additional cloud coverage is indeed formed from the by-products of GCR energy deposition, there is still uncertainty about whether the radiative forcing from these clouds would cause a net increase or decrease in global temperatures. If they are high, thin clouds, then the net forcing is positive, warming the Earth. However, if the clouds are low and thick, then the net forcing is negative, increasing the Earth's albedo and cooling the planet. This Focused Science Topic seeks to resolve the question of whether GCRs have a significant influence on total cloud cover, and therefore address the issue of GCR effects on climate change.

Goals and Measures of Success:

The goal is an objective interdisciplinary examination of relevant data and analyses of physical and chemical processes through which galactic cosmic rays influence the total cloud coverage of the planet. The measure of success is the degree to which the investigations definitively clarify the extent of their effects relative to those of solar radiative changes and other natural and anthropogenic influences.

Examples of appropriate investigations:

- 1) Experiments and/or calculations to determine the effects of particle-induced atmospheric chemistry and ionization changes on cloud cover and its associated thermal and dynamical effects
- 2) Robust examinations of the observations to quantify the relative influence of GCR precipitation on cloud cover
- 3) Numerical experiments with atmospheric models to assess the direct and indirect effects of GCR-induced alterations to cloud cover

### *3.3 Focused science topics for Strategic Goal 3 (Near Earth Radiation)*

#### *3.3.1 Integrate Non-MHD/Kinetic Effects on Magnetic Reconnection, Particle Energization, and Plasma Heating into Global Models*

Target Description:

Global MHD models of the magnetosphere are now routinely run to determine geospace conditions both retrospectively and in a forecast mode. However, such models lack the detailed physics needed to accurately describe the location, structure, and dynamics of the diffusion region where magnetic reconnection occurs, and thus the consequences. Recent advances in approaches beyond MHD (e.g. two-fluid (or Hall MHD), fully kinetic theory) have produced new insights on the role these processes play in controlling the dynamics and reconfigurations of magnetic fields, which in turn affect the radiation environment. However, there remains a gap between smaller-scale studies (involving, for example, reconnection, turbulence or collisionless shocks) and global modeling. This topic would bring together experts in two-fluid/kinetic processes, global modelers, and observers of the micro/macro scale interactions to determine how non-MHD/kinetic effects are affecting the global models and to develop schemes for including them.

Goals and Measures of Success:

The goals of this Focused Science Topic are to determine how the treatment of non-MHD effects in MHD codes affects the results, including simulated storm and substorm events and the associated particle acceleration and magnetospheric reconfigurations, and to develop schemes for incorporating such physics or parameterizations of the physics into global models. Reconnection and shock physics are of special importance for this Focused Science Topic. Measures of success include the ability to better simulate storm and substorm initiation and their effects. The availability of an approach to parameterizing effects of reconnection in heliophysics MHD models in general would be an especially desirable outcome.

Examples of appropriate investigations:

- 1) Development of magnetosphere models with the capability of accommodating subgrid scale physical phenomena

- 2) Development of kinetic and MHD or Hall MHD simulations that can be used to test parameterizations of the kinetic processes involved in reconnection
- 3) Application of such models to real or idealized magnetospheric disturbances to assess the importance of non-ideal-MHD physics in governing the dynamics of geospace.
- 4) Observational studies that identify sites where reconnection, particle energization, and plasma heating occur and characterize their consequences (local as well as global)
- 5) Observational studies that span multiple spatial scales providing information on how non-MHD processes affect global scales.

### *3.3.2 Develop a scheme for including substorm injections in Radiation Belt models*

#### Target Description:

The significance of substorms in modifying the near-Earth radiation environment is well known. Substorms are a primary source of ring current particles during magnetic storms and can also accelerate ambient electrons to hundreds of keV and ions to several MeV. The electrons that are injected earthward to inside of synchronous altitudes are further accelerated to relativistic energies that can impact spacecraft operations. Some current radiation belt models allow for transient activity, but these are generally driven by external conditions such as interplanetary shock passage rather than internal realistic substorm physics. The challenge for this Focused Science Topic team is the description of the internal injections of particles into the radiation belt, for eventual use global MHD simulations. This challenge has the added aspect of considering substorms that are both externally and internally triggered.

#### Goals and Measures of Success:

The goal of this Focused Science Topic is a description of substorm-associated particle injections that can be used in global magnetospheric models to analyze the radiation belt consequences. While the simulation of the inner magnetosphere in these models is in itself an important problem, it is not necessarily required as part of an investigation to achieve useful and important results. Measures of success might include injection parameterizations based mainly on magnetotail and ionospheric dynamics, for example. The results of such parameterizations should ultimately be usable with global models containing the inner magnetospheric physics.

#### Examples of appropriate investigations:

- 1) Detailed analyses of observations from THEMIS and older mission data sets to produce semi-empirical particle injection schemes or to guide model injection development.
- 2) Numerical experiments with global MHD magnetosphere models to gain further insight into differences between externally and internally triggered substorm conditions
- 3) Model-based and observational analyses that clarify the relative roles of substorm injection and the acceleration of in-situ populations in enhancing the radiation belts.

### *3.3.3 Determine the influence of critical boundaries and their evolution on the near-Earth radiation environment*

#### Target Description

Boundaries in geospace are known to affect the Earth's radiation environment. A classic example is the role of the plasmopause in creating instabilities and channeling waves effective in scattering particles into the loss cone, leading to radiation belt structure and time scales for decay. The atmosphere density profile that defines the loss cone creates another boundary, as does the changing division between magnetospheric open and closed field lines on both the dayside and nightside. Processes that affect these various boundaries, such as enhanced solar wind convection electric fields, solar EUV flux changes, and changing interplanetary field orientation produce radiation environment consequences that can be predicted and incorporated into radiation environment forecast models.

#### Goals and measures of success:

The goal of this Focused Science Topic is improved understanding of the processes controlling geospace boundaries that affect the Earth's radiation environment. This includes a picture of how these processes ultimately contribute to the changes of the Earth's radiation environment during a magnetic storm. Of particular interest is improved physical understanding that leads to better prediction of the radiation environment in globally coupled models of geospace, as a function of solar wind conditions and the conditions of the various modeled subregions (thermosphere, magnetosphere, etc.).

#### Examples of appropriate investigations:

- 1) Theoretical and modeling studies that predict how geospace boundaries relevant to the radiation environment evolve and change with solar wind conditions, solar activity (EUV flux), and during geomagnetic storms
- 2) Observational studies of the relationships of radiation belt properties to the various boundaries. Establish which boundaries are most important for the different particle populations.
- 3) Create versions of radiation belt models that take into account the prevailing states of the critical boundaries.

### *3.4 Focused science topics for Strategic Goal 4 (Ionosphere-Thermosphere)*

#### *3.4.1 Determine and quantify the responses of atmospheric/ionospheric composition and temperature to solar XUV spectral variability and energetic particles.*



#### Target Description:

With the recent availability of comprehensive solar spectral measurements at X-ray and ultraviolet (XUV) wavelengths, together with upper atmospheric chemistry and transport models, quantification of the full range of solar effects on chemically active minor constituents and ion composition in the ionosphere-thermosphere (I-T) system is now possible. Additional solar-driven variation is caused by the energetic particle environment, ranging from auroral fluxes to galactic cosmic rays. These sources have important influences on the chemistry, energetics, and dynamics of the lower thermosphere and ionosphere (e.g., on nitric oxide and ozone) via direct energy deposition and modulation of ion-neutral frictional heating. Observations of neutral composition and temperature for different phases of the solar cycle and for sporadic events are available through NASA missions like UARS and TIMED, as well as from other space- and ground-based instruments. Observations of ionospheric electron density are available through a variety of sources. In view of these advances, models of atmospheric/ionospheric composition and energetics that fully exploit the available estimates of external energetic inputs can now be developed to more accurately quantify solar effects in the middle and upper atmosphere.

#### Goals and Measures of Success:

The goal of this topic is to determine how well our understanding of atmospheric/ionospheric processes, as incorporated in state-of-the-art models, is able to explain observed compositional and temperature effects in the middle and upper atmosphere caused by external energetic inputs, in order to be able to predict these effects under both normal and extreme conditions. The measure of success will be the ability to obtain closure between observations and models of short-term, solar-cycle, and long-term variability as functions of altitude.

#### Examples of appropriate investigations:

- 1) Development of global and regional process models and the application of such models to assess the response of the I-T system to variable energy inputs.
- 2) Data analyses that provide new descriptions of external energy drivers.
- 3) Observational studies that characterize atmospheric/ionospheric composition and temperature responses to energetic inputs.
- 4) Development of models that use data assimilation to reproduce past conditions as a test, and then use them to forecast future conditions and to make a case for certain ongoing observations.

### **3.4.2 Determine the influence and evolution of critical boundaries on ionospheric structure.**

#### *Target description:*

Space weather effects in the ionosphere are often associated with boundary regions, where dominant physical processes change significantly across a narrow region. Examples are the auroral to mid-latitude transitions of particle precipitation and of ion convection, and the plasmapause boundary that separates regions of high and low plasma density in the top-side ionosphere and inner magnetosphere. The distinction between different physical processes occurring across these boundaries makes it important to be able to identify boundary locations in relation to various geospace regimes, such as the polar-cap boundary, inner edge of the ring current, and midlatitude ionospheric troughs. Gradient-related processes in the plasma and neutral gas around these boundaries can have both local and global impacts, and can influence the evolution of geomagnetic storms, yet are poorly understood.

*Goals and measures of success:*

The goal of this Focused Science Topic is improved understanding of the micro and macro-scale neutral and plasma processes controlling boundaries that affect the near-Earth plasma environment. This includes a picture of how these processes ultimately contribute to ionospheric structure and its changes during a magnetic storm. Of particular interest is improved physical understanding that leads to better prediction of the ionosphere in globally coupled models of geospace, as a function of solar wind conditions and the conditions of the various modeled subregions (thermosphere/ionosphere, plasmasphere, magnetosphere).

*Examples of appropriate investigations:*

- 1) Theoretical and modeling studies that predict how geospace boundaries relevant to the ionosphere evolve and change with solar wind conditions, solar activity (EUV flux), and during geomagnetic storms.
- 2) Observational studies of the relationships of ionospheric properties to the various boundaries.
- 3) Theoretical and modeling studies that evaluate how the special physics associated with boundaries affects the global ionosphere and thermosphere, especially during storms.

### **3.4.3 Improve Predictions of the Upper Atmospheric Response to Transients in Solar Irradiance**

Target description:

The solar extreme ultraviolet (EUV) radiation is highly variable on all time scales with variations over short time scales (minutes, flares) and longer-term (years, solar cycle) that range from factors of two to a hundred (wavelength dependent). During the most recent solar maximum, intense solar flares had major impacts on the upper atmosphere-ionosphere. Major technological systems, including the Federal Aviation Administration's Wide Area Augmentation System, were significantly affected by large changes in the Earth's ionosphere occurring over a few minutes. Society would benefit from advance prediction of such geoeffective transient solar irradiance. Improved scientific understanding of the following questions will ultimately lead to practical benefits: 1) what are the ranges of flare EUV spectra and

time histories relevant to upper atmosphere effects?; 2) what physics determines the upper atmospheric response to a given transient EUV spectrum?; and 3) to what degree can flares' atmospheric effects be predicted in advance?

Goals and measures of success:

The goal of this focused science topic is to develop the understanding necessary to eventually predict the upper atmospheric consequences of a wide variety of solar flare events. Several research areas can contribute to this goal: improved understanding of solar flare eruptions (including predictability); improved understanding of the flare emission physics and flare spectra; and improved understanding of the upper atmospheric (ionosphere/thermosphere) response. New observations from the SEM instrument on SOHO and the SEE instrument on TIMED are providing time-resolved solar flare data permitting new scientific understanding and modeling of solar flare spectra. In 2008, Solar Dynamics Observatory will carry the advanced EVE instrument that measures the EUV irradiance with unprecedented spectral range, and spectral and temporal resolution. The accurate time-resolved spectra from EVE will significantly increase our understanding and modeling of transient flare spectra. Measures of success for this Focused Science Topic include utilization of these and other observations toward a scheme for modeling the atmospheric impacts of flares, and for predicting the likelihood of various levels of impact at a particular time.

Examples of appropriate investigations:

- 1) A survey of the spectral and temporal properties of flares, taking into account their potential atmospheric effects
- 2) Development of models that use flare properties to simulate global and local effects, dependent on season and other relevant factors
- 3) Analyses of extreme events and atmospheric responses, including compound responses to accompanying/subsequent magnetic storm-related inputs to the atmosphere

#### **4 POSSIBLE JOINT FOCUS TOPICS WITH EARTH SCIENCE, PLANETARY SCIENCE, ASTROPHYSICS**

##### ***4.1 Determine the implications of solar activity for extrasolar planet investigations***

Target description:

The search for and characterization of extrasolar planets is being vigorously pursued within NASA and other agencies, and has captured public interest. This area of research serves to educate the broader population about the Earth as one of many planets whose stewardship is in our best interests. However efforts to characterize extrasolar planets are challenged by their distance as well as by the possible impacts of both central star characteristics and activity on any interpretation. For example, some extrasolar planet discoveries or results have been later retracted

because further analyses revealed their signatures were either due to, or compromised by, variability of their parent stars. This topic seeks to clarify the impacts of central star activity on both extrasolar planet observations and their interpretation by using our Sun and solar system as a model. In addition, work that leads to improved and observationally testable concepts of the nature and consequences of the star-planet connections on extrasolar planets is also sought.

Goals and measures of success:

This science focus topic will have succeeded if it establishes a community of extrasolar planet researchers who are able to exploit the latest understanding of the possible ranges of the planet-stellar wind interactions, as well as the details of the different types of stellar activity (e.g. flares, CMEs, high speed stellar wind streams) and their specific planetary effects. Workshops enabling transfer of information between LWS scientists and extrasolar planet interpreters may be useful to foster interchange. Oral and written scientific communications describing these LWS phenomena must be made useful and widely available to the extrasolar planet community. Some investigations may also reveal aspects of the extrasolar planet observations that tell us more about solar-like stellar winds, which are difficult to directly observe, from their planetary influences.

Examples of appropriate investigations:

- 1) Observational analyses of central star activity and comparisons to their solar counterparts;
- 2) Theoretical models and simulations to establish what star-planet connections for various extrasolar planets may be like, based on the understanding of our own solar wind interactions.
- 3) Re-examinations of extrasolar planetary system evidence for effects of central star activity

#### *4.2 Investigate the differences and similarities of the climates of Venus and the Earth, and their causes and implications*

Target Description:

Venus has long been regarded as a ‘twin Earth’ whose runaway greenhouse led to its present inhospitable, uninhabitable state. Missions to Venus have revealed much information about its atmosphere, surface, and solar wind interaction, but the evolutionary path that led to its condition is still not understood- and is currently the scientific objective of planned missions to Venus. It is thus timely, in this era of a warming Earth, to focus knowledge of both Venus and Earth toward understanding the sensitivity of the Earth’s climate to factors such as the inevitable continuing increases in greenhouse gases, and the reasons why Venus’ situation diverged so much from the Earth’s. This area is also complementary in interests to the topic of extrasolar planets insofar as it investigates the broader range of terrestrial planet characteristics that can lead to or discourage habitability.

Goals and Measures of Success:

The goal of this Focused Science Topic is the cross-fertilization of Venus and Earth atmosphere/climate modeling communities toward results that improve understanding of the nature

and causes of climate instability on both planets. Measures of success will be the ability to use the Venus and Earth comparison in considering the causes of climate extremes, and the ability to say with greater certainty whether Venus represents an arguable model for a past and future Earth.

Examples of appropriate investigations:

- 1) Development of climate models that make it possible to simulate the different paths that can be taken by Earth-like planetary atmospheres.
- 2) Venus-Earth comparative observational studies that illustrate the photochemical, thermal and dynamical consequences of volcanism, absence of oceans, and other likely influences.
- 3) Studies of extreme environments that provide insights on key measurements that can add critical information about climate history on future Venus missions.

## 5 RECOMMENDED FY09 STRATEGIC CAPABILITIES

### 5.1 *Solar Spectral Irradiance Models on Multiple Time Scales for Coupling to Atmospheric/Climate Models*

Capability Description:

A model of the solar spectral irradiance and its variability from 1 to 2500 nm based on solar imagery and/or wavelength proxies, to inform and provide inputs to climate studies

LWS Strategic Need:

Many atmospheric/climate models employ inadequate solar irradiance inputs that do not take into account the most recent state-of-the art observations or models of the solar spectral variations. Typically, the spectrum is divided into rather broad bands and the terrestrial atmospheric transmission/reflection/radiation processes are only coarsely captured as a result. Improvements are needed, not only in the irradiance variability inputs (solar irradiance models), but also in the way that the climate/atmospheric models use those inputs. Progress requires that the solar and atmospheric/climate modeling communities collaborate on these efforts.

The sensitivity of the Earth's atmosphere to incident solar irradiance is highly wavelength dependent, allowing variations in solar radiation to affect differing heights in the Earth's atmosphere differently. With the recent successes of the TIMED (2001) and SORCE (2003) missions, terrestrial atmosphere modelers now have access to daily solar spectral irradiance observations spanning 1 nm to 2700 nm. Developing a solar spectral irradiance model will:

- allow detailed climate sensitivity studies to spectral irradiance variability;
- quantify the relative magnitudes of variations at different wavelengths on time scales from one day to centuries;
- identify portions of irradiance fluctuations which are attributable to particular manifestations of solar magnetic activity; and

- allow solar spectral irradiance estimates to be made based on ground – or space – based solar images/wavelength proxies when direct measurements (either past or future) are missing.

Such estimates 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. Additionally, solar spectral irradiance models may facilitate simplification of future instrumentation, if measurements at select wavelengths can be identified which either allow accurate estimates of full spectral range or capture the most important variabilities.

Desirable Features:

Characterizes solar spectral properties and variation on time scales from months to centuries in ways most useful to atmospheric/climate models;

Correlates measurements of solar spectral irradiances with solar features and magnetic activity;

Uses existing spectrally continuous solar irradiance data from spacecraft measurements;

Spans the spectral range available from current spacecraft instruments (1 to 2500 nm);

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;

Identifies select “proxy” wavelengths from which accurate, spectrally continuous solar irradiances can be estimated;

Identifies key solar spectral variability in solar terrestrial coupling.

Involves collaborative efforts between space physics, aeronomy, and climate scientists.

## *5.2 Scheme for Routine Simulation of Real CMEs and their Propagation*

Capability Description:

A model of the propagation of CMEs from the Sun to Earth to predict the arrival time and the shock/sheath and driver (ejecta) properties at 1AU

LWS Strategic Need:

A primary objective of LWS is to develop physics-based models of the Sun-Earth system to understand and to predict the major causes of space weather disturbances. The propagation of CMEs from their initiation at the Sun to their arrival at Earth through the highly variable and structured solar wind is one of the primary requirements of forecasting space weather. An accurate model of how the CME evolves and how the solar wind is disturbed both in front of and be-

hind the CME is essential to predicting the resulting disturbance and its consequences at Earth. This type of model is also required for: 1. testing CME initiation concepts; 2. testing background solar wind models; and 3. developing solar energetic particle models that depend on the shock and solar wind properties and on the interplanetary magnetic field connecting the disturbance to a particular heliospheric location of interest.

Several data sets essential or advantageous for this task are now available from the upcoming SDO mission, together with STEREO, SOHO, Hinode, ACE and WIND, and ground-based magnetographs such as GONG and SOLIS. In the past decade there have also been modeling developments and efforts that have demonstrated the potential for applying coupled corona and solar wind models toward this task, but so far only selected event studies have been achieved with mixed results. It is thus timely to make this capability a more routine and accessible part of LWS scientific endeavors to take the next step toward forecasting Earth impacts of CMEs.

Desirable Features:

The ability to accurately model the continuous background solar wind;

Data-assimilation or data-driven capabilities using measured solar and solar wind parameters;

Capability to launch model CMEs initiated by a variety of schemes into the heliosphere;

The ability to extract shock and sheath properties to drive local models such as particle acceleration algorithms.

Practical/usable approaches that can be applied to any event.

Ease of comparison with observed characteristics.

### *5.3 Integrated model of the atmosphere and ionosphere*

Capability Description:

Develop an integrated model of atmospheric dynamics, composition, chemistry, radiation, and plasma properties, from the Earth's surface to the top of the thermosphere/ionosphere, driven by: inputs of solar spectral irradiance; natural and anthropogenic gases and aerosols; solar, magnetospheric, and galactic energetic particles; and magnetospheric electric fields and currents.

LWS Strategic Need:

Many hypothesized solar influences on climate and on atmospheric ozone involve dynamical, chemical, radiative, and/or electrical coupling between the lower atmosphere and the middle/upper atmosphere. Conversely, day-to-day variability and long-term trends of the thermosphere and ionosphere are influenced by dynamical and composition changes coming from the lower atmosphere. In order to evaluate how coupling among the troposphere, middle atmosphere, and upper atmosphere modulate solar-terrestrial effects, state-of-the-art models that encompass the entire atmosphere will be an essential tool. Such models allow consolidation of knowledge, testing of hypotheses, clarification of poorly understood or overlooked processes,



and prediction of as-yet unobserved phenomena. Additionally, models that encompass the entire atmosphere broaden the scope of observations that can be used for data assimilation: for example, even observations of ionospheric variability, when assimilated into an integrated atmosphere-ionosphere model, can constrain the uncertain state of the middle and lower atmosphere. :

The proposed capability should include a three-dimensional, time-dependent general circulation model of fully coupled atmospheric/ ionospheric dynamics, energetics, chemistry, and plasma processes. The model must include provision for inputs of variable solar spectral radiation, magnetospheric energy inputs, and solar and galactic energetic particles.

Desirable Features:

Interactive ozone chemistry.

Realistic exchanges of mass, momentum, and energy at the Earth's surface.

Ability to simulate realistic atmospheric tides.

Provision for interchangeable modules of different processes, for intercomparison of different algorithms and for model upgrades.

Inclusion of aerosol physics and chemistry, including stratospheric and polar mesospheric cloud physics.

Capability of coupling with magnetospheric/plasmaspheric models.

Capability of coupling with models of physical and biological processes at the Earth's surface.

Inclusion of physics of the atmospheric electrical circuit.

Capability for forward modeling of observable parameters of the atmosphere and ionosphere.

Adaptation for assimilation of lower- and upper-atmospheric data.

#### *5.4. Global Electric and Magnetic Field Model of the Inner Magnetosphere*

Capability Description:

Develop and release for community use a high temporal and spatial resolution model of the dynamic electric and magnetic fields of Earth's inner magnetosphere as a function of appropriate parameters such as solar wind conditions and geomagnetic indices. Provide "hooks" to allow the coupling of this model to kinetic particle models and MHD models of the outer magnetosphere.

LWS Strategic Need:

The global dynamics of inner magnetospheric magnetic and electric fields drive a broad range of space-weather phenomena such as radiation belt variability, ring current and plasmasphere evolution, as well as generation and propagation of various plasma waves. These magnetospheric phenomena are known to have a strong impact on ionospheric variability and dynamics. The magnetic field is severely distorted by the ring current pressure in the inner magnetosphere and

the inner magnetospheric electric field undergoes spatial-temporal variations that can only be explained by magnetosphere-ionosphere coupling.

A reasonable level of understanding exists on specific mechanisms that control the magnetic and electric fields of the inner magnetosphere, but we lack a quantitative framework that connects these mechanisms into a realistic global model. Existing models account for only a subset of specific mechanisms that we know about, and their dynamic ranges do not account for the large degree of observed variability. They are also limited in their capacity to describe key particle drift mechanisms, global electric and magnetic fields spatial variability, and boundary conditions. The need to account for transport, energization and loss of magnetospheric plasma populations is thus compromised. An improved quantitative capability to fill this modeling gap will be of critical importance for space weather missions such as RBSP, and for future realistic simulation of the inner magnetospheric particle dynamics.

#### Desirable Features:

Mathematical flexibility to reproduce fields in storm main and recovery phases down to  $<1$  Re spatial resolution and down to substorm injection time scales.

Options for use of advanced techniques for data ingestion and assimilation such as magnetic and electric field measurements, plasma pressure distributions, field-aligned currents, ionospheric flows and conductance, and the measured morphology of the plasmasphere.

Capability to describe severely distorted magnetic fields during the storm main phase due to the asymmetric ring current.

Capability to describe significant inner magnetospheric electric field enhancements due to the closure of magnetospheric currents through the sub-auroral ionosphere

Capability to describe plasma properties in the inner magnetosphere

Capability of coupling with global MHD models.

## 6 LWS POSTDOCS

The previous TSC recommended 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 allows successful candidates to request limited support for LWS research activities of their own devising.

#### *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.

### *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.

## **7 FINAL YEAR REPORTING BY FOCUSED SCIENCE TEAMS**

For teams that are in their final year, additional information is solicited. As part of their annual reporting to NASA, and for discussion at the annual Town Hall Meetings, these Focused Science Teams are asked to provide answers to several questions. These may also be useful to potential proposers in formulating their LWS project concepts:

What overall progress has been made by your team and where does this fit within the LWS strategic goals?

What unresolved questions remain that need to be addressed urgently?

What models or model improvements need to be developed before more progress in your area can be made?

What kinds of data need to become available before more progress in your area can be made? Of these data, which just need to become accessible to a wider community and which are new measurements requiring new instrumentation? Be specific.

Is the problem you are working on mature enough to define a "Strategic Capability?"

What value did the team concept bring to the scientific output of the group?

How will the community access your results and products?

These teams will also be asked to submit written summaries of their accomplishments as a final report.

#### APPENDICES/ATTACHMENTS

e.g. Town Hall meeting and TSC meeting agenda