Pre-Helio 2050 Workshop: Magnetosphere-Atmosphere Interactions

LINK TO MIRO VIRTUAL WHITEBOARD:

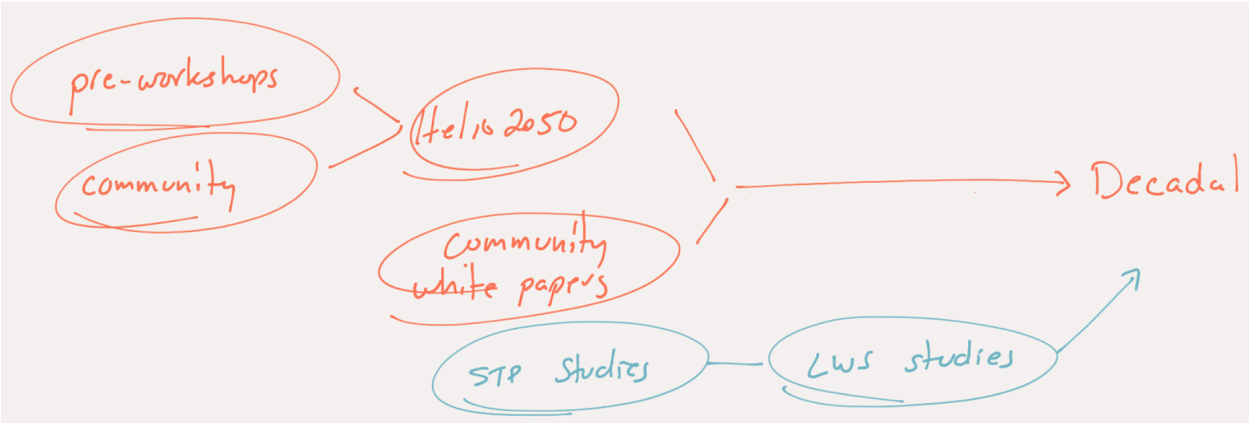
https://miro.com/welcomeonboard/XbQAnp7NyfRJCTpbXyzZnpOdTqSlcQeBqTGteE8mc1CdmTpPrWYXdwYe2w6K66OE

Contents (click to jump)

Background

As part of various meetings leading up to the Heliophysics 2050 workshop (May 3-7), we are hosting a special series of sessions to discuss the exoplanetary magnetospheres, ionospheres, and atmospheres. Our hope is to develop the compelling science questions that should be answered by 2050. The goal of these sessions will be to synthesize the scientific priorities in this field and discuss ways in which transformational research can come about from interdisciplinary study between Helio and the other science divisions. The results of these sessions will be available to the community for possible use during the Heliophysics 2050 session: Expanding the Frontiers (May 6th). This activity will hopefully facilitate connections for White Papers to be written as input to the upcoming Heliophysics Division Decadal Survey.

Decadal Process Overview (from Larry Kepko):



Meeting Schedule
Meeting #1 (students, post-docs and 5 years post-degree only): Thursday, April 8th, 2021 from 3:30-5pm Eastern Time
Registration link:
https://uiowa.zoom.us/meeting/register/tJwofuqhqjotEtYEjj_QBk7uxD3kNPVd8ysd

Meeting #2 (open to all): Tuesday, April 13th, 2021 from 1:30-3pm Eastern Time
Registration link:
https://uiowa.zoom.us/meeting/register/tJElfuCvrzsjHtMUrZznXVkeVTgveryZypEL

Meeting #3 (open to all): Friday, April 23rd, 2021 from 2:30-4pm Eastern Time
Registration link:
https://uiowa.zoom.us/meeting/register/tJIuduqhqzgpHNWY_aDDuM8Q-LOV4T9IuA-v

Meeting Guidelines

- Be respectful of all attendees - no interrupting, talking over, disparaging comments, etc.
- Follow 'yes, and..' strategy for responding during the conversation
- Let's have more of a discussion than a series of monologues (don't monopolize the conversation)
- Feel free to use chat, edit google doc and/or have side conversations as we go
    - Can return to this Google Doc at any time, during meetings, prior or after - feel free to share with others and contribute to the discussion
- We are thinking **thirty years down the road** - not what will happen next year or next MIDEX call. How can we build toward a unified, long-term vision?

Open Questions
What are the big open questions/mysteries regarding the impacts of particle precipitation on our atmosphere? (Think of impacts directly - so not simply what causes the precipitation but how that cause might be tied to some effect in the atmosphere.)

(Allison) The effects of EPP (energetic particle precipitation) on the mesosphere, lower thermosphere means that space weather has a direct impact on terrestrial weather and climate systems. Need to quantify and understand this link. Modeling together with observations.

(Grant) What are the spatial scales of EPP? How can we use that info to better understand what drivers affect precipitation, and how can those scales affect atmospheric response? (Can EPP scale size be used as a proxy for wave activity in the magnetosphere?)

(Brian Harding) How does particle precipitation cause and/or regulate atmospheric escape?

(Cora Randall) What are the mechanisms that redistribute energy from EPP throughout the atmosphere? What roles do planetary and gravity waves from below play in controlling the response of the mesosphere, thermosphere, and ionosphere to EPP?

(Lynn Harvey) To what extent do spatial and temporal variations in EPP and in the polar vortex affect atmospheric impacts? i.e., is the atmosphere-magnetosphere system more geo-effective when high EPP regions overlap the longitude/latitude of the polar vortex?

(Katrina Bossert) Aurora generates gravity waves. GWs redistribute energy deposited as well as particles themselves. From troposphere up to 300-400 km.

(Xiaohua Fang) To what extent do the EPP effects in the lower thermosphere, mesosphere, and stratosphere have a feedback to the magnetosphere? The feedback at high altitudes through ionospheric conductance regulation is known, but it is unclear how the climate change resulting from EPP effects at low altitudes impacts the magnetosphere.

(Allison) Meso-scale EPP from diffuse aurora: how much of a contribution is this? The fluxes are low, but can extend over large distances and persist for long times so integral effect may be very significant. Recent results shows electrons up to relativistic energies can be included in types of diffuse precipitation like pulsating aurora.

(Kris) Different auroral characterizations - what kind of precipitation comes along with these “new” forms of aurora? What kinds of processes other than precipitation can cause visible emissions, such as instabilities of local ionospheric currents, thermal ionospheric electrons? E.g. STEVE, FAE (https://doi.org/10.5194/angeo-39-277-2021), picket fence aurora. Feedback, cause of emissions, what implications comes along with that.

(Austin) How do EPP events modify the aeronomy and temperatures in the polar regions and on global scales?

(Rafael Mesquita) How does particle precipitation and substorms affect the individual neutral atmospheric forcing terms in the E- and F-regions? (modeling results are available, but observations are sparse)

(Mike Shumko) How can we use ground-based observations (imagers, magnetometers, radars, VLF, etc.) to remote sense radiation belt dynamics? (Alexa) don’t forget riometers and balloons!

(Mike Shumko) How can we globally observe, model, and predict how solar wind pressure pulses drive wave growth and the subsequent precipitation? OR How can we globally observe, model, and predict how solar wind pressure pulses drive wave growth and the subsequent precipitation? (Furthermore, what particle energies are scattered? For example, 1 MeV electrons drift in 15-20 minutes, and they see all of these waves along their drift trajectory).

(Bruce Fritz) Are there any atmospheric effects that provide feedback to the magnetosphere and/or its drivers? Do any specific atmospheric conditions have an impact on how we perceive magnetospheric impacts, and to what degree are they relevant (neutral density, winds, etc)?

(Ashley Greeley) What energy ranges are feeding into the lower atmosphere effects? Interesting to look across the broad range rather than focusing on several keV or multi MeV

(Sarvesh Mangla) Radio interferometers have also been used to study and characterize the ionosphere as they have better sensitivity than many instruments like GNSS. Can a radio telescope be used to detect geomagnetic storms in great detail? (Jacob) Space weather tie-in.

(Adam Kellerman) What are the long-term climatological effects of EPP on the atmosphere - solar cycle to solar cycle.

(Kris Sigsbee) Wave propagation through the lower altitudes down to what we observe on the ground from ULF pulsations and EMIC waves up to radio waves (radio frequencies, open to citizen science, HamSCI community?)

(Robyn) System-level observations that aren't being utilized right now. Long-term outlook. Meso-scale and large-scale observations - how can that lead to better understanding. (Steve) Need to understand the effects through campaigns or experiment before using the distributed measurements.

(Steve Kaeppler) How does precipitation affect conductivity that then feeds back to the M-I system (in terms of electrodynamics / precipitation), and the atmosphere below? (How that plays a role in closing FACs)

(Jacob) Need to figure out how multiple interactions of different plasma waves create the precipitation that we observe. Nonlinear vs quasilinear scattering. Better handling on the scattering efficiencies/rates. Time domain structures too.

(Joe) EPP → conductivity channel to low altitudes (50 km), shorting the E field. Integrated effects on the atmosphere over large region.

(Todd) atmospheric driving of EPP → Mostly thinking about lightning whistlers causing pitch-angle scattering in the radiation belts, but what about other terrestrial or atmospheric sources? Possibly anthropogenic sources? (Kris) sferics.

(Aaron) - overall size and properties of microburst regions. Small regions (~1 hr MLT) don't produce significant e- loss on storm timescale but larger regions (~3 hrs) do (e.g. Bret Anderson's work using BARREL and satellites) (Jacob) precipitation regions in general (what creates scale sizes (e.g. auroral structures)?). (Drew) extended MLT regions or curtains, and Lauren's precipitation bands. Sudden flashes - dumping into BLC, and almost none into the DLC. → has effects on all regions

(Mike Shumko) EPP on atmospheric chemistry - do 100s keV have an impact? There are relatively less more energetic particles, but they scatter deeper in the atmosphere (definitely)
(Cora) Particles with energies > 300keV are not generally included in the models, WACCM, etc. yet

(Yihua) What about the 'middle child' of SEPs? Protons!!! Also, space weather.

(Bob Marshall) Pitch angle distinction is important (and see comment by Seth below)

DRIVERS vs. EFFECTS

(Lindsay Goodwin) What is the link between solar parameters and EPP? (or more broadly, the links between solar parameters and anything in the ITM system are still mysterious)

(Nithin) Changes in conductance - affect everything from substorms, to upwelling/outflow

(Doug Rowland) To what extent does low-altitude ring current charge exchange / precipitation serve as a significant energy source for the mid-latitude thermosphere?
(Doug Rowland) To what extent do upper atmospheric discharge (and high tropospheric discharges like TGFs) impact the atmosphere at mesosphere / D-region ionosphere altitudes? To what extent are TGFs and related phenomena sources for energetic radiation (probably secondary / pair production electrons and positrons from the gamma rays that make it to higher altitude?) To what extent do energetic particles from the magnetosphere / solar / cosmic ray sources modify electrical discharge phenomena in the stratosphere and troposphere? Great questions - need to incorporate

(Drew) Radiation dose from aircraft flights down to 11km altitude attributed directly to radiation belt electrons (above GCR/SEP 'background'), even during quiet times (2<L<7) - SWW presentation, Kent Tobiska, AET

DEFINITIONS

(Doug Rowland) -- in this context, what is the "E" in "EPP"? Are we mostly considering particles to be "energetic" based on their source, or on their impact? The atmosphere responds very differently to ions vs. electrons -- and the altitude where the particles interact / deposit energy is strongly energy dependent. A lot of the conductivity and related discussions (E- and F-region) are due to "auroral" energy particles. Are we focusing in this group on higher energy (pulsating aurora, radiation belt / microburst, ring current charge exchange? Or all the way down to "superthermal"?

(Allison) For this discussion, I was planning to focus primarily on the energetic particles that can affect D-region and lower, but it's true that lower "auroral energy" can still contribute to

atmospheric impacts since the chemistry can be circulated to lower altitudes and thus end up affecting the atmosphere. So that needs to be included in sub-questions or related topics.

(Doug) Sounds good -- this is an area (energetic particles that can affect D-region ionosphere / mesosphere and lower) that is getting some (but limited) amount of discussion in the ITM and magnetosphere groups.

Overall Science Goals

What do we want to accomplish within the timeframe of 30 years from now? Can we phrase these goals to be compelling to both Helio and Earth (and even Planetary!) sciences? This will be the distillation of our Open Questions above.

(Austin) Can we encourage spacecraft constellation missions for simultaneous wide-coverage polar observations? For planetary sciences, a typical argument for funding is to tie the target planet to Earth as an analogue; perhaps there could be discussions about setting up polar missions to other planets with atmospheric probes? Also, emphasizing the important feedback loop between modeling, remote observations, and in-situ measurements may create more involvement.

(Mike Shumko) To understand the coupling across energies and populations in the magnetosphere and ionosphere to uncover the impact that these populations have on the atmosphere. For example, the plasmasphere, ring current, and the radiation belts are co-aligned but are often treated independently. However, as an example, the electron number density in the plasmasphere controls how effectively chorus waves scatter radiation belt electrons.

(Ravinder) Talking about radiation belt electron scattering, how effective are chorus waves in this process ? Do other wave modes play a similar role with equal effectiveness ? Kinetic-scale vs. global (ULF) waves. FLC scattering.

Vision Statement

Construct a vision statement that can serve as a guiding force for white papers, future proposals, advocacy, etc. An overarching theme or motif can be helpful for boosting this science.

(Austin) Perhaps we could emphasize the need to include multiple disciplines to gain different perspectives and a more thorough understanding of EPP effects. For example, “Be interdisciplinary to explore all facets.”

Challenges
What do we need to overcome to accomplish the stated goals? Are there structural barriers to achieving a truly interdisciplinary science?

(Allison) Barriers at funding agencies
(Cora) For example, NASA SMD separation of earth science and heliophysics. Artificial barriers exist, but they are being transcended more and more. NASA prioritizes team science, interdisciplinary, etc.

(Katie Garcia-Sage) And Planetary. These topics are highly relevant to exoplanet community - also an opportunity.

(Lynn) Fundospheres and fundopauses don't make sense in system science!

(Allison) Barriers due to specialization: jargon, siloed science, data access

(Ashley) Funding availability for untested instruments, even on low cost missions. Communication between related fields.

(Bob Marshall) This is a particular problem in Heliophysics. LCAS is too small a program to enable new instrument concepts. It would be great to have a PICASSO/MATISSE-like track in Helio.

(Seth) To measure EPP and resolve some of the noted science questions unambiguously, you really need pitch-angle resolved particle measurements from a high LEO orbit (~1500 - 2000 km). High LEO is very important anything below that and you are mostly in the drift-loss cone.

(Bob) Space debris and re-entry challenges
(Gang) In addition to pitch-angle resolved energy spectra, we also need comprehensive MLT/MLAT coverage of EPP measurements with sufficient temporal cadence in order to use the data in coupled atmospheric models such as WACCM and other GCM models.

(Aaron) Related to the above comment, GTO launch opportunities for CubeSats are really needed. These can include "dipper" type missions that sample high LEO.

(Jacob) sacrificial cubesats to low LEO - nice vertical profiles out of this

(Doug) dipping to 120 km -- but not an instantaneous / localized "vertical profile -- typically 10 degrees of latitude (1000 km horizontally) for 10 km of altitude near perigee

(Kris) simultaneous measurements, conjunction measurements, SmallSats bigger than CubeSats - more capacity for fuel and payload, but smaller than a SMEX

(Robyn) mapping! (Joe) this is being worked on at equatorial latitudes

(Aaron (based on Robyn's comment)) Making better use of existing data sets (e.g. for comprehensively studying M-I coupling) as well as creation of new datasets required for system scale studies.

(Nithin) In 30 year time scales, the funding landscape could substantially change (for the worse), perhaps it is important to consider clarify and publicize the importance of EPP from the perspective of climate, sub-orbital flights, near-Earth space travel to the wider scientific community, policy makers, and the public.

(Grant) To add on to mission/data availability, how can we get more energetic particle or wave instruments onboard other missions, as ride-along opportunities. Tech development to make smaller, cheaper (in both $ and SWAP-size, weight, power) instruments would go a long way in motivating these opportunities.

(Grant) Also, how can we use existing data in new and creative ways, using cross-disciplinary data sets, etc. (using background noise on unrelated sensors as a proxy for energetic particle measurements, e.g.) *how to get funding for ^, and other high-risk type proposals like this

(Grant) (slightly unrelated) As we discover new phenomena, naming them using descriptive names versus naming them after the discoverers (also an issue of equity and academic in-fighting) (thinking of Peterson, Birkland currents, etc.)

(Nithin) Recognizing that definitions (like EPP ranges) are for communicating what we mean, rather than strict limits. We have to keep in mind that everything is a coupled system, and our definitions of different events are just for convenience & communication. Though this is not a scientific challenge, I think it really affects the future direction and fruitfulness of the research we do.

(Lindsay, paraphrasing a bunch of people) We need to promote better collaborations.
-This can be done by holding dedicated sessions for collaborations.
- AGU also is a good platform for interdisciplinary collaborations, and they just need to improve their scheduling
- Funding agents want collaborations, but have issues funding it (we need to fix these issues)
- We need to create more programs like CaNoRock (literally putting a bunch of people who barely know each other in a tiny hut in the middle of nowhere has created some very excellent collaborations and research results) (Allison) US version of CaNoRock is being worked on!!!

(Jacob) We talk a lot but don't necessarily understand each other (between disciplines).

(Ryan McG) the fact that interdisciplinary work/innovation is slower at first (adopting new approaches requires longer initial time), and funders/universities seldom have patience for the needed spin-up period

---

Opportunities

What opportunities exist that we can leverage or build on? We can start here to strategize about Decadal white papers.

(Ashley Greeley) - AGU may be a natural place to tagup (Allison) Will it be in person though?

- Session at AGU: SM/SA with Earth Science/Atmosphere
- AGU Chapman? mini-Chapman?
- (Katrina) Educational session with overlapping communities - 2-hour session
- (Seth)
- (Kris) Setup a collaborative space at AGU meetings (similar to AGU SciComm dedicated space, or tutorial room for the IGY 50th anniversary activities at AGU meeting) - where science topic, data set, & tools tutorials, etc. will be held to reach out beyond narrow discipline; EPO materials available; drop-in hours with NASA personnel, industry, & academic partners who can provide advice to potential PIs on proposing CubeSats, sounding rockets, other LCAS projects.

(Austin) With so many conferences and symposia having remote options, this is a great way to get involved in any/all opportunities: GEM, CEDAR, URSI, COSPAR, AGU, etc. It would be incredibly beneficial for all future meetings to include remote options for a wider collaboration environment, allowing participation even for those with little funding support.

(Ryan Dewey) Comparative planetary/magnetospheric opportunities. We should leverage the diversity of solar system objects (and the folks that study them) to contextualize and understand terrestrial processes. For example, Mars has rich multi-point datasets (both orbital and ground-based) and occupies a unique parameter space (induced magnetosphere, different solar wind conditions, different atmospheric properties). Mercury is the counterpoint - with precipitation but not atmosphere.

(Lindsay) We need to re-evaluate how we collaborate with tech industries (e.g. SBIR) and work more cohesively with them. We really need to start addressing what they and society needs, rather than just collaborating with them to get what we want.

+ (Frankie) Two way communication channels so scientists can understand which research the industry stakeholders want investigated.

Special issues + funding for interdisciplinary studies + PhD summer school

University-level departments - P&A + earth science + atmospheric science - cohesive

(Austin) Be more clear about vocabulary and terms used so different disciplines can still understand each other

(Sam) - A simple way to begin collaborations could be invited in-person (when possible) seminars. Aside from the seminar there could be a day of discussions between the speaker and members of the host department/group. Could be a focus on inviting cross-disciplinary speakers. This has worked really well in previous experiences. This could also be done virtually.

Thinking of something smaller scale than a full seminar series, to allow more detailed discussions and higher likelihood of making a lasting connection/collaboration. (Allison) Great idea! Will incorporate to poster.

(Grant) Leveraging more R2O (Research to Operations) and O2R (Operations to Research)-type funding opportunities from EPP's more anthropological-focused impacts (satellite damage, airline radiation, climate change, etc.)

`(Nithin) Funding the spaces in between different disciplines. [Allison, please edit this]

Related Helio 2050 posters and white papers
Helio 2050 poster on particle precipitation effects on the atmosphere - will include some ideas from this document.
Sign on as co-author if you'd like to be included (poster draft to be linked when available):
https://docs.google.com/document/d/14LZwTSvPwAqYYfIep2zgkIBr5mEaOWXJZ9r4WB5MDDg/edit

<<Add more things here if you want to!>>

Not directly related Helio 2050 activities

Not directly related:
Posters that are getting formed for Helio 2050 as a Community, focusing on representation, accessibility, DEI themes, etc. Feel free to join on as co-author to any or all:

An Open-Access Community: Why we need to prioritize our scientific environment as a welcoming space
https://docs.google.com/document/d/1Kopjksrla_NUNw88jIe3Zq2me3c2Bv8iQGkIqEYRCBk/edit

2050 - Enabling and advancing scientific innovation through cultivating a collaborative, inclusive, diverse, and safe community culture
https://docs.google.com/document/d/1AQ89LuCt-GMmgxP3A3JhUo8POJD9-DizZx6teMAHAFo/edit