Living With a Star
Abstracts of Selected Proposals
(NNH16ZDA001N-LWS)

Below are the abstracts of proposals selected for funding for the Living With A Star program. Principal Investigator (PI) name, institution, and proposal title are also included. Sixty three proposals were received in response to this opportunity. On August 24, 2017, twenty proposals were selected for funding.

Michael Denton/Space Science Institute
Characterizing the Earth's Radiation Environment: A Flux Model of the Inner Magnetosphere.
16-LWS16_2-0003

The goal of the project is to advance a currently existing model of the electron and ion fluxes in the inner magnetosphere by extending the spatial coverage to L~2-7, and extending the energy coverage to ~0.001-2000 keV. The project will build on the framework and methodology of a freely-available and independently-tested model that currently delivers forecasts of the ion and electron fluxes at geosynchronous orbit (GEO) [Denton et al., 2015; Denton et al., 2016]. Since its development the model has been successfully utilized by a variety of groups in the community with a science, operations, and commercial focus.

The methodology is based on statistical analyses of large spacecraft datasets, primarily from the Van Allen Probes mission, supplemented by data from the GOES and LANL satellite clusters. Following on-orbit intercalibration, the data will be coupled into the existing model, which is currently driven by either the Kp index or the solar-wind electric field (-vswBz). The latter allows flux forecasts with a ~1 hour lead-time. Predictions at GEO are in good agreement with independent observations. To produce model outputs that provide a robust and accurate predictive capability throughout the entire inner magnetosphere we will extend the current model by ingesting the new data to permit spatial predictions inwards from GEO and also elevate the maximum energy of model from ~40 keV to ~2 MeV. All available data will be assigned to spatial bins in L (and/or L*) and local-time, at discrete values of Kp and -vswBz, and energy. Tri/quad-linear interpolation will be used to produce model flux values for any chosen input parameters. The final product will be made freely available to the community and will permit the mean flux, median, standard deviation, and percentiles all to be output at an arbitrary time cadence for all possible energies. It is envisaged that two different models will evolve (one for GEO and one for the magnetosphere inwards of GEO).

The objectives are:

1. Statistically determine the variation of the ion and electron fluxes as a function of Kp, and as a function-vswBz, using the extensive database of Van Allen Probes, GOES, and LANL observations.

2. Test/quantify model predictions from Objective 1 with in-situ data using normalized RMSD and Heidke Skill Score metrics.

3. Generate a total-dose-prediction capability for satellites of arbitrary orbit within the inner magnetosphere based on historical input data over the satellite lifetime.

The compelling nature of this proposal lies in the ability of the current model to produce reliable flux forecasts at GEO, and hence the likely successful completion of the objectives outlined above. Improving the error estimates will form a large part of the effort in the work effort of the project.

The timeliness of the proposal arises from the maturity of the three satellite constellations with each having substantial datasets for robust statistical analysis.

The feasibility of the work is demonstrated by the fact that the model has already produced independently tested flux forecasts at GEO. The data required for the work have already been taken - the proposal is inherently low risk. Also, the proposal team has a proven track-record of developing data-analysis and modeling techniques for large-data sets and for case-study analysis of individual events.

PROPOSED CONTRIBUTIONS TO THE FOCUS TEAM EFFORT: The PI is keen to serve as Team Leader for the Focus Team Effort. He will ensure that the individual teams collaborate to avoid unnecessary duplication of effort. Also he will aim to introduce common metrics for analyzing uncertainties between the different groups to aid comparisons.

The proposal is relevant to Key Science Goal 2 from the National Research Council Decadal Survey on Heliophysics: Determine the dynamics and coupling of Earth s magnetosphere, ionosphere, and atmosphere and their response to solar and terrestrial inputs .

Valeriy Tenishev/University of Michigan
Effect of solar variability on the geospace radiation environment
16-LWS16_2-0014

The aim of the proposed investigation is to characterize the time-varying Earth s radiation environment due to SEP and CGRs, and response of this environment to their temporal variability affected by the Sun. In order to achieve these goals we will determine fluxes and energy spectra of SEP and GCRs in the region starting from the magnetopause to the LEO s altitudes.

In this investigation we will analyze energetic proton spacecraft observations, and use them for the model validation. The necessary modeling that will be performed as a part of the proposed study includes two major components: 1) kinetic simulation of SEP and GCRs by tracing them in the magnetosphere starting from the magnetopause to the LEO s altitudes, and 2) MHD modeling of the magnetosphere to obtain the global variations of magnetic and electric fields.

The novel feature of our approach is that the necessary modeling of the magnetosphere, SEP, and GCRs will be performed simultaneously as two part of the same model run, where a magnetic field acting upon energetic particles will be time-dependent and updated as modeling of the magnetospheric plasma progresses.

Distribution and energy spectra of SEP and GCRs in the magnetosphere will be determined by tracking their trajectories starting from the magnetopause where they are injected into the magnetosphere. Flux and energy spectrum of SEP at the magnetopause will be derived from modeling of the SEP propagation from the Sun to the Earth performed with the Field-Line-Advection Model for Solar Particle Acceleration (FLAMPA) model. Parameters of GCRs at the magnetopause will be specified with the ISO-15390 model.

Propagation of SEP and CGRs inside the magnetosphere will be simulated with the Adaptive Mesh Particle Simulator (AMPS) that will trace their trajectories as they move inside the magnetosphere. Electric and magnetic fields that are needed for calculating of these trajectories will be derived from MHD modeling of the magnetosphere conducted with a global MHD model BATSRUS. At altitudes bellow the lower limit of the BATSRUS simulation domain we will use the IGRF magnetic field model, and neglect an effect of the electric field on energetic particle propagation.

The model results will be validated by comparing the calculated SEP and GCRs fluxes and energy spectra with observation of high-energy proton fluxes made at different locations in the magnetosphere, which includes GOES EPEAD (0.74 900 MeV) and GOES HEPAD (330 700 MeV, > 700 MeV) measurements in GEO, Van Allen Probes RPS (50 MeV to 2 GeV) and REPT (above 100 MeV) inside GEO, and ISS AMS-02 at LEO.

The proposed research program is focused on assessment of the geospace radiation environment starting from ISS s altitudes of 300-400 km, and up to GEO. It combines both modeling of the SEP, GCRs, and the magnetospheric plasma with the spacecraft energetic proton observations for tuning and validating of the employed models. The proposed work addresses fundamental questions of the temporal variability of the geospace radiation environment that has important implications for evaluating effects of the solar variability, GCRs and SEP on performance and operation in space in a varying environment. The most important contribution of the proposed work to the Focused Team Effort will be characterization of the geospace radiation environment due to SEP and GCRs during quiet, active, and extreme conditions, which is important for understanding of the dynamics of the inner radiation belt, and for assessing of the spacecraft radiation environment due to energetic protons. All above makes the proposed investigation relevant to the Focus Science Topic Characterization of the Earth Radiation Environment supported by LWS.

W Kent Tobiska/Space Environment Technologies
RADIation environment using ARMAS data in the NAIRAS model (RADIAN)
16-LWS16_2-0017

This study, called RADIation environment using ARMAS data in the NAIRAS model (RADIAN), will expand a physics-based modeling capability using Kalman filter data assimilation. Recent, current epoch, and a few hours of forecast radiation environment information will be available from this system to specify the global dose rate environment from the surface of the Earth into Low Earth Orbit. This task addresses a primary goal and measure of success of the 3.1.2 Characterization of the Earth s Radiation Environment FST, i.e., demonstrating the temporal, spatial, and magnitude variability in the radiation environment, from tropospheric altitudes to the radiation belts, using observations and existing models reported with appropriate metrics of uncertainty.

These results can be used in applications for informing pilots and air traffic control of radiation hazards. Aircrew, high-altitude pilots, frequent flyers and ultimately commercial space travelers face radiation hazards originating from Galactic Cosmic Rays (GCRs), Solar Energetic Protons (SEPs), and trapped particle energetic electrons particularly when traveling at and above commercial aviation altitudes greater than 8 km. GCRs originate from outside the solar system, SEPs originate from flaring events on the Sun, and energetic electrons originate in the outer Van Allen radiation belt. These particles impact the atmosphere where secondary and tertiary particles then collide with the aircraft hull and interior components, people, or fuel to cause a further alteration of the radiation spectrum. This complex radiation spectrum has components shown to cause an increased cancer risk.

The current state-of-the-art radiation environment model is the NASA Langley Research Center (LaRC) Nowcast of Atmospheric Ionizing Radiation for Aviation Safety (NAIRAS) system. The NAIRAS data-driven, physics-based climatology gives the time-averaged radiation weather conditions using HZETRN radiation transport code. It characterizes the global radiation environment from the surface to LEO for radiation dose rate and total dose hazards. Global data-driven data are currently reported hourly at http://sol.spacenvironment.net/~nairas/index.html. However, to produce more realistic weather of the radiation environment NAIRAS will be updated to assimilate near real-time data using a Kalman filter technique. A primary data type is Total Ionizing Dose (TID) that can be reported as either absorbed dose in silicon or ambient dose equivalent for tissue relevance. The Automated Radiation Measurements for Aerospace Safety (ARMAS) NASA program developed through a Space Environment Technologies (SET) SBIR activity already provides TID data streams from aircraft at commercial altitudes. It uses Iridium satellites to transfer data to the ground and provides NAIRAS data comparisons at http://sol.spacenvironment.net/~ARMAS/index.html. ARMAS uses a Commercial-Off-The-Shelf (COTS) TID micro dosimeter combined with a microprocessor and a variety of real-time data collection methods (Iridium transceivers, Bluetooth, RS232, Ethernet, or micro SD data logger) to report the dose rate from aircraft during flight. This Technology Readiness Level (TRL) 8 system has been flying on aircraft since 2013 using the NASA Armstrong Flight Research Center (AFRC) DC-8, B-747, ER-2, the NOAA and NSF/NCAR G-IV and G-V Gulfstreams, and commercial Boeing 737, 747, 757, and 777 as well as Airbus 319 and 320 jets. The NASA Goddard Space Flight Center (GSFC) Community Coordinated Modeling Center (CCMC) has a vision and capability to independently compare and validate NAIRAS modeled results, ARMAS measurements, and their integration through data assimilation. SET, LaRC, and CCMC have joined in this study to promote the innovative development of a calibrated data source integrated into a physics-based model for understanding the dynamic variation of the radiation environment from the recent past into the near future.

Olga Verkhoglyadova/California Institute of Technology
Understanding the Impacts of Dynamic Drivers on Global Storm-time Ionosphere-Thermosphere (IT) System
16-LWS16_2-0018

In Global Circulation Models (GCMs), solar wind driving of the high-latitude ionosphere is generally represented by an evolving set of quasi-steady-state electrostatic processes. Empirical models of high-latitude electrodynamics are typically based on statistical averages and ignore inductive fields. High-latitude electric field variability can be an important contributor to ionospheric Joule heating which is one of the major energy dissipation pathways in the IT system. Effects of dynamic driving on ionospheric electron density distribution, thermospheric cooling, neutral winds, etc. are generally unknown.

We propose a cross-disciplinary research program focused on quantifying new and distinct effects in global IT dynamics caused by magnetosphere-ionosphere (MI) wave coupling and inductive electric fields. The target time scales of the driver variability will be from several seconds to several minutes, with corresponding target spatial scales from hundreds to several kilometers. There is a knowledge gap in how time-varying inductive

electric fields produced by ULF waves incident upon the high-altitude ionosphere can be adequately incorporated into GCMs, and how such time-varying regional drivers alter complex 3D ionospheric electrodynamics. There is a strong and timely need in the scientific community to incorporate dynamic drivers into GCMs, to develop corresponding predictive tools, and to improve our understanding of the dynamically driven IT system. Our science objectives are:
Objective 1. Quantify dynamic IT driving using FAST and ISR measurements.
Objective 2. Adapt GITM (Global Ionosphere Thermosphere Model) to dynamical driving by ULF wave field inputs.
Objective 3. Quantify impacts on global and regional IT caused by dynamic MI coupling in intense storms.
Objective 4. Determine energy budget of dynamically driven IT system.

In contrast with previous theoretical and modeling efforts, we propose to focus on establishing dynamic boundary conditions for ionospheric (rather than magnetospheric) modeling and fully resolve global circulation and electrodynamics in the IT. We plan to develop the first empirical model of electric field variability based on analysis of high-resolution FAST data and implement this model into a GCM as a driver for high-latitude ionosphere. We will use high time-resolution ISR measurements to estimate convective electric field in selected high-latitude regions to drive a GCM and compare with FAST estimates. We will analyze storm-time IT dynamics by adapting GITM to time-varying and small scale drivers. We will evaluate the impact of dynamic inputs on ionospheric TEC (Total Electron Content), infrared cooling emissions and thermospheric composition in the model, and cross-compare with ground-based and satellite observations. We will extend the definition of IT energy budget and estimate contributions of inductive fields to Joule heating in dynamically driven IT system. We will collaborate with other teams on data assimilation and modeling. Improved models of ionospheric conductivity, if addressed by other teams, can substantially aid in refining our dynamic driving approach. We will directly address one of the LWS program objectives to Understand solar variability and its effects on the space and Earth environments& and will target one of the most critical interconnections in the complex Heliophysics system. The proposal is well-aligned with the FST Studies of the Global Electrodynamics of Ionospheric Disturbances with its target on the determination of storm-time ionospheric electrodynamics from observations& quantitatively testing existing empirical and physics-based models, and deriving advances in modeling capabilities to improve quantitative predictive capability .

Igor Sokolov/University of Michigan
Magnetic Data Driven Global Model for Simulating the Solar Atmosphere and Inner Heliosphere in Real Time.
16-LWS16_2-0019

Science Goals and Objectives. The Sun's atmosphere and solar wind play a critical role in space weather. Understanding of the global state of the inner heliosphere to 1 AU underlies LWS Strategic Science Areas, especially ``Physics-based Solar Energetic Particle Forecasting Capability''.

We will develop a magnetic data driven global model to simulate the time-dependent state of the inner heliosphere - from the top of chromosphere to 1 AU. The model will use AWSoM-R global MHD model developed at the University of Michigan (see I.V. Sokolov et al. arXiv:1609.04379 (2016)) which has already achieved the faster than real time performance. This effort will lead to improved predictions of the solar wind in the heliosphere and at 1 AU, which is vital for CIR and CME simulations. The background wind is vital for CME propagation travel time. Magnetic field vector data driving will significantly improve the accuracy of predictions of the magnetic connectivity of active regions to the Earth, which is vital for the SEP predictions.

The time-dependent coronal modeling will include such effects as quasi-periodic streamer blowouts and the accumulation and expelling of the magnetic helicity. The latter study requires vector magnetic field data to be incorporated into the model.

Methodology. To improve a prediction of the solar atmosphere and solar wind we will innovatively use of sequences of magnetograms and/or synoptic (Carrington rotation) magnetic maps in combination with other data products. High-cadence (about 2 hours) and high-quality magnetograms will be provided by a software package MAGIC (developed at the CCMC) and employed as a dynamical boundary condition for the AWSoM-R model. As an alternative we will also use new synoptic map data products recently developed at the NSO including synoptic (Carrington rotation) maps of vector magnetic field. This new data product will benefit the modeling of coronal magnetic field, interplanetary magnetic field and solar wind properties by better representing true radial component of magnetic field as compared with currently used pseudo-radial magnetograms, which are derived under a restrictive assumption that field is radial in the photosphere. Integer Carrington rotation and near-real time (NRT) synoptic maps for more recent data will be produced as the part of the proposed work.

A non-linear force free field (NLFFF) model will be applied to describe the state of the low solar corona using the vector magnetograms as low boundary condition. The model was previously tested on selected vector data from SOLIS and HMI (e.g., T. Tadesse et al, Solar Physics, 289, 4031 (2014) and references therein). NLFFF provides a better representation to global magnetic connectivity in the corona. It will also be used to derive new parameters (e.g., distribution of free magnetic energy with height in solar corona), which will allow us to quantify the flare activity of the Active Regions. The application of vector magnetograms as well as the NLFFF model with non-zero free energy would allow a critical evaluation of uncertainties in modeling outcome based on traditional assumptions. The developed model will be validated both with the observations from the existing missions and with the WSA model predictions for the solar corona and inner heliosphere.

Contributions to the team effort. We propose a global model simulating the solar atmosphere and inner heliosphere to incorporate all contributions from other modelers and to compare the model predictions with the observational data. Among the model outputs there will be the predictions of heliospheric MHD quantities at 1 AU and the magnetic free energy in the solar corona. We will also provide the magnetogram data products (MAGIC, vector synoptic maps, NLFFF) for the use by the focused topic team. The team will evaluate the advantages/disadvantages of vector synoptic maps and develop approaches to mitigate potential shortcomings.

Gang Lu/University Corporation for Atmospheric Research
Global Ionospheric Electrodynamics and Its Influence on the Thermosphere
16-LWS16_2-0022

Because the ionosphere and magnetosphere are intrinsically coupled via magnetic field lines, the distributions of ionospheric electrodynamic fields are strongly controlled by dynamical processes taking place in the magnetically conjugate regions, such as the rate of magnetic reconnection at the magnetopause and in the magnetotail, and the energization and precipitation of magnetospheric plasmas. Ionospheric electrodynamics has a profound impact on the thermosphere. During geomagnetic storms, strong electric fields and currents driven by magnetospheric forcing produce enhanced Joule heating and energetic particle precipitation in the auroral zone. Consequently, the conductivity of the ionosphere is increased, the neutral winds are accelerated, the thermosphere is heated, and its composition is modified. In order to gain quantitative understanding of the dynamical coupling between the ionosphere and thermosphere, it is critically important to be able to describe and quantify the ionospheric conductivity, electric fields, and currents as accurately in space and time as possible. This proposal will directly tackle one specific challenge outlined by the LWS program concerning the global ionospheric electrodynamics. Toward that end, we propose to address the following outstanding scientific questions: (1) How does auroral conductivity affect ionospheric properties such as electric fields, currents, and Joule heating? (2) How do the global distributions of ionospheric electrodynamic fields vary with geomagnetic activity? (3) How does ionospheric electrodynamics influence thermospheric dynamics?

The main goal of this proposal is to quantitatively characterize storm-time ionospheric electrodynamics based on various space and ground based observations, together with advanced data assimilation techniques and numerical simulations. This investigation will make extensive use of data from both current and past NASA missions, including TIMED, IMAGE, and Polar, leveraged by other space and ground based observations, in order to obtain the most realistic specification of global ionospheric electrodynamic fields under different solar wind and geomagnetic conditions by applying the Assimilative Mapping of Ionospheric Electrodynamics (AMIE) procedure. We will also use the Thermosphere-Ionosphere- Electrodynamics General Circulation Model (TIEGCM) to delineate the various physical processes affecting the thermosphere. Numerical experiments will be conducted to determine how the different specifications of ionospheric electrodynamic fields affect thermospheric dynamics globally.

The proposal directly addresses the Focus Science Topic (FST) 3.1.3 (Studies of the Global Electrodynamics of Ionospheric Disturbances) and also contributes to the LWS 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). It is highly relevant to the 2nd high-level science goal of the Heliophysics Decadal Survey: Determine the dynamics and coupling of Earth s magnetosphere, ionosphere, and atmosphere and their response to solar and terrestrial inputs , and to NASA s Strategic Goals to explore the physical processes in the space environment from the Sun to the Earth and to develop the knowledge and capability to detect and predict extreme conditions in space to protect life and society as outlined in the Heliophysics Science and Technology Roadmap for 2014-2033. Our proposal is fully in line with these high-priority science objectives. The proposed investigation will advance our understanding of electrodynamical processes in the near-earth space environment, a critical step toward a more reliable specification, and eventual forecast, of ionospheric and thermospheric disturbances.

Sarah Gibson/University Corporation for Atmospheric Research
Data-Optimized Modeling of ICMEs with Internal Magnetic Structure
16-LWS16_2-0028

If we are ever to predict the magnetic orientations and hence space-weather impact of interplanetary coronal mass ejections (ICMEs), we need to understand how they evolve from Sun to Earth. Progress hinges on being able to answer key questions such as:

* How does internal magnetic structure, including magnetic flux, topology, and orientation, affect ICME evolution during propagation, including distortion and shock formation, deflection and rotation, and magnetic reconnection/erosion?

* What is the role of ICME/solar-wind interactions in these processes, and what is their dependency on variation in properties of the background solar wind, such as magnetic field (strength and structure), dynamic pressure, and velocity distribution?

These questions, central to Heliophysics, cannot be answered by models or observations alone.

Our overarching goal is to develop a new method for incorporating solar and heliophysics data into models to describe and interpret ICME propagation and evolution in the solar wind in (near)-real time.

Our objectives are:

- to couple solar-heliospheric models in order to analyze physical processes driving ICME evolution and the role of internal magnetic structure and ICME/solar-wind interactions

- to compare model predictions to observations in a climatological study to understand when, where, and to what degree these physical processes occur

- to develop a data assimilation approach that uses event-specific solar and heliospheric data along with climatological constraints to forecast ICME properties at 1 AU.

Our methodology includes:

- Parameterized model examining how variations in ICME magnetic structure and the ambient solar wind affect evolution and propagation. We evaluate Gibson & Low (GL) self-similarly erupting CMEs at 20 Rs , insert them into Wang-Sheeley-Arge (WSA) corona/solar-wind models driven by ADAPT photospheric boundaries, and use the Lyon-Fedder-Mobarry heliospheric model extension (LFM-helio) to propagate the resulting ICMEs out to 1 AU.

- Posterior predictive distributions of model parameters conditional on observed solar and heliospheric climatology, for four phases of the solar cycle. We employ Bayesian statistics and the ROAM optimizer; climatological data include SOHO and STEREO solar/coronal observations, STEREO heliospheric imaging, and in-situ data as catalogued by OMNIWeb.

- Event studies yielding probabilistic forecasts of ICME properties. We test the method with synthetic data in Observing System Simulation Experiments (OSSEs), undertaking sensitivity studies for a range of observations and viewpoints (e.g. L5). We then apply it to real data for cases with good coronal/heliospheric/in-situ coverage and time-evolving ADAPT boundaries.

This study directly addresses the Heliophysics Decadal Survey goal to predict the variations in the space environment. Our contribution to the Focused Science Team effort will be a statistical, data-assimilative framework for (near) real-time prediction of properties of ICMEs at 1 AU, based on well-established models and climatological and event-specific observations from NASA spacecraft. We will apply this method to a particular analytic-numerical ICME/solar-wind model coupling, but it is broadly applicable. We will use both solar and heliospheric observations, including EUV, white-light, solar-wind HI and in-situ data. Through the OSSE, we will do a sensitivity study of all these observations, and also consider observations currently not available, e.g., from the L5 viewpoint. Uncertainty analysis, including propagation of errors, is built into the Bayesian statistical approach.

Harry Warren/Naval Research Laboratory
Using Far-Side Imaging to Provide Improved Magnetic Maps to Drive Atmospheric and Solar Wind Models
16-LWS16_2-0029

The photospheric magnetic fields drive the solar atmosphere, the solar wind, and are responsible for the production of space weather events such as solar flares and coronal mass ejections. Currently one of the biggest limitations for determining the global state of the solar atmosphere and inner heliosphere is the absence of reliable magnetic data for the far-side of the Sun. While advances in far-side Helioseismology are able to provide a probability that a far-side Active Region (AR) may exist (with an estimate of the location and the amplitude), this does not include details about the structure of the AR (e.g., polarity separation). Furthermore, some ARs do not show up until they actually appear in the nearside observations. Our group has developed an innovative technique which utilizes far-side EUV data as a proxy for magnetic field strength (Ugarte-Urra et. al., 2015). We have found that this information can be incorporated into the Advective Flux Transport (AFT; Upton and Hathway 2014a,b) model to accurately reproduce the evolution of the total unsigned flux in an Active Region prior to being observed on the near-side of the Sun and continuing for multiple solar rotations.

Goals and Objectives:
-- Develop magnetic proxy maps of the far-side photospheric magnetic field.
-- Perform Data Assimilation of far-side proxy maps into AFT (AFT+304 maps).
-- Provide real-time AFT+304 maps and predictive AFT+304 maps.
-- Evaluate the errors and uncertainties associated with these maps and forecasts.
-- Compute potential field source-surface extrapolations from these maps
-- Compute proxies for solar activity based on these maps
-- Evaluate the impact of revised maps on the solar wind observed at Earth and with STEREO
-- Adapt our technique for Future Missions.

Methodology:
In the last few years, Surface Flux Transport (SFT) models have made considerable progress in reproducing the evolution of the photospheric magnetic field. By advecting the flows with an evolving convection pattern, described by Hathaway et al. (2010), the AFT model is able surpass the realism (including the production of a magnetic network) that can be obtained by traditional SFT models which use a diffusivity coefficient to account for the turbulent motions. We have found that even once data assimilation is halted, AFT can accurately reproduce the active region evolution of the total unsigned flux in an Active Region to within a factor of 2 for multiple solar rotations (Ugarte-Urra et. al., 2015). Furthermore, AFT can incorporate magnetic sources in two different ways:

either by manually inserting bipolar ARs or by using data assimilation to directly incorporate magnetic data from magnetograms.

We will begin by using STEREO 304 Å images to develop proxy maps for ARs occurring on the far-side of the Sun. We will then use data assimilation to incorporate these proxy maps into AFT, producing full-Sun synchronic maps of the Sun's global photospheric magnetic field (AFT+304 maps). These AFT+304 maps are ideal for atmospheric and solar wind models which require a time-dependent sequence of boundary conditions. We will automate the process so that we can provide these maps in near real time. Additionally, we will allow AFT to run in its predictive mode to provide forecasts of the Sun's global magnetic field configuration. Finally, we will adapt our process for future missions, including Solar Orbiter.

Proposed Contributions to the Focus Team Effort:
By combining assimilation of nearside data with far side data from 304 Å measurements, AFT+304 will be able to provide the most complete picture of the magnetic field configuration of the entire Sun. This has significant implications for space weather predictions, such as solar irradiance, solar wind, and coronal field models. We propose to contribute both the far-side proxy maps and the AFT+304 maps to the team for use as magnetic source data to drive the solar atmosphere or solar wind models.

Aleksandr Ukhorskiy/JHU/APL
Data-constrained predictive model of radiation belt dynamics
16-LWS16_2-0036

During intervals of increased geomagnetic activity, the intensities of relativistic electrons trapped in Earth s radiation belts vary by orders of magnitude. Elevated levels of electron radiation can damage and disable satellites. To mitigate hazardous radiation effects it is necessary to quantify and predict radiation belt enhancement events. While many individual mechanisms of electron acceleration and loss have been identified, the net effect of all processes acting in concert is not understood because no unified physics-based model exists in which all of these effects are included.
The primary goal of this proposal is to provide a data-constrained modeling capability for prediction of the near-Earth radiation environment including its dynamic variability in response to different solar wind driving. Our model incorporates all key electron acceleration and loss mechanisms by combining a self-consistent description of global electromagnetic fields, that drive convection and radial transport, with an empirical specification of high-frequency plasma waves, that produce local acceleration and loss. Global evolution of radiation belt intensities is calculated with a test-particle approached, with time-dependent initial conditions specified by an empirical model based on a combination of statistics and near-realtime spacecraft measurement. Such global data-driven specification of radiation belt intensities over the full rage of spatiotemporal scales is timely and possible due to new unprecedented datasets (Van Allen Probes and

THEMIS), recent progress in modeling capabilities, and the growth of computational power.

Armed with a global data-driven model, the proposed science investigation will enhance our understanding of the fundamental processes that sculpt the near-Earth radiation environment during coronal mass injection (CME) storms and during high solar speed (HSS) streams by addressing the following outstanding science questions:

1. What are the relative roles of global convection and transient mesoscale injections in the buildup of the radiation belt seed population?
2. What are the parameters of interplanetary shocks that produce new relativistic electron populations in the slot region and in the inner radiation belt?
3. What are the relative contributions of direct injections and diffusive radial transport to the buildup of radiation belt intensities?
4. How do radial transport and local wave-particle interactions compete in the buildup of radiation belt intensities?
5.What are the relative roles of atmospheric precipitation and magnetopause losses in depleting radiation belt intensities?

Proposed Contribution to the Focus Team Effort

The proposed research is directly relevant to Focused Science Topic (2) Characterization of the Earth s Radiation Environment . We will bring a unique set of modeling capabilities unified in a validated data-driven framework for specification and prediction of the near-Earth radiation environment. We will also collaborate with the rest of the Team who may develop new data streams or models (empirical or physics-based) of wave-particle interactions for inclusion in our global coupled framework.

Interactions with User Communities

Most disruptive effects of radiation belt electrons on orbiting spacecraft are associated with internal charging and discharging. Internal charging occurs during intense radiation belt events when relativistic electrons penetrate the shielding of the spacecraft deep enough to accumulate in dielectric components. Global distribution of radiation belt intensities, produced by our model, can be used to compute the internal current charging, and then converted to the anomaly probability for a spacecraft at a given orbit. Such tool would be useful to spacecraft operators for designing sensible mitigation strategies to avoid descriptive effects of internal charging.

Bernard Jackson/UCSD

A NASA Focused Science Topic to Combine World IPS Data and Standardize its Analysis

16-LWS16_2-0045

We propose a Living With a Star Focused Science Topic to promote interplanetary scintillation (IPS) investigations by the Worldwide IPS Stations (WIPSS) group. Groups using IPS techniques have recently agreed to adopt a more uniform data analysis system whose results can supplement and enhance those from NASA spacecraft. These cross-disciplinary studies already use ground-based data to modify and improve models that estimate plasma-parameter values for density, velocity, and magnetic-field components at L1 and globally throughout the heliosphere.

Present-day individual IPS systems are deficient in that each views near the Sun only while that portion of the sky is overhead. Thus, at one Earth location on any given day, much of the observing time is spent not viewing near the Sun. Given that the fastest Coronal Mass Ejections (CMEs) take less than a day to reach Earth, these can escape detection at a single location. The problem is mitigated when IPS observations from different geographic longitudes are combined. Moreover, the resulting enlarged data set covers more sky and has more redundancy than that from any single radio site.

Our heliospheric effort is centered on time-dependent 3D reconstruction modeling developed at the University of California, San Diego (UCSD). This imposes uniform processing of IPS data from each institution. The analysis reconstructs the heliosphere globally in near real time, allowing visualization and characterization of both Stream Interaction Regions (SIRs) and CMEs. Currently designed to incorporate radio arrays dedicated to IPS analyses, this effort also spurs development of remote sensing heliospheric techniques from the newest ground-based radio arrays; MWA and LOFAR, and space-based heliospheric imagers.

Results of this modeling provide a forcing input to the magnetospheres and atmospheres of the terrestrial planets, as well as a characterization of how they are bombarded by high-energy particles. The overall intent is to advance a near real time description of the solar atmosphere and inner heliosphere ; great progress has been made in this effort to date. IPS analyses, as do results from observations/measurements by NASA spacecraft and ground-based facilities, provide an appropriate data input for a variety of solar wind models that characterize the global heliosphere.

Current tomographic analysis uses a kinematic modeling kernel that iterates rapidly and updates heliospheric conditions every six hours. The full analysis can employ ENLIL, and other first-principle 3D-MHD global prediction models. ENLIL also operates at several space weather prediction centers worldwide. Early versions of both the UCSD tomography and ENLIL operate independently at the NASA-Goddard Community Coordinated Modeling Center (CCMC) and characterize space weather effects throughout the inner heliosphere. UCSD tomography also drives the ENLIL model in near real time at several additional institutions worldwide, including the UK Rutherford Appleton Laboratory, the Korean Space Center, and George Mason University.

In this NASA LWS Focused Science Topic, we propose to exploit the IPS analyses to explore the large-scale heliospheric structure of the background solar wind and CMEs. The primary Decadal Survey science goal, of locating the origin of different types of solar activity, and the prediction of variations in the space environment are expected to be met by our determination of the:

* 3D locations of CIR structures and more transient features that modify them,
* 3D origin, location, and speeds of different CMEs, and

* Enhancement of 3D modeling efforts to verify and provide mid-course corrections of CMEs and other heliospheric structures being observed and modeled in near real time.

Ultimately, this effort will relate global IPS reconstructions to NASA analyses from Solar Orbiter and Solar Probe Plus data, by providing 3D locations for structures viewed in detail from these spacecraft.

Alex Glocer/
Predicting Radiation Variability in Earth s Magnetosphere
16-LWS16_2-0046

Science Goals and Objectives
The intensification of the radiation belts and ring current has significant impacts on the space environment. Moderate energy (~10 to 100 keV) electrons can cause surface charging effects, and relativistic (~0.1 to 5 MeV) electrons can cause deep-dielectric charging on space systems. While energetic ions do not cause substantial charging, they are indirect drivers of the radiation belts via wave generation, magnetic and electric field perturbations, etc. Therefore, understanding the physical processes that are controlling the dynamics of the radiation belts and ring current during active periods and being able to predict their variability have important space weather significance.
A number of models have been established to simulate the radiation belt and ring current dynamics during magnetic storms. However, it is still a challenge to accurately predict the absolute intensities of energetic electron and ion fluxes. The user community therefore is often forced to rely on empirical models, which are limited to an averaged picture of the radiation environment but are of limited utility in understanding a particular event.
The primary goal of this project is to build an accurate and reliable radiation environment model of the inner magnetosphere and ionosphere and use it to assess impact on spacecraft charging. Specific science objectives to be addressed are:
1. To characterize how different solar wind inputs affect the radiation environment in the inner magnetosphere and ionosphere.
2. To quantitatively assess the influences of the radiation belts on the charging of spacecraft materials and space systems in various orbits and under different conditions.
The project will include extensive model-data comparisons for model validation and further improvement of the model predictability. A systematic modeling of storm events will help characterize the uncertainty in the radiation environment.
Methodology
To address our first question we will use first principles models of the space environment system. Specifically we use the Comprehensive Inner Magnetosphere-Ionosphere (CIMI) Model. This model combines Radiation Belt Environment (RBE) model and the Comprehensive Ring Current Model (CRCM) to produce a complete, and extensively tested and validated, model of the ring current and radiation belt populations. Recently, CIMI has been coupled with the BATSRUS global MHD model. This combined

modeling capability is thus able to simulate the effects of HSS, CME and other solar wind input on the radiation environment in the inner magnetosphere and ionosphere.

We will also assess the implications of the radiation belt variation for spacecraft charging. Surface charging is caused by enhanced fluxes of moderately energetic electrons, such as those encountered during substorms and storms. Models like NASCAP and SPIS are used to model spacecraft charging, but these require as inputs a description of the space plasma and radiation environment. Internal or deep dielectric charging occurs due to penetrating electrons from the radiation environment that become embedded deep inside insulating materials, and are not easily dissipated via sunlight or the cold plasma environment. The relative rates of deposition and dissipation of charge depend on the time variability of the radiation environment due to space weather and spatial variations over a spacecraft orbit.

Proposed Contributions to the Focus Team Effort
The project directly addresses the objectives of the focus science topic Characterization of the Earth s radiation environment . It contributes to the LWS Strategic Science Areas SSA-1 and SSA-6. This project also contributes significantly to the mission and spacecraft design community. The simulation and observational data available to this proposal team will be shared with the entire focus science team and the boarder science

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Natchimuthuk Gopalswamy/NASA Goddard Space Flight Center
The Global State of the Solar Atmosphere and Inner Heliosphere during Cycles 23 and 24
16-LWS16_2-0048

Science Goals and Objectives: The scientific goal of this proposal is to understand the global state of the solar atmosphere and inner heliosphere over two solar cycles. The scientific objective is to examine the properties of large scale heliospheric structures such as coronal mass ejections (CMEs), corotating interaction regions, and the associated phenomena that reflect the global state of the inner heliosphere including the solar atmosphere. The proposed work will build upon the initial discoveries made on the weak geomagnetic disturbances, lack of high-energy solar particle events, and overabundance of halo CMEs in cycle 24 (Gopalswamy et al. 2014, Geophys. Res. Lett., 48, 2673; Gopalswamy et al. 2015, ApJL 804, L23; Gopalswamy et al. 2015, JGR 120, 9221) and focus on the question: How does the state of the inner heliosphere (including the solar atmosphere) affect the large-scale solar/heliospheric structures? Answering this question will help characterize the inner heliosphere thus contributing directly to the advances on the Focused Science Topic.

Methodology: The methodology involves making accurate measurement of solar and heliospheric phenomena that are directly affected by the state of the inner heliosphere: speed and width of coronal mass ejections (CMEs), the plasma and magnetic contents of CMEs reaching 1 AU, CME rate and modulation of galactic cosmic rays, and properties of corotating interaction regions. All these properties will be compared between cycles 23 and 24 to characterize how the physical state of the heliosphere affects the properties of these large-scale structures. The proposed work will exploit the availability of complete multi-spacecraft data for two solar cycles (23 and 24) so that both inter-cycle and intra-cycle variability in the state of the inner heliosphere can be studied. The variability in the physical state is reflected in the physical quantities such as the total pressure in the heliosphere, total pressure inside CMEs, flow speeds, and the heliospheric magnetic field.

Relevance to the Focused Science Topic: The proposed work represents important advances that will greatly facilitate "Near Real Time Description of the Solar Atmosphere and Inner Heliosphere". Understanding the global state of the solar atmosphere and inner heliosphere is also important in achieving physics-based geomagnetic and solar energetic particle forecasting capabilities as identified in Strategic Science Areas 1 and 3. Thus, the proposed effort is highly relevant to the scientific objectives of the Focused Topic "3.1.1 Advances toward a Near Real Time Description of the Solar Atmosphere and Inner Heliosphere."

Tzu-Wei Fang/NOAA/SWPC
Quantifying the variability of equatorial electrodynamics during disturbed geomagnetic conditions using first-principle models
16-LWS16_2-0052

Studies have suggested that the tides and waves associated with terrestrial weather can significantly contribute to the day-to-day variability of the equatorial electric field under low solar activity and quiet geomagnetic conditions. When geomagnetic activity increases, the electrodynamics is further influenced by the disturbance wind dynamo and a penetration electric field originating in the magnetosphere. The temporal and spatial variations of storm-time equatorial electrodynamics strongly depend on the evolution of geomagnetic disturbance, the nature of the energy inputs to the ionosphere and thermosphere and the response of the thermospheric dynamics. The corresponding changes in the ionosphere-thermosphere (I-T) system become much more complex and with the temporal and spatial variations of equatorial electric fields reflecting different physical processes occurring during geomagnetic storms.

Science goals and objectives: To better understand the I-T responses under storm conditions and their impact on the equatorial electrodynamics, four specific science questions are identified:
1) What are the temporal and spatial variations in equatorial electrodynamics under the impact of geomagnetic storms?
2) What is the contribution of changes in ionospheric conductivity and thermosphere neutral winds in driving the storm-time equatorial electrodynamics?
3) How does the lower atmosphere variability modulate the electrodynamic response to a geomagnetic storm?

4) How well can we forecast the storm-time responses of the system using state-of-the-art models?

Methodology: We will utilize a fully coupled Whole Atmosphere Model (WAM) and the Ionosphere Plasmasphere Model (IPE) to quantify the relative roles of the disturbance dynamo and prompt penetration electric field. The magnetospheric drivers used in WAM-IPE will be derived from the combinations of AMIENextGen, Michigan Geospace Model (MGM), and Prompt Penetration Equatorial Electric Field Model (PPEEFM1). The responses of equatorial electric fields and I-T changes at mid- and low-latitudes under moderate and strong storms will be simulated and validated. The WAM-IPE will also be run with the NOAA-SWPC operational Geospace model, which is driven by real-time solar wind data, to examine the forecast capability of predicting the I-T conditions when geomagnetic activity increases. Running WAM under disturbed geomagnetic activity, the contributions of the disturbance dynamo and tides/waves from the lower atmosphere will be better estimated and their impact on the equatorial electric field will be quantified. Simulated storm-time I-T changes and equatorial electrodynamics will be compared with observations from multiple satellites (DMSP, C/NOFS, GOCE), and ground-based measurements (incoherent scatter radar, Fabry-Perot Interferometer, ionosondes, GPS-TEC). Simulation results will provide a good estimation of the storm-time electrodynamics and yield to a better understanding of the physics that connects the high-latitude drivers and low-latitude electrodynamics.

Contributions to the Focus Team Effort: The proposed study aims to expend our current understanding on the equatorial electrodynamics, ionospheric changes, and neutral wind perturbation during geomagnetic storms, which fits into the Focus Science Topic of Studies of the Global Electrodynamics of Ionospheric Disturbances that is targeted for the 2016 Heliophysics Living With a Star program. The investigation will provide state-of-the-art models as powerful simulation tools to the focus team members. The comprehensive whole atmosphere-ionosphere model, combined with the well-described high-latitude electric field and energy inputs, will enable us to systematically analyze and quantify the impact of geomagnetic storms on the I-T system.

Joachim Raeder/University of New Hampshire
Storm Enhanced Density, Tongues of Ionization, and Sub Auroral Polarization Streams
16-LWS16_2-0059

Science goals: The Total Electron Content (TEC) is a critical ionosphere state parameter with significant space weather implications, primarily affecting communication and navigation systems. Sub-Auroral Polarization Streams (SAPS), also known as Sub-Auroral Ion Drifts (SAIDs), are fast westward flows in the ionosphere that occur at latitudes lower than auroral precipitation, and well separated from the high-latitude convection pattern. Although SAPS were first observed in the ionosphere, they can also be seen in the magnetosphere, and they are believed to be driven by a combination of region-2 currents and low ionospheric conductance. SAPS are thus governed both by magnetosphere and ionosphere processes and require self-consistently coupled models of the outer magnetosphere, the inner magnetosphere and the ring current, and the ionosphere-thermosphere system. In conjunction with the convection patterns associated by SAPS, plasma with high electron density is convected both sunward and upward through the cusp and forms a region of strongly enhanced TEC that extends over the polar cap, creating Storm Enhanced Density (SED) and the Tongue of Ionization (TOI). Over extended time periods, the TOI can reconnect with the convection pattern in the night side. SED, SAPS and the TOI are primarily storm time phenomena, and they produce depletion as well as enhancements in TEC. Thus, understanding the underlying physics and developing predictive models is important.

Specifically, we will address the following questions:

1. How do SAPS and TOI depend on solar wind drivers?
2. What are the mechanism that control SAPS, such as recombination, transport, and inner magnetosphere plasma populations?
3. How do SED, SAPS and the TOI connect to the magnetosphere?
4. How do SAPS affect the penetration electric field?
5. Does the proposed positive feedback mechanism between flows, recombination, and conductance exist and does it require a threshold of convection to become effective.

Methodology: We will primarily use the OpenGGCM-RCM coupled model, which includes all of the required physical processes and feedbacks. In particular, the ionospheric conductance is computed self-consistently from both magnetosphere electron precipitation, solar ionization, and ionospheric chemistry within the fully dynamical CTIM sub model of OpenGGCM. Furthermore, CTIM includes the recombination feedback of streaming ions. The ability of the coupled model to reproduce SAPS events has recently been demonstrated. During the course of the investigation, CTIM will be replaced by a more sophisticated ionosphere model, the Ionosphere Plasmasphere Electrodynamics (IPE) model developed at NOAA and CU. The latter model provides a unified treatment of the ionosphere over all latitudes, and a plasmasphere model as well. We will also use available data, such as radar, TEC maps, LEO satellite data, and inner magnetosphere data from the VAP, MMS, and THEMIS missions, to validate model results. Physical processes will be investigated by, for example, calculating energy and momentum flows, examining Poynting fluxes, examining the current systems, and by turning on or off various coupling terms.

Contributions to the FST effort: We will particularly address LWS topic SSA-4 Physics-based TEC forecasting capability, and also contribute to SSA-5 because scintillations result from TEC gradients.

Craig DeForest/Southwest Research Institute
FRAN: Fluxon Rapid Assimilative Nowcasting
16-LWS16_2-0063

Advances Toward a Near Real time Description of the Solar Atmosphere and Inner Heliosphere

We propose to adapt three current demonstrated analysis methods into a nowcasting facility for the solar wind near the Sun. The methods are:

- Fluxon modeling of global magnetic field evolution in the vicinity of the Sun
- Magnetic tracking of magnetic footpoints in photospheric magnetograms
- Direct, automated measurement of wind flow speed via Fourier speed filtering in coronagraph and heliospheric imager data

These three techniques, combined, have the potential to replace WSA with a more physics-based, integrative and assimilative model of the solar wind at the base of the heliosphere.

The fluxon model, FLUX, was developed at SwRI and treats the solar magnetic field as a skeleton of magnetic field lines, each of which supports a 1-D plasma model; this greatly reduces the computational load required to develop 3-D reduced-MHD coronal models, by eliminating numerical resistivity; the cost is that only discrete, and not continuous, reconnection can be modeled. The code is currently undergoing development, internally funded by SwRI, to produce quasi-smooth reconnection and enable global integrative simulation.

SWAMIS is a pioneering magnetic tracking code, that has been used for numerous applications but was originally developed specifically to drive global fluxon models.

Direct, measurement of wind speed via image speed-spectrum analysis was recently pioneered and demonstrated by the PI. We now propose to use it to integrate wind speed data into the suite of 1-D wind models embodied in a global fluxon simulation of the Sun. By evolving the model with input from SWAMIS and from routine coronagraph images, we will produce an improved nowcasting model that can be used to drive a heliospheric predictive simulation such as ENLIL.

We will disseminate the model to the community via CCMC and direct code distibution.

Relevance:
Our effort works directly to attack the problem of improved nowcasting of space weather, by: (1) producing a low-computational-cost physics based model of the corona that is intermediate in complexity between semi-analytic extrapolation (CSSS; WSA) and full 3-D simulation; (2) producing a new data product   wind speed extracted maps   from existing synoptic coronagraph data; (3) integrating those two elements; and (4) sharing both our integrated work and its components with the selected Focus Team.

Proposed Contributions to the Focus Team Effort:
We will work closely with the focus team, by:
- identifying further applications for the tracked magnetic data input;
- working to adapt and cross-compare our 1-D simulations with 3-D solutions used by the rest of the team
- sharing our ongoing wind-speed data for integration by other simulations to produce the best teamwide-integrated tool.

Peter Schuck/Heliospheric Science Division
Developing Vector Magnetic Maps from SDO/HMI that can Drive Space Weather Models
16-LWS16_2-0065

We propose a comprehensive program of innovative observation, analysis, and theoretical interpretation to attack the central goal of the Focused Science Topic: Advances toward a near real-time description of the solar atmosphere and inner heliosphere. We will make two critically required contributions toward achieving this goal: (1) develop temporally stable, Solar Dynamics Observatory (SDO) Helioseismic Magnetic Imager (HMI) vector magnetograms, and (2) develop accurate, self-consistent photospheric flows in Active Regions (ARs) that can be used to calculate estimates of the energy and helicity transport through the photosphere for characterizing the near real-time state of the corona. The photospheric magnetic fields play a critical role in many models of the solar atmosphere. Therefore, improving photospheric vector magnetograms has a cascading impact on all modeling that depends on this boundary.

There are three major obstacles to implementing HMI vector magnetograms for driving models and computing accurate estimates of the energy and helicity transport: (1) the orbital artifacts that contaminate the observations (Hoeksema, 2014a; Schuck 2016) (2) the temporal stability from image to image of the disambiguation needed to resolve the direction of the transverse magnetic field, and (3) the statistical uncertainties. Our program will address all these issues with the following methodology:

* We will correct the vector magnetograms by utilizing two different methods. We recently discovered that the free-spectral-ranges (FSRs) of the optical elements in were only measured to an accuracy of 1%. Whereas inversion of the HMI filtergrams to produce Dopplergrams and magnetograms (vector and line-of-sight) requires a specification of 0.06% (Scherrer and SDO HMI Team, 2016). We will optimize FSRs of the seven optical elements of HMI by reprocessing the spectra and minimizing the oscillations in the observables. Additionally, we have made a major breakthrough in HMI data analysis by developing a powerful procedure, COADRED, that removes the orbital artifacts in the downstream Dopplergrams produced by the Very Fast Inversion of the Stokes Vector (VFISV) in the HMI Pipeline. We will modify the COADRED procedure to operate on the vector magnetic field inversions (Schuck, 2016).

* We will implement a new disambiguation module that minimizes temporal fluctuations in the direction of the transverse magnetic field from image to image.

* We will use the resulting vector fields combined with the Differential Affine Velocity Estimator for Vector Magnetograms with Doppler Velocities to estimate the photospheric plasma velocities.

* We will compute the energy and helicity transport for an ensemble of both erupting and non-erupting active regions to characterize the coronal state.

* Uncertainties will consistently be propagated from beginning to end through our analysis process.

Proposed contribution to the FST: We will provide modelers with consistent and accurate photospheric boundary conditions, consisting of vector magnetic field and plasma velocities, for near real-time models of the solar corona and inner heliosphere.

This work directly addresses the LWS program objective: "Understand solar variability and its effects on the space and Earth environments with an ultimate goal of a reliable predictive capability of solar variability and response."

Geoffrey Crowley/
Ionospheric Electrodynamics   A Quantitative Characterization
16-LWS16_2-0066

This proposal addresses FST 3.1.3 Studies of the Global Electrodynamics of Ionospheric Disturbances. Deriving storm time iono-spheric electrodynamics is of particular importance to: LWS SSA-2 Physics-based Satellite Drag Forecasting Capability; SSA-4 Physics-based TEC Forecasting Capability; and SSA-5 Physics-based Scintillation Forecasting Capability. We propose to determine storm-time ionospheric electrodynamics from observations as fully as possible using various satellite and ground-based datasets, and quantitatively test existing empirical and physics-based models, thus deriving advances in modeling capabilities to improve quantitative predictive capability of storm-time ionospheric electrodynamics. We will (1) assess storm-time ionospheric electrodynamics from observations including the ionospheric conductivity, currents, and electric fields; (2) quantify the validity of existing empirical and physics-based models of ionospheric electrodynamics; (3) identify key areas of discrepancy and assess techniques, including data-assimilation, to incorporate available data into ionosphere/thermosphere models and to infer external forcing where not well measured; (4) translate modeled/assimilated global electrodynamics to both magnetometer and GIC measurements that can be validated on the ground. The study will consider uncertainties and how the sources of error impact the results. NASA will facilitate interaction with user communities.
We will address the following Science Questions:

1) What are the impacts of ionospheric conductance on Region 2 currents and global ionospheric electrodynamics
2) What are the effects of the inner magnetosphere physics (Region 2 currents, penetration E-fields, energy deposition from the ring current and precipitation) to the global ionospheric electrodynamics?
3) Over what spatial and temporal scales do systematic departures from observations and our next-generation models occur?
4) How does an improved specification of the ionospheric conductance affect the specification of ground induced currents?

We will:
1) Derive stormtime Ionospheric Electrodynamics from a broad set of ionospheric observations, by using multiple existing data sources at ASTRA (DMSP, SuperDARN, AMPERE, magnetometers) and models to improve the E-field specification from AMIE
2) Validate the electrodynamics encapsulated in existing models, and a new coupled model described in the text.
3) Examine the effect of conductivity on AMIE, and explore ways to improve the specification of conductivity by combining AMIE, TIEGCM, and IDA4D. We will also couple the Goddard CIMI model with the TIEGCM and AMIE. We will also compare CIMI electrodynamics (ring current, SAPS E-fields, region-2 currents, etc) with AMIE, AMPERE, etc.

4) Use AMIE and the physics-based models to predict GICs and ground-based magnetic perturbations from which GICs will be com-puted, and then compare with existing magnetometer and GIC data
5) Bring theoretical understanding to interpret the validation results, especially differences between models and data, to infer scientific gaps in our understanding, and to suggest future research areas
6) We will compare ionosphere/ thermosphere data with TIEGCM simulations driven by AMIE electrodynamics to specify the high latitude forcing. The TIEGCM predicts the response of the winds, temperatures, composition, density, and the ionospheric response. TIEGCM output will be compared with various I-T data (Ne, composition, winds, etc.) to infer shortcomings of the I-T forcing terms. Model outputs will be analyzed using already-developed postprocessors and spectral analysis tools to reveal and understand the mechanisms operating in the I-T response. The CIMI model has been coupled with global MHD models, and the coupled model can provide potentials and currents at high latitudes that are alternate inputs to TIEGCM.

Dr. Crowley proposes to act as the FST Team Leader.

Stanislav Sazykin/Rice University
Ionospheric Storm-Time Electrodynamics: Coupling Across Latitudes and Magnetospheric Imprint
16-LWS16_2-0067

Science goals and objectives: We propose a systematic investigation of the role of disturbance electric fields of magnetospheric origin on the ionospheric electron density dynamics, redistribution, and occurrence of spread-F type instabilities. These transient latitude, MLT, and longitude-dependent electric fields are known to produce large changes in ionospheric electron densities, and affect conditions favorable for occurrence of spread F instabilities. Both recent observations and theory indicate that transport in the plasma sheet, which controls formation of region-2 currents, is a bi-modal process of fast and narrow channels of depleted entropy regions (bubbles) sporadically superimposed on the background large-scale convection. Specific science questions:
1.What are the signatures of changes in IMF Bz on ionospheric penetration electric fields when the bi-modal physics of plasma sheet transport is included in models of M-I coupling? How do penetration electric fields vary with plasma sheet temperature, solar wind density, and frequency of dipolarizations in the tail?
2.What are the consequences of penetration electric fields on the ionospheric electron densities? Under what conditions do penetration electric fields lead to enhanced linear growth rates of spread F instabilities at low latitudes?
3.What are the longitudinal variations of penetration electric fields and storm-time electron density redistributions?
4.What is the role of the IMF y-component and/or rotations of IMF vector on penetration electric fields?

Methodology: Our methodology will be systematic data analysis guided by first-principled simulations, aided by model development as needed. Each of the science questions can be answered with data analysis and simulations. We will use a version of the Rice Convection Model (RCM) that uses Euler potentials, includes a realistic IGRF intrinsic magnetic field, and allows for inter-hemispheric asymmetry. With idealized parametric simulations, we will study the morphology and time dependence of penetration electric fields for different plasma sheet, solar wind, and IMF By conditions. The expected outcome is improved physical understanding of how various parameters affect magnitudes, MLT and longitudinal dependence, and duration of penetration fields. We will use available data from CINDI (C/NOFS) mission (IVM ion drift velocities and F-region densities, and VEFI zonal drifts), F-region ion densities from the FPMU instrument suite on board the International Space Station (ISS), supplemented by Swarm mission data, DMSP ion drift and topside density data, and equatorial measurements by the Jicamarca radar (incoherent-scatter and coherent-scatter experiments) to construct empirical models of penetration electric fields and to study their role in occurrence of equatorial spread F. We will also use RCM coupled to the SAMI3 first-principles ionosphere, to predict density response and areas of likely spread F occurrence. With further parametric studies, we plan to identify the areas of best and least agreement between model results and data. The outcome is expected to be an improved model

(RCM) of M-I coupling that is predictive, includes longitudinal variations, and is available to the research community.
The project is directly relevant to the LWS science solicitation as it will result in an improved predictive model of ionospheric disturbances at low latitudes induced by geoeffective solar transients.

Proposed contributions to the Focused Team Efforts: Largely improved understanding and forecast of global prompt penetration electric fields and their low latitude ionospheric effects. Improved empirical models of low-latitude storm-time penetration electric fields with solar wind and magnetospheric input parameters and with longitudinal variation. Detailed validation and improved RCM M-I coupling model, event simulations of several storm-intervals with the RCM model, and availability of RCM runs.

Scot Elkington/University of Colorado, Boulder
Effects of advective and diffusive transport of trapped energetic particles in radiation belt models
16-LWS16_2-0070

Science Goals and Objectives
We propose to investigate and contrast the effects of stochastic (diffusive) transport processes with transport resulting from coherent interactions of energetic particles with large scale magnetospheric disturbances. Processes affecting the dynamics of energetic particles in the inner magnetosphere may be broadly categorized as either stochastic processes, describing individually-random dynamics of an ensemble of particles interacting with a spectrum of magnetospheric waves; or coherent processes, whereby the dynamics of the particles are collectively driven in one direction in energy or space. On timescales longer than the drift period stochastic processes lead to radial diffusion, whereby particles move randomly through regions of higher or lower magnetic field strength, gaining or losing energy in accordance with the conservation of the particle's magnetic moment. The radial profile of phase space density determines whether a net increase in energy occurs resulting from a positive outward gradient or a net loss of energy from a negative gradient. Coherent processes, by contrast, result from interactions with convective or impulsive transfers of energy with a well-defined direction. Examples of key coherent processes in the inner magnetosphere include plasmasheet injections into the stable trapping region during substorms, and injections of previously-trapped particles from high L values during impulsive events induced by shocks in the solar wind.
The proposed work applies to dynamical simulations based on a Fokker-Planck framework, which traditionally describe trapped particle dynamics in terms of only diffusive motion. Specifically, we address the following science questions:
1) How do we characterize the quantitative effect of advective processes on overall radiation belt dynamics, and how does this compare to the stochastic processes that lead to radial diffusion for specific events?

2) How do we characterize the physical characteristics of the drivers of advective transport affect the efficiency of the process? Specifically, how does particle transport vary with injection front amplitude, propagation speed, azimuthal extent, and pulse width or steepness?

Methodology

This work will use state-of-the-art simulation models in combination with observations of the solar wind and radiation belts from NASA missions, with emphasis on Van Allen Probes, MMS, and THEMIS data sets. Global magnetohydrodynamic (MHD) simulations of the Earth's interactions with the solar wind will be used to drive test particle models of the radiation belts, the results of which will be used to specify the relative contribution of advective and diffusive transport in the framework of a Fokker-Planck formalism. Analytic models of advective transport will be used to parameterize and augment understanding of the physical characteristics and dependencies of the transport process for quiet, active, and extreme conditions. Simulation results will be compared in detail to measured fluxes to demonstrate the importance of each transport mechanism and quantify associated sources of uncertainty in the models.

Proposed Contributions to Focus Team Effort

The results of this effort will provide an efficient Fokker-Planck formalism for including advective transport in dynamical models of the Earth's radiation environment. Parameterized advection and diffusion coefficients will be provided to other members of the Focus Science Team and the community at large to improve future modeling efforts and define sources of uncertainty in physical models of the radiation belts.

James Leake/NASA Goddard Space Flight Center
Implementing and Evaluating a Vector-Magnetogram-Driven Magnetohydrodynamic Model of the Magnetic Field in the Low Solar Atmosphere (NASA GSFC)
16-LWS16_2-0076

We propose to develop, evaluate, and implement, for the first time, a data-driven magnetohydrodynamic (MHD) model above solar active regions (ARs) that uses photospheric vector-magnetograms and derived quantities, and includes the physics of the low solar atmosphere.

Knowledge of the coronal field is vital in solar physics, not only for the investigation of outstanding science questions, but for the development of real time modeling of the corona, solar wind, and heliosphere, and to predict geo-effective space weather events. Unfortunately the best measurements of the solar atmospheric field lie at the photosphere, and coronal field models must bridge the gap between the high-beta, weakly ionized photosphere and the low-beta, fully ionized corona, including the relevant physical mechanisms in the layers between.

To solve this problem we will develop, evaluate, and implement techniques to use the time-evolving observed photospheric vector magnetic field from NASA's Helioseismic and Magnetic Imager (HMI) to accurately evolve the plasma and magnetic field from the photosphere up through the chromosphere and into the corona. Our proposed methodology is:

- Analyze photospheric HMI vector magnetic field observations to derive the photospheric velocity, density and temperature necessary to drive MHD models of the atmosphere above ARs.

- Develop and implement a data-driven MHD model using this data to predict the coronal field. Supply coronal field predictions to other FST team models and answer science questions.

- Evaluate the accuracy and uncertainty inherent in the resulting solution, using previously run AR simulations. Investigate propagation of errors from various sources into the coronal field prediction, such as reduced temporal/spatial cadence and instrument bias and noise.

Proposed Contributions to the FST Effort:
This proposed study addresses the Focused Science Topic ``Advances Toward a Near Real Time Description of the Solar Atmosphere and Inner Heliosphere" by ``directly addressing the innovative use of sequences of magnetograms and/or magnetic maps in combination with other data products for the purposes of predicting the state of the solar atmosphere and/or solar wind parameters." In particular we are focusing on ``Studies that innovatively use magnetograms/magnetic maps, either space or ground-based, to drive

models," and ``Studies that develop mathematical techniques for incorporating data into solar atmosphere/solar wind models (e.g., assimilation, data driving, etc.)."

Our proposed model is a vital component to this FST, providing coronal field predictions, driven by the photosphere and processed by the physics of the low atmosphere, to FST team members' models which do not include such physics. We will work with the FST team to determine how to inform these various models, and determine which observed ARs to focus on.

Overarching Science Goal: What accuracy can we achieve in an MHD model of the coronal magnetic field above ARs using the state of the art photospheric data?

Science Objectives: Use data-driven MHD models of the low solar corona to answer the following science questions: How much of the observed magnetic flux in active regions emerges into the corona? How are free magnetic energy and helicity injected into the corona in ARs? How forced is the coronal field, and above what height is it primarily force-free?
