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The GEMstone Newsletter

Notes from the GEM Chair

Vania Jordanova

We certainly live in unusual and quite challenging times, and we hope everyone is healthy and doing well. For the first time in almost 30 years, because of the current COVID-19 crisis, the GEM Steering Committee decided to cancel the in-person GEM Summer Workshop and organize a virtual meeting in its place. The Virtual GEM will occur during the same week as the originally scheduled in-person workshop, July 20-23, with Monday July 20 as the student day. We will try to maintain the original format of GEM as much as possible, with plenary sessions in the morning, Focus Group breakout sessions in the afternoon, and poster sessions in the evening. Please provide your full support to the meeting organizers to help make this first VGEM a great success! As of now, we still plan to hold the GEM 2021 summer workshop in Hawaii from July 26-30, 2021, with a GEM student day on July 25. This workshop will be back-to-back with SHINE (to occur at the same hotel the week after GEM) - please consider attending both!

Last year's GEM 2019 summer workshop was held in sunny Santa Fe, New Mexico, from June 23-28, 2019, and was a resounding success! It was attended by 330 participants, 90 of which were students (all with financial support), a record number to date. There was a Student Day on June 23 and a Joint GEM-CEDAR Workshop on June 22. For the first time, we provided family-care grants of ~$400 to 6 participants to offset their childcare costs during the meeting. Following the highly successful presentation on microagressions at the GEM 2018 meeting given by the New Mexico Women's Organization, we piloted an Under-Represented Minority (URM) lunch event that was attended by ~50 participants. The primary goal was to provide a safe space for community members to talk about diversity, equity, and inclusivity (DEI) at GEM. We know that diversity and inclusion are at the top of everyone's mind these days, and we want to reemphasize GEM's commitment to these values. We are currently updating GEM's anti-harassment policy, and we will be adding similar DEI events in the upcoming VGEM workshop. Please find further details in the report from the meeting organizers Chia-Lin Huang and Chris Mouikis.

This issue of the GEMStone includes reports from the Focus Groups (FGs) that are part of the 5 Research Areas (RAs) that form the GEM program, as well as reports from the GEM Liaisons who represent our connection to the worldwide space science community. As two FGs came to an end last year, two new FGs were selected to start this year – "The Impact of the Cold Plasma in Magne-

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tospheric Physics" (IMAG research area, co-led by Gian Luca Delzanno, Natalia Buzulukosva, Barbara Giles, Roger Varney, and Joe Borovsky) and "Self-Consistent Inner Magnetospheric Modeling" (IMAG research area, co-led by Cristian Ferradas, Chao Yue, Jacob Bortnik, Qianli Ma, and Sam Bingham). In addition, the Modeling Methods and Validation FG was converted into a standing committee: the Methods & Validation Resource Group will consist of four members serving staggered four-year terms, with Lutz Rastaetter selected as the Liaison for Methods and Validation. I would like to also thank Benoit Lavraud who served the community for more than 15 years as the GEM Liaison to Europe, and to welcome Andrew Dimmock as the new Liaison to Europe and Tom Elsden as the new Liaison to MIST/UK.

During the past year the GEM governance has undergone some significant changes that are briefly described here. First, the Steering Committee (SC) changed the duration of the terms of its members as follows: (1) terms for RACs are now four years instead of six, and (2) At-Large positions are four years instead of three. The terms will be staggered so that a major part of the SC does not rotate off at the same time. The intention of the term changes is to allow more new people the opportunity to join the SC and to bring fresh ideas to GEM, while simultaneously better preserving institutional memory. Second, the GEM SC considered several options to enhance its efficiency, transparency, and ability to address urgent issues as they arise. It was decided that virtual meetings of the GEM SC Voting Members, which would also include the NSF MAG Program Officer as an observer, will be held regularly and the SC minutes will be posted in a timely manner at the GEM Wiki. Third, the GEM community has been working towards a transition in its communication. We thank Peter Chi for coordinating the GEM Messenger, Wiki, and the GEMstone for many years through UCLA. The GEM Messenger will henceforth be distributed through MailChimp and coordinated by the GEM SC Chair and Vice Chair. The GEMstone will be generated by two At-Large SC members on a rotating basis, and we thank Allison Jaynes for compiling the current issue. The GEM Wiki will be maintained by another At-Large SC member, with thanks to Adam Kellerman for fulfilling this role at present. Lastly, many thanks are due to Paul Cassak for his great contribution and service to the GEM community as a GEM Chair; with him stepping down in March, I became the new GEM Chair and Adam Kellerman became the Interim Vice Chair. We will reopen the search for the GEM Vice Chair position in a few months, please consider applying and/or nominating candidates from the GEM community!

Finally, don't forget about the ongoing search for a new GEM Logo by the SC! This is a great opportunity to be a part of refreshing the face of GEM while interacting with the community during these challenging times. A competition is being conducted by the SC to reward the winning design; please submit entries to the meeting organizers Chia-Lin (chia-lin.huang at unh.edu) and Chris (Chris. Mouikis at unh.edu) ASAP. The winners will be announced at VGEM!

We look forward to seeing you all virtually in July.

Notes from the GEM Program Director

Lisa Winter

On behalf of myself and the NSF Geospace Section, I send my wishes for good health to you and your loved ones. During this difficult time, our thoughts and best wishes are with you. Please feel free to reach out to me directly (lwinter at nsf.gov) over any concerns related to your on-going grants or future proposals, and to inform of COVID-19 related impacts to your work.

I am personally very impressed and humbled by the dedication of the GEM community and extend my thanks on behalf of NSF to those who have given their valuable time as panelists, reviewers, and organizers/steering committee members for the GEM meeting. Thank you! And for anyone who would like to volunteer for future panels (particularly early career scientists), please send an e-mail to me directly.

This fiscal year, many exciting new awards have been made by the Magnetospheric Physics program. Congratulations to Raluca Ilie from the University of Illinois Urbana-Champaign on being awarded a **CAREER** grant! Her work focuses on determining how particle injections are formed and driven by potential vs. inductive electric fields through numerical simulations and comparison with data. Her educational project is an exciting development of 3D electric and magnetic field visualizations for Virtual Reality headsets to teach physics to undergraduate and high school students. Raluca's VR development is particularly important and relevant to education in the new-normal era of physical distancing. New submissions to the NSF CAREER program are due August 11, 2020. Please encourage eligible early-career faculty to apply! For new post-docs (within 2 years of the PhD), please consider applying for the NSF Postdoctoral Research Fellowship with submissions accepted at any time.

The Magnetospheric Physics program and Geospace section have made significant investments in continuing magnetometer measurements into the future. As examples, the inner Magnetospheric Array Geospace Studies (iMAGS) project will develop a new research quality, low-cost and low-power ground magnetometer to revitalize existing ground-magnetometer arrays. The Magnetometer Array for Cusp and Cleft Studies (MACCS), in operation for 25 years, will continue measurements and scientific studies into the next solar cycle. The DASI MagStar project will improve the spatial coverage of US magnetometers for space weather research and operations. Additionally, the SuperMAG and AMPERE projects provide valuable ground-based and space-based magnetic field measurements to the scientific community. New proposals to the Magnetospheric Physics and GEM programs utilizing these datasets are encouraged. Also, proposals utilizing and giving access to the community of datasets currently not accessible to the public are also encouraged (including obtaining new or historical data sets).

Both the Magnetospheric Physics and GEM programs continue to accept proposals with no deadline. I anticipate the program having panels twice a year (fall and spring). Please send us your new ideas! Remember that NSF proposals are evaluated on both intellectual merit and broader impacts and if there are any questions about what makes a good broader impacts component, feel free to reach out!

Meeting Organizer Report

Chia-Lin Huang and Chris Mouikis

2019 was a transition year for the GEM meeting organizers. After a decade of serving tirelessly the GEM community, the Virginia Tech team, Bob Clauer and Zhonghua Xu, handed over the meeting organization to the University of New Hampshire. We are very appreciative not only for their effort all these years, but also for their assistance while planning our first GEM summer workshop in Santa Fe. We also want to welcome to our team Umbe Cantu, a long-term friend of the GEM community. We are looking forward seeing her performing her "magic" in securing new and exciting destinations for our future summer workshops.

GEM 2019 Summer Workshop

The GEM 2019 Summer Workshop was held at the La Fonda Hotel in Santa Fe, NM, June 23rd-28th. In addition, in coordination with the CEDAR steering committee, we organized the one-day GEM/CEDAR joint meeting on June 22nd that was attended by ~100 participants from the CEDAR and GEM communities. The main topics of the joint meeting were (1) observational platforms, (2) outflow/inflow, (3) conductances / conductivities, and (4) extreme events. The joint meeting was very successful, and we are already planning another joint meeting in 2022.

Furthermore, we hosted the MMS SWT meeting as part of the broader GEM workshop. Since the two communities have overlapping science interests, it was deemed beneficial to everybody to run the two meetings concurrently and engage the GEM focus groups and the MMS SWT organizers to coordinate shared sessions. As a result, one MMS plenary talk and four GEM/MMS sessions were added to the GEM program. This led to a very productive week for scientists from both communities and resulted in time, cost and productivity savings for the broader community overall.

There were 335 attendees which is a 13% increase from the 2018 meeting and is the highest number of all GEM meetings. 90 students and postdocs were supported by NSF funding. The male and female ratio between all participants was 29% women and 71% men, while between students it was 30% women and 70% men. To help GEM members with young children attending the summer workshop, a new Family Care Grant (~$400) was available for all GEM participants to apply. This grant is intended to help offset the cost of childcare and will be available every year, though recipients will be responsible for arranging their own childcare. This year, we had six grant recipients.

A number of student activities were coordinated during the week. **Sunday Student Day** was a half-day meeting with 10 student tutorial talks on various GEM-related topics including computer simulations and spacecraft missions. **Student Monday Dinner** was an evening social event with guest speakers to talk about "Choosing an early career path" from several GEM young career scientists. **Student Thursday Lunch**, new this year, was held to wrap up the student activities with an election on the new student representatives.

In addition, we helped organize the Under-Represented Minority (URM) lunch event with 50 participants that was led by Paul Cassak. This was an engaging and productive discussion promoting the conversation of Diversity, Equity and Inclusion (DEI) in the GEM community. We also helped to organize the LWS discussion during Monday lunch break and a town hall to discuss Decadal midterm assessment on Monday evening.

The poster sessions have become a staple of the GEM Summer Workshops. Students that accept the financial support from NSF are asked to at least present their work during the poster sessions. This year we had two poster sessions scheduled with 190 posters presented that were very well attended. The student representatives continued the tradition of organizing the GEM Student Poster Competition.

We gave out a survey toward the end of the GEM meeting and have received feedback from over 100 participants (thank you all!). The survey topics include the conference location and facility, the GEM websites, the plenary, concurrent, and poster sessions, and the GEM organization. We have read through all the comments (mostly positive!) and will definitely consider the community's feedback when running GEM and planning our future meetings.

The plenary session tutorial talks together with the Python tutorial were recorded and the videos are available on the "NSF GEM Workshops" YouTube channel: https://www.youtube.com/channel/UChd0dRgzvr8JVIL48zHxPGA.

In addition, the plenary tutorial presentations are available on Google Drive: https://drive.google.com/drive/folders/1goAaT7k57H4lqPHldDvaDeZm1-ZMarG-?usp=sharing

GEM 2019 Mini-Workshop

This year the mini-GEM 2019 Workshop was held at the Holliday Inn Hotel in San Francisco, CA, on December 8th. This is a half day meeting that runs from 12 pm to 5 pm the day before the start of the Fall AGU meeting. This year we hosted 3 concurrent sessions with six parallel sessions each. This allowed the FGs to communicate and coordinate their research with the community. At the end of the concurrent sessions the new FG proposals were presented. We had a record number of participants, ~250, which shows that the mini-GEM is an integral part of the scientific calendar of the GEM community.

Student Representative Report

Ryan Dewey, Matthew Cooper, and Agnit Mukhopadhyay

This year 84 students attended the GEM Summer Workshop in Santa Fe, New Mexico. Student Day was held on Sunday, 23 June, and featured ten student speakers. Similar to previous years, several tutorials focused on basic plasma physics and different magnetospheric regions, however, this year we also included tutorials on topics chosen by the student community. These four "advanced" tutorials focused on the details of magnetic reconnection, plasma waves, modeling types & theory, and data processing & visualization. The student representatives opened the day with a discussion of the history and structure of GEM, and concluded the day with a description of student activities during the week of the workshop.

This year, continuing the trend of the last several years, the student representatives hosted a panel conversation with four career scientists during the Monday night Student Dinner. The topic of conversation this year, "Choosing an Early Career Path", was selected after conversations with students during the 2018 Mini-GEM Student Town Hall. The GEM student representatives would like to extend a special thank you to our panelists: Matina Gkioulidou, Doğacan Ozturk, Seth Claudepierre, and Andrew Gerrard.

The student representatives continued the tradition of organizing and hosting the GEM Student Poster Competition. Sixty-four students and fifty-four volunteer judges participated in the competition. The student representatives would like to thank the judges again for volunteering their time and feedback. As with last year's poster competition, winners are awarded for each Research Area. The winners from this year are:

Yi Qi -------------------- UCLA -------------------- SWMI
Subash Adhikari -------- University of Delaware --- GSM
Emil Atz ----------------- Boston University -------- GSM
Riley Troyer ------------- University of Iowa -------- MPS
Longzhi Gan ------------ Boston University -------- IMAG
Agnit Mukhopadhyay -- University of Michigan --- MIC

Other student-related activities included the student-invited plenary session, given this year by Matthew Argall on the topic of machine learning, and NSF open office hours, hosted by Lisa Winter and Mike Wiltberger. Several students volunteered to record the plenary sessions, introduce plenary session speakers, and run the microphone during the question sessions, and the student representatives would like to thank them for their dedication to helping the morning sessions run smoothly.

This year, Agnit Mukhopadhyay (University of Michigan) was elected as the next GEM student representative and will replace Ryan Dewey (University of Michigan). The student representative selection process was expanded upon from previous years, with the major changes including an extended nomination time and a Student Lunch on Thursday to allow students of the community to interact with the nominees. Agnit's term will run through the 2021 GEM workshop. Outgoing student representative Ryan Dewey would like to thank everyone at GEM, and in particular the GEM Steering Committee, for their continued support of students, their creation of a cordial environment, and their allowing for the opportunity to serve the GEM community. Ryan would also like to thank his predecessor (Suzanne Smith) and fellow representative, Matthew Cooper (NJIT), for their continued support and help during his tenure.

In Memoriam: Ted Fritz

Brian Walsh, Howard Singer and Joe Borovsky

In the spring of 2020 we mourned the loss of GEM community member Ted Fritz, Emeritus Professor, Boston University. Ted was a dynamic member who embodied the GEM spirit. He spent much of his career studying energetic particle dynamics and made significant contributions to the cusp and radiation belt focus groups. True to the GEM spirit he always enjoyed engaging in lively discussion and scientific debate.

Solar Wind - Magnetosphere Interaction (SWMI) RA Reports

Coordinators: Steve Petrinec and Brian Walsh

Dayside Kinetic Processes in Global Solar Wind-Magnetosphere Interaction

Heli Hietala, Xochitl Blanco-Cano, Gabor Toth, Andrew P. Dimmock, Ying Zou

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 held four sessions in the Summer 2019 Workshop.

UMEA/Dayside Kinetics/IHMIC joint session

The theme of the session was to consider the ULF wave response to dayside transients with different temporal/spatial scales and asymmetries. The guest convener Tom Elsden first introduced the session and the questions posed to the participants:

1. How are ULF wave properties affected by asymmetries in the upstream driver? What modelling/observational work is required to answer this?
2. Further, how then do the resulting ULF wave asymmetries impact the M-I system?
3. How does the 3D structure of dayside kinetic phenomena (e.g., spatial scale of magnetopause disturbance, location relative to magnetic equator) affect the ULF response in different hemispheres/LT sectors?
4. Can we use magnetospheric observations to determine the size (localized vs global) of a dayside transient? Is the response well-enough understood?

Ferdinand Plaschke gave an invited overview of dayside transients generating ULF waves inside the magnetosphere: solar wind variations, foreshock phenomena (e.g., hot flow anomalies, foreshock bubbles, foreshock waves), magnetosheath jets and mirror modes, as well as magnetopause processes (e.g., flux transfer events and the Kelvin-Helmholtz-instability). Magnetosheath jets have recently become the focus of scientific interest as they occur often, have significant impact, and act as a long-range link between the bow shock and the magnetopause, ultimately connecting foreshock processes with effects observable on ground.

Tom Elsden discussed recent results from a newly developed 3D MHD code looking at ULF wave excitation in the outer magnetosphere. He showed the importance of understanding the normal waveguide modes of the system in order to predict 3D FLR structure/location, as well as commenting on future uses of the code to study ULF waves driven by local magnetopause disturbances.

Boyi Wang presented recent observations of the role of foreshock/magnetosheath disturbances in triggering magnetospheric Pc5 ULF waves. Significant magnetosheath disturbance was observed with a foreshock transient in the pre-noon sector. The disturbance further triggered a series of Pc5 ULF wave and the wave can propagate from dayside all the way to midnight.

Bob Lysak and collaborators have investigated quarter-wave field line resonances, which are observed when one footpoint of the field line is in sunlight and the other is in darkness, using a numerical simulation of ULF waves in the inner magnetosphere. They have found that such quarter-wave emissions excited by a shock-like impulse at the magnetopause, can occur on field lines within the plasmasphere near the terminator, consistent with the observations of Obana et al. (2015) that showed the resonant frequency nearly doubling when the magnetometer observing the wave passed from darkness into sunlight.

Xueling Shi presented Conjugate Observations of ULF Waves during an Extended Period of Radial IMF. The ULF waves were observed over a wide range of dayside local times and outer magnetospheric L shells. The upstream ion foreshock during an extended period of radial IMF probably plays an important role in providing a seed perturbation for the growth of the KH instability which generates the dayside ULF waves.

Finally, UMEA Focus Group co-chair Michael Hartinger reviewed discussions from previous GEM Workshops related to the session theme. While numerous past GEM presentations indicated a relationship between dayside kinetic phenomena and magnetospheric ULF waves, there are unresolved questions concerning the effectiveness of different transients in driving waves. Statistical studies and modeling efforts are needed to determine how transients related to different spatial distributions and speeds on the magnetopause affect wave activity.

Dayside Kinetics/Bow Shock joint session

The theme of the session was to discuss new studies of key kinetic processes which are important to both the bow shock and dayside region. The main topics included transmission of transients/waves through the shock, impact of shock processes on the downstream region, and the formation of shock-like structures in different dayside regions.

Ian Cohen presented MMS data from 8 Jan 2018, when it encountered its only interplanetary shock to-date, observing electron heating, near-specularly reflected ions, and apparent significant non-linear electric field structures. The high-resolution particle and field measurements enabled multiple approaches to calculate the cross-shock potential for this marginally supercritical shock.

Xin An used particle-in-cell simulations to reveal the formation process of foreshock transients and to provide clear evidence on the critical role of electric fields in shaping the magnetic field structures, as well as in coupling the energy of hot ions to that of the secondary shock, which is subsequently dissipated through the excitation of magnetosonic waves. They further demonstrated that higher Mach number of the parent shocks favors the formation of the secondary shocks, which will be appealing to consider in particle acceleration of high Mach number astrophysical shocks.

Yann Pfau-Kempf presented Vlasiator simulation results on the transmission of foreshock ULF waves to the magnetosheath.

Michael Balikhin showed the first direct observations of quasi-perpendicular bow shock nonstationarity, which was achieved during a Cluster close separation campaign. The main result was that nonstationarity is initiated by electron scale structures within the ramp, agreeing with the gradient catastrophe model, but not those proposed by some numerical PIC simulations.

Heli Hietala presented global 3D hybrid simulations of magnetosheath jets. The jets identified from the simulation using similar criteria as in spacecraft observations extend from the bow shock into the subsolar magnetosheath and have very irregular shapes.

Terry Liu's statistical study using THEMIS shows that high solar wind dynamic pressure, large solar wind plasma beta, and high bow shock Alfven Mach number favor the formation of magnetosheath jet-driven bow waves. Jets with a bow wave have higher probability to have larger particle energies than jets without a bow wave.

Reconnection/Dayside Kinetics joint session

Magnetic reconnection itself is a key dayside kinetic process and it is closely related to other kinetic processes, including waves and turbulence. The goal of this session was to understand fundamentals of dayside reconnection. The main topics included:
1. What are the characteristics of magnetic reconnection on the dayside?
2. What role does reconnection play in forming various dayside transients?
3. What are the new approaches/opportunities of studying magnetic reconnection?

Katariina Nykyri presented MMS observational and global simulation results on the generation mechanism of a new kind of magnetic bottle structure with energetic particles of both solar wind and ionospheric origin at the southern dayside magnetospheric boundary layer formed by low latitude reconnection. The center bottle, characterized by weak magnetic field, was filled with high fluxes of 90 degree pitch angle energetic electrons and ions.

Andrew Dimmock gave an overview of the SMILE Soft X-ray Imager (SXI) which will observe the dayside-magnetosphere interaction in soft X-rays resulting from solar wind charge exchange. The novel dataset can be used to track the motion of the magnetopause and cusps, making it possible to investigate the fundamental modes of solar wind-magnetosphere interactions.

Brian Walsh presented an update on the development of the CuPID Cubesat Observatory. The 6U cubesat will image ion dispersions in the cusps to study meso- and macro-scale properties of magnetic reconnection.

Xuanye Ma compared the Kelvin-Helmholtz (KH) instability in a fluid simulation with test particles with a hybrid simulation. The Hall MHD with test particles and hybrid simulation give almost identical particle mixing rate in the KH instability. Test particle results show the KH instability can form an anisotropic velocity distribution.

Karlheinz Trattner considered the dynamics of elongated dayside X-lines using MMS observations and the maximum shear model.

Marcos Silveira and collaborators surveyed flux transfer events observed by the MMS mission in the vicinity of the Earth's magnetopause from Y = -12 to 12 R_E with a large range of characteristic time and cross-section length. One case of a small-scale flux transfer event with an electron scale structure was presented.

Dayside Kinetics/MMV joint session

This session focused on the Dayside Kinetics Southward IMF Challenge. We discussed the progress in comparing observations and modelling results for the event on 2015-11-18 01:50-03:00 UT, featuring an MMS-Geotail magnetopause conjunction with SuperDARN radar observations. Heli Hietala first presented a summary of the Challenge progress so far. We then moved on to new observation-modelling comparisons, in particular of the magnetopause transients (are they due to simple boundary layer motion or more FTE-like?).

Sarah Vines presented an overview of the MMS observations from the Challenge event that were provided for the data-model comparisons (magnetic field and plasma moments in the published LMN system and dB power spectra), and the results of an initial run of the maximum magnetic shear model. Additionally, she discussed low-energy ion composition for this event, particularly the heavy magnetospheric ions (He^+, O^+) reaching the outer magnetosphere and magnetopause that are energized in the current layer and reconnection exhaust.

Karlheinz Trattner presented new maximum shear model results for the event and comparison with MMS. According to their analysis, MMS observed a single clean magnetopause crossing bracketed by several boundary layer encounters before and after the crossing. Each boundary layer encounter showed southward accelerated ion beams indicating the presence of an X-line north of the satellites, with no FTE signatures on the southern side of the X-line.

Zhifang Guo used a three-dimensional global-scale hybrid simulation to study the MMS observations during the event. The location of the magnetopause reconnection, the global distribution of the X-lines, the spatial and temporal variation in reconnection, the electromagnetic power spectra, and the ion velocity distributions were compared with the observations.

Marcos Silveira compared the MMS observations with Yuxi Chen's MHD-EPIC results for the challenge event, where the model observed some of the structures at a location similar to that of MMS3. The simulation reproduces qualitatively the MMS observations of magnetopause transients, suggesting the probes observed edges of possible flux transfer events in the magnetosphere.

We finished with a discussion on the wrapping up of the Challenge, including JGR-Earth and Space Science Special Issue manuscript coordination.

Particle Heating and Thermalization in Collisionless Shocks in the MMS Era

Lynn Wilson, Li-Jen Chen, Katherine Goodrich, Ivan Vasko

We had two shock-only sessions and one joint-session with the dayside group.

Session 1:

Attendance: ~40+ people (standing room-only in back)

S.J. Schwartz: Gave a tutorial on quasi-static fields in collisionless shocks. This was the only tutorial-/lecture-like presentation in both sessions, which was intentional, to give context for our first year goals.

L.-J. Chen: Presented new MMS observations of quasi-static fields in collisionless shocks. This talk generated a lot of questions and discussion leading to a very lively presentation. The interesting point is that Li-Jen's work actually provides evidence against the standard cross-shock potential interpretation of particle dynamics. That is, her results suggest there are quasi-static (well, very low frequency) fields that play a significant role in the particle dynamics but it is not a static electric potential.

Jonathan Ng: Presented some new, preliminary results from his 2D PIC simulations of collisionless shocks finding evidence for electron heating due to microinstabilities in the shock.

Shan Wang: Presented recently published results showing MMS observations of magnetic reconnection occurring in the shock transition region of a quasi-perpendicular shock. The interesting part is if reconnection is common or necessary, it begs the question of how we need to modify our conceptual picture of collisionless shock dynamics and evolution.

Session 2:

Attendance: ~30+ people (much bigger room so people were more spread out, but still well attended)

Naoki Bessho: Presented some 2D PIC simulation of magnetic reconnection occurring in the shock transition region of collisionless shocks. He presented some interesting results showing that some regions seem to be electron-only type reconnection while others also involve ion dynamics. Again, if reconnection is common and/or necessary for energy dissipation in collisionless shocks, this would be a paradigm shifting idea.

Ilya Kuzichev: Presented recent results examining the whistler heat flux instability in the context of collisionless shocks. The work can also be extrapolated to the general solar wind as one of the biggest questions in that field is how the suprathermal electrons evolve as they propagate away from the sun. The results suggest there may be some whistlers near collisionless shocks, but their influence on the suprathermals is still difficult to ascertain as there is another competing instability, the temperature anisotropy instability.

Anton Artemyev: Presented very interesting results on nonlinear wave-particle interactions specific to collisionless shocks. This is obviously a big open question, i.e., can nonlinear waves act as a mechanism to transform the incident bulk flow kinetic energy into random kinetic energy (heat) to serve as a dissipation mechanism? Observations from Polar, Wind, STEREO, THEMIS, and MMS all show extremely large amplitude electromagnetic and electrostatic fluctuations but their effect on particle dynamics is still in debate. Anton's work is showing some evidence that waves play an important role.

Terry Liu: Presented some unexpected(?) observations of energetic particles that appeared to be accelerated by bow waves occurring in the magnetosheath. The bow waves are driven by energetic jets of solar wind plasma ramming into the slower sheath flow and can sometimes even drive shock waves within the sheath. One of the interesting things is that these observations add further evidence to the fact that collisionless shocks are not closed, smooth, planar surfaces.

Session Style:

In both sessions, Lynn Wilson, the session leader made formal statements that he wanted open discussions and that the speakers should expect to be interrupted by audience members. Our first session was much more lively and full of discussion than our second. It is speculated this was due to timing and the second one starting after lunch. All of the presenters were also emailed in advance to discourage them from giving AGU-style talk. This effort was deemed a success.

Magnetotail and Plasma Sheet (MPS) RA Reports

Coordinators: Matina Gkioulidou and Chih-Ping Wang

The Tail Environment and Dynamics at Lunar Distances

(final report)

Chih-Ping Wang, Andrei Runov, David Sibeck, Viacheslav Merkin, Yu Lin

This is a summary of the "Tail Environment and Dynamics at Lunar Distances" focus from 2015-2019. Compared with the near-Earth tail, the magnetic field in the tail at lunar distances (mid-tail) is weaker while the shocked magnetosheath becomes more solar-wind like, resulting in a far more dynamic environment. The topics discussed in this FG also extends to the near-Earth and distant tail, as well as the connection between the tail and the ionosphere. This FG has uncovered many important processes, which are summarized below in 4 topics. The observational studies of this environment and the associated processes presented in this FG were mainly based on the measurements from the two ARTEMIS spacecraft. Two modeling challenges were conducted to test the ability and limitations of current global models (MHD and hybrid) in simulating this mid-tail environment.

We held 2-3 sessions at every summer workshop and one session at every AGU mini-GEM. The average number of attendance for each session was ~20-30. The sessions were conducted in GEM style with open discussion and arguments. We also held joint sessions with "Magnetotail Dipolarization and its Effect on the Inner Magnetosphere" and "Magnetic Reconnection in the Magnetosphere" FGs in 2017, and with "Model Method and Validation" FG in 2016, 2017, and 2019.

Topic-1: Tail Plasma and Magnetic Field Structures

• Ivan Vasko presented the current sheet observed by Geotail in mid-tail and distant tail. He found that abundant thin and intense current sheet in the 30-50 and 80-100 RE regions, more intense near midnight. Intense current is found to be associated with fast ion flow and electrons likely the main current carrier. (2015)

• Anton Artemyev presented simultaneous observations of the magnetotail current sheet from THEMIS D (r~10 RE), Geotail (r~30 RE), and ARTEMIS P1 (r~55 RE). Distributions of plasma (ion) density and temperature along and across the magnetotail are studied for fourteen events (each event includes several current sheet crossings at different downtail distances). He demonstrated that plasma temperature varies across and along the magnetotail more significant than plasma density does. This temperature variation across the tail mainly contributes to the cross-tail pressure balance. (2016)

• 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. (2018)

• Anton Artemyev presented a study of multicomponent ion population in the magnetotail. He showed that the ions consist of three populations: a subthermal field-aligned anisotropic population (contributing ~90% to the total density but only ~20% to the total pressure), an isotropic thermal population (contributing ~10% of the total density and ~60% of the total pressure), and a transversely anisotropic suprathermal population. (2019)

• 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. (2018)

• Steven (Sixue) Xu presented statistics of the current sheet at lunar distances. He showed that temperature and density profiles are relatively more curved than near Earth current sheets, and the ion to electron temperature ratio is higher at the flank and in slow flows. (2019)

• San Lu presented his investigation of ion temperature gradient in the Earth's magnetotail using multi-spacecraft observations and 3-D global hybrid simulations. He demonstrated that the ion temperature ZGSM-profile is bell-shaped at different geocentric distances. Using 3-D global hybrid simulations, he showed that mapping of the

XGSM-gradient of ion temperature along magnetic field lines produces such a bell-shaped profile. (2017)

• 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. (2018)

• San Lu presented that the current sheet in Earth's magnetotail is usually not a Harris current sheet but a current sheet with polarized electric field in which the current is most carried by the electrons. He investigated magnetic reconnection in the polarized current sheet and compare the results with that in the Harris current sheet, and he found that reconnection in polarized current sheet occurs easier, earlier, but slower compared to that in the Harris current sheet. (2019)

• 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. (2018)

• Jiang Liu presented event studies of field-aligned currents (FACs) in the magnetotail computed from the 3 THEMIS satellites. In some of the events, he found that ions can be a significant carrier of FACs. (2019)

• 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 RE. (2018)

• Fekireselassie Beyene presented his method of estimating the total amount of magnetotail flux observed in mid-tail by ARTEMIS and showed the results from a storm time and substorm time interval. He concluded that during the substorm interval the peak flux was double the minimum flux and that during the storm interval the peak flux was less than twice the minimum flux. (2017)

• Denny Oliveria presented Open GGCM MHD simulations of a shocked magnetotail due to an interplanetary shock on 2012-03-08 and compared with the ARTEMIS observations at 60 RE. He found that enhanced current density in the current sheet due to shock compression and the center of magnetotail shifted to Y = –20 R_E due to the strong V_Y shear, which is consistent with the observations. MHD predicts interesting features of R-1 FACs that need to be compared with ground magnetometers. (2015)

• Rob Fear discussed magnetotail structure associated with transpolar arcs. He showed an event with Cluster in the lobe at X ~ –8 RE and Z ~ -12 RE, which saw perpendicular electron fluxes indicating closed field lines at very high latitudes, and IMAGE saw a transpolar arc, which supports that magnetotail reconnection during N IMF can be a candidate for transpolar arcs. Newly reconnected field lines map sequentially deeper into the polar cap. Thus, when a transpolar arc extends across fully to the dayside, this closed field line structure will extend a long way downtail. (2015)

Topic-2: Flows and Reconnection

• Stefan Kiehas presented his investigation of midtail flows from a five year (2011–2015) statistical survey of ARTEMIS data at around 60 RE downtail. He found that a significant portion of fast flows is directed earthward (43% (v_X > 400 km/s) to 56% (v_X > 100 km/s)). A dawn–dusk asymmetry in the flow occurrence is seen with about 60% of tailward perpendicular flows occurring in the dusk sector. On the other hand, earthward flows are nearly symmetrically distributed over the dawn and dusk sectors. This indicates that the dawn-dusk asymmetry is more pronounced in the near-Earth region than further downtail. (2017)

• Anton Artemyev presented the unique dataset gathered by two ARTEMIS spacecraft in 2010 at radial distances between lunar orbit and ~ 200 Earth radii. He identified an X-line at around ~80 Earth radii and collected statistics on hot plasma flows originating from this distant X-line. Ion spectra within these flows are well fitted by a power-law distribution with the exponential tail starting at energy ~ 2-5 keV. He estimated that the hot ion population transported toward Earth can contribute significantly to high-energy (> 50 keV) ion fluxes in the near-Earth magnetotail. (2017)

• Chih-Ping Wang presented an ARTEMIS event with the two probes at different X around –60 RE observed the earthward propagation of the same BBF structure and, from the time delay between the two probes, was able to obtain the earthward propagation speed of 340 km/s. (2017)

• Miles Bengtson discussed an ARTEMIS event showing high tailward ion and electron flow speeds possibly originating from mid-tail reconnection site. Significant electric fields were observed during the event as well as the reversal of the electron to ion temperature ratio. (2016)

• Shin Ohtani described the statistical study of dipolarizations observed by the Van Allen Probes in the inner magnetosphere. 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. (2018)

• John Lyon showed LFM simulations at lunar distances for the substorm growth phase and sawtooth event. He found that for growth phase conditions (IMF changes from N to S) bubble initiates at lunar distance. For the sawtooth event driven by O+ outflow, the X-line is seen to move between near-Earth neutral line and lunar distance. (2015)

• Joachim Birn presented results from test particle tracing in the dynamic fields of a 3-D MHD simulation of near tail reconnection and plasmoid ejection, associated with tailward propagating "anti-dipolarization fronts" (ADFs). Tailward moving energetic ions near the plasma sheet boundary typically were accelerated close to the near-Earth x-line and ejected along the magnetic field, while energetic particles near the equatorial plane underwent more complicated trajectories with possible acceleration at multiple sites within the tailward moving plasmoid and ADF. (2016)

• 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. (2018)

Topic-3. Wave Environment

• Sheng-Hsien Chen presented observation of waves in mid-tail LLBL and lunar wake. He found that there is a lack of periodicity in ULF (~1 - 60 min) surface waves in LLBL. There is a presence of kinetic waves in LLBL and lunar wake. He pointed out two main questions for discussion: (1) How is the interaction of LLBL plasma with the moon in the mid-tail subjected to kinetic Kelvin-Helmholtz instability, lower-hybrid instabilities, kinetic ballooning/interchange instability, and reconnection? (2) What are the typical values for plasma scale lengths (L), anomalous resistivity due to lower-hybrid drift wave (η), associated diffusion coefficients ($D_{\alpha\alpha}$), and Lundqvist number ($\mu_0 L V_A/\eta$) across the interfaces? (2015)

• 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 observation of KHWs on the same side of the magnetosphere is needed to confirm the time evolution of KHWs along the Earth's magnetopause. (2018)

• Chih-Ping Wang presented an ARTEMIS event showing enhancements of Pi2 waves observed within an earthward-moving plasma bubble at X ~ −60 R_E and suggested that the waves were driven by firehose instability. (2018)

• Peter Chi presented ion cyclotron waves at the Moon and their connection to the plasma sheet and the lunar exosphere. He showed that the tail environment at lunar distances can be influenced by the presence of the Moon. The Moon can be a dominant particle source in the tenuous magnetotail. He suggested to identify the generation mechanism(s) of ion cyclotron waves at the Moon (through studying the morphology of ICW and the wave/particle data). Also, if the pickup ions are the source of ICW, the amount of exospheric particles (and their escape) can be estimated by the measurements of ICW. (2015)

• Peter Chi presented an investigation of the nature of the narrowband ion cyclotron waves at the Moon in the magnetotail using ARTEMIS observations, a type of waves first detected by the Apollo Lunar Surface Magnetometers. The combination of ARTEMIS field and particle measurements and wave modeling suggests that these waves can be generated by asymmetric velocity distributions due to (1) the absorption of plasma sheet particles by the Moon or (2) pickup ions from the lunar exosphere. ARTEMIS also detected right-handed waves at approximately the proton gyrofrequency, a different wave type associated with the ion/ion resonant instability in the PSBL previously observed by ISEE and Geotail. (2016)

• Katariina Nykyri created 2.5-D macro-scale local simulation based on ARTEMIS event which showed quasi-periodic (~10 minutes) oscillations of the plasma parameters at the mid-tail dusk side flank. The observations of the virtual probe in the simulation created in the magnetospheric inertial frame were compared with the ARTEMIS measurements. The simulations were in good agreement suggesting that the vortex with the size of 8 RE was created by a 12-20 RE KH wave. (2016)

• Yu Lin, Lei Cheng, and Jay Johnson used the 3-D Global Hybrid simulation model (ANGIE3D) to show:(1) Alfvénic waves are generated in reconnection, propagating earthward and tailward near the plasma sheet boundary layer (PSBL). (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. (2017, 2018)

Topic-4: Connection With the Ionosphere

• Chih-Ping Wang presented the first observational event showing the connection between an earthward moving plasma bubble in mid-tail at X ~ –60 RE and equatorward moving high-latitude ground magnetic bays at ~70° latitude. Enhancements of Pi2 waves were observed both within the plasma bubble and magnetic bays. (2018)

• Shin Ohtani proposed based on his model calculation and reexamination of previous observations that the poleward boundary intensification (PBI) of auroral emission is an effect of ionospheric polarization caused by a polar-cap flow channel approaching the auroral oval, rather than an ionospheric manifestation of distant reconnection. The distant reconnection may start independently of PBIs or may be triggered by the Alfvén wave reflected at the ionosphere changes the plasma and magnetic configuration in the distant plasma sheet. (2016)

• 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. (2018)

Modeling Challenges

Challenge-1: Mid-tail response to a prolonged N IMF period (2016, 2017 sessions)

Two intervals were selected:

(1) Steady solar-wind/IMF, 3-7 UT, 13 Feb 2014. The two ARTEMIS probes were in the northern lobe near the dusk flank and observed mesoscale perturbations in plasma and magnetic field.

(2) IMF B_Y change, 18-23 UT, 14 Feb 2014 (IMF B_Y changed from +6 to ~0 at ~19 UT and returned to +6 at 21 UT. IMF B_Y was ~0 and IMF B_Z ~ +4 nT from 19-21 UT). ARTEMIS probes were near midnight and observed plasma sheet plasma with no significant flows, indicating that the tail plasma sheet extended beyond 60 RE.

Modeling: Simulations using 3D hybrid code (ANGIE3D) and MHD code were conducted. The MHD simulations, including GUMICS, BATS-R-US, LFM, and OpenGGCM, were conducted on NASA CCMC with the highest grid resolutions and also by different modelers with even higher grid resolutions.

Evaluation: The simulation results were compared with ARTEMIS observations in midtail and also observations in the ionosphere and ground, including flows and convection maps from SuperDARN, particle precipitations and aurora images from DMSP, field-aligned currents (FACs) from SWARM and AMPERE, and ground magnetometers.

Xueyi Wang presented results from Auburn University 3-D hybrid simulations, ANGIE3D. He showed the magnetotail dynamics for different steady IMF conditions. For this challenging event, the large-scale tail configuration from the hybrid simulation is found to be similar to those of the CCMC global MHD simulations.

Ilja Honkonen compared the performance of different global MHD models in different regions from the near-Earth magnetosphere to the magnetotail. For this event, he presented the results from GUMICS simulations. GUMICS predicted well large-scale response to IMF B_Y direction changes and the agreement is better for higher resolution run.

Joseph Jensen presented results from OpenGGCM with high grid resolution and compared the results with the lower grid run from CCMC OpenGGCM. The high-resolution run produced mesoscale perturbations on the flanks under steady solar wind and northward IMF that were not seen in the lower-resolution CCMC OpenGGCM run. The mesoscale perturbations are likely caused by waves propagating tailward along the flanks.

Slava Merkin presented results from an LFM run with grid resolution twice higher than that of the CCMC LFM run. The high-resolution run produced both K-H perturbations along the flanks and mesoscale current sheet flapping across the mid-tail. The flapping was not seen in the CCMC LFM run.

The differences between the predictions from different CCMC global MHD simulations conducted and the differences with observations are presented for the two intervals:

(1) For the interval of steady solar wind/IMF, both LFM and OpenGGCM predict mesoscale perturbations in midtail. The cross-tail configurations of GUMICS and BATS-R-US are similar to those of LFM and OpenGGCM in large scale but without mesoscale variations. The perturbations in LFM are near the flanks and likely caused by Kelvin-Helmholtz (K-H) vortices, while the perturbations in OpenGGCM are mainly in the tail current sheet associated with flapping motion. The higher-resolution OpenGGCM run does produce some flank perturbations, but it remains to be determined whether they are associated with K-H vortices. The LFM simulations (both the CCMC and high-resolution runs) qualitatively account for the mesoscale variations of B_X, n, V_X observed by ARTEMIS, and the Pc-5 perturbations observed by SuperDARN ionosphere flow velocities and ground magnetic fields. The FACs strengths from the high-resolution run are higher than the CCMC run and are closer to those of SWARM. The polar-cap size predicted by LFM is in better agreement with the aurora image from DMSP than other models.

(2) For the interval of IMF B_Y change, only OpenGGCM predicts that the tail plasma sheet remained longer than 60 R_E when IMF B_Y became ~0 between 19-21 UT. Both LFM and OpenGGCM predict small reverse convection cells on dayside high latitudes when IMF was predominantly northward, in agreement with the SuperDARN convection maps. The predictions of polar-cap size by OpenGGCM are in much better agreement with DMSP aurora images on the nightside than other models. OpenGGCM also predicts the formation of an elongated north-south structure of closed field-line region within the polar-cap after IMF B_Y returned from ~0 after 21 UT, which is in qualitative agreement with the north-south cross polar-cap arcs observed by DMSP. The model shows that this polar-cap closed field-lines structure is connected to tail. The thermal energies for the precipitating ions and electrons within the polar-cap arcs observed by DMSP were very close to those observed by ARTEMIS, supporting the OpenGGCM predictions.

In conclusion, even for this prolonged N IMF event the midtail structures and variations predicted by the four global MHD models are very different. Using higher grid resolutions can improve some of the predications. But it remains a big challenge to identify other factors that can help further improve the predictions.

Challenge-2: Global tail response to IMF southward turning (2019 session)

Event: From ~06 to 12 UT on 9 July 2017, 8 satellites were approximately aligned along the noon-midnight meridian ($|Y| < 10$ R_E). Cluster and Van Allen Probes were on the dayside, GOES 13 and 15 were on the nightside, Geotail was at X ~ –12 R_E, MMS at X ~ –22 R_E, and ARTEMIS P1 and P2 were at X ~ –62 R_E. 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.

Modeling: BATS-R-US, LFM, and OpenGGCM, were conducted on NASA CCMC with the highest grid resolutions.

Evaluation: The simulation results were compared with satellites in the magnetotail, and in the ionosphere with SuperDARN for the cross polar-cap potential (CPCP) and flows, AMPERE and Spheric elementary currents (SECS) for currents, and DMSP and Ovation Prime for conductance.

In the magnetosphere (presented by Chih-Ping Wang), for the northward IMF period, OpenGGCM better simulate the plasma and magnetic field at the three tail distances (X = –12, –22 and –62 R_E) than the other two models. After IMF turned southward and the solar wind energy was input to the tail lobes, LFM better reproduces the gradual increase of the lobe magnetic field strength and the amount of increase. However, the tailward propagation of the lobe field increase is almost twice faster than the observed. Another LFM run is then conducted with the auroral conductance doubled, it is found that the tailward propagation speed is improved but still not sufficient to account for the observed speed.

FACs (presented by Sarah Vines, Brian Anderson for AMPERE and James Weygand for SECS): All three models qualitatively reproduce the changes of FACs seen by AMPERE and SECS associated with the IMF B_Z southward and northward turnings on dayside MLTs, but only LFM better reproduce the changes on nightside MLTs. The FAC magnitudes of the LFM are almost twice lager than the AMPERE.

CPCP and flows (presented by Xueling Shi): All the models significantly overestimate the CPCP during the southward IMF. The CPCP from SuperDARN is ~50-60 kV, BATS-R-US is ~100 kV, and OpenGGCM and LFM are over 200 kV.

SuperDARN shows the flows on the dayside quickly weaken after IMF turned northward, while MHD flows decrease gradually within 30 min to 1 hour.

Conductance (presented by Betsey Mitchell): The magnitudes of auroral conductance of BATS-R-US and LFM are similar to the empirical values of Ovation Prime, while the OpenGGCM conductance is much higher. But the OpenGGCM is close to the conductance obtained from the DMSP passes during the event.

In conclusion, none of the three models can adequately describe the magnetotail state globally for both northward and southward IMF periods. OpenGGCM performs better during N IMF while LFM is better for S IMF. BATS-R-US does not perform well in the tail beyond X = −20 R_E. The discussion during the session suggest that more realistic auroral conductance may improve the overall response in both the magnetosphere and ionosphere.

Testing Proposed Links between Mesoscale Auroral and Polar Cap Dynamics and Substorms (final report)

Toshi Nishimura, Kyle Murphy, Emma Spanswick, Jian Yang

1. Background

The THEMIS mission has significantly advanced the community's understanding of substorms, dipolarization, and plasmasheet dynamics. Further, the new high-fidelity ionospheric observations have allowed new ideas of substorm onset mechanisms to be discovered and studied. However, despite these advances and discoveries the community has not reached a consensus on the sequence of events leading to substorms, the physical mechanism resulting in substorm onset, or the relation between magnetospheric and ionospheric observations. The difficulty in reaching a consensus is in part because each study tends to use a different set of events, with different criteria for analyzing the events which is often qualitative as opposed to quantitative. For example, plasma sheet and auroral features are often qualitatively and subjectively defined making it difficult to reproduce results by other scientists or to create a definition that can be widely accepted in the community. The Testing Proposed Links between Mesoscale Auroral and Polar Cap Dynamics and Substorms focus group (FG) aimed at holding discussions toward achieving community-wide consensus on the question of substorm triggering and related magnetosphere-ionosphere processes. We had 6 major activities through the FG sessions: (1) event discussion, (2) tools and methods, (3) mapping, (4) streamers, (5) joint sessions, and (6) general contributions. We summarize those activities and accomplishments below.

2. Event discussion

The FG began the first sessions with review talks by three substorm experts. Larry Lyons gave a review of precursor streamer scenario, presented his view of the Kepko et al. [2009] event, and raised outstanding issues. Mike Henderson reviewed a historical aspect of substorm triggering by IMF orientation changes and commented on substorm pre-onset scenarios and near-Earth instability. Larry Kepko discussed the similarities and differences between existing substorm onset scenarios and pointed out that there is no quantitative definition of an auroral streamer which makes it difficult to reproduce studies and statistics relating streamers to substorms onset.

In years 1-3, the FG held sessions which discussed specific challenge events with regard to the mechanism of substorm onset. Prior to each workshop, the FG co-chairs selected events and invited experts to analyze those events using their methods. In the event discussion sessions, they presented their interpretations of the events which led to lively discussions and debates. Table 1 lists the events, presenters, and whether they identified a pre-onset streamer or not.

In the 2008-2-25 event (published earlier by Kepko et al. [2008]), all presenters agreed that the substorm was preceded by a streamer. Larry Lyons showed that a streamer formed and contacted the growth phase arc prior to the onset. In contrast to Kepko et al.'s suggestion, they found that the streamer did not originate in the middle of the auroral oval but from a poleward boundary intensification (PBI). Shin Ohtani and Tetsuo Motoba found that an auroral structure propagating from poleward boundary touched the auroral oval around the demarcation between the dawn and dusk convection cells and then, the auroral beads started to form without any noticeable delay. They also noted that the beads formation started noticeably dawnward of the convection demarcation and expanded dawnward toward the demarcation. Kyle Murphy analyzed Kepko et al. event using a technique to track auroral structures. This method automatically identifies streamers and the growth phase arc and showed that streamers contacted the growth phase arc prior to the onset. In this

GEM2015	Lyons	Murphy	Ohtani	Miyashita
20080225 0530 UT	Yes(Streamer)	Yes(Streamer)	Yes(Streamer)	Yes(NENL)

miniGEM2015	Lyons	Murphy	Kepko	Ohtani	Miyashita
20080228 1110 UT	Yes(Streamer)	No(disturbed)	No(offset)	?	No(timing)
20080305 0604 UT	Yes(Streamer)	No	No(convection)	?	No(timing)

GEM2016	Lyons	Kepko	Lui
20141026 0542 UT	Yes(Streamer)	No(viewing angle)	Maybe (w gap)
20140927 0926 UT	Yes(Streamer)	Yes(Streamer)	Yes(Streamer)
20140926 0423 UT	Yes(Streamer)	Yes(Harang)	No(timing)

miniGEM2016	McPherron	Gabrielse	Rae	Liang
20160210 6:30 UT	Yes(but small)	Yes(but small)	No(wave)	?

GEM2017	Nishimura	Motoba	Murphy
20170303 5:12 UT	Yes(Streamer)	Yes(Streamer)	Yes(disturbed)

Table 1: A summary of substorm event discussions led by selected speakers. "Yes": the speaker identified a precursor streamer, "No": the speaker did not identify a precursor streamer, "Maybe": the speaker identified a pre-existing feature but without confidence, "?": the speaker did not address the streamer question.

event, his analysis supports Kepko et al.'s conclusion that the substorm onset is preceded by plasma sheet flows ; however, he also noted that this event occurred at the very edge of the FOV of the ASI where warping by the fish-eye lens makes any analysis difficult to interpret. Yukinaga Miyashita suggested that for any discussion regarding substorm triggering, requires a clear definition and accurate timing of three critical features in the development of the aurora 1) the initial brightening, 2) the enhancement of wave-like structure, and 3) the poleward expansion.

In contrast, in the 2014-10-26 event, three presenters came to different conclusions. Larry Lyons presented auroral images, suggesting PBI formation and equatorward propagation of a streamer minutes before onset. He also suggested a streamer made close contact with a growth phase arc. However, comments were raised about whether the near-Earth plasma sheet between ~8 to 18 RE could be mapped less than 1 degree in latitude. Larry Kepko's analysis showed that the poleward expansion of onset arc did not seem to disturb an existing arc poleward of the expanding one. He suggested that viewing angle might mislead our perception of aurora motion. Tony Lui mentioned that a streamer was present before onset but there was a considerable separation from the thin onset arc.

Through the discussions of the 8 events in Table 1, scientists identified substorm precursors in 57% of times, did not identify precursors in 30% of times, and did not make clear determination in 13%. In 3 events, all the presenters came to an agreement of substorm precursor sequence. This is a substantial progress in the long-lasting arguments of substorm pre-onset sequence in the substorm community. However, the rest of events led to a wide variety of interpretations without an agreement among the speakers. The differences often occurred because of difficulties in clearly defining faint auroral features and quantifying the time sequence of events. This highlights that there is still a need to establish either a quantitative definition of each auroral signature in the substorm sequence of events or a quantitative method of studying substorms that does not rely on a subjective interpretation of events. Either way, such steps forward would help in making substorm science reproducible and allow the community to reach a consensus regarding substorm triggering and onset.

3. Tools and Methods

One of the key objectives of the FG was to investigate and identify methods for quantifying key substorm signatures and for studying the sequence of events leading to substorm onset. Bob McPherron presented a detailed overview on point processes and how this analysis could be applied to substorm research. Using data from ground-based magnetometers Bob McPherron compared and contrasted different substorm lists including the SuperMAG, IMAGE, mid-latitude positive bay and the Nishimura substorm lists. Bob McPherron demonstrated that the SuperMAG, IMAGE and mid-latitude positive bay list were all in excellent agreement while the Nishimura list was poorly correlated with the others. Nadine Kalmoni presented a new analysis technique for characterizing the spatiotemporal evolution of auroral beads observed at substorm onset. The technique is able to determine both the auroral wave length and growth rates observed at substorm onset. These wavelengths and growth rates can then be compared to theoretical values to determine the most likely instability leading to development of auroral beads. Kyle Murphy presented a new analysis technique for auroral tracking. The quantitative algorithm tracks aurora and is able to determine whether streamers are a necessary condition for substorm onset. The event presented did not show a pre-onset streamer. Bea Gallardo-Lacourt presented initial results of optical flows and Toshi Nishimura analyzed the same event investigated by Murphy et al. using optical flows and showed that a faint streamer signature exists prior to the onset. Emma Spanswick and Eric Donovan presented a circle gram substorm aurora analysis technique. The circle gram determines whether onset occurs spontaneously within a discrete region or is triggered by aurora outside of the region.

4. Mapping

The mapping sessions concentrated on understanding how optical signatures in the ionosphere relate to magnetotail signatures and fast flows in the plasmasheet. In year-1, Emma Spanswick showed using an array of ground-based riometers that the development of the substorm injection can be tracked in latitude, longitude and time. She also introduced new 2D red line auroral imagers, and new results demonstrating that the imagers can routinely track the polar cap boundary across MLT and in time. Shin Ohtani discussed the overlap region of R1 and R2 currents where substorm onset can occur and which can be driven unstable by the interchange instability and discussed the mapping of R1 and R2 current relative to electron and ion plasma sheets. Jiang Liu presented detailed observations of the substorm current wedge from the THEMIS constellation. Chao Yue presented a new technique for mapping the growth phase auroral arc from the ionosphere to equatorial plane. Chao Yue's mapping suggests that substorm onset occurs in the inner magnetosphere in a region that is characteristically unstable to a ballooning instability.

Year-2 was dedicated to discussion regarding the coupling of tail-ionosphere system during substorms concentrating on the link between flow bursts, injections, and MI coupling during substorms. Yan Song discussed the formation of discrete aurora in ionosphere and the role of Alfven waves and parallel electric fields. Bob McPherron presented a data-model comparison of substorm dynamics and tail flow bursts. Christine Gabrielse provided a comprehensive overview of the propagation and evolution of the injection region from multi-point in-situ THEMIS observations and ground-based all-sky imager and riometer observations. Eric Donovan presented a detailed overview of "STEVE", a new auroral arc identified by citizen scientists apart of the Alberta Aurora Chasers Facebook Group working with www.Aurorasaurus.org.

5. Streamers

The objective of these sessions was to address the broad science questions "How commonly do substorm precursors occur?" and "What are the similarities and differences of PBIs/streamers/plasma sheet flows during isolated substorms, active-time substorms and non-substorm times?" outlined in the Focus Group Proposal. To this end the session discussed the role of streamers in substorms onset and ionospheric dynamics, the relation between substorm onset and fast flows, and the penetration of flows into the inner magnetosphere. Katie Garcia-Sage, Bashi Ferdousi, Bob Lysak and Jian Yang presented simulations of substorms and plasmasheet flows discussing (a) the differences between convective and substorm initiated flows, (b) mapping of plasma sheet flows to the ionosphere and the resulting auroral/streamer signatures, (c) substorm onset, and (d) the relation between growth phase bubbles and streamers. Xianging Chu and Bob McPherron presented a statistical analysis of fast flows and substorm onset using Point Processes to determine whether the two phenomena were statistically linked. Nadine Kalmoni presented statistics of the azimuthal structuring of the onset arc demonstrating that all arcs are structured and that auroral beads observed at onset are simply a special case when the structuring is very clear. Jiang Liu presented a statistical analysis of field-aligned currents from THEMIS. Toshi Nishimura discussed the similarities and differences between streamers during different geomagnetic activity and Drew Turner presented observations from the Van Allen Probes and MMS discussing how injections can make it deep into the inner magnetosphere.

6. Joint sessions

As a GEM FG we actively coordinated with other FGs (ULF, dayside, interhemispheric, and dipolarization FGs) to discuss substorms and the link between magnetospheric processes and utilizing ground-based observations for understanding global magnetosphere-ionosphere interaction processes. In particularly joint sessions with the Dipolarization FG, challenge events were selected to study stormtime substorms, isolated substorms, and steady magnetospheric convection (SMC), and the effects that these different modes of tail activity have on the inner magnetosphere. 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 presented initial global MHD results from the Solar Wind Modeling Framework for each challenge event. Kyle Murphy presented injection signatures from the LANL spacecraft and Anna DeJong presented ground-based observations regarding the steady magnetospheric convection event.

7. General contribution

In addition to the focused topics described above, the FG also held a number of sessions highlighting new and important results in the form of contributed talks. Selected presentations are summarized below:

Joachim Birn presented results from test particle tracing in an MHD simulation of near-tail reconnection and flow bursts, demonstrating the formation of field-aligned ion beams in the PSBL. The ion beams were generated by direct non-adiabatic acceleration in the vicinity of the neutral line, consistent with PIC simulation results, but adiabatically deformed into crescent shaped velocity distributions from propagation toward higher magnetic field. The energy dispersion of the beams permits a remote identification of the acceleration site.

Phil Pritchett showed results from a 3D PIC simulation of a portion of the magnetotail indicating that the ballooning/interchange instability should produce structuring of auroral streamers similar to THEMIS ASI observations. He emphasized that 3D PIC simulations have evolved to the point where they can be used to investigate other issues of relevance such as the influence of dayside flow channels in initializing localized tail reconnection.

Misha Sitnov discussed PIC simulations of dipolarization fronts and their ionospheric implications. Pritchett, Coroniti and Nishimura (JGR, 2015) first noticed that while equatorward portion of the streamer showed multiple arcs, the poleward portion of the streamer might stay essentially as a single arc. This observation is consistent with his 3D PIC simulations of fronts. Misha Sitnov showed that, in contrast to flapping and buoyancy-driven perturbations of the dipolarization front causing its modulation in the dawn-dusk direction, the region well behind the front, including the new X-line forming in its wake, remains largely unstructured in the dawn-dusk direction, except relatively long wavelength flapping motions.

Vassilis Angelopoulos presented plans of the upcoming Heliophysics/Geospace System Observatory (HGSO). Although satellite missions are generally driven by their own mission goals, he proposed to coordinate satellites as well as ground observatories for studying cross-scale and cross-regional coupling processes in a broader scale than previously possible. HGSO will help to coordinate satellite missions and ionospheric measurements for investigating (1) global effects of dayside transients, (2) cusp-dayside connections, (3) nightside reconnection and tail-inner magnetosphere coupling, (4) global processes, and (5) cross-scale coupling.

Robert McPherron and Mostafa El-Alaoui presented an MHD simulation of 2008-3-14 substorms and streamers. They emphasized the presence of a series of BBFs, sometimes with more than one of them aligned azimuthally. The BBFs showed tilting and winding, originating in a dynamic X-line. They found an overall qualitative agreement with THEMIS observations of flows.

Liz MacDonald showed a beautiful auroral image taken by a professional photographer. The aurora exhibited spatially quasi-periodic beads, each accompanied by vertical rays. It happened during a storm main phase. Eric Donovan and Jun Liang showed results comparing time series of >30 keV electron flux and ground riometer data. One application is to improve the magnetic field mapping accuracy. Shin Ohtani modeled the PBI orientation and width in the ionosphere. Dick Wolf presented criteria of Kelvin-Helmholtz instability and interchange stability in the near-Earth plasma sheet high pressure region that corresponds to a growth-phase arc. Misha Sitnov used system science approach to investigate the substorm triggers and drivers. Larry Kepko presented auroral images, suggesting beading as a consequence of a flow braking.

James Weygand discussed spherical elementary current (SEC) distributions and demonstrated how the SECs could be used to characterize the rate of change of the ionospheric magnetic field dB/dt during substorms. Understanding the geographical distribution of dB/dt during substorms is a key component to characterizing geomagnetically induced currents during substorms.

Shin Ohtani showed an ionosphere model of PBIs and proposed ionosphere triggering of PBIs. He discussed how his model relates to magnetospheric signatures of PBIs. their relation to distant tail reconnection suggesting that they may not be ionospheric manifestation of tail reconnection.

Grant Stephens reported an updated version of Tsyganenko magnetic field model with AL effects considered. The model magnetic field successfully reproduced substorm-time magnetic field variations.

Christine Gabrielse presented a statistical study of ionospheric fast flows associated with auroral streamers. Ionospheric measurements were found powerful for characterizing 2-d structure and evolution of flow channels that are difficult to measure in space. Drew Turner showed multipoint measurements of narrow and wide injections. These two presentations led to a discussion of potentially holding a joint session with the dipolarization FG for combining multipoint space and ground conjunction studies of 2-d injection evolution.

Sarah Vines presented observations of field-aligned currents from AMPERE during an interval of steady magnetospheric convection. Grant Stephens presented new results from the latest iteration of the Tsyganenko empirical magnetic field model which ingests ground-based magnetometer data (AE and Dst) to aid in modeling of the global magnetic field.

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 conductance before and during the events play a key role in whether a substorm subsequently develops into steady magnetospheric convection following onset.

Magnetotail Dipolarization and its Effects on the Inner Magnetosphere

Christine Gabrielse, Matina Gkioulidou, David Malaspina, Drew L. Turner, Slava Merkin

The Dipolarization Focus Group had three sessions during the summer 2019 GEM Workshop that were categorized by topic. The Focus Group leaders organized a session on Energy Transfer and Dissipation to guide presentations towards answering specific questions:

1. Can we estimate a percentage that energy is dissipated into waves, direct ion heating, etc.?

2. Can we determine if and to what extent a dynamo in the transition region (driven by pressure gradients or vorticity) converts energy dissipated from the tail into field-aligned currents to drive dissipation in the ionosphere?

3. What are the ways to estimate these values (simulation or theory or observational)?

It was especially timely to address these questions since the MMS mission had an overlapping Science Working Team meeting, bringing more of our European colleagues to GEM and multiple experts on energy dissipation to the session.

Focus Group leaders also solicited contributed presentations, resulting in two community-driven sessions organized by two prevailing topics. The first topic, Particle Energization and Injections, had an even split between observation and modeling presentations. The second topic, Currents, was a natural follow-on to the session on Energy Transfer and Dissipation.

The following list provides the speaker's name and title of presentation from each of the three sessions. Summaries submitted by presenters for this GEMStone article are included. Note that Focus Group leaders have been collecting publications that are in part thanks to or discussed in this Focus Group on the GEM Wiki page.

Topic 1: Particle Energization/Injection

- Raluca Ilie - The role of inductive electric fields on particle energization

- Jianghuai Liu - The role of inductive electric fields on particle energization (continued)

- Sam Bingham - Adiabatic Particle Energization using MMS

- Wonde Eshetu - Simulations of electron energization and injection by BBFs using High-Resolution LFM MHD fields

- Christine Gabrielse - Heliophysics System Observatory observations of small and large-scale injections: DFBs vs. large-scale dipolarization
    1. The injection region's formation, scale size, and propagation direction have been debated throughout the years. How do temporally and spatially small-scale injections relate to the larger injections historically observed at geosynchronous orbit? How to account for opposing propagation directions—earthward, tailward, and azimuthal—observed by different studies?
    2. A combination of multi-satellite and ground-based observations was used to knit together a cohesive story explaining injection formation, propagation, and

differing spatial scales and timescales.
3. A case study was used to put statistics into context.
4. Fast earthward flows with embedded small-scale dipolarizing flux bundles transport both magnetic flux and energetic particles earthward, resulting in minutes-long injection signatures.
5. A large-scale injection propagates azimuthally and poleward/tailward, observed in situ as enhanced flux and on the ground in the riometer signal. The large-scale dipolarization propagates in a similar direction and speed as the large-scale electron injection.
6. Small-scale electron injections result from earthward-propagating, small-scale dipolarizing flux bundles, which rapidly contribute to the large-scale dipolarization.
7. Large-scale dipolarization is the source of the large-scale electron injection region, such that as dipolarization expands, so does the injection.
8. Ion injection region >90 keV in the plasma sheet is better organized by the plasma flow.

• Bob McPherron - MHD simulation of substorm including progressive approach of X-lines, flow channels, and flow penetration to the inner plasma sheet

1. An interval of moderate magnetic activity from 0-8 UT on March 14, 2008 has been investigated with a global MHD simulation using high spatial and temporal resolution.
2. Observations show several distinct substorms during this interval. One of these with expansion onset at 04:48 UT is also seen in the simulation with onset at 04:44 UT.
3. The simulation shows that reconnection is continuously present at multiple sites throughout the interval. During the growth phase, the number of x-lines and their total length increase with time and their locations approach the Earth. The x-lines create multiple fast flow channels with dipolarization fronts. The total length and area of these channels increase during the growth phase as they penetrate closer to the Earth carrying more magnetic flux.
4. The 04:44 UT onset in the simulation was preceded by the growth of an x-line that eventually extended 55 RE long from X ~ −12 RE premidnight to X ~ −50 RE on the dawn side. It produced a narrow flow channel parallel to the x-line that eventually penetrated inside 10 RE rapidly depositing magnetic flux as the expansion phase developed.
5. Despite good agreement in expansion onset time the ground and satellite observations suggest a quiet growth phase with a sudden onset of reconnection.
6. It may be possible to explain the difference between observations and simulations if all growth phase activity in the simulation map to the ionosphere at very high latitudes.

• Tetsuo Motoba - Azimuthally localized dispersionless injections inside GEO

1. Tetsuo Motoba presented a case study of deep energetic particle injections observed by the two Van Allen Probes (RBSP-A and -B) in the premidnight sector.
2. Although the spacecraft separation was only ~0.5 RE in the azimuthal direction, the injection signatures were different between the two probes: RBSP-B observed dispersionless electron and ion injections, while RBSP-A observed the corresponding injections but they were characterized by an energy-dispersed flux enhancement and/or by a relatively weak flux enhancement.
3. Such different injection signatures are attributed to the presence or absence of a transient, strong dipolarization front (DF). The two closely located RBSP observations suggest that the azimuthal scales of deeply penetrating DF and injection region are highly localized.

• Discussion on Particle Energization/Injection

1. Role of different fields?
2. Large vs. Small-scale?
3. This discussion was inspired by the main points and questions presented.

Topic 2: Energy Transfer and Dissipation

• Misha Sitnov - Kinetic dissipation in dipolarization fronts and magnetic reconnection

1. Irreversibility of magnetotail dipolarizations is provided both by the collisional dissipation in the ionosphere and by collisional Landau dissipation in the magnetotail.
2. Misha Sitnov pointed out that the Joule heating rate, which is a good measure of collisional dissipation and which is widely discussed in MHD models, is not appropriate as a measure of collisionless dissipation in the magnetotail: Values of J*E' in ion and electron frames practically coincide. Thus, j*E' cannot be a measure of ion and electron Landau dissipation processes, which are very different.
3. Sitnov discussed kinetic analogs of the Joule heating rate, the so-called Pi-D parameters. PIC simulations show that the ion Pi-D peaks of the dipolarization front (DF), while the electron Pi-D peaks behind DF or earthward of the X-line.
4. Measurements of the Pi-D parameters, which have

become possible due to the MMS mission, remain very challenging: Because of the small probe spacing (~10 km), DFs often pass the MMS tetrahedron in times smaller than the plasma instrument cadence. This prevents calculating the spatial derivatives of the bulk flow velocity, the key elements of the new kinetic dissipation parameters.

• Rumi Nakamura - MMS observations of multi-scale field-aligned currents during dipolarization in the near-Earth plasma sheet

1. Substorm current wedge contains multi-scale field-aligned currents.
2. Ion-scale process is essential in generating field-aligned currents in near-Earth magnetotail.
3. Intense field-aligned currents correspond to generator region in the flow braking region. Two types of generator region observed. (1) Embedded current layer in return flow region of localized BBF. (2) Electron flow shear region in thin Hall-current layers ahead of BBF.

• Olivier Le Contel - Multiscale kinetic processes associated with fast flows and dipolarization fronts

1. Two dipolarisation front events associated with fast plasma flows detected by the MMS mission in August 2016 have been presented.
2. Intense lower-hybrid drift waves associated with parallel electric fields have been identified (frequency, phase speed) at the dipolarization front as well as fast electromagnetic electron holes moving tailward. Possible coupling between the lower-hybrid waves and electron holes was discussed.

• Amy Keesee - Concurrent enhancements in ion temperatures and auroral brightenings seen by TWINS and ASIs

1. At the 2018 GEM summer workshop, Amy Keesee showed movies of ion temperature maps during two of the challenge storm intervals.
2. Also at 2018 GEM, Toshi Nishimura showed movies of all sky imager auroral maps of the same intervals, and we discovered enhancements in both at the same time.
3. Keesee reported on their ongoing collaboration to use these intervals to study the connections from the magnetosphere to the ionosphere.
4. Keesee and Nishimura are working on mapping algorithms to identify intervals that have concurrent enhancements when the Van Allen Probes are in a favorable location to study the detailed particle distributions.
5. Keesee also discussed the availability of a database of TWINS ion temperature maps being made available at CDAWeb through the support of a H-DEE award.
6. They are also developing an automated detection algorithm to identify regions of ion temperature enhancement in that database for further studies.

• Joachim Birn - Energy release and conversion and dynamo action in the tail on the basis of MHD simulation

1. Joachim Birn used an MHD simulation of tail reconnection associated with a flow burst and dipolarization to identify energy conversion, dynamo and load, and field-aligned current generator regions.
2. Two regions stand out as loads (**E•J**>0): slow shocks and the dipolarization front, where incoming Poynting flux is converted primarily to enthalpy flux.
3. Dynamo actions (**E•J**<0) are found in the braking region and at higher latitude on the outside of the Region 1 type field-aligned currents, built up by vortical flow in and near the equatorial plane.

• San Lu - Strong energy dissipation at the transition region

1. Pritchett and Lu (2018) investigated the response of magnetotail to a longitudinally limited, high-latitude driver using 3-D particle-in-cell simulations.
2. After the onset of localized reconnection caused by the external driver, the later response involves sudden disruption of the plasma sheet in the transition region with much stronger energy dissipation and particle energization than that at the reconnection site.

• Shin Ohtani - Dissipation and the ionosphere

1. Shin Ohtani discussed the transport of energy from the magnetotail to the ionosphere during substorms by synthesizing the results of previous observational and modeling studies.
2. He concluded that (1) the area around the duskside poleward boundary of the auroral bulge (i.e., auroral surge) is a unique and persistent sink of substorm energy, and it accounts for a few tens of percent of the ionospheric substorm energy dissipation; (2) kinetic energy carried by BBFs is comparable to the energy deposited to the ionosphere in association with auroral streamers, and each BBF accounts for ~1% of the total substorm energy deposition, which may sum up to 10% throughout the expansion phase.

• Discussion on energy dissipation

1. Can we estimate a percentage that energy is dissipated into waves, direct ion heating, etc.?
2. Can we determine if and to what extent a dynamo in the transition region (driven by pressure gradients or vorticity) converts energy dissipated from the tail

into field-aligned currents to drive dissipation in the ionosphere?
3. What are the ways to estimate these values (simulation or theory or observational)?

Topic 3: Currents

• Misha Sitnov - Dipolarizations and their connection to the ring current buildup and magnetic reconnection
1. The new data-mining (DM) technique applied to magnetospheric storms and substorms was presented by Misha Sitnov (in collaboration with Grant Stephens and others).
2. The DM reconstruction of the magnetosphere resembles launching swarms of ~50,000 synthetic probes.
3. It shows that the response of the inner magnetosphere to magnetotail dipolarizations is very diverse: 1) both the TCS and the ring current increase in the substorm growth phase; 2) the decay of a thin current sheet (TCS) associated with the tail dipolarization on substorm scales (~0.5 hour) is followed by the buildup of a proton-ring current in the inner magnetosphere on the time scales of several hours; 3) the response of the ring current to magnetotail dipolarizations may have both storm and substorm time scales; 4) sometimes magnetotail dipolarizations during substorms do not modify the near-Earth ring current at all.

• Shin Ohtani - Double-wedge current system based on the GOES-RBSP comparison of dipolarization signatures
1. Shin Ohtani showed, based on the timing comparison of dipolarization signatures at RBSP and GOES, that the dipolarization region expands earthward.
2. He argued that the result apparently contradicts the conventional substorm current wedge model, which suggests that dipolarizations take place simultaneously everywhere inside the current wedge.
3. He proposed that the actual substorm current system has a R2-sense current wedge on the earthward side of the (conventional) R1-sense current wedge, and the dipolarization region expands earthward as the R2-sense current wedge moves earthward.

• Yi-Hsin Liu - An explanation of the opposite dawn-dusk asymmetry at magnetotails of Earth vs. Mercury
1. PIC simulations reveal that the dawn-ward transport of the normal magnetic flux (B_Z) by electrons beneath the ion kinetic scale is a critical feature of current sheets.
2. While the normal magnetic field in the tail geometry suppresses reconnection onset, the reconnected magnetic field (i.e., also B_Z) enhances reconnection after the x-line develops. These all together will result in the competition of opposite dawn-dusk asymmetries.
3. Liu proposed that the vastly different global dawn-dusk scale of the magnetotails at Earth and Mercury will lead to opposite outcomes in this competition of asymmetry. This new finding can be important to the on-going ESA-JAXA mission, BepiColombo.

• Ryan Dewey - Flow braking of dipolarizations in Mercury's magnetotail
1. Ryan Dewey presented statistical observations of dipolarizations in Mercury's magnetotail and demonstrated that their associated fast flows typically brake before reaching the nightside surface of the planet.
2. Due to the small spatial scales of Mercury's magnetosphere, a small fraction of dipolarizations (~10%) may impact the planet while the majority brake and contribute to flux pileup.
3. Whether this pileup is associated with a current wedge system remains to be constrained.

• Xiangning Chu - The generation of STEVE and penetration of fast flows to the plasmapause

Inner MAGnetosphere (IMAG) RA Reports

Coordinators: Seth Claudepierre and Raluca Ilie

System Understanding of Radiation Belt Particle Dynamics through Multi-spacecraft and Ground-based Observations and Modeling

Hong Zhao, Lauren Blum, Sasha Ukhorskiy, Xiangrong Fu

At the 2019 GEM summer workshop, the newly selected focus group (FG), System Understanding of Radiation Belt Particle Dynamics through Multi-Spacecraft and Ground-Based Observations and Modeling, had four sessions, including one joint session with the FG ULF wave Modeling, Effects, and Applications (UMEA). All sessions were well attended and filled with discussions. Most presentation slides from the 2019 summer workshop can be found at the google drive:

https://drive.google.com/drive/folders/1jNmoHdN9v-ph29UG7-LpPifahSzejSS9c?usp=sharing

Session 1: Introduction of New Focus Group and Discussion of Open Radiation Belt Questions

In the very first session of this new focus group, a brief introduction to the focus group's science goal, deliverables, expected activities, and the yearly plan was presented by the chairs. Then, two invited speakers, Seth Claudepierre and Wen Li, talked about the recent advances and open questions in radiation belt studies as well as a review of the previous radiation belt focus group and challenges of multipoint measurements to radiation belt modeling, respectively. The current state of the art of radiation belt studies was discussed, and open questions regarding both observations and simulations were raised. Following the two invited talks, attendees had fruitful open discussions on the current state and future directions of the radiation belt studies. The great achievements of the Van Allen Probes mission were recognized, while urgent needs to continue radiation belt studies post Van Allen Probes era were also pointed out. As the discussions suggested, this focus group is very timely and will help coordinate collaborations between various satellite missions post Van Allen Probes era.

Session 2: Challenge Events and General Contributions on Radiation Belt Particle Studies

In this session, two types of potential challenge events were discussed: the precipitation conjunction events and the close conjunction events. Invited speakers Mike Shumko and Ashley Greeley presented an overview talk on precipitation conjunction events, and two contributed talks on optical signatures of the radiation belt boundary, by Nithin Sivadas, and direct observations of sub-relativistic electron precipitation driven by EMIC waves, by Wen Li, were delivered. Open discussions followed these talks. The importance of utilizing conjunctive measurements near the magnetic equator and at LEO on energetic particle precipitation studies was emphasized. Another type of potential challenge event, the close conjunction events, was discussed by the invited speaker Ian Cohen (on Close Conjunction Events between Van Allen Probes, MMS and ARASE) and Justin Lee (on EMIC wave activity during MMS-RBSP Close Conjunctions). Afterward, open discussions centered on these presentations. The list of conjunctive events between MMS and Van Allen Probes was available on request to the speaker Ian Cohen and Drew Turner.

At the 2019 workshop, our FG grouped general contribution talks by their topic. In this session, talks focusing on the radiation belt particle studies were presented. Geoff Reeves presented on identifying the magnitude and occurrence frequency of radiation belt enhancement events. Maulik Patel showed simulations using LFM and test particle code to reproduce drift echoes observed by the Van Allen Probes during the 16 July 2017 event. Then Seth Claudiepierre showed a detailed study on electron lifetimes from RBSP observations and comparison with theoretical estimates due to pitch angle diffusion by various wave modes. Also, Sasha Drozdov showed a statistical analysis focusing on the depletion of multi-MeV electrons and the role of EMIC waves in it. After this group of talks, interactions and active participation from the audiences occurred.

Session 3: EMIC Waves and Their Effects on Radiation Belt Particles (Joint with UMEA)

This was a joint session with the UMEA FG on EMIC waves and their effects on radiation belt particles, led by Maria Usanova and Sasha Drozdov. A group of talks related to EMIC waves and their effects was delivered, and detailed discussions were conducted.

Session 4: General Contribution Session: Inner Belt and Slot region, Radiation Belt Waves, and Radiation Belt Modeling

This general contribution session included three main topics of talks: the inner belt and slot region, radiation belt waves, and radiation belt modeling. All presentations in this session were requested to have a maximum of 3 slides plus 1 slide discussing the benefit/challenge of multipoint measurements to the study, so that ample time was arranged for discussions.

Focusing on the inner belt and slot region, Xinlin Li presented the study on the source and loss processes of 10s of MeV inner belt protons and their solar cycle variations based on multipoint measurements and detailed analysis. Zheng Xiang focused on the trapped electron dynamics in Earth's inner radiation belt due to atmospheric scattering losses and CRAND as a source through both observations and modeling. These studies pointed out the potentially important role of cosmic rays on the inner belt protons and electrons. Man Hua showed results on modeling electron acceleration and butterfly pitch angle distributions in Earth's inner radiation belt and slot region, which suggested that the butterfly pitch angle distribution in the low L region could be caused by the wave-particle interaction of hiss, VLF, and MS waves. Following these three presentations, open discussions centered the inner belt and slot region particle dynamics were kicked off.

On radiation belt waves, seven speakers presented their research results focusing on various modes of plasma waves and their effects on radiation belt particles. Specifically, Dave Hartley showed the angular distribution of chorus waves and the important role of the plume in the chorus-to-hiss mechanism. Xin An explored the generation mechanism of whistler-mode waves, especially regarding their nonlinear wave structures. Shangchun Teng showed the typical properties of whistler-mode waves based on Van Allen Probes measurements. Ivan Vasko focused on the electrostatic steepening of whistler-mode waves in the radiation belts. Jinxing Li suggested that Landau resonance plays an essential role in the formation of two-band chorus waves in the outer belt. Homayan Aryan showed some discrete equatorial magnetosonic waves observed by the Cluster satellites. And Oleksiy Agapitov presented results on the factors affecting the efficiency of precipitation or acceleration of radiation belt electrons by whistler-mode waves, revealed by the Van Allen Probes observations and simulations. Group discussions followed these talks.

The last part of this session focused on radiation belt modeling. Anthony Chan and Scot Elkington, focusing on the theory development and simulation results, respectively, showed a new technique for radiation belt modeling, the K2 model. Yihua Zheng presented materials regarding model validation methods. Finally, Liheng Zheng presented a modeling method and results on the drift shell bifurcation effects on radiation belt electrons using Markov chains.

Overall, researchers shared their most recent research results using concise presentations, and productive discussions between presenters and audiences filled this session. This is a format of general contribution session that this focus group is considering to follow at the next GEM workshop.

Magnetosphere – Ionosphere Coupling (MIC) RA Reports

Coordinators: Shin Ohtani and Hyunju Connor

Merged Modeling & Measurement of Injection Ionospheric Plasma into the Magnetosphere (M^3I^2) and Its Effects -- Plasma Sheet, Ring Current, Substorm Dynamics

Rick Chappell, Shasha Zou, Barbara Giles

Measurements beginning in the 1980's have shown the large outflow of ionospheric ions upward into the magnetosphere. There are two general categories of these ions—the polar wind outflow and the outflow from the auroral zone. The polar wind occurs as a result of the Sun shining on the upper atmosphere and creating the ionosphere with its outflow caused by a charge separation electric field in the topside ionosphere around the F-peak (Banks and Holzer). This outflow is expected anywhere the Sun's effects send plasma upward into flux tubes that are not filled. The auroral zone outflow is caused by the deposition of energy in the form of precipitating particles and waves from the solar wind or magnetosphere downward into the atmosphere and ionosphere, creating and energizing ions which flow upward into the magnetosphere (Strangeway et al.). Together, these two sources can send more than 10^26th ions per second upward which populate the magnetosphere and affect its dynamics.

Early studies of the magnetosphere concluded that the bulk of the plasma found in the magnetosphere came from the entry of the solar wind into the Earth's magnetic envelope. This conclusion is still a dominant one in the solar-terrestrial community. With the continuing measurement of the large magnitude of ion outflow from the ionosphere to the magnetosphere, the identification of clearly ionospheric O+, N+ and NO+ in the magnetosphere and the development of new ways of measuring the initially low energy ionospheric particles, the role of the ionosphere in populating the magnetosphere and affecting its dynamics has led to enhanced study of this phenomenon. This GEM focus group was formed in order to encourage and coordinate this study.

The three-pronged approach of measuring the outflow from the ionosphere, measuring the presence of the ionospheric particles in the magnetosphere and encouraging merged modeling of the ionospheric outflow and the magnetospheric particle populations and dynamics have guided the focus group throughout its existence. This was very evident in the four sessions that were organized and carried out at the GEM meeting on June 24-28 2019. Throughout the focus group activities, an emphasis has been placed on the ability to separate H+ ions coming up from the ionosphere from H+ ions entering the magnetosphere from the solar wind. These sources cannot be distinguished with instrumentation without the ability to separate charge state. This is where the merged modeling efforts have a larger role to play. The new merged models have opened up exciting new avenues of understanding the relative roles of the ionosphere and solar wind as suppliers of plasma to the magnetosphere.

The four sessions that took place at the 2019 GEM meeting contained an emphasis on the three pronged approach. Session 1 began with new insights into the sources of the dominant H+ which is found in the magnetosphere by having an overview of the new merged modeling which separates the two sources of H+ (Welling and Glocer). Driven by the solar wind Bz magnetic component of the solar wind combined with its velocity, the contribution of the ionosphere is seen to increase dramatically during southward B_Z, becoming very prominent in the plasma sheet and dominating the ring current. This new context will be influential on the interpretation of observations such as from the Cluster and MMS spacecraft. Insights into the electrostatic potential drops in the ionosphere were presented (Khazanov) together with O+ circulation (Gkioulidou) and ion upflow from MMS (Wang).In addition to the merged polar wind/MHD models, the individual ion trajectories (Huddleston) show how the initially cold (eV) ionospheric outflowing particles can become energized as they move through the magnetosphere, creating the different plasma regions.

The second session focused on the observation and modeling of the outflowing ions adding understanding both of the processes which control the outflow models and the direct measurement of the outflowing ions, both the clearly ionospheric-origin O+ and the more ambiguous H+. The composition, energy and location of the polar wind and auroral zone upflowing ions as they leave the ionosphere is fundamentally important in determining their ultimate contribution in the magnetosphere. Modeling of the outflow was also presented (Varney, Krall, Lin) as well as measurements from Kitamura, Burleigh, Yue and Xiangning.

The third session used measurements in the magnetosphere to clarify the processes through which the ions filled the magnetosphere. Although unable to separate the ionospheric H+ from the solar wind H+ directly, an indication of their different origins could be implied from the ratio of H+ with solar wind ions such as He++ as well as the ratio of the different ions with the clearly ionospheric O+ (Kistler) and their effects on reconnection could be assessed (Fuselier, Kitamura, Chen) as well as their effects on wave generation and propagation (Lee) and their involvement in substorm growth (Runov).

The final session centered around future coordinated studies both in choosing particular storm periods to model (Giles, Garcia-Sage) and identifying other data sets that could be brought to bear on the ionosphere/magnetosphere merging challenges (Yau, Giles).

Throughout the years of the M^3I^2 focus group, a focus on efforts to bring together the ionospheric outflow and the magnetospheric dynamics groups has been encouraged. This has been successful in that several combined sessions of multiple focus groups have been accomplished and the creation of workshops on this topic outside of the GEM workshop have happened. It is clear that the enhanced interest and cooperation has been successful and will be particularly important when combined with the emerging ionospheric/magnetospheric models which will be able to separate the ionospheric H+ from the solar wind H+ in the different important driving regions of the Earth's magnetospheric environment.

3D Ionospheric Electrodynamics and Its Impact on the Magnetosphere-Ionosphere-Thermosphere Coupled System (IEMIT)

Hyunju Connor, Doğa Ozturk, Gang Lu, Bin Zhang

The focus group titled "3D Ionospheric Electrodynamics and its impact on the Magnetosphere – Ionosphere – Thermosphere coupled system (IEMIT)" had four sessions during the 2019 GEM summer workshop. The first two sessions were stand-alone sessions, and the last two sessions were joint sessions with the MMV focus group and the UMEA focus group.

Session 1: stand-alone IEMIT session

Dr. Olga Verkhoglyadova presented a brief summary and highlights of the 2019 CEDAR session titled "Reconciling observations and models of high-latitude IT processes". Speakers presented discrepancies between model predictions and data for specific events and ways to mitigate them. This session addressed the following science questions:

1. How well do models capture energy input, transport and dissipation in high-latitude IT at relevant scale sizes in space and time,
2. How can measurements from various platforms be utilized to determine high-latitude drivers for IT modeling,
3. Which quantities can be used to test model performance and identify sources of discrepancies,
4. How can data be utilized in improving modeling efforts, and
5. How can we quantify the discrepancies and their propagation across different scales and processes?

Dr. Hyunju Connor investigated the magnetosphere – ionosphere responses during sudden enhancements of solar wind dynamic pressure using the OpenGGCM-CTIM model. For southward IMF, dayside reconnection contributes more to CPCP while for northward IMF, nightside reconnection dominates. During northward IMF, high-latitude magnetopause reconnection produces sunward ionospheric flows, weakening the typical dawn-to-dusk ionospheric potential and the dayside contribution on CPCP.

Dr. Doğacan Ozturk discussed about the role of meso-scale electric fields in the magnetosphere – ionosphere – thermosphere (MIT) coupling. She used the PFISR electric field observations as an input for the GTIM ionosphere – thermosphere (IT) model. The meso-scale electric field structures observed at PFISR produce the enhancement in the ion temperature and the perturbation in the ionospheric convection.

Dr. Kevin Pham reported current development efforts on the LFM-IPWM-TIEGCM (LIT) coupled magnetosphere – ionosphere – thermosphere model. The LIT model will include multi-fluid MHD and ion outflows that are crucial to understand the IT feedback to the magnetosphere.

Dr. Dong Wei talked about the magnetospheric drivers of Double-peak Subauroral Ion Drifts (DSAIDs). The DSAIDs, characterized by two high-speed flow channels, is a newly identified flow structure in the subauroral ionosphere. He suggested that recurrent ion injections intensify the partial ring current and create double pressure peaks in the near-Earth dusk-to-midnight region, leading two Region-2 FACs to flow into the ionosphere. The two Region-2 FACs are thus responsible for the DSAIDs formation.

Dr. Qianli Ma discussed about diffusion coefficients during the chorus waves and electron precipitation features. He calculated the electron precipitating fluxes in a global scale using a statistical whistler mode chorus wave distribution and an empirical electron flux model. His analysis indicates strong electron precipitation due to chorus waves in the nightside-dawn sectors at $4<L<7$ with characteristic precipitating energy of about 20 keV.

Dr. Dmytro Sydorenko reported the development of a photoelectron effect module for a comprehensive model of coupled magnetosphere – ionosphere system.

Dr. Zihan Wang suggested a new mechanism that segments a SED plume into polar cap patches. He ran the 2017-Sep-07 geomagnetic storm using the BASRUS-RCM-GTIM model. In this simulation, westward partial ring currents produces enhanced boundary flows between the Region 1 and 2 field aligned current regions and in turn break the SED plume into patches.

Session 2: stand-alone IEMIT session

Dr. Christine Garbrielse presented statistical studies of the storm time mesoscale plasma flows in the nightside high-latitude ionosphere. Mesoscale flows are faster during the main phase of the storms. Faster flows >400 m/s are more frequent and probable during CME storms as compared to HSS storms, but more flows occur during HSS storms. Polar cap flows are wider during CMEs than during HSSs. There is a post-midnight preference for polar cap mesoscale flows during storms, especially during recovery phase and during HSSs.

Dr. Jiang Liu reported strong eastward plasma flows in the dawn sector auroral oval, termed as dawnside auroral polarization stream (DAPS). The DAPS occurs at the boundary between Region 1 and 2 currents, and likely result from enhance R2 currents during active convections in the magnetotail. DAPS should be important for ionospheric Joule heating and instabilities in the magnetosphere-ionosphere system.

Dr. Ying Zou discussed effects of substorms on high-latitude upper thermospheric winds using a chain of Scanning Doppler Imagers (SDIs) and find that substorm-associated wind disturbances vary with magnetic local time (MLT) and latitude. Mosaics of wind disturbances at different MLTs from SDIs allow us to explore the substorm effects in the upper thermosphere in two dimensions as a function of time. Her findings suggest that substorms significantly modify the upper-thermospheric wind circulation by changing the wind direction and speed, and are hence important for the entire magnetosphere-ionosphere-thermosphere system.

Dr. Sebastijan Mrak presented the storm-time MI coupling at mid-latitude. He identified multiple mid-latitude troughs in ionospheric TEC maps: ordinary mid-latitude trough and secondary troughs that are located between the mid-latitude trough and the equator. The secondary troughs are magnetically conjugated and appear coincidently with deep ring current injection. From DMSP and RBSP observations, he reported the plasma density irregularities at the equatorward boundary of secondary troughs and the reversal of horizonal ionospheric plasma flow and magnetospheric electric fields inside the secondary trough.

Dr. Brian Anderson talked about GIC events in the pacific northwest and corresponding ionospheric electrodynamics. He compared power transformer GIC data from the Bonneville Pawer Associates with the AMPERE field-aligned currents and the SuperDARN ionospheric convection data. GICs correlate well with strong variations in currents and convection. He also reported that sudden impulse and sudden storm commencement can drive GICs and that nightside onset (large-scale substorms) can be associated with GICs.

Dr. Denny Oliveira talked about sporadic aurora observed at the low-latitude regions and sometimes near the magnetic equator. Sporadic aurora takes place during very low or even quiet geomagnetic conditions and develops mostly after dusk. There are very few reports on sporadic auroras. The geographic locations of these auroras were also presented.

Session 3: IEMIT-MMV joint session

Dr. Shin Othani discussed solar illumination dependence of the auroral electrojet intensity. He statistically examined northward geomagnetic disturbances in the auroral zones in terms of solar zenith angle (SZA) and dipole tilt angle (DTA). Westward electrojet is more intense for larger SZA and larger |DTA|. Westward/Eastward electrojet is more intense in the dark/sunlit hemisphere.

Dr. Toshi Nishimura presented a technique to reconstruct precipitating energy flux and characteristic energy maps in the nightside auroral oval using the THEMIS all-sky imagers. The technique allows to provide realistic energy flux and energy maps that preserve dynamic evolution of auroral arcs, which contribute to a few tens of % of the total energy flux.

After the first two speakers, the session was dedicated to the ionospheric conductance challenge. This year, the focus group selected a geomagnetic storm on 2013-Mar-17 and gathered all the modeling efforts to understand ionospheric conductance and its influence on the magnetosphere – ionosphere – thermosphere coupling.

Dr. Doğacan Ozturk presented the results from the GTIM IT-only model, suggesting that a self-consistent treatment of particle precipitation and electric potential is important to understand the magnetosphere – ionosphere – thermosphere system holistically. She also introduced a framework that can utilize high-latitude, meso-scale electric field measurements as input to run a global IT model.

Dr. Agnit Mukhopadhyay introduced a new conductance module for the Space Weather Modeling Framework and presented the 2013-Mar-17 storm results. This module uses auroral precipitations obtained from both the BATS-RUS global MHD model and the RCM ring current model for the conductance calculation. With this new module, SWMF show a better agreement with the DMSP aurora precipitation and electric potential pattern.

Dr. Margaret Chen presented the magnetosphere – ionosphere electron precipitation dynamics and conductance during the Mar-17-2013 storm. She updated the conductance module inside the RCM-E model using Khazanov's conductance formula derived from the STET kinetic electron transport model. The updated RCM-E model show a better agreement with the PFISR conductance estimates.

Dr. Lutz Rastaetter presented comprehensive model-to-model comparison. LFM-MIX, SWMF, OpenGGCM, VERB, CIMI, RCM, TIEGCM, CTIPe, and GTIM were simulated for the 2013-Mar-17 storm. Total hemispheric current, Joule heating, and CPCP were compared. Additionally, field-aligned currents, Pederson and Hall conductance at Poker Flat were compared.

Dr. Hyunju Connor presented the comparison of OpenGGCM, AMIE, and Robinson electrodynamics models for the 2013-Mar-17 event. All models show similar CPCP pattern during the geomagnetic storm. Modeled auroral hemispheric powers (HP) were also compared with the HP obtained from the THEMIS all sky camera. AMIE and Robinson models underestimate aurora precipitation, while OpenGGCM overestimates aurora precipitation.

Finally, the focus group discussed the model-data comparison strategies.

Session 4: IEMIT-UMEA joint session.

This session report is posted under the UMEA focus group report.

Interhemispheric Approaches to Understand M-I Coupling (IHMIC)

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 that the interhemispheric differences 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 three sessions at the GEM 2019 Workshop: one stand-alone session and two joint sessions with the "Testing Proposed Links between Mesoscale Auroral and Polar Cap Dynamics and Substorms", "ULF Wave Modeling, Effects, and Applications (UMEA)" and "Dayside Kinetic Processes in Global Solar Wind-Magnetosphere Interaction" focus groups.

Session 1: Monday, June 24, 3:30 pm - 5:00 pm

This session began with Denny Oliveira's report on asymmetric satellite orbital drag effects during magnetic storms to address space weather aspects of interhemispheric asymmetries. Using data from the CHAMP and DMSP spacecraft as well as a background density model, he showed orbital decay rates in the context of magnetic storms.

Zhonghua Xu investigated the role of interplanetary shock angle in asymmetric magnetic response on the ground by conducting a statistical survey using the interhemispheric conjugate ground-based magnetometer network. Onset time differences and intensity ratios were examined to conclude that the first response is generally observed in the hemisphere that shocks struck first, which is attributed to travel time via Alfven waves. The intensity, however, does not seem to be affected by the impact angle. He noted that more controlling factors should be incorporated in the statistical study.

An update on simultaneous northern and southern hemisphere seasonal/diurnal variations of latitudes and intensities of Birkeland currents from AMPERE has been reported by Brian Anderson. His study suggests that the interhemispheric current ratio appears to be related with conductance difference (including different magnetic fields) and geometry in day/night EUV.

Shini Ohtani reported the dependence of the auroral electrojet intensity on the solar illumination and dipole tilt using SuperMAG data. His study shows that both westward and eastward electrojets are more intense when the dipole tilt is smaller and this effect is comparable to the effect of solar illumination. The westward electrojet is found to be more intense during dark ionosphere, which is likely to be attributed to diffuse auroral precipitation and ionospheric conductance.

Christine Gabrielse compared SuperDARN data for meso-scale high-latitude ionospheric plasma flow speeds between summer and winter hemispheres, pointing out that faster flows were observed during the summer in the nightside. An opposite case has been expected due to higher conductivity under sunlit conditions (Ohm's Law). However, a new suggestion is that higher conductivity can occur under dark conditions due to auroral precipitation on the nightside.

Tetsuo Motoba reported asymmetric Pc5 signatures observed at the magnetically conjugate pair of Syowa-Iceland for 19–21 UT on 27 May 2017. The Syowa-Iceland magnetometer observations showed that the Pc5 amplitude was about 2 times larger at Syowa Station, Antarctica than at Iceland, only when the concurrent diffuse auroral pulsations approached the zenith of Syowa Station. He showed that the Syowa-Iceland conjugate points are displaced by ~0.7 degrees in geomagnetic latitude, and discussed a possible mechanism in which the secular variation in the geomagnetic field leads to an interhemispheric displacement of diffuse auroral precipitation regions.

Session 2: Tuesday, June 25, 10:30 am - 12:00 pm

This session was held jointly with the "Testing Proposed Links between Mesoscale Auroral and Polar Cap Dynamics and Substorms" focus group. The session began with Toshi Nishimura's study of Strong Thermal Emission Velocity Enhancement (STEVE). From multipoint observations, he suggested the structured boundary and scattering by waves (subauroral ion drift or SAID) as the magnetospheric source of STEVE. He also reported an interhemispheric conjugacy of the STEVE phenomenon.

Larry Lyons raised outstanding questions on the role of meso-scale flow channels in the coupled M-I system, emphasizing the importance of understanding propagation and characteristics of polar cap flow channels, dawnside auroral polarization stream, and feedback of flow channels on the large-scale system.

Anders Ohma presented asymmetric auroral activities in the context of tail reconnection and IMF By orientation. His study showed that asymmetry was reduced when the nightside reconnection increased, concluding that enhanced tail reconnection reduces lobe pressure which controls asymmetries in the magnetosphere.

Mike Hartinger suggested possible coordinated experiments/observational campaigns to explore interhemispheric asymmetries during the upcoming 2020/2021 southern hemisphere solar eclipses as they can provide opportunities for unique experiments to understand the relationship between asymmetries and ionospheric conductivity. The two FG teams (IHMIC and UMEA) will work together to coordinate campaign observations during the eclipse.

Shane Coyle reported preliminary results from investigation of ULF waves observed by the interhemispheric conjugate magnetometer network. The conjugacy of the ground magnetic response was compared with ionospheric conductivity based on solar zenith angle and ovation particle flux, concluding that observations most closely match the resonant prediction profile.

Session 3: Wednesday, June 26, 10:30 am – 12:00 pm

Joint session with the UMEA and Dayside Kinetics focus groups. See the Dayside Kinetic focus group report (Heli Hietala)

Global System Modeling (GSM) RA Reports

Coordinators: Alex Glocer and John Lyon

Modeling Methods and Validation (final report)

Katherine Garcia-Sage, Rob Redmon, Mike Liemohn, Lutz Rastaetter

The Modeling Methods and Validation Focus Group held one standalone session and four joint sessions at the 2019 Summer Workshop.

Joint sessions with Tail Environment and Dynamics at Lunar Distances; ULF wave Modeling, Effects, and Applications; 3D Ionospheric Electrodynamics and Its Impact on the Magnetosphere-Ionosphere-Thermosphere Coupled System (IEMIT); and Dayside Kinetic Processes in Global Solar Wind-Magnetosphere Interaction are summarized in those Focus Group reports.

The standalone session included two contributions focused on general validation topics:

Natalia Ganjushkina presented on "Metrics for Minute-Scale Variations of keV Electrons in the Inner Magnetosphere." She summarized Ganushkina et al., Space Weather, 2019, discussing the difficulty of estimating model performance over several orders of magnitude. Threshold and percentile-based metrics can be useful, but cannot be applied universally and may not be physically meaningful. With these considerations, they applied a range of event threshold metrics, as well as calculated the symmetric signed percentage bias to assess the IMPTAM model.

Adam Kellerman presented on "Validation of 3D electron radiation belt modeling using in situ measurements: Implemented at the CCMC." He showed the implementation of a radiation-belt model verification framework that has been implemented at CCMC. This verification framework, which relies on comparisons with pre-computed phase-space density from observations, was demonstrated for the VERB 2.0 model for the St. Patrick's Day 2013 event.

Following these talks, Lutz Rastaetter presented an update on tools available at the CCMC, including a tutorial on the CAMEL model validation tool for event studies (https://ccmc.gsfc.nasa.gov/camel/). The session ended with a discussion led by Katherine Garcia-Sage on updates and planning for the focus group. The concluding discussion focused on the plan to transition Modeling Methods and Validation Focus Group to a standing Methods and Validation Resource Group. This proposal was ultimately accepted by the Steering Committee at the end of the week, and the continuing and new Resource Group leaders, Mike Liemohn, Lutz Rastaetter, Josh Rigler, and Alexa Halford, welcome your input into this new phase of the Validation Group.

ULF wave Modeling, Effects, and Applications

Michael Hartinger, Kazue Takahashi, Alexander Drozdov, Maria Usanova, 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 six breakout sessions at the 2019 GEM workshop: two standalone and four joint with other focus groups. Several presentations are posted on the GEM wiki (https://gem.epss.ucla.edu/mediawiki/index.php/FG:_ULF_Wave_Modeling,_Effects,_and_Applications), along with updates on HGSO coordination for ULF wave studies and the ULF wave modeling challenge.

1. Recent advances in ULF wave research: Modeling – Joint with MMV

In this session we discussed ULF wave modeling advances and challenges, as well as new tools available to modelers for validation and data-model comparisons. The session began with UMEA FG updates and a general overview of the 27-28 May 2017 ULF wave challenge event. Several talks in the session described simulations and data-model comparisons for the challenge event, with background information and model runs posted to the UMEA page on the GEM wiki. These talks included (1) analysis of global ULF wave power maps from SuperMAG that indicated strong local time dependence of wave power, (2) ground magnetometer observations of Pi2 wave properties near PFISR placed in context with statistical Pi2 wave properties, (3) LFM simulations of wave activity during the event indicating a realistic inner magnetosphere model and high resolution grid are needed to capture wave activity during the event. The idealized ULF wave modeling challenge was also discussed; different simulation codes produce different wave properties despite having the same driving conditions, and this is due in part to different grids, radial density profiles, and ionosphere boundary conditions. Other talks described how new SuperMAG ULF wave analysis tools that take advantage of high resolution (1 second) data can be used for ULF wave studies, and how particle tracing in global MHD simulations can be used to interpret satellite observations of residual flux oscillations during interplanetary shock compression events.

2. The ULF response to dayside transients with different temporal and spatial scales – Joint with Dayside Kinetics and IHMIC

Discussion leader: Tom Elsden

See Dayside Kinetics FG report: https://gem.epss.ucla.edu/mediawiki/index.php/2019_Summer_Workshop,_Santa_Fe,_NM#UMEA.2FDayside_Kinetics.2FIHMIC_joint_session

3. ULF wave modeling challenges associated with M-I-T coupling – Joint with IEMIT

Discussion leader: Doğa Ozturk

In this session researchers from the ULF wave and M-I-T coupling research communities discussed challenges associated with realistically modeling M-I-T coupling processes associated with ULF waves, including discussion of the ULF wave challenge event. The first two talks discussed coordinated investigations of M-I coupling during the challenge event, showing (1) that large ULF modulations of ionospheric electron density/conductivity coincide with conjugate satellite and ground-based magnetometer wave observations, and that these conductivity modulations could in turn affect wave properties and (2) the ionospheric electron density/conductivity modulations may be driven by VLF waves which are themselves modulated by ULF waves throughout the entire dusk sector. Other talks in the session focused on theory and modeling needed to determine the role of ULF waves in M-I and M-I-T coupling: (1) results from the Global Ionosphere Thermosphere Model driven with meso-scale drivers (GITM-MD), in which the localized 2D electric field measurements from PFISR were used – the simulated electron density periodicities were similar to wave periodicities observed in ground magnetometer signatures, (2) new ULF wave numerical simulations that allow for inductive ionosphere boundary conditions as well as realistic layered ground conductivity models, the latter shown to be very important for specifying ground magnetic perturbations at frequencies above a few 10's of mHz, (3) theory of the generation of parallel electric fields, which are needed to describe auroral particle acceleration and, in general, the relationship between ULF waves and the aurora. Finally, several talks focused on observations used to determine the role of ULF waves in M-I-T coupling: (1) observations and simulations of enhanced wave activity/small scale waves near the plasmapause related to the ionospheric feedback instability, (2) ground magnetometer ULF perturbations that are strongly correlated with solar wind perturbations, indicating a solar wind direct driving mechanism, (3) ground magnetometer statistical study of magnetic impulse events indicating that many occur on the nightside during periods without substorms, and that they can be highly spatially localized (radius<300 km). Finally, a summary of the high-latitude I-T processes session at CEDAR was presented.

4. EMIC waves: Joint with RB FG

As EMIC waves fall into the ULF frequency range but are specifically important for the radiation belt dynamics, the EMIC wave session was organized jointly with the RB focus group. There were nine presentations encompassing the topics of wave observations, their properties and their effect on numerical simulations.

Robert Allen presented EMIC wave observations in the outer magnetosphere and focused on wave source regions characterized by Cluster. Sarah Vines focused on EMIC wave properties in the outer magnetosphere and presented MMS observations from an off equatorial dusk region on October 28, 2015. Justin Lee presented EMIC wave observations by MMS FGM waves and performed polarization analysis, as wave polarization may point at non-local growth. Chao Yue talked about the relationship between EMIC wave properties and proton distributions based on Van Allen Probes observation. Kristine Sigsbee reported EMIC wave observations during Van Allen Probes conjunction in the recovery phase of a CME storm. Hyomin Kim presented on particle loss due to injection-associated EMIC waves. Yuri Shprits addressed deepening minimums in PSD as evidence of localized loss of electrons by EMIC waves. Richard Denton presented hybrid PIC simulations of EMIC wave propagation in a dipole magnetic field and pitch angle scattering of radiation belt electrons by these waves. Qianli Ma discussed pitch angle scattering of radiation belt electrons due to statistical EMIC wave power spectra from Van Allen Probes.

See the GEM UMEA wiki page for links to presentations and a full report: https://gem.epss.ucla.edu/mediawiki/index.php/FG:_ULF_Wave_Modeling,_Effects,_and_Applications#2019_GEM_meeting_schedule

5. Recent advances in ULF wave research: observations

This session focused on recent advances in ULF wave research with focus on observations and a general discussion of Heliophysics/Geospace System Observatory coordination for ULF wave studies. Several talks focused on the unique contributions of recent satellite missions/conjunctions to ULF wave research: (1) a review ULF wave observational studies using the Van Allen probes, including a discussion of the unique capabilities/conjunctions (e.g., Arase) provided by these satellites as well as some caveats in using the observations, (2) demonstration of how the 4 MMS satellite tetrahedron can be used to obtain accurate k vectors for EMIC waves via the curlomter technique, (3) demonstration of how unique periods where 5 geostationary GOES satellites are available can be used to obtain detailed information about ULF wave mode numbers, (4) use of balloon (BARREL) conjunctions with THEMIS satellites, combined with solar wind observations, to show that density structures in the solar wind drive modulated precipitation of energetic electrons near the loss cone, and (5) THEMIS/GOES satellite conjunctions that were used to statistically determine how often Pi2 waves are observed on the nightside at both geostationary orbit and deeper in the magnetotail. Other talks in the session focused on new ground-based observational tools and experiments: (1) new SuperMAG ULF wave analysis tools using 1 second resolution measurements (rather than standard 1 minute), (2) techniques for artificially heating the ionosphere with HAARP to excite ULF waves, (3) techniques using the dense EMMA ground-based magnetometer network to construct keograms and remote sense the fine spatial structure and time evolution of ULF wave activity and determine the wave mode(s).

6. ULF waves driven by wave-particle interactions and instabilities

Discussion leader: Xueling Shi

In this session, modelers and observers discussed the underlying processes that drive/damp internally driven ULF waves, their impact(s) on the M-I system, and the models/observations needed to better understand wave dynamics. The session began with a general overview of ULF wave-particle resonances and how they can be detected in spacecraft measurements in the range of 10's of keV to several MeV energies, including both the classic theory and modifications to the theory that account for realistic time evolution and spatial localization of ULF wave fields. Several subsequent talks focused on theory/modeling of ULF waves associated with wave-particle interactions and warm plasmas: (1) use of a new global drift-kinetic model that demonstrates how ULF waves can be self-consistently driven by interactions with injected ions, (2) theory and numerical simulations of buoyancy waves showing they are mostly likely to be driven/observed in regions with stretched field lines, are compressional, and have frequencies in the 2-12 mHz range with frequency varying with radial distance, (3) theory and observations showing that the drift-mirror instability criteria can be satisfied in at least some conditions in the inner magnetosphere. Other talks focused on observations of inner magnetosphere waves: (1) observations of high-m number waves from low-Earth orbiting satellites, geostationary satellites, and ground magnetometers demonstrating the need for more satellite measurements of high-m waves and the difficulties of mapping/estimating high-m magnetospheric wave fields using ground-based observations, (2) satellite observations showing that dipolarizing flux bundles can drive ULF waves deep in the inner magnetosphere/inside the plasmasphere, (3) observations demonstrating that ULF waves during storms can penetrate deep into the magnetosphere due to the modification of the Alfven continuum caused by an enhanced ring current.

Magnetic Reconnection in the Age of the Heliophysics System Observatory

Rick Wilder, Shan Wang, Michael Shay, Anton Artemyev

The GEM 2019 Workshop at Santa Fe was a productive one for the “Magnetic Reconnection in the Age of the Heliophysics System Observatory” focus group. The Workshop as joint with the Magnetospheric Multiscale “MMS” science working team meeting, allowing for a showcasing of the newest reconnection research to come from the mission, as well as from theory and modeling. Overall, there were 30 presentations from both the GEM community and the MMS team.

The first session focused on the local and kinetic physics of magnetic reconnection. Binbin Tang showed that the agyrotropic electron distributions, which is unstable for plasma waves, can be found either in the reconnecting or non-reconnecting magnetopause. Jason Shuster demonstrated the capability of instrumentation comprising the Fast Plasma Investigation (FPI) onboard the four-spacecraft Magnetospheric Multiscale (MMS) mission to detect and assess the balance of the temporal, spatial, and velocity-space gradient terms in the electron Vlasov equation, which provides the first observational verification of kinetic theory within an electron scale current sheet inside the magnetopause reconnection exhaust region. Yi-Hsin Liu showed that through considering the dawn-ward transport of the normal magnetic flux by electrons and the reconnection physics, Yi-Hsin et al. propose that the difference of the global cross-tail size in Mercury vs. Earth will result in the opposite dawn-dusk asymmetry. Li-Jen Chen showed Electron dynamics driven by nonlinear waves in a guide-field reconnection layer. Finally, Jonathan Ng presented a study of three-dimensional instabilities in the symmetric reconnection layer with a moderate guide field.

The second session also focused on local magnetic reconnection physics. Using new 3-D PIC simulations of the magnetotail current sheet, Misha Sitnov showed that kinetic dissipation parameters (the so-called Pi-Ds) have different distributions around dipolarizations fronts (DFs): While for ions Pi-D^i is enhanced at and ahead DF, for electrons Pi-D^e is enhanced behind DF and/or earthward of the X-line. He also mentioned, that in most interesting cases, the ion Pi-D cannot be assessed by MMS because FPI time resolution is insufficiently high given extremely small probe separation. Stefan Eriksson presented Nascent flux rope observations at the earth’s dayside magnetopause. Marty Goldman showed that Standard velocity moments of a disjoint particle velocity distribution measure during reconnection contain false thermal parts which can be removed by taking multibeam moments. David Newman presented A method for constructing anisotropic current-sheet equilibria with agyrotropic features based on observed electron-crescent distributions was described, with the results used to initialize 1D and 2D PIC simulations in order to study particle orbits and assess current-sheet stability. Sanni Hoilijoki presented results of a dayside magnetopause crossing where MMS observes a complicated magnetic structure consisting of force-free flux rope like part and non-force free magnetic enhancement adjacent to an Electron Diffusion Region (EDR). Finally, Daniel Graham discussed the role of lower hybrid waves in magnetic reconnection.

The third session focused on the relationship between magnetic reconnection, waves and turbulence. Rick Wilder presented a survey of EDR events observed at the dayside magnetopause, and showed that a majority of the wave activity occurred on the magnetospheric side of the current layer, with current corrugations, large amplitude parallel electric fields and the lower hybrid drift instability being most likely to approach the stagnation point and x-line. Wenya Li discussed large-amplitude electron Bernstein waves observed near the EDR of dayside magnetopause reconnection. The electron Bernstein waves are driven by crescent-shaped agyrotropic electrons. These waves trap and thermalize electron crescents, and modify electron pressure tensor. San Lu demonstrated that PIC simulations show that temperature inhomogeneity across pre-reconnection current sheet significantly increases turbulence level and particle acceleration efficiency in collisionless reconnection by continuous formation of numerous secondary magnetic islands. Prayash Sharma Pyakurel explored the structure and properties of 3D electron-only reconnection soon after the initial onset of reconnection motivated by the extremely large parallel electric field observed during MMS crossings of electron exhausts in the magnetosheath. Normalized to the simulation upstream magnetic field and the electron exhaust velocity, he found that the normalized parallel electric field in the 2D simulation is ~0.25 while the 3D simulation shows enhanced $E_{||} \sim 0.6$. Though the reconnection rate is still considerably below the recent MMS observations, we find that 3D magnetic reconnection is clearly faster reconnection than 2.5D reconnection. Matt Argall presented Observations of kinetic entropy in the diffusion region of magnetic reconnection. Finally, Blake Alastair Wetherton presented on how the anisotropic electron equations of state of Le et al. (2009) can be used to estimate the electron heating in the exhausts of high guide field reconnection.

The fourth session was on the system influences on and consequences of magnetic reconnection, with emphasis on the Earth's magnetotail. Anton Artemyev presented MMS, Artemis and optic observations of the magnetotail reconnection. Misha Sitnov, Grant Stephens and coauthors presented the global empirical picture of the July 11, 2017 EDR event. They showed that mining 20+ years of magnetometer data from many missions, including the first 2 years of MMS observations, helps reveal the global shape of the corresponding X-line, which is located close to MMS observations. The data-mining reconstruction also shows that the magnetotail reconnection is inherently unsteady. Narges Ahmadi discussed the role of turbulence and large electric fields in energy conversion in the magnetotail reconnection process and accelerating electrons to energies as high as 100 keV. These acceleration events are common and located in an Earthward or tail-ward flow and they are associated with turbulent electric and magnetic fields and large J•E measurements. Analysis of pitch angle distributions showed that electrons are trapped inside magnetic holes generated by turbulence. The trapping process facilitates the acceleration process and gives enough time to electrons to interact with large amplitude electric fields. Chih-Ping Wang showed an event (2017-06-09) of simultaneous earthward and tailward busty flows observed by the two ARTEMIS in mid-tail (60 R_E) and showed that the observed spatial structures, waves, and instabilities within the flows are qualitatively consistent with a PIC simulation of the reconnection exhausts. Chris Bard showed Hall MHD effects on tail reconnection for a Earth-like, miniature magnetosphere. Finally, Olivier Le Contel presented examples of electron phase-space holes (fast electromagnetic, fast and slow electrostatic) all moving tailward and related to different contexts (dipolarization front, PSBL, outer plasma sheet), which were discussed in term of generation mechanisms (Buneman vs two stream instability) and link to a tailward reconnection region

The final session also focused on system influences on and consequences of magnetic reconnection, this time with emphasis on the dayside and flank magnetopause. Katariina Nykyri showed observations of High latitude diamagnetic cavities. Andrew Dimmock presented the SMILE SXI instrument: a global imager for solar wind – dayside interactions. Brian Walsh presented progress on a Cubesat mission to study magnetic reconnection. Xuanye Ma showed that Kelvin-Helmholtz (KH) vortices in Hall MHD simulation can form large magnetic islands to transport plasma. Plasma mixing is mainly through diffusion in hybrid simulation of the KH instability. Anisotropic temperature can be formed by the nonlinear KH instability, which can drive kinetic-scale waves. Karlheinz Trattner showed that The MMS satellites observed repeated encounters with the magnetopause boundary layer for about 40 minutes while the IMF was continuously rotating. That allowed the MMS satellite to be connected to various sections of the component and anti-parallel reconnection line, covering about a distance of 15 R_E along the X-line, which included an EDR and the transition from the anti-parallel to the component reconnection scenario. Finally, Marcos Sylveira presented flux transfer events observed at the dayside magnetopause by the MMS mission.

Liaison Reports

CEDAR Liaison Report

Shasha Zou

The current CEDAR science steering committee (CSSC) chair is Delores Knipp. The CEDAR workshop organizer is Astrid Maute, the conference administrators are Kendra

Greb and Michelle McCambridge, and the new NSF CEDAR Program manager is Alan Liu.

The 2019 CEDAR workshop was held at Santa Fe, New Mexico, June 16-21, just before the GEM workshop. A GEM-CEDAR workshop was held on Saturday, June 22, 2019, and attracted more than 100 attendees. Four science topics were selected by the GEM/CEDAR day committee, focusing on mass and energy exchanges between the ionosphere-thermosphere and magnetosphere, including ion upflow and outflow, conductance, observational platforms, and September 2017 geomagnetic storm. A total of 333 participants (109 students) from 104 different institutions and 16 different countries registered for the CEDAR workshop. Overall, 72 participants were new to the CEDAR workshop, and 47 of them were students. The traditional Sunday student workshop was under the theme "Core Aeronomy and Data Science". The student workshop was organized by the student representatives, Nithin Sivadas and Matthew Grawe, and was very well attended. There were a couple of student activities besides the workshop, including "location hunting" following the student workshop, a hackathon on Monday evening and "lunch with a scientist" on Tuesday. The new student representative is Komal Kumari coming in for outgoing Nithin Sivadas.

The CEDAR meeting spanned 4.5 days and included 29 sessions, covering a broad range of themes as proposed by the community. Details about these sessions can be found on the CEDAR work-shop webpage http://cedarweb.vsp.ucar.edu/wiki/index.php/2019_Workshop:Main.

One new grand challenge topic was selected, "Coordinated Ground and Space-based Observations of the Ionosphere Thermosphere System" in light of the GOLD and ICON missions. Xinzhao Chu from University of Colorado, Boulder, gave the 30th CEDAR Prize lecture about "Coupling from the atmosphere to geospace in Antarctica". Cheryl Huang from Air Force Research Laboratory gave the Distinguished Lecture with the title "Solar wind forcing of the high-latitude ionosphere-thermosphere system". There were also four science highlights and four early-career science highlights during the workshop. CSSC also organized a pilot event "LGBTQ+ gathering" on Tuesday night, which will continue in the future.

Due to the COVID-19 pandemic, the in-person 2020 CEDAR workshop has been canceled and replaced with a virtual meeting.

SHINE Liaison Report

Joe Borovsky

The SHINE 2020 workshop in Honolulu has been canceled with no announced plans for a virtual workshop.

The SHINE community remains busy: (1) there is continued unprecedented data for the NASA Parker Solar Probe which is inching its way closer to the Sun with every perihelion pass, (2) the (mostly ESA) Solar Orbiter spacecraft is in the commissioning phase, and (3) DKIST (Daniel K Inouye Solar Telescope) is coming online.

The SHINE community looks forward to a joint meeting with the GEM community in 2021.

NASA Liaison Report

Mona Kessel

While all of our work habits and patterns have been adjusted since March, NASA is working hard to support the community and the research we do. NASA's Research Opportunities in Space and Earth Science (ROSES) for 2020 will still be moving forward, but all panel reviews will be virtual going forward in 2020. The ROSES Heliophysics Appendix B can be accessed here, to see the future opportunities.

NASA HQ has already had the first fully virtual Authority to Proceed selection meeting for the SunRISE mission. SunRISE is an array of six CubeSats operating as one large radio telescope. This mission will investigate the orgins of solar particle storms, and is led by Justin Kasper at the University of Michigan.

In addition to SunRISE, NASA has recently announced these Mission Selections for 2020: Atmospheric Waves Experiment (AWE), Sun Radio Space Experiment (SunRISE), Polarimeter to Unify the Corona and Heliosphere (PUNCH), Tandem Reconnection and Cusp Electrodynamics Reconnaissance Satellites (TRACERS), and Interstellar Mapping and Acceleration Probe (IMAP).

From its space station perch, AWE will focus on airglow to determine what combination of forces drive space weather in the upper atmosphere, investigating how gravity waves in the lower atmosphere impact the upper atmosphere. The mission is led by Michael Taylor at Utah State University in Logan.

TRACERS was selected as a NASA-launched rideshare mission, meaning it will be launched as a secondary payload. TRACERS will observe particles and fields at Earth's northern magnetic cusp region, and will study particles accelerated down toward the atmosphere after magnetic reconnection events. The mission is led by Craig Kletzing at the University of Iowa in Iowa City.

PUNCH focuses on the corona and the generation of solar wind, and will image and track the solar wind as well as coronal mass ejections to better understand their origins and evolution. PUNCH is led by Craig DeForest at the Southwest Research institute in Boulder, Colorado.

IMAP will reside at L1 and observer Energetic Neutral Atoms (ENAs) to capture observations of the boundaries of the heliosphere and how it interacts with interstellar space. IMAP also carries a comprehensive suite to map the local space at L1, in situ. IMAP is led by Dave McCommas at Princeton University.

NASA HQ works hard to amplify heliophysics research. We share such information with NASA leadership and the public. If you have information you'd like us to know about, pleases submit it here.

Recently, NASA has released these magnetospheric news stories:

- In Solar System's Symphony, Earth's Magnetic Field Drops the Beat
- Streaks in Aurora Found to Map Features in Earth's Radiation Environment
- High-Flying Spacecraft Finish 1000th Lap Around Earth!
- NASA's MMS Marks its 5th Year Breaking Records in Space
- NASA's MMS Finds Its 1st Interplanetary Shock
- Ten Highlights From NASA's Van Allen Probes Mission

Lastly, the Magnetosphere Online Seminar Series meets every Monday at noon, featuring overview talks marching through the magnetosphere, interspersed with software, mission, and instrument tutorials. Following these, the Seminar Series will transition to invited and contributed science talks and tutorials.

NOAA Liaison Report

Howard Singer

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.

The GEM Steering Committee's May 1988 Report on "Geospace Environment Modeling-A New Research Initiative Proposed" expressed GEM's scientific goal as: "understand the solar-terrestrial system well enough to be able to formulate a mathematical framework that can predict the deterministic properties of geospace ("weather in space") and the statistical characteristics of its stochastic properties ("climate in space")." In line with those GEM goals, SWPC continues to invest in modeling for space weather prediction. Modeling the space environment is a significant challenge that will lead to major benefits for those impacted by space weather. A few newsworthy items from SWPC, related to modeling, are that the NOAA-USGS E-field model was deployed to SWPC operational systems on September 17, 2019 and an upgrade to the University of Michigan's Geospace model is planned for late this year. To elaborate, the NOAA/USGS E-field model combines real-time magnetic variations from the US Geological Survey (USGS) and Natural Resources Canada (NRCAN) with a ground-conductivity model to calculate and display the regional gridded geoelectric field. The geoelectric field can be used by power grids for situational awareness and as input to their models that calculate geomagnetically induced currents. With regard to the University of Michigan's Geospace model, it has been used in operations since 2016 with initial products that provide forecasters and web-based users with regional predictions of geomagnetic disturbances. The upcoming Version 2.0 upgrade will provide higher resolution and better capture features such as auroral currents.

SWPC has also been working to advance Research to Operations and Operations to Research (R2O2R). In part, these activities are in response to the National Space Weather Strategy and Action Plan (NSW-SAP) released in 2019 (see link at: https://www.swpc.noaa.gov/news/national-space-weather-strategy-and-action-plan-released-0). One of the actions in the NSW-SAP is to: "Identify mechanisms for sustaining and transitioning models and observational capabilities from research to operations that will include academic, private sector, and international partnerships." Working together with agency partners, SWPC has been developing plans for a "NOAA Testbed and Proving Ground" that will enable developmental testing, include researchers and operational scientists/experts, and involve government agencies, academia, private sector and international partner participation. One of the goals is to have a facility where we can conduct collaborative exercises and experiments under quasi-operational conditions.

As one of the actions in the NSW-SAP, SWPC engaged Abt Associates, Inc. to produce a report on the Social and Economic Effects of Space Weather and they have recently completed a comprehensive user survey on Customer Needs and Requirements for Space Weather Products and Services. Links are provided here for the two reports that GEM participants may find useful.

Customer Needs and Requirements for Space Weather Products and Services, March 2019: https://www.swpc.noaa.gov/news/customer-needs-requirements-space-weather

Social and Economic Impacts of Space Weather in the United States, September 2017: https://www.weather.gov/media/news/SpaceWeatherEconomicImpactsReportOct-2017.pdf.

Also, this year, SWPC has continued its partnership with NASA and NSF to collaborate on funding opportunities for Operations to Research/Research to Operations (O2R/R2O) applied research that is likely to result in improved capabilities for operations.

Solar wind observations from the upstream L1 location are critical for both science and space weather operations. NOAA's Deep Space Climate Observatory (DSCOVR) continues to provide real-time data for both of these purposes. DSCOVR operations, which were interrupted for about nine months, returned with improved operations on 2 March 2020. During the outage, NOAA utilized NASA's ACE satellite for serving space weather customers. Development of future L1 observations is progressing with plans for launching NOAA's Space Weather Follow On (SWFO) satellite in 2024 as a rideshare to L1 with NASA's IMAP mission. Selections have been made for the SWFO magnetometer (Southwest Research Institute) and the SupraThermal Ion Sensor (STIS) (UC Berkeley), and work is continuing on a Compact Coronagraph (Naval Research Laboratory). (Development is also underway for a compact coronagraph that is planned for launch on GOES-U). Additional instruments to be flown on SWFO, the spacecraft procurement and ground-processing plans are progressing in preparation for a 2024 launch.

GOES observations have been used for decades by GEM researchers and other scientists, as well as at SWPC and by other nations to support space weather operations. Currently SWPC is using observations from the first of a new generation of GOES satellites, GOES-16, and is preparing to use GOES-17 data later this year. While real-time data are available from SWPC, we work closely with our NOAA colleagues at the National Centers for Environmental Information (NCEI) where the GOES archived data are made available. See https://www.ngdc.noaa.gov/stp/satellite/goes-r.html as well as reprocessed 2 Hz GOES-8-15 MAG data with multiple geophysical frames at https://satdat.ngdc.noaa.gov/sem/goes/data/science/mag/. (In addition, some GOES data continue to be available through NASA's CDAWeb and the THEMIS satellite database.)

The 2020 Space Weather Workshop, co-sponsored by NOAA, NASA and NSF, along with probably every other face-to-face meeting in our science community, was cancelled as a result of COVID-19. Prior to cancellation, the Space Weather Workshop organizers, including the University Corporation for Atmospheric Research (UCAR) and an expert and enthusiastic steering committee, had developed an exciting program that was 95% complete. The planned meeting included greater diversity, an enhanced student program, exciting new research results, and operational space weather impacts. We look forward to next year when the meeting that brings together researchers, commercial and government space weather service providers, and users of space weather services is planned for April 19-23, 2021 in Boulder, Colorado.

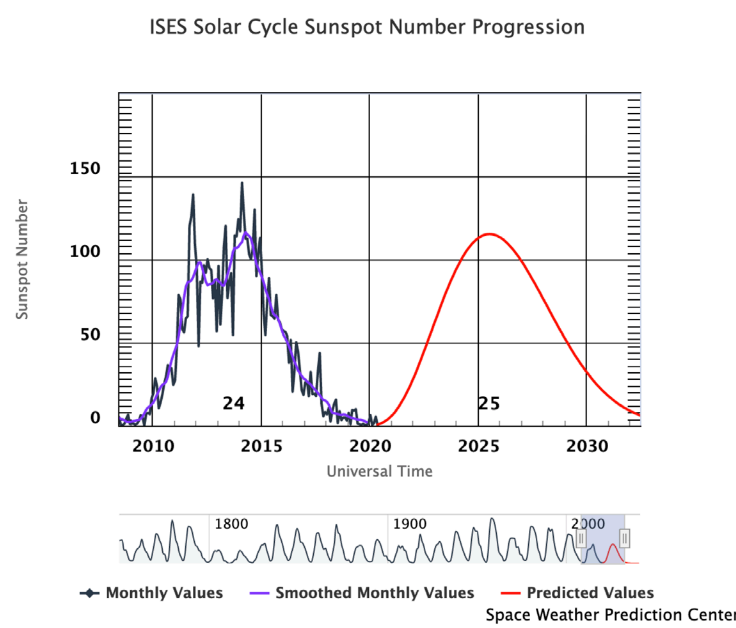


Figure 1: Solar Cycle interactive plot from new SWPC webpage. (https://www.swpc.noaa.gov/products/solar-cycle-progression)

Finally, Solar Cycle 24, peaking in April 2014, was one of the smallest solar cycles on record; however, as we head toward solar minimum (likely already reached), 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. Recently, the NASA funded, NOAA led, effort to predict Solar Cycle 25, with an international team of experts, has stated that Solar Cycle 25 will have a peak Sunspot Number of 115 (± 10) in July 2025 and that Solar Cycle 24/25 minimum will occur in April 2020 (± six months) (see Figure 1 above).

AFRL Liaison Report

James McCollough

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. This year's report focuses on the ongoing Demonstration and Science Experiments (DSX) mission.

The DSX spacecraft is conducting 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 launched at 12:30 AM MDT on Tuesday, June 25, 2019 as co-primary payload on the Space Test Program-2 (STP-2) mission.

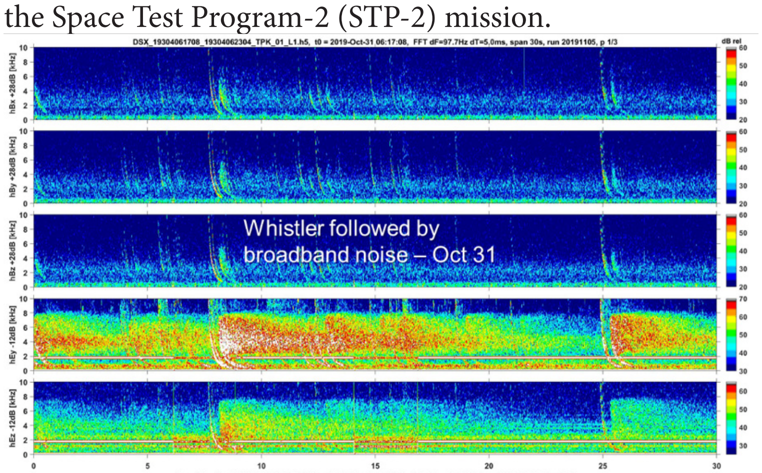


Figure 2: VLF Receiver data from DSX showing lightning-generated whistlers.

DSX is operating in a 6000 km x 12000 km x 42° orbit.

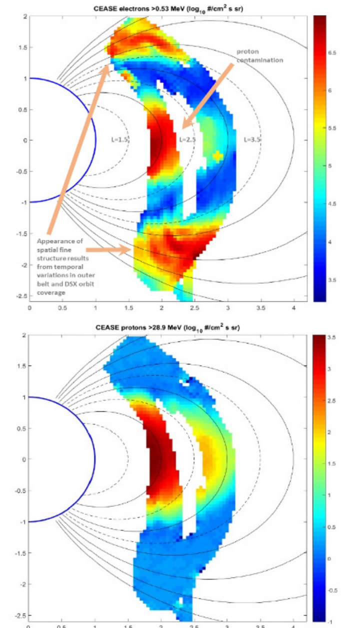


Figure 3: Meridional Plots of integral fluxes of electrons (Top) and protons (bottom) from the CEASE instrument on DSX.

On DSX, the Wave-Particle Interactions (WPIx) payload suite utilizes a high-power VLF transmitter in order to investigate the interactions of VLF waves with trapped energetic electrons in the magnetosphere. DSX is also characterizing the transmitter's far-field radiated patterns using conjunctions with space-borne VLF receivers, as well as natural wave-particle interactions at MEO (see Figure 2).

The Space Weather (SWx) suite of instruments has been surveying 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 has made comprehensive observations of the "slot region" between the inner and outer radiation belt (see Figures 3 and 4).

AFRL's VLF Propagation Mapper (VPM) cubesat was deployed from the ISS in February, and has completed early operations and commissioning activities. Outfitted with a VLF receiver, VPM will coordinate with DSX and other experiments to provide VLF measurements at LEO of natural and artificial origin.

In addition to DSX/VPM, AFRL has ongoing efforts to model outer zone electrons and develop a ground-based geomagnetic disturbance monitoring capability for the Department of Defense. AFRL plans to sustain research activities related to space weather phenomena and will continue to seek dialog with community partners.

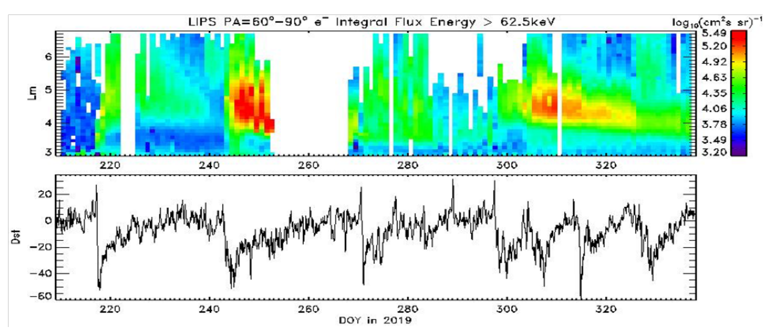


Figure 4: Electron fluxes vs. Lm and time from the LIPS payload on DSX.

USGS Liaison Report

Josh Rigler

The following is a brief summary of operations and research undertaken or supported by the U.S. 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.

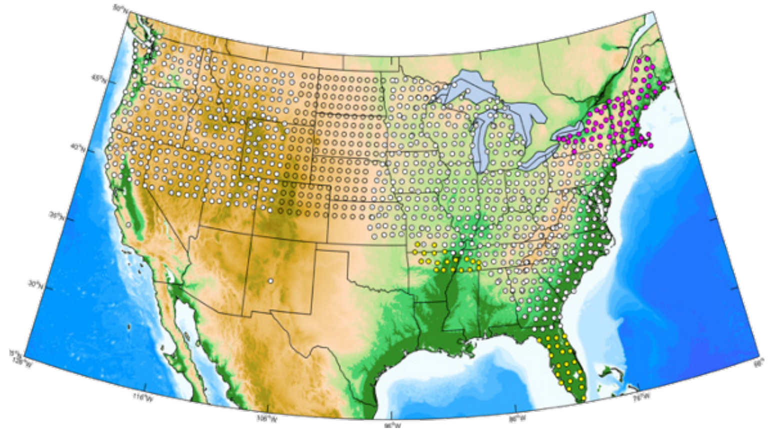
Magnetic Observatory Operations and Data

The USGS Geomagnetism Program monitors the Earth's magnetic field with high accuracy, (time) resolution, and reliability. It operates 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. In 2019, a pilot program was initiated in partnership with the USGS' Albuquerque Seismic Laboratory to co-install lower-cost, off-the-shelf magnetometers at select Global Seismic Network stations. Data quality from these magnetic variometers is not as rigorously controlled as traditional observatory data, but it is available in real-time, and is expected to have comparable operational continuity.

Magnetotelluric Surveys

The USGS has been closely associated with NSF's Earthscope USArray program that completed a gridded magnetotelluric (MT) survey of the northern two-thirds of the conterminous United States (CONUS) and archived these data using modern standardized formats (Kelbert, 2020 – Geophysics) in a publicly accessible online database (ds.iris.edu/spud/emtf). USArray covered the Pacific Northwest, the Upper Midwest and Great Lakes, Appalachia, and New England. The USGS conducted smaller-scale regional MT surveys to augment USArray coverage and support specific industry needs, most notably in Florida, southern Missouri, northern Arkansas, and Tennessee. Even with this augmentation, MT data are lacking for most of the



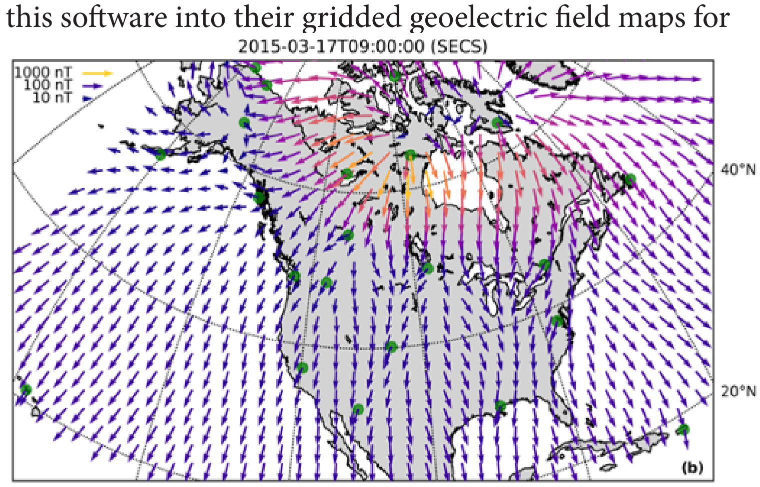
southern third of CONUS. In FY2020, USGS received omnibus appropriations for the first year of completion of the magnetotelluric survey for the southern CONUS, which will provide MT information critical for generating complete geoelectric hazard maps of CONUS. This work will be completed through a cooperative agreement with Oregon State University.

Targeted Research

The USGS Geomagnetism Program has a small but active research component that is largely focused on geomagnetically induced currents (GICs), and their impact the U. S. electric power transmission grid.

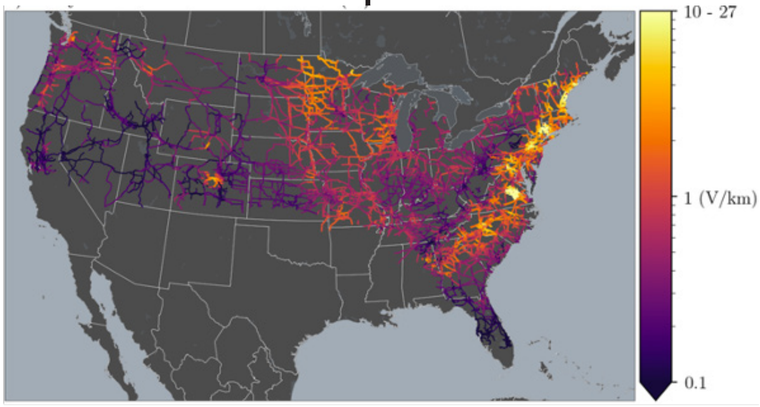
Geomagnetic Disturbance Maps

As part of a multi-agency collaboration including NASA, NOAA, and NSF (via NCAR's High Altitude Observatory, HAO), the USGS has developed a real-time operations-oriented open-source Python software package that employs spherical elementary current systems (SECS) to interpolate geomagnetic disturbance given sparse geomagnetic observations (github.com/usgs/geomag-imp). NOAA's Space Weather Prediction Center (SWPC) incorporated this software into their gridded geoelectric field maps for



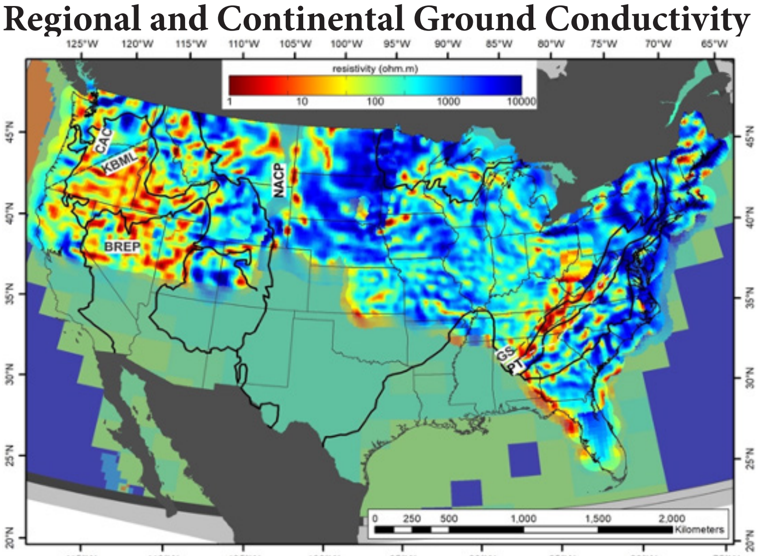
the continental United States (CONUS) using near real time data from the USGS and Natural Resources Canada (NRCan) as input. A 2nd generation of this software is under development that combines machine learning with sophisticated global simulations to better constrain SECS solutions. (Rigler et al., 2019 – AGU Monograph Series)

Geoelectric Hazard Maps



The USGS, in collaboration with NOAA, NASA, and Los Alamos National Laboratory, is working 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. 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 much of CONUS that were projected onto the power grid to generate an industry-relevant induction hazard map. (Love et al., 2017 – GRL; Love et al., 2018 – Space Weather; Lucas et al., 2020 – Space Weather)

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. (Kelbert, 2020 – Surveys in Geophysics)

Argentina Liaison Report

Laura F. Morales

In the last decade Argentina has been developing several new research activities in Space Physics and Sun-Earth connection, with a significant interaction with the international scientific community. Many groups are spread throughout Argentina for instance working in Buenos Aires, Corrientes, Tucumán, Mendoza, etc. I will report two main activities: the first one in the province of San Juan and the second one in Antarctica.

Particularly, the year 2019 and the beginning of 2020 was very productive. For the solar eclipse of July 2nd, 2019 part of the community organized the conference: Towards Future Research on Space Weather Drivers (2-7 of July, 2019). The meeting promoted the exchange of information in the area of space weather, from the point of view of the phenomena that drive it from their origin in the solar atmosphere, through their evolution in the interplanetary medium, to their arrival in geospace. The meeting was accompanied of school aimed to students and young researchers who seek to gain a broad overview of space weather domains, concepts, tools and resources.

Group photo: Towards Future Research on Space Weather Drivers (2-7 of July, 2019)

A Topical Collection of the journal Solar Physics was organized by the SOC & LOC of the Conference and will be published in the course of the northern summer.

Also in the Southern summer of 2019 a the LAMP group (Laboratorio Argentino de Meteorología del esPacio, www.iafe.uba.ar/u/lamp) whose PI is Sergio Dasso. Installed a Space Weather laboratory and a cosmic ray detector (called 'Neurus') in Antarctica, in the argentine Marambio station. The detector was designed and completely developed at IAFE (Instituto de Astrofísica del Espacio) and is part of the LAGO Latin American collaboration. The project is multi-instituional: IAFE (UBA-CONICET), the Instituto Antártico Argentino (IAA/DNA), and the Departamento de Ciencias de la Atmósfera y los Océanos/ Departamento de Física (DCAO/DF, Facultad de Ciencias Exactas y Naturales, UBA) collaborate.

The four researchers who are carrying out the installation of the laboratory and the detector in the Antarctic argentine station. From left to right: Adriana Gulisano, Sergio Dasso, Omar Areso and Matías Pereira.

The group spent also the summer of 2020 in Antarctica extending the capabilities of the laboratory.

The solar eclipse of December of 2020 will allow more research and interaction with several groups provided that the COVID-19 crisis is solved.

ISAS, Japan Liaison Report

Yoshizumi Miyoshi

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

1. GEOTAIL

GEOTAIL project took a mission extension review in the beginning of 2019 and GEOTAIL operation was approved to extend 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. Data plots of GEOTAIL, THEMIS, and MMS can be found 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, DSX, and ground-based observations. More than 500 conjunction events between Arase and Van Allen Probes had been observed until October 2019, and ~40 conjunction operations between Arase and DSX have been realized. The initial science results were published in the special issue of Geophysical Research Letters, and the new special issue about collaborative studies in the inner magnetosphere are now opened in Journal of Geophysical Research. CDF files of the calibrated science data obtained by each instrument are available and data analysis software, which is a 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 AT stp.isas.jaxa.jp and PIs of each instrument.

3. NASA-ISAS Sounding Rocket Experiment: LAMP

LAMP is a souding rocket project led by NASA, which is dedicated for understanding the generation mechanisms of sub-relativistic, microburst electron precipitations under the activities of pulsating aurorae. ISAS with several Japanese universities are developing one of the instrument packages to be onboard LAMP. LAMP will be launched from Porker Flat Research Range in Fairbanks, Alaska after the integration testing at NASA Wallops Flight Facility. Japanses team will also contribute to ground-based supporting observations at Alaska during the launch campaign. Launch of LAMP will be late 2020, but it may delay due to COVID-19.

4. BepiColombo Mio

BepiColombo Mio was launched on 20 October 2018. Commissioning activities of the onboard instruments were completed in February 2020. Test observations of the Earth's magnetosphere during the Earth flyby were successfully performed in April 2020.After the Earth Flyby, the 1st Venus Flyby is scheduled in October 2020. After arriving at Mercury in December 2025, Mio will make a comprehensive observation of Mercury's magnetosphere together with ESA' s Mercury Planetary Orbiter (MPO).

Taiwan Liaison Report

Lou Lee

FORMOSAT-5 Mission (Launch 2017)

The FORMOSAT-5 is a self-reliantly finished program by National Space Organization in Taiwan. The FORMOSAT-5 mission provides 2-m resolution panchromatic and 4-m resolution multi-spectral imagery with capability of two-day revisit and global coverage. After two years of successful on-orbit operations, it has been verified that images benefit the people's livelihood and welfare. For example, Prof. C. Y. Huang of National Central University builds underwater topography maps with the multispectral imagery, which applied to electronic navigational charts; the team led by Prof. T.H. Chu of National Taiwan University, using multispectral imagery to interpret rice field serves as an important reference basis for the Council of Agriculture. In addition, the science payload-Advanced Ionospheric Probe (AIP) has collected more than 76 GB science data since November 2017 and fulfilled its 2-year mission life. The Level-1 science data and quick-look displays are open to public via NSPO FS-5 AIP SDC webpage (http://sdc.ss.ncu.edu.tw/). AIP data have been used to study seismo-ionospheric precursors in 2017 Iran-Iraq earthquake, global distributions of ionospheric plasma density irregularities, and nighttime ionospheric observations in density and vertical velocity.

FORMOSAT-7/COSMIC-2 Mission (launch 2019)

The FORMOSAT-7/COSMIC-2 is a collaborative program between Taiwan and the U.S. due to the success of FORMOSAT-3. The program launched the cluster of 6-satellites into low-inclination orbits on June 25, 2019. The FORMOSAT-7/COSMIC-2 mission is 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 Taiwan-US team has worked intensively to evaluate instrument performance and optimize processing algorithm since launch. Since the first radio occultation data has been measured on July 16, 2019, Central Weather Bureau of Taiwan has begun the evaluation aggressively. Considering the data collected from mid- and low- latitude, CWB has optimized the numerical weather prediction system so that the data can be applied to front, tropical depression, typhoon, and space weather more efficiently. The provisional data was released on December 10, 2019.

UK Liaison Report

Tom Elsden & Jasmine Sandhu

I would firstly like to thank the GEM steering committee for accepting a UK liaison, and in this first report look forward to presenting the many aspects of geospace science covered by the UK. Geospace research is primarily undertaken in the UK by university research groups, together with government funded research organisations under the framework of UK Research and Innovation (UKRI). UK research associated with GEM related science is represented by the MIST (Magnetosphere Ionosphere Solar Terrestrial) community - a Royal Astronomical Society (RAS) affiliated group, covering research areas as encompassed by its title. Highlighted in this report is the UK involvement in present and upcoming missions, together with key research areas with large cross-institution involvement/ funding.

1. Solar Orbiter

The UK is leading two of the in-situ instruments on board the recently launched (10th Feb 2020) ESA Solar Orbiter mission. The MAG Magnetometer - (PI Tim Horbury, Imperial College London) will measure the magnetic field surrounding the spacecraft. This will be used to determine the link between the Sun's magnetic field and that in the solar wind and how this varies in time. The SWA: Solar Wind Plasma Analyser – (PI Chris Owen, Mullard Space Science Laboratory, University College London) will measure the solar wind's bulk properties e.g. density, velocity and temperature. Both of these instruments are working well following the launch.

2. SuperDARN

The Super Dual Auroral Radar Network (SuperDARN) has been operating for over 20 years, consisting of a network of 33 ground-based coherent-scatter radars. It facilitates a range of geospace science, most notably in the field of magnetosphere-ionosphere coupling. The UK continues to have a strong involvement in the development of the network and SuperDARN data analysis, in particular with the British Antarctic Survey (BAS) managing two of the radars. Developments are underway (being led by UK institutions) to build another mid-latitude radar in Europe (deployment date and location TBD).

3. EISCAT

The European Incoherent Scatter Scientific Association (EISCAT) operates incoherent scatter radars in Northern Scandinavia and Svalbard, to which the UK contributes significantly. A new phase of the project is underway called EISCAT_3D, which will use separate stations in Norway, Sweden and Finland to make three-dimensional measurements of the plasma density and temperature, as well as the direction of plasma motion.

4. SMILE

The Solar Wind Magnetosphere and Ionosphere Link Explorer (SMILE) will be the first joint European Space Agency (ESA) / Chinese Academy of Sciences (CAS) science mission, with UK-based scientists and UK institutions playing key roles in the mission proposal, development and execution (co-PI Graziella Branduardi-Raymont, University College London). After the planned launch in 2023, it will enter a highly-inclined elliptical orbit, from where it will directly observe the solar wind interaction with the magnetosphere at the dayside magnetopause and the polar cusps. The instrumentation on board involves a magnetometer, a light-ion analyzer, a soft X-ray imager (PI Steven Sembay, University of Leicester) and an UltraViolet Imager.

5. RadSat

Rad-Sat is a consortium grant funded by the UK government (through the Natural Environment Research Council (NERC)), aimed at improving our understanding, modelling and forecasting of the radiation belts. Running from April 2017 until April 2021, it involves five UK institutions (British Antarctic Survey (BAS), University of Reading, University of Sheffield, University College London and Imperial College London), encompassing around 25 researchers. The principal investigator is Richard Horne (BAS).

6. SWIMMR (Space Weather Instrumentation, Measurement, Modelling and Risk)

This four-year research program has recently received £20 million, to develop and deploy new instruments, models and services to support the UK space weather community and the UK Met Office Space Weather Operations Centre. It is intended to create a direct link between research institutions and government research priorities. The three outlined priority areas are involved in mitigating space weather effects on a) satellites and aviation operations, b) communications and global positioning and c) electric power distribution. This will involve multi-institution collaboration and given the significant sum of money, will be very important for how the UK as a whole approaches the modelling and forecasting of space weather in the future.

7. SWIGS (Space Weather Impact on Ground-based Systems)

This consortium grant lasting for four years (May 2017 – May 2021, 10 institutions, 28 researchers), investigates how space weather and geomagnetic activity drives electric fields in the Earth, and aims to quantify the impact of this on national power grids. A key aspect of this research team is to bring together space physicists and geophysicists studying the solid Earth and upper atmosphere.

GEM Steering Committee

NSF GEM Program Director
- Lisa Winter

Steering Committee (Voting Members)
- Vania Jordanova (Chair, 2020 - 2022)
- Adam Kellerman (Interim Vice Chair, 2020)
- Allison Jaynes (2018 - 2021)
- Yihua Zheng (2019 - 2022)
- Lynn Kistler (2019 - 2022)
- Research Area Coordinators (see below)
- Meeting Organizers (see below)

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- Xochitl Blanco-Cano (Liaison to Mexico)
- Lou Lee (Liaison to Taiwan)
- Thomas Elsden (Liaison to MIST/UK)
- Lutz Rastaetter (Liaison for Metrics and Validation)

Meeting Organizers
- Chia-Lin Huang and Chris Mouikis (2018 -)

Student Representatives
- Matthew Cooper (2018 - 2020)
- Agnit Mukhopadhyay (2019 - 2021)

Research Area Coordinators

Solar Wind - Magnetosphere Interaction (SWMI, previously known as Dayside)
- Steve Petrinec (2015 - 2021)
- Brian Walsh (2018 - 2024)

Magnetotail and Plasma Sheet (MPS, previously known as Tail)
- Matina Gkioulidou (2015 - 2021)
- Chih-Ping Wang (2018 - 2024)

Inner MAGnetosphere (IMAG, previously known as IMS)
- Seth Claudepierre (2015 - 2021)
- Raluca Ilie (2018 - 2024)

Magnetosphere – Ionosphere Coupling (MIC)
- Shin Ohtani (2015 - 2021)
- Hyunju Connor (2018 - 2024)

Global System Modeling (GSM, previously known as GGCM)
- Alex Glocer (2015 - 2021)
- John Lyon (2018 - 2024)

GEMstone Editor
- Allison Jaynes

GEM Online

GemWiki: https://gem.epss.ucla.edu/mediawiki/index.php/Main_Page

GEM Workshop Website: https://gemworkshop.org/

GEM Messenger (Electronic Newsletter):
- To subscribe, post announcements or read back issues: https://gem.epss.ucla.edu/mediawiki/index.php/GEM_Messenger

GEM Virtual Workshop 2020: https://gem.epss.ucla.edu/mediawiki/index.php/2020_Virtual-GEM_Workshop

GEM Focus Groups

Focus Group	Duration	Co-Chairs	Associated Research Areas				
			SWMI	MPS	IMAG	MIC	GSM
Tail Environment and Dynamics at Lunar Distances (TAIL)	2015 - 2019	Chih-Ping Wang, Andrei Runov, David Sibeck, Viacheslav Merkin, Yu Lin	∗	*			∗
Testing Proposed Links between Mesoscale Auroral and Polar Cap Dynamics and Substorms (MAPS)	2015 - 2019	Toshi Nishimura, Kyle Murphy, Emma Spanswick, Jian Yang		*			
Modeling Methods and Validation (MMV)†	2016 - 2019	Katherine Garcia-Sage, Rob Redmon, Mike Liemohn, Lutz Rastaetter					*
Merged Modeling & Measurement of Injection Ionospheric Plasma into the Magnetosphere (M3I2) and Its Effects -- Plasma Sheet, Ring Current, Substorm Dynamics	2016 - 2021	Rick Chappell, Shasha Zou, Barbara Giles				*	
ULF wave Modeling, Effects, and Applications (UMEA)	2016 - 2021	Michael Hartinger, Kazue Takahashi, Alexander Drozdov, Maria Usanova, Brian Kress					*
Dayside Kinetic Processes in Global Solar Wind-Magnetosphere Interaction (DAYS)	2016 - 2021	Heli Hietala, Xochitl Blanco-Cano, Gabor Toth, Andrew Dimmock, Ying Zou	*				∗
Magnetotail Dipolarization and Its Effects on the Inner Magnetosphere (DIP)	2017 - 2022	Christine Gabrielse, Matina Gkioulidou, Slava Merkin, Drew Turner, David Malaspina		*	∗		
3D Ionospheric Electrodynamics and Its Impact on the Magnetosphere-Ionosphere-Thermosphere Coupled System (IEMIT)	2017 - 2022	Hyunju Connor, Doğa Ozturk, Gang Lu, Bin Zhang				*	∗
Magnetic Reconnection in the Age of the Heliophysics System Observatory (RX)	2018 - 2023	Rick Wilder, Shan Wang, Michael Shay, Anton Artemyev					*
Interhemispheric Approaches to Understand M-I Coupling (IHMIC)	2018 - 2023	Hyomin Kim, Robert Lysak, Tomoko Matsuo			∗	*	
System Understanding of Radiation Belt Particle Dynamics through Multi-spacecraft and Ground-based Observations and Modeling (RB)	2019 - 2024	Hong Zhao, Lauren Blum, Sasha Ukhorskiy, Xiangrong Fu			*		
Particle Heating and Thermalization in Collisionless Shocks in the MMS Era (BSH)	2019 - 2024	Lynn Wilson III, Li-Jen Chen, Katherine Goodrich, Ivan Vasko	*				
The Impact of the Cold Plasma in Magnetospheric Physics (CP)	2020 - 2024	Gian Luca Delzanno, Natalia Buzulukosva, Barbara Giles, Roger Varney, Joe Borovsky			*		
Self-Consistent Inner Magnetospheric Modeling (SCIMM)	2020 - 2024	Cristian Ferradas, Chao Yue, Jacob Bortnik, Qianli Ma, Sam Bingham			*	∗	

†MMV is now a Standing Resource Group led by Mike Liemohn, Lutz Rastaetter, Alexa Halford and Josh Rigler

* - Primary research area
∗ - Secondary research area