Heliophysics Data Environment Enhancements
Abstracts of Selected Proposals
(NNH18ZDA001N-HDEE)

Below are the abstracts of proposals selected for funding for the Heliophysics Data Environment Enhancements program. Principal Investigator (PI) name, institution, and proposal title are also included. 4 proposals were received in response to this opportunity. On December 18, 2018, **4** proposals were selected for funding.

Barbara Giles/NASA Goddard Space Flight Center
Full Plasma Distributions and Moments for the Polar Thermal Ion Dynamics Experiment (Polar/TIDE)

Over the past three decades, it has become obvious that the Earth s ionosphere is a significant source of plasmas within the Earth s magnetosphere and a strong influence on the dynamics of the near-Earth space environment. This seemingly benign source is now known as a significant contributor to the formation of the plasmasphere, the plasma sheet and the ring current and, through wave particle interactions, plays a major role in the formation of the radiation belts. Hence, understanding the strength and dynamics of the outflow of ionospheric particles up into the magnetosphere and their subsequent energization and movement is of critical importance to understanding how the magnetosphere is populated and influenced by these initially very low energy, few eV particles.

The science goal for this proposal is to provide additional means to understand the origin, energization, and dynamics of ion outflow through both measurement and merged modeling. This will significantly advance Heliophysics community s ability to build and test an accurate and successful Geospace General Circulation Model. This addresses NASA Strategic Objective 1.1: Understand the Sun, Earth, Solar System, and Universe.

There are several NASA and NSF-funded initiatives focused on the upflow and outflow of terrestrial plasmas. There are at least five known research grants addressing the topic, a large NASA center ISFM task group, NSF sponsors a GEM Focus Group that regularly draws 60-80 participants, and there are at least two mission concepts in pre-formulation (MEME-X and GDC) that include outflows as a component. Specifically germane to this proposal, the data-model comparisons underway within the GEM group include both new datasets and also older, specialized types of data that are no longer being collected via the system observatory. The Polar TIDE dataset is an important example of the latter.

Polar was a NASA mission to study the polar magnetosphere and aurora. Launched in February 1996 it continued operations until terminating operations in April 2008. TIDE was specifically designed for kinetic diagnostics of the low-energy, low-density ion polar wind and upflows/outflows of the auroral zones. No other instrument has since flown with the sensitivity, energy resolution, and dwell time in the regions of interest. TIDE had seven large apertures, focusing electrostatic optics, and time-of-flight mass analysis with

32-energy channel coverage of the range ~0 eV up to 450 eV, all ideal for the study of ionospheric outflows.

Due to system architecture limitations at the time of data archiving, the publicly available TIDE dataset only provides the plasma moments of density, velocity, and temperature plus omni-directional energy and spin angle spectrograms. Because TIDE is fully 3D -- equivalent to a single head of this team s MMS FPI spectrometers-- it is important to return to this dataset and publish the complete catalog of observations.

We propose to produce the full Polar TIDE dataset in CDF format including a wide complement of spectrograms for quickviews, the full range of calibrated plasma moments using definitive versions of the magnetic field and spacecraft potential and we will release for the first time the fully calibrated Polar TIDE 3D plasma distributions. We recently resurrected on new equipment the previously developed Polar TIDE ground system software and will merge that with our current system used to generate distributions and moments for the Magnetospheric Multiscale (MMS) Fast Plasma Investigation (FPI). This leverages advances from the FPI ground system that will allow for rapid implementation and a greater emphasis on providing error statistics, quality flags, metadata enhancements and other types of data validation.

Lynn Kistler/University of New Hampshire, Durham
Improved Data Products for FAST TEAMS

Science Goals:
      The NASA Fast Auroral SnapshoT (FAST) mission was designed to study the dynamics of the auroral region. FAST was launched in 1996 into a 350 km by 4175 km orbit, with 83 degree inclination. The payload included an ion composition instrument, TEAMS, which covered the energy range 1 eV/e to 12 keV/e. The mission operated until 2009, providing an extensive dataset for studying the auroral outflow variations over a full solar cycle. There have been no subsequent missions focused on this region, so it remains the primary dataset for studying auroral phenomena in situ. This data can be used to study mass-dependent ion acceleration and outflow in the auroral region. Understanding the drivers of ion outflow is a key aspect of the the high priority question identified by the NASA 2014 Strategic Plan, "How do geospace and planetary environments respond" to variable solar wind input.
      However, three problems made analysis of the data problematic in the later years. The first was the decline of the efficiencies in the spin-plane instrument positions. Because these positions were used to generate the standard pitch angle data product, this significantly affected the counting statistics for science involving pitch angle analysis. A second problem was that the angular classification occasionally failed. When the angular classification failed, the data was put into angular bin zero, "bin 0", which is one of the instrument spin-plane positions. During later years, when the efficiencies of the spin-plane positions had declined, most of the data in the spin plane positions used for the pitch angles was from bin 0. By using the full 3D measurement and removing bin 0, a much better pitch angle product can be produced.

The third issue is a problem that occurred in one of the two time-to-amplitude converter (TAC) boards in the TEAMS instrument. This began with a partial failure that caused a fraction of the O+ events to be misclassified as He++, or "mass 2". After 2002, all events measured with this TAC board had very low time-of-flight, so were classified as either H+ or He++ (depending on energy). Because the behavior of the failed board is consistent, it is possible to correct for the misclassifications.

We propose to create a new 3D energy/angle/time product and a new pitch angle/energy/time data product for the four species, H+, He++, He+, and O+ in physical units at the same resolution as the original data that uses the full 3D distribution and has the "bin 0" and "mass 2" problems corrected.

Methodology

Replacing the spin-plane pitch angle product with the 3D product requires a more extensive cross-calibration of the different positions within the instrument than has currently been performed. This will be done by identifying time periods when the pitch angle distribution is peaked at 90 degrees. All of the positions within the instrument measure 90 degrees at some time in the spin. By assuming that all positions should measure the same flux at this pitch angle, the efficiencies for the different positions can be normalized.

For the "Mass 2" problem, we have used the individual event data (called "Pulse Height Analysis", or PHA data) that gives the full information on time-of-flight and position for a subset of particles, to characterize the misclassified data. An algorithm has been developed that corrects for the misclassification.

Using the revised position efficiencies, and the mass 2 correction algorithm, we create new 3D data products at the same energy, angle and time resolution as the original data. We will then create a new pitch angle product from the revised data, using the full 3D distribution. The new data will be put into ISTP-complaint CDF format with SPASE metadata, and delivered to the NASA Space Physics Data Facility.

Sushanta Tripathy/Association Of Universities For Research In Astronomy, Inc. Subsurface Zonal and Meridional Flows from Reconstructed MDI Dopplergrams

Subsurface Zonal and Meridional Flows from Reconstructed MDI Dopplergrams

Science goals and objectives: The proposed work will provide a unique data set of zonal and meridional
flows in the upper convection zone using continuously available low-telemetry Dopplergrams from Michelson
Doppler Imager (MDI) instrument on board Solar and Heliospheric Observatory. This would be a unique data
set for the solar physics community since the continuous MDI observations have never been used to produce
subsurface flows using ring-diagram (RD) technique.

The objective is to infer subsurface horizontal flows using the ring-diagram technique, one of the most

successful tools of local helioseismic analysis. This method has been widely used to measure the flows
using high-resolution Dopplergrams from GONG, MDI and HMI. However for ring analysis, the
observations from MDI have been suitable only during the "Dynamics Program" which normally
occurred about 2 months in a year. Due to telemetry limitations, the data from other periods were
down-sampled, truncated at outer solar limb and downloaded in lower resolution which is not suitable
for standard ring analysis.   As a result, RD analysis using MDI data can be carried out infrequently
only during the 2-month period in a year although MDI observations are available continuously over a
period of 15 years covering two minimum and one maximum periods of solar activity. Thus, our aim is
to use the continuously available low-telemetry MDI data from the low-activity period before cycle 23
through the rising phase of cycle 24. This will allow us to produce contemporary data sets of zonal and
meridional flows in the upper convection zone for the complete solar cycle 23. Note that the flows from
GONG are available from June 2001 and do not cover the low-activity and rising phase of cycle 23.

Methodology: We will use MDI spherical harmonic (SH) time series from JSOC, to reconstruct several
30 by 30 degree patches around central meridian and equator. Use of this SH time series has several
advantages; first, it has been generated from the corrected velocity images (distortion, apodization etc.),
and secondly, a smooth transition near the surface layers can be performed by applying specific filters
to the SH time series in spherical geometry.   Reconstruction of velocity images using the SH
coefficient time series (inverse SH decomposition) will be carried out with the existing time-distance
pipeline developed by us at National Solar Observatory. This pipeline is well tested and validated by
measuring deep meridional flow properties.

These big ring patches (30 degree in diameter as opposed to 15 degree patches used in the standard ring
diagram) will be subsequently used to infer subsurface flow to a depth of 30 Mm by performing custom

ring analysis. It should be noted that, our data product, the meridional flow and its temporal variations
at different depths over 15 years will provide an additional independent data set to compare with
measurements obtained from the time-distance technique. Availability of this data product will allow
interested research teams to investigate solar cycle and long-term variations of flows and dynamics of
the upper convection zone over the whole MDI time epoch in contrast to those available over a limited
period of only two months a year.

In summary, we plan to generate new data products from the continuous MDI observations spanning a
period of about 15 years. These products include: (i) zonal and meridional flows as a function of the
latitude, depth and time, (ii) custom data cubes in and around well-known large active regions for
better investigation of flow pattern around them, and (iii) reconstructed Dopplergrams for the entire
duration of MDI observations. These data products will enhance the usage of MDI Dopplergrams.
All these data products will be available to the public.

Leslie Woodger/Dartmouth College
BARREL Data Enhancement for Electron Precipitation Studies

The NASA BARREL (Balloon Array for Radiation Relativistic Electron Losses) mission used instrumented high-altitude balloons to remote-sense electron precipitation from Earth s radiation belts over broad geographic regions. Each payload s primary instrument was a NaI spectrometer, which measured bremsstrahlung X-rays from precipitating electrons. In measuring energetic electron losses, BARREL was a mission of opportunity in support of NASA s Van Allen Probes mission. Forty payloads were deployed in two Antarctic summers from the British Antarctic Station, Halley Bay, and the South African Antarctic Station, SANAE, creating an array of slow-moving measurement stations.

Following the Antarctica campaigns the BARREL team conducted two extra balloon campaigns out of Kiruna, Sweden using spare payloads. Unlike the Antarctic campaigns, all balloons and instruments in Sweden were recovered and re-flown. During these flights, BARREL observed multiple electron precipitation events in conjunction with Van Allen Probes and LEO satellites such as FIREBIRD. For the second Kiruna campaign, a data logger recorded X-rays at higher energy and time resolution. Considering the volume and resolution of the extra data (240 hours/2.5 GB), and concurrence with satellite wave/particle data, the newly-acquired data from the Sweden flights is valuable in addressing these science goals:

1. Test wave-particle interaction theory by combining BARREL measurements of electron precipitation with simultaneous Van Allen Probe in situ wave, plasma, and energetic particle measurements.

2. Rank the importance of different classes of precipitation and their associated precipitation mechanisms from measurements at a range of magnetic local times and latitudes. The loss rate for different types of precipitation can be estimated and further quantified during periods of conjunctions with LEO satellites to determine their relative importance.

3. Explore high temporal and spatial structure within observed electron precipitation. These features can be compared to coherence scales of wave observations, to shed light on their underlying processes.

This proposal aligns with the Heliophysics strategic objective to understand the sun and its interactions with Earth and the solar system, including space weather and addresses one of the four high-level science goals from the Heliophysics Decadal Survey: Determine the dynamics and coupling of Earth s magnetosphere, ionosphere, and atmosphere and their response to solar and terrestrial inputs .

In support of our three science goals, three enhancements to the BARREL dataset are proposed.

1. Produce and publish (CDAWeb) CDF files of the BARREL Sweden data. For compatibility with the Antarctic data, new CDF files shall include the same data products. This would provide additional electron precipitation observations in conjunction with Van Allen Probes and various other LEO satellites and extend the latitudinal coverage of the BARREL observations.

2. Higher resolution X-ray data products, recovered from the data loggers, shall be produced and published as CDF files. This data product would allow for more in-depth case studies as described in science goal three above.

3. Finally, a catalog data product for BARREL shall be constructed and published. This product includes Van Allen satellite conjunctions, other coordinated satellite data collections, and identifies electron precipitation events. For instance, throughout each BARREL campaign coordinated efforts between the BARREL team and conjunctive satellites teams resulted in time periods of high resolution data telemetered by request from these other missions. These times are currently not documented, yet can greatly enhance the ability of the science community to utilize BARREL data.