Heliophysics Infrastructure and Data Environment Enhancements Program
Abstracts of selected proposals
(NNH15ZDA001N-HIDEE)

Below are the abstracts of proposals selected for funding for the Heliophysics Infrastructure and Data Environment Enhancement program. Principal Investigator (PI) name, institution, and proposal title are also included. 14 proposals were received in response to this opportunity. On December 11, 2015, 8 proposals were selected for funding.

Shing Fung/NASA Goddard Space Flight Center
Data Services Upgrade: Perfecting the ISIS-1 topside digital ionogram database_2

This proposal continues from the selected 2013 proposal "Data Services Upgrade: Perfecting the ISIS-1 topside digital ionogram database" with Yongli Wang as PI and S. Fung, R. Benson, and D. Bilitza as collaborators. Work on that proposal started late, due to a government shutdown, and ROSES 2015 is the first opportunity to propose a continuation of the successful work performed based on the 2013 proposal. The work from that first proposal produced version-2 ISIS-1 (International Satellites for Ionospheric Studies) topside digital ionograms from all available version-1 ISIS-1 ionograms archived at NASA s Space Physics Data Facility (SPDF) for the northern mid-latitude Ottawa telemetry station (~ 80,000 files covering a time span greater than a solar cycle {1969-83}) and all available version-1 ISIS-1 ionogram files from the equatorial Quito telemetry station in 1972 (~ 2,000 files).

The above data upgrade to version-2 files was necessary because many of the version-1 files produced during the original analog-to-digital (A/D) conversion of selected Alouette-2, ISIS-1, and ISIS-2 analog telemetry tapes into digital ionogram files [Benson and Bilitza, 2009, Radio Science, 44, RS0A04] were not suitable for auto-processing into topside electron-density Ne(h) profiles. Difficulties in processing version-1 files occurred when the ionogram frame-sync pulse and/or one or more of the frequency-marker pulses were not properly identified. Software for correcting these problems [Benson et al., 2012, Radio Sci., 47, RS0L04] was improved to produce more than 80,000 version-2 ISIS-1 digital topside ionogram files during work supported by the first proposal. The value of these files was demonstrated in three papers presented at the 2015 Ionospheric Effects Symposium in Alexandria, Virginia from 12 14 May 2015:
(1) Wang et al., demonstrated the key steps for creating the version-2 files and their use in auto-production of topside vertical Ne(h) profiles, illustrated the use of these profiles in upper transition-height determinations (O+ to H+), and emphasized their importance in improving the International Reference Ionosphere (IRI) model,
(2) Benson et al., used some of the version-2 profiles in their paper relating magnetic-storm-induced high-latitude profile changes to solar-wind parameters, and
(3) Osherovich and Fainberg determined the appropriate time shift between Dst values and solar-wind parameters as required in the previous paper.

The proposal goal is to apply the software improvements and experience gained from our earlier work to expand the latitudinal coverage of the ISIS-1 ionospheric topside Ne(h) profiles in the American sector by creating version-2 files for all available years from the version-1 files from Quito (geographic latitude of -1o; ~ 23,000 files), Santiago (-33o; ~18,000 files), and Resolute Bay (75o; ~ 33,000 files). Since >80,000 version-2 files were created during the first year, it is feasible to process the combined total of ~ 74,000 files from the above 3 stations. If time and resources permit, the high-latitude coverage will be expanded in longitude by processing data from Tromso (70o; ~ 9,000 files) and Fairbanks (65o; ~ 6,000 files) or the low latitude coverage will be expanded to cover Ouagadougou (14o; ~ 25,000 files). The digital ISIS-1 topside-ionogram database will complement the 35-mm film topside-ionogram database as many original ionograms were never processed into film. This large ISIS-1 (with elliptical polar orbit extended from 500 to 3,500 km) topside electron-density profile database, with profiles extending well above those from ISIS-2 (with fixed altitude of 1,400 km), is unique for improving the IRI model, which is known to be deficient at high altitudes [see Fig.10b of Benson and Bilitza, 2009]. These files will be archived at the SPDF and made accessible and searchable through the NASA s Virtual Wave Observatory (VWO).

Dennis Gallagher/NASA Marshall Space Flight Center
Migration of Raw IMAGE EUV Data from UDF to CDF (A Data Services Upgrade)

This effort is to migrate The Imager for Magnetopause-to-Aurora Global Exploration Mission Extreme Ultraviolet Imager level 1 data content from the Universal Data Format into the NASA Common Data Format and to provide those data to NASA s Space Physics Data Facility along with the necessary metadata and basic software to enable practical, long term access to these highly valuable observations of helium ions in the plasmasphere.

The proposal team has computer systems successfully executing the Universal Data Format (UDF) suite of software, including the interface to the Exelis Interactive Data Language (IDL), which is to be used to read the UDF files and reproduce that data in the Common Data Format (CDF). The International Solar-Terrestrial Program (ISTP) standard definitions for CDF will be used and the raw data values contained in the UDF will be retained in the CDF. NASA Goddard Space Flight Center personnel at the SPDF will be consulted to insure compatibility with the ISTP CDF, to conform to the SPASE Data Model, and to insure that the necessary software is made available to integrate the new data product into the SPDF software architecture. This software will include the latest flat field corrections and EUV camera merging algorithm. The IDL computer software will be used for to convert EUV observations from UDF to CDF. The IDL already contains the necessary capability to create output data files in the CDF.

Nearly 500 peer-reviewed papers have been published since May 2000 involving the IMAGE EUV instrument observations of the plasmasphere in the journals published by the American Geophysical Union alone. As a direct result of this mission our view of the plasmasphere has permanently changed. Even our language for the plasmasphere has

changed to include: plumes, shoulders, notches, channels, and crenulations. While no longer operating, what we have learned and continue to learn from EUV observations frame new measurements of the plasmasphere by the Cluster, Van Allen Probe, and TIMED missions. Our theoretical modeling of inner magnetosphere and reconnection/convection plasma dynamics has and continues to be profoundly challenge by what EUV observations reveal.

Today, relatively few researchers have unrestricted access to the IMAGE EUV observations owing to the difficulty of using the UDF software architecture. An element of the original data processing involved the production of EUV in CDF and its archival in the SPDF. However, this CDF dataset does not contain the original data, but a processed data product based on outdated techniques that cannot be used to recover the original measurements.

Our proposed effort is modest in that we are narrowly focused on retaining the completeness and flexibility of analysis present in the original UDF data as we migrate it to the CDF and archival in the SPDF. The effort is profound in that access to the UDF content is fragile as operating systems and all the other supporting software elements that underlay use of the UDF software architecture continue to change. What is a modest effort today will soon become a significant challenge. Clearly no one can predict how our computer software infrastructure will evolve in the future, however the VxO and the CDF is the best we have today and our current best choice for preserving the utility of these highly valued space observations for which we have invested so much to obtain.

Rudolf Komm/Association Of Universities For Research In Astronomy, Inc.
Subsurface Helicity: a Dataset for Studying Active Regions

Science goals and objectives: We propose to create a well-documented calibrated dataset of the helicity of subsurface flows, derived from SDO/HMI, for scientific investigations by the Heliophysics community. Helicity plays an important role in a broad range of solar phenomena from the dynamo to flares and coronal mass ejections (CMEs). Helicity-loaded fields are very probably responsible for the most geo-effective solar phenomena such as CMEs and flares. Excess of helicity in coronal magnetic structures can lead to their instability and eruption. The signature of helicity flow from the solar interior to the photosphere and chromosphere is therefore vital for a better understanding of the role of helicity in solar flare/CME activity. The kinetic helicity of subsurface flows can be used as a proxy of magnetic/current helicity in the solar interior and will be crucial for studies of the evolution of active regions, their flare activity, and the propagation of helicity. The proposed data product will thus provide a crucial link between the evolution of magnetic fields below the surface and that observed in the solar atmosphere using magnetograms. This will be the first time that such a data set will be made available to the community. Methodology: We will produce three data products: the kinetic helicity, its vertical contribution, and the Normalized Helicity Gradient Variance (NHGV) parameter that captures the variation of kinetic helicity with depth and time. The input measurements are the daily subsurface flows from the surface to a depth of 16 Mm derived from SDO/HMI Dopplergrams using the DRMS ring-diagram pipeline. From these measurements, we

will calculate the proposed data products as a function of disk position covering the whole Sun including active as well as quiet regions. The subsurface helicity of quiet regions provides a solar background and will be used to calibrate the helicity of active regions. The cadence and the spatial grid of the full-disk maps will be given by those of the input data. We will remove any systematic effects present in the subsurface flow measurements before calibrating the helicity data products. We have already tested our method deriving the helicity quantities from existing subsurface flow data. Work plan: We will create the data products from existing (archived) subsurface flow data including their calibration and documentation. We will continue to create new data products as soon as subsurface flow measurements become available, which occurs typically within a few days from SDO/HMI (via JSOC), and will add them to the data set. In this way, we will create a dataset that can be used for statistical studies with large samples as well as for an analysis of active regions that are still present on the Sun. We will make the data products (FITS and ASCII files) available in the public domain through website archives and virtual observatories (with the help of software engineers based at NSO). Relevance: Making the subsurface helicity available as a data resource to the Heliophysics community will greatly enhance the scientific return from SDO/HMI and will be crucial for understanding magnetic activity from the interior through the solar atmosphere. This proposal thus addresses NASA s strategic subgoal 2.2: Understand the Sun and its interactions with Earth and the solar system.

KD Leka/NorthWest Research Associates, Inc.
Data Services Upgrade: The Mees CCD Halpha Imaging Spectroscopy Database

Data Services Upgrade: The Mees CCD H-alpha Imaging Spectroscopy "Mission"

The U. Hawai`i Mees CCD Imaging Spectrograph ("MCCD", Penn et al, 1991) created a unique database spanning 1989 -- 2005, covering solar cycle 23. The MCCD was run in a full-day "sit & stare" synoptic mode at the Mees Solar Observatory, in coordination with other instruments (including NASA missions such as Yohkoh, TRACE, and SoHO) through the Max Millennium program. Its capabilities in this "flare-mode" setup were (and are) unique: fast (10-30s) scanning over an entire target active region with moderate spatial and spectral resolution but wide spectra coverage: H-alpha +/- 10Angstrom. The data archive has come to the attention of research groups presently investigating pre-flare signatures, flare chromosphere physics, and active region evolution -- but the data are on Exabyte tapes, and effectively inaccessible. The proposing team wishes to retrieve the tapes, rescue the data, and make the data readily available to the broad research community.

Enabled Science Goals: MCCD H-alpha data have contributed to studies on active region emergence and evolution, solar flare and chromospheric surge initiation, pre-flare filament activation, and flare-related particle acceleration. Recently, two teams from the International Space Sciences Institute (ISSI) have expressly identified MCCD data as key for their particular investigations (on flaring chromosphere conditions and on pre-flare signatures). Enabling full access would allow the extension of prior research from case studies to statistical efforts. Community-identified research topics would address two

Science Goals from the latest Heliophysics Division Roadmap: "Solve the Fundamental Mysteries of Heliophysics (F)" and "Build the Knowledge to Forecast Space Weather Throughout the Heliosphere (W)". In particular, the analysis of MCCD data could address goals F1 and F2 (Understanding Magnetic Reconnection and Plasma Processes), and W2 (Develop the capability to predict the origin, onset, and level of solar activity).

Methodology to Enable Science Goals: The MCCD Instrument PI, Dr. Richard Canfield, supports finding a new "curator" for the data; Co-I Penn helped develop the MCCD and published with data from the instrument, as did PI Leka. Tapes will be acquired from U. Hawai`i (Co-I Habbal will enable the transfer). Software Engineer Wagner will automate a data retrieval, reduction, and hosting pipeline. A student intern will handle tape tasks in conjunction with participation in a research project utilizing recovered MCCD data. NWRA possesses suitable hardware and storage infrastructure for this project, and will augment appropriately. MCCD Level-0 raw data are in native FITS format, and will be nominally calibrated and headers updated for WCS compliance for Level-1 dissemination (although calibration to physical units without the possibility of acquiring additional calibration data may be impossible). The archive will be hosted at an NWRA website with full access and searchability, including quick-look context data. Descriptors following the Space Physics Archive Search and Extract (SPASE) guidelines will be prepared for registration of the data archive at a NASA data center to ensure good visibility and access for the broad research community.

Michael Liemohn/University of Michigan
Stormtime plasmapause locations derived from IMAGE EUV

In the proposed study we will complete the creation of a comprehensive database of plasmapause locations derived from NASA s Imager for Magnetopause-to-Aurora Global Exploration (IMAGE) Extreme Ultraviolet (EUV) instrument, provide critical metadata, and archive all of this at the NSSDC in a format compatible with the VxO architecture.

The plasmasphere contains the bulk of the plasma in the inner magnetosphere and thus plays an important role in the dynamics of the ionosphere, ring current, and radiation belt. The plasmapause defines the edge of the plasmasphere, where the density may drop by one or more orders of magnitude over as little as delta-L=0.1. The plasmapause coincides with the radiation belt slot region and, by following its motion, one component of the local electric field can be derived. During storms, convection increases, the plasmapause shrinks, and a plasmaspheric drainage plume forms.

IMAGE gave an unprecedented view of the plasmasphere during its mission (2000-2005), with the EUV imager measuring scattered 30.4 nm flux during its extended apogee passes . The data can be converted to He+ densities and mapped to the equatorial plane.

The MLT-dependent plasmapause position (Lpp) has been determined from IMAGE EUV snapshots for 39 intense (Dst d -100 nT) geomagnetic storms. Katus et al. [submitted] describes the automated method used to determine the sharpest gradient at

each MLT. The method requires that the satellite be at least 1 RE above the equatorial plane such that the data can be properly mapped. The method also requires Lpp to be between 1.5 and 7 RE and the He+ density to be between 40 and 800 cm-3. The resulting Lpp were then validated using manually determined positions. Lpp(MLT) were statistically examined as a function of storm time and categorized by solar wind driver. The analysis revealed a systematic difference between plasmasphere dynamics for subgroups of ICMEs.

This proposed work will extend the efforts of Katus et al. [submitted] to include moderate (Dst d -50 nT) storms that occurred during the mission lifetime. This will more than triple the number of events, allowing future investigations of Lpp dynamics across a broad range of solar wind driving conditions. We will make all of the data available in proper format on CDAWeb with metadata describing the error as well as magnetospheric and solar wind conditions. This work will enable analysis of Lpp in terms of storm size and solar wind driver to determine parameters such as the convection electric field, corotation speed of the plume, plasmaspheric loss and refilling rates, and will significantly augment ring current and radiation belt investigations.

Chang Liu/NJIT

Data Services Upgrade: Improving the Digitized Full-disk BBSO H-alpha Data

Determining the origins of the Sun's activity and predicting the variations in the space environment are important goals identified by NASA's Heliophysics Decadal Survey. The related research depends heavily on NASA's Heliophysics space missions. Nevertheless, there is a general consensus that ground-based solar observations are highly complementary in that they may cover some unique wavelengths and the data may span a relatively long period of several decades. Through a project partially sponsored by NASA under grant NNX11AC05G, we have recently finished digitizing full-disk solar H-alpha images from 1953 to 2000 recorded by National Solar Observatory at Sac Peak and Big Bear Solar Observatory (BBSO). The data have a nominal cadence of 1 minute. Also almost all the high-resolution BBSO film data taken during the period of 1969 to 1995 have been digitized. From the year 2000, we are also obtaining 1 minute cadence full-disk digital H-alpha images with the 8-station Global Halpha Network (GHN), which enable many solar studies including flare forecasting. Using the digitized and digital H-alpha data, we have obtained some significant results mainly on major solar eruptive events.

Due to the nature of the digitized film data and the large data volume, upgrades are greatly desired to improve metadata before useful science information can be fully extracted. Also, the digitized and digital H-alpha data are currently provided through two separate data archiving systems. It is thus expected that after upgrading the digitized film data and consolidating them with the digital data, a unique archive covering nearly six solar cycles can be formed to better help enhance the science return of NASA missions. The integrated database will enable many important science goals closely related to NASA Heliophysics investigations. Some key objectives include large-scale structure of solar eruptions related to the global magnetic topology, and long-term variation of the

statistical and cycle dependent properties of filaments, which carry important information on the magnetic signature of the solar cycle. Our methodology includes the followings.

Improving metadata and data quality. Due to the large data volume, the film images have gone through limited reduction procedures when they are initially digitized and archived. A special problem is that the observation time information is imprinted on film images. For a majority of the full-disk and high-resolution H-alpha data, the time stamp comprises a series of bright digits. In this proposed effort, we will implement optical character recognition and machine learning for an automatic time digit decoding. To improve the data quality, we will also further develop data processing procedures, including background subtraction, intensity normalization, circularization of disk, and removal of scratches in the images.

Facilitating data interpretation. We will produce processed digitized full-disk \ha\ images with information of the decoded observation time, disk center location, and pixel scale. We will make daily, monthly and yearly H-alpha movies, synoptic H-alpha maps for all the available Carrington rotations and solar cycles, catalog of filaments including movies of filament eruptions, and movies of all observed flares extracted from full-disk and high-resolution observations.

Improving data access tools. After consolidating the digitized and digital data, a uniform and web-queryable database will be established using MySQL, PHP and HTML. A preliminary system has been built by this proposal team for the Global H-alpha network. In addition to the calibrated images in FITS format, we will provide a unified front-end website for data services, including links to data and event catalogs, movies, synoptic maps, and any available related space observations from NASA missions.

Christopher Mouikis/University of New Hampshire
Delivery of the background corrected Cluster/CODIF ion composition dataset

The CODIF instrument on Cluster measures ion composition over the energy range 40 eV to 40 keV. During the mission, UNH has had responsibility for the rather extensive in-flight calibration effort, as well responsibility for developing software for data enhancements such as background subtraction, and dead-time corrections. The Cluster/SC4 dataset provides a continuous measurement of the ion composition in the magnetosphere over more than a full solar cycle from 2001 to the present. The Cluster mission has now been extended until 2016, with a likely further extension to 2018, which will allow for continued collaboration with Van Allen Probes missions and MMS. However, NASA no longer funds Cluster MO&DA. Thus there are no longer any funds to continue the calibration efforts or to produce enhanced data products.

The CODIF calibrations have been finalized through the end of 2013. Our background subtraction algorithms have recently been perfected, as we have worked to finalize an inner magnetosphere statistical dataset. In addition, we have improved our algorithms to subtract spillover from H+ into He+. Thus we have new and better algorithms, but we have not been able to process the data to create valid background corrected datasets. The

full distributions that are currently available at the Cluster Science Archive (CSA) do not have these corrections.

We propose to do two tasks for this data enhancement proposal:
1) Extend the CODIF in-flight calibration through at least the end of 2015, and into 2016, as the grant time allows.
2) Produce a dataset of the 3D distributions of the species, H+, He+, and O+ that includes all background subtractions, and deadtime corrections (in the magnetosheath). The dataset will be produced in multiple formats to be compatible with the Cluster Science Archive (CSA) but also in CDF format for submission to NASA. This dataset will extend from 2001 to at least the end of 2015.
The results of this will be a validated dataset that can be used in conjunction with the recent missions, Van Allen Probes and MMS, as well as older missions such as Themis, to study inner magnetospheric science, reconnection, and global magnetospheric dynamics.

James Weygand/The Regents of the University of California
Data Services Upgrade: Expansion of the Spherical Elementary Current System Data set for Magnetosphere-Ionosphere Coupling

Ground magnetometer data from a number of groups are available through individual magnetometers arrays and from large consortiums like Tromsø Geophysical Observatory, SuperMAG, and others. These magnetometer data can be used to calculate equivalent ionospheric currents. Except for the IMAGE array covering only a fraction of Scandinavia, none of these magnetometers arrays provide equivalent ionospheric currents to the community. Ionospheric currents are invaluable for studying magnetosphere-ionosphere coupling. In conjunction with the THEMIS spacecraft mission and ground campaign Weygand et al. [2010; 2012] started a project using ground magnetometer data from about 9 ground magnetometer arrays to calculate the equivalent ionospheric currents (horizontal and vertical currents) over North America and Greenland using the Spherical Elementary Current (SEC) method developed by Amm and Viljanen [1999]. The SEC project later received NASA HIDEE funding to calculate SECs covering mainly the THEMIS spacecraft tail season up to July 2012. These data were made available through the Virtual Magnetospheric Observatory (VMO) and have been used in approximately 17 refereed publications. However, SECs for the most recent 2 plus years have not been calculated and the recent available data do not have quick look images. The main goals of this study will be to calculate the spherical elementary currents for the remaining 29 months, produce quick look plots for these data, and make both available through the VMO. These additional SEC values could be combined with the SuperDARN/StormDARN network, incoherent scatter radar data, THEMIS all sky images, and many different auroral and magnetospheric spacecraft including the recent Van Allen Probes and Swarm missions to support studies on the full electrodynamics of the ionosphere as well as magnetosphere-ionosphere coupling over a large area with spatial and temporal resolution in more detail than previous studies. The SECs can be used to answer such questions as are the region 2 current system ionospheric currents driven by pressure gradients observed by Van Allen Probes in the inner magnetosphere?

By combining the Van Allen Probes plasma and magnetic field data and the SECs one can determine if the calculated field aligned currents in the inner magnetosphere correspond with the simultaneous conjugate SECs derived on the ground. The SECs will also compliment the AMPERE mission field aligned currents and will provide currents during the Van Allen Probes mission when AMPERE has a data gap (May 2013 to March 2015) that may not be filled for years.

Our methodology will be simple and will be completed over a 1 year period by the principle investigator, Dr. J.M. Weygand. Out first task will be to calculate the remaining 29 months of SECs from Aug 1, 2012 to Dec 31, 2014 and make these currents available through the VMO. The programs to complete this task are complete. Our second task will be to create quick look plots for the SECs, write the appropriate meta data for these plots, and submit the plots and meta data to the VMO.

The results of our data enhancement will help others address one of NASA s decadal science plan objectives, which is to understand the Sun s effects on the Earth through magnetosphere-ionosphere coupling and understanding how human society and technological systems are affected by magnetosphere-ionospheric coupling. With the regular availability of the North American ground magnetometer network, the VAN Allen probes dataset to study the inner magnetosphere, the SWARM mission to study Earth s magnetic field and field aligned currents, and the gap in the AMPERE dataset, now is the ideal time to extend our data set of SECs for the community to investigate single event studies and large statistical studies of the ionospheric current system.