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The GEMstone Newsletter

Notes from the GEM Chair

Vania Jordanova

After two years of a global COVID-19 pandemic and two virtual GEM workshops, we are delighted to be organizing the in-person GEM 2022 summer workshop at the Alohilani Resort Waikiki Beach Hotel in Honolulu, Hawaii! The meeting will be held during June 20 – 24, 2022 (the Student Day is on June 19), back-to-back with the annual meeting of the SHINE community on June 27 – July 1, 2022. There will be a joint GEM-SHINE meeting on June 25 – 26 with science sessions in the mornings, while the afternoons will be kept open for informal discussions and social activities to enhance collaborations between both communities. The Steering Committee (SC) is busy planning an exciting program; we hope you will be able to join us, both to share and enrich your own research, as well as brainstorm the most important and timely science questions for the community to investigate.

The Virtual GEM (VGEM) 2021 summer workshop, similarly to 2020, was held online via the Zoom platform from July 26 to July 30, with a Student Day on Sunday July 25. It was extremely well attended with >500 registered participants (>200 students, from which ~50% were first-time attendees), highlighting again cost-effectiveness and easy access as big advantages of virtual meetings. All GEM research areas were represented with excellent plenary tutorials, where the speakers were introduced and the sessions moderated by graduate students; we plan to adopt several successful features (like the virtual aspect, student participation, and handling of Q&A) for future GEM workshops too. We also had great discussions in the Focus Group (FG) breakout oral sessions and "Gather.town" poster sessions, which continued over the GEM Slack channels (gem-workshop.slack.com). In addition, this year marked the 30th anniversary of the first GEM meeting and the SC organized several events that are highlighted below to celebrate this significant milestone. The Meeting Organizers (MOs) Chia-Lin Huang and Chris Mouikis and the UNH IT team, have once again done a fantastic job with the organization of VGEM 2021. I would like to thank them as well as the GEM SC, FG leaders, and student representatives, for their exceptionally hard work to make this virtual workshop such a great success!

At a special VGEM 2021 plenary session on "GEM History, Present and Future", and in the plenary tutorials and agency talks throughout the meeting, we heard from past leadership about the origin of GEM, its uniqueness, and long-term goals. The GEM program began with the creation of a new funding wedge at NSF in 1990 and continued to grow and evolve guided by the magnetospheric

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research community. Among the noted GEM successes were the development of major geospace models and their delivery to CCMC; these models have become great tools for space physics studies, education, and outreach. Also, GEM became a central forum for discussing geospace science and identifying leading research directions for ground-based capabilities and space missions. Finally, the increase of GEM participants and student populations from early to present days was emphasized as a testimony of the importance of a community and collaborations for both career advancement and scientific progress.

To help organize efforts around the upcoming Heliophysics Decadal Survey, we held a "Decadal Future Panel." In the panel, we heard a debrief from the Helio2050 workshop and heard directly from the National Academy, NSF, NASA, and NOAA agencies about their expectations and developing plans. In a special stand-alone session "Geospace System Assets", we discussed how to combine ground-based observations and modeling with forthcoming spacecraft missions, towards the central goal of GEM of understanding the coupled geospace system. In addition, the Research Area Coordinators (RACs) held concurrent sessions for topical decadal white paper discussions. Their objective was to emphasize unresolved science questions for every research area, as well as needs for new capabilities and interdisciplinary research that could be formulated as decadal survey white papers. These discussions were followed by a plenary session "Decadal Future and Beyond" that coordinated, at the top-level, magnetospheric community white papers to help lay out a long-term strategy for magnetospheric science. Many of these papers are listed at the following site for community member to join on as desired: tinyurl.com/HelioWP.

In support of GEM diversity, equity, and inclusion (DEI) efforts, it is becoming a tradition to have DEI-focused plenary sessions, part of our broader "Sam Bingham Community Cares Initiative (SBCCI)". This past year we had two sessions: a DEI tutorial given by Janet Vertesi on sociology topics for scientists, and a SBCCI tutorial given by Mary McMillan on mental health in academia. The large participation in both events demonstrates the support and willingness of GEM members to learn and change in order to enhance the well-being within the community and beyond. In addition, we organized a "Bystander Intervention" training for the GEM SC and FG leads that was very well received and we are extending it this year for the whole GEM community.

We initiated the GEM Encourage & Elevate (GEMEE) Mentoring Program to encourage an intergenerational exchange of professional knowledge and insights, with the goal of elevating the career of future GEM scientists. More than 20 students participated in GEMEE during its inaugural year. Most participants rated the program as excellent and described very good mentor/mentee interactions; the most popular topics were career development and sharing past experiences. Based on the survey feedback the DEI subcommittee prepared detailed guidelines for mentors and mentees. The GEMEE program continues this year, and we strongly encourage your participation!

We thank all contributors to the new GEM logo competition. The SC reviewed all 16 entries and presented a short list for voting to the community. The winning design was announced at the last VGEM 2021 plenary session, and we urge the GEM community to start using it. As part of GEM 30th anniversary celebrations, and to capture the spirit of GEM, we collected over 150 photos and videos of GEM (past or present) from the community. This photo collection was shown at the SBCCI social hour at the end of the VGEM 2021 meeting.

Throughout the year the GEM SC continued its operations via regular virtual meetings; the minutes from these telecons were posted in a timely manner on the GEM Wiki (gem.epss.ucla.edu) to increase transparency. Several members of the SC ended their terms and we conducted searches for their replacement. Please join me in thanking Matina Gkioulidou, Seth Claudepierre, and Shin Ohtani for their excellent service as RACs and welcoming Kevin Genestreti as the new Magnetotail and Plasma Sheet (MPS) RAC, Lunjin Chen as the new Inner Magnetosphere (IMAG) RAC, and Sarah Vines as the new Magnetosphere – Ionosphere Coupling (MIC) RAC. Also, the SC welcomed Elizabeth Vandegriff to the position of student representative, Ying Zou as the new Liaison to CEDAR, and Junga Hwang as the new liaison to Korea. The SC thanks Agnit Mukhopadhyay, Shasha Zou, and Jaejin Lee for their service as the previous student representative and Liaison to CEDAR and Korea, respectively. Finally, we would like to express great thanks to Chia-Lin Huang who stepped down from her role as GEM Meeting Organizer and welcome Jing Liao who will be helping Chris Mouikis with the meeting organization.

The SC solicited new FG proposals since several FGs ended this year. Many thanks to all proposers, the applications were fantastic and the competition was tough! After proposal presentation and discussion at a public Virtual GEM session, followed by a closed SC session, three new FGs starting in 2022 were accepted: 1) Understanding the causes of geomagnetic disturbances in geospace for hazard analysis on geomagnetically induced currents (Lead: Xueling Shi); 2) Magnetospheric Sources of Particle Precipitation and Their Role on Electrodynamic Coupling of Magnetosphere-Ionosphere-Thermosphere Systems (Lead: Dogacan Su Ozturk); and 3) Mesoscale Drivers of the Nightside Transition Region: Ionospheric and Magnetotail Evaluations (Lead: Bea Gallardo-Lacourt). You may find more information about focus group activities and what is happening in the worldwide space science community in the FGs' and Liaisons' reports included in this GEMstone issue.

Currently, several GEM SC members are rotating off: the GEM SC Vice-Chair (Chair-Elect), one GEM SC At-Large Member, and two RACs (for the Solar Wind – Magnetosphere Interaction (SWMI) and the Global System Modeling (GSM) research areas). Please consider applying or nominating excellent candidates for these positions. And don't hesitate to reach out to any SC member with further questions, comments or suggestions, we need your input.

Thank you for your support of GEM and we look forward to seeing you all in Hawaii in June!

Notes from the GEM Program Director

Chia-Lin Huang

I am sure you all know that Lisa Winter is now the NSF Solar-Terrestrial Program Director. Under her management of Magnetospheric Physics in the past three years, she has guided the program toward the NSF goal of a broadly inclusive science and engineering workforce. A special thank you to her for setting the program up for a successful and productive future. Since January, I have served as Magnetospheric Physics and GEM Program Director as an IPA from the University of New Hampshire. It is my great privilege to work with the GEM community, so please do not hesitate to reach out to me (chihuang@nsf.gov).

A few more personnel updates in the Geospace Section. After serving two years as the Aeronomy Program Director, Zhuangren (Alan) Liu is our new Section Head. Tai-Yin Huang is the new Program Director for Geospace Data System, a new role based on the recommendation from Geospace Portfolio Review.
The target date for the GEM solicitation was re-instated this year (March 30 and September 30.) The new solicitation encourages projects related to the following topics:

1. Currently active GEM Focus Groups
2. Connections of the magnetosphere with climate
3. Incorporate machine learning/artificial intelligence techniques
4. Comparative magnetosphere studies

A significantly increased number of proposals were submitted, and the review process is now underway. The Magnetospheric Physics Base Program still accepts proposal submissions anytime to allow PIs to propose their best ideas at times that work for them.

After a series of continuing resolutions, we have finally received the full allocation of the program's FY2022 base funding. We plan to make the award decision in the coming months. I would encourage PIs to please submit their annual reports, particularly if they are overdue, so that we may release increments and make new awards efficiently.

This fiscal year, many exciting new awards have been made by the Magnetospheric Physics program. Congratulations to Yi-Hsin Liu from Dartmouth College on being awarded a CAREER grant! This project will improve our understanding of fast magnetic reconnection in the geospace environment. The educational component is a unique combination of Science and Art to elevate the awareness and accessibility of space plasma physics to the next generation of the STEM workforce. New submissions to the NSF CAREER program are due July 27, 2022.

Please encourage eligible early-career faculty to apply! For new post-docs (within 2 years of the PhD), please consider applying for the AGS Postdoctoral Research Fellowships with submissions accepted at any time. Another exciting news is that NSF is investing approximately $12 million in seven ANSWERS awards, which will advance space weather research, resilience, and education.

There are several Dear Colleague Letters out which have relevant content for Magnetospheric Physics, including Geoscience Lessons for and from Other Worlds (GLOW), Opportunities for Mid-Career Scientist Support in AGS, and NSF Regional Innovation Engines Program. Consider looking into these for potential future funding and for alignment with NSF priorities. Please reach out if you have any questions or concerns (chihuang@nsf.gov).

I hope to see everyone in Honolulu, HI, for the GEM summer workshop!

Meeting Organizer Report

Chia-Lin Huang and Chris Mouikis

While still in the midst of the COVID pandemic, the 2021 GEM Summer workshop was a virtual one again. This year we were also celebrating the 30th year anniversary of GEM. The year before, the challenge was how to run a successful virtual meeting. This time the challenge for the Steering Committee was how to run an engaging virtual meeting while admittedly everyone being "Zoom fatigued".

VGEM 2021 took place from July 25th to July 30th using the Zoom platform with the full support from the University of New Hampshire Audiovisual Services department. The plenary sessions started at 11:00 am EST every day and were followed by two concurrent sessions in the afternoon. The Tuesday poster session was planned at the end of the concurrent sessions as always, but this time the Thursday poster session was planned much earlier in order to allow for participants living in different local times and/or having different daily family schedules to also participate.

This year, we used the Gather Town platform to create a virtual space where the meeting took place. Participants could stroll through this virtual conference hall and engage with other participants, retreat in virtual rooms for discussions, access information. Gather Town was visited by many participants. In particular, the Gather Town platform proved to be extremely effective for poster discussions. More than 150 posters were presented. Participants would upload their posters on our vgem.org site where they could also add a video with their presentation. This database was then linked to Gather Town in an arrangement reminiscent of a big poster hall where participants would "walk" to each poster and engage with discussions through individualized virtual sessions. During each poster session about 200 participants visited the posters.

Other Gather Town exhibits/spaces included the new GEM logo competition, the Photo Gallery from past meetings, the 3D Printed Magnetosphere Model, the NSF Office Hour, the Student Representative Election Candidates presentations, the SBCCI-DEI and SBCCI-Support Each Other spaces, and the beach area "preparing" us for the workshop in Honolulu in 2022!! At the end of the meeting, we all gathered at the beach one last time and took virtual photos. Next stop Honolulu!!

Many thanks to our wonderful team that contributed immensely making this year's virtual meeting such a success; Esther L. Chen who volunteered to design the Gather Town GEM, Greta Gadbois who developed the vgem.org site and created the Gather Town posters hall, Katie Whitman who has developed and maintains the gemworkshop.org site and Andy Dolph from the UNH Academic Media Services who was responsible for the Zoom Webinar plenary sessions and worked with all presenters before the meeting.

Overall, the participation was overwhelming once more. More than 500 participants and more than 200 students are numbers that no in-person only meeting can ever achieve. The virtual meeting necessity taught us that future meetings could and should include a virtual component as well. The responses to the questionnaire at the end of the meeting were very positive.

There were 8 family care grants that were provided to families.

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

Pictures of VGEM 2021 are included at the end of this GEMstone newsletter.

GEM 2021 Mini-Workshop

The mini-GEM 2021 workshop was organized for the first time as a hybrid meeting. The in-person component was held at the Hilton Garden Inn in New Orleans, LA, on December 12th, the Sunday before the start of the 2021 Fall AGU hybrid meeting. We had 12 FG sessions, out of which 2 sessions were held as virtual only sessions. In addition, the student representatives organized a hybrid town-hall meeting and, in the evening, a hybrid GEM Steering Committee meeting was held. We had 177 registered participants, 69 in-person and 108 remote. For most of us it was the first time in two years that we were among our fellow community members. Although it was not mandatory, participants used face masks and appropriate sanitizing practices. Since all participants were there for the Fall AGU meeting as well, it meant that we were all up to date with COVID vaccinations.

Organizing a hybrid meeting for the first time meant that we had to overcome some technical difficulties. However, those were tackled swiftly with the support by the A/V company representatives. We also had to buy more internet bandwidth to ensure that the heavy two-way usage of Zoom sessions run satisfactorily.

As was also the experience with the Fall AGU meeting that followed that week, the hybrid meeting format produced varied levels of participation and compared to the logistical/organizational difficulties, the "hybrid mentality" of the participants proved to be more difficult to overcome.

Student Representative Report

Agnit Mukhopadhyay, Mei-Yun Lin and Elizabeth Vandegriff

This year, GEM was held virtually due to safety protocols enacted by the GEM Steering Committee as part of the ongoing COVID-19 pandemic.

Student Activities

GEM Student Day was held virtually on the Sunday preceding the week's activities. Like VGEM 2020, this year saw a similar spike in student attendees. Over 200 students registered for the conference, with ~90 maximum participating in the virtual environment designed for Student Day. Additionally, the demographics of the student community continued to evolve significantly, as student population garnered >51% international participation. On Student Day, six tutorials covered basic plasma physics theory and the major regions of the magnetospheric system, in addition to covering the emerging fields of numerical modeling and data science. An invited tutorial topic about the ongoing Decadal Survey was also included, which was presented to the student community by Dr. Ian Cohen. Due to this year's virtual setup, we elected to forgo hosting the normal Student Dinner on Monday night. The Student Poster competition was also not held this year. However, we chose to replace the Thursday lunch with a Wednesday panel discussion involving student representative nominees.

Student Involvement & Volunteering

Several students volunteered to record the plenary sessions, introduce plenary session speakers, and run the microphone during the question sessions. Student volunteers for VGEM 2021 are listed in the following:

Rachel Rice, Austin Brenner, Waqar Younas, Lengying Khoo, Chi Zhang, Riley Troyer, Mike Coughlan, Longzhi Gan, Aaron F West, Hsinju Chen, Nehpreet Walia, Elizabeth Vandegriff, Onyinye Gift, Tanmay Das, Harshita Gandhi, Pauline Dredger, Man Hua, Osanyin T. Olusayo, Khan Tran, Brians C. Amadi.

The student representatives would like to thank them for dedication to helping the morning sessions run smoothly. Other student-related activities included the student-invited plenary session, given this year by Dr. Banfsheh Ferdousi on the topic of machine learning.

Virtual Environment & gather.town

To facilitating this year's online arrangement, the student representatives introduced a fun element to this year's Student Day and larger week-long workshop through the online app, gather.town. Gather.town is an online simulator that was designed by the representatives to create a virtual conference hall to host the events. The environment was designed by Esther Chen (Lounge and Lobby) and Greta Gadbois (Poster Hall). Along with GEM Organizers, Chia-Lin Huang and Christopher Mouikis, the student representatives would like to thank both designers for their creative ideas and dedication to help run the workshop better than last year.

Student Leadership & Future Organizing

This year, Elizabeth Vandegriff (University of Texas at Arlington) was elected as the next GEM student representative, and will replace Agnit Mukhopadhyay (University of Michigan). This year's student election process was run similar to last year due to the online nature of the workshop. Student nominees sent in a short bio and agenda, as well as a short video describing why they were running for the position. SurveyPlanet app was used for election polling. The student representative selection process was expanded upon, with the major change including a Student Rep Nominee Panel on Wednesday to allow students of the community to interact with the nominees. Elizabeth's term will run through the 2023 GEM workshop. Outgoing student representative Agnit Mukhopadhyay 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. Agnit would also like to thank his predecessors (Ryan Dewey & Matthew Cooper) and fellow representative, Mei-Yun Lin (University of Illinois at Urbana-Champaign), for their continued support and help during his tenure.

In addition, the student representatives introduced the concept of a student advisory committee to advise the elected representative in organizing future events and helping decide on tutorial topics. The decision comes after recent changes in student demographics and population, which demand a gradual change in leadership strategy. Selection of this committee in addition to future directions for student-led events would be specified by Mini-GEM 2022.

Solar Wind - Magnetosphere Interaction (SWMI) RA Reports

Coordinators: Steve Petrinec and Brian Walsh

Dayside Kinetic Processes in Global Solar Wind-Magnetosphere Interaction

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

Final Report

Goals & Objectives

The "Dayside Kinetic Processes in Global Solar Wind-Magnetosphere Interaction" Focus Group (Dayside Kinetics; 2016-2021) aimed to bring researchers together in joint modeling and observational efforts to understand kinetic processes in a global context. Understanding these cross-scale coupling processes is crucial in the development and validation of models which aim to characterize and predict the solar wind–magnetosphere coupling accurately and reliably.

Broad goals of the focus group were to contribute to the understanding of (including but not limited to):

- Bow shock and foreshock dynamics: particle acceleration in foreshock transients; effect of foreshock transients on bow shock structure and their transmission downstream
- Magnetosheath: propagation of meso-scale variations such as high-speed jets and filamentary density structures; reconnection in turbulence; waves generated by instabilities and FTEs
- Response of magnetopause processes to upstream variations: reconnection, surface waves, and Kelvin-Helmholtz vortices
- Response of the dayside inner-magnetosphere: excitation of waves; radiation belt effects

Key Activities During Summer Workshop

During the 2016-2019 in-person Summer Workshops, the Dayside Kinetics had four sessions at each workshop. One of these was typically dedicated to our observation-modeling Challenge(s), while the other sessions were joint sessions with other focus groups around a common science theme. In the 2020 and 2021 virtual summer workshops we had two sessions each. Many of these non-Challenge sessions consisted of short, contributed talks addressing the science theme, followed by discussion. We would like to highlight two exceptions to this format: In 2018, we held an "open questions and unresolved problems" discussion session, which included one discussion starter presentation by Drew Turner and Terry Liu, and another one by Mike Shay. The session was very well received. In 2019, our joint session on the "ULF wave response to dayside transients with different temporal/spatial scales and asymmetries" with UMEA and IHMIC focus groups had Tom Elsden as a guest convener. He posed the session participants four science questions. An invited overview talk by Ferdinand Plaschke was then followed by contributed talks and discussion. Finally, UMEA Focus Group co-chair Michael Hartinger reviewed discussions from previous GEM Workshops related to the session theme. This format also worked very well.

In addition to the Summer Workshops, we generally had one or two sessions at mini-GEM meetings focusing on work in progress.

Significant Accomplishments

The main accomplishments of the Dayside Kinetics Focus Group include:

1. Special issue "Results of the GEM Dayside Kinetics Southward IMF Challenge" published in Journal of Geophysical Research- Space Physics and Earth and Space Science in 2020

2. Collaboration with the Modelling Methods and Validation focus group to find the best ways for model-data and model-model comparisons

3. Bringing modellers together such that multiple models were actively compared and discussed

4. Sustained synergy and collaborations with other GEM focus groups

The special issue consists of seven research articles and a commentary article. The issue documents the challenge event from November 18, 2015, and our understanding of the magnetospheric condition at the time, by collecting the various available data sets and their analyses to a common location. We also conduct comparisons between (1) observations and models with different levels of kinetic physics, (2) different models, and (3) in situ and remote observations. We wish to highlight the current state-of-the-art tools and the capabilities of different methods as well as their limitations and uncertainties. Furthermore, the commentary article "The Challenges and Rewards of Running a Geospace Environment Modeling Challenge" [Hietala et al., JGR 2020] recounts our experiences of organizing such a collaborative activity. We give suggestions on planning, managing, funding, and documenting these activities, which provide valuable opportunities to advance the field. The collection sets the stage for further developments and enables future benchmarking and validation.

The Challenge efforts were organised in close collaboration with the Modeling Methods and Validation focus group and included several dedicated workshop sessions and discussions. The special issue includes papers stemming from those activities such as [Chen et al., ESS 2020] and [Guo et al., JGR 2020], where different models and observations are directly compared.

The Dayside Kinetics focus group also had a mini-challenge on dayside-nightside connections. An event from December 25, 2015, was reported to imply a potentially important role of dayside kinetic processes (high-speed jets) in a triggering nightside substorm. We then held a joint session with Modeling Methods and Validation focus group to call for community attention to achieve better understanding of the event. The event is described in [Nykyri et al., JGR 2019].

The Dayside Kinetics focus group fostered sustained collaborations with the other focus groups, in the form of themed joint sessions. The main science themes addressed with other focus groups throughout the years were: (i) magnetospheric and ionospheric effects of dayside transients; (ii) magnetopause processes, especially magnetopause reconnection; and (iii) processes at the bow shock/foreshock. In particular, the magnetospheric effects of dayside kinetic processes benefitted from a holistic, joint focus group approach due to its cross-scale and cross-region nature.

Community Engagement and Participation

Our sessions at the in-person meetings typically had 30-40 participants, more in joint sessions. Virtual sessions had a peak attendance of about 85.

At the in-person meetings we often dedicated some time to organize the meeting room layout to encourage interaction (e.g., curved instead of straight rows of chairs, small group tables). The session chairs also facilitated interaction by setting discussion tasks to small groups or pairs of attendees. The sessions addressing the Challenge events naturally required intensive collaborative work and interaction between the participants in between and in the lead up to the workshop sessions.

During the course of the focus group, we opened a few online surveys to gather community input and feedback. The participation to these was very limited. Dedicated discussion time at the sessions was a more fruitful means.

GEM is both US and international community. We actively worked towards a diverse set of participants in term of, e.g., career stage and institutions. In part, internationality arises naturally as researchers move between institutes and countries, including our focus group co-chairs. After the first two years of the focus group, we also expanded our leadership team – Ying Zou joined us in 2018. Her science expertise diversified and complemented the existing skill set and reflected the emerging directions of the focus group activities. Furthermore, having five co-chairs made the focus group more resilient in later years.

Assessment of Progress Toward Goals

The past six years have seen great progress in understanding dayside kinetic processes in a global context. These include, for example, characterizing foreshock transients and magnetosheath jets, as well as their effects on the magnetosphere. Several factors have contributed to these advancements. In situ spacecraft observations now include large statistical datasets spanning over a solar cycle, multipoint conjunctions offered by the Heliospheric System Observatory, and detailed small-scale measurements by the Magnetospheric Multi-Scale Mission. Ground-based remote measurements are used in tandem with satellites. Global simulation models featuring kinetic physics have progressed from 2D to 3D. Crucially, the community is using these assets collaboratively, as evidenced by the special issue papers. The focus group sessions have also included several presentations of new or future mission concepts, such as THOR, CuPID, SMILE, LEXI, and STORM.

Particle Heating and Thermalization in Collisionless

Shocks in the MMS Era

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

Goals & Objectives

The broad goals of the Focus Group are to address (1) the structure of the quasi-static electric fields in collisionless shocks, (2) waves/structures in collisionless shocks and their generation mechanisms, (3) contributions of quasi-static and high-frequency electric fields to particle heating and thermalization and (4) enabling advances of MHD, hybrid, and PIC simulations to model the Earth's bow shock and magnetosheath plasma.

The corresponding objectives of the Focus Group for the 5 years are (1) to quantify the relevance of quasi-static fields in particle heating, quantify the spatial scales and amplitude of the quasi-static field, and determine their influence on particle heating and thermalization; (2) to carry out analysis of the properties and occurrence rates of waves/structures observed in the Earth's bow shock; (3) to quantify the contributions of quasi-static vs. high frequency fields on particle heating and thermalization in the Earth's bow shock; (4) testing results of various numerical simulations in their ability of reproducing microphysics of the Earth's bow shock as well as plasma parameters (electron and proton temperatures) in the magnetosheath downstream of the Earth's bow shock.

Key Activities During Summer Workshop

The key activities can be classified into three groups: (1) quasi-static electrostatic field and kinetic-scale waves in and around the Earth's bow shock, (2) numerical simulations of electron heating and waves in collisionless shocks, (3) new resources for collisionless shock research.

(1) The four reports on whistler waves in and around the Earth's bow shock showed that (a) electron distributions in the upstream region are often unstable to quasi-parallel whistler waves (Ilya Kuzichev), (b) low-frequency whistler waves in the foot region are most likely produced by instabilities associated with reflected protons (Ahmad Lalti), (c) high-frequency whistler waves observed within the bow shock can provide electron acceleration up to a few keV (Anton Artemyev), (d) high-frequency whistler waves in the bow shock are produced by local instabilities driven by the appropriate gradients of the electron velocity distribution in the phase space (Brent Page). The report by Ivan Vasko was on the current progress in the analysis of properties and origin of electrostatic fluctuations in the Earth's bow shock. The report by Steven Schwartz was on analysis of optimal methods for reconstructing the cross-shock electrostatic potential using MMS measurements. The report by Terry Liu was devoted to analysis of particle acceleration around hot flow anomalies and foreshock bubbles.

(2) The reports of the second group were focused on numerical simulations of microscopic processes in collisionless shocks, including electrostatic Buneman waves (Artem Bohdan) and electrostatic waves produced by electron beams (Vadim Roytershteyn), formation of slow shocks during magnetic reconnection (Nehpreet Walia) and electron acceleration by magnetic reconnection in collisionless shocks (Naoki Bessho).

(3) The two talks of the third group were devoted to the new database of shocks (Andrew Dimmock; https://sharp.fmi.fi/) and a new shock-oriented MAKOS mission (Katherine Goodrich).

Significant Accomplishments

The running of the Focus Group has stimulated discussions among researchers working on numerical simulations of collisionless shocks and experimental analysis of waves and particle heating/acceleration processes in the Earth's bow shock and interplanetary shocks. We can point out three important accomplishments presented at and stimulated by the Focus Group sessions.

- The high-resolution multi-spacecraft MMS measurements allowed performing the most detailed analysis of quasi-static electric fields and various waves in the Earth's bow shock. Thanks to MMS measurements now we much better understand the origin and properties of waves observed in the Earth's bow shock. In particular, it was shown that low-frequency whistler waves in the foot region can be produced by reflected protons, while high-frequency whistler waves observed across the shock are produced locally by appropriate gradients of the electron distribution function in the phase space and this instability cannot be classified in terms of a heat flux or a temperature anisotropy instability. The analysis of electrostatic fluctuations uncovered the properties of electrostatic solitary waves and electrostatic wave packets observed in the Earth's bow shock and suggested that the source of these electrostatic waves/structures is most likely ion-streaming instabilities. The theoretical studies showed that whistler waves in the Earth's bow shock may provide acceleration of thermal electrons (10–100 eV) to suprathermal energies (1–10 keV).

- Due to the discussions between modelers and experimentalists now we better understand to what extent modern numerical simulations reproduce properties of various waves and particle heating processes observed in the Earth's bow shock. In particular, now we know that amplitudes of small-scale waves observed in simulations are significantly lower than those in observations (Wilson L., Chen L-J. & Roytershteyn V., 2021, doi: 10.3389/fspas.2020.592634), which may cause a difference in the contribution of these waves into particle heating in simulations and realistic shock waves. Numerical simulations showed that particle heating can occur due to various microscopic processes, including cross-shock potential, wave-particle interactions and magnetic reconnection, but a detailed analysis of these processes in the Earth's bow shock and interplanetary shocks is still ongoing.
- The running of the Focus Group stimulated discussions of a design and goals of new shock-oriented spacecraft missions and, specifically, of the MAKOS mission (PI: Katherine Goodrich), which was selected by NASA for Heliophysics Mission Concept Study (HMCS). There was an agreement among the participants of the Focus Group that a new spacecraft mission should have plasma instruments specifically designed to resolve ion distribution functions in the solar wind and also electric fields at various spatial scales across the Earth's bow shock.

The near-term plans of the Focus Group include the GEM workshop in summer of 2022, where we plan to have reports on the recent progress in the analysis of various waves, quasi-static electric fields and mechanisms of ion and electron heating in the Earth's bow shock and interplanetary shocks. We plan to invite modelers to report on numerical simulations of collisionless shocks in the parameter range typical of collisionless shocks in the heliosphere. We plan to have several overview talks given by modelers and experimentalists, which would stimulate discussions of the Earth's bow shock properties that are still not reproduced in modern numerical simulations.

Community Engagement and Participation

(i) During the Summer GEM workshop we had two sessions on July 27 and 28, and the list of contributed presentations to each of the sessions is given below

Session 1 (July 27)

- Ilya Kuzichev, whistler wave stability around interplanetary shocks
- Ahmad Lalti, Source of whistler precursor waves at quasi-perpendicular shocks
- Brent Page: On the origin of whistler waves in the Earth's bow shock
- Anton Artemyev: Electron acceleration by whistler waves in the Earth's bow shock
- Ivan Vasko: Electrostatic waves in the Earth's bow shock
- Artem Bohdan, Electron heating at high Mach number planetary and astrophysical shocks (PIC simulations)
- Vadim Roytershteyn, Electrostatic and electromagnetic instabilities in collisionless shocks (PIC simulations)

Session 2 (July 28)

- Andrew Dimmock, An MMS bow shock database using machine learning: EU H2020 SHARP project
- Steven Schwartz, Evaluating the de Hoffmann-Teller cross-shock potential at real collisionless shocks
- Alexandra Brosius Conformal mapping and topological techniques for waveform analysis
- Terry Liu, Statistical study of foreshock ion conditions for hot flow anomalies and foreshock bubble
- Nehpreet Walia, Study of slow-mode shocks in magnetic reconnection based on hybrid simulations and satellite observations
- Naoki Bessho, Electron acceleration by magnetic reconnection in the Earth's bow shock

(ii) The approximate number of participants in each session was 20–30.

(iii) The presentations of each session were ordered in such a way that a session would include reports on the results of numerical simulations and observations of realistic collisionless shocks. Each presenter was provided 5–7 minutes for a presentation and we spent about 2–3 minutes for Q&A right after the report. A session concluded with about 15 minute discussion of all the talks and discussion of differences/similarities between observations and numerical simulations. The appropriate ordering of the presentations and inviting of modelers' reports has strongly stimulated the discussion among the participants of the Focus Group.

(iv) Two of the Focus Group leaders (Katy Goodrich and Li-Jen Chen) are women. We actively try to invite speakers from a diverse range of backgrounds and try to prioritize inviting non-white-male presenters, when possible. This focus group has seen wide international diversity in its attendants. It has not achieved, however, an ideal level of diversity across racial and gender lines. The Focus Group leaders will aim for better diversity by reaching out to female and POC scientists individually and encouraging them to share their work at subsequent meetings. The Focus Group leaders will also encourage established collaborators to recruit more members to participate in GEM as well as their associated research groups.

Assessment of Progress Toward Goals

The recent MMS measurements allowed a significant progress in understanding the structure of the quasi-static field fields in the Earth's bow shock and interplanetary shocks, but that progress was mostly reached within a few case studies. To entirely address the first objective of the Focus Group, "address the structure of the quasi-static electric fields in collisionless shocks", we need statistical analyses of the quasi-static electric field in various bow shock crossings and its dependence on the shock parameters.

The plasma and wave measurements aboard MMS have substantially advanced our understanding of the origin and properties of whistler waves and electrostatic fluctuations in the Earth's bow shock. In particular, there were established mechanisms of generation of low-frequency whistler waves (modified two-stream instability), high-frequency whistler waves (appropriate gradients in the electron phase space), and the most likely mechanisms of generation of electrostatic waves (ion-streaming instabilities). To entirely address the second objectives of the Focus Group, "address waves/structures in collisionless shocks and their generation mechanism", we need statistical studies of the properties of whistler waves and electrostatic fluctuations in the Earth's bow shock and interplanetary shocks.

Some progress has been reached in understanding the mechanisms of electron heating in the Earth's bow shock. In particular, it was shown that small-scale quasi-static electromagnetic fields may result in bulk acceleration of electrons in the shock transition region, while the accelerated electrons are then thermalized by electrostatic waves (see publication [8] indicated in the next section of this report). There is still no detailed understanding on how common this heating mechanism is and what are the overall contributions of quasi-static and high-frequency electric fields into electron heating in the Earth's bow shock. Thus, more case studies as well as statistical analyses are necessary to address the third objective of the Focus Group that is "address contributions of quasi-static and high-frequency electric fields to particle heating and thermalization".

The discussions between experimentalists and modelers during the Focus Group sessions revealed that we are still far from a comprehensive understanding of what properties of the Earth's bow shock can/cannot be reproduced in modern numerical simulations. The numerical simulations definitely reproduce some instabilities (modified two-stream instability, some electrostatic instabilities) as well as the structure of quasi-static electric fields, but simulations predict different particle heating mechanisms (cross-shock potential, wave-particle interactions, reconnection) to dominate in different parameter ranges. More efforts should be concentrated in the future Focus Group sessions to reach a progress on the fourth objective of the Focus Group, that is "enabling advances of MHD, hybrid, and PIC simulations to model the Earth's bow shock and magnetosheath plasma".

Significant Publications

Several publications, the results of which were reported or stimulated by discussions at the Focus Group sessions are listed below.

Group leaders are highlighted.

[1] **Wilson L. B.**, **Chen, L.-J.**, and Roytershteyn, V. (2021), The discrepancy between simulation and observation of electric fields in collisionless shocks, Frontiers in Astronomy and Space Sciences, V. 7, doi:10.3389/fspas.2020.592634.

[2] Schwartz S. J., Ergun R. E., Kucharek H., **Wilson L. B., Chen L.-J., Goodrich K. A.**, et al., Evaluating the de Hoffmann-Teller Cross-Shock Potential at Real Collisionless Shocks (2021), Journal of Geophysical Research, V. 126 (8), doi: 10.1029/2021JA029295.

[3] Cohen I. J., Schwartz S.J., **Goodrich K.A.** et al. (2019), High-Resolution Measurements of the Cross-Shock Potential, Ion Reflection, and Electron Heating at an Interplanetary Shock by MMS, Journal of Geophysical Research, V. 124 (6), doi:10.1029/2018JA026197.

[4] Page B., **Vasko I. Y.**, Artemyev A. V., and Bale S. D., Generation of High-frequency Whistler Waves in the Earth's Quasi-perpendicular Bow Shock (2021), The Astrophysical Journal Letters, V. 919 (2), doi:10.3847/2041-8213/ac2748.

[5] Wang R., **Vasko I.Y.**, Mozer F.S. et al. (2021), Electrostatic Solitary Waves in the Earth's Bow Shock: Nature, Properties, Lifetimes, and Origin, Journal of Geophysical Research (Space Physics), V. 126 (7), doi: 10.1029/2021JA029357.

[6] Bessho N., **Chen L.-J.**, Wang S., Hesse M., **Wilson L. B.**, and Ng J. (2021), Magnetic reconnection and kinetic waves generated in the Earth's quasi-parallel bow shock, Physics of Plasmas, V. 27 (9), doi:10.1063/5.0012443.

[7] **Vasko I. Y.**, Wang R., Mozer F. S., Bale S. D., and Artemyev A. V. (2020), On the nature and origin of bipolar electrostatic structures in the Earth's bow shock, Frontiers in Physics, V. 8, doi:10.3389/fphy.2020.00156.

[8] **Chen L.-J.**, Electron Bulk Acceleration and Thermalization at Earth's Quasi Perpendicular Bow Shock (2018), Physical Review Letters, V. 120 (22), doi:10.1103/PhysRevLett.120.225101.

Other Activities

The first important activity is the special issue on "Collisionless Shock Research: Current State and Perspectives" in the Frontiers in Physics with the Focus Group leader, Lynn Wilson, as one of the Topic Editors. The special issue is currently open for submissions, and there are already papers published in this special issue, which were inspired by discussions at the Focus Group sessions. The announcement of the special issue and the already published papers can be found here: https://www.frontiersin.org/research-topics/26437/collisionless-shock-research-current-state-and-perspectives

The second important activity is the Working Group "Resolving the Microphysics of Collisionless Shock Waves" at the International Space Science Institute (ISSI), Bern, Switzerland, which meets once per year to discuss the progress in understanding the microphysics of collisionless shocks. Three of the GEM Focus Group leaders (Lynn Wilson, Ivan Vasko and Katherine Goodrich) are members of the ISSI Working Group. The problems discussed during the GEM Focus Group sessions are also actively discussed during the ISSI workshops. The website of the ISSI Working Group along with 60 papers already published as a result of this activity can be found here: https://www.issibern.ch/teams/collisionlesshockwave/

The third important activity is the MAKOS mission (PI: Katherine Goodrich), which was selected by NASA for Heliophysics Mission Concept Study (HMCS). One of the Co-Is (Lynn Wilson) is a Co-I on this MHCS proposal. The Focus Group sessions allow the research community working on shocks to discuss optimal characteristics for future shock-oriented spacecraft missions.

Magnetotail and Plasma Sheet (MPS) RA Reports

Coordinators: Matina Gkioulidou and Chih-Ping Wang

Magnetotail Dipolarization and its Effects on the Inner Magnetosphere

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

Goals & Objectives

The overarching goal of this focus group is to utilize both in situ and ground-based observations alongside state-of-the-art models and theories to better incorporate magnetotail dipolarizations in global stand-alone and coupled magnetospheric models, refining our conceptual models of this phenomenon and examining its impacts on the inner magnetosphere.

In our pursuit of that goal, we work with the community in formulating and investigating science questions that pertain to this focus group topic and its overarching goal, some examples of which include:

1. What are the mechanisms responsible for both elementary and global magnetotail dipolarizations and are they captured by current state-of-the-art models?
2. What is the role of reconnection and/or other plasma instabilities in producing elementary magnetotail dipolarizations?
3. What is the relationship, if any exists, between elementary magnetotail dipolarizations and more global dipolarization during substorms?
4. What is the role of elementary magnetotail dipolarizations in:
    - enhancements of the ring current?
    - creating the seed electron population for the radiation belts?
    - the generation of different wave modes (e.g., ULF, chorus, hiss, EMIC, equatorial noise, etc.) in the inner magnetosphere?

Key Activities During Summer Workshop

During the summer 2021 Virtual GEM workshop, we held two sessions. Session 1 had 75 participants online and 7 speakers. Session 2 had 66 participants online and also 7 speakers. Since we had too many requests for speaking slots and the time was limited, we had no time for additional discussion. This was partly intentional since under the umbrella of the 2050 discussions, our FG supported the corresponding session held by the MPS RA.

Significant Accomplishments

One significant accomplishment is our Focus Group's ability to listen to the community and provide a Focus Group that fits their needs. We heard there was confusion on terminology, so we began our Focus Group with a panel that discussed terminology. We heard there was lack of understanding on the different types of models, so the following year we had a panel of modelers explain what their models are capable of studying in terms of the physics. Next, we heard that trying to debate in real-time was difficult. Although audience members have interesting and valid counter-points to a speaker, without any time to reflect and respond it is difficult to have meaningful discourse. So, we responded by creating the "Challenge Question" format, where a Challenge Question, highlighted by the community, is posed months ahead of time. Community members can address the question by submitting their talk title/opinion about the answer. Focus Group leaders facilitate the debate by coordinating the speakers ahead of time. At the GEM meeting, speakers debate amongst each other, having had adequate time to prepare. Audience participation is very welcome.

For 2021 specifically, our first session highlighted new insights on current systems and MI coupling associated with dipolarization structures in Earth's magnetotail. In particular, attention was given to some of the microscopic to mesoscale currents and Poynting flux associated with dipolarization fronts, energy transfer into the ionosphere, and how the current systems associated with dipolarization fronts close through the ionosphere and contribute to the global scale R1/R2 current systems. New details and insight on the multi-scale (micro to macro) nature of particle acceleration associated with bursty bulk flows and dipolarization fronts were also discussed. The second session focused on global-scale asymmetries and more on meso-scale structures in the context of MI-coupling and multi-scale, multi-point observations. Finally, data-model comparisons were discussed including new results from a machine learning model that successfully predicts the location of magnetotail X-lines and thin current sheets and statistical results from test-particle simulations in high-resolution MHD fields that successfully reproduced observed statistical characteristics of mesoscale structures and plasma characteristics associated with bursty bulk flows and dipolarization fronts.

2021 has had some challenges, not just with Covid but with extra meetings (e.g., Helio2050) that has left the community a bit tired. Despite the challenges, we had decided to hold a hybrid mini-GEM meeting during the Fall AGU 2021 meeting. It included science discussions as well as a discussion of our next Challenge Question(s). A brief report of the mini-GEM meeting is included below under "Other Activities".

We do fully intend to continue our Challenge Question format going forward, as this format had resounding support when we asked for feedback from the community.

Community Engagement and Participation

(i) For the summer 2021 workshop, all presentations were contributed. The list of speakers included:

- Jiang Liu. Embedded Region 1 and 2 currents: consequence of enhanced convection in the plasma sheet, newly recognized from LEO observations
- James Weygand. Magnetic Perturbation Events observed in ionospheric current systems including events during substorms and north-south streams
- Hongtao Huang. Understanding the magnetic dip ahead of the dipolarization fronts using PIC simulations: the dependence on the guide field.
- Kun Bai. Ion trapped acceleration at rippled dipolarization fronts
- Louis Richard. Turbulent Jet Fronts and Related Ion Acceleration.
- Sheng Tian. Evidence of Alfvenic Poynting flux as the primary driver of auroral motion During a geomagnetic substorm.
- Larry Lyons. Two-dimensional structure of flow channels within the inner magnetosphere and associated upward field-aligned currents: model and observations.
- Chih-Ping Wang. North-south asymmetry of the tail lobe density and magnetic field.
- Amy Keesee. Mesoscale plasma sheet structures observed with energetic neutral atom imaging with TWINS.
- Grant Stephens. Reconstructing the global x-line configuration by data mining spaceborne magnetometer observations.
- Slava Merkin. Mesoscale electrodynamics and ring current formation.
- Andrew Menz. Investigating substorm-related flows and thinning using multi-point spacecraft and all sky imager data.

- Joachim Birn. Dipolarizing flux bundle braking: Energetic ions.

(ii) Session 1 had 75 participants online and 7 speakers. Session 2 had 66 participants online and also 7 speakers.

(iii) We used Slack Channel and video chat software.

(iv) We try to give early career folks a platform and facilitate the discussion so that people with different backgrounds and personality types can be heard. When we invite speakers, we do try to bring in underrepresented groups.

Assessment of Progress Toward Goals

We have made significant progress towards our goals. An example are the list of papers that have been presented at or have come from the GEM Focus Group, found here: https://gem.epss.ucla.edu/mediawiki/index.php/FG:_Magnetotail_Dipolarization_and_Its_Effects_on_the_Inner_Magnetosphere

A lot of interest, and therefore effort, has gone into addressing the third science topic from our proposal, “What is the relationship, if any exists, between elementary magnetotail dipolarizations and more global dipolarization during substorms?” as evidenced by the papers listed under the Significant Publication header below.

Significant Publications

Papers that explicitly call out the Focus Group in the acknowledgments section:

Birn, J., Liu, J., Runov, A., Kepko, L.,& Angelopoulos, V. (2019). On the contribution of dipolarizing flux bundles to the substorm current wedge and to flux and energy transport. Journal of Geophysical Research: Space Physics,124,5408-5420. https://doi.org/10.1029/2019JA026658

Ohtani, S. (2019), Substorm Energy Transport From the Magnetotail to the Nightside Ionosphere. Journal of Geophysical Research: Space Physics, 124. https://doi.org/10.1029/2019JA026964.

Nishimura, Y., L. R. Lyons, C. Gabrielse, J. M. Weygand, E. F. Donovan & V. Angelopoulos (July 2020), Relative contributions of large-scale and wedgelet currents in the substorm current wedge. Earth Planets Space 72, 106. https://doi.org/10.1186/s40623-020-01234-x

Gabrielse, C., Spanswick, E., Artemyev, A., Nishimura, Y., Runov, A., Lyons, L., et al. (July 2019). Utilizing the Heliophysics/Geospace System Observatory to understand particle injections: Their scale sizes and propagation directions. Journal of Geophysical Research: Space Physics, 124, 5584-5609. https://doi.org/10.1029/2018JA025588

Other papers that resulted from Focus Group discussions (but without explicit acknowledgment):

-Merkin, V. G., Panov, E. V., Sorathia, K., & Ukhorskiy, A. Y. (Oct 2019). Contribution of bursty bulk flows to the global dipolarization of the magnetotail during an isolated substorm. Journal of Geophysical Research: Space Physics, 124, 8647-8668. https://doi.org/10.1029/2019JA026872
-Ohtani, S., J. Gjerloev (August 2020), Is the Substorm Current Wedge an Ensemble of Wedgelets?: Revisit to Midlatitude Positive Bays, Journal of Geophysical Research: Space Physics, https://doi.org/10.1029/2020JA027902
-Turner, D. L., Cohen, I. J., Michael, A., Sorathia, K., Merkin, S., Mauk, B. H., et al. (2021). Can Earth's magnetotail plasma sheet produce a source of relativistic electrons for the radiation belts? Geophysical Research Letters, 48, e2021GL095495. https://doi.org/10.1029/2021GL095495
-Turner, D. L., Cohen, I. J., Bingham, S. T., Stephens, G. K., Sitnov, M. I., Mauk, B. H., et al. (2021). Characteristics of energetic electrons near active magnetotail reconnection sites: Tracers of a complex magnetic topology and evidence of localized acceleration. Geophysical Research Letters, 48, e2020GL090089. https://doi.org/10.1029/2020GL090089
-Cohen, I. J., Turner, D. L., Mauk, B. H., Bingham, S. T., Blake, J. B., Fennell, J. F., et al. (2021). Characteristics of energetic electrons near active magnetotail reconnection sites: Statistical evidence for local Energization. Geophysical Research Letters, 48, e2020GL090087. https://doi.org/10.1029/2020GL090087
-Sorathia K. A., Michael A., Merkin V.G., Ukhorskiy A.Y., Turner D. L., Lyon J.G., Garretson J., Gkioulidou M., Toffoletto F.R. (2021), The Role of Mesoscale Plasma Sheet Dynamics in Ring Current Formation, Frontiers in Astronomy and Space Sciences, 8, 192, doi: 10.3389/fspas.2021.761875.

Other Activities

We maintain and update the FG page on the GEM Wiki. Each year we also organize an AGU session on the FG topic, as was the case at the recent Fall AGU 2021 meeting. The title of the AGU session is “The Importance of Mesoscale Magnetotail Processes in Global and Kinetic-scale Magnetospheric Dynamics”. It included oral, eLightning, and poster sessions. In addition, this year the participants of our FG have contributed significantly to the discussions during the NASA Helio 2050 workshop as well as the Decadal Survey and White Papers session on Thursday afternoon during the GEM summer 2021 workshop.

At the mini-GEM preceding the 2021 Fall AGU, Andrei Runov discussed a recent publication, "Magnetotail Dipolarizations and Ion Flux Variations During the Main Phase of Magnetic Storms", that acted as a backbone for discussion on the topic in general. The community discussed how although some works have looked at how mesoscale injections and dipolarizations affect the ring current (e.g., Gkioulidou et al., 2014), we still don't really understand the relative role that they play. We also discussed the future of the Focus Group, including other Focus Groups we might do joint sessions with in Summer 2022.

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, Sean Fu

Goals & Objectives

The Earth's radiation belts are filled with energetic particles, which exhibit acceleration, transport, and loss processes under the influence of many physical mechanisms at timescales from minutes to days. Understanding the effectiveness and relative importance of physical mechanisms on radiation belt particles is of both scientific interest and practical needs. Since the discovery of Earth's radiation belts 60 years ago, much progress has been made on understanding the radiation belt dynamics based on in situ and ground-based observations as well as modeling efforts. Specifically, many mysteries of radiation belt particles have been discovered with recent missions such as Van Allen Probes, Arase, and CubeSats. However, single-point measurements have limitations in revealing underlying physical mechanisms on the radiation belt particles due to spatial/temporal ambiguities and limited coverage. Our focus group (FG) aims to deepen understanding of radiation belt particle dynamics on both local and global scales through coordinated measurements from multi-spacecraft and ground-based observations, combined with theoretical and modeling efforts. The science goals of our FG are to advance our understanding of newly explored topics that will greatly benefit from such coordinated measurements, specifically: 1) the physical mechanisms related to radiation belt electron acceleration and loss on short timescales (minutes to hours); 2) quantification of energetic electron precipitation into the atmosphere and the related physical mechanisms; 3) the properties and spatiotemporal distribution of waves in radiation belts and their effects on radiation belt particles; and 4) dynamics of inner belt and slot region particles.

Key Activities During GEM Summer Workshop

Our FG held two virtual sessions in the 2021 Virtual GEM Summer Workshop.

Session 1 included a panel discussion, "Radial Transport vs. Local Acceleration: the Long-standing Debate", and decadal discussions. The panel discussion was a joint effort between our FG and UMEA FG. Chaired by Lauren Blum, Alexander Drozdov, and Mike Hartinger, the panelists Hayley Allison, Mary Hudson, Allison Jaynes, Solene Lejosne, and Louis Ozeke discussed the current state-of-the-art understanding and the gaps of radiation belt electron acceleration mechanisms via various aspects including theory, observations, and simulations. They also discussed the path to solving this long-standing question in radiation belt studies. Following the panelists' presentations, a Q&A session was conducted with rich discussions.

Session 2 was a general contribution session. Chaired by Hong Zhao and Xiangrong Fu, 17 speakers presented in this session on a variety of topics on observations and simulations of radiation belt particles and waves.

Significant Accomplishments

The panel discussion on "Radial Transport vs. Local Acceleration: the Long-standing Debate" yielded fruitful results. Based on inputs from panelists and participants, the consensus was that both mechanisms contribute to the radiation belt particle acceleration, though the relative importance and effectiveness vary under different conditions. The current gaps exist in the phase space density analysis, which is hindered by both limited in-situ observations and inaccuracy in geomagnetic field models; the influence from the plasma environment; the variability of outer boundary conditions; and event-specific inputs to the radiation belt models. In order to advance our understanding on this topic, utilizing multi-point measurements from various platforms including satellites at various orbits, balloons, imaging, and ground-based observations, having an accurate geomagnetic field model or conducting detailed comparisons of modeled and measured magnetic field, incorporating the event-specific plasma environment and radial diffusion coefficients, and using PSD outer boundary conditions constrained by all available observations are the keys. As a result of this panel discussion, one commentary led by one of the session chairs, Alexander Drozdov, has been submitted to Earth and Space Science, and one review paper on this topic led by one of the panelists, Solene Lejosne, is in preparation and to be submitted to Frontiers.

In our general contribution session, 17 speakers each gave a brief presentation about their research results on a wide range of topics. These new results include the observations and simulations of radiation belt electron acceleration and loss, various plasma waves (chorus, hiss, ULF, EMIC, equatorial noises, electrostatic solitary waves, etc.) and wave-particle interactions, and radiation belt modeling. Due to the time constraint, each presentation and Q&A were limited to 5 minutes; but rich discussions and interactions were conducted via online chats.

Community Engagement and Participation

Session 1: Panel discussion on "Radial Transport vs. Local Acceleration: The Long-standing Debate"

Chairs: Lauren Blum, Alexander Drozdov, and Michael Hartinger

Panelists: Hayley Allison, Mary Hudson, Allison Jaynes, Solene Lejosne, and Louis Ozeke

There are about 100 participants at peak.

In this panel discussion session, each panelist gave a brief presentation talking about their opinions on the topic. Following all presentations from the panelists, a Q&A session was held, and rich discussions were carried out among participants and panelists. This format allows the engagement of the community and interactions between participants and panelists. When organizing this panel discussion session and inviting the panelists, our chairs also paid special attention to the diversity and inclusion of this panel by including scientists with different genders and career stages.

Session 2: general contribution session

Presentations:

Leonid Olifer: On the Formation of Phantom Electron Phase Space Density Peaks in Single Spacecraft Radiation Belt Data

Yuxuan Li: Characteristics of Three-belt Structure of Sub-MeV Electrons in the Radiation Belts

Ian Cohen: Investigating the Link Between Outer Radiation Belt Losses and Energetic Electron Escape at the Magnetopause

Rick Wilder: Electrostatic solitary waves in the magnetosphere observed by MMS

Anthony Saikin: Low frequency hiss model parameterized by plasmapause location

Jaya Joseph: The effects of equatorial noise on the inner belt proton density structure

Lengying Khoo: Modeling the effect of NWC transmitter using Van Allen Probes and PROBA-V measurements

Longzhi Gan: Dependence of Nonlinear Effects on Whistler-mode Chorus Wave Bandwidth and Amplitude: A Perspective from Diffusion Coefficients

Jinxing Li: Multipoint Observations of Quasiperiodic Emission Intensification and Effects on Energetic Electron Precipitation

Luisa Capannolo: The drivers and properties of relativistic electron precipitation in the nightside

Mike Shumko: Concurrent and Nonconcurrent Aurora and Relativistic Electron Precipitation

Riley Troyer: Understanding the higher energies of pulsating aurora through a statistical study with the Poker Flat Incoherent Scatter Radar

Murong Qin: Multi-point observation of global ULF-modulated energetic electron precipitation

Adam Michael: Incorporating local wave-particle interactions into CHIMP and their impact on the radiation belts during the recovery phase of the March 17, 2013 storm

Simon Wing: Untangling the solar wind and magnetospheric drivers of the radiation belt electrons

Sasha Drozdov: A Comparison of Radial Diffusion Coefficients in Long-Term Radiation Belt Simulations

Scot Elkington: radiation belt modeling

There are about 100 participants at peak.

In this general contribution session, each presenter gave a brief, 5-min presentation. Though the time for each presentation is limited, the virtual format gave participants great opportunities to ask questions and discuss with presenters via online chats, which enhanced the interactions between participants and presenters. Similarly, when organizing this session, our chairs specifically encouraged and prioritized students, early-career scientists and those from under-represented groups to present.

Assessment of Progress Towards Goals

The broad goal of our FG is to deepen understanding of radiation belt particle dynamics through coordinated multi-mission measurements, combined with theoretical and modeling efforts. Through the panel discussion on the long-standing debate over the effectiveness and significance of the two radiation belt electron acceleration mechanisms, the state-of-the-art understanding of radiation belt electron acceleration, the current gaps preventing a deeper understanding of this question, and the future directions to further address this problem have been extensively discussed and summarized. Based on the panel discussion results, one commentary was submitted and one review paper is in preparation and to be submitted, which would greatly contribute to our community's advanced understanding of radiation belt particle acceleration. On the other hand, the contributed talks in our general contribution session covered a wide range of topics on radiation belt studies, many of which addressed our FG specific science topics, including 1) improving the understanding of physical mechanisms related to radiation belt electron acceleration and loss on short timescales (minutes to hours); 2) quantifying the radiation belt electron precipitation into the atmosphere and understand the related physical mechanisms; 3) improving the understanding of the properties and spatiotemporal distribution of waves and their effects on the radiation belt particles; and 4) advancing the understanding of inner belt and slot region particle dynamics

Significant Publications

One commentary of our panel discussion, led by Alexander Drozdov and authored by the chairs and panelists, is currently under review in Earth and Space Science. One review paper also based on the panel discussion results, led by Solene Lejosne, is in preparation and to be submitted to Frontiers.

Alexander Y. Drozdov, Lauren W. Blum, Michael Hartinger, Hong Zhao, Solene Lejosne, Mary K. Hudson, Hayley J. Allison, Louis Ozeke, and Allison Jaynes, Radial Transport vs. Local Acceleration: The long-standing debate, Earth and Space Science, under review.

Self-Consistent Inner Magnetospheric Modeling

Qianli Ma, Jacob Bortnik, Chao Yue, Cristian Ferradas

Goals & Objectives

This focus group aims to improve the understanding of the development and decay of the storm-time ring current and its broader impact on the inner magnetosphere and magnetosphere-ionosphere (MI) system in order to further the capabilities of self-consistent modeling. To achieve the goal of our focus group, we will engage the GEM community to put- forth and answer science questions related to gaps in our current ability to:

1. represent the electric and magnetic fields self-consistently
2. quantify the relative roles of different loss mechanisms to the ring current
3. derive wave growth rates self-consistently
4. understand wave-particle interactions involving thermal, suprathermal, and ring current populations
5. evaluate the non-linear effects of waves on particles
6. assess the relative importance of different mechanisms leading to the development and decay of the electron ring current

Key Activities During GEM Summer Workshop

Our main activities at the VGEM 2021 Summer Workshop were chairing two sessions, one focused on the ring current dynamics and the other focused on wave-particle interactions. The program for each session consisted of contributed talks by the community, followed by a discussion of our FG challenge events. Our FG has chosen three geomagnetic storms (May 2017, September 2017, and August 2018 storms) as challenge events to be studied by the broader community.

Our FG also participated in the Decadal Survey Discussion session that took place during the VGEM Summer Workshop, by providing input about the unsolved questions in the study of the ring current environment and dynamics.

Significant Accomplishments

We are pleased to see a consistent large engagement of the community in our FG sessions, evidenced by the attendance to our sessions. We are also excited to see the continued participation of graduate students through contributed presentations during the two years of our

FG's lifetime. Our near-term plans start with working on engaging the broader community in our proposed challenge events. To do this, we will hold joint sessions with the IEMIT and DIP FGs to advertise our FG challenge events and invite researchers working on other related topics, such as near-Earth tail dynamics and magnetosphere-ionosphere coupling, to participate in the study of our challenge events.

Community Engagement and Participation

Below is a list of presentations for each of our FG sessions during 2021. The approximate attendance per session for our Mini-GEM 2020 and VGEM 2021 sessions was 60-70 participants and for our Mini-GEM 2021 session was 20-30 participants. Each session took place via Zoom, and we encouraged the use of the chat feature in Zoom for participants to engage in the discussions. We also used the Slack channel for our FG to continue the discussion beyond the duration of our FG sessions. Efforts to address diversity and inclusion? The attendance to each of our FG sessions include graduate students, postdoctoral researchers, and scientists at different career levels. In particular, the list of presenters in our sessions (below) indicates the high interest in our FG topics from the young generation. Each of our sessions is open to the public, and well-attended by the students and researchers from all over the world. We plan to keep encouraging the participants from different backgrounds and especially provide our FG resources to the next-generation researchers.

Mini-GEM 2020 (January 21, 2021)

1. Yiqun Yu: The impact of lower-energy (<30 keV) electrons on the spacecraft surface charging environment

2. Jinxing Li: Self-consistent particle-in-cell simulation of two-band chorus waves in the radiation belts

3. Zefan Yin: Inner magnetospheric magnetic dips and energetic protons trapped therein: Multi-spacecraft observations and simulations

4. Xingzhi Lyu: Radial diffusion of energetic protons in the Earth's inner magnetosphere

5. Li Li: Observations of the drift resonance between charged particles and compressional-toroidal ULF waves

6. Hyomin Kim: The role of injected ring current ions in generating EMIC waves and scattering radiation belt particles

7. Longzhi Gan: Numerical study of the formation mechanism for bursts of electron butterfly distribution

8. Gonzalo Cucho-Padin: Understanding the role of exospheric density on the ring current recovery rate

9. Oleksiy Agapitov: The outer radiation belts electrons lifetime model: the update from the cold plasma effects

10. Chao Yue: Sustained oxygen spectral gaps and their dynamic evolution in the inner magnetosphere

VGEM 2021 (July 27, 2021)

Session 1: Ring Current Dynamics

1. Mostafa El Alaoui: Particle Injection into the Inner Magnetosphere: An MHD with Embedded PIC Simulation

2. Jason Derr: A New Way to Include Inertia in the Rice Convection Model

3. Chao Yue: MLT-Dependence of Sustained Spectral Gaps of Proton and Oxygen in the Inner Magnetosphere

4. Xingzhi Lyu: Comparative Dropout Studies of Radiation Belt Electrons and Ring Current Protons

5. Matthew Cooper: Results of a Polynomial Model Recreation of Inner Magnetospheric Flux Measurements Taken by the Van Allen Probes RBSPICE Mission

6. Artem Smirnov: Storm-Time Evolution and Empirical Modeling of Equatorial Electron Pitch Angle Distributions Based on Van Allen Probes Data

Session 2: Wave-Particle Interactions

1. Xin An: Particle-in-Cell Simulations of Two-Band Chorus Excitation

2. Xiaojia Zhang: Superfast Precipitation of Energetic Electrons as Observed by ELFIN CubeSat

3. Haobo Fu: Frequency-Dependent Responses of Plasmaspheric Hiss to the Impact of an IP Shock

4. Qianli Ma: Simultaneous Occurrence of EMIC and Magnetosonic Waves: Wave Generation and Particle Scattering Effects

5. Suk-Bin Kang: Superthermal Electron Production and Ionospheric Conductivity due to Energetic Particle Precipitation from the Inner Magnetosphere

6. Xu Liu: A Parametric Study of Oxygen Ion Cyclotron Harmonic Waves by an Oxygen Ring Distribution

Mini-GEM 2021 (December 12, 2021)

1. Matthew Cooper: An inner magnetospheric empirical model of the ring current: preliminary statistical analysis of a physics-based basis set

2. Haobo Fu: Frequency-dependent responses of plasmaspheric hiss to the impact of an IP shock

3. Qianli Ma: Energy transfer of different energy protons through the coupling with magnetosonic waves and EMIC waves

4. Minghui Zhu: Effects of polarization reversed EMIC waves on the ring current dynamics

Assessment of Progress Towards Goals

Our FG's main goal is "*to improve the understanding of the development and decay of the storm-time ring current and its broader impact on the inner magnetosphere and magnetosphere-ionosphere (MI) system in order to further the capabilities of self-consistent modeling*". To this end, we have divided our efforts into two main research areas: ring current dynamics and wave-particle interactions. Efforts from the community in these two areas have been encouraged. For the ring current dynamics area, efforts include studies to understand the impact of particle injections to the ring current and the role they play in the generation of EMIC waves, the storm-time pitch angle distributions of electrons, and the distribution of ion spectral features in the inner magnetosphere. For the wave-particle interactions area, efforts to study the relation in observations of EMIC and magnetosonic waves, the impact of wave-driven particle precipitation on the ionospheric conductivity, and the relation between ion cyclotron harmonic waves and ion ring distributions have been performed. We consider that these efforts show progress toward our goal. However, we expect that in the coming year we will see more significant progress through the community involvement in our FG challenge events.

Significant Publications

Although the publications below [1-13] did not explicitly acknowledge the FG activities, they are the outcome of our FG efforts and highly relevant to the science topics of ring current dynamics or the interactions with EMIC/magnetosonic waves. Therefore, the publications are listed as a reference.

[1] Yue, C. et al. Sustained Oxygen Spectral Gaps and Their Dynamic Evolution in the Inner Magnetosphere. (2021) J. Geophys. Res. Sp. Phys. 126, e2020JA029092, https://doi.org/10.1029/2020JA029092.

[2] Chen, A. et al. Ring Current Decay During Geomagnetic Storm Recovery Phase: Comparison Between RBSP Observations and Theoretical Modeling. (2021) J. Geophys. Res. Sp. Phys. 126, 1–12, https://doi.org/10.1029/2020JA028500.

[3] Ren, J. et al. The Link Between Wedge-Like and Nose-Like Ion Spectral Structures in the Inner Magnetosphere. (2021) Geophys. Res. Lett. 48, e2021GL093930, https://doi.org/10.1029/2021GL093930.

[4] Cucho-Padin, G., Ferradas, C. P., Waldrop, L. & Fok, M.-C. Understanding the role of exospheric density in the ring current recovery rate. (2021) Earth Sp. Sci. Open Arch. ESSOAr, https://doi.org/10.1002/essoar.10505770.1.

[5] Ferradas, C. P. et al. The Role of Substorm Injections on the Extreme Geo-Effectiveness Observed in the Inner Magnetosphere on the 8 September 2017 Geomagnetic Storm. (2021) Earth Sp. Sci. Open Arch. ESSOAr, https://doi.org/10.1002/essoar.10506099.1.

[6] Ferradas, C. P. et al. The effects of the location and the timing of local convection electric field enhancements in the formation of ion multiple-nose structures. (2021) J. Atmos. Solar-Terrestrial Phys. 105534, https://doi.org/10.1016/j.jastp.2020.105534.

[7] Ferradas, C. P. et al. Observations of Density Cavities and Associated Warm Ion Flux Enhancements in the Inner Magnetosphere. (2021) J. Geophys. Res. Sp. Phys. 126, 1–16, https://doi.org/10.1029/2020JA028326.

[8] Teng, S., N. Liu, Q. Ma, and X. Tao (2021), Characteristics of low-harmonic magnetosonic waves in the Earth's inner magnetosphere, Geophysical Research Letters, 48, e2021GL093119. https://doi.org/10.1029/2021GL093119.

[10] Teng, S., N. Liu, Q. Ma, X. Tao, and W. Li (2021), Direct observational evidence of the simultaneous excitation of electromagnetic ion cyclotron waves and magnetosonic waves by an anisotropic proton ring distribution, Geophysical Research Letters, 48, e2020GL091850, https://doi.org/10.1029/2020GL091850.

[11] Teng, S., Q. Ma, and X. Tao (2021), Simultaneous observations and combined effects of electromagnetic ion cyclotron waves and magnetosonic waves, Geophysical Research Letters, 48, e2021GL093885, https://doi.org/10.1029/2021GL093885.

[12] Zhang, X.-J., D. Mourenas, X.-C. Shen, M. Qin, A. V. Artemyev, Q. Ma, et al. (2021). Dependence of relativ-

istic electron precipitation in the ionosphere on EMIC wave minimum resonant energy at the conjugate equator, Journal of Geophysical Research: Space Physics, 126, e2021JA029193, https://doi.org/10.1029/2021JA029193.

[13] Min, K., J. Kim, Q. Ma, C.-W. Jun, and K. Liu (2021), Unusual high frequency EMIC waves: Detailed analysis of EMIC wave excitation and energy coupling between EMIC and magnetosonic waves, Advances in Space Research, 69, 1, 35-47, https://doi.org/10.1016/j.asr.2021.07.039.

[14] Yue, C., Liu, Y., Zhou, X., Zong, Q.-G., Reeves, G. D., & Spence, H. E. (2021). MLT-dependence of sustained spectral gaps of proton and oxygen in the inner magnetosphere. Journal of Geophysical Research: Space Physics, 126, e2021JA029935. https://doi.org/10.1029/2021JA029935.

[15] Fu, H., Yue, C., Ma, Q., Kang, N., Bortnik, J., Zong, Q.-g., & Zhou, X.-z. (2021). Frequency-dependent responses of plasmaspheric hiss to the impact of an interplanetary shock. Geophysical Research Letters, 48, e2021GL094810, https://doi.org/10.1029/2021GL094810.

[16] Jang, E. J., Yue, C., Zong, Q. G., Fu, S. Y. and Fu, H. B. (2021). The effect of non-storm time substorms on the ring current dynamics. Earth Planet. Phys., 5(3), 1–8, https://doi.org/10.26464/epp2021032.

[17] Yin, Z.-F., Zhou, X.-Z., Zong, Q.-G., Liu, Z.-Y., Yue, C., Xiong, Y., et al. (2021). Inner Magnetospheric Magnetic Dips and Energetic Protons Trapped Therein: Multi-Spacecraft Observations and Simulations. Geophysical Research Letters, 48, e2021GL092567, https://doi.org/10.1029/2021GL092567.

Other Activities

We organized an oral session and a poster session during the 2021 AGU Fall Meeting entitled 'Advances in Understanding and Modeling the Ring Current and Its Coupling With Other Particle Populations'. The oral session (SM51A) had 7 presentations, and the poster session (SM45A) had 16 presentations. Both sessions were well-attended with insightful discussions during the AGU meeting.

We keep updating our focus group activities on the GEM Wiki website (https://gem.epss.ucla.edu/mediawiki/index.php/FG:_Self-Consistent_Inner_Magnetospheric_Modeling). The presentations during each meeting are listed on the website. During the past year, we have identified the three geomagnetic storms as our challenge events, which are posted on the website to invite contributions.

The Impact of the Cold Plasma in Magnetospheric Physics

Gian Luca Delzanno, Natalia Buzulukova, Barbara Giles, Roger Varney, Joe Borovsky

The FG had three sessions at the 2021 VGEM meeting.

The first session was held on July 26th 2021 at 1 PM ET with the objective of discussing strategies for white papers that could be submitted to the Upcoming Decadal Survey and possible team building from interested parties. The session started with two five-minutes talks (plus questions) on mission concepts associated with white papers that were submitted to the Helio2050 workshop and that are also likely to be submitted to the Decadal Survey. The first talk was given by David Malaspina from U. Colorado on the Plasma Imaging, LOcal measurement, and Tomographic experiment (PILOT) mission concept. PILOT involves a 20-30 spacecraft constellation (mostly microsats) that combines Radio tomography for equatorial images of total plasma density with meridional EUV imaging and some in-situ measurements of cold-ion distributions (including composition) and waves. It aims to identify and quantify the processes that govern mass and energy transfer between the magnetosphere and ionosphere, the mass transport through and out of the inner magnetosphere and how the cold plasma regulates coupling between different populations. The second talk was given by Philippa Molyneux from SWRI on the Synchronized Observations of Upflow, Redistribution, Circulation, and Energization (SOURCE) mission concept. SOURCE is based on 5 spacecraft with different instrumentation to understand the processes and pathways of the cold ions flowing from the ionosphere and how they are energized and transported throughout geospace. The remaining 70 minutes of the session were completely devoted to open discussion of potential white paper ideas. There was a general consensus among the participants that a white paper that makes a strong scientific case for the need of robust cold-electron and cold-ion measurements and advocates for innovations in instrument development was necessary. Another point of discussion was on cold electrons, which might not be as appreciated as cold ions in the community, but that are critically important for the energy coupling among various particle populations in space. Several aspects associated with the impact of cold electrons (waveparticle interactions, structuring and photoelectrons) were discussed as potential topics of interest for one or more white papers. Cold-ion outflow and various aspects of cold-ion heating were also discussed and there was a general consensus that important questions such as understanding where heating occurs and what processes (with their relative importance) determine ion heating would be critical to advance cold-ion science in the next decade. Several people expressed interest in contributing to white papers on the topics discussed above and in the next months the FG will help coordinating these efforts.

The second session, on July 26th 2021 at 3 PM ET, focused on near-term progress that could be achieved in cold-plasma science and was essentially a full discussion session. It was in part stimulated by a NASA Living With a Star (LWS) open call where the cold plasma is one of the Focused Science Topics. The NSF GEM program is another venue where cold-plasma proposals could be submitted. The session was moderated by Joe Borovsky, who started the session by introducing the objectives of the LWS call. The initial part of the discussion was heavily centered around the warm plasma cloak (an oxygen-rich ion population of energies between a few eV and a few hundred eV that 'wraps' around the plasmasphere). The cloak is considered a 'low-hanging fruit' since its broad range of energies makes its measurement less susceptible to spacecraft-charging problems. Moreover, the cloak can impact the magnetosphere-ionosphere system at many fundamental levels, such as altering the characteristic frequencies of ULF waves or affecting the day-side reconnection rate. Examples of open questions associated with the cloak are: what are the solar-wind drivers and controlling factors of the cloak? What is its origin? What are the properties of cloak electrons? Some discussion also touched upon the use of machine-learning techniques to advance modeling of the cold-particle populations, including the cloak. A second topic of discussion was about identifying a set of cold-plasma challenges that could be tackled in the next years of the FG. Some debate occurred on whether these challenges should be more traditional GEM-type challenges (where a specific data set is identified for use for model validation) versus simply converging on a set of open scientific questions and let the community 'self-organize' around those. In general, it was noted (also by members of other FGs) that in the context of a virtual meeting it has been hard to gather sufficient community feedback to identify new challenges. One of the open scientific questions that was proposed as a possible challenge was to identify the source of the long-lived drainage plumes. Another one focused on plasmaspheric refilling, aimed at understanding why available codes do not produce accurate refilling rates. Another option involves wave-particle interactions and our ability to model accurately the generation and propagation of the waves. One complication to execute this challenge is that cold-plasma data is not always available and hence suitable data sets need to be carefully selected. Discussions of this potential waveparticle-interaction challenge in collaboration with the Self-Consistent Inner Magnetospheric Modelling (SCIMM) FG will be pursued in the next months. The last part of the discussion was soliciting ideas for sessions that could be planned for the 2022 GEM meeting. Several ideas were discussed ranging from cold-plasma surveys of old datasets, a more general session focusing on the cold plasma at the magnetopause versus a narrower session focusing on the cloak, and incorporation of cold-plasma physics into global models. The latter session might be of particular interest since it interfaces directly with the Merged Modeling & Measurement of Injection Ionospheric Plasma into the Magnetosphere and its Effects (M3-I2) FG. Since M3-I2 is ending its activities in 2021, we will coordinate with M3-I2 to understand what kind of activities could be carried forward by our FG.

The third session occurred on July 30th 2021 at 3 PM ET. It was organized jointly with the ULF wave Modeling, Effects, and Applications (UMEA) Focus Group, with the objective of identifying the status and open questions relating ULF waves and the cold particle populations. The session started with a 20-minutes scene-setting talk by Richard Denton, who reviewed the recent advances in ULF waves for both Alfven and electromagnetic ion cyclotron (EMIC) waves. Richard closed his presentation by identifying areas that need future improvements. Specifically, we need: 1) better models of mass density and ion composition, 2) a better description of how ULF wave power penetrates into high density structures, such as the plasmasphere, and how ULF waves are affected by small-scale structures, 3) a better understanding of the effect of ionospheric boundary conditions on ULF waves, and 4) understanding the relative importance of conventional EMIC generation mechanisms (i.e. temperature anisotropy) relative to other mechanisms such as mode conversion. Five short (5- minutes) talks followed. Alex Degeling showed his latest modeling results on how ULF waves evolve while trapped in a developing plasmaspheric plume. Eun-Hwa Kim used full-wave modeling to study the effect of heavy ions on the propagation of EMIC waves to the ground. Bob Lysak showed modeling results of the propagation of Pi2 pulsations with an asymmetric model of the plasmasphere to understand whether the cavity frequency can depend on local time. Yixin Hao showed observational studies of the interaction of ULF waves with cold electrons and cold ions, focusing both on the plasmapause and the magnetopause. Mike Hartinger closed the short-talk part of the session by discussing the relation between the global ULF wave properties and the radial Alfven speed profile. The last part of the session (~30 minutes) was devoted to open discussion of the future of ULF wave research. There was a general consensus that research must continue to improve the characterization of the cold particle populations and in particular of the mass density (and hence of the Alfven speed). For instance, an ongoing ULF wave challenge has shown how more realistic plasmaspheric profiles can drastically change the ULF wave response. Along the same lines, future models will also need to include a more realistic ionosphere. Another research direction that was highlighted is to develop predictive capabilities to understand how the waves are driven, including wave coupling. From the perspective of the radiation belts, accurate specification of ULF wave power remains a critical research area in need of improvements. In this vein, a suggestion was made to organize a joint session between the radiation belt and cold plasma focus groups at the 2022 GEM meeting with the ULF waves as the unifying theme.

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

Shasha Zou, Barbara Giles, Rick Chappell

Final Report

Goals & Objectives

The Earth's ionosphere is a significant source of plasma to the magnetosphere and a strong influence on the dynamics of the geospace environment. The ionospheric source is contributing plasma to the plasmasphere, the plasma sheet, and the ring current and through wave-particle interactions is playing a major role in the formation and dynamics of the radiation belts. Hence, understanding of the strength and dynamics of the ion upflow/outflow particles up into the magnetosphere is of critical importance to understanding how the magnetosphere is populated and influenced by these initially low-energy particles.

Key components of this goal:

(1) refined outflow models through comparison to measurements and inter-model comparisons

(2) merge GGCMs with coupled ion-outflow models

(3) quantitative and qualitative understanding of the ion upflow and the effects of ion outflow on plasma sheet, ring current, substorm dynamics

(4) Decadal Survey recommendations for M-I studies & future satellite missions.

Key Activities During GEM Summer Workshop

We have hosted two virtual sessions during the 2021 GEM summer workshop.

Significant Accomplishments

This is the last year of the focus group. Besides the regular research presentations, a community discussion has been hosted to identify critical areas of improvement for the near future.

Community Engagement and Participation

During the 2021 GEM workshop M3-I2 sessions, six presentations were given:

1. John Foster & Philip Erickson, O+ observations at the geospace plume.

2. Naritoshi Kitamura, On the relationship between energy input to the ionosphere and the ion outflow flux under different solar zenith angles.

3. Alex Glocer, Scaling of outflow with different types of energy input.

4. Leonardo Regoli, MMS observation of O+ outflow to the inner magnetosphere.

5. Jonathan Krall, Counterstreaming cold H+, He+, O+ and N+ outflows in the plasmasphere

6. Shasha Zou, SED contribution to ion upflow during

storms.

Following the presentations, a discussion on the current state of the focus group goals was hosted. In addition, we have advertised the focus group sessions in various community mailing lists to engage the community. There were about 40-50 participants during each of the online sessions.

Assessment of Progress Towards Goals

During the discussion session, we accessed the progress towards the focus group goal and identified key issues that should be tackled in the next decade.

Understanding the ionospheric mass contribution to the magnetosphere and its impact on the coupled geospace system dynamics is the ultimate goal of the focus group. A lot of progress has been made in the last few years. However, achieving the ultimate goal in the next 10 years is difficult because of severely under-sampled data in the critical energization region (above 1000 km), where ion upflow turns into the outflow. The lack of observations in this energization region hinders the numerical models to model ion outflow energization and impact appropriately. In addition, a fully coupled geospace model is required to understand the impact of the IT dynamics at lower altitudes on ion upflow/outflow. Furthermore, improved measurements of meso-scale electric field and thermospheric wind, as well as exospheric density, are essential. Innovative method to image O+ outflow should be explored. Better coordination between ground- and space-based measurements is needed.

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

Hyunju Connor, Doğa Öztürk, Gang Lu, Bin Zhang

Goals & Objectives

The ultimate goal of this focus group is to advance our physics-based understanding of global magnetosphere – ionosphere – thermosphere coupling dynamics. We are particularly interested in the following topics:

- Momentum/Energy input from the magnetosphere to the upper atmosphere: The small and large-scale patterns of field-aligned currents, auroral precipitation, and Poynting flux during various geomagnetic events will be carefully examined using observations, theoretical calculations, and numerical simulations.
- Responses of three-dimensional IT system to the magnetospheric input: This FG will investigate the impact of magnetospheric momentum/energy inputs on the three- dimensional IT system using global MIT models and/or global IT models coupled with AMIE. We will address how the spatiotemporal dynamics of magnetospheric input modifies the altitudinal profiles of electron density, ionospheric conductivity, and Joule heating. We will also study how this modification influences global ionospheric electrodynamics.
- IT feedbacks to the magnetosphere: Variations in global ionospheric electrodynamics can influence the magnetospheric convection patterns and modify the magnetic reconnection rates. The coupled magnetosphere – ionosphere – thermosphere models can be a good tool to investigate the IT dynamics and their impact on the magnetospheric phenomena. Additionally, strong Joule heating and enhanced ionospheric temperature can produce ion outflows and modulate the reconnection rates. The outcome from this FG can be a good asset for the ion outflow modelers.

Key Activities During GEM Summer Workshop

During the 2021 GEM Summer Workshop, we held three sessions. One of the sessions was joint with the UMEA Focus Group on Tuesday July 27th, and the other two were stand-alone sessions held on Wednesday July 28th. During these sessions we had presentations from 9 speakers, all of which were contributed talks.

Our focus was on understanding the needs of the community moving forward as the IEMIT FG ends in 2022. To accomplish this goal we solicited input from the community, which will also be used for the Heliophysics Decadal Survey. We have sent out a survey and announcements regarding the form in GEM newsletter. The form specifically sought to understand past, present, and future efforts on Magnetosphere-Ionosphere-Thermosphere coupling.

Lastly, we held a Discussion session at the end of our contributed talks to discuss the future of M-I-T coupling research. The presenters and audience had the opportunity to speak about where they see the immediate future developments and what obstacles lie ahead.

Significant Accomplishments

As the IEMIT FG is nearing its 5 year term, we have also solicited input from the community regarding the next big problems for M-I-T coupling in the aforementioned survey. Figure 1 shows the result from the survey where participants identified the following two as the most important problems to understand for the future of M-I-T coupling:

- M-I-T coupling across different scales
- M-I-T coupling through particles

Based on the responses, understanding particle precipitation at different scales emerged as an important next step for making progress in M-I-T coupling studies. While the IEMIT FG provided a venue for such topics to be explored, a new FG that specifically focuses on the magnetospheric origin, properties, and the effects of precipitating particles

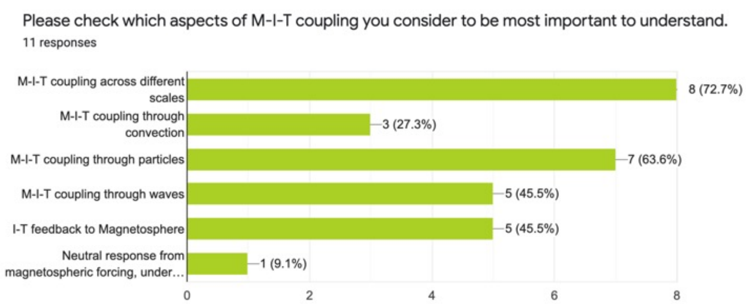


Figure 1: The histogram showing the results of Question 2 in 3D IEMIT Decadal Survey Input distributed during the GEM 2021 Summer Workshop. The full survey can be found at : https://forms.gle/FpjEL7BQdUpHGSAi7

was deemed necessary. Therefore, one of the co-conveners of the IEMIT FG assembled a team of experts and proposed a new FG titled "Magnetospheric Sources of Particle Precipitation and Their Role on the Electrodynamic Coupling of Magnetosphere-Ionosphere-Thermosphere Systems". This new FG will not only take over the flag from the IEMIT FG but also will bring together different domains, scales, and GEM FGs that were outside of the scope of the IEMIT FG.

Some of the most significant accomplishments of the IEMIT FG team in the 2020-2021 term are listed as follows.

1. The FG Team led a Helio2050 White paper and a presentation titled "A Collaborative Approach to Understanding Auroral Region Magnetosphere-Ionosphere-Thermosphere Coupling Through Ionospheric Conductivity" with 30 co-authors
2. In collaboration with the MMV FG, the IEMIT FG team authored a Living with a Star (LWS) Focused Science Topic (FST) solicitation titled "Auroral Region Drivers of the Ionosphere-Thermosphere System".
3. In collaboration with the MMV FG, the IEMIT FG team led an opinion article at EOS titled "All hands on deck for ionospheric modeling".

Community Engagement and Participation

i. List of presentations:

• Longxing Ma: Statistical Characteristics of the 39 keV Proton Isotropic Scattering Region (ISR) and its Relationship with Field Line Curvature Scattering

• Xingbin Tian: Statistical relations between ionospheric conductances and electron precipitation using the 5 years of DMSP and ISR observations

• Hyunju Connor: Diffuse electron aurora and ionospheric conductance derived from the Chorus Wave Statistics

• Margaret Chen: The Effect of Stormtime DIffuse Auroral Precipitation on Ionospheric Conductance and Conductivity: Comparison of RCM-E Simulations with Observations

• Michael Liemohn: Considerations about improving the Robinson formulas

• Toshi Nishimura: Cusp dynamics and polar cap patch formation associated with IMF southward turning

• Dong Lin: Subauroral polarization streams (SAPS) in Multiscale Atmosphere-Geospace Environment (MAGE) simulations

• Agnit Mukhopadhyay: Physics-driven MAGNIT auroral precipitation model (stand-alone IEMIT session)

• Jiang Liu: The impact of active-time plasma sheet convection on the magnetosphere-ionosphere-thermosphere system: embedded Region 1 and 2 FACs and dawnside auroral polarization stream

ii. Approximate number of participants: 80

iii. Tools employed to engage the community:

• Slack channel

• Google Survey

• Online interactive tools, i.e: Mentimeter, to solicit community input

• Recordings made available for limited time on GEM Wiki

iv. Efforts to address D&I:

• Moderation of Zoom session by early-career researchers and students

• Moderation of Q&A by early-career researchers and students

• Practices to achieve diverse representation while organizing Discussion Panels (gender, nationality, career stage, geography, area of expertise)

Assessment of Progress Towards Goals

The IEMIT FG was first proposed because of the need to understand global dynamics of the coupled magnetosphere-ionosphere-thermosphere systems. The goals of the focus group were to better understand and quantify: i. the momentum and energy input from the magnetosphere to the upper atmosphere, ii. responses of 3D I-T system to such magnetospheric inputs, and iii. I-T feedback to magnetosphere.

Figure 2 shows the results from the recently conducted survey. Given various options, participants identified the following as the mostly likely scenarios for the M-I-T coupling studies in the next ten years.

- Magnetospheric energy input to the I-T system is characterized across different scales.
- The 3D Ionosphere and Thermosphere systems are included in MHD models.
- Ionospheric conductance and conductivity can be predicted with a certain error margin.

It is very encouraging that the community identified the three main goals of the IEMIT FG as the areas as the areas

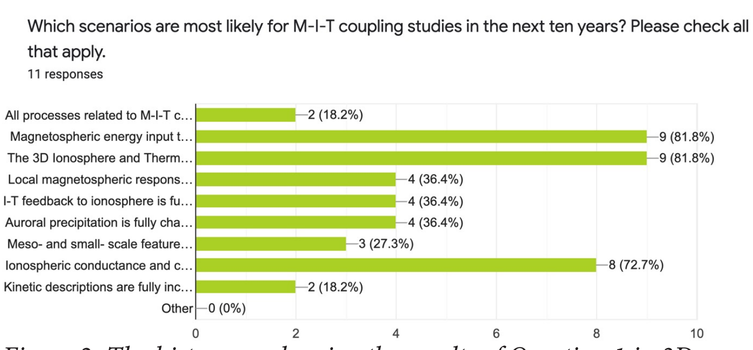


Figure 2: The histogram showing the results of Question 1 in 3D IEMIT Decadal Survey Input distributed during the GEM 2021 Summer Workshop. The full survey can be found at : https://forms.gle/FpjEL7BQdUpHGSAi7

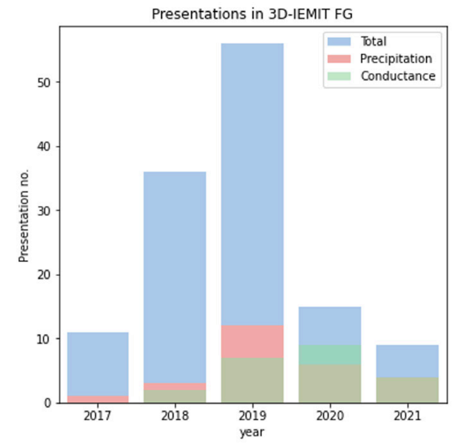


Figure 3: The histogram showing the presentation numbers each year the FG was active (2017-2021). The blue columns show the total number of presentations, the red columns show the presentations related to particle precipitation, and the green columns show presentations related to conductance.

in which progress was imminent.

Figure 3 shows the papers presented each year at the IEMIT FG sessions. Even though the ongoing COVID-19 pandemic significantly affected the number of presentations, the overall percentage of talks related to precipitation and conductance increased from 10% to 40%. This is an important indicator that our community is now realizing the precipitation and conductance as the immediate next steps in understanding the M-I-T coupling and improving the modelling of the geospace environment.

The IEMIT FG brought together experts in the field, provided a venue for them to share their research, and form collaborations. Owing to the hard work of researchers, the community now feels closer to achieving the IEMIT FG goals in the near future as indicated by the survey results and presentation numbers.

Significant Publications

Öztürk, D. S., K. Garcia-Sage, and H. K. Connor (2020), All hands on deck for ionospheric modeling, Eos, 101, https://doi.org/10.1029/2020EO144365. Published on 20 May 2020.

Interhemispheric Approaches to Understand M-I Coupling (IHMIC)

Hyomin Kim, Robert Lysak, and Tomoko Matsuo

Goals & Objectives

The main goal of this focus group is to understand the interhemispheric symmetry/asymmetry in geomagnetic fields and its effects on M-I coupling. Observational and modeling studies have shown the interhemispheric differences which are manifested in various signatures, e.g., large-scale current systems, auroral forms, waves, ion upflow, outflow, particle precipitation, high-latitude convection and thermospheric winds. The focus group addresses questions as to how to incorporate interhemispheric differences and their effects on M-I coupling in observations and modeling/simulations. The overarching science questions that this focus group will be addressing are:

1. In what aspect does the asymmetry in geomagnetic fields play a role in M-I coupling?
2. How are the interhemispheric differences related to solar wind and geomagnetic activities?
3. What are interhemispheric differences in storm and substorm signatures, wave activity and particle precipitation? What controls these differences?
4. How do interhemispheric differences in ionospheric conductivity affect solar wind coupling to the magnetosphere, ionosphere and thermosphere?
5. What are effects of the neutral wind dynamo in the application of Ohm's law to ionosphere-magnetosphere coupling? Does the neutral wind dynamo contribute to the interhemispheric asymmetry in M-I coupling?

Key Activities During GEM Summer Workshop

Two focus group sessions were held virtually on July 26, 2021. Speakers and their presentation titles are listed in the later section of this document (Community Engagement and Participation) and can also be found in the GEM Wiki page: https://gem.epss.ucla.edu/mediawiki/index.php/FG:_Interhemispheric_Approaches_to_Understand_M-I_Coupling_(IHMIC). The CEDAR community members were also encouraged to present and join the sessions to promote more extensive discussions regarding the focus group topics. Outstanding questions, challenges to achieve the scientific goals and plans to overcome such challenges have also been discussed to address the community input for Decadal Survey. During the hybrid mini-GEM workshop (New Orleans or Zoom, December 12, 2021), two sessions were held jointly with the 3D Ionospheric Electrodynamics and Its Impact on the Magnetosphere-Ionosphere-Thermosphere Coupled System (IEMIT) session. Speakers and their presentation titles are listed in the later section of this document (Community Engagement and Participation) and can also be found in the GEM Wiki page.

Significant Accomplishments

A wide range of research topics have been presented at the focus group sessions. Various data sets (e.g., spacecraft – DMSP, AMPERE, Van Allen Probes; ground-based instruments: magnetometers, GPS/GNSS, SuperDARN, etc.) were utilized to examine asymmetric features in solar wind-magnetosphere-ionosphere coupling processes (e.g., Birkeland currents, Poynting flux input, ULF waves, convection flow, etc.) and space weather effect (e.g., Geomagnetically Induced Currents or GICs). Model simulations have been performed to investigate asymmetric geomagnetic environments and parametrize the level of asymmetry in an effort to identify the controlling mechanisms. Some of these studies have also been leveraged to plan the December 4, 2021 Antarctic eclipse campaign, which engaged a number of scientists in various fields from various countries. The community also collaborated with the members involved in one of the NASA DRIVE centers called the Center for the Unified Study of Interhemispheric Asymmetries (CUSIA) for synergistic research. The CUSIA team established the Capabilities Assessment Matrix (CAM) to better understand asymmetries and identify challenges in conducting such studies. In addition, the virtual mode of GEM Workshop enabled a number of international scholars to join the focus group sessions, generating increased interests in asymmetry studies. One of the focus group leaders, Hyomin Kim, co-hosted the virtual CEDAR workshop: Interhemispheric IT asymmetries and their causes and effects (June 24, 2021, Lead: Astrid Maute), in which GEM community members have also presented their work. The focus group will continue to encourage participation from the diverse and international community. Observational and modeling challenges will be planned to promote a more extensive and synergistic community participation.

Community Engagement and Participation

The focus group leaders encouraged a workshop-style format, promoting short, informal talks and open discussions. The CEDAR community and international scholars were reached out to broaden and diversify topics and discussions, which is shown in the presentations listed below. Each session engaged approximately 40-50 participants. Speakers and their presentation titles for the focus group sessions are listed below.

2021 VGEM Sessions (Virtual)

Session 1: Monday, July 26, 1:00 - 2:30 pm (US Eastern Time)

- Mark Engebretson - Magnetic Perturbation Events (MPEs) that cause GICs: Investigating their inher-hemispheric conjugacy
- Dan Welling - Understanding Asymmetries using the Capabilities Assessment Matrix
- Viacheslav Pilipenko - Electromagnetic fields of magnetospheric ULF disturbances in conjugate ionospheres: Current/voltage dichotomy
- Matthias Foerster - Implications of the Earth's magnetic field asymmetry for the M-I-T coupling
- Doga Ozturk/Ilya Kuzichev - Investigating Interhemispheric Asymmetry Across Modeled Ionospheric Parameters
- Mike Hartinger - Planning for the 4 December 2021 Antarctic eclipse
- Christian Bagby-Wright, Asymmetric Effects of Reflected By on Polar Activity
- Anders Ohma - IMF By induced asymmetries and tail reconnection

Session 2: Monday, July 26, 3:00 - 4:30 pm (US Eastern Time)

- Anthea Coster - Interhemispheric Asymmetries as observed by GNSS TEC
- Yining Shi - Interhemispheric Asymmetries in Magnetosphere Ionosphere Magnetic Field Residuals Between Swarm Observations and Earth Magnetic Field Models
- Sungjun Noh - Ground signatures associated with HFA/FB
- Zhonghua Xu - The correlation study of ULF wave responses on the ground under different interplanetary shock conditions
- Sarah Vines - Probing Interhemispheric Asymmetries in the Birkeland Currents with AMPERE
- John Coxon - The interhemispheric asymmetry in Birkeland currents
- James Weygand - Interhemispheric Asymmetry in the Cusp Spherical Elementary Currents
- Delores Knipp - Hemispheric Asymmetries in derived DMSP Poynting Flux
- Ivan Pakhotin - Northern Preference for Poynting Flux Input into the Dayside and Nightside Ionosphere

2021 mini-GEM (hybrid) Session Schedule (held jointly with the IEMIT session)

Location: Hilton Garden Inn New Orleans Convention Center (1001 South Peters Street New Orleans, LA 70130) or Zoom

Session 1: Sunday, December 12, 14:00 - 15:30 (US Central Time)

- Christine Gabrielse - Precipitating Energy Flux, Average Energy, and Hall Auroral Conductance from THEMIS All-Sky-Imagers during Two Substorms: Mesoscale Contributions
- Dillon Gillespie - Diffuse Aurora and Ionospheric Conductance derived from Chorus waves in the inner magnetosphere
- Zihan Wang - COMPASS: a new COnductance Model based on PFISR And SWARM Satellite observations
- Shannon Hill - Capturing Theta Aurora Observations: SWMF Simulation Results
- Yining Shi - Interhemispheric Asymmetries in Large Magnetosphere and Ionosphere Magnetic Field Residuals between Swarm Observations and Earth Magnetic Field Models
- Astrid Maute - Influence of MI and lower atmospheric coupling during a moderate geomagnetic storm
- John Coxon - The interhemispheric asymmetry in Birkeland currents

Session 2: Sunday, December 12, 15:45 - 17:15 (US Central Time)

- Agnit Mukhopadhyay - Global Driving of Auroral Precipitation - Balance of Sources
- Mark Engebretson - Interhemispheric conjugacy of magnetic perturbation events that cause GICs
- Yu Hong - Inter-Hemispheric Asymmetry in the Ionosphere-Thermosphere System During the 8-9 October 2012 Geomagnetic Storm: Multi-Instrumental Observations and GITM Simulations
- Hyomin Kim - Characterization of Interhemispheric Asymmetries Driven by External Drivers
- Sungjun Noh - Interhemispheric Pc 1 wave propagation associated with foreshock transient events during quiet solar wind condition
- Zhonghua Xu - Influence of MI and lower atmospheric coupling during a moderate geomagnetic storm

- Xueling Shi - Multipoint conjugate observations of dayside ULF waves during an extended period of radial IMF
- Marc Hairston - Variations in the Ionospheric Penetration Electric Field During the 2013 St. Patrick's Day Storm Between the Northern and Southern Hemispheres

Assessment of Progress Towards Goals

The interhemispheric asymmetries remain an area fraught with unknowns and open questions, representing a barrier to understanding the magnetosphere-ionosphere-thermosphere system. The Interhemispheric asymmetries and their causes can be better understood if 1) Interhemispheric asymmetries are quantified in different spatiotemporal scales and 2) their controlling parameters are identified, and relative contributions are quantified in the complex coupled system. However, in reality, one asymmetry will cascade and cause more asymmetries throughout the entire magnetosphere-ionosphere-thermosphere system, leading to unknown and unexpected effects. It is challenging to comprehensively study asymmetric effects at the system level. Interhemispheric asymmetries are often investigated through statistical averaging of individual variables and/or idealized simulations focused on one causal effect. Underlying physical processes are dynamic and complex, resulting from multiple asymmetric coupling mechanisms that are operating simultaneously. Consequently, it is important to avoid treating interhemispheric asymmetries in isolation. In addition, magnetosphere-Ionosphere coupling processes that cause asymmetries have not been fully incorporated in numerical models. To answer the outstanding questions as stated in #1 and #2, the following should be achieved: a) Establishment of observing capabilities (e.g., magnetometer/radar/auroral imager network) in the South comparable to the Northern counterpart to observe asymmetries in a more extensive spatiotemporal range; b) Development of models to better predict when and where asymmetries occur and to quantify the level of asymmetries and relative contributions from each controlling parameter; c) Re-assessment and improvement of the current data-driven modeling approaches along with a more comprehensive data assimilation strategy to address the asymmetries due to the dipole tilt and offset more extensively. The focus group sessions enabled the following to address the aforementioned outstanding questions and challenges: i) identify data sets available for interhemispheric studies; ii) collaborate with various groups to expand the region of interest (solar wind, magnetosphere, ionosphere, and thermosphere and their coupling); iii) identify challenge events to focus; iv) collaborate between observation and modeling groups; v) promote the diverse community and expertise inclusion in the focus group presentation and discussion.

Other Activities

Center for the Unified Study of Interhemispheric Asymmetries (CUSIA): A Phase II proposal has been submitted to the NASA DRIVE Center program (PI: Daniel Welling, University of Texas, Arlington). This focus group effort has largely been leveraged to address outstanding questions, and observational/modeling challenges and to identify available resources. A number of scientists who have been contributing to this focus group are involved in the CUSIA project as Co-Is and collaborators.

International Space Science Institute (ISSI) Team Project - Understanding Interhemispheric Asymmetry in MIT Coupling (Team Lead, Hyomin Kim): The team was formed in 2021, involving scientists representing seven countries with the expertise covering magnetospheric, ionosphere and atmospheric sciences.

Global System Modeling (GSM) RA Reports

Coordinators: Alex Glocer and John Lyon

ULF wave Modeling, Effects, and Applications

Michael Hartinger, Kazue Takahashi, Alexander Drozdov, Xueling Shi, Maria Usanova, Brian Kress

Final Report

Goals & Objectives

UMEA's goal is to bring together modelers, theorists, and experimentalists to address the following questions: What excites ULF waves? How do ULF waves couple to the plasmasphere/ring current/radiation belt populations? What is the role of ULF waves in MI coupling?

Addressing these questions will (1) improve understanding of the physics of ULF waves and (2) improve the specification of ULF waves in a variety of models with applications in space weather prediction. UMEA facilitates data-model and model-model comparisons that address the basic science questions listed above and can lead to improved specifications of ULF waves in space weather models.

Key Activities During GEM Summer Workshop

UMEA ran 2 standalone sessions and three joint sessions at the 2021 virtual GEM Summer workshop. The "Recent Advances in ULF Wave Research" had a range of contributed talks related to the ULF wave modeling challenge and research highlights from recent ULF wave studies. "The Future of ULF Wave Research" session reviewed UMEA's goals, topics covered in the last 5 years, and unresolved questions in ULF wave research including the need for future ULF wave FGs. The "Role of ULF waves in M-I Coupling" session (joint with IEMIT) began with an invited review talk by Prof Hui Zhang, with the rest of the session for contributed talks on the relationship between ULF waves and GICs, particle precipitation, and other phenomena. The "Radial Transport versus Local Acceleration" joint session (led by RB FG) was a panel discussion focused on outstanding questions concerning this longstanding debate, that resulted in submission of a commentary to the Earth and Space Science journal and preparation of a review in a Frontiers special issue. Finally, the "Coupling Between ULF Waves and Cold Plasma Session" (joint with CP) began with an invited review talk by Richard Denton, with the rest of the session for presentations on recent advances and outstanding questions in this research area.

All sessions had lively discussions and were typically well attended (e.g., 94 participants in the panel discussion and 74 in the cold plasma session). The meetings also featured numerous contributions from early career scientists, including numerous presentations and guest hosts/moderators.

Mini-GEM 2021: UMEA had a joint session with the Radiation Belt focus group that discussed recent findings in various areas of Electromagnetic Ion Cyclotron (EMIC) wave research. During the session 3 presentations were presented followed by open discussion.

Significant Accomplishments

In the final year of our FG, we held several sessions that continued our FG's proposed goals to bring together modelers, theorists and experimentalists to address ULF wave research questions. As part of these discussions, we encouraged presentations related to topics that could be carried forward in future GEM FGs. This included geomagnetic perturbations, and one of the UMEA FG co-chairs, Dr. Xueling Shi, will be leading a new FG on this topic starting in 2022. Other topics will continue to be discussed in existing FGs, including the cold plasma and radiation belt FG; both of our joint sessions with these FGs in 2021 were very well attended with lively and engaging discussions, and the material from these presentations is being used for three separate manuscripts submitted or planned for submission by February 2022.

Our near-term plans/final goals to wrap up the FG include (1) submitting a mini-review to a special issue of Frontiers ("Plasma Waves in Space Physics: Carrying on the Research Legacies of Peter Gary and Richard Thorne"), (2) participating in a separate review in the same special issue reviewing topics related to a local acceleration versus radial diffusion panel discussion (led by Dr. Solene Lejosne), (3) publishing a separate Earth and Space Science Commentary summarizing the panel discussion.

Community Engagement and Participation

In the virtual Summer 2021 GEM workshop:

(i) There were a total of 5 sessions with 3 invited regular presentations, 5 invited panelists who also gave short presentations, and 21 contributed presentations. We also received help from 3 graduate students in running the sessions. A full list of speakers/presentations is shown below.

(ii) Participants ranged from ~40 to a maximum of 94 in the sessions.

(iii) We relied on Slack and Zoom chat to keep the community engaged. Our FG usually had 2-3 co-chairs monitoring the chat/Slack for questions and keeping presenters on time so there would be time for discussion. We also took steps to have more inclusive discussions (e.g., avoid having a small number of people dominate the conversation by checking for raised hands in Zoom, calling on different people).

(iv) As part of planning for GEM 2021, we reviewed lists of invited speakers/panelists to make sure we had a diverse pool of speakers (including gender, nationality, career level, organization). We also contacted several speakers to encourage them to submit contributed talks on their research. Finally, during the sessions we provided multiple channels to ask questions or comment on the presentations (unmute, Zoom chat, Slack) and monitored to make sure questions/comments were addressed.

(Note: During the 2021 mini-GEM workshop in December, there were 3 speakers presenting their results followed by open discussion – these are also shown in the table below.)

Green highlights indicate invited speaker.

	Name	Title (short version - see wiki)
Recent Advances	Michelle Salzano	IPDP-Pi1B
	Aditi Upadhyay	EMIC at Maitri
	Yangyang Shen	KAW during electron injection
	Chih-Ping Wang	Pi2s associated with BBFs
	Tom Elsden	FLR variability during storms
	Denny Oliveira	Shock-induced ULF waves
	Muhammad Fraz Bashir	ULF driven EMIC/VLF precipitations
Future of ULF	Mike Hartinger	Retrospective on UMEA
	Martin Archer	Surface waves
	Tom Elsden	3D FLRs / future modeling and theory
	Alexander Drozdov	Radial Diffusion
	Ayomide Olabode / Michelle Salzano	Ground magnetic perturbations
	Mark Engebretson	Pc1 waves / MMS k-vector technique
	Xueling Shi	Applications of TEC observations
MI Coupling	Hui Zhang	Role of ULF waves in M-I coupling
	Chaosong Huang	Global Pc5 pulsations
	Tetsuo Motoba	Pc5 waves / diffuse aurora
	Anton Artemyev	ULF driven precipitation
	Mark Engebretson	Magnetic Perturbation Events
	Denny Oliveira	dB/dt variations related to shocks
	Xueling Shi	Sources of intense geoelectric fields
Local vs Radial	Solene Lejosne	Panelist
	Mary Hudson	Panelist
	Hayley Allison	Panelist
	Louis Ozeke	Panelist
	Allison Jaynes	Panelist
Cold Plasma	Richard Denton	Review
	Alex Degeling	ULF waves in plume
	Eun Hwa Kim	EMIC wave propagation to ground
	Bob Lysak	Asymmetric plasmasphere cavity modes
	Yixin Hao	ULF wave-cold plasma interaction
	Mike Hartinger	ULF waves / radial Alfven profile

Mini-GEM join session	Justin H. Lee	MMS measurements of cold and hot ion composition and EMIC waves
	Kristine Sigsbee	Statistics of Electromagnetic Ion Cyclotron (EMIC) Rising Tones
	Michael Hartinger	Short overview of open questions

Assessment of Progress Towards Goals

In the final year of the FG, we completed the remaining topical sessions we described in our original FG proposal. The notes taken during these sessions are currently being used to prepare final publications documenting our FG's discussions over the last 6 years (see next section).

We also continued to discuss the ULF wave modeling challenge, including both the idealized modeling challenge and the challenge event on 27-28 May 2017. As part of the FG's effort, several resources were made available from CCMC and a wide range of experimentalists to facilitate data-model comparisons during the event. These include SWMF, LFM, and OpenGGCM model runs on CCMC, new tools developed by CCMC to perform wave analysis, survey plots of data collected during the challenge event, and global densities obtained from assimilative models; all of these resources are linked on the UMEA page on the GEM wiki. Several studies have been published on the 27-28 May 2017 storm event that grew out of discussions at the GEM workshop, including Wang et al., [2020] (reference below). Publications on the modeling challenge itself are still in preparation; this includes a study led by Lutz Rastaetter at CCMC that documents the results of the idealized ULF wave modeling challenge. The draft is nearly complete, but it is being revised based on co-author comments.

We completed our FG's main proposed goals, but significantly more work is needed to understand model-model and data-model discrepancies related to various ULF wave modes. Several other FG's are planning to carry forward this effort.

Wang, B., Nishimura, Y., Hartinger, M., Sivadas, N., Lyons, L. L., Varney, R. H., & Angelopoulos, V. (2020). Ionospheric modulation by storm time Pc5 ULF pulsations and the structure detected by PFISR-THEMIS conjunction. Geophysical Research Letters, 47, e2020GL089060

Significant Publications

Drozdov, A., Blum, B., Hartinger, M.D., Zhao, H., Lejosne, S., Hudson, M., Allison, H., Ozeke, L., Jaynes, A. (submitted), "Radial Transport vs. Local Acceleration: The long-standing debate", Earth and Space Science

Hartinger, M.D., Takahashi, K., Drozdov, A., Shi, X., Usanova, M., Kress, B. (in preparation for submission on Jan 31 journal deadline). ULF wave modeling, effects, and applications: accomplishments, recent advances, and future, Frontiers special issue invited contribution, "Plasma Waves in Space Physics: Carrying on the Research Legacies of Peter Gary and Richard Thorne"

Other Activities

CCMC ULF wave modeling challenge

This website describes activities relating to the ULF wave modeling challenge at CCMC, including links to simulations and other resources: https://ccmc.gsfc.nasa.gov/challenges/ulf-wave-modeling/

Magnetic Reconnection in the Age of the Heliophysics System Observatory

Rick Wilder, Shan Wang, Michael Shay, Anton Artemyev

Over 2021, the focus group “Magnetic Reconnection in the Age of the Heliophysics System Observatory” made progress in our understanding of magnetic reconnection, though due to the virtual nature of the GEM workshop, not as much as would have been made in the absence of the COVID-19 pandemic. During the summer virtual workshop, we had two sessions, with the second session being joint with the Dayside Kinetic Processes focus group. In the first session, we focused on magnetotail phenomena and kinetic physics of magnetic reconnection. Ivan Vasko presented observations of reconnecting current sheet sin the solar wind. Shan Wang showed simulations of lower hybrid drift waves and their interaction with symmetric magnetic reconnection using zero guide field simulations. Results were discussed in terms of MMS observations. Mikhail Sitnov presented two studies, one looking at comparisons between pic simulations and magnetic reconnection observations by MMS in the magnetotail. He also showed that data mining reconstructions of the magnetotail could capture most of the 26 ion diffusion region events identified in the magnetotail by MMS. Finally, Xin An showed examples of magnetic reconnection in the magnetotail with strong electron currents. During the second session, Seung Ho Choi showed whistler waves generated by electron beams during asymmetric guide field reconnection, which have been an ongoing topic of study in dayside magnetic reconnection. Ying Zou led a discussion on the steadiness of magnetic reconnection during quasi-steady solar wind driving, with open topics for discussion including magnetosheath variability. Jaewoong Jung presented a simplified magnetosheath model based on MHD, gas-dynamic and analytic models. Finally, Frederick Wilder showed a survey of the different plasma waves that occur during dayside magnetic reconnection, with current corrugations and lower hybrid drift waves getting the closest to the diffusion region.

The focus group organizer, Frederick Wilder, also presented on the state of magnetic reconnection research in the decadal survey sessions. He suggested several important topics for the next decade of reconnection studies. These include 3-D reconnection, the interplay between reconnection and turbulence, the role of reconnection in shocks, and how local reconnection physics feeds back into the geospace system. Kelvin-Helmholtz waves, flux transfer events, and energetic particle acceleration were all suggested areas where this feedback could be studied.

During the fall mini-GEM, due to the hybrid nature of the meeting and rising omicron variant cases, our session was sparsely attended. Rather than having scheduled talks talks, we led a discussion on what directions the focus group should take for its remaining duration. A major theme that arose was that the local vs. global consequences of reconnection, and how local physics feeds back into the large-scale system will be an important topic in the future. Additionally, joint sessions with groups beyond the dayside kinetic group, including the shock groups and depolarization groups, were recommended. Some discussion of the modeling obstacles for connecting local and global physics occurred.

Stand-Alone Session Reports

Methods and Validation (M&V) Resource Group

Lutz Rastaetter, Mike Liemohn, Alexa Halford, Josh Rigler

The M&V Resource Group started its activities in 2020 with 4 members: Lutz Rastaetter (NASA), Mike Liemohn (U. Michigan), Alexa Halford (NASA) and Josh Rigler (USGS). Lutz and Mike have remained from the earlier MMV Focus Group led by Katie Garcia-Sage. We have been continuing research on ULF wave modeling and ionosphere conductance specification and modeling in collaboration with the ULF and IEMIT focus groups. Current activities include designing a survey directed to all focus groups on model-data comparison study design in their field of research and special methods used in calculating success metrics. We also extend the survey to past focus groups to create a living document of past and current M&V efforts and lessons learned, including best practices for running community modeling challenges. In 2020 the M&V resource group sponsored a plenary talk by Tara Jensen on adapting validation tools used in terrestrial weather studies to space weather.

In 2021 we began drafting concepts for a White Paper in the current Heliophysics Decadal Survey efforts and long-term planning in our field of geospace research.

Machine Learning in Geospace

Matt Argall

VGEM 2021 was again a successful year for Machine Learning in Geospace. We had two sessions jampacked with activities. The first session focused on applications of machine learning to research in geospace by the community. It started with an ice-breaker social then proceeded to presentations of finished work in a format where speakers could obtain feedback on works in progress and ask for help getting started with machine learning. The second session focused on designing a community led Kaggle competition. It started with talks from a Kaggle representative and other invited speakers about what goes into a successful competition, then transitioned to a community-led discussion about how such a machine learning competition can address a large, inter-disciplinary science problem using. The sessions again attracted nearly 100 attendees each.

Session one started with a 10 minute ice breaker in breakout rooms of 3-5 people randomly assigned. The icebreaker question was: What is/was the hardest part about getting started with ML? and the discussion was spurred onward by the results of an opening MentiMeter poll that asked:

1. In your opinion, what is the most difficult part of getting started with Machine Learning?

2. Which aspect of Machine Learning are you most comfortable with?

The goal of the activity was to create, deepen, and solidify connections within the machine learning geospace community.

The icebreaker was followed by seven talks, the first being an invited talk by Arys Narok about Ethical AI. With ethical AI being a topic of future agency and publisher policies, this was a timely and informative presentation. In subsequent talks, Matthew Blanden presented predictions of ground magnetic field disturbances with neural networks, Sheng Huang modeled global plasmaspheric density with recurrent neural networks, Michael Coughlan assessed the risk of exceeding a dB/dt threshold for space weather applications using convolutional neural networks, Chris Bard performed MHD reconstructions with neural networks, Anthony Saikin derived outer radiation belt electron flux with NARX neural network, and Eric Donavan prepared the THEMIS-ASI dataset for machine learning applications.

Session two was geared toward garnering interest in a grass-roots community-backed Kaggle competition. The first talk was by Addison Howard from Kaggle about how to design a successful Kaggle competition. He was followed by Manoj Nair's summary of the DataDriven competition to model the Dst index hosted by NOAA. Next were three educational talks, one by Wendy Carande about common problems encountered when getting started with machine learning, another by Raphael Attie who presented a Jupyter Notebook containing a Python Bokeh application for manual classification of data, and the last by Barbara Thompson who described AI-ready datasets.

Following this, the audience split into breakout rooms to discuss topics and datasets that would lead to a successful Kaggle competition. The discussion took place in a shared JamBoard. Afterward, Shasha Zou, Andrés Muñoz-Jaramillo, and Enrico Camporeale led a panel to summarize the results of the breakout sessions, pulling together the "what" and "how" of a potential competition. Finally, the remaining time was left as an open community discussion.

Geospace System Science Assets and Science

Larry Lyons, Yihua Zheng, Steve Petrinec

Larry Lyons: Intro
As we have heard several times already this week, understanding of the full system can be viewed as the central goal of GEM. Our field now has a variety of spacecraft missions that have been selected or are currently being considered for selection. So it is particularly timely for GEM to address how to make best use of these missions, in concert with the large array of ground-based observations and significant modeling capability, towards the GEM goal of understanding the system as a sum of its parts.

Each speaker has been invited to discuss how their asset can best be used to understand how the full system works.

Jesper Gjerloev: EZIE project scientist

EZIE consists of 3 cubesats with a pearls-on-a-string configuration. The primary goal is to evaluate the ionospheric electrojet and its underlying physics. The system is more dynamic than is usually thought. Questions to be considered include the configuration of the substorm current wedge, still hotly debated after 45 years of study, the relative contributions of large-scale current circuits versus much smaller scale wedglets, and the structure and dynamics of the equatorial electrojet. They invite collaborations, and precise neutral wind measurements was called out specifically.

Kristina Lynch: ARCS PI

The 32 satellite project stems from decades of sounding rocket research, and focuses on Alaska. The longitude span of Alaska will be covered simultaneously by the spacecraft and ground-based imaging. Topics to be considered include the three-dimensional auroral oval and electrodynamics, the role of the ionosphere in the creation of auroral arcs, how the auroral ionospheric system works, and links to the magnetosphere. Applications to other planets with auroras will also be considered. Three-dimensional modeling will be guided by the data driven GEMINI model. Collaboration with other missions and data is encouraged.

Kyle Murphy: STORM Science/Project Coordinator

STORM focuses on the Dungey/convection, substorm, and geomagnetic storm processes/cycles, with the goal of obtaining a system-science view of the complex solar-wind interaction, including energy transfer at the dayside magnetosphere, energy circulation to and through the magnetotail, sources and sinks for the ring current, and ring current feedback on the outer magnetosphere. STORM's self-standing mission observes the solar wind plasma and IMF input in situ while imaging the magnetopause, the auroral oval (including fine-scale aurora), and the ring current. Global connections are central to the project's plans. The project offers opportunities for all aspects of the GEM program, including in-situ missions, ground-based instruments, and simulation development.

Robyn Millan: Small Sats

Small sats give us multiple vantage points of the larger-scale system of coupled systems. They have included long-term monitoring, such as via SAMPEX. The more recent even smaller SmallSats, called CubeSats, were described as a disruptive innovation that greatly augments larger flight missions (for example FIREBIRD, AC6 and CSSWE have augmented Van Allen Probes). Rockets and balloons also augment these missions. CubeSats can also fill gaps in time and location - coming in between larger missions to fill in time periods or locations where we have data gaps for longer term coverage and for more comprehensive coverage. It was also mentioned that we should find a way to include small missions (CubeSats, rockets and balloons (and ground-based)) into the Heliophysics System Observatory. Furthermore, they are useful as a pathfinder for future opportunities, and have the potential to enable large constellations of spacecraft.

Mike Hartinger: Ground systems for system science

They provide an extensive historic record, such as 500 years of space weather storms data (ground-based measurements), that enables us to explore past events to better understand and predict future events. They also enable us to directly sample space weather impacts such as GICs, providing complementary information to satellite observations of the phenomena that drive these impacts. Dense ground-based networks can sample mesoscale structures over large spatial regions, including in both hemispheres simultaneously, thus can provide global coverage of the magnetosphere-ionosphere system on a range of scales. There has been important work across disciplines with new datasets, such as GNSS for TEC maps, and magnetotelluric surveys for subsurface electrical conductivity needed for GIC investigations. There has also been crucial planned support for space missions, such as with THEMIS, and important serendipitous support for other missions like Van Allen Probes, as well as remote sensing of otherwise difficult to reach locations. They have also allowed us to take advantage of the power of citizen scientists, such as via HamSCI, AuroraSaurus, and space weather underground.

Joe Borovsky:

System science needs to understand not only the behaviors of the individual parts, but also to analyze how the different components work together to form the behaviors of the whole, complex system. Many different parameters can be used, including Kp, convection, AE, SME, AL aurora, Dst, Asy index, .and polar cap indices. Spacecraft can add MBI, electron penetration, polar cap size, mPe for electron precipitation, mPi for ion precipitation, and the isotropy boundary to indicate tail stretching. Possible future indices include GPS multi sat radiation index, total dayside reconnection rate, energy inflow rates, mass-transport rates, polar cap outflow rate, auroral outflow rate, ion composition, dayside mass density, and waves indices. To further help, we could monitor the electron and ion plasma sheet, the electron and ion radiation belt and ring current, substorm-injected electrons, the plasma cloak, the plasmasphere and the drainage plume, the LLBL and Mantle, and ionospheric conductance if we could find a way to measure it.

Toshi Nishimura: Using ionospheric measurements to probe magnetosphere dynamics
It is difficult to specify meso/small-scale structures in the global system due to limited coverage/resolution. Knowledge of precipitation/conductance is limited, and of plasma outflow is even more limited. We have remote sensing of magnetospheric processes such as using measurement of cold plasma via TEC in the ionosphere and as mapped to the magnetosphere, and we have some means for remote sensing of magnetospheric processes, such as through auroral imaging and particle precipitation observation. We have made much progress on system science of storms and other geomagnetic disturbances using high-resolution convection from SuperDARN. We know now that convection dynamically varies, even with driving by steady southward IMF. This is manifested as, for example, strong dynamic variability of dayside reconnection and repetitive day-night propagation of flow channels. CEDAR had a grand challenge session 2018-2021 multiscale ionosphere-thermosphere system dynamics. Now GEM needs a forum to discuss major issues regarding fully coupled system.

Yu Lin: Modeling, with focus on Hybrid codes
Hybrid modeling is giving strong support to system science by investigating nonlinear physics processes from the ion kinetic to global scales. Examples include supporting TRACERS, the 18 Nov 2015 dayside magnetopause reconnection kinetic challenge event, tail dynamics, and dayside ULF physics associated with foreshock transients, hot-flow anomaly asymmetry and impacts on ionosphere, ionospheric ion outflow and effects on tail dynamics

Katherine Garcia-Sage: Modeling, with focus on global codes
Global models give a view of the global state of the system and allow for testing physics questions with numerical experiments or for putting localized observations into a global perspective, an example being recent modeling of SAPS. It becomes possible to isolate specific physical mechanisms of interest and see how they interact across the system and across scales. The models are also valuable for space weather prediction, and for getting an idea of what may be happening at places or times where we cannot make direct measurements. Validation is crucial to understand applicability and limitations, as is using assimilation of data to improve the validity of models. Global models are useful for planning future observations.

Harlan Spence: Helioswarm
Primary goal is space plasma turbulence, inspired by the decadal survey inspired science goals. Its primary goal is turbulence in the solar wind at 1AU, with geospace turbulence as a secondary goal. By using multiple (9) close-together spacecraft, measurement capability moves beyond a single point and a single scale. Scales would span MHD to sub-ion regimes. Measurements would be made in the pristine solar wind, CME/CIR regions, the foreshock, and within the magnetosphere. With the magnetosphere, a 3D, polyhedral spacecraft configuration would be used from >30 to 60 Re, and a string of pearl configuration at smaller radial distances (<30 Re). Would provide measurements of ion heating produced by turbulence at sub-MHD scales and be able to resolve small scale plasma/field structures and different pathways for dissipation.

Liaison Reports

CEDAR Liaison Report
Ying Zou

The current CEDAR science steering committee (CSSC) chair is Larisa Goncharenko. The main CEDAR workshop organizer is Astrid Maute, and the NSF Aeronomy Program manager is Alan Liu.

The 2021 CEDAR workshop was held virtually from June 20 to June 25. It was kicked off with the student workshop on Sunday organized by the student representatives Komal Kumari and Meghan LeMay. Based on feedback from the previous year, the students decided to have lightening type of talks, which were pre-recorded, and speakers were available after a set of talks to answer questions. The focus was on providing an overview of “Instrumentation and techniques” and “Back to the Basics”. The CEDAR workshop spanned five days. The individual workshop sessions were 2 hours long and 9 blocks were provided for the 36 individual workshops, covering a broad range of topics. Details about these sessions can be found on the 2021 virtual CEDAR workshop webpage. The poster session was virtual and the posters would be on display for 1 year.

There is a significant increase in international participation in the posters and an increase of undergraduates. The poster judging subcommittee organized the poster judging and selected a 1st, 2nd prize for graduate students and up to 1 honorable mention for an undergraduate student.

The CEDAR prize lecture was selected in 2020 but given this year by Dr. Marty Mlynczak (NASA) about "Energy Balance and Long-Term Change in the Upper Mesosphere and Lower Thermosphere". The presentation was very well received and provided a great overview of the broad topic and the challenges. The CEDAR Distinguished Lecture was also selected in 2020 and postponed to 2021. Prof. Bob Schunk (USU) talked about "Modeling, Specifying and Forecasting Space Weather" providing a great overview of different model developments and the future of ensemble modeling forecast.

To measure Diversity, Equity and Inclusion (DEI) at CEDAR, a group led by Mack Jones Jr. formed in 2020 as the DEI task force. Optional questions were added to the registration to obtain demographic information about race and gender identity, and a DEI focused talk by Dr. Brandon Jones (NSF-GEO/OAD) was included in workshop plenary session. A DEI focused session was also organized.

In total 839 participants registered the 2021 CEDAR workshop from 42 countries around the world. The US has the largest number of participants (518), followed by India (43). Especially noteworthy is the increased participance from Peru and from African states. There was an almost even distribution between students, early career, mid-career and senior scientists among the participants.

The 2022 CEDAR workshop will be held in person from June 19 to June 24, 2022 in Austin, Texas.

SHINE Liaison Report

Joe Borovsky

SHINE did not meet in 2021, but this year the SHINE Workshop is in Honolulu June 27-July 1, the week following the 2022 GEM Summer Workshop. There will be a GEM-SHINE Joint Meeting June 25 and 26 at the Alohilani Resort on the weekend between GEM and SHINE. The GEM-SHINE session topics are under development. The joint GEM-SHINE team is Yihua Zheng, Lynn Wilson, Sarah Vines, Nicky Viall, Gang Li, Alex Glocer, and Joe Borovsky.

NASA Liaison Report

Jesse Woodroffe

I first attended a GEM conference as an undergraduate in 2003. The community I found there and its devotion to supporting early career scientists helped me find my way as a scientist and was key to helping me to where I am today. With this in mind, I'd like to encourage us to all consider how important GEM is to us, both as a organizing force for scientific collaboration as well as a nucleus for community growth.

As the NASA representative to the GEM community, I'm happy to report that the NASA Heliophysics System Observatory continues to grow and evolve, providing unprecedented opportunities for investigations of the space environment. Bigger and better than ever, we're now taking measurements everywhere from the the surface of the sun out into interstellar space, with assets near the moon, on the surface of Mars, and all throughout geospace. Our traditional research opportunities have recently seen near-record high selection rates due to generous, bipartical congressional support for Heliophysics science and overall recognition of the importance this community's efforts research is ever-growing – if the future is in space, then the road the future is through Heliophyics. And the GEM community is helping to pave the way.

The past year has been an exciting – and busy – one for NASA Heliophysics. Seven (!) missions – IMAP, PUNCH, SunRISE, ESCAPADE, GLIDE, HERMES, TRACERS – successfully passed KDP-C and were approved for implementation. And just this past February, we announced the selection of two new midscale explorers (MidEx) missions that will provide key measurements to help us characterize magnetospheric drivers and, ultimately, improve our understanding of geospace and its dynamic processes. Exciting things are on the horizon!

The Multi-slit Solar Experiment (MUSE), will help scientists understand the forces driving the heating of the Sun's corona and the eruptions in that outermost region that are at the foundation of space weather. The mission will offer deeper insight into the physics of the solar atmosphere by using a powerful instrument known as a multi-slit spectrometer to observe the Sun's extreme ultraviolet radiation and obtain the highest resolution images ever captured of the solar transition region and the corona. The primary goal of the MUSE mission is to investigate the causes of coronal heating and instability, such as flares and coronal mass ejections, and gain insight into the basic plasma properties of the corona.

HelioSwarm will be a constellation (or "swarm") of nine spacecraft that will capture the first multiscale in-space measurements of fluctuations in the magnetic field and motions of the solar wind known as solar wind turbulence. HelioSwarm consists of one hub spacecraft and eight co-orbiting small satellites that range in distance from each other and the hub spacecraft. This variety of measurments across large areas is critical for understanding the characteristics of plasma turbulence, which is an inherently multi-scale phenomenon.

Large missions aren't the only thing the community should be excited about, however – great things can also come in small packages! In this past year, Heliophysics has also selected six new CubeSats (CODEX, DYNAGlow, WindCube, PaDRE, CubIXSS, and SunCET) through its H-FORT program element. These small satellite investigations will demonstrate new cutting-edge measurement technologies and operating concepts that will help to close critical measurement gaps and lay the groundwork for future flagship missions. And CubeSats aren't the only platform on which innovative measurements are being tested! With the easing of restrictions on travel, we have also been able to support a bevy of sounding rocket launches at sites around the globe. Since my last update, we have launched at least 8 sounding rockets, including investigations of the ionosphere (DYNAMO-2, Endurance, INCAA, LAMP), cusp (C-REX 2), and sun (CLASP-2.1, EVE, MaGIXS). These experiments are important for both technology maturation and mission development – and they can provide the scientific community with unique observations that may not be available elsewhere.

In addition to its numerous observing mission, Heliophysics continues to support a very robust research program, and earlier this year we were pleased to announce the selection of three DRIVE Science Centers (DSCs): The Center for Geospace Storms (CGS), Consequences Of Flows and Fields in the Interior and Exterior of the Sun (COFFIES), and Solar wind with Hydrogen Ion charge Exchange and Large-Scale Dynamics (SHIELD). Recommended by the 2013 Decadal Survey, the DSCs represent the culmination of years of effort by the scientific community to advocate for, organize, and ultimately enable NASA to support such potentially revolutionary efforts. In the realm of Space Weather, we have recently announced the "Space Weather Centers of Excellence", an opportunity that will support collaborations whose focus is on supporting transformative innovations to overcome critical challenges in space weather.

To follow along with updates from NASA Heliophysics, join the newsletter here. You can also let Heliophysic Communications know what you've been working on or volunteer for a panel.

NOAA Liaison Report

Howard Singer

This brief report describes recent highlights and future plans related to NOAA's space weather activities with relevance to the Geospace Environment Modeling (GEM) community.

The National Oceanic and Atmospheric Administration (NOAA) supports robust space science and space weather programs with elements that include: modeling, observations, understanding, transition of research to operations and operations to research (R2O2R), forecasting and operational services. These programs are related to Geospace Environment Modeling (GEM) goals to "understand the solar-terrestrial system well enough to be able to formulate a mathematical framework that can predict the deterministic properties of geospace and the statistical characteristics of its stochastic properties." Within NOAA, these activities are carried out mostly in the National Weather Service (NWS) Space Weather Prediction Center (SWPC) and in the National Environmental Satellite, Data, and Information Service (NESDIS) which includes the Office of Projects, Planning, and Analysis (OPPA), the GOES-R Series Program Office, and the National Centers for Environmental Information (NCEI). At SWPC our mission is well-described by our new mission statement: "Safeguarding society with actionable space weather information."

Modeling the space environment is a significant challenge that will lead to major predictive capabilities and benefits for those impacted by space weather. This past year has seen progress on many fronts, including the WAM-IPE model (WAM: Whole Atmosphere Model; IPE; Ionosphere Plasmasphere Electrodynamics) transitioning to operations on NOAA's supercomputers; models in operations to support the aviation industry; and improvements in solar wind modeling; however, this report will focus on a few newsworthy achievements related to geospace environment modeling.

- **Geospace Modeling:** SWPC continuously provides users with predictions of regional geomagnetic variations on the ground from its operational Geospace model (using components of the University of Michigan's Space Weather Modeling Framework) and with regional geoelectric variations from its operational Geoelectric model (developed in collaboration with partners, including the USGS). The Geospace model, driven by solar wind observations at L1, provides short-term predictions of the geomagnetic field variations while the Geoelectric model is driven by ground-based magnetometer observations, providing near real-time geoelectric conditions. During the past year, we have demonstrated the ability to use the Geospace model predicted magnetic variations as input to the Geoelectric model, in place of the ground-based magnetometer observations. This configuration results in a predictive Geoelectric model. Further work, running the Geoelectric model in a predictive mode will support power grid operations that can use the predicted geoelectric field to drive geomagnetically induced currents in their systems. Furthermore, SWPC staff have stayed abreast of other community efforts, such as the work being carried out at Johns Hopkins University Applied Physics Laboratory's Center for Geospace Storms (CGS). Given resources and community developed models with predictive skill, such as those anticipated from CGS and others, one can envision a future when operations will be running ensemble models as well as utilizing machine learning techniques to improve space weather services for those affected by geomagnetic variations.

- **Geoelectric Modeling:** a major advance this year improved geoelectric predictions over the continental U.S. by incorporating more Canadian stations through a collaboration with Natural Resources Canada (NRCan) partners. In the near future, working together with Canadian partners, we will have a joint U.S.-Canadian operational product. In addition, we have been working with USGS, and other partners, to improve geoelectric modeling by incorporating new conductivity maps from magneto-telluric surveys that have been recently completed in the southwest U.S.

- **Auroral Modeling and Observations (model data fusion):** For several years, SWPC has been providing auroral products using the Oval Variation, Assessment, Tracking, Intensity, and Online Nowcasting (OVATION) model that was originally developed at Johns Hopkins University Applied Physics Laboratory. This empirical model, driven by solar wind observations made at L1, predicts particle precipitation into the auroral oval and is used to predict the probability of auroral intensity and location. This past year, a test product (Figure 1) has been developed that overlays the NOAA Visible Infrared Imaging Radiometer Suite (VIIRS) instrument observations from the Joint Polar Satellite System (JPSS). The images from the VIIRS Low-Light-Band imager have a 90–120-minute delay but are useful for assessing context and confidence in the model results. Future improvements are expected.

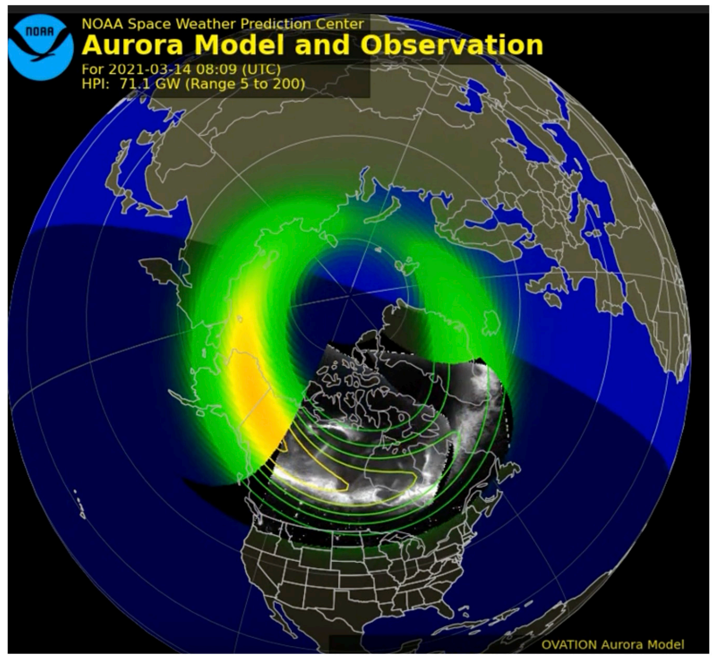


Figure 1: Auroral Test Product: OVATION with auroral image overlay. (Courtesy Rodney Viereck)

Observations are critical for driving models, for validation, for assimilation, and for providing situational awareness. NOAA operations benefit from both ground and space-based observations and from both NOAA and partner observations. There have been many new developments in the past year, but here we will just note a few recent highlights relevant to GEM. NOAA real-time solar wind observations continue to be provided by NOAA's Deep Space Climate Observatory (DSCOVR). In addition, NOAA NESDIS is leading efforts for a follow-on satellite, NOAA's Space Weather Follow On-L1 (SWFO-L1) satellite that is progressing towards an early 2025 launch as a rideshare to L1 with NASA's IMAP mission. SWFO-L1 will monitor the solar wind but will also carry a coronagraph (another coronagraph will launch with GOES-U in about 2024). Last year's GEM report contained additional details about these missions. At geosynchronous orbit, GOES-T (now called GOES-18) was launched on March 1, 2022. The GOES-T satellite includes a new magnetometer (different from what was flown on GOES-16 and 17). In early 2023, GOES-18 will take over the role of GOES West from the current GOES-17.

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. For GOES-R series data, see https://www.ngdc.noaa.gov/stp/satellite/goes-r.html as well as reprocessed 2 Hz GOES-8-15 MAG data in multiple geophysical frames at https://satdat.ngdc.noaa.gov/sem/goes/data/science/mag/

Another set of critical observations for input to models and for use in space weather operations comes from the near-real-time NSF Global Oscillation Network Group (GONG) run by the National Solar Observatory (NSO) and supported by NSF as well as substantial SWPC funding for GONG operations.

Space Weather Workshop: The 2022 virtual Space Weather Workshop, co-sponsored by NOAA, NASA, and NSF, and organized by the University Corporation for Atmospheric Research (UCAR) and an expert, enthusiastic and diverse steering committee will be held April 26-28 (two weeks after submitting this update). The meeting brings together industry, academia, and government agencies in a lively dialog about space weather. The outcomes of the meeting will advance the global space weather enterprise and better protect a society that is vulnerable to space weather conditions. The workshop is growing beyond our every expectation with, to date, over 700 registrants from 54 nations, including 139 students. We expect about 70 posters, about 68 oral talks, and 24 lightning talks (including student presentations). Particular attention is being given to the benefits of Diversity, Equity, and Inclusion (DEI) in both the steering committee makeup and the oral presentations. The workshop provides an opportunity to hear presentation from many of those who have been recipients of the NASA-NOAA-NSF Operations to Research (O2R) grants. We look forward to next year's Space Weather Workshop that will be held April 17-21, 2023, in Boulder, CO. Hopefully, that will be an in-person workshop.

R2O2R and Space Weather Policy: SWPC is 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.sworm.gov/publications.htm). 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 developed 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. 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. With regard to these activities, just recently, the Space Weather R2O2R Framework was released publicly by the Office of Science and Technology Policy (OSTP) https://www.whitehouse.gov/wp-content/uploads/2022/03/03-2022-Space-Weather-R2O2R-Framework.pdf. The development of the Space Weather R2O2R Framework was led by NOAA's Space Weather Prediction Center and NASA's Science Mission Directorate Heliophysics Division in coordination with the Space Weather Operations, Research, and Mitigation (SWORM) Subcommittee. This document describes the organizing Framework required to leverage talents and resources of the space weather enterprise to accelerate and enhance R2O and enhance O2R and is also in response to the Promoting Research and Observations of Space Weather to Improve the Forecasting of Tomorrow Act or the "PROSWIFT Act." https://www.congress.gov/116/plaws/publ181/PLAW-116publ181.pdf

More detailed information about NOAA SWPC, NESDIS and NCEI (previously NGDC) can be found at:

https://www.swpc.noaa.gov/

https://www.nesdis.noaa.gov/about/our-offices/office-of-projects-planning-and-analysis

https://www.ngdc.noaa.gov/stp/stp.html

USGS Liaison Report

E. Joshua Rigler

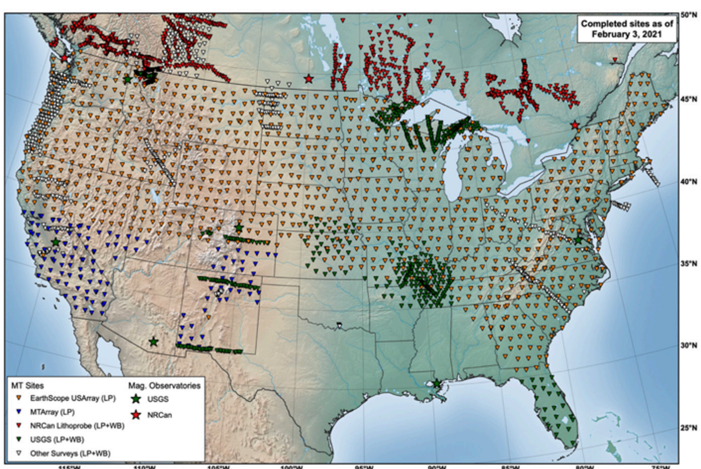
The following is a brief summary of operations and research undertaken or supported by the U.S. Geological Survey (USGS) with relevance to the NSF's Geospace Environment Modeling (GEM) program. It is not exhaustive, nor is it indicative of long-term continued efforts.

Magnetic Observatory Operations and Data

The USGS Geomagnetism Program monitors the Earth's magnetic field with high accuracy, high (time) resolution, and high reliability, operating 14 magnetic observatories distributed across the United States and its territories. Provisional baseline-adjusted magnetometer data are available in near real time through USGS web services (https://geomag.usgs.gov/), or the INTERMAGNET consortium (https://www.intermagnet.org/). "Quasi-definitive" and "Definitive" data are cleaned and calibrated, and typically released within ~1 month and ~1 year of acquisition, respectively. Upgrades to all observatories, including magnetic sensors and acquisition systems, were initiated in 2020, and will continue until complete. The USGS has received FY2022 omnibus appropriations to support the expansion of the USGS' magnetometer network. These efforts will include increasing the number of magnetic observatories as well as utilizing lower-cost magnetic variometers to increase spatial sampling in support of space weather applications.

https://www.usgs.gov/media/images/geomag-observatory

Magnetotelluric Surveys

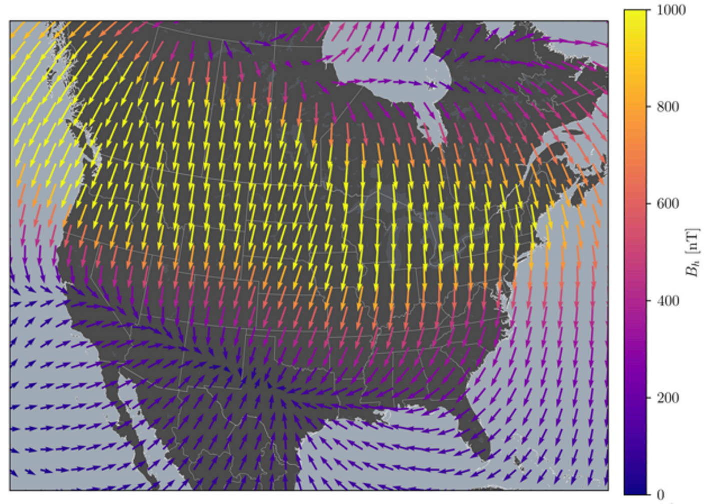


Courtesy A. Kelbert, 2021, USGS Geomagnetism Program

The USGS has been closely associated with NSF's Earthscope USArray program, which completed a gridded magnetotelluric (MT) survey of most of the northern two-thirds of the conterminous United States (CONUS), with data publicly accessible through an online database (https://ds.iris.edu/spud/emtf). Smaller regional MT surveys were used to augment USArray coverage and support specific industry needs. In FY2020, the USGS received omnibus appropriations to extend an MT survey into the southern third of CONUS, which will provide information critical for generating complete geoelectric hazard maps of the entire CONUS. This work is ongoing and being conducted through a cooperative agreement with Oregon State University.

Targeted Research

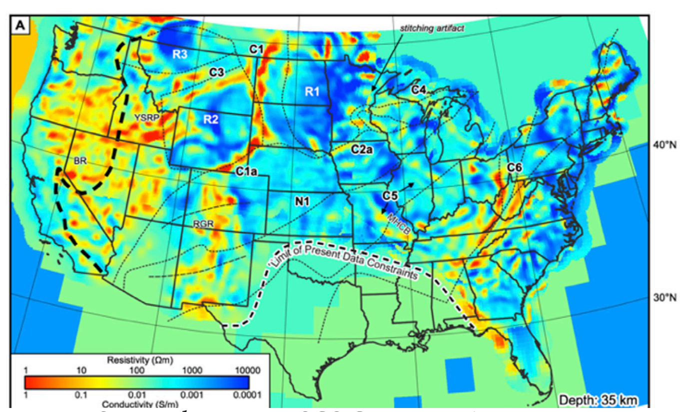
Geomagnetic Disturbance Maps



Courtesy E. J. Rigler et al., USGS Geomagnetism Program

As part of a multi-agency collaboration including NASA, NOAA, and NSF (via NCAR's High Altitude Observatory), the USGS developed and continues to update an operations-oriented Python software package for interpolating geomagnetic disturbance given sparse geomagnetic vector input observations (https://code.usgs.gov/ghsc/geomag/geomag-imp). NOAA's Space Weather Prediction Center (SWPC) incorporated this software into their gridded geoelectric field maps for CONUS.

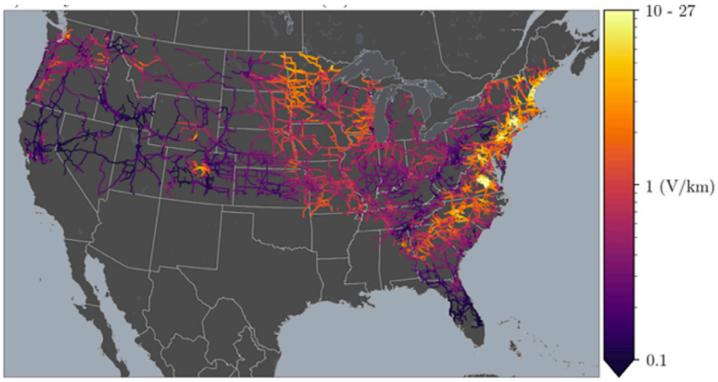
Regional and Continental Ground Conductivity



Courtesy B.S. Murphy, 2022, USGS Geomagnetism Program

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 uses all available MT 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.

Geoelectric Hazard Maps



From Lucas et al., 2020 (https://doi.org/10.1029/2019SW002329)

The USGS, in collaboration with NOAA, University of Colorado, and other partners, is working to map time-varying geoelectric fields and evaluate geoelectric hazards that are of concern for the power-grid industry. Geoelectric fields are estimated using MT surface impedances and geomagnetic disturbance. Following this approach, it is possible to calculate induced geoelectric fields over extended periods for which USGS and other geomagnetic data are available, but geoelectric field measurements are not. Relatively spatially complete extreme event statistics can be calculated for much of CONUS and projected onto the power grid to generate an industry-relevant induction hazard map. Recent and ongoing studies suggest that, for some parts of the CONUS, the USArray MT survey spacing may be insufficient, resulting in both over- and under-estimates of the true induction hazard, depending on the location.

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Des Moines Sunday Register
SECTION 2
DES MOINES, IOWA, SUNDAY MORNING, MAY 15, 1921.

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To be able to distinguish so clearly the pictures of practically every individual in a group of 1,000 people? The Sunday Register is the ONLY Iowa paper in position to print Iowa pictures so clearly.

MAGNETIC STORM CRIPPLES WIRES

STIPP ATTACKS REWARD SYSTEM IN POLICE WORK
Kelley Testifies Rewards Are Split Among All Cops on Case.

Governor Guest of Honor at Fourteenth Cavalry Review and Tournament

ADAMS THEATRE COMPANY GOES TO A RECEIVER
Active Operation to Continue With Same Bookings for Season.

NORTHERN LIGHTS, THE CINEMA OF THE SKIES, IN BRILLIANT SHOWING

CAVALRYMAN GETS FIVE YEARS IN PEN FOR THEFT OF CAR

Static "Shimmy" Most Violent in Years, Outs Nationwide Capers With Communication.

OLD CITY BASTILE COMMUNITY CENTER
Building to Be Remodeled for September Opening.

CITY IS ORGANIZED FOR HEALTH WEEK

CAR ARBITRATORS TO MEET WEDNESDAY

BODY OF T. H. MARTIN IS ON WAY BACK FROM BATTLEFIELD

Courtesy J.J. Love, 2021, USGS Geomagnetism Program

In addition, theoretical geomagnetic disturbances have been combined with CONUS MT maps to more realistically assess risk associated with electromagnetic pulses (EMP) arising from high-altitude nuclear detonations. Finally, the USGS is working to uncover and refine under-utilized historical datasets with a particular focus on intervals of extreme geomagnetic activity (for example, May 1921, and March 1989), and present these in context relevant to modern geoelectric hazard analysis.

European Liaison Report

Andrew Dimmock

This report serves as a brief status update on European missions and activities that could be important and beneficial to the GEM community.

SMILE

The Solar wind Magnetosphere Ionosphere Link Explorer (SMILE), is a joint mission between the European Space Agency (ESA) and the Chinese Academy of Sciences (CAS). Using images of the dayside magnetosphere in soft X-rays, in situ plasma measurements, and UV auroral images, SMILE will measure the solar wind and its interaction with the magnetosphere. The structural models of instruments and the spacecraft were built and are due for testing in the following months. The launch is planned for the end of 2024 with a window that extends to June 2025. For those interested to be involved in SMILE, the mission runs active modeling and ground-based working group meetings. Details can be found here: https://www.mssl.ucl.ac.uk/SMILE/

Cluster

The Cluster spacecraft (launched July/August 2000) continues to provide data. The mission is currently funded to operate until the end of 2022. However, the science case has been submitted that will extend operations until the end of 2025. This will be the final extension since the spacecraft will re-enter the Earth's atmosphere on 2024/09/08 (C2), 2025/11/04 (C1), 2026/08/21 (C3), and 2026/08/22 (C4).

Of particular interest to the community will be conjunctions with other missions. There will be multiple conjunctions with MMS at the magnetopause (2022-03-06), bow shock (2022-03-13), and the magnetosheath (2022-03-06, 2022-03-13). In addition, there will be tail various conjunctions with THEMIS and MMS across July-October 2022.

Solar Orbiter

Solar Orbiter (SolO) was launched in February 2020. SolO carries a suite of both in situ and remote sensing instruments and investigates the solar wind processes and their connection to the Sun. Data is freely available on the ESA Solar Orbiter archive (http://soar.esac.esa.int/soar/). To date, SolO has completed three perigees, two Venus flybys, and an Earth flyby. The scientific activities are coordinated by the SolO working groups, which are open and free to all levels. There are a variety of working groups focusing on in situ data, remote sensing observations, and a combination of these. Recently SolO performed its first close perihelion (around 0.33 AU), with more planned over the coming years before raising the orbit to view the polar regions. SolO also recently captured the highest ever resolution image of the corona at more than 83 million pixels. Of interest to the community is also the various alignment intervals with the Parker Solar probe and BepiColombo, which allows for additional science opportunities. There are also indications that solar activity is increasing, which means more ICMEs, shocks, and other solar wind transients are being observed that are of high interest.

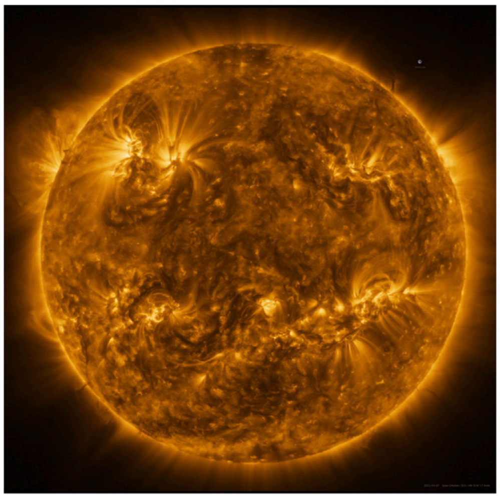


Image credit: Credit: ESA & NASA/Solar Orbiter/EUI team; Data processing: E. Kraaikamp (ROB).

BepiColombo

Many instruments onboard BepiColombo (ESA/JAXA) have been operating during the cruise phase across the inner heliosphere (0.28-0.5 AU). This has and continues to facilitate new scientific opportunities for both individual in-situ data analysis and also utilizing multi-spacecraft conjunctions with PSP and SolO. These activities were recently summarized by Hadid et al., 2021.

Swarm

The three Swarm spacecraft (launched on 22 November 2013) continue to deliver high-quality data to study the Earth's magnetic field and the ionosphere. The spacecraft are in good health with no major issues and at present, the mission is extended to the end of 2022. To get Swarm A and C over the coming solar maximum and the associated increased air drag they will be lifted, in three steps, from presently about 440 km height (above spherical Earth) to around 500 km height.

Canada Liaison Report

John Manuel

The Canadian scientific community continues its pursuit of the strategic vision, priorities, and investments described in the 2020 Canadian Solar-Terrestrial Science Roadmap. The Roadmap presents a path by which Canada, both independently and in partnership with other nations, will make strides toward the resolution of fundamental science questions relating to heliophysics, space weather, and the terrestrial and lunar space environments. Among the activities identified in the roadmap are the Geospace Observatory (GO) Canada initiative and the RADiation Impacts on Climate and Atmospheric Loss Satellite (RADICALS) mission concept, both of which have recently seen significant developments.

1. Geospace Observatory (GO) Canada

The Canadian Space Agency's (CSA's) GO Canada initiative supports the operation of arrays of 120+ ground-based science instruments deployed across Canada's North. The instruments include magnetometers (CARISMA, AUTUMN), riometers (U Calgary), ionosondes and GNSS monitors (CHAIN), radars (SuperDARN, ICEBEAR), and all-sky imagers (TREx). More than any other CSA initiative, GO Canada is recognized as being responsible for many of the national and international successes of the Canadian community. Later this year (2022), a CSA competitive opportunity is expected to provide partial support for arrays of ground-based instruments such as these, with additional funds being secured by PIs from other sources.

The CSA recently expressed its interest in developing a coordinated program for observing and understanding space weather above North America through a transcontinental network of geospace observatories. This program would bring several existing initiatives into one program and would be designed and optimized to complement upcoming international space missions, such as NASA's Geospace Dynamics Constellation mission. The CSA is consulting regularly with the Canadian community as it explores the idea.

2. RADiation Impacts on Climate and Atmospheric Loss Satellite (RADICALS)

The RADICALS mission will be a low-Earth orbiting satellite targeting the transport and loss of energetic particles from the radiation belts into the atmosphere and the subsequent potential impact of high-energy particle precipitation would be designed and optimized to complement upcoming international space missions, such as NASA's Geospace Dynamics Constellation mission. The CSA is consulting regularly with the Canadian community as it explores the idea.

2. RADiation Impacts on Climate and Atmospheric Loss Satellite (RADICALS)

The RADICALS mission will be a low-Earth orbiting satellite targeting the transport and loss of energetic particles from the radiation belts into the atmosphere and the subsequent potential impact of high-energy particle precipitation on climate. The proposed instrument payload includes high-energy particle telescopes (U Alberta), X-ray instruments (U Calgary), fluxgate magnetometers (U Alberta), and a search coil magnetometer (U Alberta). The project team includes additional ground-based array, modelling, and atmospheric and space weather partners from U Saskatchewan, Athabasca U, U New Brunswick, and Natural Resources Canada. The satellite will be based on a microsatellite bus from the UTIAS Space Flight Laboratory, making this an entirely Canadian mission. The PI, Ian Mann of U Alberta, received funding from the Canadian Space Agency, the Canada Foundation for Innovation, and the province of Alberta, and has begun concept development (Phase A). The goal is to launch in 2026.

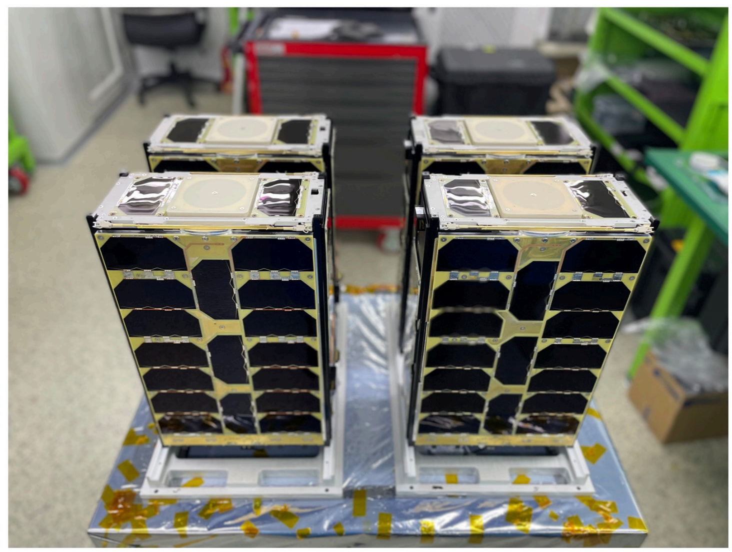
3. New Projects Developing Geospace and Space Weather Models

Also this year, PIs of 13 new, CSA-funded projects began developing and advancing a wide variety of empirical and physical models of geospace. For each project, model development is informed by coordinated data analyses aimed at capturing the new knowledge and insights in code for use in later research projects and applications. These projects investigate a variety of topics, such as how space weather affects Global Navigation Satellite Systems (GNSS) and radio wave propagation, and space weather risks to technology both on the ground as well as in orbit. Through its support of these projects, the CSA aims to advance understanding of the physical processes that generate space weather, particularly as it affects Canadians.

Korea Liaison Report

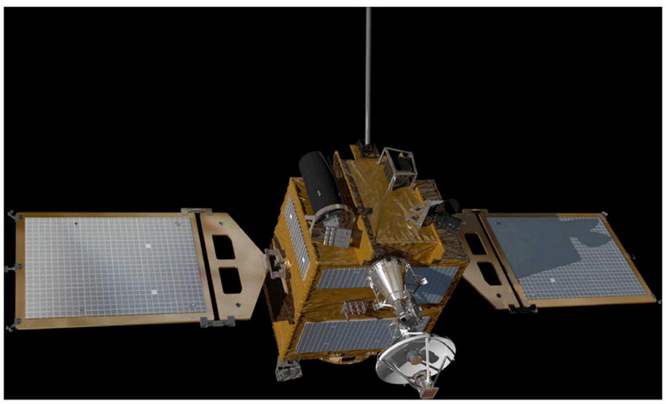
Junga Hwang

(1) KASI (Korea Astronomy and Space Science Institute) finishes the flight model development of the SNIPE (Small-scale magNetospheric and Ionospheric Plasma Experiment) mission, which consists of four nanosatellites of ~10 kg. The SNIPE mission, planned to be launched in Dec. 2022, will perform formation flying in low earth orbit (~550 km) to investigate ionospheric plasma irregularities and electron precipitation with sophisticated instruments, two Langmuir Probes, Solid State Detectors, and Fluxgate Magnetometers. The SNIPE passed a Critical Design Review (CDR) in Nov. 2019 and will be reviewed as to a Pre-Ship Review (PSR) in June 2022.



(2) The Korea Pathfinder Lunar Orbiter (KPLO) is South Korea's first lunar mission. It is developed and managed by the Korea Aerospace Research Institute (KARI) and is scheduled to launch in August 2022 to orbit the Moon for 1 year carrying an array of South Korean experiments and one U.S. built instrument. The objectives are to develop indigenous lunar exploration technologies, demonstrate a "space internet", and conduct scientific investigations of the lunar environment, topography, and resources, as well as identify potential landing sites for future lunar missions. The spacecraft has a cubic shape with two solar panel wings and a parabolic antenna mounted on a boom. The total mass is 550 kg. Communications are via S-band (telemetry and command) and X-band (payload data downlink). Power (760 W at 28 V) is provided through the solar panel arrays and rechargeable batteries. A mono propulsion system is used, with four 30N orbital maneuver

thrusters and four 5N attitude control thrusters. KPLO is equipped with five science instruments and a Disruption Tolerant Network experiment. The five experiments are a Lunar Terrain Imager (LUTI), a Wide-Angle Polarimetric Camera (PolCam), a Magnetometer (KMAG), a Gamma-Ray Spectrometer (KGRS), and a high-sensitivity camera developed by NASA (ShadowCam). Total scientific payload mass is about 40 kg. KPLO is scheduled to launch in August 2022 from Cape Canaveral on a SpaceX Falcon 9 Block 5 booster into a 300 km Earth orbit, followed by a translunar injection burn and a lunar transfer phase, bringing it to the Moon in mid-December. After capture into an elliptical lunar orbit, it will circularize to a 100 km nominal polar orbit (+-30 km), from which it will conduct science operations for approximately one year. If the mission has an extended phase, it will descend to a 70 km orbit or lower.



Japan ISAS Liaison Report

Yoshi Miyoshi

This report only concerns "GEM-related news" regarding major and recent ISAS missions.

Currently running space-physics satellites of ISAS is GEOTAIL, ARASE (ERG), Mio (BepiColombo)

1 – GEOTAIL

GEOTAIL project is now under the mission extension review, and the proposed mission period is until the end of March 2029 which covers 3 solar cycles on the 10 x 30 Re orbit.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. Arase project is now under the mission extension review, the proposed new mission period is until the end of March 2033 which covers the 25th solar cycle in the inner magnetosphere. 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 were observed until October 2019, and ~50 conjunction operations between Arase and DSX until May 2021 were realized. New collaboratons with cube-sat satellites for the inner magnetosphere and EISCAT_3D are planned. Any requests and suggestions about further conjugate observations with Arase are highly welcome. 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/index.shtml.en). 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 is developing one of the instrument packages to be onboard LAMP, including high-energy detector, aurora cameras, and magnetometer. LAMP was successfully launched from Poker Flat Research Range in Fairbanks, Alaska in March 2022. The Japanese team has also contributed to ground-based supporting observations at Alaska during the launch campaign.

4 – BepiColombo Mio

BepiColombo Mio was launched on 20 October 2018. Commissioning of the onboard instruments was completed by autumn 2019. After the Earth/Mercury Flyby, science observations during interplanetary cruise and Venus flyby were successfully operated, and conjugate observations between BepiColombo, the solar-telescope satellite Hinode, and Venus orbiter Akatsuki were performed for radio occultation measurements of the solar wind. 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). If you have any questions on Mio, please contact Dr. Go Murakami (Project Scientist): go AT stp.isas.jaxa.jp.

In Memoriam

George Siscoe

Howard Singer, William Lotko, Robert McPherron and David Sibeck

George Leonard Siscoe, Professor Emeritus of UCLA and Boston University passed away on April 9, 2022, at the age of 84. George was internationally known for his diverse and insightful contributions to space science, his abilities to explain and educate, his engaging and eloquent lectures and as a polymath who introduced our community to topics such as Universal Heliophysical Processes and links between meteorology and space weather. He was a founder and active member of the Geospace Environment Modeling (GEM) program and was the first chair of the GEM Steering Committee. In that role, and as a contributor to GEM for decades, he was well-known and appreciated for his ability to lead compromise and consensus around difficult issues, as well as his vision for science. At least three of his plenary GEM lectures can be found on the GEM wiki (https://gem.epss.ucla.edu/mediawiki/index.php/Main_Page) on topics including: Magnetospheric Modeling, The Cusp and its Role in Magnetospheric Dynamics, and From the Chapman-Ferraro Magnetosphere to the Dungey-Alfven Magnetosphere. George had the uncanny ability to frame important questions that could be used to extract new scientific insight, that would otherwise remain concealed, in the copious output of MHD models. In 1995, he led the establishment of a new link between research and operations when he co-organized a meeting at NOAA of GEMs Geospace General Circulation Model (GGCM) working group to emphasize the applied aspects of GEM. Eventually, this effort, merged with a meeting involving space weather users to form what was called the Space Weather Research to Operations Workshops and is now known as the annual Space Weather Workshop sponsored by NOAA, NASA and NSF. George was an amazing colleague, mentor, and friend to many. His wisdom, his memory, his mentorship, and his writings will guide us, and our field, for many years to come. We extend our condolences to Nancy Crooker (George's wife and long-time GEM contributor) and their entire family.

While this remembrance is focused on just a few of George's connections to the GEM community additional thoughts and memories are expressed by Nancy Crooker in the SPA SECTION NEWSLETTER,Volume XXIX, Issue 27, April 28, 2022.

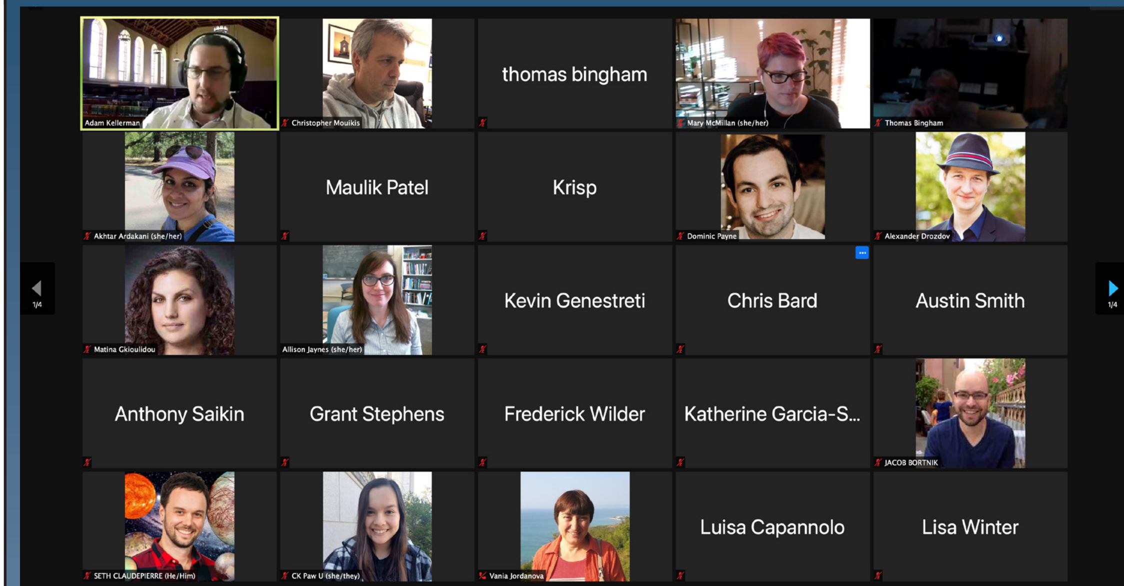
VGEM 2021 Photo Gallery

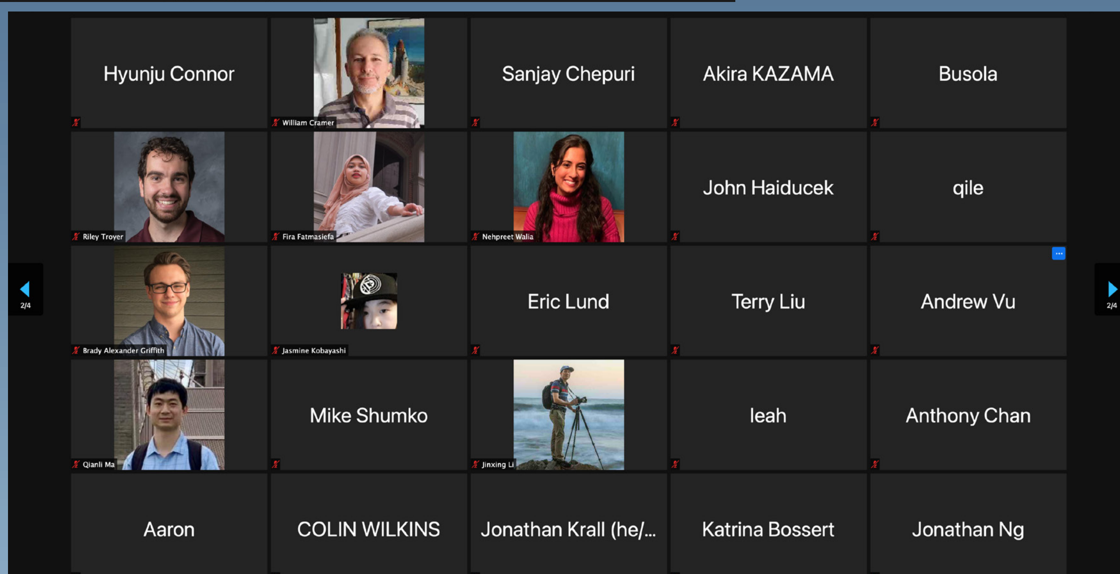
Student Day!

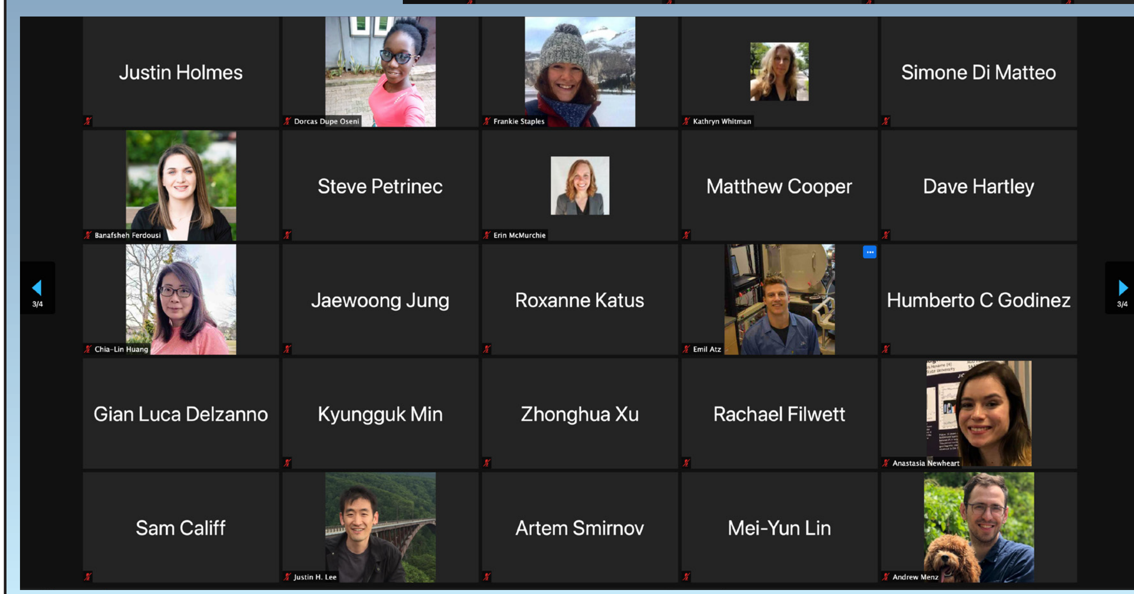
Lots of conversations with Lisa in the NSF office hour

Dance party on the beach (soon to happen IRL in Honolulu)

VGEM 2021 Photo Gallery



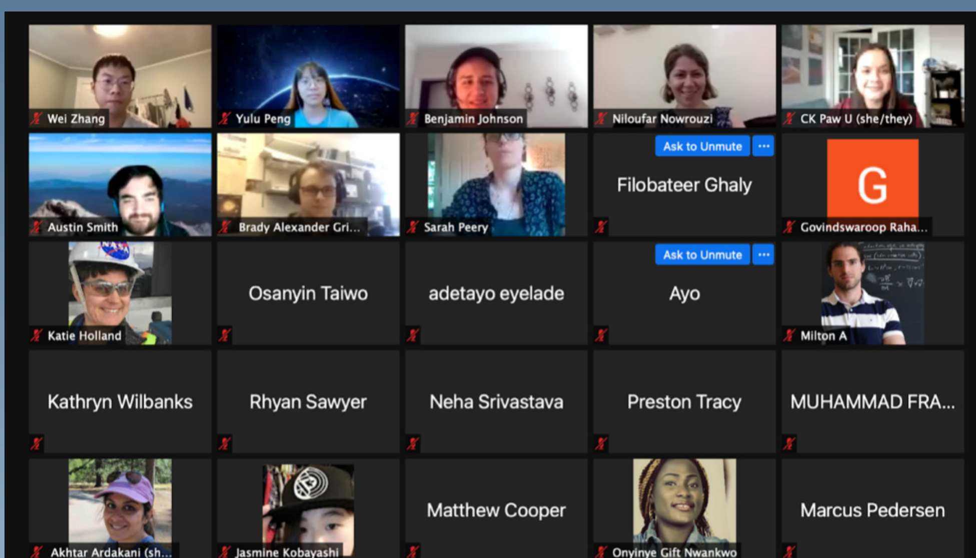




Participants at the SBCCI session on mental health in academia

VGEM 2021 Photo Gallery

Student Day & Student Rep Elections



GEM Steering Committee

NSF GEM Program Officers
- Chia-Lin Huang
- Lisa Winter

Steering Committee (Voting Members)
- Vania Jordanova (Chair, 2020 - 2022)
- Adam Kellerman (Vice Chair, 2020 - 2022 - Rising Chair)
- Ian Cohen (2021 - 2025, At-Large 1)
- Allison Jaynes (2018 - 2022, At-Large 2)
- Yihua Zheng (2019 - 2023, At-Large 3)
- Lynn Kistler (2019 - 2023, At-Large 4)
- Research Area Coordinators (see below)
- Meeting Organizers (see below)

Steering Committee (Liaison Members)
- Ying Zou (Liason to CEDAR)
- Joe Borovsky (Liaison to SHINE)
- Masha Kuznetsova (Liaison to CCMC)
- Jesse Woodroffe (Liaison to NASA)
- Howard Singer (Liaison to NOAA)
- James McCollough (Liaison to AFRL)
- Josh Rigler (Liaison to USGS)
- Andrew Dimmock (Liaison to Europe)
- Laura Morales (Liaison to Argentina)
- Brian Fraser (Liaison to Australia)
- John Manuel (Liaison to Canada)
- Chi Wang (Liaison to China)
- Yoshizumi Miyoshi (Liaison to ISAS, Japan)
- Jaejin Lee (Liaison to Korea)
- Xochitl Blanco-Cano (Liaison to Mexico)
- Lou Lee (Liaison to Taiwan)
- Thomas Elsden & Jasmine Sandhu (Liaison to MIST/UK)
- Lutz Rastaetter (Liaison for Metrics and Validation)

Meeting Organizers
- Chris Mouikis (2018 - present)
- Jing Liao (2022 - present)

Student Representatives
- Mei-Yun Lin (2020 - 2022)
- Elizabeth Vandegriff (2021 - 2023)

Research Area Coordinators
Solar Wind - Magnetosphere Interaction (SWMI, previously known as Dayside)
- Steve Petrinec (2015 - 2022, RAC-1A)
- Brian Walsh (2018 - 2024, RAC-1B)

Magnetotail and Plasma Sheet (MPS, previously known as Tail)
- Chih-Ping Wang (2018 - 2023, RAC-2A)
- Kevin Genestreti (2021 - 2025, RAC-2B)

Inner MAGnetosphere (IMAG, previously known as IMS)
- Raluca Ilie (2018 - 2023, RAC-3A)
- Lunjin Chen (2021 - 2025, RAC-3B)

Magnetosphere – Ionosphere Coupling (MIC)
- Hyunju Connor (2018 - 2023, RAC-4A)
- Sarah Vines (2021 - 2025, RAC-4B)

Global System Modeling (GSM, previously known as GGCM)
- Alex Glocer (2015 - 2022, RAC-5A)
- John Lyon (2018 - 2024, RAC-5B)

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 Chair's Chat Blog:
https://gemchairschat.home.blog/

GEM Focus Groups

Focus Group	Duration	Co-Chairs	Associated Research Areas				
			SWMI	MPS	IMAG	MIC	GSM
Magnetotail Dipolarization and Its Effects on the Inner Magnetosphere (DIP)	2017 - 2023	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, Doğacan Öztürk, Gang Lu, Bin Zhang				*	⁎
Magnetic Reconnection in the Age of the Heliophysics System Observatory (RX)	2018 - 2024	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 - 2025	Gian Luca Delzanno, Natalia Buzulukosva, Barbara Giles, Roger Varney, Joe Borovsky			*		
Self-Consistent Inner Magnetospheric Modeling (SCIMM)	2020 - 2025	Cristian Ferradas, Chao Yue, Jacob Bortnik, Qianli Ma			*	⁎	
Understanding the causes of geomagnetic disturbances in geospace for hazard analysis on geomagnetically induced currents (GIC)	2022 - 2026	Xueling Shi, Dogacan Su Ozturk, Mark Engebretson, Zhonghua Xu, E. Joshua Rigler				⁎	*
Mesoscale drivers of the nightside transition region: ionospheric and magnetotail evaluations (MESO)	2022 - 2026	Bea Gallardo-Lacourt, Gareth Perry, Emma Spanswick, Yari Collado-Vega, Bashi Ferdousi		*		⁎	
Magnetospheric Sources of Particle Precipitation and Their Role on Electrodynamic Coupling of Magnetosphere-Ionosphere-Thermosphere Systems (MPEC)	2022 - 2026	Dogacan Su Ozturk, Dong Lin, Yiqun Yu, Katherine Garcia-Sage, Stephen Kaeppler				*	⁎

Links to Focus Group pages and past Focus Groups can be found here:
https://gem.epss.ucla.edu/mediawiki/index.php/GEM_Focus_Groups

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

* - Primary research area
⁎ - Secondary research area