Global Environment Modeling

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The GEMstone

Notes from GEM Chair

Jacob Bortnik

The GEM community is all aflutter in anticipation of this year's summer workshop, scheduled to begin almost exactly one month from today and to be held at the La Fonda hotel, Santa Fe, NM, over the period June 22-28, 2019. As with last year's summer workshop, GEM and its sister community CEDAR will hold back-to-back meetings, with CEDAR taking place on June 16-21, and having a CEDAR-GEM overlap day on Saturday June 22nd which will take advantage of the unique opportunity presented by both communities being at the same place at the same time. Although last year's summer workshop was the largest one to date, this year seems to be on track to meet and exceed last year's record with 285 registered participants, 84 of which are students (that's already 11 more students than last year's final number and we are still a month out from the meeting!).

This year we are delighted to welcome our colleagues from the Magnetospheric Multiscale (MMS) mission Science Working Team, which will be held in conjunction with GEM, as well as piloting an Under-Represented Minority (URM) lunch event on Wednesday afternoon, following the highly successful presentation on microagressions at last year's meeting, given by the New Mexico Women's Organization. We are also offering (for the first time) family-care grants of ~$400 to offset the costs of childcare for scientists with young children who would like to attend the GEM meeting and need assistance with childcare.

The current issue of the GEMStone is a little unusual in that it combines Focus Group (FG) final reports (divided according to the 5 Research Areas

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that comprise the GEM program), with the GEM Liaison reports, possibly explaining the 50+ pages of the text that follows. Yet, it is a reflection of the nature of GEM: vibrant, dynamic, and bursting with activity. You will notice in reading the GEM workshop schedule that every slot is filled, often with 3 or 4 concurrent sessions, with activities extending over lunches and into dinner-time. As FGs conclude, new ones are launched; two newly selected FGs starting this year are the "System Understanding of Radiation Belt Particle Dynamics through Multi-spacecraft and Ground-based Observations and Modeling" group (IMAG research area, period 2019 – 2023, co-led by Hong Zhao, Lauren Blum, Sasha Ukhorskiy, and Xiangrong Fu), and the "Particle Heating and Thermalization in Collisionless Shocks in the MMS Era" (SWMI research area, period 2019 – 2023, co-led by Lynn Wilson III, Li-Jen Chen, Katherine Goodrich, and Ivan Vasko). We also want to extend our thanks and a warm welcome to the new NSF MAG program director, Dr. Lisa Winter, who will be overseeing the GEM program, and remind GEM members that due to our regular Steering Committee rotation, we are actively seeking nominations and applications from the GEM community for the GEM Vice Chair position and two at-large steering committee members. Please apply!

The second part of the GEMStone is a set of reports from our GEM Liaisons, who represent our connections to the broader Space Science community: our NSF sister-organizations, government agencies, research laboratories, and international colleagues. I encourage everyone to read through these reports carefully to get a sense of the breadth and diversity of activities going on nationally and around the world. To present a few tantalizing snippets I will highlight NOAA's renewed focus on meeting societal needs and advancing space weather understanding and services according to the recently revised National Space Weather Strategy Action Plan, which includes planning for the SWFO (Space Weather Follow On) satellite to L1. We note NASA CCMC's role as a hub for collaboratively advancing operational space weather capabilities (note the Python-based Kamodo analysis suite, and recall the Python training session at this year's GEM meeting on Monday afternoon). A host of projects are described including the USGS's Geoelectric Hazard Map, ESAs Debye mission, AFRLs upcoming DSX mission (to be launched during the GEM workshop!), CASs IMCP and Meridian Project II, as well as Taiwan's 6-satellite Formosat-7/Cosmis-2 mission, ESAs SMILE mission, and Australia's array of 52 autonomous optical sky imagers! There is certainly no shortage of interesting projects to get involved in!

Finally, I'd like to personally thank our outgoing GEM workshop coordinators, Bob Clauer and Zhonghua Xu from Virginia Tech who have led the workshop organization tirelessly for over a decade, and welcome our new workshop coordinators Chris Mouikis and Chia-Lin Huang from the University of New Hampshire, and Ms. Umbe Cantu who is a former GEM workshop organizer and long-term friend of the GEM community. We are excited about this year's GEM summer workshop and invite all GEM members to check out the latest news and information on the workshop website, at https://gemworkshop.org/index.php. If you haven't yet subscribed to the GEM messenger, please do so at: http://lists.igpp.ucla.edu/mailman/listinfo/gem.

No good story is complete without a cliffhanger, so I conclude by saying that the rumors are true! GEM and SHINE are in the midst of planning a back-to-back meeting in Hawaii sometime around mid-July of 2020, with exact dates and locations TBD. Please stay tuned!

We look forward to seeing you all in Santa Fe in June.

Jacob Bortnik on behalf of the GEM Steering Committee.

Notes from GEM Program Director

Lisa Winter (NSF)

It is with great pleasure that I address you as the NSF Magnetospheric Physics Program Director and I look forward to meeting with many of you at the up-coming GEM meeting in Santa Fe. I came to NSF from Los Alamos National Laboratory, where I was a research scientist in the Intelligence and Space Research group working on a variety of GEM-related topics. Since joining NSF, there have been many exciting new developments that I am pleased to share with you.

First, I would like to congratulate the two new 2019 **NSF CAREER** awardees, both with exciting research and education programs at Boston University. Wen Li was awarded her project to study the role of whistler waves in plasmaspheric plumes on radiation belt dynamics and conduct an ambitious outreach program for K-12 students that will engage >200 young women in STEM. Brian Walsh was awarded his project to study the dynamics of magnetic reconnection in 3D and to develop a new spacecraft mission design course and develop space weather lessons for the BU UDesign summer program. NSF looks forward to supporting early-career scientists and we encourage all eligible new faculty to consider applying to the program which has a due date of July 19. For post-doctoral scholars, I'm happy to announce that the **Atmospheric and Geospace Sciences Postdoctoral Research Fellowships** (AGS-PRF) solicitation is now out and we invite applications at any time as there is no deadline.

In March we had the first Geospace **NSF Ideas Lab**, which is an intensive meeting to find innovative cross-disciplinary solutions to a grand challenge problem. The Ideas Lab focused on new constellations and/or swarms of CubeSats to advance geospace science. Engineers and scientists met together for an intense one-week workshop to come up with entirely new mission concepts that will develop cutting edge technologies enabling a constellation/swarm of 10-100 satellites to transform space-based science investigations. Full proposals for this program are due May 30 and we look forward to informing the GEM community of the results shortly!

Additional programs include the **Faculty Development in the Space Sciences** program (due May 24) and the **Distributed Array of Small Instruments** (due April 19), both of which were recommendations to NSF from the Heliophysics Decadal Review. Of course, there are still the many exciting research results and studies being supported by both the GEM and Magnetospheric Physics base program. These proposals have no deadline so send us your new ideas at any time! We have many exciting new projects that were funded this year spanning a range of topics such as magnetotail reconnection, wave particle interactions, cosmic ray albedo neutron decay, auroral radio emissions … Please send in your next exciting GEM-related project ideas to the no-deadline NSF GEM program solicitation (18-543)!

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.

Solar Wind-Magnetosphere Interaction Research Area Report

Coordinators: Steve Petrinec and Brian Walsh

Tail Environment and Dynamics at Lunar Distances Focus Group

Co-Chairs: Chih-Ping Wang, Andrei Runov, David Sibeck, Viacheslav Merkin, and Yu Lin

The Tail Environment and Dynamics at Lunar Distances FG held two sessions at the 2018 GEM summer workshop. There were a total of 12 presentations.

1. Robert Allen presented observations from the Cassini Earth fly-by of keV ions in the distant magnetosheath. These observations suggest both a high variability in the width of the distant magnetosheath, as well as indications of a distinct magnetosheath population as far down-tail as 6000 R_E.

2. Jay Johnson (presented for Yu Lin) presented the generation, structure, and propagation of kinetic Alfvén waves in the magnetotail associated with fast flows based on 3D global hybrid simulations using ANGEL3D. The results show (1) Alfvénic waves are generated in reconnection, propagating earthward and tailward near the plasma sheet boundary layer. (2) Alfvénic waves propagate to the north (along the direction of B) in the Northern Hemisphere and to the south (against B) in the Southern Hemisphere in the dipole-like field region. Kinetic Alfvén waves associated with bursty flows in the plasma sheet observed by THEMIS and in the ionosphere by DMSP were also shown.

3. Shin Ohtani described the statistical study of dipolarizations observed by the Van Allen Probes in the inner magnetosphere (Ohtani et al., 2018). The statistics showed that dipolarizations (i) take place more frequently closer to the Van Allen Probes apogee distance and (ii) propagate earthward. He suggested that these results can be explained by assuming two wedge current systems, one with the R1 sense staying outside of geosynchronous orbit and another with the R2 sense moving earthward along with injections. He discussed this idea in the context of the flow braking and the plasma bubble penetration.

4. Joachim Birn presented results from further analysis of an MHD simulation of the current diversion in the substorm current wedge (SCW) (applicable also to individual flow bursts), showing, from lower to higher latitude, field-aligned currents of region 2, region 1, and region 0 sense. While R1 and R2 FACs were associated with pressure gradients, and thus persisting for longer times after the generating flows subside, the R0 current, recently observed in the tail by Rumi Nakamura, were " inertia-driven", and thus likely short-lived and less likely to map to Earth. He also showed the energy flow and conversion from magnetic to flow energy, which suggests enthalpy flux as the ultimate energy source feeding the SCW.

5. Jiang Liu presented coordinated observations of flows measured by Swarm and omega band aurora from all sky imagers. The observations show: (1) An ionospheric flow shear exists near the poleward boundary of the omega band arc and leads to an eastward flow peak poleward of the arc. (2) The flow shear is located near the boundary separating region 1 and region 2 currents and maps to a nightside L shell of 6-11. (3) The flow shear may drive the omega band via Kelvin-Helmholtz instabilities.

6. Xiaochen Shen presented Kelvin-Helmholtz waves (KHWs) observed simultaneously in the near-Earth space by Geotail (X ~ -5 R_E, dawn side) and mid-tail region by ARTEMIS (X ~ -50 R_E, dusk side). Results suggest that both the phase velocity and spatial scale of KHWs may increase as they propagate along the magnetopause. Further observations of KHWs in the same side of the magnetosphere is needed to confirm the time evolution of KHWs along the Earth's magnetopause.

7. San Lu presented three-dimensional PIC simulation results showing a dawn-dusk asymmetry of the magnetotail thin current sheet. This asymmetry is formed through ExB drift in the Hall electric field on a small spatial scale and a short time scale. The asymmetry of magnetotail current sheet properties can explain why there are more magnetotail reconnection occurrences, transients, and substorm onsets observed on the duskside as compared to the dawnside.

8. Anton Artemyev presented a local 3D structure of the thinning current sheet with a dataset collected by three THEMIS spacecraft and GOES 15. He demonstrated that the near-Earth current sheet thinning is accompanied by the formation of the equatorial plasma gradients directed toward midnight. Formation of these gradients is accompanied by an intensification of the dawn-dusk current (current sheet thinning) and field-aligned currents with opposite polarities at the dawn and dusk flanks. An increase of the equatorial plasma pressure (and lobe magnetic field) is provided by a cold plasma density increase in the near-Earth tail.

9. Stefan Kiehas presented modeling results of a bent magnetotail current sheet built by means of a generalization of the Harris–Fadeev–Kan–Manankova family of symmetric solutions of the Vlasov–Maxwell equations. He showed and discussed the conditions that a bent current sheet can destabilize the magnetotail.

10. Andrei Runov presented tail current sheet structure at lunar distances observed by ARTEMIS. The results show: (1) Magnetic field shear makes a significant contribution to the pressure balance for 50% of observed current sheets. (2) Intense field-aligned currents 1–10 nA/m^2) exist at the lunar distance magnetotail.

11. Chih-Ping Wang presented a candidate event for the next modeling challenge. From ~06-12 UT on 9 July 2017, 8 satellites were approximately aligned along the noon-midnight meridian (|Y| < 10 RE). Cluster and Van Allen Probes were on the dayside, GOES 13 and 15 were on the nightside, Geotail was at X ~ –12 RE, MMS at X ~ –22 RE, and ARTEMIS P1 and P2 were at X ~ –62 RE. IMF was northward from 0600 to 0830 UT with the solar wind dynamic pressure gradually increased from 2 to 5 nPa. IMF turned sharply southward at 0830 UT and stayed southward until 10 UT. AE jumped sharply at ~09 UT. SYM-H was > 0 during the entire event.

12. Jiang Liu presented field-aligned currents (FACs) computed from the 4 MMS satellites. The results show: (1) In the magnetotail, localized, intense field-aligned currents are often observed by MMS. (2) The collective effect of many such intense FACs is the Region 1 and Region 2 currents.

Dayside Kinetic Processes in Global Solar Wind-Magnetosphere Interaction Focus Group

Co-Chairs: Heli Hietala, Xochitl Blanco-Cano, Gabor Toth, and Andrew Dimmock

The "Dayside Kinetic Processes in Global Solar Wind-Magnetosphere Interaction" Focus Group (Dayside Kinetics; 2016-2020) seeks to bring researchers together in joint modeling and observational efforts to understand kinetic processes in a global context.

We're currently using an online form to collect your ideas, opinions, and feedback on future plans and activities for the Focus Group. **Please**

use this link to submit your input, especially if you were unable to attend the Summer Workshop:
https://docs.google.com/forms/d/e/1FAIpQLScvvPORcIEAYS6Y19noaucJ5PLtEsbeedRld7oJwPAEE0jCeQ/viewform

Monday 10:30 AM - 12:00 PM - Open Questions

We discussed dayside open questions and unresolved problems, facilitated by short "discussion starter" presentations. The emphasis was on MMS observations and kinetic scale processes. Drew Turner begun the discussion on foreshock transients, followed by Mike Shay with magnetosheath turbulence and electron-only reconnection. The session had about 50 participants.

Drew Turner talked about particle acceleration associated with hot flow anomalies and foreshock bubbles. He presented observations where ions are accelerated to ~1 MeV and electrons to 100s keV. During Turner's presentation, there were two mini-debates: 1) Whether the accelerated ions have a solar wind or a magnetosphere origin. Sun Lee believes the ions may originate from the magnetosphere, while Drew Turner and Terry Liu attributed the acceleration to multiple fermi-acceleration as the particles bounce between the bow shock and the discontinuity in the solar wind. 2) Whether kinetic physics is necessary for explaining the formation of foreshock transients. David Sibeck pointed to interesting MHD simulations by Antonious Otto.

Mike Shay noted that magnetosheath turbulence is different from solar wind turbulence in that the sheath turbulence has a more limited cascade in k space and much faster cascade rate. Because of these reasons, the sheath turbulence might have its unique properties that cannot be applied to turbulence in other systems. He presented Tai Phan's recent observations of a thin current sheet where only electrons exhibit jets while ions don't. The electron jets exhibit a reversal in direction, indicating that reconnection has occurred. During Shay's talk, there was discussion about whether electron-only reconnection can be identified via Walen relation.

Towards the end of the session we discussed future plans and activities for the Focus Group. One of the future directions proposed for the FG would be to understand thin current sheets: solar wind, foreshock, magnetosheath, as well as in the laboratory. It would be interesting to statistically characterize the current sheet properties, categorize into reconnection & non-reconnecting conditions, and compare the thin current sheets in different regions. Another proposed future direction would be to understand magnetopause reconnection extent. Potential efforts include spacecraft conjunctions (MMS, THEMIS, Cluster, Geotail), space-ground coordination, and modeling.

Tuesday 1:30 PM - 3:00 PM & 3:30 PM - 5:00 PM - Dayside Challenges (w/ MMV FG)

Part I: Southward IMF Challenge: simulation-observation comparisons

Heli Hietala first introduced the background of the southward IMF challenge event (2015-11-18) and reviewed the current understanding based on solar wind, MMS-Geotail, and radar observations. To proceed with the analysis, two participating modeling teams (Yuxi Chen with MHD-EPIC and Yu Lin with a global 3D hybrid) had joined forces with observers (Sarah Vines and Sun Lee, respectively).

We first heard each collaboration present their simulation-observation comparisons on five prescribed topics: magnetic field and plasma signatures, waves, magnetopause location, and X-line dynamics. The MHD-EPIC simulated magnetic field and ion density and temperature agreed well with observations inside the magnetosheath, but showed some inconsistencies in the magnetosphere. The simulated ion reconnection jets were a factor of two smaller. The simulation well reproduced the magnetopause location and X-line extent. Sun Lee presented their preliminary hybrid simulation results. The simulated magnetic field and particle moments are qualitatively consistent with observations, but there were clear differences as well. The simulated X-line extent seemed broader than MHD-IPIC or observations. More careful analysis will be performed for the hybrid simulation.

Yuxi Chen, Sarah Vines, and Sun Lee then presented their additional findings of the challenge event. Sarah Vines discussed the magnetopause thickness (>1 ion inertia length), presence of warm oxygen cloak, impact of plume (assumed to be small), and the location of the spacecraft observations relative to the X-line location predicted by maximum shear angle. Yuxi Chen discussed electron dynamics in the MHD-EPIC simulation including electron jet and electron heating. Sun Lee showed D-shaped ion distributions away from the reconnection X-line in observations and the hybrid simulation.

Potential future modeling efforts include performing a baseline MHD simulation and comparing it with the MHD-EPIC and the hybrid simulation, as well as comparing particle distributions in MHD-EPIC and the hybrid.

You can find more information of the Southward IMF challenge at: https://ccmc.gsfc.nasa.gov/support/GEM/Dayside_Kinetic_Processes/Dayside_Kinetic_Challenge/Introduction.php

Part II: Day-Night Connection Challenge: a substorm triggered by magnetosheath jets?

Ying Zou introduced the second challenge event – day-night connection challenge. The event from 2015-12-25 was reported by Katariina Nykyri at the last Summer GEM and it was found to imply a potentially important role of dayside kinetic processes in a triggering nightside substorm. The event was therefore selected as the challenge event to call for community joint efforts to achieve collaborative analysis and understanding.

First Chih-Ping Wang provided an introduction to the theme by reporting observations of a different event where a foreshock transient continuously propagated from upstream to ~60 Re downstream of the Earth in ~1-2 hr.

Katariina Nykyri then presented the current progress of the challenge event. In the event, the IMF turned from southward to northward and stayed northward for ~40 min. Yet interestingly, the IMF also had a large Bx component, and MMS in the quasi-parallel magnetosheath observed several jets with southward magnetic field. These jets are expected to trigger dayside low latitude reconnection when impinging on the magnetopause, likely further triggering the substorm disturbance in the nightside magnetotail. With respect to whether dayside magnetopause was active, Simon Wing presented DMSP observations. He found that the dayside auroral oval stayed at significantly lower latitudes than typical northward IMF condition, indicating that dayside reconnection was active, likely due to the magnetosheath jets. Xueling Shi presented SuperDARN observations, where she found anti-sunward cusp convection following the detection of magnetosheath jets, again implying active magnetopause reconnection. She further observed radar signatures of substorm disturbances in the nightside including flow channels and Pi2 pulsations. Future follow-up of this challenge event includes modeling/simulations.

The sessions had 40-50 participants.

Wednesday 3:30 PM - 5:00 PM - Joint session with the Reconnection FG

This was a joint session between the Dayside Kinetics and Reconnection focus groups, and revolved around magnetic reconnection at the Earth's magnetopause and in the Earth's magnetosheath. Brian Walsh used global MHD simulations to discuss reconnection spreading at the dayside magnetopause, and showed that a typical MHD front moving through the magnetosheath and draping along the magnetopause is sufficiently fast and would likely not limit the spreading speed of reconnection. Mike Shay presented results from MMS that have shown reconnection occurring in the turbulent magnetosheath. The reconnection events found, however, are "electron-only" reconnection, where the ions do not participate in the reconnection process. Sarah Vines showed comparisons between the expected reconnection electric field derived from AMPERE and the LFM-MIX model and observations by MMS, and found the rates are on the order of 0.5 and 1 mV/m and were generally consistent. Allison Jaynes showed election enhancements up to over 100 keV in concert with elevated power in the whistler mode wave band during many crossings by MMS of the low latitude boundary layer. There are often intense parallel electric fields observed along with these signatures, indicating a non-linear component to the whistler mode waves and pointing towards the potential acceleration mechanism. Jason Shuster demonstrated the ability of the MMS Fast Plasma Instrument to compute terms in the Vlasov equation. Techniques for determining spatial and velocity-space gradients of the distribution function from the skymaps provided by FPI were presented and applied to thin current sheet observations in the magnetosheath. In support of the upcoming Solar wind - Magnetosphere - Ionosphere Link Explorer (SMILE), Hyunju Connor suggested an equation that represents magnetopause motion as a function of magnetopause reconnection rate and solar wind dynamic plasma pressure. This equation will help the SMILE team to extract the reconnection rate from the observable magnetopause motion. Ari Le presented a set of 3D fully kinetic simulations matching plasma parameters of three different MMS magnetopause diffusion region encounters with varying guide fields. Lower hybrid drift fluctuations contributed to electron transport and heating, while the anomalous dissipation in Ohm's law was very weak.

La Fonda, Santa Fe:
Venue of 2019 GEM-CEDAR Joint Workshop and GEM Summer Workshop

Magnetotail and Plasma Sheet Research Area Report

Coordinators: Matina Gkioulidou and Chih-Ping Wang

Testing Proposed Links between Mesoscale Auroral and Polar Cap Dynamics and Substorms Focus Group

Co-chairs: Kyle Murphy, Toshi Nishimura, Emma Spanswick, and Jian Yang (substorms) and Christine Gabrielse, Matina Gkioulidou, Slava Merkin, Drew Turner, and David Malaspina (dipolarizations)

The Testing Proposed Links between Mesoscale Auroral and Polar Cap Dynamics and Substorms Focus Group was apart of three joint sessions at 2018 GEM; one with the ULF wave Modelling, Effects and Applications Focus Group and the Magnetotail Dipolarization and its Effects on the Inner Magnetosphere Focus Group; and two with the Magnetotail Dipolarization and its Effects on the Inner Magnetosphere Focus Group. This report covers the two joint sessions with the Magnetotail Dipolarization and its Effects on the Inner Magnetosphere Focus Group. The first of the joint sessions was dedicated to challenge events and presentations from both an observational and modelling perspective. The second session was dedicated to contributed talks focusing on dipolarizations, fast flows, modelling, tail modes, and the effects these processes have on the inner magnetosphere.

Joint Session – Challenge Events

The focus of this session was to compare and contrast observations of storm-time substorms, isolated substorms, and steady magnetospheric convection (SMC), and the effects that these tail modes have on the inner magnetosphere. Four events where chosen for initial studies: (1) an SMC event between 2013 August 24-28, storm time substorms on (2) 2016-09-04 ~7:20 UT and (3) 2016-09-27 ~04:30 UT, and (4) an isolated substorm on 2017-02-02 ~4 UT. An overview of the events can be found at goo.gl/zCeiAa. Ground-based, in situ, and model results were presented including, all sky imagers, riometers, ground-based magnetometers, in situ plasma and wave measurements and global MHD simulations. Christine Gabrielse and Toshi Nishimura presented detailed observations from the THEMIS probes, ASI, and ground-based riometers. Drew Turner presented observations from MMS and the Van Allen Probes. Amy Keese presented observations from TWINS. Lauren Blum presented EMIC wave observations from the Van Allen probes. Colin Komar present initial global MHD results from the Solar Wind Modeling Framework for each challenge event. Kyle Murphy presented injection signature from the LANL spacecraft and Anna DeJong presented ground-based observations regarding the steady magnetospheric convection event.

One of the major highlights from the session was discussion regarding steady magnetospheric convection: how it was manifested in in situ, geosynchronous, and ground-based data, how steady/stable steady magnetospheric convection needs to be considered as an SMC event, and whether or not SMCs can be accurately defined without global auroral imaging. Christine Gabrielse showed that during the SMC event, there was almost one-to-one correlation between AE enhancements and riometer observations of precipitating electrons from injection. (This was part of what led to the discussion regarding SMC definition. If AE varied that much, was it really an SMC?) Anna DeJong argued that the event was not truly an SMC for this reason. Toshi Nishimura correlated injections observed at MMS with THEMIS all-sky-imager observations of auroral streamers. Drew Turner also presented initial observations from MMS that elude to direct loss of tail injected plasma to the dawn-flank magnetopause. Lauren Blum showed evidence of EMIC wave activity during storm-time substorms but saw little activity during the SMC and isolated substorms. At geosynchronous Kyle Murphy showed clear differences between the SMC event and storm-time substorms – the SMC event showing little injection activity while the storm-time substorms showed both numerous and intense injections. Future sessions will narrow in on some of these highlights for additional discussion.

Contributed Talks

Sarah Vines presented observations of field aligned currents from AMPERE and tail flows from MMS during an interval of steady magnetospheric convection on 2017 June 21-22. Sarah demonstrated that during the SMC interval there were sustained Birkeland currents but no clear identification of major onsets in the night side field aligned currents; MMS however showed clear Earthward flows and dipolarizations between -15 - -25 R_E, indicating that reconnection was occurring in the more distant tail during this event but without the development of any major nightside FAC onsets. Grant Stephens presented new results from the newest iteration of the Tsyganenko empirical magnetic field model which ingests ground-based magnetometer data (AE and Dst) to aid in modelling of the global magnetic field. Grant used the new empirical model to model two of the Joint Focus Groups challenge events, a storm-time substorm and an isolated substorm and showed that both events show a characteristic thinning of the plasma sheet during the growth phase and an enhancement in the ring current during the expansion phase. Slava Merkin presented a new framework to incorporate the ring current into global MHD simulations. Using the new TS07d empirical magnetic field model a derived ring current pressure is coupled to the Gamera global MHD model, allowing for a more complete global simulation. Sasha Ukhorskiy presented results from the coupled LFM Chimp global magnetosphere model which uses LFM magnetic field to drive test particles in the Earth's magnetosphere. New results elucidate the motion of particles in the magnetosphere including where and how they are lost. Anna DeJong presented a detailed case study contrasting ionospheric conductance during an interval of steady magnetospheric convection and a substorm. Anna showed that ionospheric conductance before and during the events play a key role in whether a substorm subsequently develops into steady magnetospheric convection following onset. Shin Ohtani discussed poleward boundary intensifications and their relation to distant tail reconnection suggesting that they may not be ionospheric manifestation of tail reconnection. Bea Gallardo-Lacourt presented a correlative study of polar cap boundary identification using DMSP and redline auroral images to develop a new method to statistically and routinely identify the polar cap boundary using optical data.

Magnetotail Dipolarizations and Their Impact on the Inner Magnetosphere Focus Group

Co-Chairs: Christine Gabrielse, Matina Gkioulidou, David Malaspina, Slava Merkin, and Drew Turner

Session 1. ULF waves during particle injections and dipolarizations: Joint with ULF Wave Modeling, Effects, and Applications Focus Group and Substorm FGs

See UMEA Focus Group Summary, this issue.

Sessions 2 and 3. Observations of the challenge events, discussion of steady magnetospheric convection, storm-time substorms, and isolated substorms and their effects on the inner magne-

tosphere: Joint sessions with the Substorm Focus Group

See Testing Proposed Links between Mesoscale Auroral and Polar Cap Dynamics and Substorms (a.k.a. "the Substorm") Focus Group Summary, this issue.

Session 4. Panel Session on the topic of Dipolarization and Global Modeling

The Dipolarization FG held a panel discussion session to focus on how magnetotail dipolarization is currently captured in global models and how those models need to be developed to better simulate dipolarization and its effects (in the inner magnetosphere and ionosphere) based on what observations are telling us about the nature of the system. Approximately 70-80 members of the greater GEM community were in attendance. The panelists included: Katie Garcia-Sage, Colby Lemon, San Lu, Yann Pfau-Kempf, Jimmy Raeder, and Misha Sitnov. Christine Gabrielse chaired the panel and guided the conversation with comments and questions.

Prior to the panel session, panelists were sent the following three questions to consider and respond to as guidance for the topics that were to be discussed during the session:

1) Given our current modeling capabilities, discuss which kinds of models are best at capturing which aspects of dipolarization events and their effects in the magnetosphere.

2) What determines the dipolarization scale size in different models? (e.g., physical description, boundary conditions, model input parameters, ionosphere conditions, etc.?)

3) The transition region is where both inertia and energy dependent drifts are important. No existing models treat that region correctly.

- (a) How do we move forward?
- (b) Or, more specifically, address the question of dipolarization front deceleration: (i) How do various models treat dipolarization deceleration as they approach the inner magnetosphere? (ii) What processes are decelerating the fronts in the models? (iii) What inner magnetosphere processes are missing (e.g. plasmasphere, complex ionospheric conductivity models) and does excluding these processes lead to different deceleration predictions?
- (c) And/or address: (i) What are the relative roles of ExB, energy-dependent drifts and particle trapping in transport and energization in the transition region? (ii) To what extent are these processes adiabatic for particles of different energies? (iii) What is their overall contribution to the ring current build up?

Types of Modeling: Which are best for what questions?

Christine started the panel discussion by reviewing some of the responses she had received from the panelists concerning question 1. The panel then moved into open discussion on that topic. There was general consensus that the relevant physics are global in nature, and in particular that the role of the ionosphere and small-scale physics are both relevant and not properly being captured by any of the models. Models must capture both the plasma sheet and dipolar inner magnetosphere correctly plus the feedback loop provided by the non-idealized ionosphere.

San stressed that a combination of models, such as global MHD with embedded PIC and global hybrid models is our best current approach for capturing both global and critical small-scale processes. Concerning small-scale physics, Misha raised the point that we still don't have a good sense of where in the tail the reconnection X-line typically forms and whether the models are capturing even that correctly. He also stressed that with empirical models, such as TS07, we can much more accurately capture individual events. Yann introduced the Vlasiator model, and stressed that the location of inner boundary conditions and 2D limitations in the global hybrid model are still a major limitation for accurately capturing magnetotail reconnection, dipolarization, and substorm activity. Jimmy focused on the differences between global MHD and other models, stressing that global MHD has a "lack of knobs" that is both limiting in one sense but more trustworthy in another sense. Jimmy also stressed the importance of the ionosphere and also the transition region in and around GEO, where reconnection fronts (dipolarization fronts and the associated BBFs) start to decelerate and deflect in the inner magnetosphere; he stressed that once these plasma "bubbles" start to slow down and disperse, the fluid picture no longer applies, so it is difficult to say how well MHD model results showing that represent reality. **There was also general consensus that data-model comparisons are very important and we need to continue developing those capabilities and approaches.**

From the audience, Andrei Runov asked about the nature of the X-line in the magnetotail: did the panelists think it was a global scale feature? The panelists consider X-lines in the tail to be fragmented and spread out throughout the tail between around X_GSE of -15 and -20 RE. Misha Sitnov thinks the typical X-line lies further downtail, more like -30 RE or beyond, and that models that include too much resistivity will get this closer to Earth. Andrei also stressed the tailward side of the picture, that is, those reconnection jets that are ejected tailward from an active X-line. From recent ARTEMIS results, the reconnection jets observed at lunar orbit (-60 RE) are still localized in nature, which is further evidence that the X-lines in the magnetotail are also localized.

Dipolarization Scale Sizes

Christine next steered the panel to question 2. Katie stressed that the resolution in global MHD tends to break down in the ionosphere, which might fundamentally limit the scale sizes of features in the magnetosphere. She also mentioned that ion composition and ionospheric outflow are not well captured in global models currently but might play a key role in scale sizes of magnetotail dipolarization via instability leading to reconnection, reconnection scale sizes, and the global magnetotail properties. Colby also agreed that the grid resolution in the ionosphere in the RCME model was also a major limiting factor. Two grid points in the ionosphere in the model map to a very large region of the magnetosphere, meaning that the model might not be able to capture localized features in a stretched magnetotail. Colby stressed that RCME seems to be doing a good job capturing the Y (i.e. cross-tail, azimuthal) scales of flow channels (BBFs) but is concerned about how well they are capturing the X (downtail) scales.

From the audience, Shin Ohtani asked about time scales: at 500 km/s velocity, it takes only a few minutes to go from 20 RE to GEO, which is similar to the Alfvén speed travel time from the reconnection site to the ionosphere, so does the ionospheric feedback really matter? Colby responded that was a good but unresolved question. Jimmy disagreed, saying the speed is much faster down to the ionosphere. Bob Lysak mentioned that models often don't capture the density along field lines correctly, but that with the current best estimates, the travel time for information down to the ionosphere was a few minutes.

That discussion transitioned into the importance of Pi2 waves. Joachim Birn mentioned that oscillation in the transition/stopping region is on the scales of the ionospheric travel time (Pi2 period timescales). He again stressed the importance of the transition region and how many of our challenges currently fall back into that region around GEO. Yann showed a movie from Vlasiator, and stressed that with a perfectly conducting "ionosphere" at 5 RE, the speeds were too fast in their simulations. They were seeing peak flows around 2000 km/s. He also stressed that with 2D simulations, all of the reconnection in the system was forced into the XZ plane. The Vlasiator simulations take some time to get reconnection after initialization, and they are actively investigating how the addition of oxygen ions to the plasma sheet will affect that delay time.

Larry Lyons introduced another question of the audience. He asked, "Do dipolarizations only oc-

cur in thin current sheets?" He stressed that with streamers being observed under a variety of different conditions, is a thin current sheet a necessary condition to get dipolarization fronts and BBFs in the plasma sheet? Misha stressed that the problem is multiscale and that no, a thin current sheet is not a necessary condition. Tail reconnection, dipolarization fronts, and BBFs may develop in a thick current sheet. San agreed with Misha's point and stressed that the thickness of a dipolarization front is determined by ion kinetic physics and that from observations, the width of a front is complicated and might have to do with the scale of the responsible X-line or with the conductance in the ionosphere or both.

San then showed results from the ANGIE3D global hybrid model. Slava Merkin asked: what determines the scale size of the X-line? San didn't know but stressed that it was not resistivity but likely an inherent property of the X-line itself, perhaps due to a non-uniform magnetotail. Shin asked why dipolarization fronts moved dawnward, and San replied that it was just a result of ExB drift. Mostafa asked if there is a correspondence between sizes of X-lines and dipolarization fronts/flows? Can larger X-lines produce smaller flows or vice versa? There was some disagreement and discussion between whether or not dipolarizing flux bundles should get smaller as they move inwards. Joachim brought up that when reconnection starts, an X-line might be extended in the tail due to solar wind driving conditions and the distribution of resistivity in the model, but over time the active X-line narrows to a few RE due to entropy reduction and the system becoming unstable to ballooning. He discussed how the tearing mode and ballooning mode can either compete or act in concert, and ultimately, that the cross tale scale depends on the region of the outflow where the BBFs go to.

Jimmy brought up an analogy to seismology and terrestrial earthquakes. He stressed that an earthquake in one place on the planet can trigger another earthquake 1000s of miles away. **He thinks that one active X-line can similarly trigger reconnection elsewhere in the plasma sheet.** The formation of the active X-line changes the entire environment in the tail; it is a disruptive event. This is of course all driven by changes in the solar wind too, which further complicates the picture. He pointed to auroral arcs as evidence that there is likely no preferred scale size for X-lines and the dipolarization fronts they spawn.

The Transition Region: How do we Move Forward?

Christine next turned the discussion to question 3. Misha kicked off the discussion on that and stressed that we do have a comprehensive picture of the transition region from a collection of many, many years of observations throughout it. He argues that with data mining, relying on observations from many, many similar cases, we have full coverage of the region. From his empirical model, which employs data mining, he finds that the transition region expands downtail from ~-8 to -18 RE during substorm dipolarization. From here, Andrei asked how Misha defines a substorm, to which Misha replied with the AL index. This sparked a debate on how to define substorms.

Katie changed the subject to stress that plasma pressure in the inner magnetosphere has to be captured correctly to properly model the transition region. This requires that plasma sheet models be coupled to accurate inner magnetosphere models. She again stressed the important role of the ionosphere, and how that can help dictate how far into the inner magnetosphere a dipolarizing flux bundle can travel and the properties of its rebound and oscillations as it comes to rest there.

Larry Lyons brought up that we had not discussed the ground based observations point of view. He asked how we can connect where reconnection is occurring in the models to what we are seeing in the aurora with streamers. He stressed that in the aurora, much of it is east/west aligned, which corresponds to azimuthal drifts in the inner magnetosphere, and streamers are the only features that can correspond to dipolarizing flux bundles and BBFs. San agreed and mentioned that localized reconnection and dipolarization fronts may be the consequences of dayside streamers loading small, localized portions of the tail. Jimmy agreed and stressed that models might be capturing the east/west features but that we just haven't focused on analyzing them. Jimmy stressed too that we had to be careful, because there is a filter effect with the ionosphere too. Not everything seen in the aurora/ionosphere is reflecting what is happening in the magnetosphere.

*****From this panel discussion, we established a GEM challenge: modelers are challenged to simulate three different cases: storm-time substorm, isolated substorm, and magnetotail reconnection during steady magnetospheric convection.** From the simulation results, how well can a given model capture the observed similarities and differences between these different cases? How will models be constrained so that they do not start reconnection prematurely? ***This challenge will be further developed and fully defined at the mini-GEM meeting at AGU 2018 and will be conducted in partnership with the focus group on mesoscale aurora, polar cap dynamics, and substorms.******

Session 5. Contributed Talks

The Dipolarization FG held a second session immediately following the panel, chaired by Drew Turner, to allow for contributed talks. Also attended by about 70-80 GEM members, the session had ten contributed talks and excellent discussion:

1. Chih-Ping Wang presented on "RCM simulations of entropy reduction caused by plasma bubbles from different MLT locations". He showed that the earthward transport of the simulated plasma bubble qualitatively explains the two-point THEMIS observation of a BBF event. He showed that the simulated entropy reduction caused by a plasma bubble varies significantly with the bubble's initial MLT and background convection. A plasma bubble starting at 23 MLT results in an entropy reduction that extends closer to the Earth and azimuthally wider than does a bubble starting at 1 MLT.

2. Ryan Dewey presented on "Dipolarization effects at Mercury and comparisons to Earth". He used MESSENGER observations at Mercury to identify dipolarizations in Mercury's near magnetotail, and discussed the statistical characteristics of these events. He showed that dipolarization fronts are short-lived (~2 s) enhancements of the northward component of the magnetotail field (~30 nT) and are associated with fast sunward flows, energetic particle acceleration, and thermal plasma heating/depletion. He discussed that these signatures are analogous to those at Earth, however, he showed that dipolarizations are most frequently observed in the post-midnight plasma sheet at Mercury, opposite to that at Earth.

3. Joachim Birn presented an MHD simulation of dipolarization braking. He showed that dipolarization penetration is deeper if it starts from farther out in the tail. He showed that a decrease in density was related to a decrease in energy flux at lower energies. He discussed the dipolarization stopping by an excess of pressure gradient force and pileup of the pre-existing medium.

4. Brian Swiger presented a talk entitled, "Do different substorm strengths accelerate keV electrons the same?" He showed that from X=-6 to -25 R_E, for all electron energies between ~5-52 keV, the average flux increase was greater for larger AE events.

5. Andrei Runov presented THEMIS and LANL observations in the near-Earth plasma sheet and at GEO, respectively, during events of prolonged, extreme solar wind/IMF driving. Events with IMF Bz <-10 nT during longer than 5 hours were selected. THEMIS measurements indicate that the magnetotail responded by a set of thinning-dipolarization events with a duration of 1 hour,

which resemble the sawtooth events. The dipolarizations were accompanied by ion and electron injections in energy ranges ~50 to 500 and ~20 to 200 keV, respectively. Dispersionless and dispersed injections in these energy ranges were also detected by LANL spacecraft at GEO.

6. Sasha Ukhorskiy presented on ion acceleration and transport from the tail to the inner magnetosphere, the effects of trapping, adiabaticity, and the role of charge. (See *Ukhorskiy et al*., 2017.) Recent analysis showed that the buildup of hot ion population in the inner magnetosphere largely occurs in the form of localized discrete injections associated with sharp dipolarizations of magnetic field, similar to dipolarization fronts in the magnetotail. Because of significant differences between the ambient magnetic field and the dipolarization front properties in the magnetotail and the inner magnetosphere, the physical mechanisms of ion acceleration at dipolarization fronts in these two regions may also be different. He discussed an acceleration mechanism enabled by stable trapping of ions at the azimuthally localized dipolarization fronts, and showed that trapping can provide a robust mechanism of ion energization in the inner magnetosphere even in the absence of large electric fields.

7. Anton Artemyev discussed regimes of ion energization during injections: adiabatic vs. nonadiabatic acceleration. The canonical approach for the guiding center theory was proposed, and using this approach the particle equations of motion were rewritten in the coordinate frame with vanishing inductive electric field (a non-inertial coordinate system). Using these equations of motion, Anton discussed three regimes of plasma acceleration: the hot plasma in a large background Bz field, the cold plasma in a small background Bz field, and the intermediary plasma/background Bz field. He referenced Zhou et al. [2018] to discuss mass dependence on energization, with more massive particles (e.g., O+) able to gain the most energy. He showed that ions of different charges at ~5-6 keV will gain a similar amount of energy, but that ions with greater positive charge (e.g., O+6 vs. O+) at ~20 keV can gain more energy.

8. Xiangning Chu discussed broadband waves on plasmapause induced by deep penetration of dipolarization front. He showed that most plasmapause observations with broadband waves are centered around pre-midnight, similar to the distribution of flows/dipolarization fronts. He also found parallel electron fluxes around the same time. He found that AE was larger when the waves were observed at the plasmapause than when no waves were observed at the plasmapause.

9. Shin Ohtani presented on “Spatial structure and development of dipolarization in the near-Earth region”. By statistically comparing the relative timing of dipolarizations at two satellites, he found that the dipolarization region expands earthward as well as away from midnight at r <= 6.6 Re. The expansion velocity was estimated at several tens of km/s, noticeably slower than outside geosynchronous orbit. He suggested that this earthward expansion of the dipolarization region can be attributed to a two-wedge current system with a R2-sense wedge moving earthward and a R1-sense wedge staying outside of geosynchronous orbit.

10. Tetsuo Motoba reported on "A near-Earth dipolarization event observed by MMS (r ~13 Re)". In the course of the dipolarization, MMS observed multiple dipolarization fronts (DFs, < 1min), energetic particle injections (> 70 keV), and oscillating flows. The injected energetic ions were field-aligned accelerated with pitch angle asymmetry, while no apparent pitch angle asymmetry was found for the energetic electrons. The MMS-GOES and MMS-ground comparisons revealed good correlation between the dipolarizations at MMS and GOES and between the oscillating flows and low-latitude Pi2 pulsations, respectively.

Inner Magnetosphere Research Area Report

Coordinators: Seth Claudepierre and Raluca Ilie

Inner Magnetosphere Cross-Energy/Population Interactions (IMCEPI) Focus Group

Co-Chairs: Yiqun Yu, Colby Lemon, Mike Liemohn

In this last year of our IMCEPI FG, we organized two focused sessions with 14 individual presentations and one session with a panel discussion. All sessions were well attended and went through with thorough discussions. The goal of our FG is to bring together researchers to address the broad questions of interest to the Inner Magnetosphere Research Area: the coupling processes across different inner magnetosphere populations and M/I systems. The two breakout sessions focused on (1) the coupling between the inner magnetosphere and the ionospheric electrodynamics and (2) plasma wave dynamics and coupling with inner magnetosphere populations. The panel session aimed to discuss about the remaining problems in the inner magnetosphere and ways to move forward.

(1) Topic 1: on the coupling between the inner magnetosphere and the ionospheric electrodynamics

We had 6 speakers presenting recent observational and modeling advances on the ionosphere-magnetosphere coupling, including the FACs and auroral physics, and their magnetospheric sources. In specific, Harneet Sangha presented bifurcated R2 field-aligned currents in the subauroral region and their statistical distributions over MLTs, invoking plenty of discussion on its relationship to SAPS. Bea Gallardo-Lacourt reported the new auroral phenomena "STEVE"—an optical structure in the subauroral region, its relation with flows/density/temperature in the ionosphere, its relation with substorm timing, its occurrence dependence on the season and solar activity, and its relative location to aurora. The STEVE remains a mystery in terms of its origin because it is found that it may be not originated from particle precipitations as the normal aurora. Nithin Sivadas presented PFISR and THEMIS observations of energetic electron precipitation, including the contribution of 10-100 keV electrons to the total energy during different substorm phases and the effects on the D-region ionosphere. Yiqun Yu talked about a self-consistent modeling effort on solving the effects of energetic electron precipitation during substorms on the low-altitude ionosphere, i.e., an extra layer of Pedersen conductivity is formed around 85 km. Chia-lin Huang reported the impact of MeV electron precipitation on the thermosphere, particularly the relativistic electrons can cause ozone loss.

(2) Topic 2: wave and plasma dynamics

We also focused on plasma waves in the inner magnetosphere and their impact on the plasmasphere/ring current/radiation belts. We had 7 speakers presenting various plasma waves in the magnetosphere and their effects in the magnetospheric particle dynamics. Mykhaylo Shumko presented evidence of microburst observed by Van Allen probes and assessed with wave-particle diffusion theory. Run Shi reported the properties and generation mechanisms of the hiss waves inside plasmasphere and plume and categorized in detail into different types of waves. Qianli Ma presented the role of EMIC waves in heating different ion populations. Sam Bingham statistically studied the chorus wave power during CIR and CME storms. Poorya Hosseini introduced non-linear wave-particle interactions at radiation belts based on ground observations.

In addition, we had 3 speakers focusing on the dynamics of inner magnetosphere populations. For example, Xiangning Chu presented a newly established neural network model: inner magnetosphere plasmasphere model DEN3D. Chao Yue quantitatively assessed the contribution of oxygen ions in the ring current pressure with Van Allen Probes. Cristian Ferradas compared the effects of different electron loss models in resolving the ring current electron dynamics during one GEM challenge event June 1, 2013. All of these studies led us to better understand the source and loss processes in the magnetosphere.

Panel discussion/Summary of FG

In the last session, our FG summarized the GEM challenge: spacecraft surface charging during March 17, 2013 event. This challenge was conducted via community-wide participation, including global modeling teams, CCMC, and Van Allen Probes teams. The initial results were presented and drafted to submit to the Space Weather Journal.

Later, an invited panel discussion was led by Vania Jordanova, Yihua Zheng, George Khazanov, and Mike Liemohn, each of who shared their thoughts and suggestions for the future inner magnetosphere research. Together with valuable inputs from the audience, we discussed some of the remaining open questions as follows:

- The effects of various processes (magnetotail injections, plasma waves, plasmasheet scattering, feedback of ionosphere-thermosphere system) on the inner magnetosphere populations,
- The missing part in the plasmasphere (e.g., reflected secondary electrons),
- How to fulfill the desire of comprehensive models that self-consistently tie the inner magnetosphere to other regions,
- Methodologies were also discussed for future research, such as data assimilation/machine learning as a highly valuable method for future scientific research, low-cost small-sat technology as an affordable means for everyone, as well as the increasing advantage of computational power for global models. The session was finally concluded with a promising direction that is full of continuous exploration and collaboration.

We greatly appreciate the support and contribution from the inner magnetosphere community in the past FIVE years, who made our FG part of GEM!

Quantitative Assessment of Radiation Belt Modeling (QARBM) Focus Group

Co-Chairs: Weichao Tu, Wen Li, Jay Albert, and Steve Morley

In the 2018 GEM Summer Workshop, "Quantitative Assessment of Radiation Belt Modeling" (QARBM) Focus Group had its final year and held three sessions on Wednesday June 20 and Thursday June 21. All of the sessions were well-attended with helpful discussions. There were two invited scene-setting talks, 21 contributed short talks, and one panel discussion over the three sessions, covering a wide range of topics, as listed below:

Session 1 - "RB enhancement"

In the first session nine talks were presented on the observational and modeling studies of the enhancements of relativistic and ultra-relativistic electrons in the Earth's radiation belts. The session started with an invited scene-setting talk on the recent advances and open questions in radiation belt (RB) enhancements. Among the following contributed talks, three talks were given on statistical data analysis of the RB enhancements, with topics including: a survey of the electron phase space densities during the Van Allen Probes era to resolve what causes RB enhancements, effects of solar wind and magnetospheric processes on the ultra-relativistic electron acceleration in the outer radiation belt, and a correlation study between the initial enhancements of energetic electrons and the innermost plasmapause locations during storm periods. In addition, there were three talks focusing on the modeling results of RB enhancements, including a quantitative analysis of the radiation-belt electron phase-space-density responses utilizing the data-assimilative VERB code, global MHD test particle simulations to quantify the relativistic electron advection during CME-shock driven storms, and VERB simulation for the RB Challenge events selected by our FG. At the end of the session, we had two talks focusing on the nonlinear wave particle interactions which can potentially lead to enhancements in the radiation belts, one on the electrostatic steepening of whistler waves, and the other on the electron nonlinear resonant interaction with short and intense parallel chorus wave-packets.

Session 2 - "RB dropout"

This session focused on observational and modeling studies of radiation belt electron dropouts. The session started with an invited scene-setting talk on recent advances and open questions in radiation belt dropout. The following three contributed talks discussed radiation belt electron loss from the observational perspective, including empirical estimates of electron lifetimes, a statistical survey of radiation belt dropouts, and MeV electron dropouts without MeV proton dropout. The next two talks focused on discussing the role of EMIC waves during the RB Dropout Challenge events selected by our FG. The following talk focused on electron bounce resonant scattering by magnetosonic waves and another one discussed the coherent spatial scale of chorus and hiss. In addition, we had one talk focusing on modeling a non-storm dropout event using the VERB code. Finally, a newly selected REAL CubeSat Mission was presented to show a great potential to improve our understanding of energetic particle precipitation in the near future.

Session 3 - "Wrap-up and Future Outlook"

The final session of the Focus Group started with brief introductions to several other upcoming satellite missions: Colorado Inner Radiation Belt Experiment (CIRBE), Compact Radiation Belt Explorer (CeREs), GTOSat, and Demonstrations and Science Experiment (DSX). This was followed by a summary of the Radiation Belt Simulation "Challenge"; the collected modeling resources will remain available on the GEM website for further work. Finally, an invited panel presented 5 individual perspectives on persistent and new problems in radiation belt studies. Some common themes included better understanding of dropouts, including the roles played by microbursts and magnetopause shadowing; better characterization of wave spatial and temporal coherence scales; the global effects of nonlinear wave-particle interactions and nonlinear/time-domain structures; the puzzling behavior of energetic electrons in the inner zone; and how to best exploit analytical tools like data assimilation and machine learning.

Magnetosphere-Ionosphere Coupling Research Area Report

Coordinators: Shin Ohtani and Hyunju Connor

Merged Modeling & Measurement of Injection Ionospheric Plasma into the Magnetosphere and Its Effects (M3-I2) Focus Group

Co-Chairs: Barbara Giles, Shasha Zou, and Rick Chappell

The Merged Modeling and Measurement of Injection of Ionospheric Plasma into the Magnetosphere (M3I2) and Its Effects—Plasma Sheet, Ring Current, Substorm Dynamics GEM focus group held four sessions at the GEM meeting in Santa Fe. The focus group sessions took place on Thursday, June 21 and Friday, June 22. The sessions consisted of a few invited talks to set the stage for the sessions, but were set up in the workshop mode so that everyone could show their data and models.

The scope of the three workshop sessions focused on the upflow/outflow from the ionosphere, the effects of outflow on the magnetosphere, and merged modeling of the ionospheric outflow and the magnetosphere population and dynamics. The fourth session was an open discussion and planning for future focus group activities. The four sessions with the speakers and their topics are shown below. The storm periods that have been chosen for study so far are: 2016 Mar 4-8 (DOY 64-68), 2016 Oct 11-15 (285-289), and 2016 May 6-10 (127-131).

General Overview

There have been exciting new results both in the observations of ion upflow/outflow and in the merged modeling of the outflow and the magnetosphere. Ground-based ISRs show clear magnetic local time, solar wind and geomagnetic activity dependences of ion upflows. Sounding rocket experiment revealed heavy ion upwelling dynamics. Observations of the composition of the magnetospheric plasmas are beginning to show the relative strengths of the ionospheric and solar wind sources. New data from the VAP and MMS spacecraft will be very important for this study in the immediate future. VAP and MMS data are also showing the ionospheric outflow in the lobes of the tail and its entry into the plasma sheet and ring current. The effects of the ionospheric source on fundamental processes in the magnetosphere was reviewed and shown to be widespread and potentially very significant.

The merged modeling of the ionospheric outflow and the magnetospheric plasmas is beginning to give a unique insight into the relative contributions of the outflowing ionospheric H+ and the solar wind H+. Multi-fluid, merged models can track the movement of each of these H+ sources separately and show their relative contributions and dynamics during the course of a storm. The details of the ionospheric source contributions in these merged models are continuing to increase enhancing the accuracy of the overall model results.

A large portion of the planning session addressed the need to bring together ionospheric upflow/outflow and inner magnetosphere/ magnetotail dynamics groups in sharing both observational data and models. The mutual interests and opportunities that exist between these two groups is significant and can be realized through joint focus group sessions as well as possible specialized topical workshops in the future. Initial discussions regarding both approaches were positive and will be pursued at the next GEM meeting. The outlook for this merged focus group approach both for observations and models holds excellent promise and will be a key to progress in magnetospheric systems studies.

Focus Group Sessions

Observations/Physical Processes of Upflow/Outflow
—Rick Chappell, Focus Group co-Chair emeritus: Overview of Working Group Goals
—Invited: Lynn Kistler of UNH: Recent Outflow Observations using MMS, Cluster, and also ARASE!
—Invited: Matina Gkioulidou: Van Allen Probe observations of ion outflow
—Marc Lessard of UNH: Rocket observations of N2+ upwelling in the cusp region
—Chih-Ping Wang of UCLA: Contribution of tail mantle and LLBL to ionospheric upflow
—Jun Liang of UCalgary: REGO and ePOP observations of Alfvenic Aurora

Observations/Physical Processes of the Coupled Ionosphere-Magnetosphere System as a Consequence to Upflow/Outflow
—Invited: Joe Borovsky of SSI in Boulder: Impacts of ionospheric plasmas on magnetospheric behavior
—John Wygant of Univ MN: Observations of Strong Field-aligned Poynting Flux in the Earth's Magnetosphere and Its Role in the Efficient Driving of Intense Outflowing Ion Energy Fluxes in the Cusp and Tail
—Tian Shen: Additional comments
—Shasha Zou of UMichigan: PFISR observations of ion upflow and downflow

Advances/Issues in Modeling of the Coupled Ionosphere-Magnetosphere System and Model-Data Comparisons
—Invited: Alex Glocer of NASA Goddard: Ionospheric Contributions to the Magnetosphere - blue H+ vs red H+!
—Invited: Roger Varney of SRI: Effects of Neutrals on Ion Outflow
—Jonathan Krall: SAMI3 simulations suggest a connection between the tongue of ionization and the plasmasphere plume.
—Rick Chappell: MMS FPI observations of ion outflows
—Naritoshi Kitamura of the Univ of Tokyo: Cold ion observations by MMS at the lobe and near PSBL
—Naritoshi Kitamura: In-situ Observation Plans in Next Japanese Space Exploration Mission (FACTORS) for Ion Acceleration/Heating Processes in the Terrestrial Magnetosphere-Ionosphere Coupling System"

Focus Group Planning Session — Further work on the Community Storm Studies for Upflow/Outflow
—Rick Chappell, Focus Group co-Chair emeritus: Summary of Progess, thoughts for the next year
—Barbara Giles of NASA Goddard Additional access to Polar TIDE outflow data base, new tools, new data products
—Chao Yue, UCLA VAP observation of O+ in the ring current

3D Ionospheric Electrodynamics and Its Impact on the Magnetosphere-Ionosphere-Thermosphere Coupling System Focus Group

Co-Chairs: Hyunju Connor, Haje Korth, Gang Lu, and Bin Zhang

The 3D ionospheric electrodynamics and its impact on magnetosphere – ionosphere – thermosphere coupled system (IEMIT) focus group held two sessions at the 2018 GEM summer workshop in Santa Fe, New Mexico. The first session was jointed with the InterHemispheric approaches to understand Magnetosphere – Ionosphere Coupling (IHMIC) focus group, and the second one was a stand-alone session. Both sessions had approximately 50 attendees.

Session 1: joint with the IHMIC focus group

There were four speakers contributed to the IE-MIT side of this joint session.

Denny Oliveira investigated impact of interplanetary shocks on geomagnetically induced currents (GICs) by studying geomagnetic disturbances at the ground magnetometer stations during 547 interplanetary shock events. He suggested that high-speed and nearly frontal shocks can produce high-risk GIC across the whole latitudes.

Hyunju Connor investigated the high-latitude thermospheric density enhancement observed on May 15 2005 when sudden enhancement of solar wind dynamic pressure (Psw) comes with the strong IMF By fluctuations. Her OpenGGCM-CTIM simulations showed that Psw enhancement is the primary source for the Joule heating and thus for the neutral density increase.

Doga Ozturk presented from the idealized BATSRUS simulations that the sudden jump and drop of solar wind pressure can produce different responses in the magnetosphere – ionosphere system. The magnetospheric compression and depression caused by the increase and decrease of Psw, respectively, produce magnetospheric flow vortices in the opposite direction, resulting in the different field-aligned currents in the ionosphere.

Kevin Pham tested impact of preconditioning on ionosphere – thermosphere system by introducing different IMF input at the beginning of simulation runs and then identical IMF input for ~12 hours. The CMIT-only simulation shows that the magnetosphere does not remember different preconditions. However, the CMIT-IPWM model suggests that the IT system remembers such preconditions and produces different ion outflows, which eventually can impact the magnetospheric memory of preconditions.

Session 2: stand-alone IEMIT session

There were seven speakers in this session, covering observations, simulations, and theory in the MIT coupling.

Marc Lessard presented the RENU2 sounding rocket observations that can unveil the neutral upwelling near the cusp. The rock passed poleward moving auroral forms and observed soft electron precipitation and enhanced electron temperature. The neutral densities below and above the rocket are also available.

Brent Sadler showed the 2D IT simulation study motivated by the RENU2 rocket observations. His model results showed that periodic soft electron precipitation can produce neutral density enhancement above 400 km altitude.

Kristina Lynch presented the observations from Isinglass rocket mission and introduced the Auroral Reconstruction CubeSwarm (ARCS) mission concept. By flying a localized swarm of 32 cubesats over dedicated auroral imagery, ARCS can investigate strong localized ionospheric flows observed in and around the nightside discrete auroral arcs.

Christine Gabrielse presented a statistical characterization of meso-scale (30-500 km) high latitude ionosphere plasma flows collected by SuperDARN. She found more flows occur in the auroral oval than in the polar cap, and that those auroral flows have a pre-midnight preference (like substorm phenomena) whereas the polar cap flows had a post-midnight preference (like polar cap arcs). The meso-scale flow orientation had an IMF By dependence that suggested the flows were generally aligned with the background convection. She also showed that the flow width did not change under most input parameters (e.g., AL index, season), but the flow speed varied between seasons (faster during summer), AL, and F10.7 (faster in the polar cap during high F10.7).

Olga Verkhoglyadova overviewed applicability and limitation of direct current (DC) and alternationg current (AC) approaches, and future developments in our understanding of energy transport in high-latitude IT. The solar wind driving of high-latitude electrodynamics is generally considered in the DC approach and is described by an evolving set of quasi-steady-state electrostatic processes. The AC approach retains the magnetic induction term that naturally includes ultra low frequency (ULF) wave solutions and describes dynamic processes occurring at temporal scales from seconds to ~15 minutes.

Russell Cosgrove discussed ways that using the electrostatic assumption can lead to incorrect results in ionospheric modeling. The electromagnetic 5-moment fluid equations were solved for Alfven (and other) waves in the E region ionosphere, and it was shown that collisions can dramatically reduce the parallel wavelength. For example, a 100km transverse wavelength wave suffers 90 degrees of phase rotation in passing from 400km to 100km in altitude, and this will greatly impact the ionospheric conductance on these scales. Effects on E region dynamos were also discussed.

Larry Lyons discussed relation between auroral zone activities and large-scale traveling ionospheric disturbances (LSTIDs). A total of 8 night observations showed that LSTIDs appear almost always during moderate substorm and streamer events. Isolated period of auroral activities leads to isolated periods of waves. Continuous auroral activities give repetitive LSTIDs.

Interhemispheric Approaches to Understand M-I Coupling (IHMIC) Focus Group

Co-Chairs: Hyomin Kim, Robert Lysak, and Tomoko Matsuo

The GEM focus group, "Interhemispheric Approaches to Understand M-I Coupling (IHMIC)" addresses questions as to how to incorporate interhemispheric symmetry/asymmetry in geomagnetic fields and their effect on M-I coupling in observations and modeling/simulations. Studies have shown the interhemispheric differences which are manifested in various signatures: e.g., large-scale current systems, auroral forms, waves, ion upflow, outflow, particle precipitation, high-latitude convection and thermospheric winds. The focus group held two sessions on Friday, June 22nd at the GEM 2018 Workshop: one stand-alone session and one joint session with the "3D Ionospheric Electrodynamics and its impact on MIT coupling (IEMIT)" focus group.

SESSION 1

The first session covered various types of interhemispheric differences: geomagnetic fields, current systems, auroras, radio emissions, etc. Michael Hartinger presented measurements from a recently completed chain of magnetometers on the East Antarctic Plateau, combined with magnetically conjugate stations on the west coast of Greenland. They used these measurements to make interhemispheric comparisons of current systems with different temporal and spatial scales. Multi-point ground magnetic perturbation observations show north-south hemisphere amplitude differences that vary with frequency. He suggested that more modeling and observations are needed to understand these differences. Kristian Snekvik presented interhemispheric differences in current systems and auroral signatures in association with the IMF By component. The flux asymmetrically added to the lobes results in a nonuniform induced By in the closed magnetosphere. The study discussed the mechanisms related to IMF By transported from open to closed field by tail reconnection and induced by asymmetric loading of the magnetospheric current systems. Observations of medium frequency (MF) radio emissions at multiple stations were discussed by James LaBelle. The emissions are emitted from the poleward expanding arc at substorm onsets. Therefore, this type of measurements can contribute to understanding hemispheric asymmetries by observing auroral radio emissions in the conjugate hemispheres. His group is now considering a new radio emission observation site in Canada conjugate to the existing station at South Pole. Using conjugate pairs of magnetometers (SYO in Antarctica and TJO in Iceland, and WSD in Antarctica and SNKQ in Canada), Robert McPherron performed a cross-correlation analysis to show that there are differences in Pi1 and Pi2 pulsation onset times and waveforms between hemispheres. The study found onsets occur later in sunlit hemisphere (difference is ~36 sec). Inter-hemispheric asymmetry in high-latitude FAC modes of variability associated with two categories of solar wind drivers: (1) high-speed streams and (2) transient flow related to coronal mass ejection are characterized by Yining Shi using empirical orthogonal function (EOF) analysis. Northern hemisphere shows stronger dayside By effect and more spatially defined EOFs. Northern hemisphere higher-order EOFs are more correlated with drivers and indices. An equinox event study (September 2017) shows stronger NH FACs for 75% of the time. Shin Ohtani presented a statistical comparison of the FAC and electron precipitation between the dark and sunlit hemispheres on the night side. In the dark hemisphere, both the R1 and R2 currents are more intense, and electron precipitation is more energetic and intense, and estimated ionospheric conductance is higher than in the sunlit hemisphere. Apparently, the system configures itself in a self-consistent way in each hemisphere, and more energy is dumped into the dark ionosphere than into the sunlit ionosphere. He discussed the result in terms of the interhemispheric asymmetry of the electron number density in the auroral acceleration region, and suggested that a local process affects a global structure of the M-I coupling. Tetsuo Motoba reported on "Asymmetric evolution of interhemispheric preonset aurora." He showed a preonset auroral arc event that was observed simultaneously at a geomagnetically conjugate Iceland-Syowa pair. Whereas the conjugate preonset auroral arc had some similarities, the temporal luminosity evolution was slightly different between both hemispheres. The associated Pi1 wave activity on the ground was also asymmetric. These results imply that the ionoshpere (auroral acceleration region) may play an active role in the evolution of the interhemispheric preonset aurora and related Pi1 pulsations.

SESSION 2

Although some speakers from the IEMIT FG did not necessarily discuss interhemispheric aspects, the joint session was arranged to promote studies of interhemispheric symmetries/asymmetries in MIT coupling processes. Robert Clauer presented initial results from the Antarctic 40- degree magnetic meridian that his group recently established. His study focuses primarily on comparison of magnetic field variations from the ground instruments, showing examples of agreements and disagreements between the conjugate locations in the context of the strong IMF By component. The results are also compared with the Weimer Ionosphere Model to show the detailed view of the inherhemispheric asymmetry in which asymmetries are more pronounced with larger By. Denny Oliveira investigated the effects of shock impact angle on ground geomagnetic field variations (dB/dt), generally associated with the generation of geomagnetic induced currents, in different latitude regions. In general, it is found that nearly frontal and high-speed shocks trigger large dB/dt enhancements. However, out of over 500 events, his study found at low latitudes 9 shocks which are associated with dB/dt > 100 nT/min. All shocks had high speed and struck the magnetosphere almost head-on, and all stations were located around noon local time. Since 100 nT/min has been recognized as a risk factor to power grid equipment, the study suggests space weather forecasters should take the shock impact angle when assessing risk prediction to human assets on the ground. Michelle Salzano statistically investigated substorm onset-associated Pi1B pulsations using ground search-coil magnetometers at conjugate ground stations. Using spectrograms of search-coil data, 154 events from South Pole and Iqaluit stations have been visually identified that are simultaneous at both stations; AL indices and SuperMAG fluxgate data have been analyzed to ensure correlation with substorm onset; a third pass of the data is currently being performed in the hopes of unearthing more events to fill in seasonal gaps; once this third pass concludes, onset time analysis will begin. Hyun-ju Connors presented satellite observations on May-15 2005 showing that thermospheric density and downward Poynting flux intensified near the cusp region shortly after a sudden enhancement of solar wind dynamic pressure. OpenGGCM-CTIM show that ionospheric Joule heating increased abruptly in the same region where the high density and Poynting flux are observed. Additionally, a pair of FACs are enhanced near the strong Joule heating region. Model experiments show that Psw enhancement is the primary source for the Joule heating and neutral density enhancements, but IMF By modulates the level of enhancement. The combined and coupled effect of Psw and IMF has a much more significant effect than the addition of the individual effects. Thus, the magnetosphere–ionosphere responds non-linearly to the coupling of different solar wind drivers. Doga Can Su Ozturk investigated the SI+ (positive sudden impulse associated with magnetospheric compression) and SI- (negative with decompression) processes and their effects on the geospace system using BATS-R-US global MHD code. The study showed that a two-step response existed in the magnetosphere and the ionosphere. The magnetospheric responses were in the form of vortex-like flows. Both in the decompression and compression cases, the initial response was related with the magnetopause boundary deformation and perturbed pre-existing flows. The second response was related with the magnetospheric flow vortices with opposite senses of rotation on the dawn and dusk sectors. These perturbed magnetospheric flows were associated with Field-Aligned Currents (FACs) during both stages and mapped to the ionosphere. Moreover, the ionospheric response due to these perturbation FACs preserved the two-step behavior, since the transient currents reversed directions between stages. The dawn-dusk asymmetry seen in the magnetospheric flows were also maintained. The GITM simulations driven with the high -resolution MHD model results showed that this behavior was further conveyed to the thermosphere, through ion-neutral coupling. Kevin Pham discussed the thermospheric impact on the magnetosphere in the one-way coupled system using various models including the Lyon-Fedder-Mobarry (LFM) global magnetohydrodynamic simulation, the Ionosphere/Polar Wind Model (IPWM), The Thermospheric General Circulation Model (TIEGCM), and the ionospheric potential solver. One of his conclusions is that magnetosphere has a short memory in the standalone LFM and LFM coupled to ionosphere-thermosphere (CMIT). More specifically, the magnetospheric outputs of potential and field aligned currents do not remember differences in disruption. Precipitation passed to TIEGCM does not have any memory of the disruption even when the IMF Bz component is varied in the system. On the other hand, both F-region ionosphere and thermosphere remember the disruption 12+ hours later. This memory is carried into the one-way coupled polar wind model (IPWM). It is anticipated that when IPWM is two-way coupled into CMIT, the memory in outflow will impact magnetospheric memory.

Global System Modeling Research Area Report

Coordinators: Frank Toffoletto and Alex Glocer

Geospace Systems Science (GSS) Focus Group

Co-Chairs: Joe Borovsky, Bill Lotko, Vadim Uritsky, and Juan Alejandro Valdivia

The Geospace Systems Science Focus Group held its fifth-year sessions at the GEM Summer Workshop in Santa Fe. Two sessions were held, entitled "System Science Progress" and "Discussion: The Future of Geospace Systems Science".

8 widely varied presentations were given in the session "Progress in System Science".

Brian Walsh spoke about solar wind propagation from an upstream solar wind monitor and uncertainties in the solar wind that hits the Earth. In solar-wind-driven models, putting in statistical uncertainties in the solar-wind parameters increases the quality of the model outputs. An example given was magnetopause location prediction.

Misha Sitnov talked about building magnetospheric models from spacecraft measurements wherein the measurements are sorted by phase of geomagnetic activity. An example was an examination of the substorm current wedge, which is highlighted by subtracing the curl of an expansion-phase model from the curl of a growth-phase model. The model-subtraction result showed remarkable agreement with theoretical pictures of the substorm current wedge.

Alexander Lipatov spoke on "Effects of transmitted interplanetary impulse interaction with plasmaspheric plume. First results from 3-D hybrid kinetic modeling". Using hybrid simulations he showed an examination of the reaction of a plasmaspheric drainage plume to the passage of an interplanetary shock past the Earth.

Shin Ohtani spoke about the link between the auroral streamer and a plasma-sheet flow channel, in the analogy to an electrical circuit. Time constants in an electrical circuit analogy to the magnetotail connected to the ionosphere were matched with time constants for auroral streamers. It was found that the time constants depend on the geometry of the plasma-sheet flow and the ionospheric-footprint shape of the flow.

Lynn Kistler spoke about the University of New Hampshire project to discern whether auroral ionospheric outflow feedback plays a role in creating sawtooth oscillations of the magnetosphere. Predictions are that auroral outflow of ions should be the source of ions in the plasma sheet. Spacecraft measurements are not supporting the prediction: (1) the source of oxygen ions appears to be the cusp (where there can be no feedback with the tail) and (2) the timing of the oxygen density is wrong for producing sawtooth oscillations. A reanalysis of FAST data is underway to look at FAST observations of outflow.

Katariina Nykyri spoke about the nonadiabatic heating in Kelvin-Helmholtz vortices on the flanks of the magnetosphere. There is an observed dawn-dusk asymmetry in the plasma sheet temperature that cannot be explained by asymmetries in the magnetosheath source. The plasma-sheet temperature asymmetry could be caused by asymmetries in the occurrence and behavior of Kelvin-Helmholtz waves on the magnetopause related to the average Parker-spiral orientation of the solar-wind magnetic field. Examination of ion distribution functions in hybrid simulations of Kelvin-Helmholtz showed non-adiabatic heating.

Joe Borovsky talked about the creation of an aggregate index of magnetospheric activity. Using canonical correlation analysis between the solar wind and the magnetospheric, an aggregate index of solar-wind-driven magnetospheric activity was derived. The aggregate index is built on multiple geomagnetic indices plus properties of the plasma sheet and the time since the last substorm onset.

Ankush Bhaskar gave a presentation on "Radiation belt response to interplanetary reverse shock". Energetic-electron and -proton measurements on a geosynchronous spacecraft were examined. The particle fluxes were observed to drop when the ram pressure of the solar wind suddenly drops as the reverse shock passes the Earth. Two competing effects act on the energetic-particle fluxes. (1) The magnetosphere expands as the ram pressure drops and radial gradients in the particle populations should lead to an increase in observed fluxes. (2) Adiabatic cooling of the particle populations as the magnetosphere expands should lead to a decrease in the observed fluxes. The conclusion is that adiabatic effects are important during the magnetospheric expansion.

The session "Discussion: The Future of Geospace Systems Science" was an audience-participation discussion. A number of topics were raised, including the effect of the past history of the magnetosphere on the reaction of the magnetosphere to the solar wind, the impact of one subsystem of the magnetosphere on the entire system, the increasing importance of machine learning and data mining, and the lack of metric tools for magnetospheric physics. The audience maintained that there is an active need for systems science approaches as part of the activities of the magnetospheric-research community.

ULF wave Modeling, Effects, and Applications (UMEA) Focus Group

Co-Chairs: Michael Hartinger, Kazue Takahashi, and Brian Kress

The "Ultra Low Frequency wave Modeling, Effects, and Applications" focus group (UMEA, 2016-2020) seeks to bring researchers together to address broad questions of interest to many GEM FG: What excites ULF waves? How do they couple to the plasmasphere/ring current/radiation belt? What is their role in magnetosphere-ionosphere coupling?

UMEA held four breakout sessions at the 2018 GEM workshop: two standalone and two joint with other focus groups. Several presentations are now posted on the GEM wiki, along with updates on HGSO coordination for ULF wave studies and the ULF wave modeling challenge.

1. ULF waves during particle injections and dipolarizations: Joint with Dipolarization and Substorm FGs

This session focused on the relationship between particle injections/dipolarizations and ULF waves (e.g., Why are waves driven in only some events? Do waves impact the ring current/radiation belts?). Model and observational results showed that Pi2 wave properties – including the arrival time of Pi2 wave packets at ground stations – are significantly affected by ionospheric conductivity and radial Alfven speed profiles. Incoherent scatter radar observations of large ionospheric electron density and conductivity variations with Pc5 frequency were shown, while SuperDARN radar measurements showed highly localized ionospheric velocity perturbations associated with poloidal ULF waves; more observations are needed to identify the source(s) of the ULF modulation of ionospheric parameters. Numerical simulation (new version of RCM) and theory of buoyancy waves were presented, demonstrating that some nightside Pc5/Pi2 waves may be associated with the buoyancy mode. Finally, theory of the relationship between ULF waves and substorms was discussed, including Alfvenic interactions that can trigger substoms.

2. Recent advances in ULF wave research

This session included presentations and discussion of recent advances in ULF wave research. Recent modeling advances included the ability to capture Alfven resonances in a realistic 3D MHD waveguide, and a demonstration that theoretical predictions for the occurrence of drift mirror modes agree with inner magnetosphere satellite observations. Recent observational advances include the use of RBSP/ARASE conjunctions to study ULF wave coupling and obtain densities via magnetoseismology. Recent satellite and ground-based observations demonstrate a connection between transient ion foreshock phenomena and ULF wave activity, with spatial scale and location of the transient feature affecting wave properties – some waves may propagate into the magnetotail. Recent RBSP satellite wave and particle measurements suggest that ULF waves can play a role in transporting ultra-relativistic electrons into the inner radiation belt. Finally, recent efforts to sonify ULF waves for citizen science demonstrated the ability to identify long lasting monochromatic wave activity during the recovery phase of storms.

3. EMIC wave generation, propagation, and interactions (Discussion led by Alexander Drozdov and Maria Usanova)

Several talks about EMIC wave observations were presented during this session. The presentations addressed ground based and satellite (Van Allen Probes, MMS, GOES) measurements. The speakers discussed the association of EMIC wave events with ion injections, variation of solar wind dynamic pressure, and other geomagnetic indices. Several case studies of linearly polarized EMIC waves, EMIC wave harmonics and high latitude ELF waves were presented, bringing up new questions about the mechanisms for these waves' generation. Additionally, it was shown that despite strong correlation between observation of He-band EMIC waves and electron injections, H+ band EMIC waves may have a different generation mechanism.

The effects of EMIC waves on the electron radiation belts were demonstrated via modeling and observations. It was shown that EMIC waves affect ultra-relativistic electrons causing narrowings of multi-MeV electron pitch angle distribution and dips in phase space density profiles. The results of the long term simulation and reanalysis were improved with EMIC waves being included. Finally, the empirical model of EMIC waves based on the various geomagnetic indices was presented at the end of the session.

4. ULF wave modeling challenge: Joint with Modeling Methods and Validation FG

The ULF wave modeling challenge was discussed, with the focus on globally distributed in situ and ground-based observations, as well as modeling results, during the recently selected 27 -28 May 2017 CME storm challenge event. Observational results that can be used as boundary conditions for models included multi-point solar wind observations, global density observations and outputs from the NURD data assimilation model, ionospheric conductivities from PFISR, and particle measurements from ARASE and other spacecraft. Numerous wave observations were presented: multi-point observations (e.g., 4 GOES spacecraft) of monochromatic waves; localized monochromatic ionospheric velocity perturbations observed by SuperDARN; north-south hemisphere asymmetries in ULF wave properties; ducted EMIC waves; ULF modulated ionospheric conductivity, precipitation, VLF waves, and aurora. Global simulation results were also presented, including ionosphere-thermosphere responses to the interplanetary shock, idealized simulations of the radiation belts, and idealized simulations of global magnetospheric ULF wave activity. Discussion of the challenge event and data-model comparisons will continue in telecons, at the 2018 mini-GEM meeting, and at the 2019 GEM workshop.

Modeling Methods & Validation Focus Group

Co-Chairs: Katherine Garcia-Sage, Mike Liemohn, Lutz Rastaetter, Rob Redmon

The Modeling Methods and Validation Focus Group held two individual sessions at the 2018 summer workshop, as well as joint sessions with the ULF Wave Modeling and Dayside Kinetics focus groups.

On Tuesday afternoon, we discussed the Dayside Challenges (2015 November 18 southward IMF event and 2015 December 25 northward IMF event) in two joint sessions with the Dayside Kinetics focus group. The report for these sessions is issued by Dayside Kinetics.

On Wednesday morning, we discussed the ULF Wave Challenge (2017 May 27 storm event) in a joint session with the ULF Wave Modeling, Effects, and Applications (UMEA) focus group. The report for this session is issued by UMEA.

On Wednesday afternoon, we held a general validation session with 6 talks, followed by a presentation and panel discussion on the role and future of validation at GEM.

Mike Liemohn presented a talk on metrics for modeling geomagnetic indices. He presented progress of the iCCMC-LWS team that has been tasked with developing standard metrics to be used for validation of modeled geomagnetic indices.

Adam Kellerman presented a talk on "Application Usability Levels: A framework for objectively measuring a projects progress towards specific applications." The talk focused on the metrics developed by the iCCMC-LWS team for Assessment of Understanding and Quantifying Progress Toward Science Understanding and Operational Readiness. He presented Application Usability Levels (AULs) as a method for tracking progress of a particular project from basic research to continuous operational use.

Adam Kellerman also presented a talk on "Verification of the UCLA real-time data assimilative VERB code over the 2016-2018 period of operation."

Lutz Rastaetter presented new visualizations and metrics that are under development by the CCMC. These new tools will enhance the ability of CCMC users to analyze magnetospheric model results.

Misha Sitnov presented “Global MHD validation of substorms and implications for kinetic simulations.” He showed how statistical magnetospheric data can be used to test the ability of global MHD to correctly model magnetospheric configuration during substorms.

Nathaniel Frissell presented "Modeling Amateur Radio Soundings of the Ionospheric Response to the 2017 Great American Eclipse." He showed a citizen science effort during the eclipse that was used to validate ionospheric models and their response to the solar eclipse.

Katherine Garcia-Sage presented slides on “GEM Validation - Issues and Ideas,” followed by a panel discussion on how to enhance model validation efforts at GEM.

Panel Participants: H Singer, H. Hietala, A. Kellerman, M. Liemohn

The panel discussed the role and importance of validation, emphasizing the importance of asking the right questions. They highlighted that models reflect current knowledge, and so validation is needed to see if we capture observed phenomena. They pointed out that end users rely on models for interpretation, so there is a need for connecting with end users. Users need to be confident in models through validation, which requires standardization of tests and metrics. SWPC operations require confidence levels.

The discussion highlighted the need to consider the full array of models for the prediction and validation. The models with best validation may not be scientific. Neural net or heavy computation vs. knowledge and physics-based models to get efficient prediction. For the purposes of validation, consider system science - ways to organize observations. e.g., super index of magnetosphere state combining 11 indices.

Next the panel and other participants in the session discussed ideas for how to implement improvements in GEM validation. H. Hietala talked about having a validation steering committee member, as well as a tutorial talk dedicated to challenge status updates. H. Singer challenged the premise of a validation focus group not being science oriented - current validation efforts are science oriented. He pointed to synergy between MMV and CCMC. MMV may not have expertise to reach out to all groups. H. Hietala emphasized that the dayside validation study benefited from MMV expertise.

Several possibilities were discussed, including keeping the focus group as it currently is. H. Singer pointed out the usefulness for MMV studies to serve as an example. S. Morley stated that validation as a separate activity may have value, but an alternative is for every focus group to have a MMV plan and convener/liaison person responsible. A. Glocer pointed out that Focus groups may exist that don't advance models. The validation group is an outlet for studies that does not fit in current science groups.

There was discussion on MMV's role as a focus group to support other groups validation and metrics studies. K. Garcia-Sage discussed the possibility of having an overarching coordinator (focus group is currently doing this to some extent) - matchmaking between other groups. The was discussion on the idea of a SC member supporting validation activities. H Hietala pointed out a need to keep records of what was successful from past challenges. K. Garcia-Sage suggested a coordinator who can take bird's eye view, pass on knowledge to a staggered cocoordinator, and advocate validation needs in the Steering Committee. M. Liemohn pointed out area coordinators each cover a wider area than validation. Validation coordinators would provide dedicated voice in SC.

P. Cassak pointed out that best practices are already on the GEM-Wiki, so a coordinator may not be needed. K. Garcia-Sage the focus group structure means validation efforts last 5 years and then time is up, relying on the hope that someone else steps up. An SC member would shows the dedication of GEM community to keep maintaining validation best practices and having a dedicated point of contact. P. Cassak had a concern that SC members are usually not benefitting from their role as members of the SC. There may be concern that SC members would be contributing to an effort that they would personally benefit from. H. Singer suggested that proposals from focus groups should include validation deliverables. C. Gabrielse suggested a proposal for MMV to be permanent and have a mechanism to rotate leadership in that group. MMV positions advertised by SC.

On Thursday afternoon we held a session on the Conductance Challenge. Events up for discussion were:

- 2016 Oct 13-15
- 2013 March 17
- 2015 Jun 21-24
- 2012 March 9

Steve Kaeppler had a talk on "Poker Flat Incoherent Scatter Radar Observations of Conductance" (presented by K. Garcia-Sage). He showed E region conductances from PFISR, which makes nearly continuous observations of

E and F region plasma. He showed limitations of the data, including the localized nature of the observations, so conductance enhancements driven by localized phenomena (e.g. discrete auroral arcs) are only locally valid. Average conductivity may be useful. Ground truth data is available for all 4 events. March 2013 Event was shown, with two different calculations of ion temperature that produce results in good agreement with each other.

George Khazanov presented "Contributions of M-I Coupling Processes to Electron Precipitation and Ionospheric Conductivity." He showed that with a primary electron precipitation flux from ECH Whistler Waves, some particles are reflected back off the ionosphere and pass through waves in the tail and then precipitate into the conjugate hemisphere. His calculations account for multiple reflections. He showed results from the October 2016 storm from LFM conductances with multiple reflections and without (i.e. Robinson formula only), resulting in a factor of 2 difference in the Pedersen conductivity.

Bob Robinson had a talk on "Auroral Precipitation: AuroraPHILE team" (presented by K. Garcia-Sage) The goal of the team is to establish quantitative means to measure the accuracy and reliability of modeled properties including precipitation, conductivity, E-fields, neutral winds, currents and Joule heating. For the following events: 9 March 2012, 17 March 2013, 21-24 June 2015, gather all available data and develop best estimates of ground truth from data. Next step will be to run models and develop a skill score for each parameter based on comparison to ground truth. He showed AMPERE, AMIE and SuperDARN for the March 2013 event.

Margaret Chen presented a talk on RCM-E (Aerospace Version). The conductance model included EUV conductance from IRI 2007, precipitating electron contributin from Robinson, and precipitating ions contribution from Galand and Richmond. Ion precipitation due to Field Line Curvature (FLC) scattering (Schulz) occurs where you get stretching of the field lines. The contribution of precipitating ions from FLC to total conductivity is very small and localized - possibly important locally, not globally. Conductance low at night pre-storm (as expected), increasing as storm develops. Comparison to PFISR is not good during the main part of storm (possibly due to discrete aurora), but better during recovery. Future steps include improving the calculation of conductance using B3c auroral transport model (Strickland et al., 1993).

Agnit Mukhopadhyay presented "Can accurate conductivity lead to better predictions of dB/dt during extreme events?" The SWMF conductance calculations were originally developed against limited coverage in FAC and were missing extreme events (i.e. only 1 month of AMIE in 1997. This led to underprediction of nightside conductance and overprediction of dayside conductance. A new Empirical Conductance Model (ECM2018) is fitted to 1 year (2003) of AMIE. This model includes extreme events, but no precipitating physics is currently included. Preliminary MHD results for SWPC Event 6: May 8, 2011 and SWPC Events 3, 5, 6 show dB/dt skill scores have improved.

Magnetic Reconnection in the Age of the Heliophysics System Observatory Focus Group

Co-Chairs: Rick Wilder, Shan Wang, Michael Shay, and Anton Artemyev

This was the first year of the focus group, which aims to use recent spacecraft missions and ground assets to further elucidate both the kinetic physics and the system context of magnetic reconnection in the Earth's magnetosphere. We had three sessions, one which was joint with the Dayside Kinetics focus group. The sessions were well attended and the talks spurred exciting discussion.

Session 1: This session focused on the local kinetic physics of magnetic reconnection. Blake Wetherton showed that MMS data provided direct confirmation of the Le et al 2009 equations of state for guide field reconnection. These equations can be used to model electrons in a hybrid simulation, and reproduce observations by MMS. Misha Sitnov argued that the conventional MHD parameter, the Joule heating rate j*E', cannot distinguish between electron and ion dissipation and it can be replaced by new parameters known as the "Pi-D" parameters. Tetsuo Motoba showed that the probe spacing on MMS might be too small to evaluate ion dissipation in the tail. Rick Wilder showed that parallel electric fields were important for dissipation in the "outer" electron diffusion region (EDR), and became dominant when the guide field exceeded 0.3 times the reconnecting electric field. Prayash Sharma Pyakurel showed properties of electron-only reconnection using pic simulations. The transition from electron only to ion-coupled reconnection is not sudden, but a gradual transition as the width of the exhaust increases. Haoming Liang showed results from an initial study to develop and apply kinetic entropy as a diagnostic in collisionless particle-in-cell (PIC) simulations in order to address irreversible dissipation. Kinetic entropy was shown to be an indicator of non-Maxwellian distributions, diffusion regions and dissipation. Finally, Kyunghwan Dokgo presented 2D PIC simulations that show electron crescent distributions could generate upper hybrid waves near the EDR by beam-plasma interaction processes.

Session 2: The second session was on the global physics of magnetic reconnection, with special emphasis on the Earth's magnetotail. Chih-Ping Wang showed evidence for magnetic reconnection through observations of distant tail plasma flows using ARTEMIS on 6 June 2017. Anton Artemyev showed conjugate observations between MMS and ARTEMIS during a mid-tail magnetic reconnection event. Andrei Runov showed THEMIS (7<R<25 RE) and ARTEMIS (~60 RE) observations of earthward and tailward rapid flux transport (RFT) events, which were interpreted as near-Earth reconnection ejecta. Comparisons of plasma properties and particle spectra revealed that ions populations within earth- and tail-ward RFTs are originated at R~25 - 30 RE, which is the most probable location of the near-Earth reconnection site. Chris Bard presented a new GPU-accelerated Hall MHD magnetosphere code and briefly showed results from a Ganymede-sized Earth-like (supersonic) magnetosphere, including an asymmetric out-of-plane B quadrupolar pattern. Joo Hwang presented MMS observations of guide-field magnetic reconnection, which occurred right after tail current sheet flapping, as well as an electron scale vortex embedded in the magnetotail flux rope. The electron vortex was accompanied by a large dissipative DC electric field (>250 mV/m) toward the vortex center. Non-linear electron phase space holes are observed to drift toward an X-line.

Session 3: This was a joint session with the Dayside Kinetics focus group, and revolved around magnetic reconnection at the Earth's magnetopause and in the Earth's magnetosheath. Brian Walsh used global MHD simulations to discuss reconnection spreading at the dayside magnetopause, and showed that a typical MHD front moving through the magnetosheath and draping along the magnetopause is sufficiently fast and would likely not limit the spreading speed of reconnection. Mike Shay presented results from MMS that have shown reconnection occurring in the turbulent magnetosheath. The reconnection events found, however, are "electron-only" reconnection, where the ions do not participate in the reconnection process. Sarah Vines showed comparisons between the expected reconnection electric field derived from AMPERE and the LFM-MIX model and observations by MMS, and found the rates are on the order of 0.5 and 1 mV/m and were generally consistent. Allison Jaynes showed election enhancements up to over 100 keV in concert with elevated power in the whistler mode wave band during many crossings by MMS of the low latitude boundary layer. There are often intense parallel electric fields observed along with these signatures, indicating a non-linear component to the whistler mode waves and pointing towards the potential acceleration mechanism. Jason Shuster demonstrated the ability of the MMS Fast Plasma Instrument to compute terms in the Vlasov equation. Techniques for determining spatial and velocity-space gradients of the distribution function from the skymaps provided by FPI were presented and applied to thin current sheet observations in the magnetosheath. In support of the upcoming Solar wind - Magnetosphere - Ionosphere Link Explorer (SMILE), Hyunju Connor suggested an equation that represents magnetopause motion as a function of magnetopause reconnection rate and solar wind dynamic plasma pressure. This equation will help the SMILE team to extract the reconnection rate from the observable magnetopause motion. Ari Le presented a set of 3D fully kinetic simulations matching plasma parameters of three different MMS magnetopause diffusion region encounters with varying guide fields. Lower hybrid drift fluctuations contributed to electron transport and heating, while the anomalous dissipation in Ohm's law was very weak.

Workshop Coordinator Report

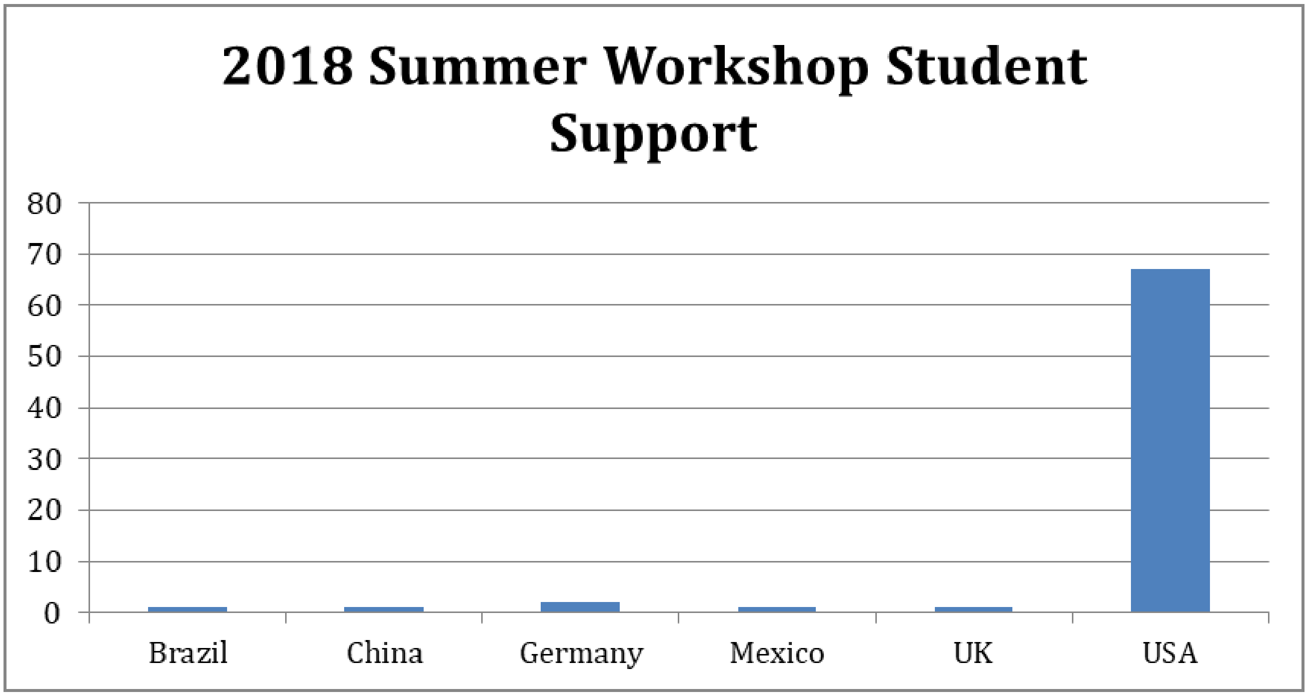
Zhonghua Xu and Robert Clauer

General Participants

The GEM 2018 Summer Workshop was held at June 17-23, 2018 at the Eldorado Hotel in Santa Fe, NM. There were 297 participants attended the workshop, which is the largest number of these years, including 224 Scientists, 73 Students/young scientists, over 30 institutions from 12 countries: Brazil, Canada, China, Finland, France, Germany, Japan, Mexico, Norway, South Korea, United Kingdom and USA. The registration information for scientist, scientist and student participants from US shows that top five groups of most participants are from NASA, University of California Los Angeles, University of Colorado Boulder, University of New Hampshire, and University of Michigan. This year, there was a joint workshop day for GEM-CEDAR on Satuday, June 23, 2018, which has 128 regsitered participants.

Student Participants

In this year, there are 73 student participants. The GEM funding provided fully supports to the 68 of 73 student/young scientist from 26 institutions in 6 countries (comparing to 68 in 2016). We managed to provide them full support, including air-tickets and lodging, and partial support as lodging. Students pay reduced student registration fee regardless whether receiving funding or not, and the GEM support pays the difference between student registration and the full registration fee. We have supported 6 students/young scientists from 5 international universities/institutes, including Brazil, China, Germany, Mexico, and United Kingdom. They were supported as the US students for their travel and lodging inside the US, except for their international flights. The top three domestic universities are UNH (11), University of Michigan (10), and The University of Texas at Dallas (5). There were 5 students using their own funding to participate the workshop. They all received the partial registration fee support from GEM. Following the suggestions of the GEM Steering Committee, all 73 graduate students supported fully or partially by GEM funding were involved and present their research in the poster or oral sessions. The rationale is that those students will benefit most from discussing the frontier research topics with our prominent scientists and professors. 64% of the graduate students are in their 3th or higher year graduate school, but the 36% students who are in 1st and 2nd year of graduate school are also showing their involvement in research and presentable results. We are glad to see more and more students involved actively in their early graduate study.



Although we see more female students in recent years than in decades ago, there is still a large imbalance. This year we supported 25 female students and 48 female students. It is the first time that the female students attending rate is over one third of all the students. The imbalance between male and female students will represent our future workforce. So our community should keep improving the awareness of this issue and provide encouragements and support to female students.

Tutorials and Training Sessions

During the workshop week, we coordinated a variety of activities, including Student Sunday Tutorials, GEM Plenary Tutorials, Agency Reports, GEM panel sessions, GEM Workshop Posters, GEM Workshop Poster Student Competition, GEM Student Invited Talk, GEM Banquet, Student Dinner, GEM Steering Committee Meeting, GEM-CEDAR joint Saturday sessions, Ground Magnetometer Chain Workshop, SPEDAS Tutorials, and others. There are 46 sessions scheduled from 13 Focus groups. There was an anti-harassment tutorial for the first time in the GEM workshop history. The "Understanding Microaggressions" presentition was given NewMexicoWomen.Org on Monday, June 18th, 2018. There were over 150 participants attended.

As previously requested and suggested by the participants, the GEM student tutorial and training sessions are recorded with video-camera for the first time. The presentation slides and video are shared via GEM Wiki UCLA (http://aten.igpp.ucla.edu/gemwiki/index.php/Main_Page), by searching "GEM Summer Workshop 2018", including:

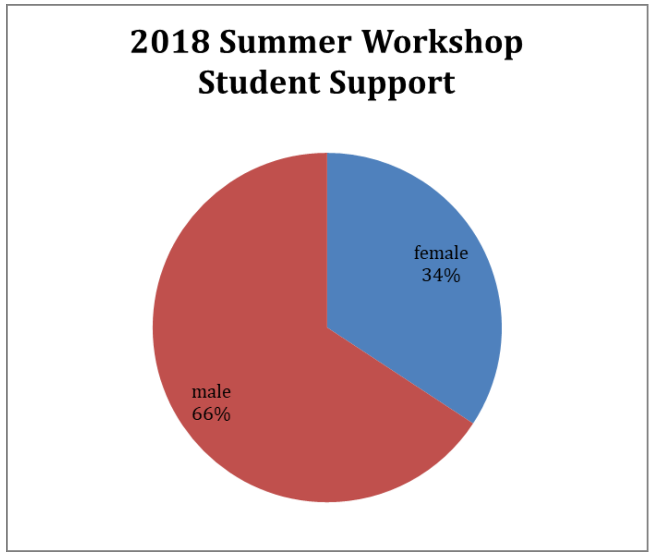
- 20180619 1 GEM tutorial Merkin, https://www.youtube.com/watch?v=YXVarEIDBQ8&list=PL4W060x_s-PdvdCSzQxZvU8OAsXHbpr1E&index=2
- 20180620 1 Sibeck GEM, https://www.youtube.com/watch?v=zNLqVO3ZUwo&list=PL4W060x_s-PdvdCSzQxZvU8OAsXHbpr1E&index=3
- 20180620 2 Spence 2018 GEM Plenary Talk, https://www.youtube.com/watch?v=gNsBmHt0-v8&list=PL4W060x_s-PdvdCSzQxZvU8OAsXHbpr1E&index=4

The anti-harassment tutorial is also available on YouTube privately through email verification.

All the presentations are uploaded to the google drive:

https://drive.google.com/drive/folders/1ZuN4CKBNJAjkrhhymVt83ksSqGKfMm5c?usp=sharing

to all the GEM participants with the permission of present owners.



SHINE Liaison Report

Joe Borovsky

The SHINE Chair is Georgia De Nolfo (NASA Goddard), the SHINE workshop coordinator is Teresa Nieves-Chinchila (NASA Goddard), and the SHINE conference administrator is Umbe Cantu (OlivEvents).

The SHINE Conference 2018 was held July 30 - August 3, 2018 in Cocoa Beach, Florida.

The SHINE Conference 2019 (https://shinecon.org) will be held August 5-9, 2019 in Boulder Colorado. The SHINE Conference is an excellent venue to learn about the latest progress and outstanding problems in solar, solar wind, and plasma physics and to participate in a discussion-oriented workshop. Sessions at the 2019 conference of interest to the GEM community include:

- “Connecting Heliophysics and Laboratory Plasma Studies”,
- “Shortcomings of current CME observations and modeling. What's next?”,
- “Achievements and Challenges of Machine Learning and Data Assimilation for Analysis and Prediction of Solar Activity”,
- “Extreme space weather events throughout the heliosphere”,
- “Global implications of kinetic-scale particle acceleration throughout the heliosphere”,
- “Observational Signatures of Turbulence and Reconnection: New Frontiers with DKIST”,
- “What are the Physical Drivers of Energetic Storm Particle (ESP) events?”, and
- “Techniques Used to Constrain 3-D MHD Models Via Remote-Sensing Observations and In-Situ Measurements”.

After decades of planning by the solar wind community, the Parker Solar Probe was launched on August 12, 2018 and will eventually work its way down to ~9 solar radii in 2022. (The Earth is at ~215 solar radii.) All instruments are working. Data should be available soon.

The SHINE community looks forward to a rumored joint GEM-SHINE conference.

CEDAR Liaison Report

Shasha Zou

The current CEDAR science steering committee (CSSC) chair is Jonathan Makela and the incoming chair starting at this year's workshop will be Delores Knipp. The CEDAR workshop organizer is Astrid Maute, the conference administrators are Kendra Greb and Michelle McCambridge, and the NSF CEDAR Program manager is Roman Makarevich.

The 2018 CEDAR workshop was held at Santa Fe, New Mexico, June 24-29, following the GEM workshop. A GEM-CEDAR workshop was held on Saturday, June 23, 2018, with 128 attendees and was very well received. A total of 338 participants (114 students) from 90 different institutions and 12 different countries registered for the CEDAR workshop. Overall, 82 participants were new to the CEDAR workshop, and 51 of them were students.

The traditional Sunday student workshop was under the theme "Fundamentals of Space Physics." The student workshop was organized by the student representatives, Nithin Sivadas and Megan Burleigh, and was very well attended. The student day concluded with a local hike. There were two student-specific events during the week with "Dine with a Scientist" on Monday and a lunch panel on Tuesday. The new student representative is Matthew Grawe coming in for outgoing Meghan Burleigh.

The CEDAR meeting spanned 4.5 days and included 28 sessions, covering a broad range of themes as proposed by the community. Details about these sessions can be found on the CEDAR workshop webpage http://cedarweb.vsp.ucar.edu/wiki/index.php/2018_Workshop:Main. One new grand challenge topic was selected, "Multi-scale I-T System Dynamics: Major Questions and Our approaches", and three grand challenge topics ended, which were "MLT- X: Frontiers in Science and Sensing", "High Latitude System Frontiers" and "Storms and Substorms Without Borders (SSWB)". Hanli Liu from HAO/NCAR gave the 29th CEDAR Prize lecture about "Whole Atmosphere Community Climate Model--eXtended (WACCM-X): Development, Validation, and Capabilities". There were four science highlights and four early career science highlights in this workshop. It was the first year time that science highlight spots were reserved explicitly for early career scientists. This CEDAR workshop included a "Women at CEDAR" breakfast with a panel consisting of Rebecca Bishop, Ruth Lieberman, and Tomoko Matsuo. Work-life balance and childcare have been discussed.

The upcoming CEDAR workshop will be in Santa Fe, NM, during June 24-29, 2019. Since the 2019 GEM workshop will be held at the same location one week after CEDAR, one-day CEDAR-GEM joint workshop has been planned on June 22, 2019. There will be four sessions, focusing on ion upflow and outflow, ionosphere conductance, observational platforms, and geospace response during the September 2017 storm.

NASA Liaison Report

Mona Kessel

NASA's Heliophysics Division, in collaboration with interagency and international partners, is poised like never before to:

- Advance fundamental understanding of solar and space physics and make amazing discoveries related to the nature of the Sun, Sun-Earth interactions, and the dynamics of our solar system;
- Enable advances in our knowledge of space weather and applications that protect humans and human-built infrastructure;
- Engage the public by sharing science, encouraging citizen science, and developing the next generation of heliophysicists.

The Heliophysics Division has a team of dedicated professionals devoted to solar research. Nicky Fox is nearing the end of her first year as Division Director, and Peg Luce works closely with her as Deputy Director. Dan Moses is serving as the division's Chief Technologist, Mona Kessel as Research & Analysis Lead, Jim Spann as Space Weather Lead, and Alan Zide as Ride Share Lead.

The Division runs three program offices devoted to managing the Heliophysics System Observatory, which together includes 18 operating missions with 26 spacecraft, and three missions in development and one in formulation.

The ***Living With a Star (LWS) program*** emphasizes the science necessary to understand those aspects of the Sun and space environment that most directly affect life and society. The goal is to provide a predictive understanding of the system and specifically of space weather conditions at Earth and in the interplanetary medium. Missions include Parker Solar Probe, the Space Environment Testbeds, Solar Orbiter Collaboration, Solar Dynamics Observatory, and Van Allen Probes.

The ***Solar Terrestrial Probes (STP) program*** addresses fundamental science questions about the physics of space plasmas and the flow of mass and energy through the solar system. The goal is to understand the physical processes that determine the mass, momentum, and energy flow in the solar system from the Sun to planetary bodies, including Earth, and to the interstellar boundary where it interacts with the local interstellar medium. Missions include the Magnetospheric Multiscale Mission (MMS), Solar Terrestrial Relations Observatory (STEREO), Hinode, Thermosphere Ionosphere Mesosphere Energetics and Dynamics (TIMED), and Interstellar Mapping and Acceleration Probe (IMAP).

The ***Heliophysics Explorers program*** provides regular, principal investigator-led flight opportunities for high-quality, high-value, and focused heliophysics science investigations that can be accomplished under a cost cap and developed relatively quickly using efficient management approaches. The specific mission objectives are defined by the PIs. Examples include the Global-scale Observations of the Limb and Disk (GOLD) and Ionospheric Connection Explorer (ICON) missions.

It's a great time to be a heliophysicist! In August of 2018 we launched Parker Solar Probe, our most ambitious mission ever to touch the Sun, and it has since made two perihelion passes. This probe is transmitting science data that will be available to the scientific community for research and analysis this fall. The Van Allen Probes are nearing the end of their exploration of Earth's radiation belts, both having begun deorbit maneuvers to position the spacecraft for an eventual re-entry into Earth's atmosphere about 15 years down the line. The Interstellar Mapping and Acceleration Probe (IMAP) was selected for formulation last summer and is being targeted for launch in 2024. It will be positioned at the Sun-Earth L1 point and will also offer rideshare opportunities for secondary payloads. The Magnetospheric Multiscale Mission

(MMS) has sampled the magnetotail and more recently the solar wind to enhance understanding of plasma turbulence in the solar wind and characterize turbulent energy flow. The Ionospheric Connection Explorer (ICON) is awaiting launch on a Pegasus XL rocket later this year. The Global-scale Observations of the Limb and Disk (GOLD) mission, the first NASA science instrument aboard a commercial satellite, is parked over the Western Hemisphere in geostationary orbit, enabling scientific understanding and situational awareness of the upper atmosphere. We established the Space Weather Science and Applications Program (SWxSAP) in collaboration with sister federal agencies, academia, and industry, and we fully funded the DRIVE initiative that was recommended by the 2013 Solar and Space Physics Decadal Survey, including provisions for early career support, technology, and other diverse elements that enable a very healthy R&A program.

CCMC Liaison Report

Masha Kuznetsova (NASA Goddard Space Flight Center)
With L. Rastaetter, C. Wiegand, R. Mullinix, Y. Zheng, D. De Zeeuw, K. Garcia-Sage, J-S. Shim, T. Tsui, 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. CCMC activities outlined in **Figure 1** are grouped into six primary functions. The CCMC hosts an expanding collection of space weather models, provides simulation services to the international research community through the ***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, maintains perpetual archive of continuous space weather information streams for space environment analysis and system science, and provides opportunities for hands-on education. By collaborating with model developers, the CCMC enables developers to enhance and/or add model features of value to the CCMC user community. In May 2019 the total number runs in the interactive RoR archive exceeded 20,000. There were more than 400 unique users of the CCMC RoR service in 2018.

During the past year more than 600 single-timestep CCMC-Vis visualizations are requested on average each day and about 26 movies-on-request per week (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 120, with 21 models running continuously 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. New model/upgrades in 2018 in geospacer domain include Space Weather Modeling Framework with CIMI (CSEM, University of Michigan and M-C. Fok, N. Busulukova at NASA GSFC), VERB 3D radiation belt model (Yu. Shprits). CCMC continues on-boarding deliverables from the LWS TR&T https://ccmc.gsfc.nasa.gov/community/LWS/. Anticipated deliverables in the geospace domain include OpenGGCM_5.0 (J. Raeder, UNH), Gkeyll (J. Raeder, UNH), and Kinetic PWOM (A. Glocer, NASA/GSFC).

To streamline model onboarding procedure the CCMC outlined a Model Onboarding Pipeline: https://ccmc.gsfc.nasa.gov/models/model_on_board.php (see **Figure 2**) that includes a Pre-Installation Questionnaire and the

Models • Hosting, maintaining, and expanding a unique collection of space research models. • Developing web-based tools for model inputs generation. • Addressing IT security compliance, portability, reproducibility. • Collaborating with developers on model coupling.	**Evaluations and R2O** • Evaluating models and applications (output quality, sensitivity to external drivers and internal assumptions, portability, robustness). • Maintaining community forecasting methods **Scoreboards** (testing predictive capabilities prior to event onset). • Developing flexible web-based systems for archiving and analysis of evaluation results and tracking progress over time. • Supporting transitioning models and applications to operations.
Simulation Services • Providing simulation services to US and international science and operations communities: • ***Instant Runs, Runs-on-Request (RoR), Continuous Runs.***	**Information Architecture** • Ingesting and maintaining perpetual archive of continuous space weather information streams. • Interfacing with Virtual Observatories and Data Centers.
Visualization and Dissemination • Developing and/or onboarding web-based *tools for visualization and analysis* of modeling results: quick-look and comprehensive interactive. • Maintaining *archive of simulations results* with SPASE metadata, API access, downloads. • Developing access, interpolation, post-processing software: **Kameleon/Kamodo**.	**Community & Missions Support** • Performing simulations and developing analysis tools in support of NASA's mission science, future missions planning, CEDAR, GEM, SHINE research. • Leading and supporting community-wide projects, challenges and campaigns. • Supporting NASA engineers on linking space weather models with models of impacts on assets in space.

Figure 1. CCMC functions.

CCMC Metadata Registry (CMR): https://kauai.ccmc.gsfc.nasa.gov/CMR/.

New visualization options for Runs-on-Requests include oblique cut planes and ensemble visualization of multiple runs (see **Figure 3**). New post-processing tools for geospace models include CalcDeltaB, which produces ground magnetic perturbations on a grid of stations (see **Figure 4**).

The CCMC is upgrading and modernizing its simulation results access and interpolation software. A new ***CCMC Kamodo Analysis Suite*** (see **Figure 5**) has been designed to be used by scientists, model developers and non-experts. The tool is developed in Python, but works with Fortran, C, LaTeX, etc. Kamodo leverages other APIs, and Python packages (HAPI, SpacePy, PlasmaPy, PySat, SymPy, Plotly. Kamodo allows model developers to represent simulation results as mathematical functions which may be manipulated directly by end users. Kamodo handles unit conversion transparently and support sinteractive science discovery through Jupyter notebooks with minimal coding and is accessible through python and fortran. The Kamodo Analysis Suite include the @kamodo python decorator to easily add new models and data to Kamodo. We have kamodofied simulations such as ARMS, TIEGCM, and GITM.

The CCMC continues supporting GEM Focus Groups by performing and archiving custom simulations, by developing tailored post-processing tools and visualization options, and by facilitating

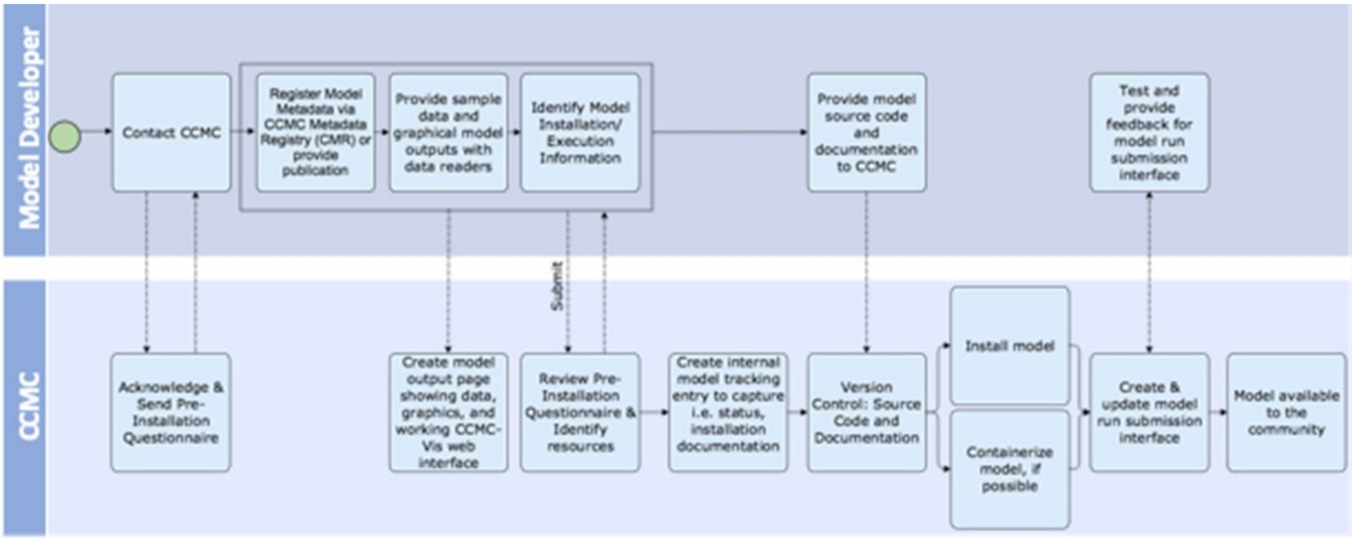


Figure 2. CCMC model onboarding pipeline.

GEM Challenges. The history of CCMC support of GEM Metrics and Validation (recently renamed to Modeling Methods and Validation) Focus Group goes back to 2005. Past successes include GEM2008 Modeling Challenge, GEM-CEDAR ETI Challenge, and Operational Geospace Model Selection Challenge. On-going projects include Mid-Tail Modeling Challenge, ULF Challenge, and Ionosphere Conductance Challenge. Plans for the upcoming year include support of Whole Heliosphere and Planetary Intervals (WHPI) Campaigns.

Building upon past successes and lessons learned from GEM, GEM-CEDAR, CEDAR and SHINE Challenges, the CCMC initiated an ***International Forum for Space Weather Modeling Capabilities Assessment***. The forum is a long-

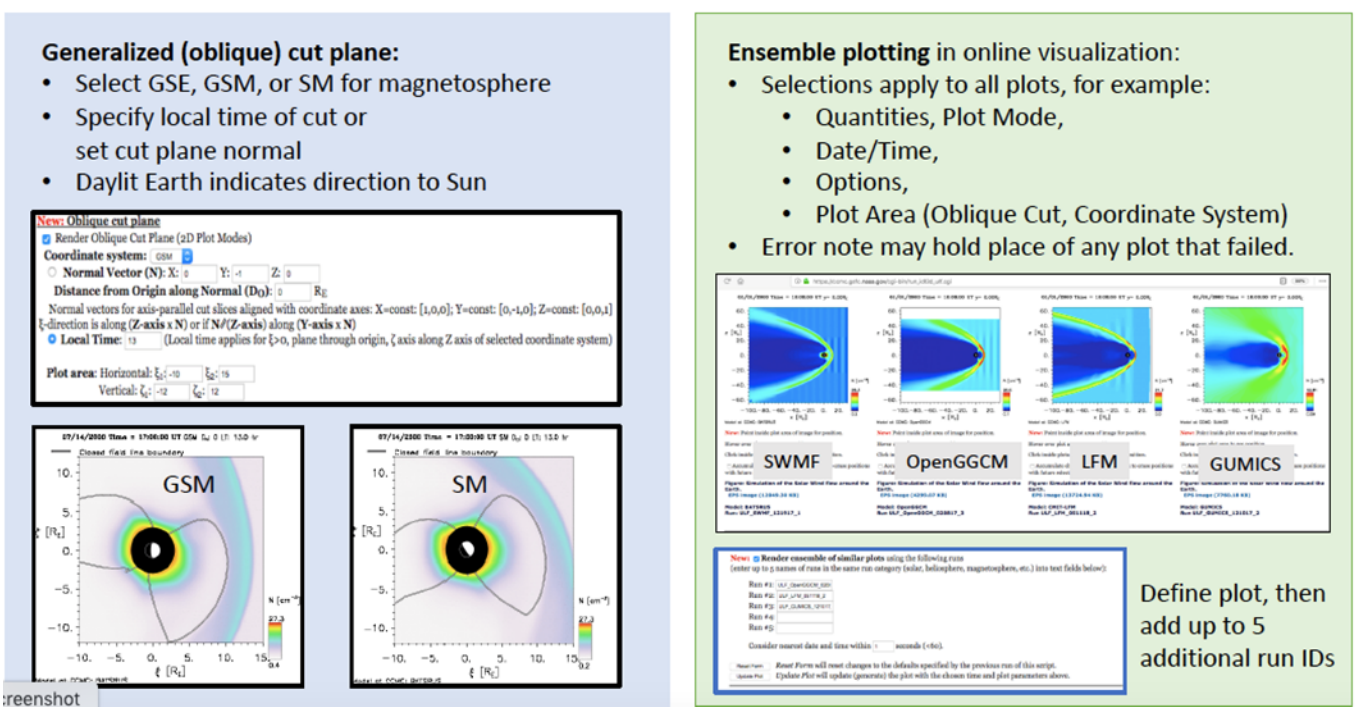


Figure 3. Updates on visualization.

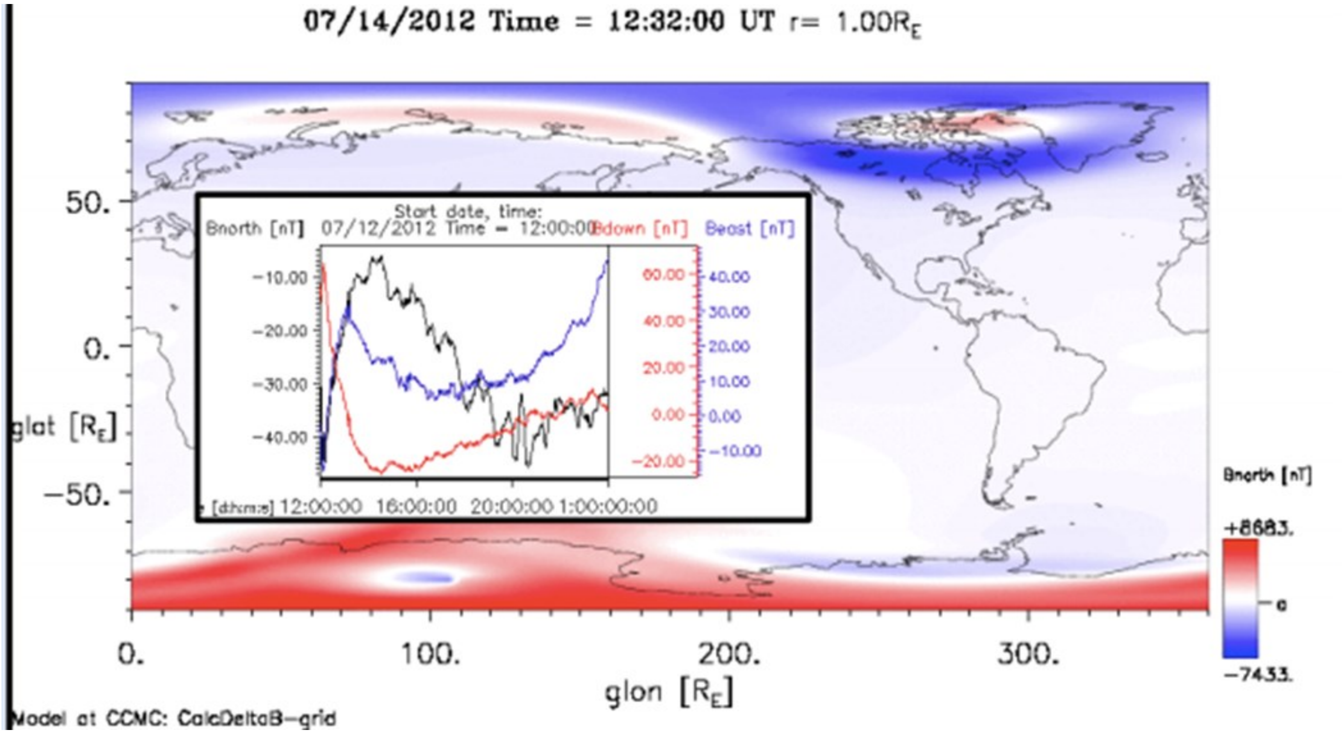


Figure 4. Magnetic perturbations (North, East, Down) on grid of stations on the ground in GEO and MAG coordinates.

term activity aiming to evaluate the current state of space environment models and applications, to address challenges in data-model comparisons, and to establish a process to trace progress over time. Model and application developers, data providers, forecasters, and end-users are working together to establish internationally recognized metrics meaningful and informative to end-users and decision makers. Forum activities have been jumpstarted at the ***International CCMC-LWS Working Meeting: "Assessing Space Weather Understanding and Applications"***, held on April 3-7, 2017 in Cape Canaveral. The forum 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 information architectures.

During the past two years the forum teams have been working though planned task schedules, and have been interacting over regular telecons and other communication channels. Several teams organized topical discussions and special sessions at GEM, CEDAR, SHINE workshops, and mini-meetings at other international community conferences. Many teams are posting periodic updates on the forum website: https://ccmc.gsfc.nasa.gov/assessment/. Contributions highlighting progress of forum working teams are being assembled in an ***AGU Space Weather Journal Special Collection "Space Weather Capabilities Assessment"***: https://agupubs.onlinelibrary.wiley.com/doi/toc/10.1002/(ISSN)1542-7390.SW_CASS. More than 20 papers have already been accepted and a few papers are under revision. The forum demonstrated a value of a global hub for international working teams focusing on different aspects of improving space weather capabilities and served as a pre-cursor and an overarching activity for International Space Weather Action Teams (ISWAT, https://ccmc.gsfc.nasa.gov/iswat) under the COSPAR Panel on Space Weather.

Comprehensive archiving of all evaluation information is critical for tracking progress over time and for analysis of sensitivity to external drivers and internal assumptions. In support of forum

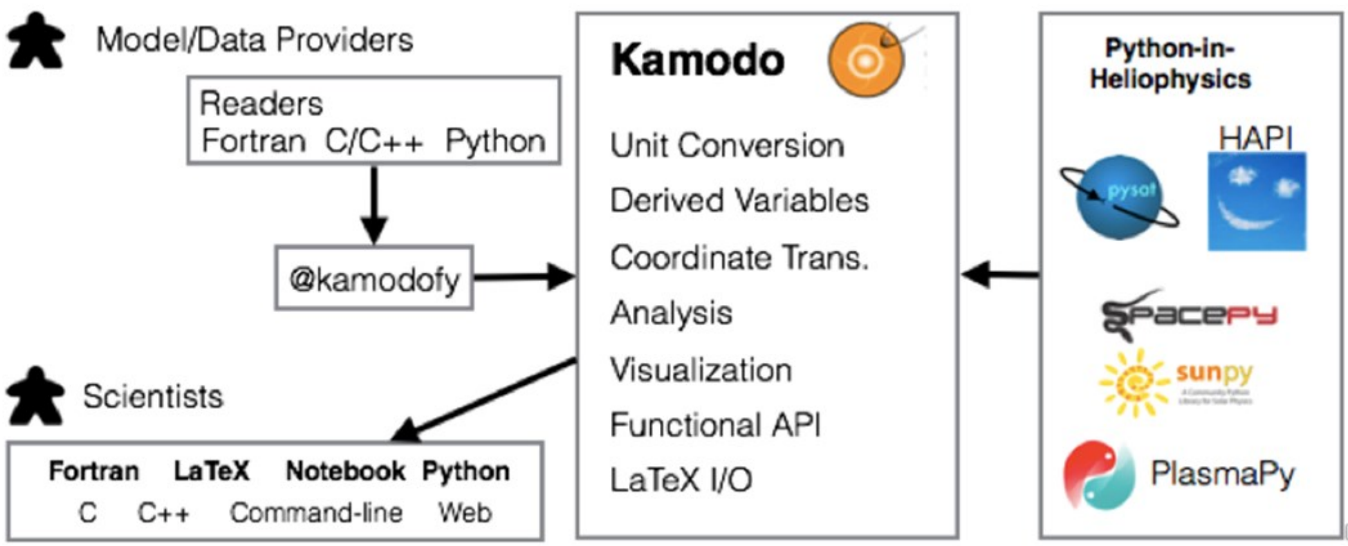


Figure 5. CCMC Kamodo Analysis Suite: Functional API for models and data.

activities, GEM Focus Group Challenges, as well as a growing number of other model-data comparison studies, the CCMC constructed a ***Comprehensive Assessment of Models and Events using Library Tools (CAMEL)***. The CAMEL framework leverages existing CCMC services including simulation results post-processing and observational data ingestion tools, and CCMC Metadata Registry that describes models and simulation runs using SPASE metadata. The CAMEL database contains tables describing each validation study and captures information about all relevant parameters. CAMEL database is coupled to a library of interpolation tools, filters and a library of model-data comparison algorithms. CAMEL is capable to calculate skill scores across multiple events (pre-defined time periods) and across multiple station or spacecraft locations to generate aggregate skill scores at each location for all selected events and at all locations for each event. The first release of CAMEL https://ccmc.gsfc.nasa.gov/camel includes results of evaluations described in the SWJ Special Collection. The CAMEL framework is still undergoing rapid development.

NOAA Liaison Report

Howard Singer (NOAA Space Weather Prediction Center)

This brief report describes recent highlights and future plans related to NOAA's space weather activities that are relevant to the Geospace Environment Modeling (GEM) community. As described below, driven by the growth and needs of customers, there are numerous recent accomplishments in the provision of space weather services, and plans for future models and observations. NOAA's Space Weather Prediction Center (SWPC) is also guided, in part, by recent national priorities for meeting societal needs and advancing space weather understanding and services as presented in the revised National Space Weather Strategy and Action Plan (March 2019), and through working with our interagency, international, academic, and commercial service partners.

Solar cycle 24, peaking in April 2014, was one of the smallest solar cycles on record; however, as we head toward solar minimum, the number of space weather customers continues to increase, and we are always prepared for an extreme geomagnetic storm that can occur, even near solar minimum. During the past year, we experienced an example of space weather activity impacts near solar minimum when a strong (NOAA G3) geomagnetic storm occurred on August 26, 2018 and reports attributed several satellite anomalies to internal charging. SWPC's customer subscription service, one of several ways we deliver services, reached 55,018 at the end of March 2019. Recently, the NASA funded, NOAA led, effort to predict Solar Cycle 25 was initiated with an international team of experts. This effort is co-chaired by Doug Biesecker (NOAA, SWPC) and Lisa Upton (Space Systems Research Corporation). This effort continues the work of previous solar cycle panels to update and predict solar cycle activity. To date, the panel predicts solar cycle 25 will be similar to solar cycle 24, but there are details, such as differences between the northern and southern solar hemispheres that are still being examined.

During the past year, NOAA space weather observations, many of which are used frequently by the GEM community, have been sustained, or improved, and new observations are planned. NOAA's Deep Space Climate Observatory (DSCOVR) (carried out in partnership with NASA and DOD) continues to provide real-time solar wind observations from the L1 Lagrange location with improved quality resulting from software modifications. At the same time, efforts are underway in NOAA for expanded capabilities at L1 with a notional launch in 2024 of the Space Weather Follow On (SWFO) satellite as a rideshare to L1 with NASA's IMAP mission. The Consolidated Appropriations Act 2019 allows the SWFO Program to complete formulation activities and initiate development. NOAA's first planned operational coronagraph, the Naval Research Laboratory's Compact CORonagraph (CCOR), will be hosted on the GOES-U spacecraft as well as SWFO. NESDIS and SWPC are also working with the European Space Agency and international partners, to coordinate European proposed measurements from L5 with the NOAA observations at L1.

Currently GOES-14 and -15 are the operational geosynchronous satellites providing in-situ energetic particle and magnetic field data and solar observations, supporting space weather operations, GEM scientists and others. GOES-16 and -17, the first two satellites of the GOES-R series are on orbit. For space weather instrumentation, some of the data are now available through NOAA's National Center for Environmental Information (NCEI, formerly known as NGDC). (See https://www.ngdc.noaa.gov/stp/satellite/goes-r.html). Regarding future operational use, and the replacement of GOES -14 and -15, GOES-16 space weather observations are expected in operations by Fall 2019 and GOES-17 in 2020. This new series of satellites continues to host the GOES series long-term measurements such as the magnetic field, integrated X-ray and EUV observations, and an extensive range of energetic particle measurements. In addition the new satellites 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). SWPC is also preparing to utilize data from the Constellation Observing System for Meteorology, Ionosphere, and Climate (COSMIC-2) satellites after their imminent launch. Also, through collaboration with NSF and the National Solar Observatory (NSO), SWPC is providing support for data processing activities for Global Oscillation Network Group (GONG) data that are used in operations as well as by the science community.

Modeling the space environment is a significant challenge that will lead to major benefits for those impacted by space weather. Since October 2016, the University of Michigan's Geospace model has been used in operations with initial products that provide forecasters and web-based users with regional predictions of geomagnetic disturbances. Plans are in place for implementing a high-resolution ver 2.0 in FY20. There is also an increased emphasis on model validation and new forecast products. SWPC is also working with partners, including USGS, NASA, NRCAN and NSF to put into operations a Geoelectric model that uses ground-based magnetic field observations and ground conductivity models to calculate the geoelectric field that drives geomagnetically induced currents in long-line conductors, such as the power grid. In another effort, SWPC, in partnership with NASA's Community Coordinated Modeling Center and the AF, is also working on model improvements to the Wang-Sheeley-Arge Enlil Cone model for predicting the background solar wind, and the impact of coronal mass ejections. For predicting dynamics in the ionosphere and thermosphere, work is continuing on the Integrated Dynamics in Earth's Atmosphere (IDEA) model. Additionally, in collaboration with the international community, through the International Civil Aviation Organization (ICAO), new models are being put in place to provide space weather advisories to support aviation.

Another major activity for SWPC this year, and other national agencies, 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." As one of the actions in SWAP, SWPC engaged Abt Associates to produce a report on the Social and Economic Effects of Space Weather and they have recently completed a comprehensive user survey of space weather data and product requirements that will soon be made available publicly. Also, this year, SWPC has continued its partnership with NASA and NSF to collaborate on funding Operations to Research/Research to Operations (O2R/R2O) applied research that is likely to result in improved capabilities for operations. Finally, another successful and exciting Space Weather Workshop was held in Boulder, CO in April 2019. The workshop, organized by the University Corporation for Atmospheric Research, is co-sponsored by NOAA, NASA and NSF and brought together the broad space weather focused communities, composed of government, commercial and academic sectors for a week of presentations, posters and panel discussions. The workshop hosted over 360 participants, with representation from 20 nations as well as student contributions. Next year's Space Weather Workshop, Boulder, is scheduled for April 20-24, 2020.

Finally, we were pleased to announce that Clinton Wallace was selected as the new SWPC Director and was sworn in on March 4, 2019. Clinton was the former Deputy Director of the National Centers for Environmental Prediction's Aviation Weather Center. He brings new leadership and ideas as well as much experience in the transition of research to operations and forging national and international partnerships.

USGS Liaison Report

E. Joshua Rigler (U.S. Geological Survey, 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.

Operations and 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 United States and its territories. Provisional baseline-adjusted magnetometer data are made available in near real time through USGS web services (geomag.usgs.gov), or via the INTERMAGNET consortium (www.intermagnet.org). "Quasi-definitive" and "Definitive" data are cleaned and calibrated, and typically released within ~1 month and ~1 year of acquisition, respectively. INTERMAGNET recently deployed a public FTP service to facilitate downloading considerably larger chunks of data than was previously possible (ftp://ftp.seismo.nrcan.gc.ca/intermagnet/).

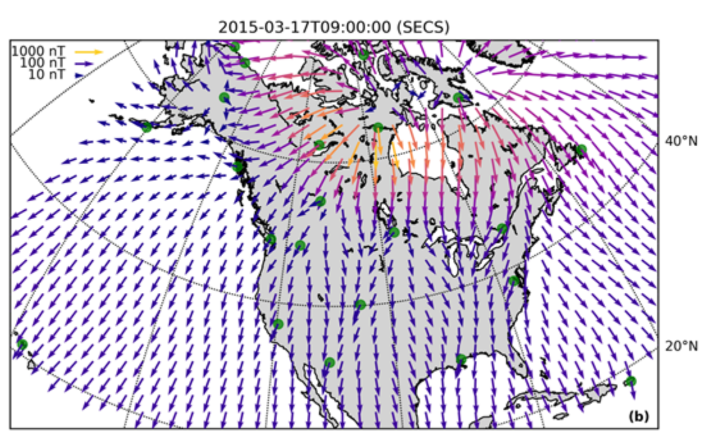
Targeted Research

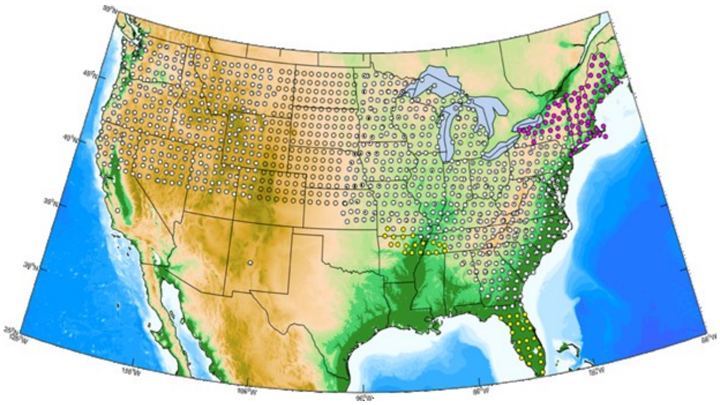
Geomagnetic Disturbance Maps

As part of a multi-agency collaboration with NASA and NOAA, the USGS developed a real time operations-oriented open-source Python software package that employs spherical elementary current systems (SECS) to interpolate geomagnetic perturbations given sparse observations (github.com/usgs/geomag-imp). NOAA's Space Weather Prediction Center (SWPC) incorporated this software into their gridded geoelectric field maps for the continental United States (CONUS) using near real time data from the USGS and Natural Resources Canada (NRCan) as input. A 2nd generation of this software is being developed that combines machine learning with sophisticated global simulations to better constrain SECS solutions in regions far removed from observations.

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 (MT) 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 recently completed New England.

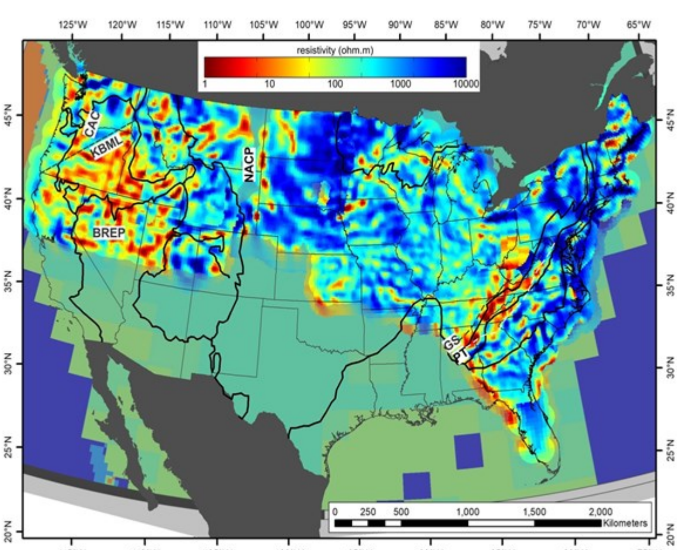


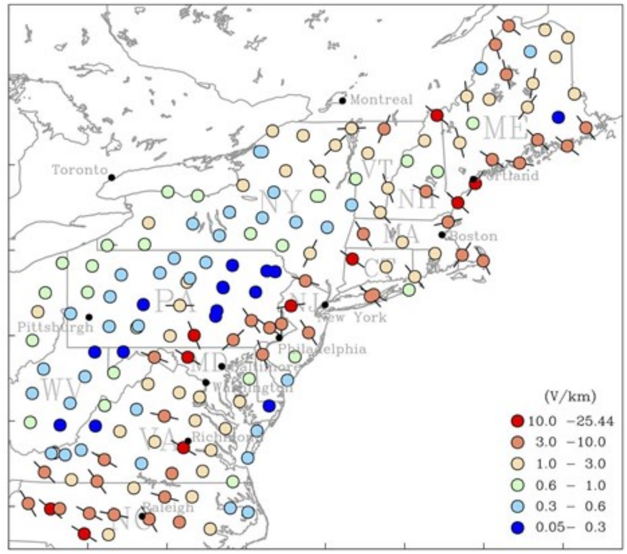


The USGS has sponsored and conducted its own smaller-scale regional magnetotelluric surveys that augment USArray coverage and support specific industry needs, most notably in Florida, southern Missouri, northern Arkansas, and western Tennessee.

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. While geoelectric fields can be measured directly, they are more practically estimated using MT surface impedances and modeled or measured geomagnetic disturbance. This approach is used for NOAA SWPC's geoelectric field maps, mentioned previously. It was also used to calculate induced geoelectric fields over extended historical periods for which USGS geomagnetic data were available, using the





dense distribution of USArray measured impedances. This allowed relatively complete spatio-temporal distributions to be constructed, and extreme event statistics to be calculated for regions of CONUS with dense populations and sensitive technological infrastructure (e.g., Eastern seaboard). Finally, geoelectric fields were integrated along real electric power grid geometries to provide industry-relevant induction hazard scenario maps.

Regional and Continental Ground Conductivity

MT surface impedances can be inverted for geophysically self-consistent conductivity models of the sub-surface. In addition to their solid-Earth scientific value, these conductivity models can be used to generate synthetic impedances at arbitrary locations and density. The USGS is using Earthscope USArray data to generate such conductivity models, and is investigating the effects of scaling and distortion on synthetic impedance grids, and how these might impact geoelectric hazard assessments. Previously, these efforts were regional in scope, but new research is leading to continental-scale models that may be directly applicable to the GIC hazard problem.

AFRL Liaison Report

James McCollough (Air Force Research Laboratory)

The Air Force Research Laboratory (AFRL) supports 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. This includes a variety of topics of interest to GEM. Highlighted below are some recent and upcoming activities in this regard.

GPS Flux Specification Model: A model that specifies flux at a given GPS location via data from rest of fleet has been developed. It bins flux in L-shell and averages over a specified time window. When no data available in the bin of interest spectra from neighboring bins are interpolated (See Figure 1). This effort provides a specification for the GPS regime to support prototyping while physical model development continues.

International Radiation Environment Near Earth (AE9/AP9-IRENE): AFRL is continuing to develop AE9/AP9-IRENE, a model suite addressing particle radiation hazards in near-Earth space for satellite design and mission planning. V1.55, just released in April, introduces first effects "kernel" for faster effects calculations. Ongoing technical efforts include: implementation of stochastic solar proton event module; sample solar cycle using historical reanalysis for realistic short timescale hazards; local time dependence in the SPM plasma model; and improved representation of gradients in LEO.

CEASE3: AFRL has developed the Compact Environmental Anomaly Sensor-3 (CEASE3), designed to monitor energetic charged particles (ECPs) that

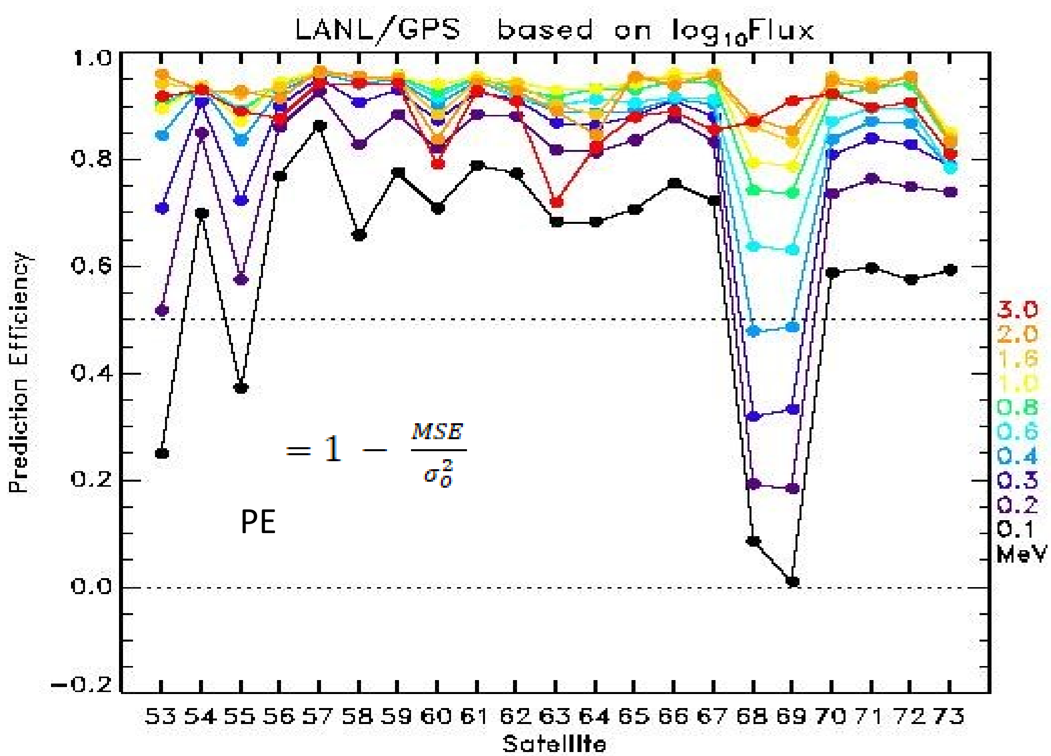


Figure 1. Prediction Efficiencies by GPS satellite for a given reference satellite.

cause spacecraft anomalies. The CEASE3-RR (Risk Reduction) prototype is currently operating on AFRL's EAGLE spacecraft, and flights are planned in the next few years to GEO and LEO. CEASE3 has four sensors for wide range of electron/proton energies, 3 telescopes and an electrostatic analyzer. It has time sampling and dynamic ranges suited for monitoring hazards in LEO, MEO, GTO, HEO, and GEO. The reference design has been transferred to industry in support of deployment of sensors on all future USAF spacecraft.

Outer Zone Model (OZM): In particular, AFRL is interested in understanding radiation belt dynamics to better specify and predict the energetic particle environment. A Phase I STTR effort on operationalizing outer zone electron models has recently concluded. Phase II selection has and work will soon commence with partners at Space Science Innovations, Inc. and UCLA. The conclusion of Phase II will be marked by a basic operational capability. OZM has been a fruitful “pathfinder” for model transition from research to operational contexts and is part of an assessment of models for promotion to operations.

Demonstration and Science Experiments (DSX): Another activity of interest to the GEM community is the upcoming launch of the Demonstration and Science Experiments (DSX) mission. When launched this summer, 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 a 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.

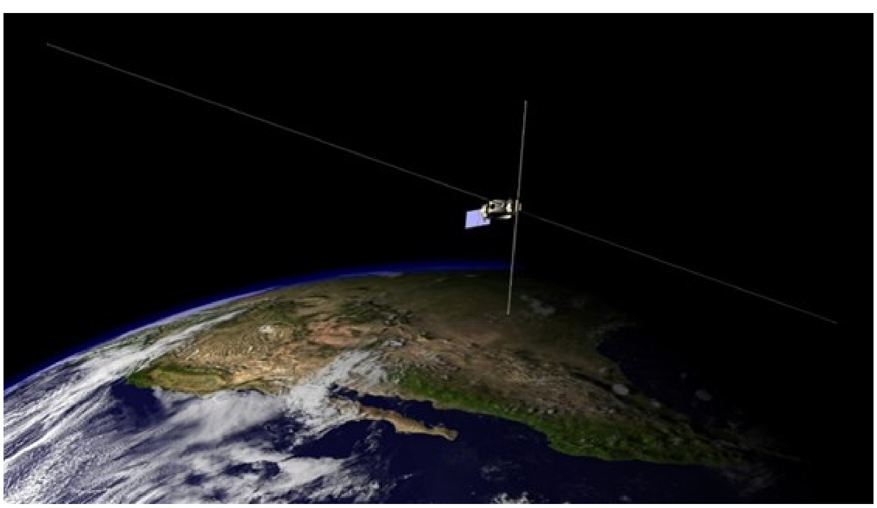


Figure 2. DSX on orbit (rendering).

ESA Liaison Report

Benoit Lavraud (IRAP, Toulouse, France)

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

1 - Cluster and Swarm

The ESA's Cluster and SWARM missions are both still operating and extended to 2022 and 2021, respectively and as of now. Further extensions may be granted at later stages.

2 - SMILE

The Solar wind Magnetosphere Ionosphere Link Explorer, or SMILE, is a joint mission between ESA and the Chinese Academy of Sciences (CAS). It was selected in 2015 and is still under development for a launch in 2023. 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.

3 - Medium-size M5 mission selection

After the non-selection of THOR as an M4 mission by ESA (ARIEL, a mission for exoplanets, was selected), the selection for ESA's M5 mission was no better for our community. As already detailed last year, none of the three missions of our community (JANUS, ESCAPE, ALFVEN) was selected for phase A study.

4 - Next ESA opportunities

As planned, ESA released in 2018 a call for a Fast mission, called F, the idea of which is to be launched as a piggy back with the M4 mission, ARIEL, in 2028. Following a first round of submissions mid-2018, 6 missions were pre-selected in December 2018. Of these, only one missions concerns our community, the Debye mission. Debye aims at studying turbulence in the solar wind at electron scales. It is composed of one mother satellite with very high-resolution electron and electromagnetic field measurements, complemented with up to 3 small daughter spacecraft with search coil magnetometers only, to perform multipoint wave analysis. The final selection, of only one mission for phase A study, is expected in the second half of 2019.

5 - Next ESA opportunities

The near-term ESA programme is somewhat unclear. As of now, there will be no M6 mission, owing to financial/planning issues. Yet, ESA is discussing the opportunity of what they call an M* mission, and an M7 mission is also planned before the next programme is put in place.

6 - Future ESA program

After the completion of the Horizon 2000 program, and now the near completion of the Cosmic Vision program (in terms of selections), ESA is now putting in place its next program, called Voyage 2050. Quoting ESA: "In keeping with the bottom-up, peer-reviewed nature of the Science Programme, the definition of the next plan relies on open community input and on broad peer review. The community input will be gathered through the Call for White Papers, while the peer review of this input will take place through a two-tiered committee structure, with a Senior Committee of 13 European scientists supported by a number of Topical Teams. Scientists interested in participating in peer review process are invited to respond to the Call for Membership of the Topical Teams". These calls for white papers and topical team membership are now open.

Australia Liaison Report

Brian Fraser

Geospace related activities in Australia are mostly connected with growing endeavours to develop new capability to manage and use space applications. Some points are listed below.

- The Australian Space Agency a public service agency is responsible for the development of Australia's space industry, coordinating domestic activities, identifying opportunities and facilitating international space engagement. It was founded in July 2018, with headquarters in Adelaide under CEO Dr. Megan Clark (https://www.industry.gov.au/strategies-for-the-future/australian-space-agency).
- A very large team has grown at the University of New South Wales, Canberra campus, focused on space situational awareness research. Activities include modelling of the LEO environment and developing and operating cubesats and in situ experiments to improve understanding of satellite-environment interactions.
- A specialist centre has been established at the University of Sydney to train students and researchers in the development of LEO cubesats and UAVs. The INSPIRE-2 cubesat was launched in May 2017 as part of the QB50 constellation, and carries plasma density, GPS and spectrograph instruments.
- Work at RMIT University is improving understanding of the causes of scintillation in the low latitude ionosphere
- The new technology SuperDARN radar at Adelaide has demonstrated the capability to detect ionospheric features at extreme range and track travelling ionospheric disturbances from auroral toward low latitudes.
- A network of 52 autonomous optical sky imagers deployed across Australia detects fireballs and meteors and determines their paths in near real time. The network has also demonstrated the ability to track small objects in orbit and is being expanded to form a coordinated global space situational awareness network.
- ***The world's largest space science conference, COSPAR, will be held in Sydney over 15 -23 August 2020.***

China Liaison Report

Chi Wang (National Space Science Center, Chinese Academy of Sciences)

Ground-Based Geospace Monitor Network in China: Meridian Project II

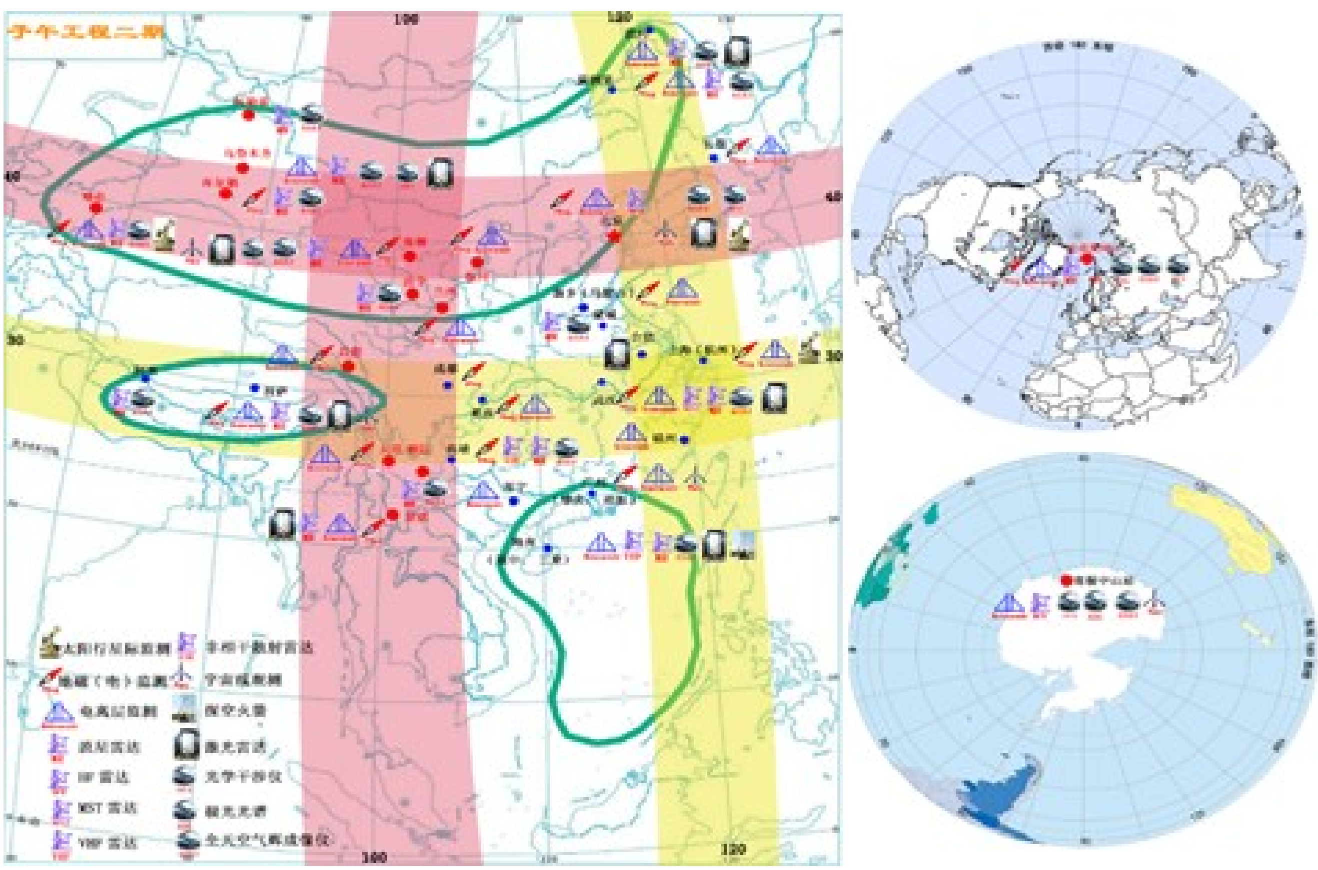
The Chinese Meridian Space Weather Monitoring Project (Meridian Project I) is a ground-based geospace monitoring chain in China. It consists of 15 ground-based observation stations located roughly along 120°E longitude and 30°N latitude. Each observatory is equipped with multiple instruments to comprehensively measure key parameters such as the baseline and time-varying geomagnetic field, as well as the middle and upper atmosphere and ionosphere from about 20 to 1000 kilometers. Chinese Meridian Project started collecting data from 2011, part of data is made public via the website https://data.meridianproject.ac.cn/.

Meridian Project II will add to the current project two observational chains, one along 100°E and another along 40°N. Together with the current 120°E and 30°N chains, a two-cross network configuration will be formed to cover nearly the whole territory of China in a sense of monitoring medium scale phenomenon, and distances between adjacent stations will be as small as 100km in some critical regions. The construction will start in the middle of 2019 and complete in 2023.

The total budget of Meridian Project II is about 8 times of that of I.

The International Meridian Circle Program (IMCP)

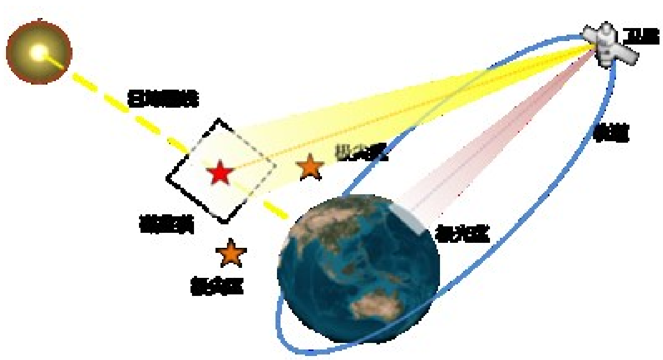
The International Meridian Circle Program (IMCP)



aims to coordinate ground-based scientific assets for integrated, global-scale studies of the coupled lithosphere-atmosphere-geospace system impacting our life and environment.

Over the past half-century, ground-based observations of the atmosphere and space have experienced a steady growth, both in number and sophistication. Now nearly 1000 instruments of different kinds are deployed and operational around the globe, with a concentration toward the great meridian circle centered on 120° E - 60° W. Up till now, networks of ground-based instruments are continental in scale at most, exemplified by the Canadian Gesopace Monitoring and Chinese Meridian Projects. In order to reach the global scale, a formal mechanism of international cooperation needs to be instituted to incorporate hundreds of instruments from different countries and harmonize the operation and data acquisition thereof. The main objective of IMCP is to create an effective international cooperation scheme to develop and operate the first global-scale network of ground-based instruments for the study of atmospheric and space phenomena.

An International Meridian Organization (IMO) is proposed as a formal international body promoting relevant scientific research along the 120° E - 60° W meridian circle. To be registered and have its headquarters based in Beijing, China, the IMO will be governed by an IMO Charter agreed and signed by the participating countries. The IMCP is the inaugural program of the IMO.



Update on Solar wind Magnetosphere Ionosphere Link Explorer (SMILE)

The Solar wind Magnetosphere Ionosphere Link Explorer, SMILE, has been given the green light for implementation by ESA's Science Programme Committee in March, 2019. For Chinese part, this mission was already approved and fully supported in November, 2016.

SMILE is a novel self-standing mission to observe solar wind-magnetosphere coupling via simultaneous in situ solar wind/magnetosheath plasma and magnetic field measurements, X-Ray images of the magnetosheath and magnetic cusps, and UV auroral images of global auroral distributions defining system-level consequences. The Solar wind Magnetosphere Ionosphere Link Explorer (SMILE) will complement all solar, solar wind and in situ magnetospheric observations, including both space- and ground-based observatories, to enable the first-ever observations of the full chain of events that drive space weather.

SMILE will fly in a polar orbit with an apogee of 20 Re to image the magnetosphere and auroras for more than 40 hours continuously per orbit. The launch is planned in November 2023.

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).

1 – GEOTAIL

GEOTAIL project is now taking a mission extension review to extend GEOTAIL operation at least until the end of Mar. 2022. NASA is continuously supporting GEOTAIL (tracking by DSN (Deep Space Network), and making level-1 data). NASA's support for GEOTAIL operation until 2020 was approved at NASA 2017 Heliophysics Senior Review. 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 the 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. Requests of GEOTAIL digital data that are not found at DARTS are to be sent to both Dr. Hiroshi Hasegawa (Project Scientist): hase AT stp.isas.jaxa.jp and Dr. Yoshifumi Saito (Project Manager): saito AT stp.isas.jaxa.jp

2 – Arase (ERG)

Arase (ERG) satellite has been observing the Earth's inner magnetosphere with the full operation mode since March 2017. We have already organized various conjugate observations between Arase and Van Allen Probes, MMS, and ground-based observations. For example, more than 300 conjunction events between Arase and Van Allen Probes have been observed until now. The information of the science instruments onboard the Arase satellite were published in the special issue of Earth, Planets, and Space. The initial science results have been presented mostly in the special issue of Geophysical Research Letters. The prime mission period completed in October 2018 and JAXA approved the extended mission until the end of March 2022 after several reviews. CDF files of the calibrated science data obtained by each instrument are available and data analysis software, which is prepared as the SPEDAS plugin, is also found in the ERG science center webpage (https:// ergsc.isee.nagoya-u.ac.jp). Any request to the Arase (ERG) science data is welcome. If you have any questions on the Arase satellite, please contact Dr. Yoshizumi Miyoshi (Project Scientist): miyoshi AT isee.nagoya-u.ac.jp, Dr. Iku Shinohara (Project Manager): iku T stp.isas.jaxa.jp and PIs of each instrument.

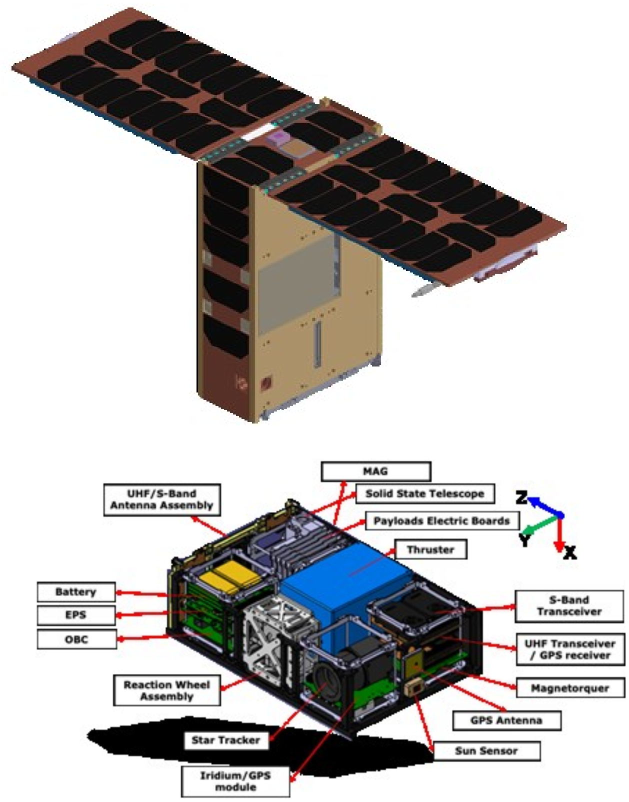
3 – BepoiColombo MMO

BepiColombo MMO [Mercury Magnetospheric Orbiter] was launched on 20 October 2018. Commissioning of the onboard instruments will be completed by autumn 2019. After the Earth Flyby in April 2020, the 1st Venus Flyby is scheduled in October 2020. After arriving at Mercury in December 2025, MMO will make a comprehensive observation of Mercury's magnetosphere together with ESA' s Mercury Planetary Orbiter (MPO).

South Korea Liaison Report

Jaejin Lee (Korea Astronomy and Space Science Institute)

1) The Magnetosphere-Ionosphere joint workshop, similar to the GEM/CEDAR joint meeting, was successfully held last summer at KOPRI (Korea Polar Research Institute), Incheon. This workshop aims to allow participants to share scientific interests and discuss the future direction of the Korean space physics community. About 72 researchers and students attended the workshop with 3 invited, 11 oral, and 27 poster presentations.
2) KASI (Korea Astronomy and Space Science Institute) is developing the SNIPE (Small-scale magNetospheric and Ionospheric Plasma Experiment) mission, which consists of four nanosatellites of ~10 kg. The SNIPE mission, planned to be launched in 2021, will perform formation flying in low earth orbit (~500 km) to investigate ionospheric plasma irregularities and electron precipitation with three sophisticated instruments: Langmuir Probes, Solid State Detectors, and Magnetometers. The SNIPE completed an PDR (Preliminary Design Review) in Sep. 2018 and will be reviewed as to Critical Design (CDR) in Sep. 2019.

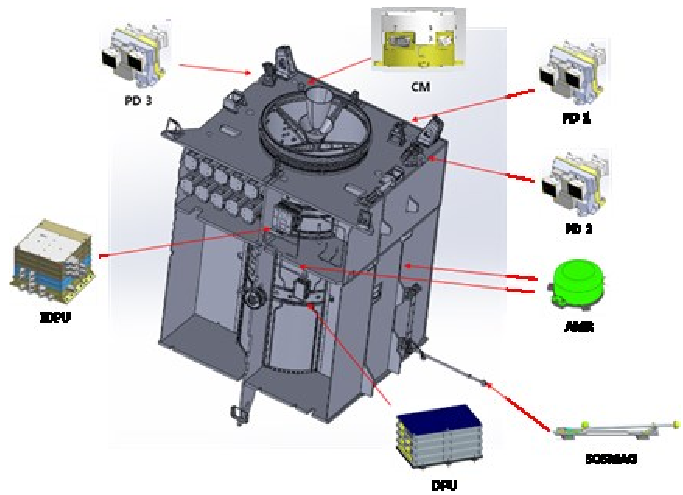


Schematic drawing of spacecraft of SNIPE Mission

Magnetosphere and Ionosphere Workshop Attendees

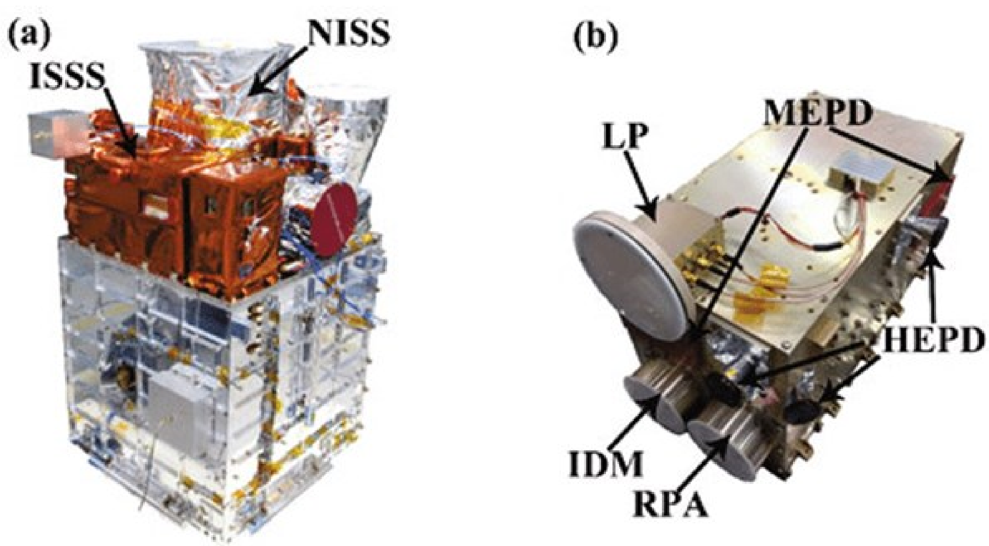
GEMSTONE

3) GK-2A, a Geosynchronous meteorological satellite funded by KMA (Korea Meteorological Administration) was launched on 4th Dec. 2018 into a longitude of 128.2° E. While the main payload is AMI (Advanced Meteorological Imager), the KSEM (Korea Space Environment Monitor) is loaded for monitoring space weather conditions at GEO orbit. The KSEM is composed of three instruments: Particle Detectors, a Spacecraft Charging Monitor, and Magnetometers. Currently, the KSEM is under the In-Orbit-Test and waiting for the normal operation.



Integrated GK-2A before launch(left) and Space Weather Instrument Suit aboard GK-2A (right)

4) Korean scientific satellite, NEXTSat-1 was launched successfully into a low earth (~570 km) polar orbit on 3rd Dec. 2018. Prof. Min at KAIST (Korea Advanced Institute of Science and Technology) leads the team for developing ISSS (Instruments for the Study of Space Storms) aboard NEXTSat-1. The ISSS is an instrument suite consisting of five space plasma instruments: High Energy Particle Detectors (HEPD), Medium Energy Particle Detectors (MEPD), Langmuir Probe (LP), Retarding Potential Analyzer (RPA) and Ion Drift Meter (IDM).



NEXTSat-1 Flight model (left) and ISSS (right)

Taiwan Liaison Report

Lou Lee

A. FORMOSAT-5 Mission (Launch in 2017)
B.

As a FORMOSAT-2 follow-on mission, National Space Organization in Taiwan has self-reliantly finished developing FORMOSAT-5 program to mainly provide 2-m resolution panchromatic and 4-m resolution multi-spectral 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 started routine operation to collect more than 52 GB science data since 1 November 2017 and has outperformed in duty cycle and data availability. Initial geophysical data have been formatted as quick-look displays for preview via NSPO FS-5 AIP SDC webpage (http://sdc.ss.ncu.edu.tw/). Preliminary results like global distributions of ionospheric plasma density irregularities on space weather and large scale average plasma density on space climate have been presented in major scientific conferences and submitted to scientific journals for publication.

B. FORMOSAT-7/COSMIC-2 Mission (to be launched on June 22, 2019)

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 a cluster of 6-satellites into low-inclination orbits on June 25, 2019. The FORMOSAT-7/COSMIC-2 mission will be operated at an orbit of 550 km altitude, 24-degree inclination angle, and a period of 97 minutes. 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. FORMOSAT-7/COSMIC-2 will provide high quality RO sounding profiles of the tropics. The instruments onboard benefit from advanced technology that will obtain a greater number of sounding profiles with higher accuracy than those provided by the FORMOSAT-3 constellation. The new technology provides sounding profiles of the atmosphere closer to Earth's surface where many forcing functions of weather prediction occur. These deep sounding profiles are expected to be especially useful in the study and forecasting of tropical meteorology, including tropical cyclones. FORMOSAT-7/COSMIC-2 mission as the largest science and technology collaboration between the U.S. and Taiwan will provide very valuable data from GNSS radio occultations for global weather forecasting, space weather monitoring and climate research.

Student Representative Report

Suzanne Smith, Ryan Dewey, and Matthew Cooper

This year 71 students attended the GEM Summer Workshop in Santa Fe, New Mexico. Student Day was held on Sunday, June 17th, and featured 13 student speakers. The students gave tutorials encompassing different magnetospheric regions, processes, models, and data sources. The GEM student representatives introduced all the focus groups briefly, as a way to give the students the opportunity to understand what they will be walking into during the week.

This year, continuing the trend of the last three years, the Student Representatives hosted a panel conversation with three career scientists during the Monday night Student Dinner. The topic of conversation this year, "Proposals and Getting Funded", was selected after conversations with students during the 2017 Mini GEM Student Town Hall. The GEM Student Representatives would like to extend a special thank you to our panelists: Alex Glocer, Christine Gabrielse, and David Sibeck.

For the third year in a row, the Student Representatives organized and hosted the GEM Student Poster Competition. As with last year's poster competition, winners are awarded for each research area. This year's winners were:

- Mei-Yun Li (University of Illinois – Urbana-Champaign) – Solar Wind - Magnetosphere Interaction
- Bruce Fritz (University of New Hampshire) – Magnetosphere - Ionosphere Coupling
- Nithin Sivadas (Boston University) – Magnetotail and Plasma Sheet
- Leng Ying Khoo (University of Colorado – Boulder) – Inner Magnetosphere
- Luisa Capannolo (Boston University) – Inner Magnetosphere

Based on the results from the post GEM student survey, the Student Representatives hope to keep improving the student experience during the week of GEM. Student Day continues to be a successful venture in introducing new students to the topics covered at GEM and the rest of the student community. We are also pleased to announce the students found the Student Dinner and Panel worthwhile as well.

This year, Matthew Cooper (NJIT) was elected as the next GEM Student Representative and will replace Suzanne Smith (Catholic University of America). Matthew's term will run through the 2020 GEM workshop. Outgoing Student Representative Suzanne Smith would like to thank everyone at GEM and the GEM Steering Committee for their continued support of students, in creating a cordial environment, and for allowing the opportunity to serve the GEM community. Suzanne would also like to thank her predecessor (Anthony Saikin) and the other Student Representative, Ryan Dewey (University of Michigan), for their continued support and help during her tenure. Yay GEM!

GEM Steering Committee

NSF Program Director
- Lisa Winter

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)
- Vania Jordanova (2017—2020)
- Allison Jaynes (2018—2021)
- Research Area Coordinators (see below)
- Meeting Organizer (see below)

Steering Committee Liaison Members
- Shasha Zou (Liason to CEDAR)
- Joe Borovsky (Liaison to SHINE)
- Masha Kuznetsova (Liaison to CCMC)
- Mona Kessel (Liaison to NASA)
- Howard Singer (Liaison to NOAA)
- James McCollough (Liaison to AFRL)
- Josh Rigler (Liaison to USGS)
- Benoit Lavraud (Liaison to ESA)
- Laura Morales (Liaison to Argentina)
- Brian Fraser (Liaison to Australia)
- Robert Rankin (—2019), John Manuel (2019—) (Liaison to Canada)
- Chi Wang (Liaison to China)
- Yoshizumi Miyoshi (Liaison to ISAS, Japan)
- Jaejin Lee (Liaison to Korea)
- Xochitl Blanco-Cano (Liaison to Mexico)
- Lou Lee (Liaison to Taiwan)

Meeting Organizer
- Robert Clauer (2005-2018)
- Chia-Lin Huang, Chris Mouikis (2018-)

Student Representatives
- Suzanne Smith (2016 - 2018)
- Ryan Dewey (2017 - 2019)
- Matthew Cooper (2018—2020)

Research Area Coordinators
Solar Wind-Magnetosphere Interaction (SWMI)
- Katariina Nykyri (2012-2018)
- Steve Petrinec (2015-2021)
- Brian Walsh (2018—2024)

Magnetotail and Plasma Sheet (MPS)
- Andrei Runov (2014-2018)
- Matina Gkioulidou (2015-2021)
- Chih-Ping Wang (2018—2024)

Inner MAGnetosphere (IMAG)
- Scot Elkington (2013-2018)
- Seth Claudepierre (2015-2021)
- Raluca Ilie (2018—2024)

Magnetosphere-Ionosphere Coupling (MIC)
- Marc Lessard (2012-2018)
- Shin Ohtani (2015-2021)
- Hyunju Connor (2018—2024)

Global System Modeling (GSM)
- Frank Toffoletto (2012-2018)
- Alex Glocer (2015-2021)
- John Lyon (2018—2024)

Communications Coordinator
- Peter Chi (2014 - 2019)

GEM on the Internet
GemWiki: http://aten.igpp.ucla.edu/gemwiki/
GEM Workshop Website: https://gemworkshop.org/
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

List of GEM Focus Groups

Focus Group	Duration	Co-Chairs	Associated Research Areas				
			SWMI	MPS	IMAG	MIC	GSM
Geospace Systems Science	2014-2018	J. Borovsky, W. Lotko, V. Uritsky, and J. Valdivia					•
Inner Magnetosphere Cross-Energy/ Population Interactions (IMCEPI)	2014-2018	Y. Yu, C. Lemon, M. Liemohn, and J. Zhang			•		
Quantitative Assessment of Radiation Belt Modeling (QARBM)	2014-2018	J. Albert, W. Li, S. Morley, and W. Tu			•		
Testing Proposed Links between Mesoscale Auroral and Polar Cap Dynamics and Substorms	2015-2019	T. Nishimura, K. Murphy, E. Spanswick, and J. Yang		•			
Tail Environment and Dynamics at Lunar Distances	2015-2019	C.-P. Wang, A. Runov, D. Sibeck, S. Merkin, and Y. Lin	•	•			•
Merged Modeling & Measurement of Injection Ionospheric Plasma into the Magnetosphere (M3I2) and Its Effects — Plasma Sheet, Ring Current, Substorm Dynamics	2016-2020	V. Eccles, S. Zou, and B. Giles				•	
ULF wave Modeling, Effects, and Applications (UMEA)	2016-2020	M. Hartinger, K. Takahashi, and B. Kress					•
Modeling Methods and Validation	2016-2020	K. Garcia-Sage, M. Liemohn, L. Rastaetter, and R. Redmon					•
Dayside Kinetic Processes in Global Solar Wind-Magnetosphere Interaction	2016-2020	H. Hietala, X. Blanco-Cano, G. Toth, and A. Dimmock	•				•
Magnetotail Dipolarization and Its Effects on the Inner Magnetosphere	2017-2021	C. Gabrielse, M. Gkioulidou, S. Merkin, D. Turner, and D. Malaspina		•	•		
3D Ionospheric Electrodynamics and Its Impact on the Magnetosphere-Ionosphere-Thermosphere Coupling System	2017-2021	H. Connor, H. Korth, G. Lu, and B. Zhang				•	•
Magnetic Reconnection in the Age of the Heliophysics System Observatory	2018-2022	R. Wilder, S. Wang, M. Shay, and A. Artemyev					•
Interhemispheric Approaches to Understand M-I Coupling (IHMIC)	2018-2022	H. Kim, R. Lysak, and T. Matsuo			•	•	•
System Universtanding of Radiation Belt Particle Dynamics through Multi-spacecraft and Ground-based Observations and Modeling	2019-2023	H., L. Blum, S. Ukhorskiy, and X. Fu			•		
Particle Heating and Thermalization in Collisionless Shocks in the MMS Era	2019-2023	L. Wilson III, L.-J. Chen, K. Goodrich, and I. Vasko	•				