Global Environment Modeling

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# The GEMstone

## Notes from Program Director

*Michael Wiltberger (NSF)*

Once again it is a time of change with the Geospace Section at the National Science Foundation (NSF). In mid-March I began my appointment as a rotator to fulfill the role of Magnetospheric Physics Program Director. Sadly, after brief but effective tenure as Geospace Section Therese Moretto-Jorgenson is leaving at the end of April to pursue her research interests at the University of Bergen. She provided the section with excellent leadership and through her stewardship of the Geospace Portfolio Review we have a firm foundation upon which to balance our investments in research, infrastructure, and innovation. I'm pleased to report that Irfan Azeem will be joining the Section as the Program Director for Space Weather in mid-April.

In 2016 36 projects where submitted to the GEM program and 21 Projects where submitted to the Magnetospheric Physics Base Program. Unfortunately, the gap between my arrival at NSF and Janet's departure created a delay in evaluating these proposals. The review process is now well underway and we plan to inform investigators on the status of their proposals in the coming months. A full report on the solicitation will be included in my remarks at the upcoming GEM meeting.

Another issue of note to the community is that until May 6th the government was funded under a continuing resolution (CR). Under the CR we had been allocated a fraction of our typical operating budget and this delayed our ability release funds for current grants and start new awards. The good news is that Congress passed and the President signed authorization bill that keeps NSF funding level so we have begun the process of releasing funds and starting new awards.

The Geospace section is following the recommendation from the Geospace

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Portfolio Review to transition over from funding grants in continuing increments to single obligations. This will, in part, allow us more flexibility in selecting awards in future years, but may impact the number of proposals awarded in the short term. The section is also looking closely at removing deadlines from programs, like GEM, to allow PIs to submit their best ideas at times that work for them. I plan to present a full update on the program and proposal process as part of my presentation at GEM.

Let me conclude this brief note with by saying as your program director I'm available to answer any questions you might have about the NSF. This is especially true for questions about the proposal process. My NSF email address is mwiltber@nsf.gov and my phone number is (703)292-4690. If you are ever in the DC area feel free to contact me for an in person visit to NSF. I look forward to seeing everyone in Portsmouth, VA for the GEM meeting.

**2017 GEM Summer Workshop**
**Portsmouth, Virginia**
**June 18-23, 2017**

The GEMstone Newsletter is edited by Peter Chi (pchi@igpp.ucla.edu) and Marjorie Sowmendran (margie@igpp.ucla.edu). The distribution of GEMstone is supported by the National Science Foundation under Grant AGS-1405565.

# CEDAR Liaison Report

*Yue Deng (University of Texas Arlington)*

The 2016 the CEDAR-GEM joint workshop was held at Santa Fe, New Mexico, June 24 - 29. The traditional Sunday student session about "The Basics of CEDAR/GEM Science" covered broad topics related to magneto-sphere-ionosphere coupling, featuring tutorials on winds in the thermosphere, particle acceleration, currents, reconnection, aurora and ionosphere, space weather, large scale modeling, and ground and space instruments to study the ionosphere.

The meeting included 16 CEDAR sessions and 23 CEDAR/GEM joint sessions, covering a range of themes as proposed by the community. Three of CEDAR sessions were selected as Grand Challenge topics, which were "Coupling and Transport Processes from the Upper Mesosphere through the Middle Thermosphere", "The High Latitude Geospace System" and "Storms and Substorms Without Borders (SSWB)." Over the past several years, CEDAR has been organically moving toward initiatives that combine space-based and ground-based measurement of the coupled "geospace system," in line with the community's 2012 strategic planning document, "CEDAR, The New Dimension." The 2016 workshop included several related science highlights, which covered the topics of acoustic energy inputs into the upper atmosphere, two new FPIs above Antarctica, GNSS for remote sensing of ionosphere, HAARP facility, and the COSMIC-2, ICON and GOLD missions. Meers Oppenheim presented the Particle-in-cell simulations in the "CEDAR Prize Lecture". At the end of the 2016 meeting, John Sahr formally took over as the Steering Committee Chair, replacing Joshua Semeter.

The next CEDAR workshop will be held in the beautiful Keystone Resort, Colorado in June 18-23, 2017. CEDAR will be back to Santa Fe, NM in June 24-29, 2018, which will be one week after GEM in Santa Fe, NM in 17-22 June, 2018. Discussions continue on a sustainable strategy for exploiting deep synergies between the GEM and CEDAR communities in different ways.

*A glimpse of the Joint CEDAR-GEM Workshop at the Santa Fe Convention Center in June 2016.*

# NOAA Agency Report

*Howard Singer (NOAA Space Weather Prediction Center)*

This brief report describes recent highlights and future plans of NOAA's space weather activities relevant to the Geospace Environment Modeling (GEM) community. As described below, driven by the growth and needs of customers, there have been numerous recent accomplishments in the provision of space weather services using current and envisioning planned models and observations. NOAA's Space Weather Prediction Center (SWPC) is also guided, in part, by new national imperatives for meeting societal needs and advancing space weather understanding and services as presented in the National Space Weather Strategy and Action Plan and through working with our interagency, international, academic, and commercial service partners.

Solar cycle 24 peaked in April 2014 and was one of the smallest solar cycles on record; however, as we head toward solar minimum, customer growth in space weather continues to increase. This is illustrated by SWPC's customer subscription service, which climbed to 50,056 at the end of February 2017 (see Figure 1). This is only one of several ways SWPC delivers services but is a good indicator of growing customer needs. At the same time that we experience a weak solar cycle, it is useful to remember that some of the largest geomagnetic storms have occurred during these smaller cycles.

During the past year, several new space weather observation capabilities have initiated. On July 27, 2016 NOAA's Deep Space Climate Observatory (DSCOVR) (carried out in partnership with NASA and DOD) began providing real-time solar wind observations from the L1 Lagrange location. DSCOVR's solar wind velocity, density, temperature and vector magnetic field data are now being utilized in space weather operations and available to the scientific community. At the same time, efforts are underway in NOAA for expanded capabilities at L1 with the Space Weather Forward Observatory (SWFO) including notional launches planned for 2022 and 2027. Current plans for SWFO include solar wind and magnetic field observations, a compact coronagraph, improved plasma measurements and a suprathermal (10keV-2 MeV) ion sensor. SWPC is also working with international partners to coordinate proposed measurements from L5 with the NOAA observations at L1.

Also during the past year, GOES-16, the first of a new series of four GOES geosynchronous spacecraft, was launched on November 19, 2016. GOES-16, in addition to continuing magnetic field, integrated X-ray and EUV, and an extensive range of energetic particle measurements will host new observing capabilities, including: ions and electrons down to 30 eV; heavy ions from 10-200 MeV/nucleon; improved energetic particle energy resolution; ultraviolet solar imagery for improved solar feature characterization with wavelength bands comparable to SDO/AIA; and a faster sampling rate for the magnetometer (10 Hz). GOES-16 data will be available later this calendar year after extensive post launch testing.

SWPC is also working to utilize data from the Constellation Observing System for Meteorology, Ionosphere, and Climate (COSMIC-2) satellites after their launch, which is planned for later in 2017. Also, through collaboration with NSF, SWPC is supporting and leading data processing activities for the National Solar Observatory Global Oscillation Network Group (GONG) data that are used in operations as well as for science. Finally, with respect to observations, working with our partners at Johns Hopkins Applied Physics Laboratory, NASA and Van Allen Probe scientists, we have introduced a new experimental product that provides a radial profile of 2-MeV electrons in Earth's radiation belts. For many years we have used GOES observations to specify the radiation environment at geosynchronous orbit. Now, with the Van Allen Probe data, we can begin to specify the radiation environment inside of geosynchronous orbit to better support the many satellites that operate in medium Earth orbits (MEO).

Modeling the space environment is a significant chal-

lenge that will lead to major benefits for those impacted by space weather. In October 2016, the University of Michigan's Geospace model went into operations with initial products that provide forecasters and web-based users with regional predictions of geomagnetic disturbances. The Geospace model is a first-principles physics-based model which includes three components: the University of Michigan's BATS-R-US magnetohydrodynamic (MHD) model of the magnetosphere; the Ridley Ionosphere electrodynamics Model (RIM) developed at Michigan; and the Rice Convection Model (RCM), an inner magnetosphere ring-current model developed at Rice University. The transition to operations took several years and benefited from working with the institutions listed above, as well as with the Community Coordinated Modeling Center (CCMC), model developers, and the GEM community. New model upgrades are planned for later this year as well as plans for coupling the output of the Geospace model to a geoelectric field model.

SWPC is also working with other models such as the Wang-Sheeley-Arge Enlil Cone model for predicting the background solar wind and the impact of coronal mass ejections, and an Integrated Dynamics in Earth's Atmosphere (IDEA) model for predicting dynamics in the ionosphere and thermosphere.

Another major activity for SWPC, and other national agencies, this year was related to carrying out actions that were defined in the National Space Weather Strategy and Action Plan. The Space Weather Action Plan (SWAP) identifies many efforts that are needed by the Nation for "improving understanding of, forecasting of, and preparedness for space-weather events." The plan includes an action for DOC and DOD, in collaboration with NASA and NSF to "develop a plan (which may include a virtual or physical center) that will ensure the improvement, testing, and maintenance of operational forecasting models. This action will leverage existing capabilities in academia and the private sector and enable feedback from operations to research to improve operational space-weather forecasting." To help define a plan, SWPC, along with our agency partners, hosted the a Space Weather Operations to Research (O2R) Workshop in August 2016 and a follow-up meeting associated with this year's Space Weather Workshop in May 2016. Work on SWAP actions will continue to be important during the coming years as space weather continues to receive much National and international attention.

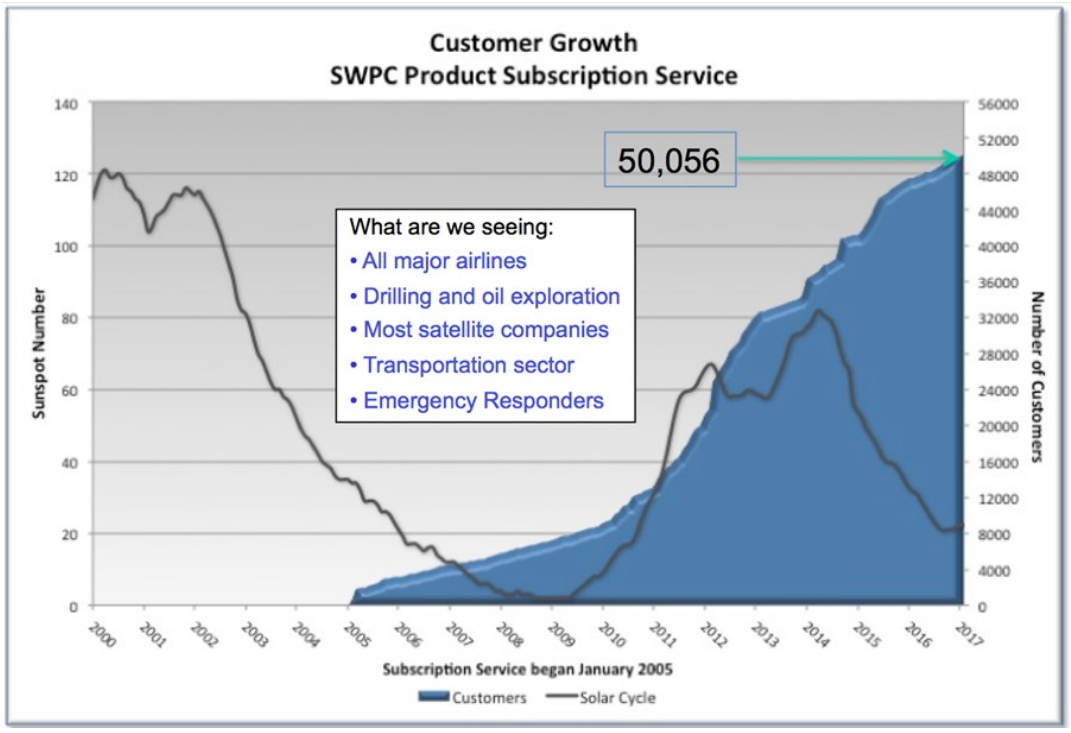



**Figure 1:** SWPC Product Subscription Service as of February 2017—one illustration of customer growth since its beginning in January 2005.

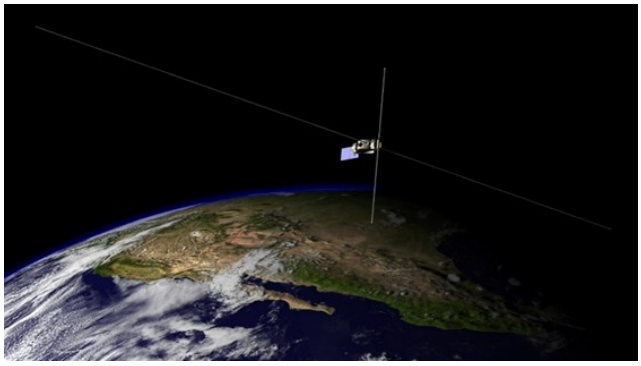
# AFRL Liaison Report

*James McCollough (Air Force Research Laboratory)*

The Air Force encourages science to better understand the space environment. This science is leveraged to extract information about specific populations and phenomena that have practical effects on things like satellites, communications, etc. AFRL's role is to perform in-house R&D and leverage community data, models, and advancements to address AF needs. While this includes a variety of topics of interest to GEM, including M-I coupling and solar wind drivers, we would like to highlight two here: radiation belt modeling and the upcoming DSX mission.

**Radiation Belt Modeling:** In particular, AFRL is interested in understanding radiation belt dynamics to better specify and predict the energetic particle environment. An upcoming Small Business Technology Transfer (STTR) opportunity will target development of an outer zone model to accurately specify outer zone electron fluxes. In addition, imminent release of AE9/AP9/SPM V1.5, including new Van Allen datasets, will continue to improve the state-of-the-art in radiation belt climatology.

**DSX:** Another activity of interest to the GEM community is the upcoming launch of the Demonstration and Science Experiments (DSX) mission. When launched in FY 2018, the Air Force Research Laboratory's Demonstration and Science Experiments (DSX) spacecraft will conduct basic research designed to significantly advance the Department of Defense's capability to operate in the harsh radiation environment of medium-Earth orbit (MEO). DSX is manifested on the Space Test Program-2 (STP-2) mission, utilizing the SpaceX Falcon Heavy launch vehicle. DSX will be flown in an elliptical orbit in MEO for one year of projected experimental operations.



On DSX, the Wave-Particle Interactions (WPIx) payload suite will transmit and receive VLF waves in the 100 Hz to 750 kHz range in order to investigate their interactions with trapped electrons in the magnetosphere. DSX will also study the behavior of an in-situ VLF antenna and characterize its far-field radiated patterns, as well as natural wave-particle interactions at MEO. The Space Weather (SWx) suite of instruments will characterize the high and low energy electron and proton fluxes and pitch angle distributions along the DSX orbit. In addition to providing observations of the plasma effects of the WPIx experiment, it will enable observation of the "slot region" between the inner and outer radiation belt.

# USGS Liaison Report

*E. Joshua Rigler (USGS Geomagnetism Program)*

The following is a brief summary of operations and research undertaken at the United States Geological Survey (USGS) with relevance to the NSF's Geospace Environment Modeling (GEM) program. It is not exhaustive, nor is it indicative of long-term continued efforts.

## 2018 Budget

The 2018 President's Budget would eliminate the USGS Geomagnetism Program, a component of the multi-agency U.S. National Space Weather Program, a reduction of $1.884 million and 15 full-time equivalent (FTE) positions. This would reduce the accuracy of National Oceanic and Atmospheric Administration (NOAA) and U.S. Air Force forecasting of the magnitude and impact of geomagnetic storms. In addition to ending the provision of data provided to partner Federal agencies, the elimination of the program will also reduce the availability of geomagnetic information to the oil drilling services industry, the geophysical surveying industry, several international agencies, electricity transmission utilities, and academia.


## Data Services

The USGS Geomagnetism Program monitors the Earth's magnetic field with high accuracy, (time) resolution, and reliability. It manages 14 magnetic observatories distributed across the Northern and Western hemispheres. "Preliminary" magnetometer data are minimally processed; but made available in near real time, through USGS web services at (geomag.usgs.gov) or via the INTERMAGNET consortium (www.intermagnet.org). "Quasi-definitive" and "definitive" data are thoroughly cleaned and calibrated; these are typically released within ~3 months and ~1 year of acquisition, respectively.

The USGS recently initiated geoelectric field monitoring at the Boulder, Colorado observatory. These data are available in near real time. Presently, no post-processing is performed on these data beyond basic quality checks. This project serves as a template for geoelectric monitoring at other observatories, should future funding allow.

## Targeted Research

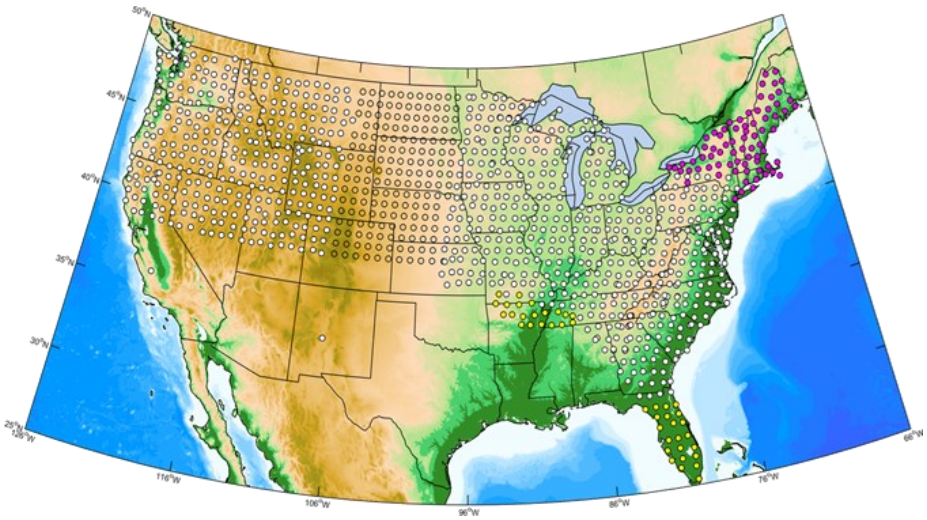
Research within the USGS Geomagnetism Program is concentrated on analysis of geomagnetic data (both real-time and historical), for the evaluation of geomagnetic hazards.

### *Geomagnetic Disturbance Maps*

As part of a multi-agency collaboration with NASA and NOAA, the USGS has developed a real time operations-oriented software package that employs the well-known spherical elementary current system (SECS) inversion technique to interpolate surface magnetic perturbations given sparse geomagnetic observations (github.com/usgs/geomag-imp). NOAA's Space Weather Prediction Center (SWPC) has adapted this software to produce operational gridded magnetic activity maps for the continental United States (CONUS) using near real time data from the USGS and Natural Resources Canada (NRCan) as input.

### *Geospace Model Validation*

The USGS collaborates with model developers to



validate global geospace circulation models (GGCMs) against ground observations. Specifically, they implemented and tested a Python-based Biot-Savart post-processing tool to estimate ground magnetic perturbations given the full geospace electric current distribution. These tools have been applied to longitudinal studies using the Lyon-Fedder-Mobarry (LFM) magnetosphere model to analyze the whole heliosphere interval (WHI). This work builds on a history of collaboration with NCAR's High Altitude Observatory (HAO).

Another aspect of GGCM validation is stress-testing. The USGS is currently working with both LFM and Space Weather Modeling Framework (SWMF) developers to study extreme sudden impulses. Early results led to recognition of the need to modify standard model configurations to accommodate theoretical extreme inputs. This research is ongoing, and adds the University of Michigan College of Engineering's Climate & Space department to our list of collaborators.

### *Magnetotelluric Surveys*

The USGS is closely involved with NSF's Earthscope USArray program, run out of Oregon State University (OSU), to perform a gridded magnetotelluric survey of the continental United States, and to assist with archiving this and related data in a publicly accessible online database (ds.iris.edu/spud/emtf). USArray covers the Pacific Northwest, the Upper Midwest and Great Lakes, Appalachia, and will soon include New England. The USGS has sponsored and conducted its own smaller-scale regional magnetotelluric surveys that augment USArray coverage and support specific industry needs, most notably in Florida, southern Missouri, northern Arkansas, and western Tennessee.

### *Regional, Continental, and Global Ground Conductivity*

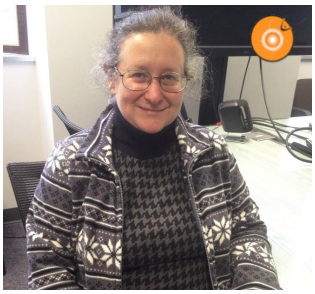
Magnetotelluric impedances are critical for converting magnetic variations into geoelectric fields, but the observed data are often sparse or unevenly distributed. Impedances can be estimated on uniform spatial grids by inverting observed impedances for a geophysically self-consistent conductivity model, then forward-modeling synthetic surface impedances at arbitrary locations. The USGS uses magnetotelluric survey data to generate such conductivity models, and is investigating the effects of scaling and distortion on synthetic impedance grids. To date, these efforts have been regional in scope, but ongoing research promises more continental-scale models that will be directly applicable to the GIC hazard problem.

### *Geoelectric Field and Geoelectric Hazard Maps*

The USGS is a lead agency working in collaboration with NOAA, NASA, and Los Alamos National Laboratory to map time-varying geoelectric fields and evaluate geoelectric hazards that are of concern for the power-grid industry. Magnetotelluric impedances, measured or synthetic, can be combined with maps of geomagnetic activity to produce maps of induced geoelectric fields. To date, statistical hazard maps have been generated using estimates of extreme-event geomagnetic activity. A prototype near real time map of geoelectric activity over CONUS, based on research and tools described above, will soon be made operational by NOAA's SWPC.

# CCMC Liaison Report

*Masha Kuznetsova (NASA Goddard Space Flight Center)*
*With M.L. Mays, L. Rastaetter, CCMC Team, and CCMC Model and Data Product Providers*



The Community Coordinated Modeling Center (CCMC) serves as a hub for advancing space sciences and collaborative development and deployment of new operational space weather capabilities. The CCMC hosts an expanding collection of space weather models (see Figure 1), provides simulation services to the international research community through the web-based Runs-on-Request (RoR) system, develops tools for visualization, analysis and dissemination of simulation results, tests and evaluates models, leads and supports community-wide initiatives, develops multi-purpose applications for space weather research and operational communities, prototypes forecasting techniques and procedure and provides opportunities for hands-on education.

In May 2017 the total number runs in the interactive RoR archive exceeded 17,000. Since January 2016 more that 700 magnetosphere simulation requests have been executed. During the past two years 8300 single-timestep CCMC-Vis visualizations are requested on average each month (including visualization requests for high resolution simulations up to 50 million grid cells). The number of models and model combinations hosted at the CCMC exceeds 80, with 21 models running in real-time and providing feeds to the CCMC Integrated Space Weather Analysis (iSWA) system. Users of the iSWA system can configure custom display layouts by selecting products of interest from a pool of more than 250 active widgets via about 500 active data feeds. The iSWA system is an invaluable tool for event analysis and system science. For example, just in 2016 alone the iSWA system was accessed by more than 33k users from over 140 different countries. The iSWA system's widget display layout is freely adjustable and populates display screens at CCMC, NASA HQ, the 557th Weather Wing, NOAA

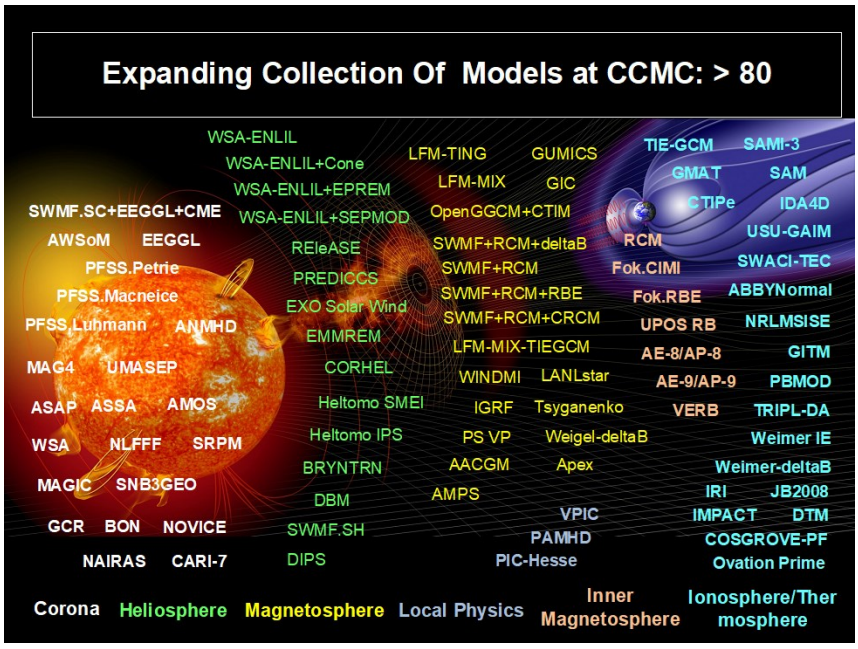



**Figure 1.** Models at CCMC.

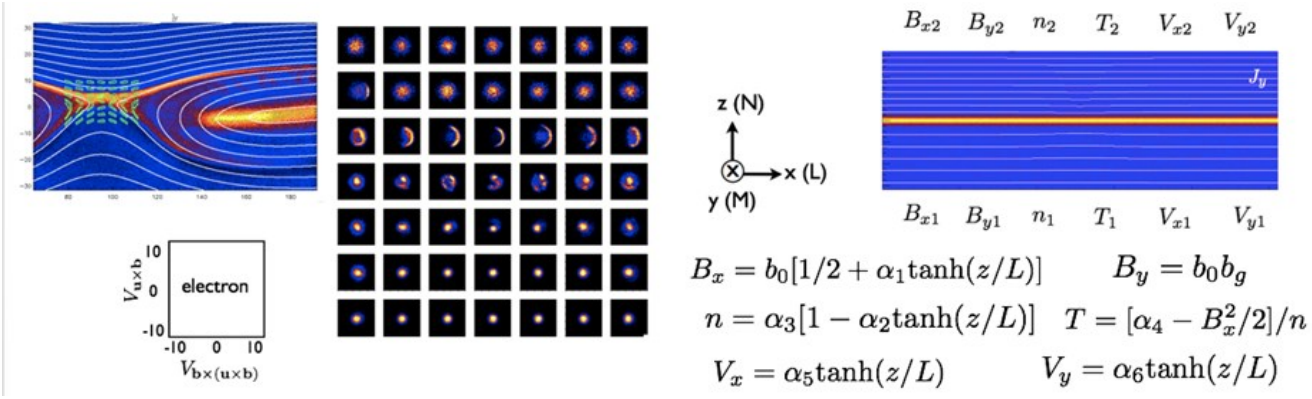



**Figure 2.** Left: VPIC-DIST tool developed by Y-H. Liu applied to the MMS 10/16/2015 Electron Diffusion Region event [Burch et al., Science, 2016]; Right: Initial configuration for custom PIC simulations available on requests by e-mail. Users are invited to request simulations by providing boundary conditions in LMN coordinate system ($B_{1L}$, $B_{1M}$ and $B_{2L}$, $B_{2M}$ in nT, $n_1$ and $n_2$ in $cm^{-3}$, $T_1$ and $T_2$ in eV).

SWPC, UK Met Office, and many educational institutions that have begun hosting classes on space weather in recent years. Future goals of the iSWA and RoR systems include better searching/filtering capabilities along with displaying relevant metadata information (i.e. model information, run information, instrument information) leveraging the CCMC metadata effort.

On request from the GEM Steering Committee and in support of the MMS dayside campaign the CCMC initiated implementation of local particle-in-cell simulations. Initially PIC model (VPIC and PIC-Hesse) simulation results were provided by model developers and made available through the CCMC web-based visualization and analysis that include fields and plasma parameters, moments (including pressure tensor components) and quick-look distribution functions. In addition, users can request custom computations of phase space density (PSD) in three-dimensional velocity space at selected locations. Recently implemented VPIC-DIST tools, developed by Y-H. Liu, computes PSDs in field-aligned coordinates (see Fig. 2, Left). PSDs can also be visualized as nested iso-surfaces using predefined density thresholds, in addition to two-dimensional slices taken from the three-dimensional distributions or two-dimensional, reduced distributions. The CCMC is now accepting orders for custom 2 ½ D PIC simulations using V-PIC or PIC-Hesse codes (see Fig. 2, Right).

To put MMS observations and local PIC simulations into global context the CCMC performed global magnetosphere simulations for all published MMS diffusion region crossing events (https://ccmc.gsfc.nasa.gov/missionsupport/MMS_support.php). A RECON-X tools developed by A.Glocer have been implemented in the new post-processing category available for requests through the RoR system. RECON-X calculates separatrix surfaces that distinguish regions of magnetic topology (based on magnetic connectivity) and separator lines where these surfaces intersect. The CCMC has developed interactive tools to visualize surfaces and lines supplied by the RECON-X using the Plotly libraries. Plotly visualization are rendered within web browsers and provide various interactions with the objects of a scene such as position value on vertices at the mouse pointer position in the view plane. Surfaces can be colored with any physical quantity that exist in the 3D space at a given location. The tool visualizes MMS and other spacecraft locations with respect to magnetospheric boundaries and calculates proximity to separator lines.

By collaborating with model developers, the CCMC enables developers to enhance and/or add model features of value to the CCMC user community. During the past few years CCMC scientists and soft-

ware developers worked with M. Jin, W. Manchester, and I. Sokolov (University of Michigan) to recast the eruptive flux-rope component in the solar corona (SC) and inner heliosphere (IH) components of the Space Weather Modeling Framework (SWMF, *Gombosi et al*), as a web-based user-driven design tool called EEGGL (Eruptive Event Generator - Gibson and Low). EEGGL loads magnetograms available through our CCMC database, to produce coronal mass ejection (CME) input parameters for SWMF/SC/IH. The user selects locations of the positive and negative field for the target active region and inputs an estimated initial CME speed. The result is an enhanced model capability enabling community users, for the first time, to design coupled coronal and solar-wind simulations that include CMEs with their own internal magnetic field. This service is offered for Runs-on-Request since November 2016 (see NASA press release, https://www.nasa.gov/feature/goddard/2017/new-space-weather-model-helps-simulate-magnetic-structure-of-solar-storms/).

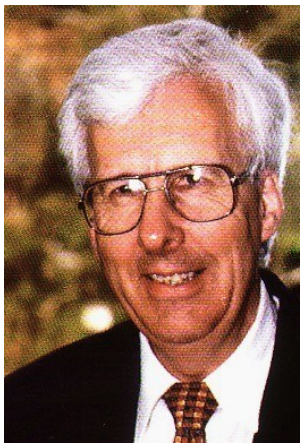
The CCMC is leading the "International Forum for Space Weather Modeling Capabilities Assessment". Its goals are to define metrics to assess the current state of space weather modeling capabilities and to help capture scientific progress in models that feed into operations. Model and application developers, data providers, forecasters, and end-users are working together to establish internationally recognized metrics meaningful to end-users and decision makers. The forum is a long-term activity to evaluate the current state of space environment applications, forecasting techniques, challenges in data-model comparison, uncertainties and sensitivities to external drivers, internal parameters and assumptions.

To address the goals of the forum, six physical domains were identified, with multiple working teams within each domain. Two additional teams were established to focus on information architecture and general scientific progress tracking issues common to all the physical domains. For a description of the domains, working teams, and progress reports please see https://ccmc.gsfc.nasa.gov/assessment/forum-topics.php. To jumpstart the forum, the CCMC organized the "International CCMC-LWS working meeting: Assessing Space Weather Understanding and Applications", held on April 3-7, 2017 in Cape Canaveral. The meeting attracted 120 participants representing all of the elements of the R2O process, including basic research, policy makers, operational modeling and forecasting, and end users. The working teams made significant progress in identifying and developing metrics optimized for their respective user and science communities, as well as identifying vital infrastructural needs such as data architectures and validation efforts. The teams planned task schedules and assignments for completion during the next 12 months, and developed individual plans for interaction through regular telecons, discussions at GEM, CEDAR, SHINE workshops, and mini-meetings at other community conferences throughout the year.

In 2016-2017 CCMC and NSF has held the fifth annual CCMC Student Research Contest. Participants were current undergraduate and graduate students who are using (or have recently used) CCMC tools and services in a research project or as a part of coursework to enter the contest. The 1$^{st}$ place winners are: Agnit Mukhopadhyay (University of Michigan, M.S. Aerospace Engineering ) "Statistical Comparison of the Magnetopause Distance and CPCP for Global MHD" (supervisor: Dr. Xianzhe Jia); Shreeya Khurana (Montgomery Blair High School) "Geomagnetic Storms: A Study of the Relationship between Geomagnetic Storms and the Interplanetary Magnetic Field, and Monitoring Geomagnetic Storms in the Ionosphere with GPS Errors" (supervisor: Dr. Yaireska M. Collado-Vega); Miles Bengtson (Embry-Riddle Aeronautical University, M.S. Engineering Physics) "Solar Wind-Magnetosphere Coupling: A Global Perspective of Substorm Onset (supervisor: Dr. Katariina Nykyri).

# Australia Liaison Report

*Brian Fraser (University of Newcastle)*



## Australian CubeSats

Three Australian designed and built CubeSats were delivered to the International Space Station in April for orbit placement in a month or so, as a contribution to the QB50 project involving 36 worldwide institutions. They will carry instruments provided through the Von Karman Institute to examine the lower thermosphere. The University of New South Wales (Sydney) CubeSat, UNSW-EC0 (QB50 AU02), is running 4 experiments including a GPS receiver, two boards testing radiation-robust software and self-healing electronics, and a module to test the satellite's chassis, built using a 3D-printed material, never before flown in space. The University of Sydney is the lead along with UNSW and the Australian National University on INSPIRE-2 (QB50 AU3), with GPS, a spectrometer and ionospheric probe payloads. The University of Adelaide CubeSat SUsat Au-01) includes atmospheric and water detectors and an ion/neutral spectrometer experiments.

## SuperDARN Radars

The three SuperDARN radar systems located on Bruny Island (Tasmania), Adelaide (South Australia) and Unwin (south end, South Island New Zealand) are in continuous operation monitoring the dynamics of the ionosphere. The Australian consortium operated by La Trobe University, the University of Adelaide, the University of Newcastle and the Australian Government Bureau of Meteorology is a member of the worldwide SuperDARN consortium.

# ESA Liaison Report

*Benoit Lavraud (IRAP, Toulouse, France)*

This report only concerns "GEM-related news" regarding major and recent ESA missions and programmatic calls.

### Cluster and SWARM

With a large number of instruments still working nominally, ESA recently decided to extend the operation of the four-spacecraft Cluster mission up to 31 December 2018. On its side, the SWARM mission (launched on 22 November 2013) is still allowing significant science advances. It recently helped in putting forth a new auroral feature called 'Steve'; cf. Figure below, ESA news link and references therein: http://www.esa.int/Our_Activities/Observing_the_Earth/Swarm/When_Swarm_met_Steve.

### Small-size S2 mission

The SMILE mission was selected in 2015 as a joint European and Chinese small mission. SMILE will be launched into a highly inclined, elliptical orbit to a third of the way to the Moon. From this orbit it will make images and movies of the magnetopause, the polar cusps, and the auroral oval for the first time based on X-ray imaging from afar. It is currently being implemented; more details are given in the GEM report from China.

### Medium-size M4 mission selection (launch 2026)

ESA selected 3 missions mid-2015 for two-year phase A studies: ARIEL (exoplanets), XIPE (X-ray astronomy) and THOR (space plasma turbulence). Of interest to the GEM community is THOR: a single spacecraft mission dedicated to the study of solar wind and magnetosheath turbulence at kinetic scales, with unprecedentedly high resolution wave and particle measurements (beyond MMS). The final selection has recently been delayed and will now occur in November 2017. The mission payload comprises significant contributions from several US space instrumentation groups.

### Medium-size M5 mission selection (launch 2028)

Recently, ESA announced that 12 of 29 proposals submitted for this call passed the technical and programmatic evaluations. The missions of interest to GEM which go further are:

- JANUS. Exploration of the asymmetric magnetosphere, with a dual spacecraft mission design on Molnya type orbits, dedicated primarily to continuous/simultaneous auroral imaging
- ESCAPE: European SpaceCraft for the study of Atmospheric Particle Escape: a single satellite on rather low-Earth orbit to study escape processes to the Earth's magnetosphere, with strong emphasis on composition measurements (Nitrogen/Oxygen)
- ALFVEN: A dual spacecraft mission in rather low Earth Orbit to study particle acceleration in strongly magnetized plasmas.

The payload of these missions also comprise contributions from several US space instrumentation groups.

# ISAS Liaison Report

*Yoshi Miyoshi (Nagoya University, Japan)*

This report only concerns "GEM-related news" regarding major and recent ISAS missions. Currently-running space-physics satellites of ISAS are GEOTAIL and ARASE (ERG).

## GEOTAIL

GEOTAIL operation will continue at least until the end of Mar. 2019. NASA is continuously supporting GEOTAIL (tracking by DSN (Deep Space Network), and making level-1 data). THEMIS-GEOTAIL conjunction, MMS-GEOTAIL conjunction observations are continuing. When you analyze THEMIS or MMS data, please also use simultaneous GEOTAIL data. You can easily browse data plots of GEOTAIL, THEMIS, and MMS at a website called CEF (Conjunction Event Finder): http://darts.isas.jaxa.jp/stp/cef/cef.cgi. At CEF, GEOTAIL data can be browsed about two weeks after the acquisition of the data. (To be more specific, magnetic field data, electric field data, and low-energy plasma data, can be browsed.) GEOTAIL digital data are open to public at a website called DARTS at http://darts.isas.jaxa.jp/stp/index.html.en. When you used the GEOTAIL data in your paper, please tell that to ISAS, for the record. The DARTS website shows where to contact. About a year ago, GEOTAIL Project Scientist was changed from Dr. Masaki Fujimoto to Dr. Hiroshi Hasegawa. Requests of GEOTAIL digital data that are not found at DARTS are to be sent to both Dr. Hiroshi Hasegawa (Project Scientist): hase@stp.isas.jaxa.jp and Dr. Yoshifumi Saito (Project Manager): saito@stp.isas.jaxa.jp.

## Arase (ERG)

Arase (ERG) satellite was launched on December 20, 2016 to explore the inner magnetosphere and the raditaion belts. After the initial operation, the Arase satellite has started the initial observations from the end of March and we have a campaign observations between Arase and ground-based observations. The information of the science instruments onboard the Arase satellite are found in the webpage of the ERG Science Center (http://ergsc.isee.nagoya-u.ac.jp). CDF files for the orbit and related software, tools are also found in the science center webpage. If you have any questions on the Arase satellite, please contact Dr. Shinohara (Project Manager) :iku@stp.isas.jaxa.jp and Dr. Miyoshi (Project Scientist) : miyoshi@isee.nagoya-u.ac.jp.

# South Korea Liaison Report

*Jaejin Lee (Korea Astronomy and Space Science Institute)*

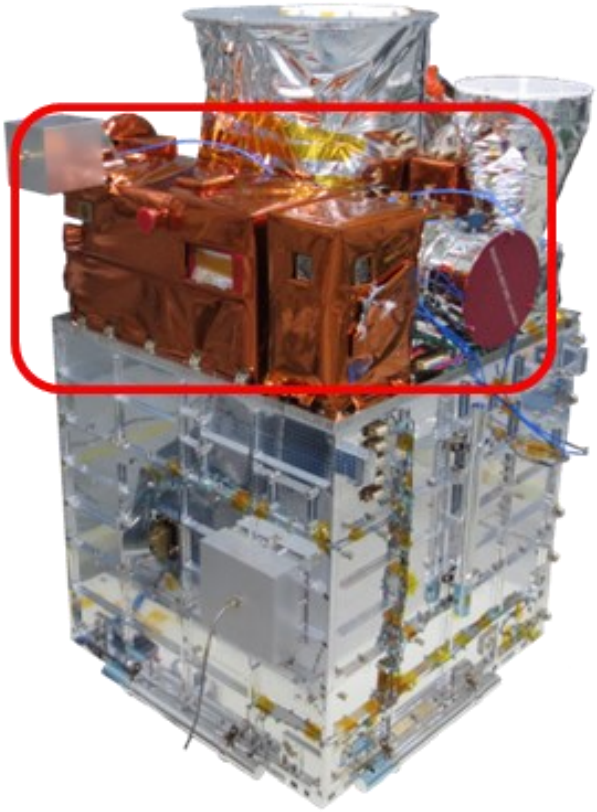
(1) The second KASI-NASA working group meeting was held on 31 March at NASA Headquarters in Washington DC. Both sides discussed of two cooperative space missions, nanosatellite constellation for Magnetospheric and Ionospheric research, and a solar coronagraph on ISS. The Working Group noted that cooperation between NASA and KASI has steadily increased as KASI has built up its experience and capabilities and that the time is right to begin to explore how best to expand Heliophysics cooperation to space-based missions. The third meeting will be held in September, during COSPAR Symposium, in Jeju, Korea.

(2) KASI (Korea Astronomy and Space Science Institute) completed SRR (System Requirement Review) of SNIPE (Small scale magNetospheric and Ionospheric Plasma Experiment) mission on April 7, 2017. The SNIPE mission consists of four nanosatellites (~10 kg) and will perform formation flying in low earth orbit (~500 km) to investigate plasma irregularities and electron precipitations. The SNIPE mission will be launched in 2020.

(3) Kyunghee University has developed space weather instruments (KSEM; Korea Space Environment Monitor) composed of three detectors, Particle Detector, Spacecraft Charging Monitor and Magnetometer to board Korean meteorological satellite, GK-2A. The satellite funded by KMA (Korea Meteorological Administration) is scheduled to be launched in 2018 into the geosynchronous orbit, longitude of 128.2° E.

KASI-NASA Working Group Meeting Participants

(4) KAIST (Korea Advanced Institute of Science and Technology) is waiting for the launch of ISSS (Instruments for the Study of Space Storms) aboard NEXTSat-1. The ISSS is an instrument suite consisting of five space plasma detectors; High Energy Particle Detector (HEPD), Medium Energy Particle Detector (MEPD), Langmuir Probe (LP), Retarding Potential Analyzer (RPA) and Ion Drift Meter (IDM). The NEXTSat-1 is a Korean scientific satellite (~ 100 kg) and scheduled to be launched in 2017 on the low earth (~ 600 km) polar orbit.



ISSS (red) installed on the NEXTSat-1

# Taiwan Liaison Report

*Lou Lee (Academia Sinica)*

There will be two satellite launches from Taiwan in 2017 and 2018. These two satellite missions can make contributions to space weather study.

### (A) FORMOSAT-5 Mission (Launch 2017)

As a FORMOSAT-2 follow-on mission, National Space Organization in Taiwan (NSPO) has self-reliantly finished developing FORMOSAT-5 program to mainly provide 2-m resolution panchromatic and 4-m resolution multispectral imagery with capability of two-day revisit and global coverage. In addition, an advanced ionospheric probe (AIP) with the heritage of FORMOSAT-1 Ionospheric Plasma and Electrodynamics Instrument is also onboard FORMOSAT-5 satellite. AIP, an all-in-one plasma sensor with up to 8192 Hz sampling rate, will provide the measurements of ionospheric plasma concentrations, velocities, and temperatures over a wide range of spatial scales to study the Earth's ionosphere and contribute to space weather study. The mission can also benefit the research of ionospheric seismic precursor and eventually to mitigate the loss of earthquake disasters.

### (B) FORMOSAT-7/COSMIC-2 Mission (1st set Launch 2018)

The FORMOSAT-7/COSMIC-2 is a collaborative program between Taiwan and the U.S. following the success of FORMOSAT-3. The program will launch the 1st cluster of 6-satellites into low-inclination orbits in 2018. Each satellite is equipped with three payloads, Radio Occultation receiver (TGRS), Ion Velocity Meter (IVM), and RF Beacon (RFB). The TGRS is capable of tracking up to 4,000 high-quality profiles per day. The IVM directly measures the ion temperature, velocity in the path of each satellite. The RFB measures the irregularity of electron densities in the ionospheric layer. The FORMOSAT-7/COSMIC-2 mission will provide a revolutionary increase in the number of atmospheric and ionospheric observations, which will greatly benefit the research and operational communities for atmospheric weather forecasting and space weather forecasting.

# GEM Steering Committee

**NSF Program Director**

- Mike Wiltberger

**Steering Committee Regular Members (Voting Members)**

- Jacob Bortnik (Chair, 2017-2019)
- Paul Cassak (Chair-elect, 2019-2021)
- Weichao Tu (2015-2018)
- Christine Gabrielse (2016 - 2019)
- Dan Welling (2016 - 2019)
- Research Area Coordinators (see below)
- Meeting Organizer (see below)

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- Yoshizumi Miyoshi (Liaison to ISAS, Japan)
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- Xochitl Blanco-Cano (Liaison to Mexico)
- Lou Lee (Liaison to Taiwan)

**Meeting Organizer**

- Robert Clauer (2005-2018)

**Student Represenatives**

- Anthony Saikin (2016 - 2017)
- Suzanne Smith (2016 - 2018)

**Research Area Coordinators**

*Solar Wind-Magnetosphere Interaction (SWMI)*

- Katariina Nykyri (2012-2018)
- Steve Petrinec (2015-2021)

*Magnetotail and Plasma Sheet (MPS)*

- Andrei Runov (2014-2018)
- Matina Gkioulidou (2015-2021)

*Inner MAGnetosphere (IMAG)*

- Scot Elkington (2013-2018)
- Seth Claudepierre (2015-2021)

*Magnetosphere-Ionosphere Coupling (MIC)*

- Marc Lessard (2012-2018)
- Shin Ohtani (2015-2021)

*Global System Modeling (GSM)*

- Frank Toffoletto (2012-2018)
- Alex Glocer (2015-2021)

**Communications Coordinator**

- Peter Chi (2014 - 2019)

## GEM on the Internet

**GemWiki:** http://aten.igpp.ucla.edu/gemwiki/
**GEM Workshop Website:** http://www.cpe.vt.edu/gem/
**GEM Messenger** (Electronic Newsletter):

- To subscribe or manage subscription: Go to the mailing list website at http://lists.igpp.ucla.edu/mailman/listinfo/gem
- To post announcements: Fill out the online request form at http://aten.igpp.ucla.edu/gem/messenger_form