Auroral Science with Heterogeneous Datasets

Cedar 2024
Friday 14 June 2024
10am-noon, Westcoast Room

Agenda

1. Shared Presentations, 10-11:30:
   a) Heterogeneous data products
   b) Scientific output
   c) Data infrastructure
2. Moderated Discussion 11:30-noon

Heterogeneous Data Products

ILLINOIS INSTITUTE OF TECHNOLOGY

Comparative Hypothesis Testing of Auroral L-Band Scintillation Layer

Gytis Blinstrubas[1] (gblinstrubas@hawk.iit.edu), Alex English[1], David Stuart[1], Don Hampton[2], Leslie Lamarche[3], Toshi Nishimura[4], Seebany Datta-Barua[1]

[1]Illinois Institute of Technology, Chicago, IL, USA, [2]University of Alaska Fairbanks, Fairbanks, AK, USA, [3]SRI International, Menlo Park, CA, USA, [4]Boston University, Boston, MA, USA

Background/Instrumentation

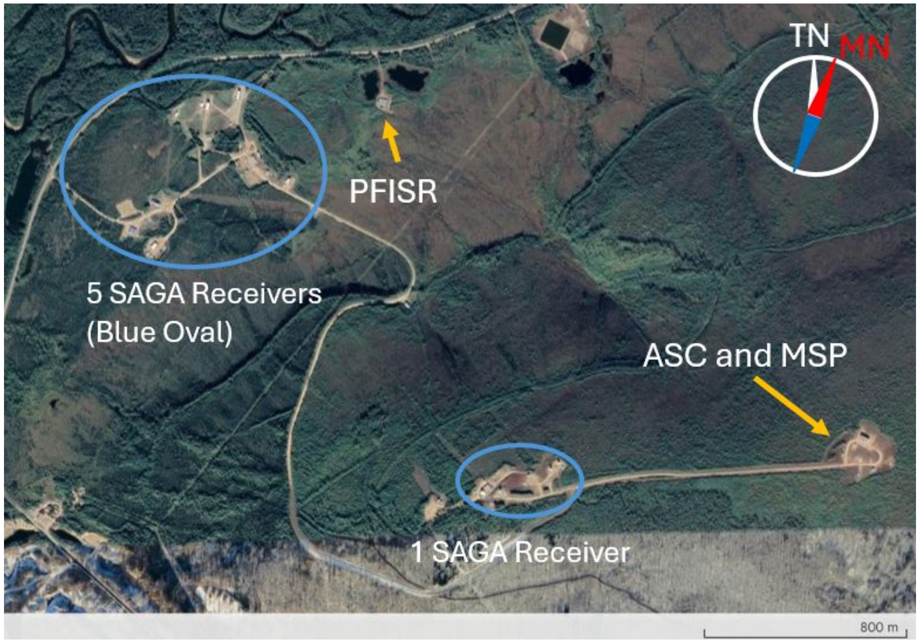


Figure: Location of instruments at Poker Flat Image Modified from Google Earth

- Scintillation Auroral GPS Array (SAGA) detects when scintillation occurs (Sreenivash et al., 2020)
- ~5000 event detected

Density Based Method

- Sreenivash et al. 2020 hypothesize where peak electron densities occur is where the scattering layer is likeliest to be
- Use Poker Flat Incoherent Scatter Radar (PFISR) to measures electron densities

Energy Based Method

- Auroral light emission can also be used to predict the scattering layer
- All-sky Cameras (ASC) measure emission related to particle precipitation

Methodology

Density Based Method

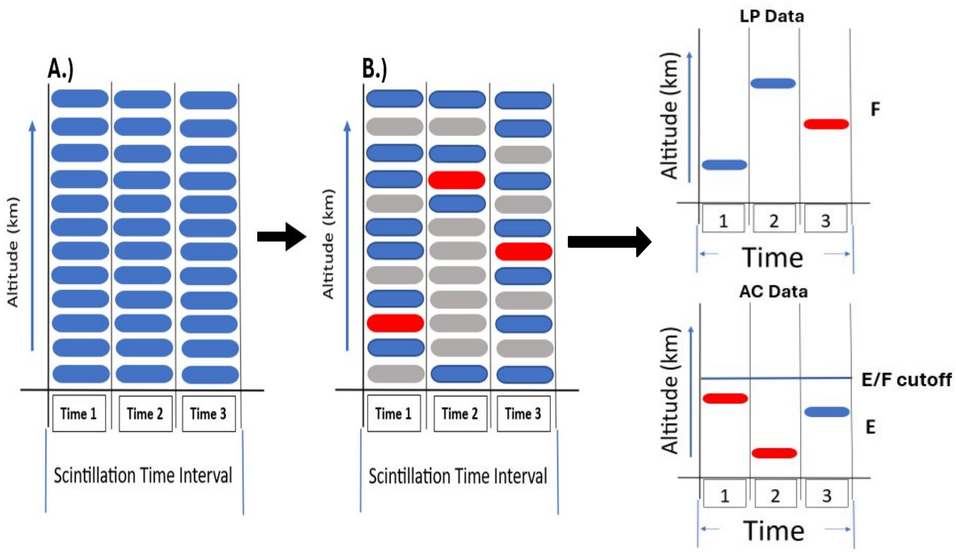


Figure: Cartoon of data filtering due to uncertainty criteria. Red ovals (max densities), gray ovals (data filtered out due to large uncertainties)

Energy Based Method

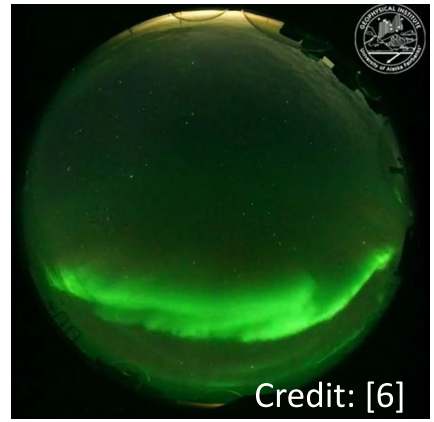


Figure: Image using an all-sky imager

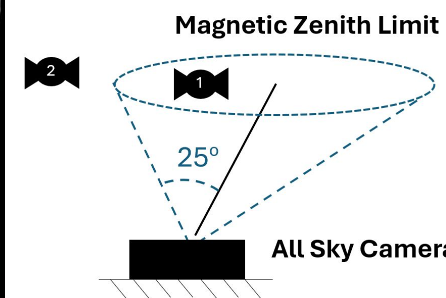


Figure: Remove satellites not within magnetic zenith limit

$$\rho_{630/428}(t) = \frac{M_{630.0}}{M_{428.0}}$$

- Use the ratio of the ASI red image (630.0 nm) pixel intensity to the blue (428.0 nm) pixel intensity
- Red/Blue ratio of 1.35 corresponds to E/F region cutoff of 135 km

Results: Comparison of Density to Energy Based Method

- Survey 174 events from 2014-2018
- Includes L1 and L2C signal
- PFISR ASI Agree 74% and disagree 26%
- Majority of scintillation occurs in E region

Total Events =174 Layer Designation		Density Based	
		E	F
Energy Based	E	114 (65%)	26 (15%)
	F	19 (11%)	15 (9%)

Table: Comparison of density-based method to energy-based method

Concluding Remarks

- Updated the density-base method to more accurately predict irregularity layers
- Used the all-sky imager to predict irregularity layers due to precipitating electrons
- **Scintillation likeliest to occur in E region**

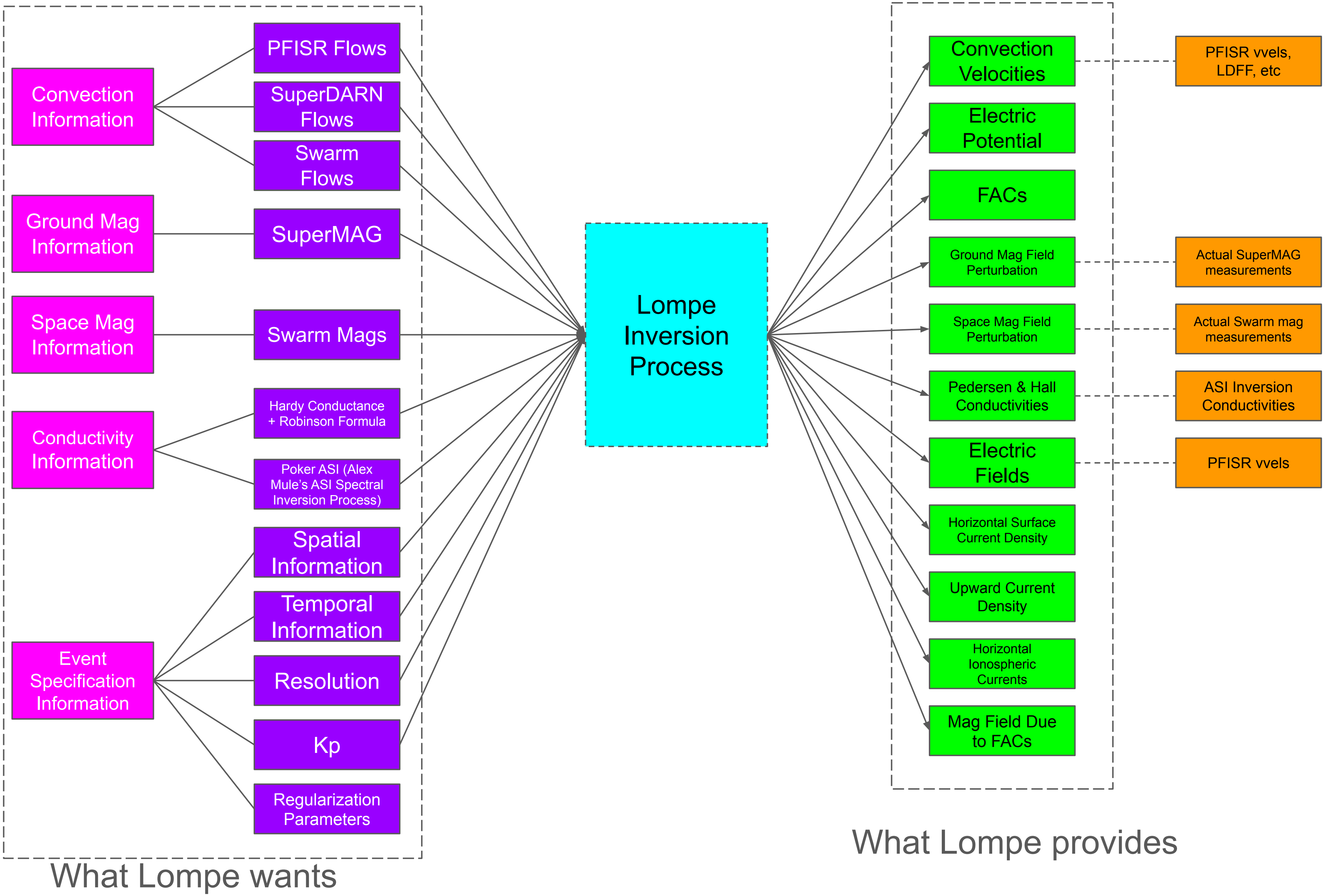
Acknowledgments

NSF AGS-1651465 and NASA award 80NSSC21K1354 supported this work.
CEDAR Student Travel Support, ISR Workshop travel support.
Vaishnavi Sreenivash, Yang Su, Pablo Reyes
PFISR Data Accessed: http://cedar.openmadrigal.org/, https://data.amisr.com/database/
ASI Data Accessed: ftp://optics.gi.alaska.edu/PKR/

References

[1] Su, Y., S. Datta-Barua, G. S. Bust, and K. B. Deshpande (2017), Distributed sensing of ionospheric irregularities with a GNSS receiver array, Radio Sci., 52, 988–1003, doi:10.1002/2017RS006331.
[2] S. Datta-Barua, P. Llado, and D. L. Hampton (2021), Multiyear detection, classification and hypothesis of ionospheric layer causing GNSS scintillation, Radio Science.
[3] Sreenivash, V., Su, Y., & Datta-Barua, S. (2020). Automated ionospheric scattering layer hypothesis generation for detected and classified auroral GPS scintillation events. Radio Science, 55, e2018RS006779. https://doi.org/ 10.1029/2018RS006779
[4] English, A., Stuart, D. J., Hampton, D. L., & Datta-Barua, S. (2024). Automated Nighttime Cloud Detection Using Keograms when Aurora is Present. Earth and Space Science, 11. doi:10.1029/2022EA002808
[5] The Poker Flat Incoherent Scatter Radar (PFISR). AMISR Radar. Retrieved: Mar. 2023. https://amisr.com/amisr/about/about_pfisr/
[6] Hampton, D. (2024) Optics. http://optics.gi.alaska.edu/optics/
Scintillation data for saga can be found at: http://apollo.tbc.iit.edu/~spaceweather/live/?q=SAGA
[7] Space Weather Prediction Center. (2024). Aura Tutorial. Retrieved from https://www.swp.noaa.gov/content/aurora-tutorial (accessed: 06.04.2023)

Hayley Clevenger (ERAU), LOMPE



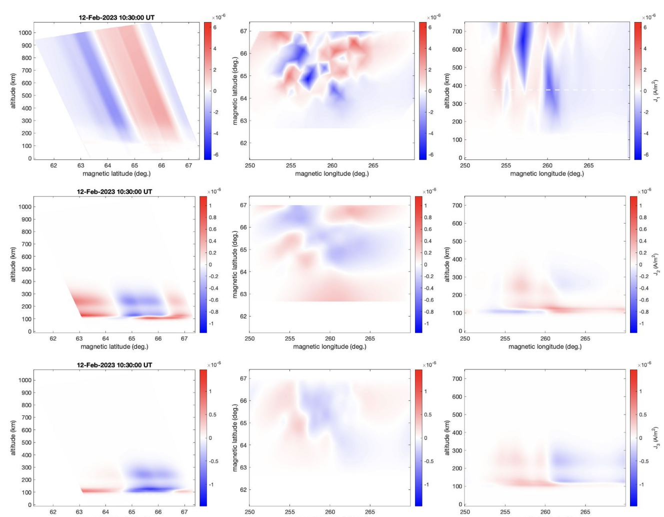
Hayley Clevenger (ERAU), LOMPE

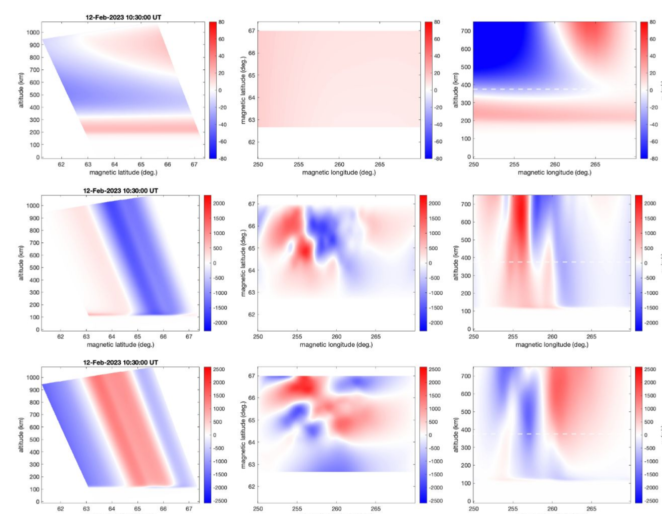
What Lompe automatically provides:

- 2D map default plots
- netcdf files of all discussed quantities, tied to specific locations (glat, glon) and times (datetime)

What you can do with it:

- Use as a means of assimilating large data sets
- Use as model inputs



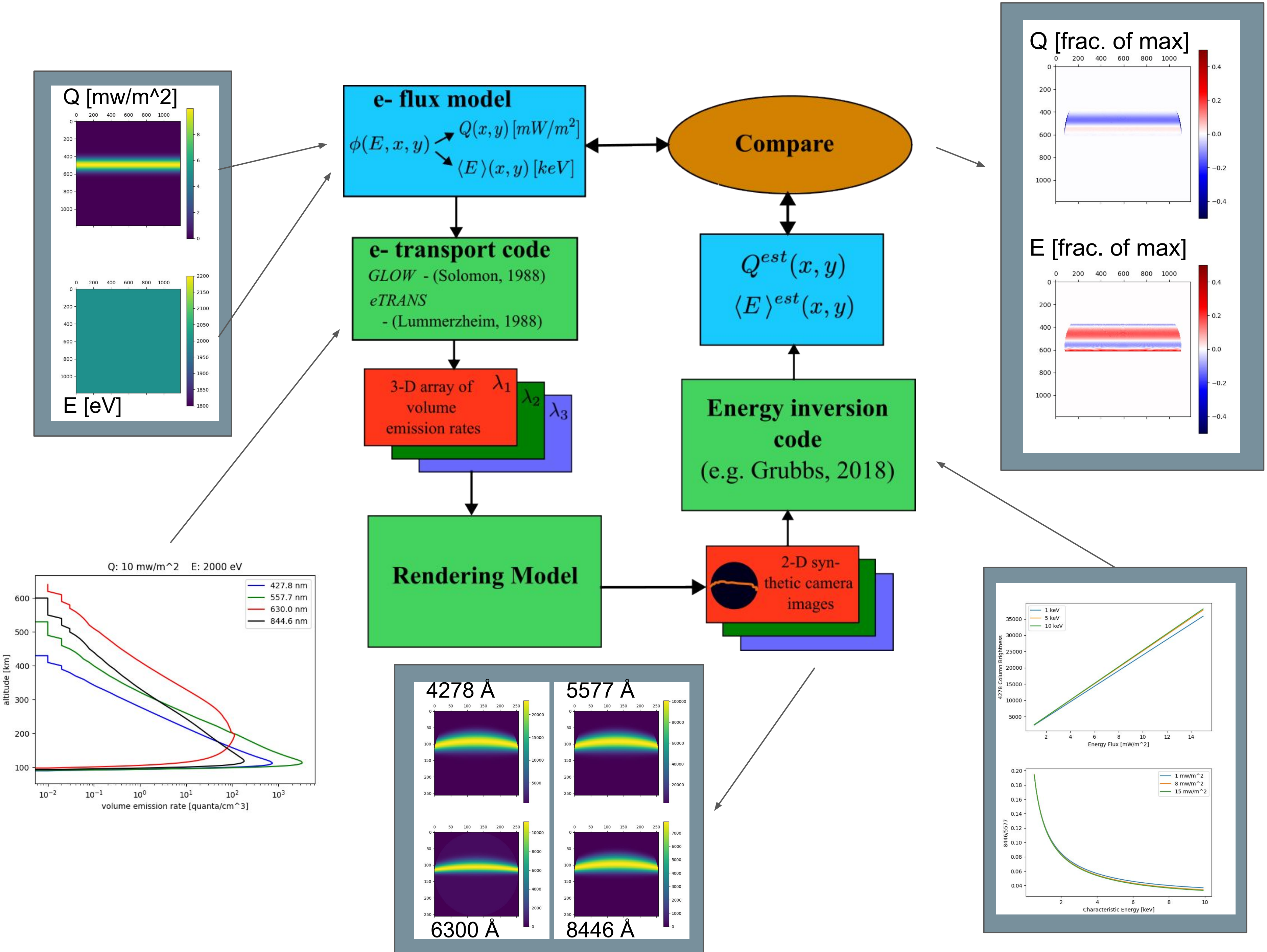


Andrew Pepper, Instrument fielding at Poker

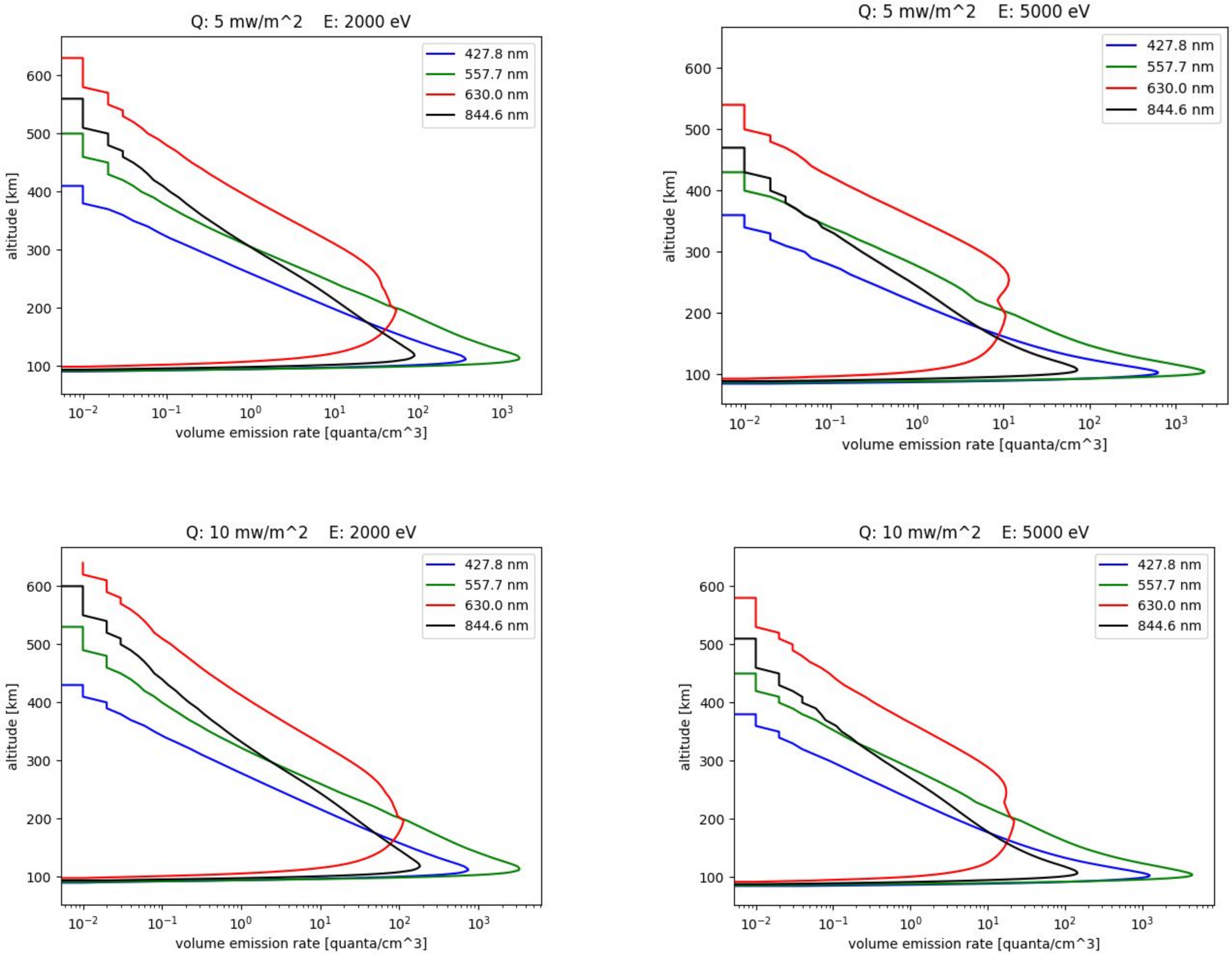
NSF CAREER Award – Rapid HF Sounders at PFRR

- How do temporal changes in the average energy and energy flux of the pulsating aurora precipitation affect the conductivity?
- Address this partially by deploying HF sounders at Poker Flat Research Range (in addition to other assets)
  - Digisonde Ionosonde demonstrated could collect 10s sweeps over limited frequency range during LAMP sounding rocket mission
  - HF sounders are "Juha style" pseudorandom code sounders to "fill in" the ionosonde sweeps
    - 4 frequencies (to be determined between 4-8 MHz) that will be transmitting nearly continuously
    - 4 receivers co-located at PFRR
    - Deployment nominally in summer of 2025
- Will be a potential other transmission of opportunity if other instrumentation deployed in field.
- P.S. – Sorry I am not there, but feel free to contact me: skaeppl@clemson.edu

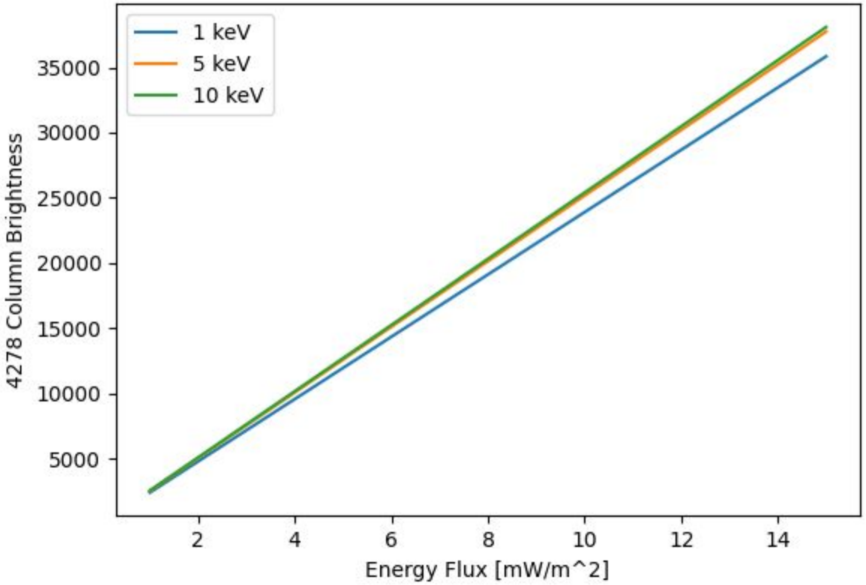
Geometric impact on optical inversions

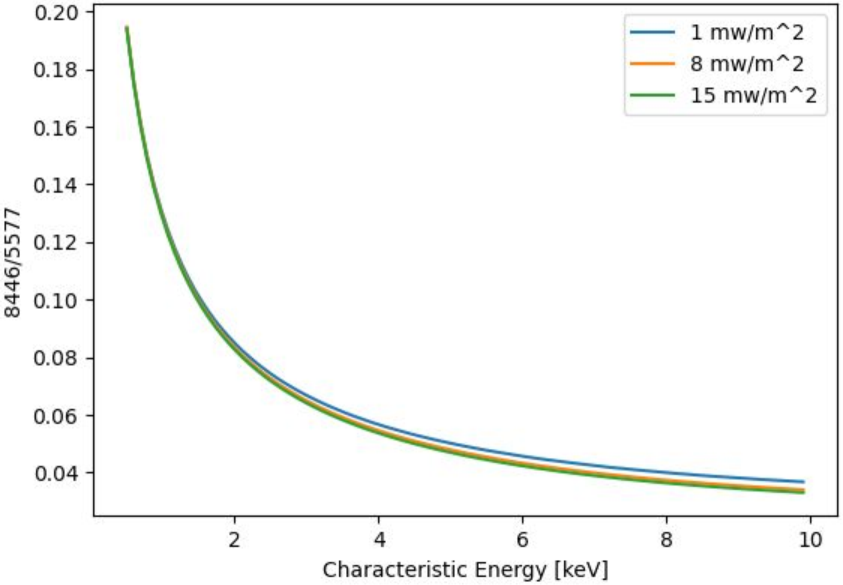


Geometric impact on optical inversions



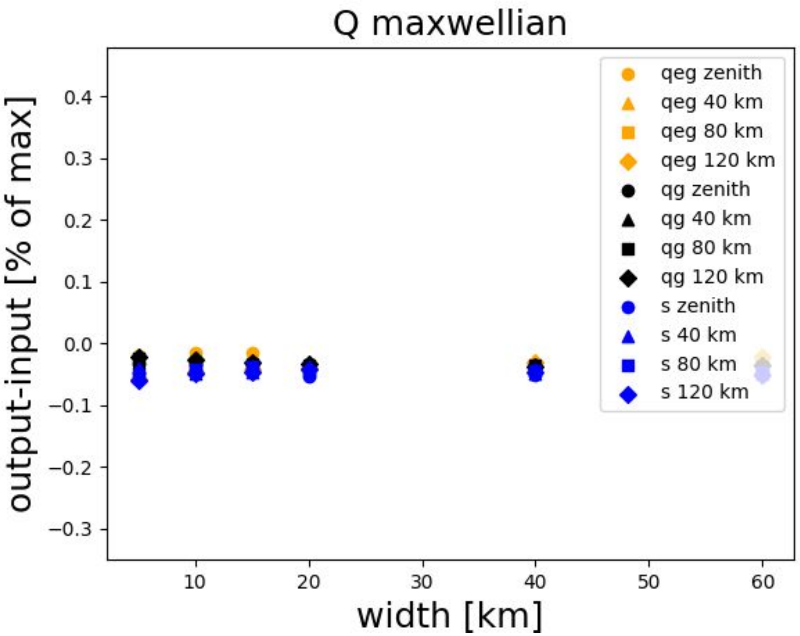
Geometric impact on optical inversions

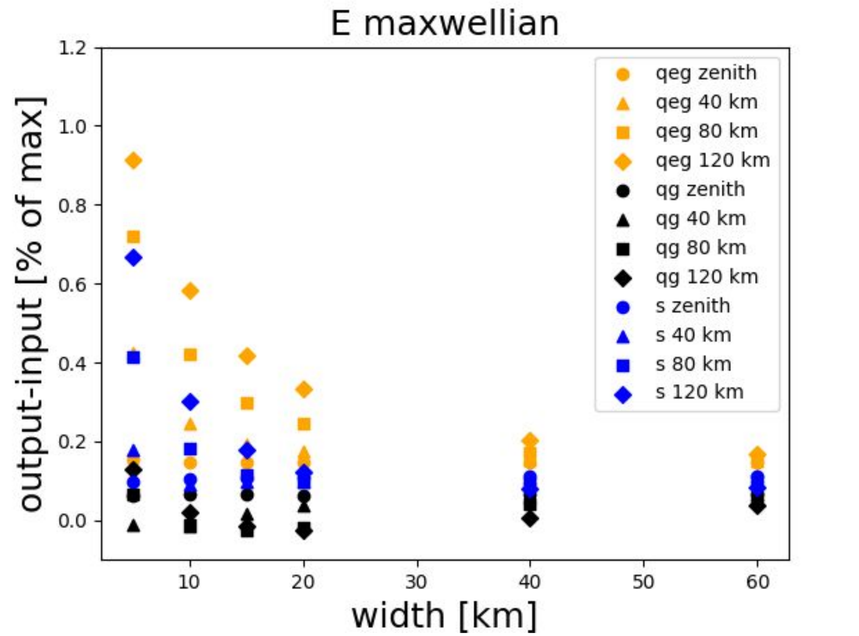




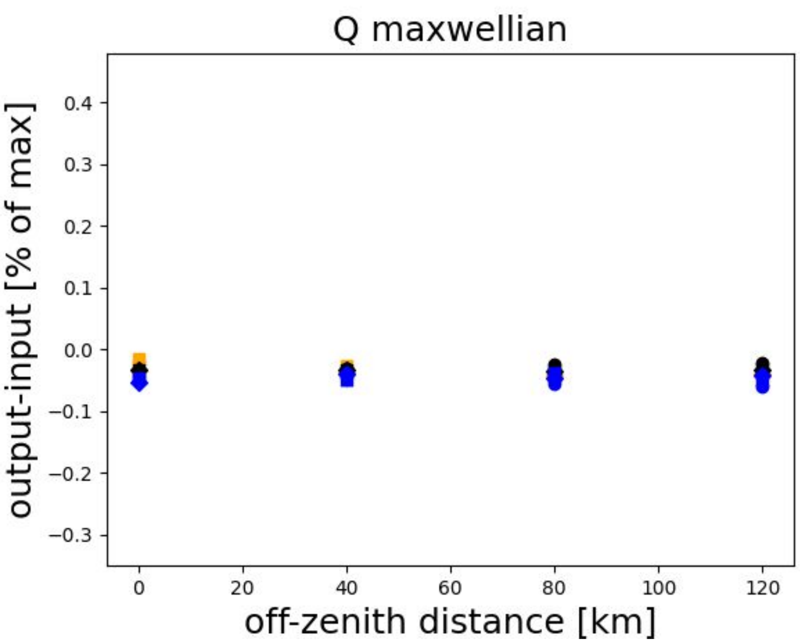
Geometric impact on optical inversions

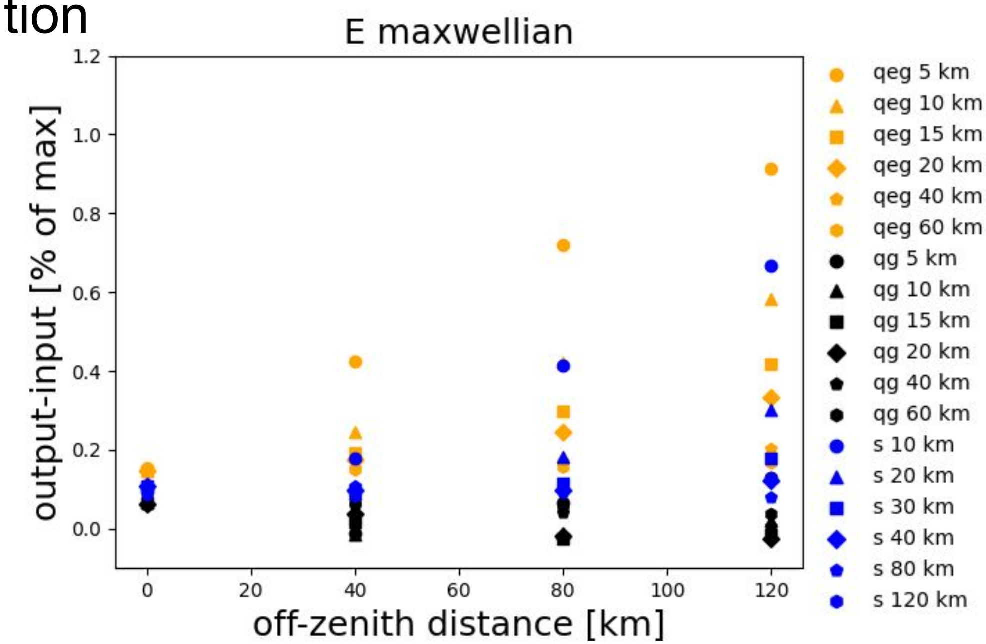
Width

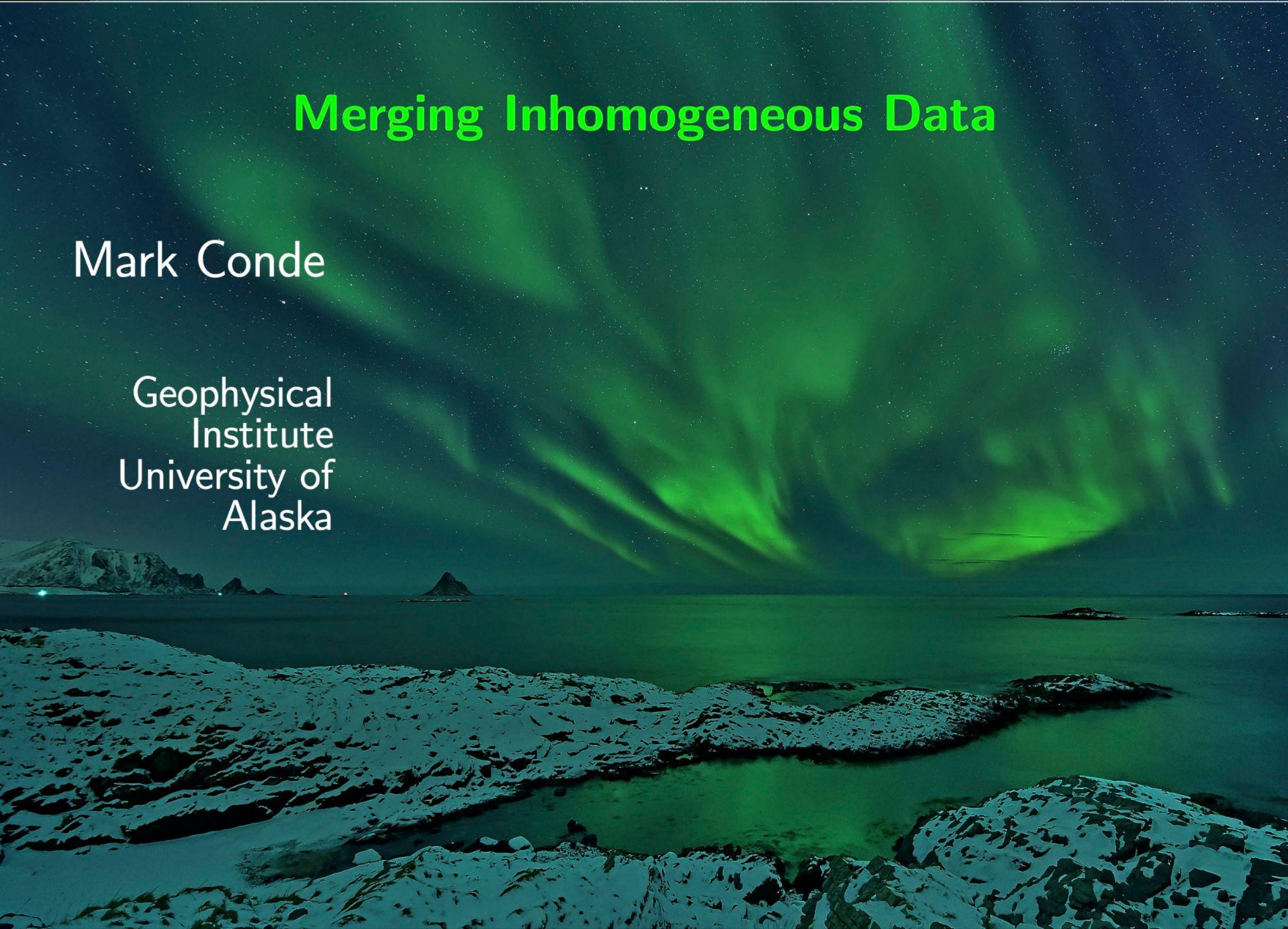




Position





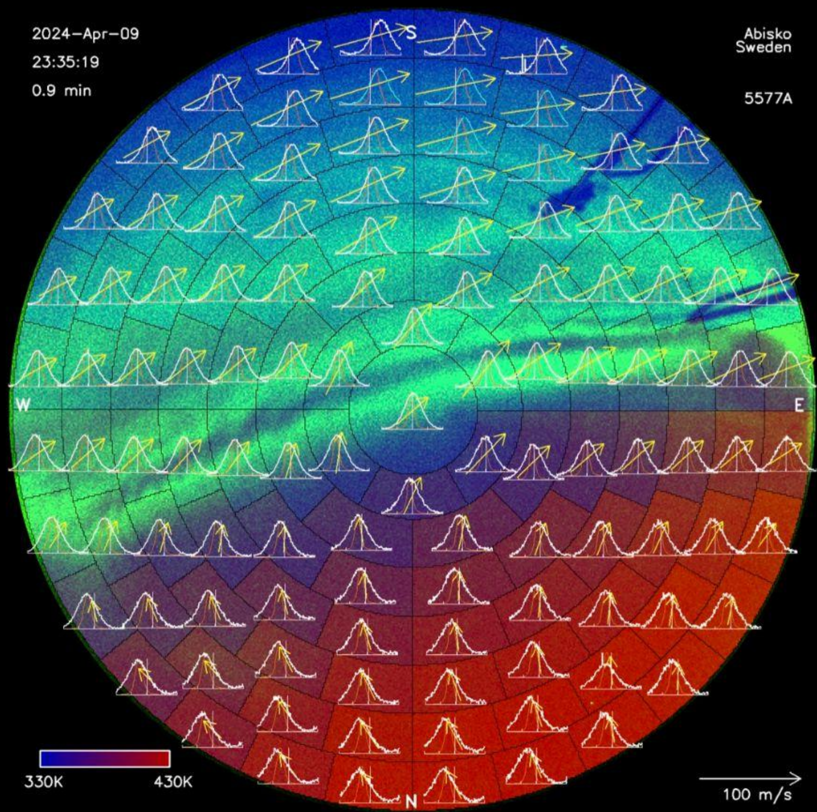


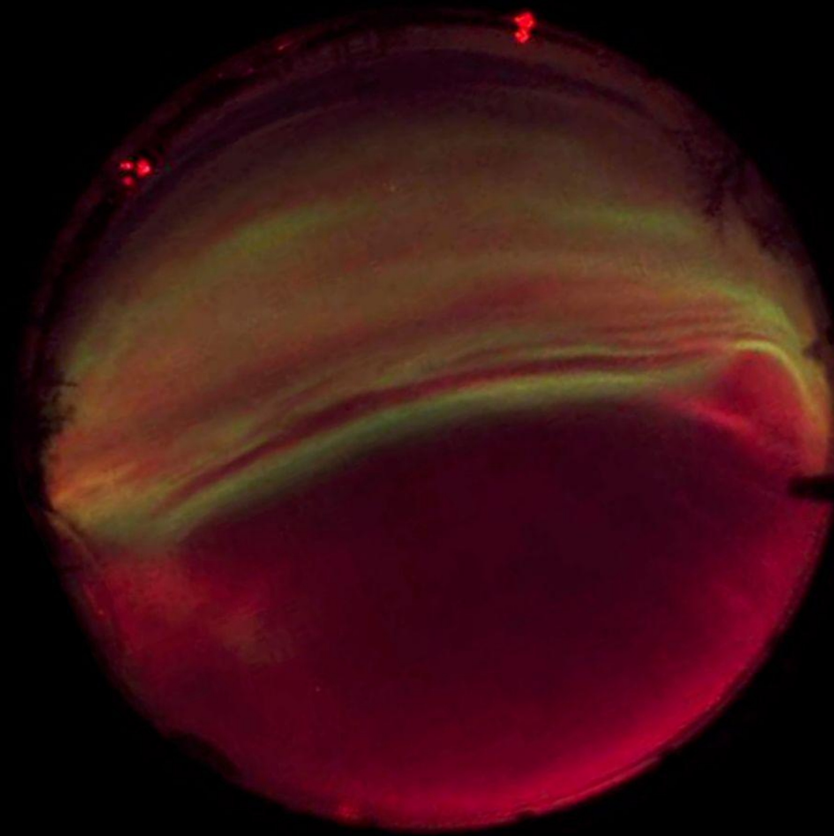
Merging Inhomogeneous Data

Mark Conde

Geophysical Institute
University of Alaska

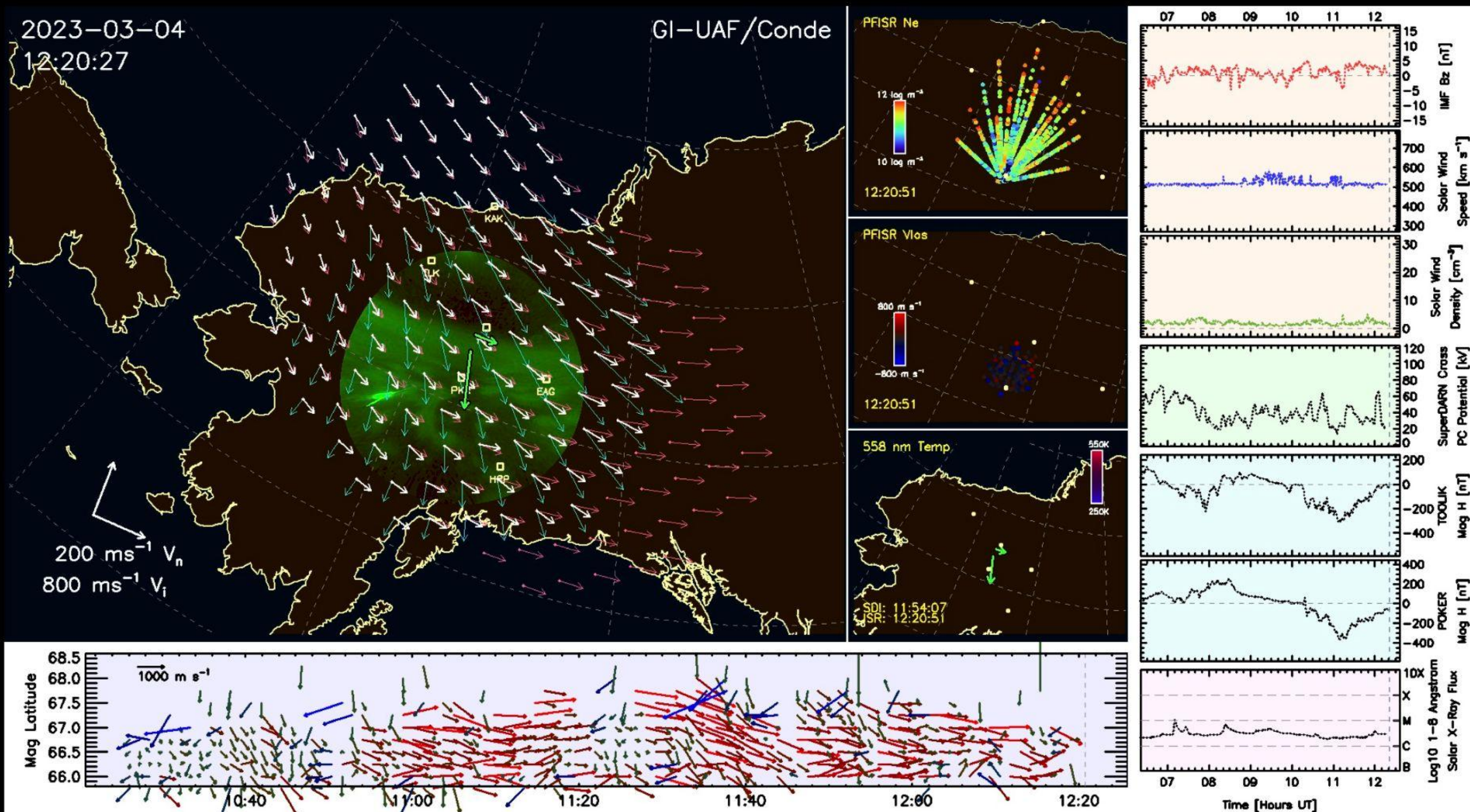
SDI and ASI Data from Abisko Sweden





Earth limb image adapted from https://www.universetoday.com/wp-content/uploads/2009/09/SED_wall_1920x1200.jpg

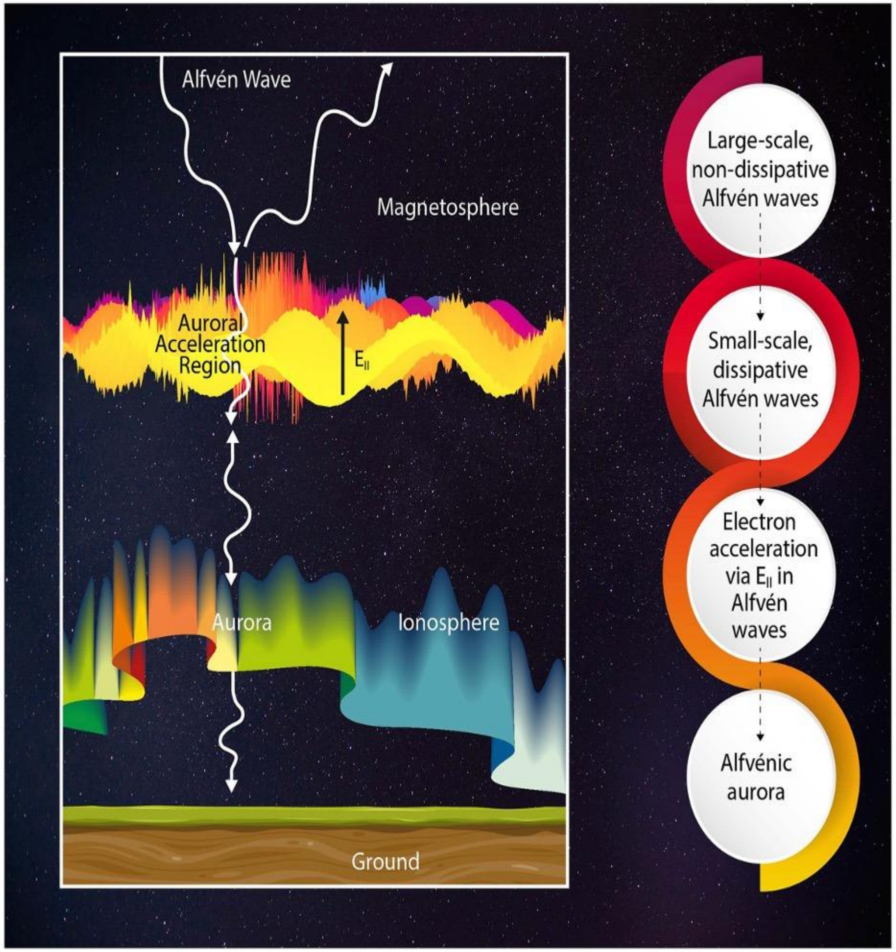
Alaskan Inhomogeneous Data



Earth limb image adapted from https://www.universetoday.com/wp-content/uploads/2009/09/SED_wall_1920x1200.jpg

First-Light 'Sentry' SWIR Imager Observations from Poker Flat, AK Spring 2024

J. Meriwether, M. B. Cooper, A. Gerrard, C. Mutiso (NJIT); M. Zettergren (ERAU); and X. Lu (Clemson Univ); D. Hampton (UAF); T. Trondsen, D. Wyatt, C. Unich (Keo Scientific, Ltd.), P. Sherwood (ITI)

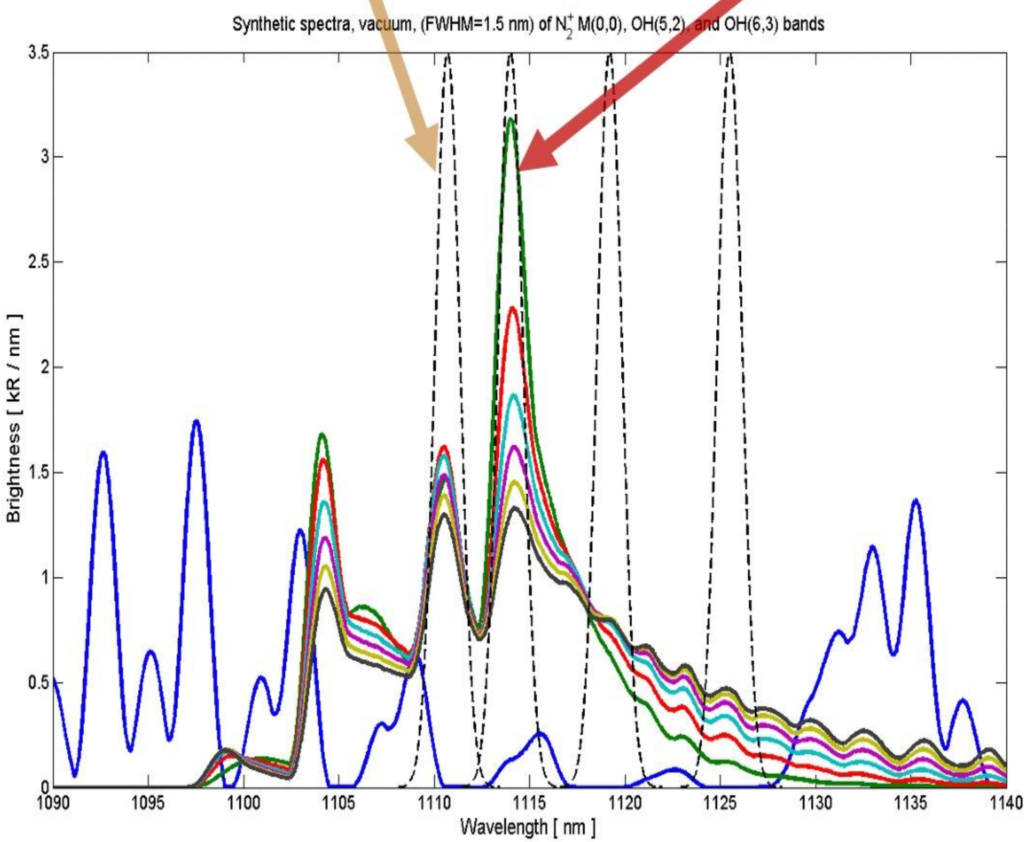


Short Wave InfraRed Imager Science Open Science Questions

- What are the relative contributions of mono-energetic electron precipitation versus magnetospheric Alfven waves in the generation of various types of auroral forms?
- What is the variability in metastable helium emission at 1083 nm during cases of active geomagnetic disturbances?
- What is the meridional gradient associated with the He winter bulge and how does it depend on geomagnetic activity?

Imager Specifications and Temperature Recovery Methodology

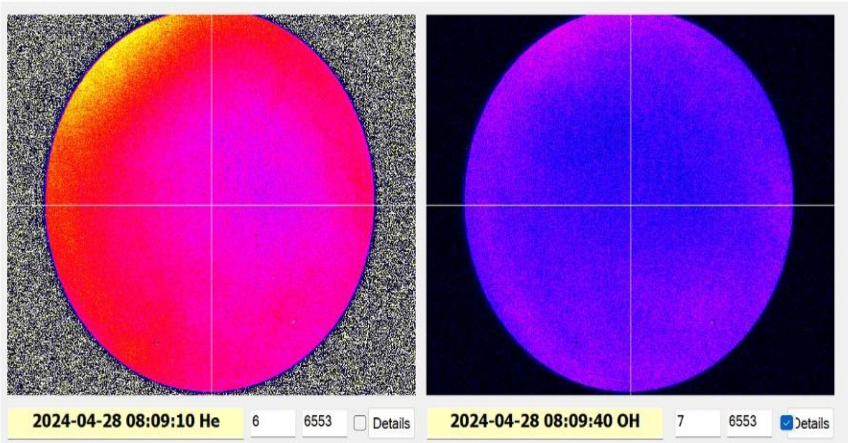
As the rotational temperature of the nitrogen 0-0 band increases, the 'Head' band signal decreases while 'Tail' band signal increases.



- Funded by DURIP 2023 award from AFOSR
- Manufactured by Keo Scientific, Ltd.
- High quantum efficiency in 900 nm to 1.700 nm range
- Low dark and readout noise for such a detector

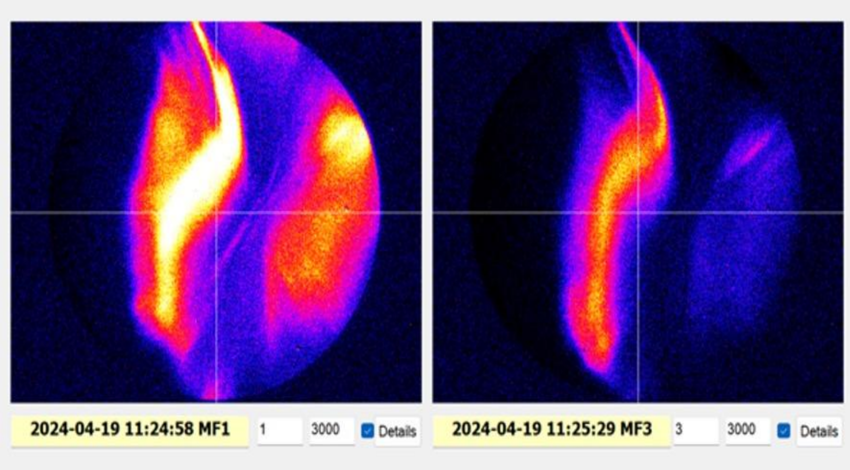
Results of Alaskan First Light Campaign at Poker Flat

April 28th, 2024



He Filter

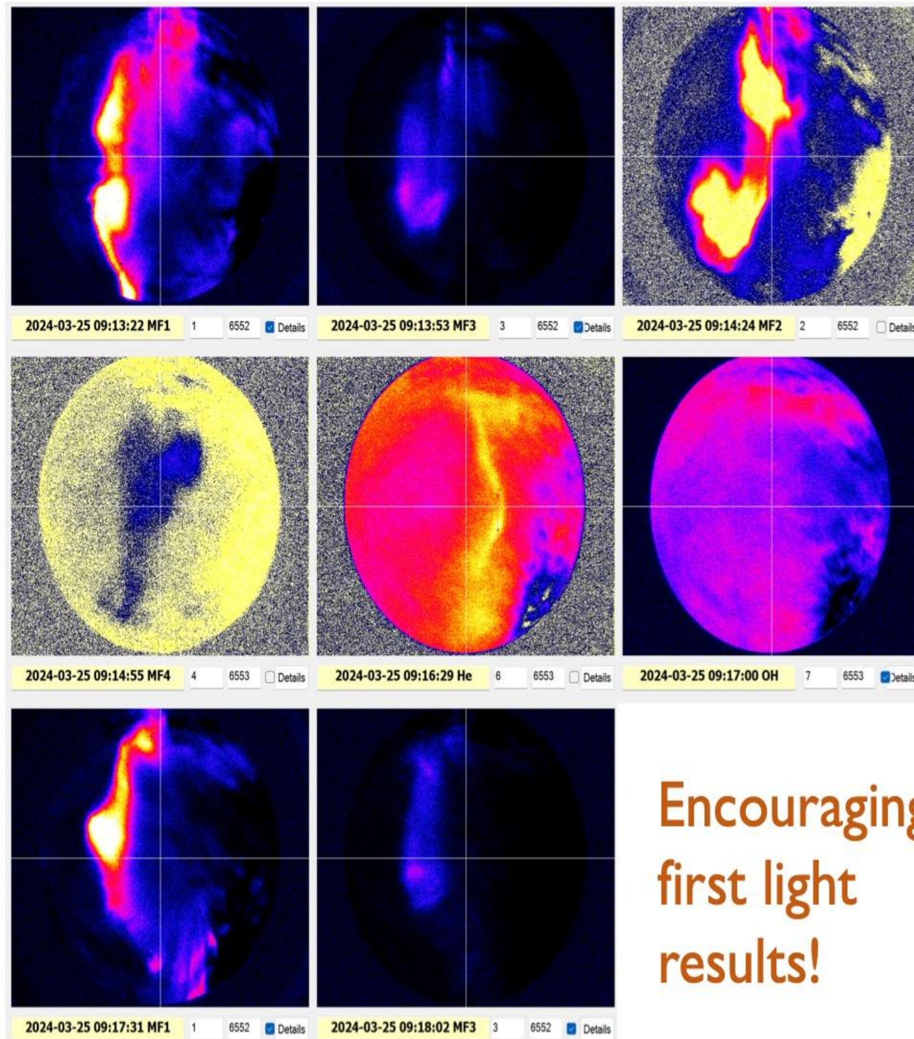
OH Filter



First Meinel Filter

Third Meinel Filter

March 25th, 2024



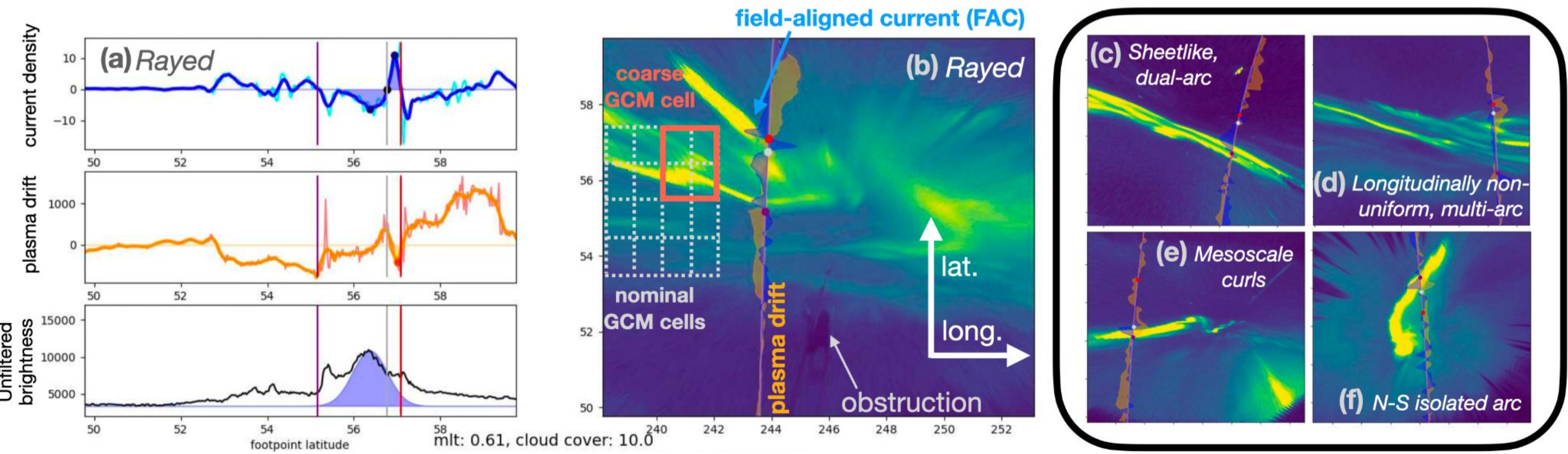
Encouraging first light results!

Scientific Output

Matt Zettergren: GEMINI plasma/neutral coupling at high latitudes

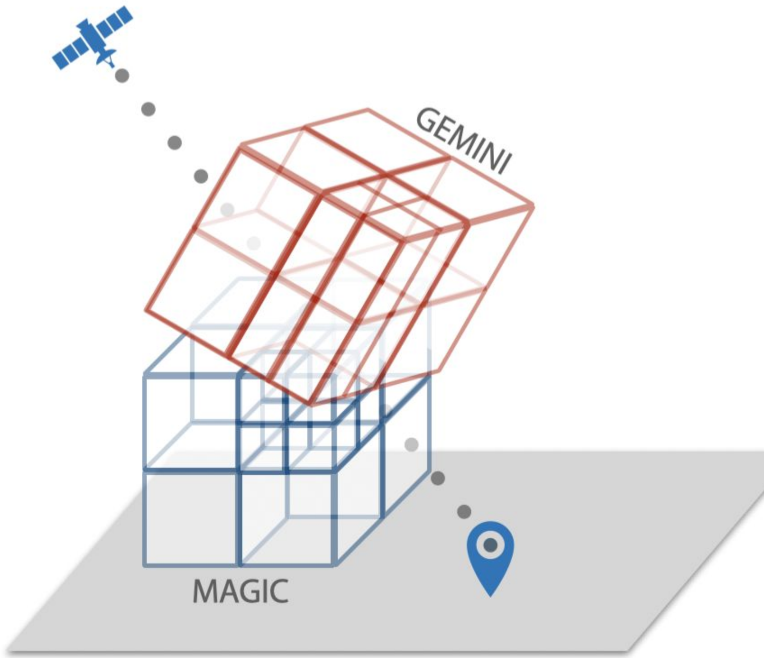
Meso-scale Ion-Neutral Coupling in Auroras

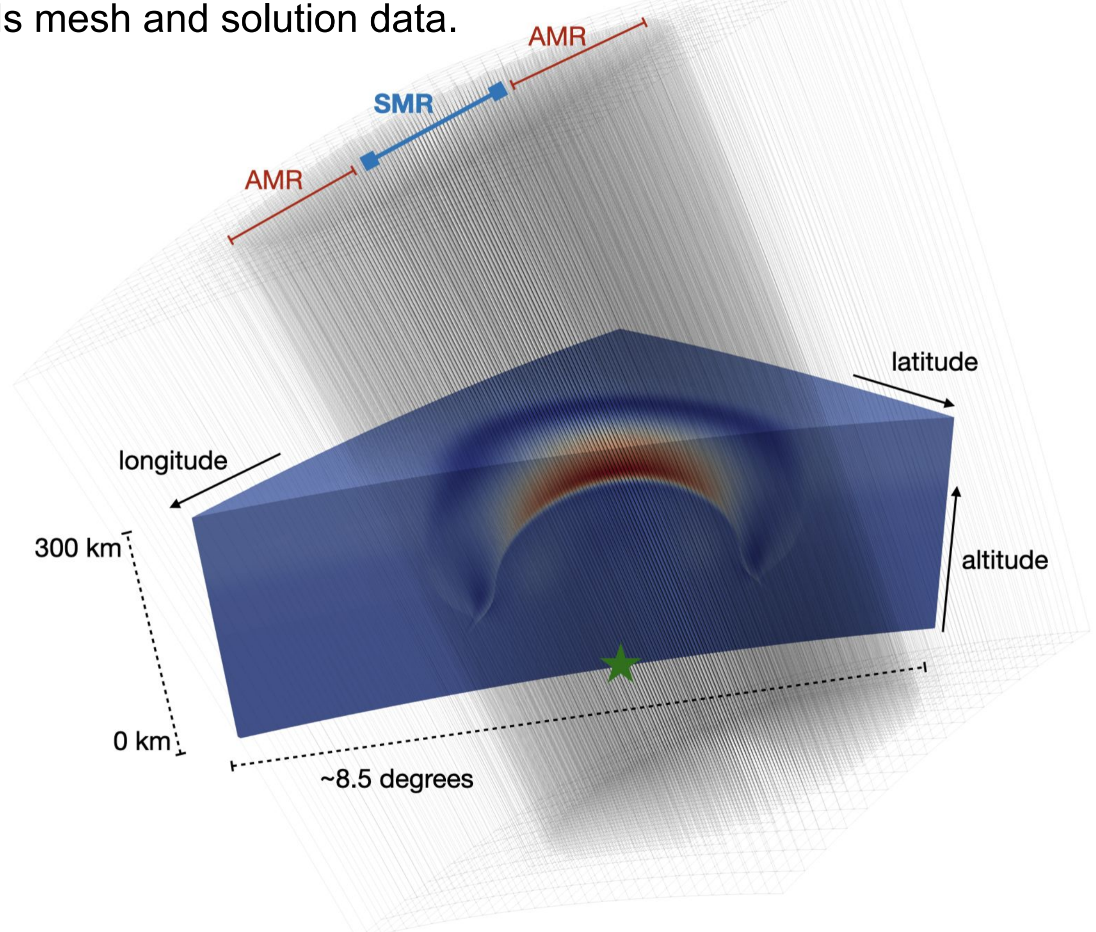
- A key issue is that the IT system sees quite intense particle flux, momentum, and energy inputs at scales well below what is resolved in current GCMs
- Additionally, typically used input specifications for electric fields and precipitation aggressively average over important small-scale features that may be significant to the overall IT energy and momentum budget



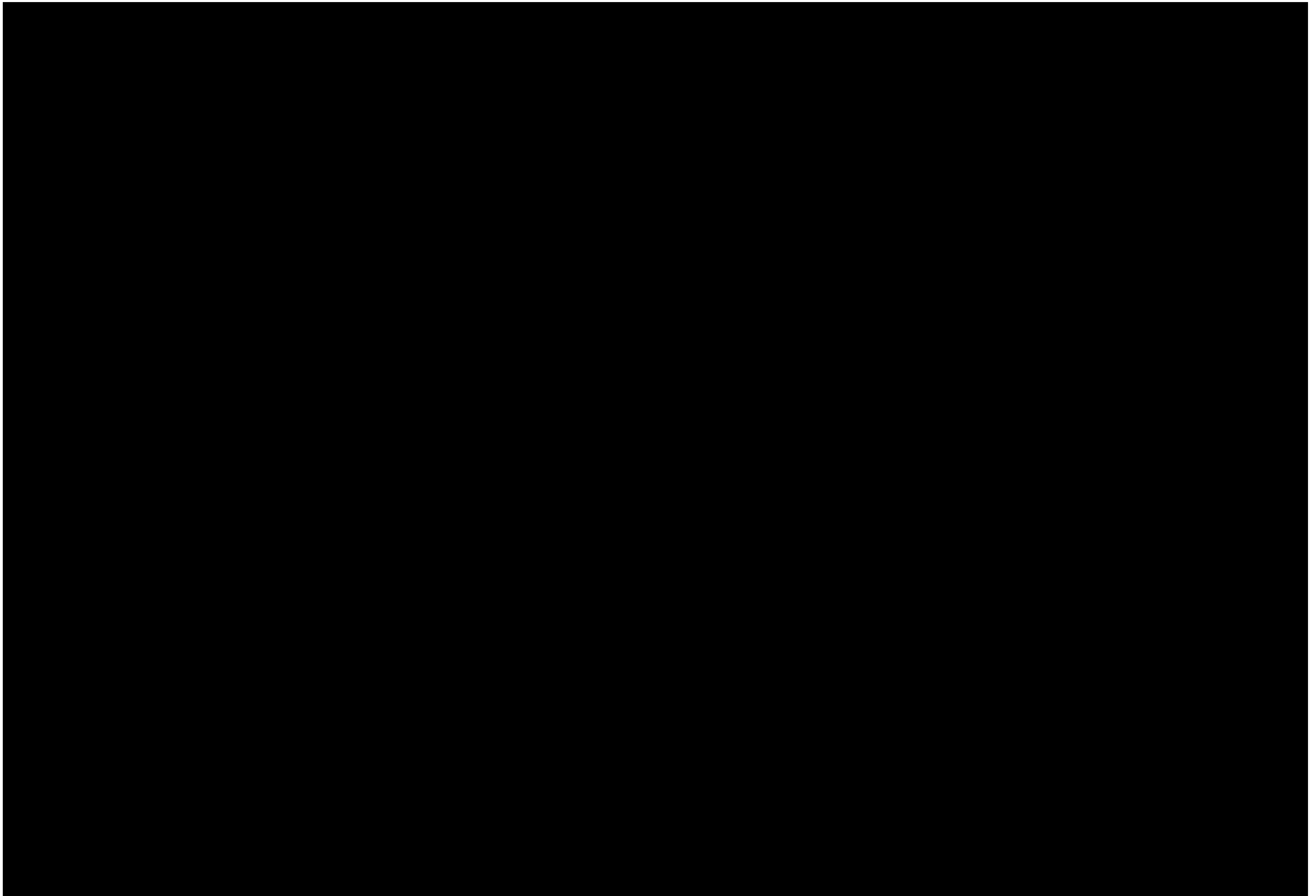
FIGMENTs - Coupled AMR Models

- Framework for Integrating GEMINI and MAGIC EnvironmeNTS
- Couple data between two (or more!) “overset” AMR meshes having different coordinate systems and levels of refinement.
- A parallel mesh search and interpolation approach, facilitated by tree-based internal data structure that holds mesh and solution data.

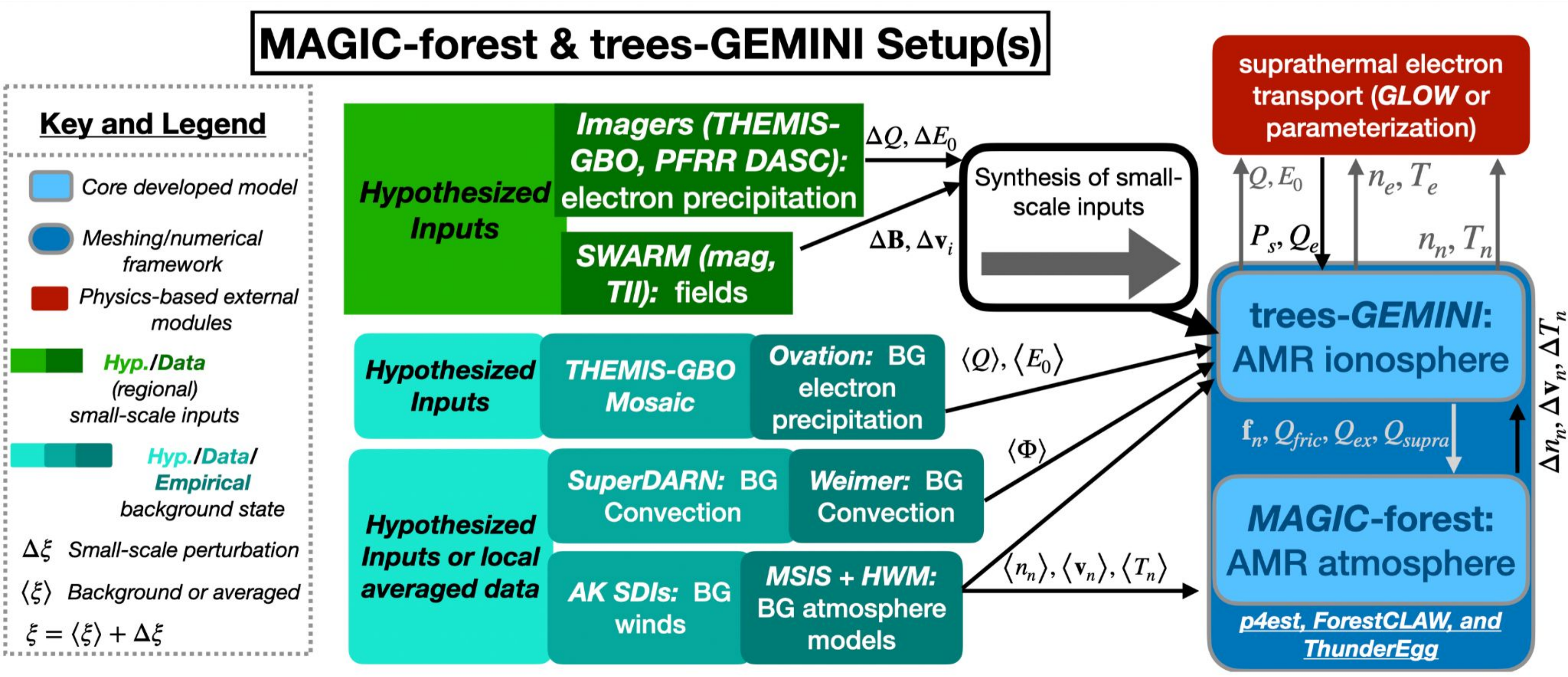




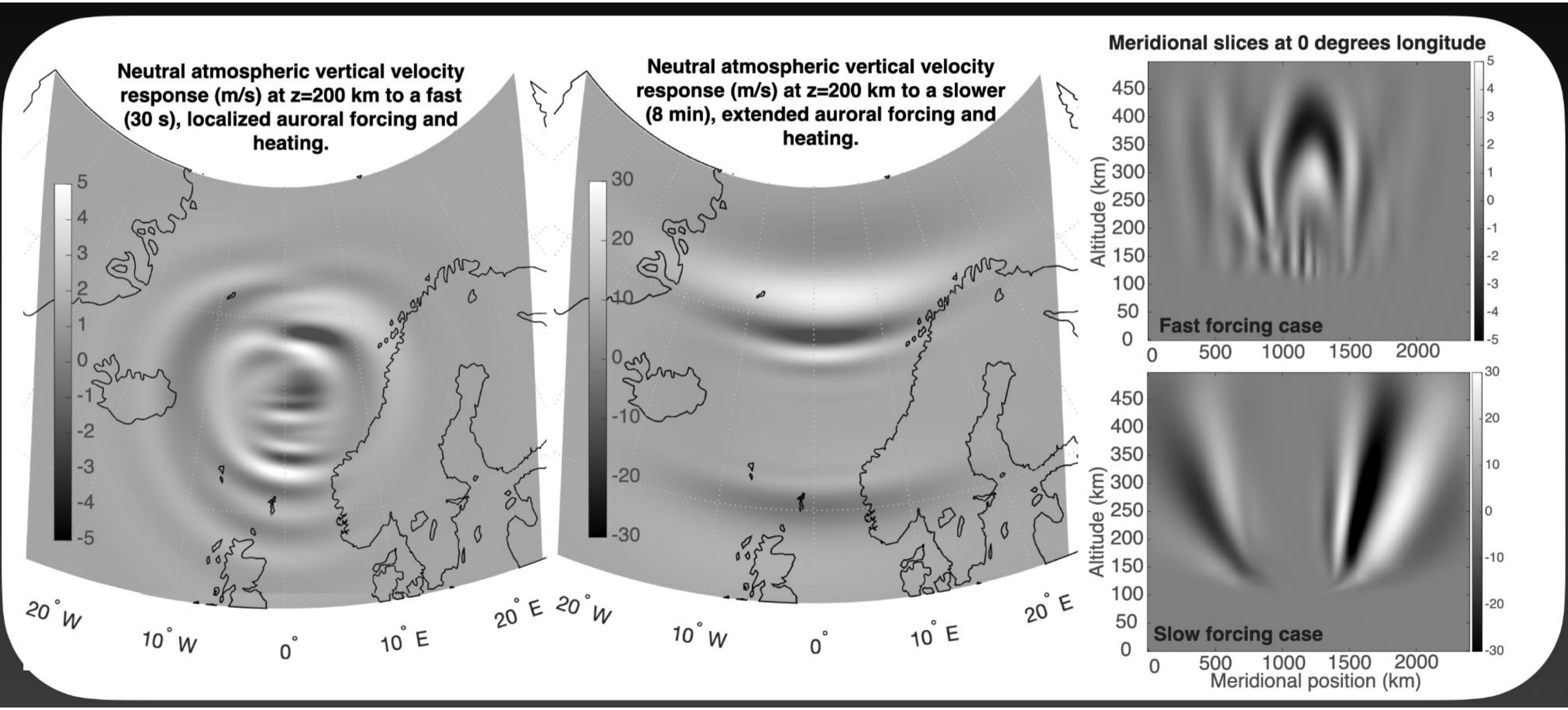
Adaptive Mesh Refinement in GEMINI



Plasma-neutral Modeling with ?Observational? Inputs

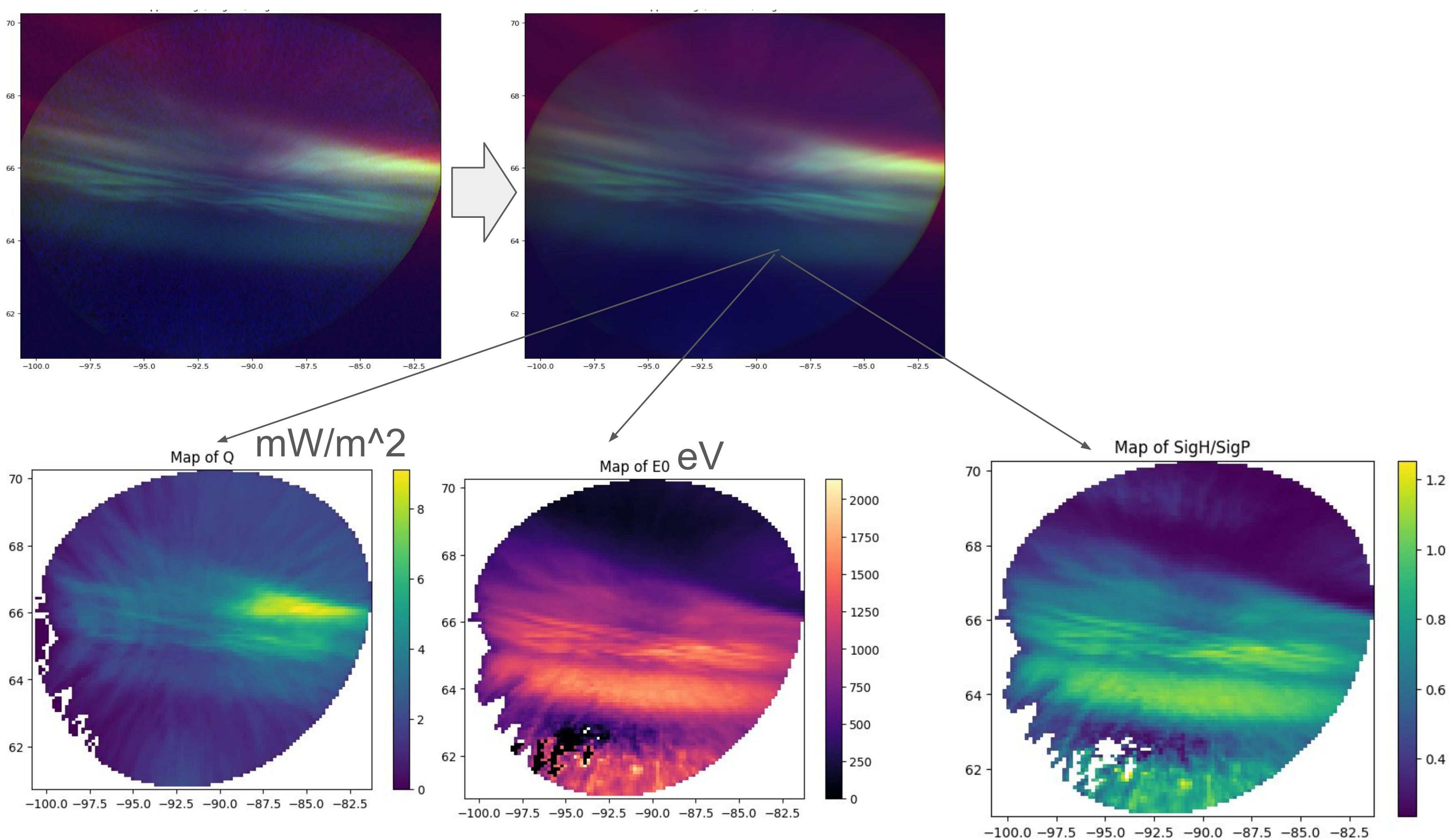


MAGIC Modeling of Waves from Plasma Energy and Force Input

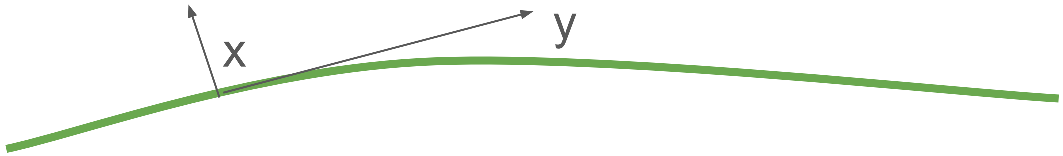


Alex Mule, Dartmouth College- Conductivity Proxies

Hall and Pedersen Conductance from Imagery



Pedersen Conductance from Swarm E and B data



From height-integrated, thin ionosphere current continuity (for example Marghitu 2012):

$$\nabla \cdot (\Sigma_P \mathbf{E} + \Sigma_H \hat{\mathbf{z}} \times \mathbf{E}) = j_{//}$$

Letting x be the across-arc direction, and y be the along arc:

$$(1/\mu_0)(\partial_x B_y - \partial_y B_x) = \partial_x(\Sigma_P E_x) + \partial_y(\Sigma_P E_y) + E_x \partial_y \Sigma_H + E_y \partial_x \Sigma_H$$

If along-arc symmetry is obeyed, gray terms can be neglected. If $(E_y\ \Sigma_H) / (E_x\ \Sigma_P)$ is very small, we can neglect the red term as well, and find:

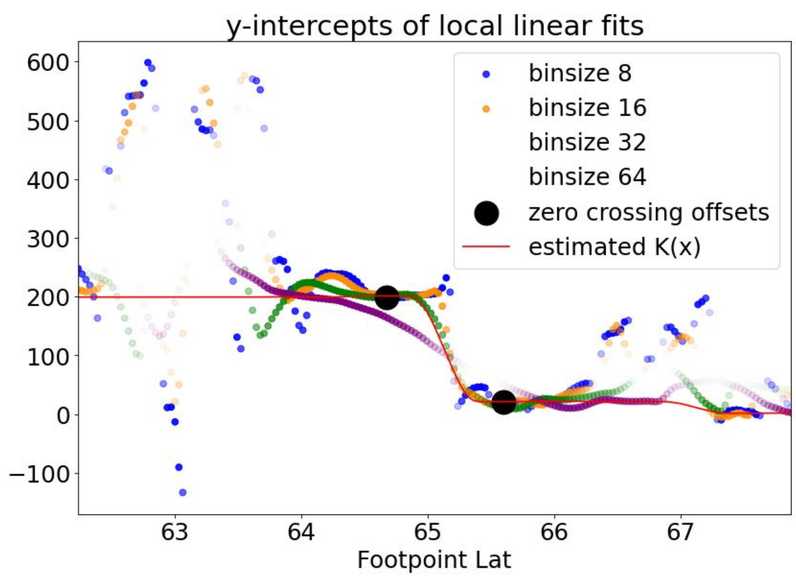
$$\Sigma_P E_x = (1/\mu_0)\ B_y + C$$

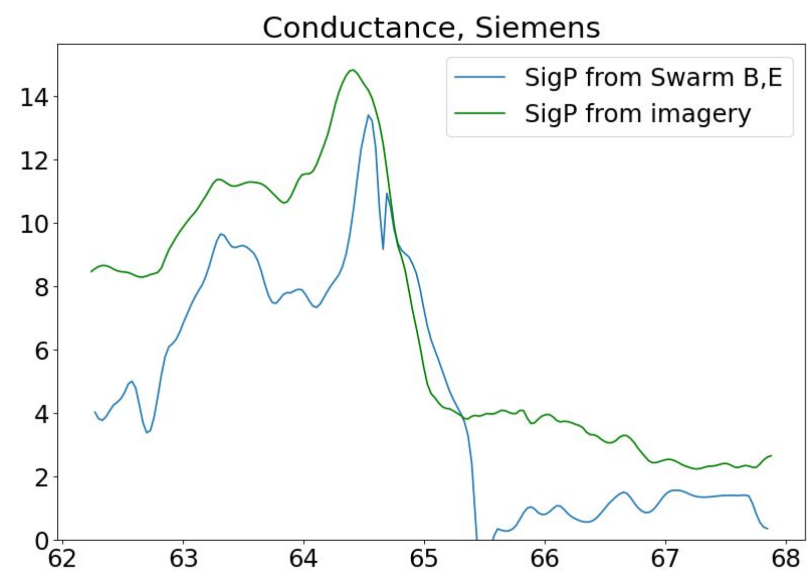
Pedersen Conductance from Swarm E and B data, cont.

If the terms that we neglected are still small but not insignificant, we instead have:

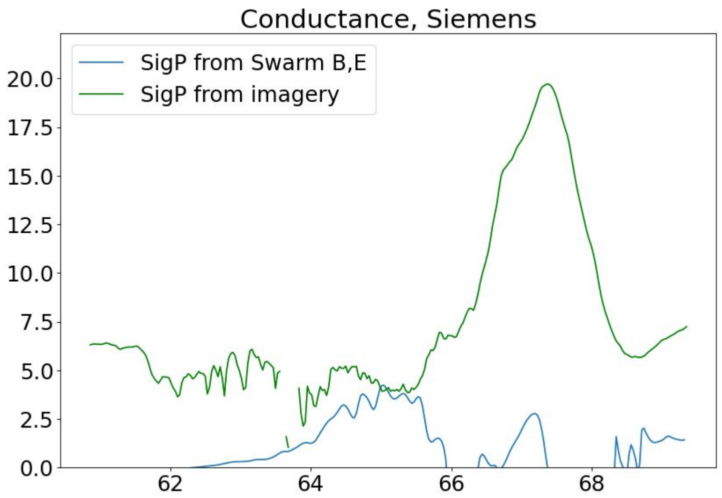
$$\Sigma_P E_x = (1/\mu_0)\, B_y + K(x)$$

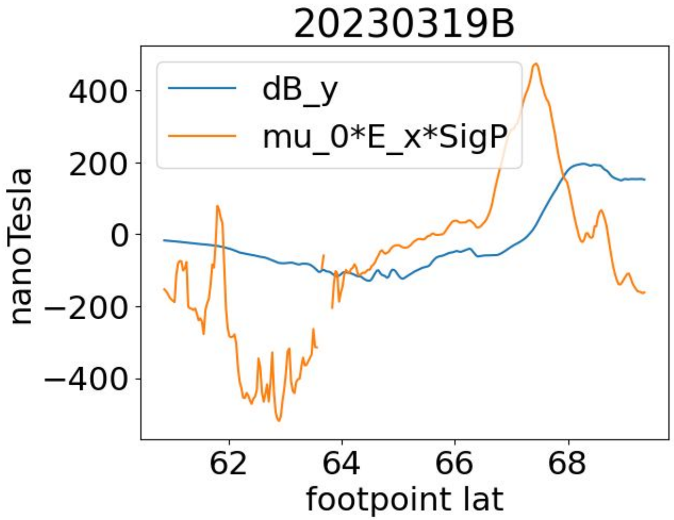
With K(x) a slowly varying function that can be fitted out by looking at local linear fits in regions of nearly uniform conductance:





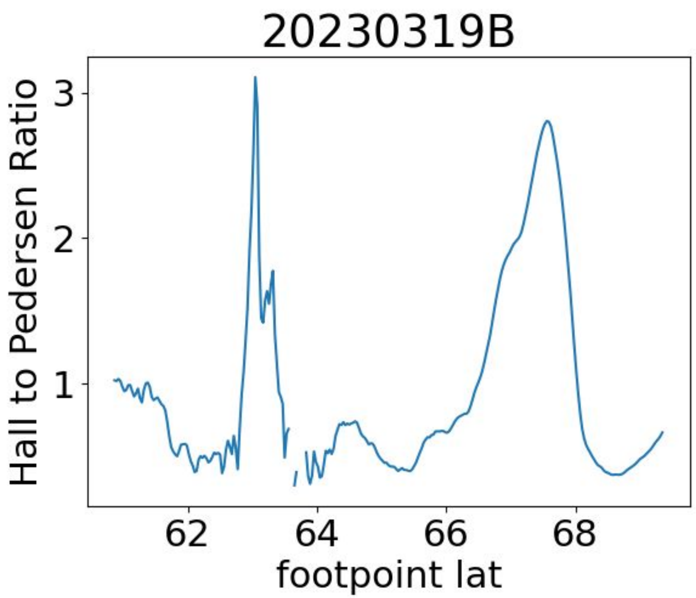
When this routine fails: 03/19 event

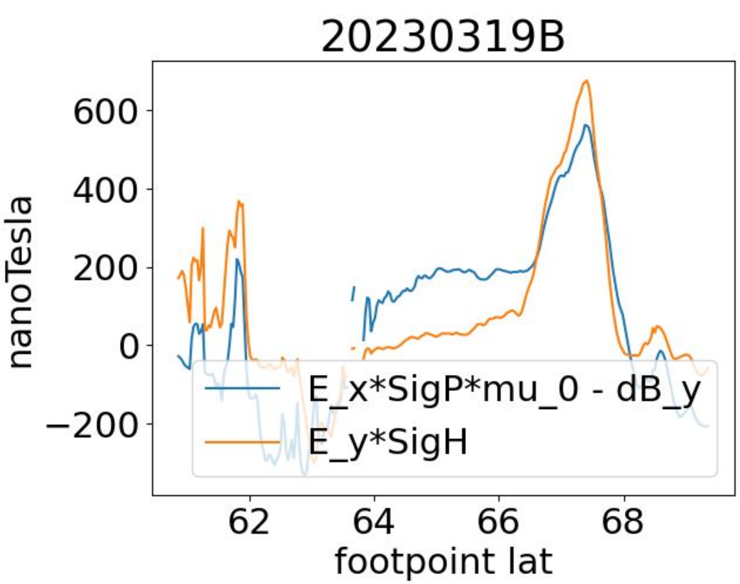




- High energy event, imagery suggests high Hall to Pedersen ratio
- Even a small along-arc electric field could contribute to Hall current closure
- Clearly, if imagery conductances are to be believed, 1d Pedersen closure terms do not add up.

When this routine fails: Diverging Hall Current



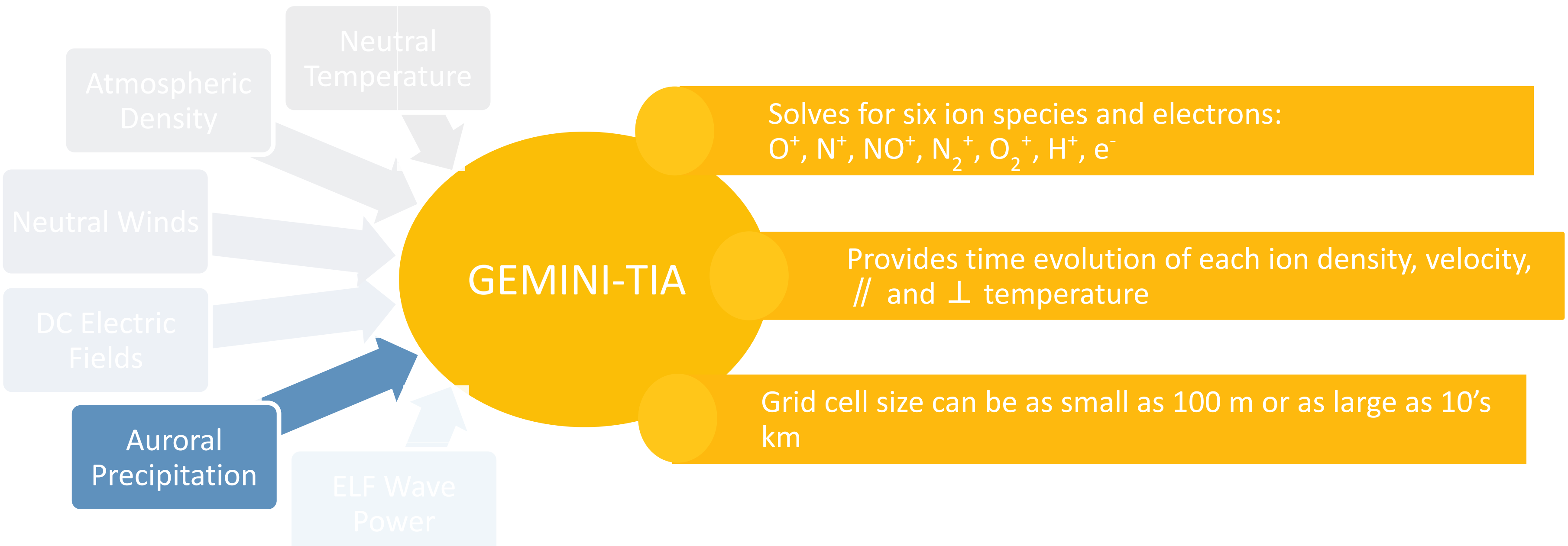


- The missing differrence between the two Pedersen closure terms is well explained by Hall current using the along-arc flow!
- Since the Pedersen current from E_x serves to directly cancel the Hall current from E_y that would otherwise produce FAC, this may be an example of high Cowling efficiency

Meghan Burleigh, RENU2

RENU2 data for driving GEMINI-TIA

The **G**eospace **E**nvironment **M**odel for **I**on-**N**eutral **I**nteractions with **T**ransverse **I**on **A**cceleration (**GEMINI-TIA**) is a **2.5D multi-fluid ionospheric model** based on a bi-Maxwellian distribution that incorporates ionospheric chemistry and transport needed to simulate ionospheric dynamics (>80km), including possible effects of low-altitude wave-particle interactions.



GEMINI-TIA is an offshoot of the isotropic model GEMINI (Zettergren and Semeter, 2012) and is well suited for **ingesting sounding rocket campaign data for investigating ionospheric dynamics**.

RENU2 sounding rocket campaign

Rocket **E**xperiment for **N**eutral **U**pwelling 2 (RENU2):

Launched December 2015 into the cusp

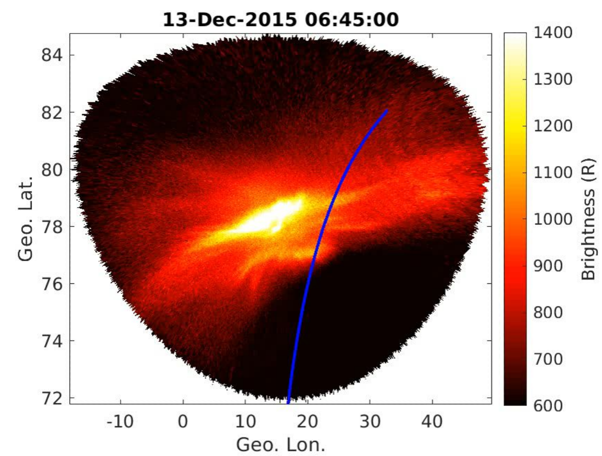
Flew through the fourth PMAF

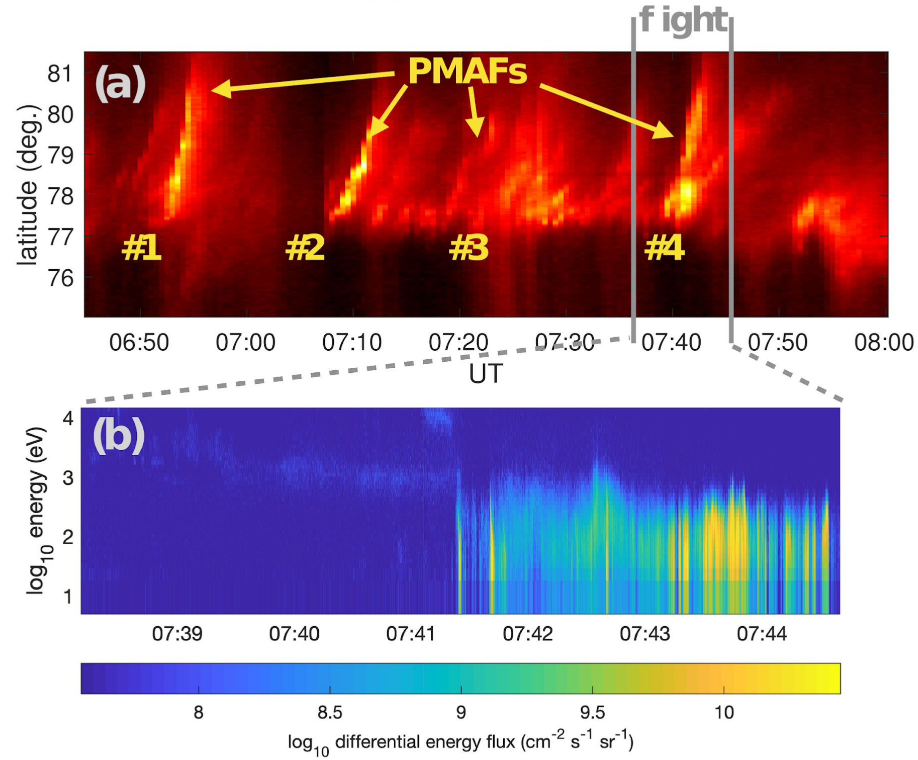
Observed soft (<300 eV) particle precipitation
- Deposits energy at ≥ 200 km altitude
- Excites strong 630 nm emission
- Heats the ambient ionospheric electrons

Use ground imager brightness and in-situ data to generate realistically variable precipitation for modeling

Explore the ionospheric response to a dynamic sequence of PMAFs.

The active motions of this type of aurora can create altitude, latitude, and temporal dependence in ion motions.

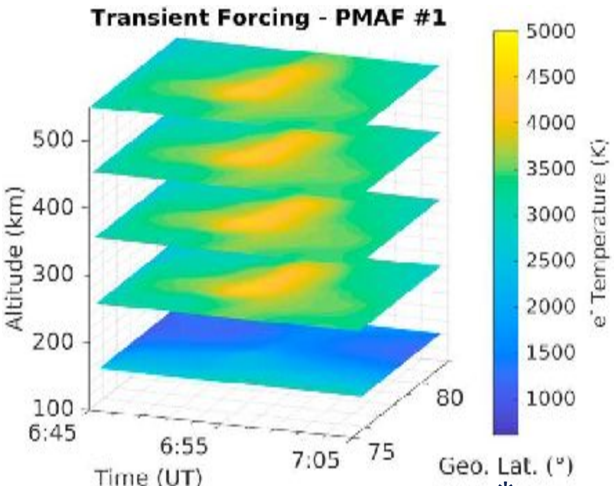


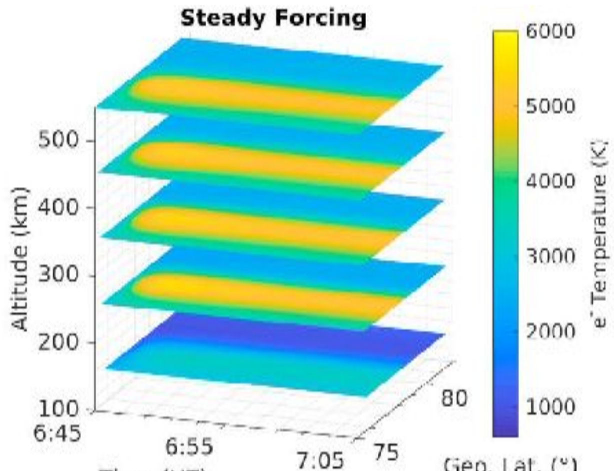


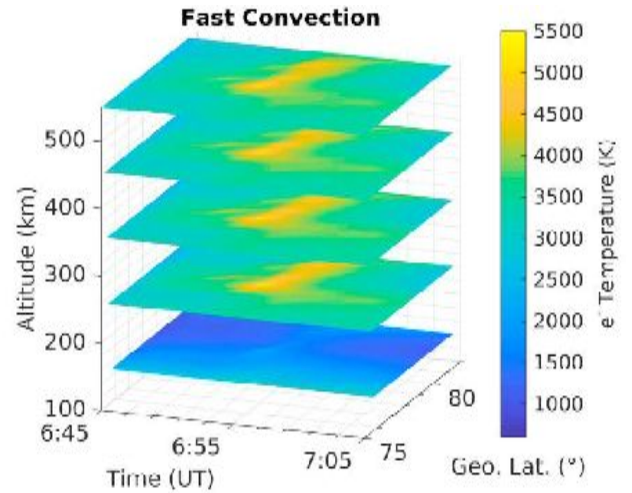
U.S. NAVAL RESEARCH LABORATORY

Modeling study of realistic forcing w/ sub-arc structure

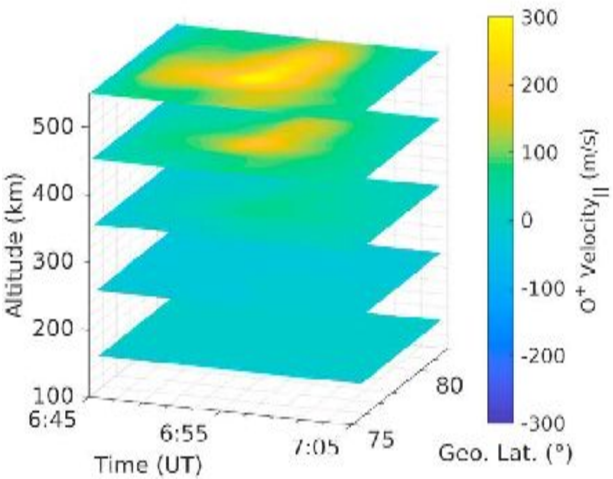
Transient Forcing (realistic PMAF dynamics)	Steady Forcing (turn-on, no motion)	Fast Convection (realistic PMAF dynamics, background convection)

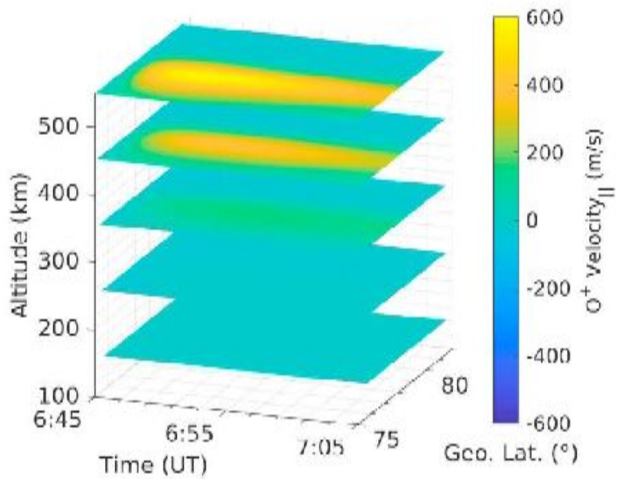


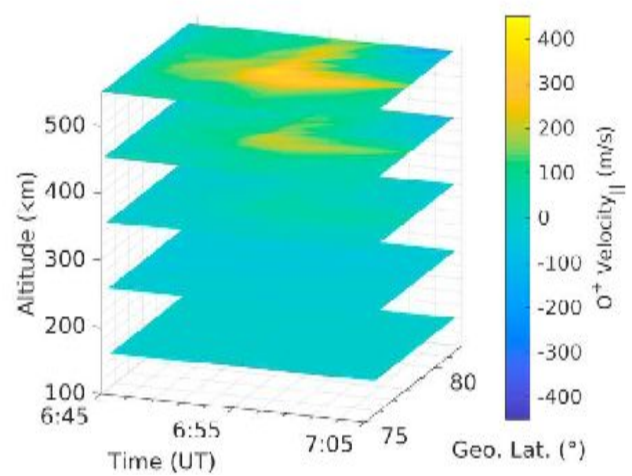




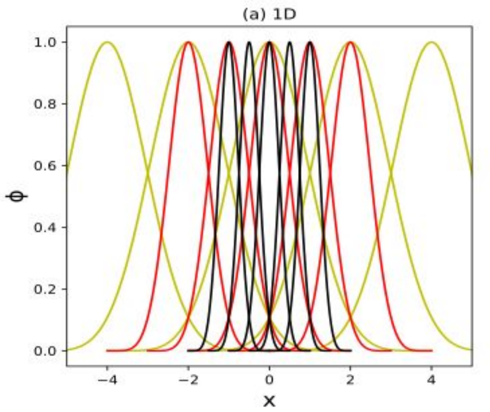
*none of the colorbar ranges are the same

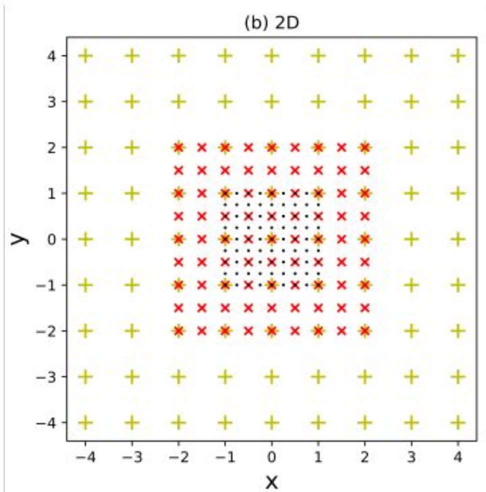


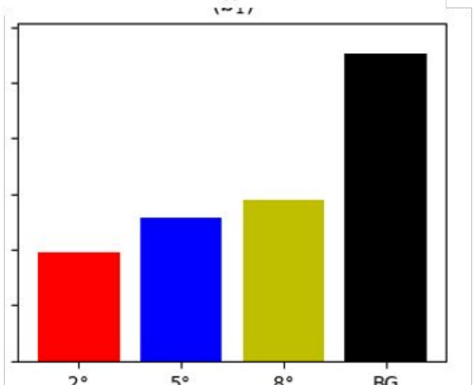




Xian Lu, Auroral data assimilation

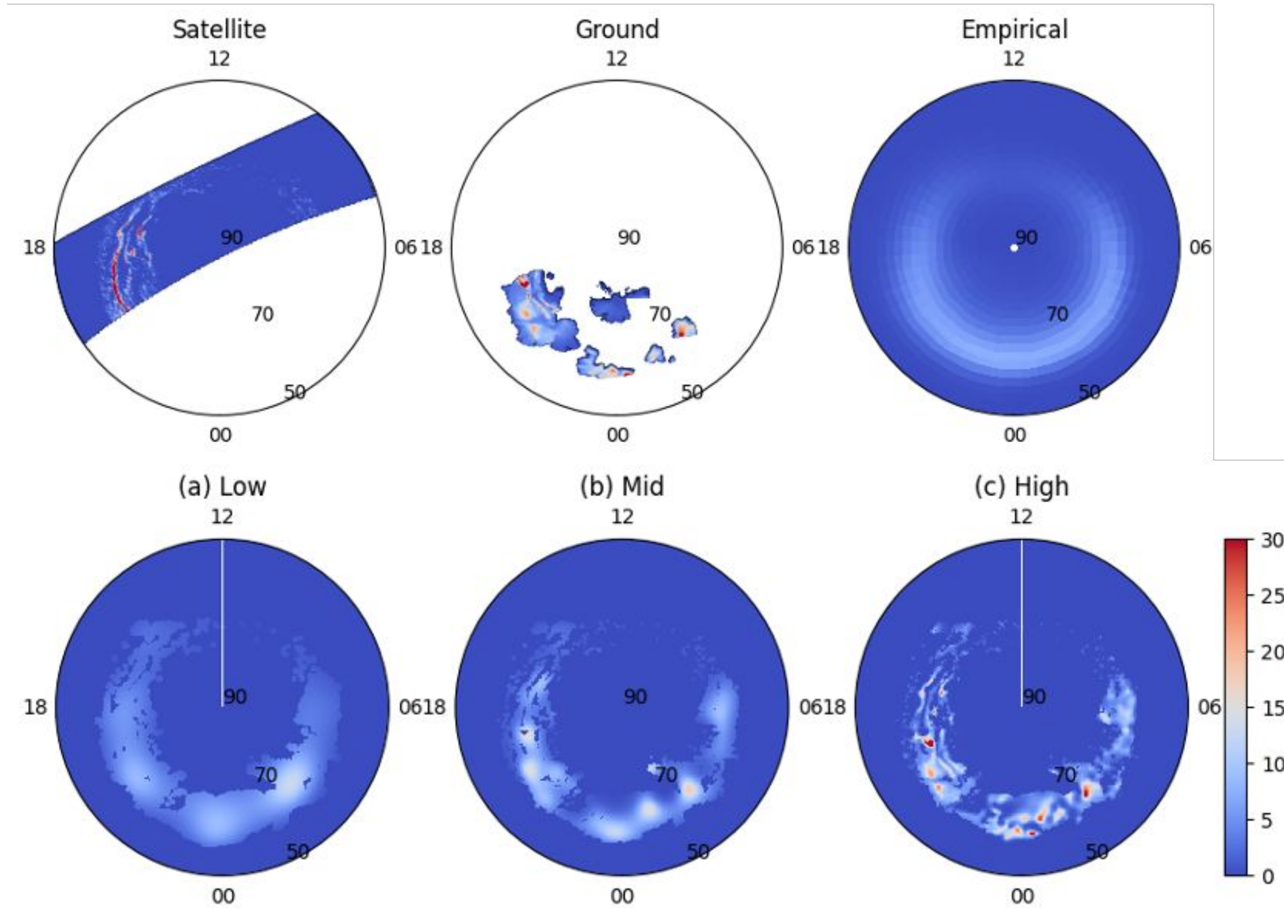






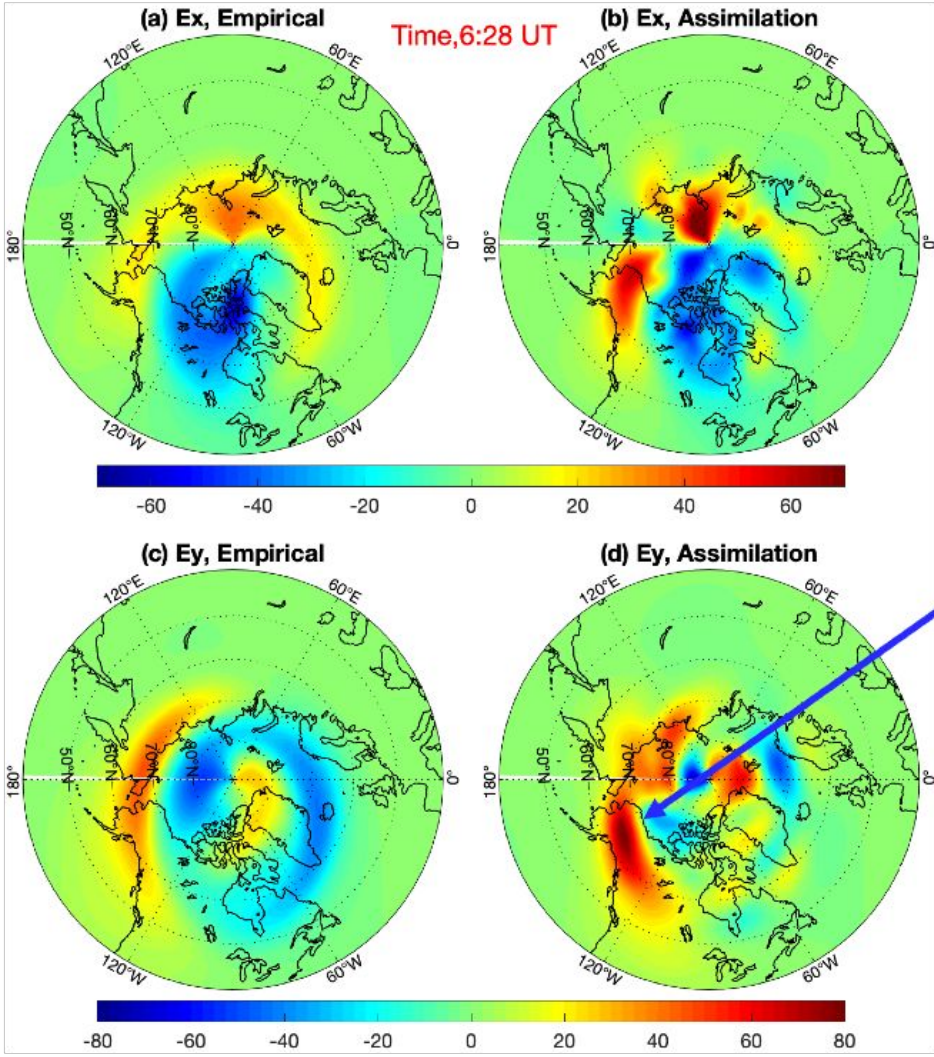
Lattice Kriging (LK) Multi-Scale Data Assimilation

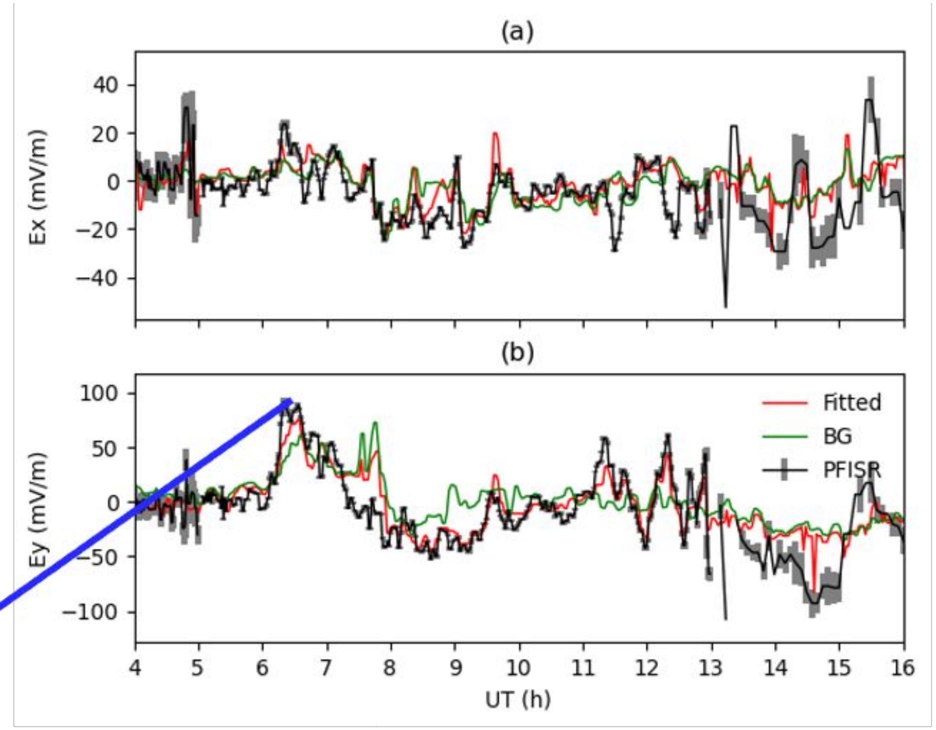
SSUSI **THEMIS** **Zhang's model**

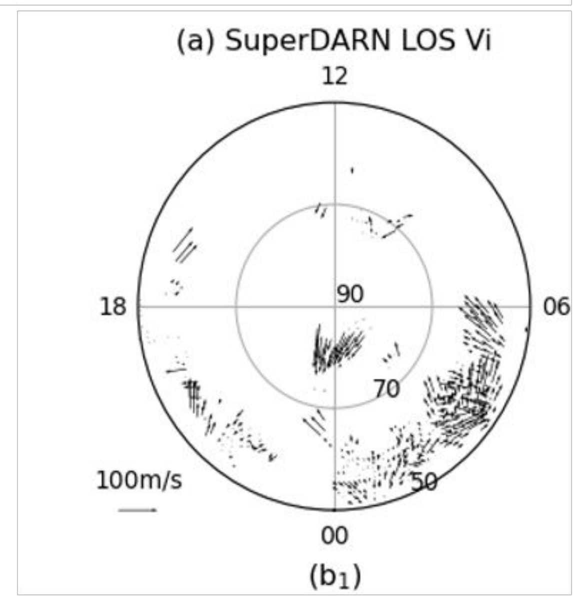


Meso-scale features

Wu and Lu., Wu et al., Space Weather, 2022

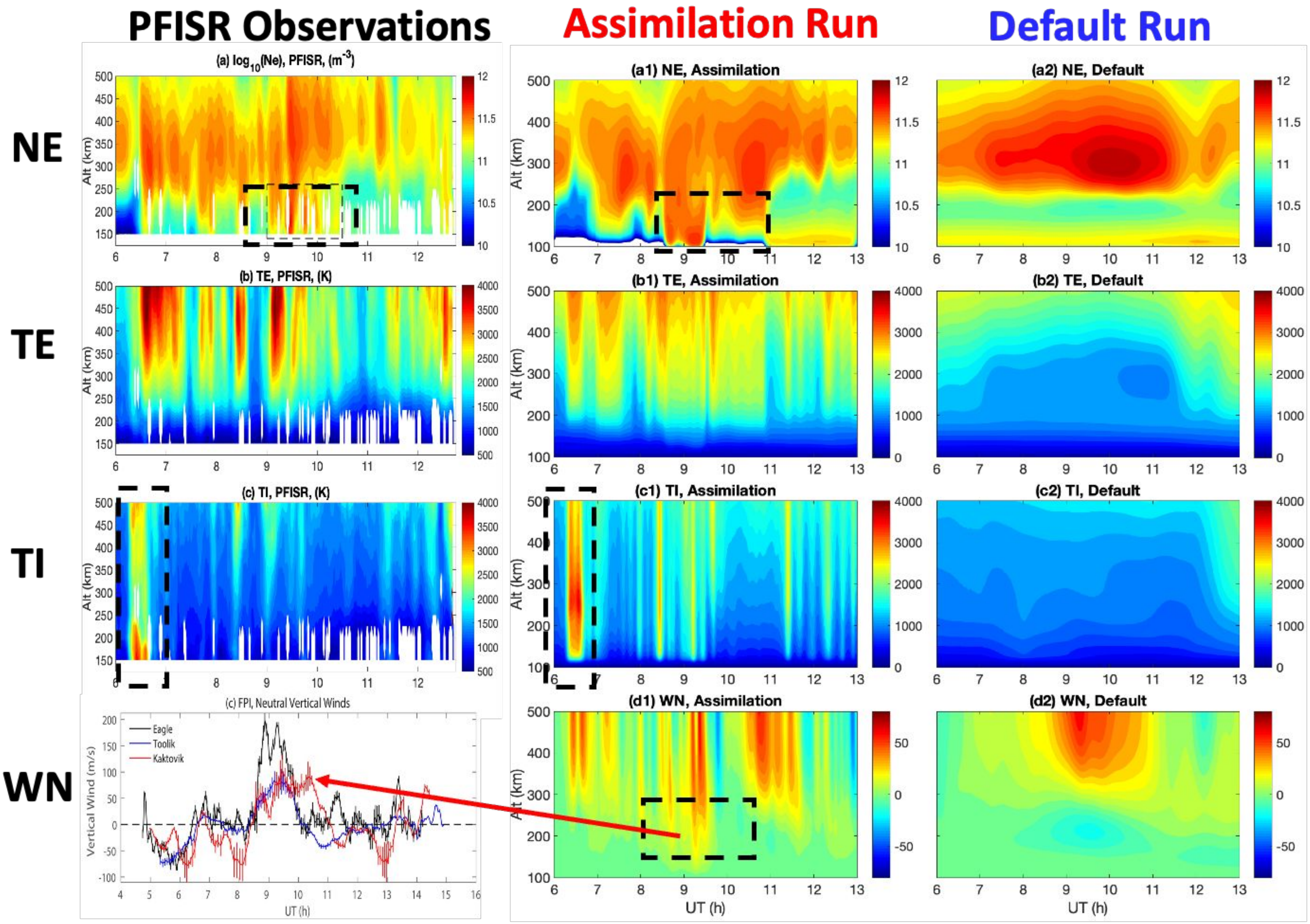




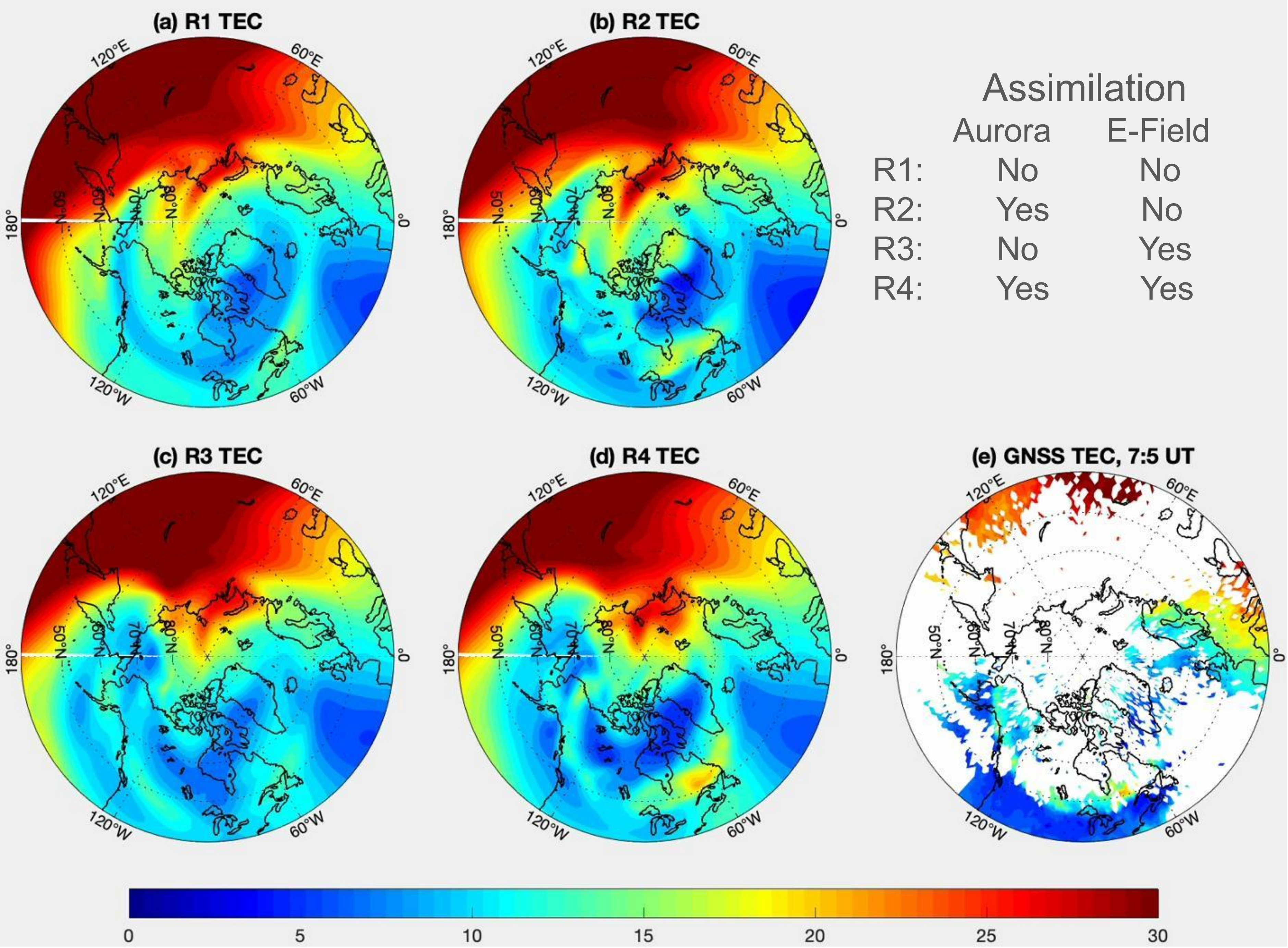


- ➢ Smaller-scale and localized features are captured.
- ➢ Temporal variability is incorporated.

Wu and Lu, Space Weather, 2022



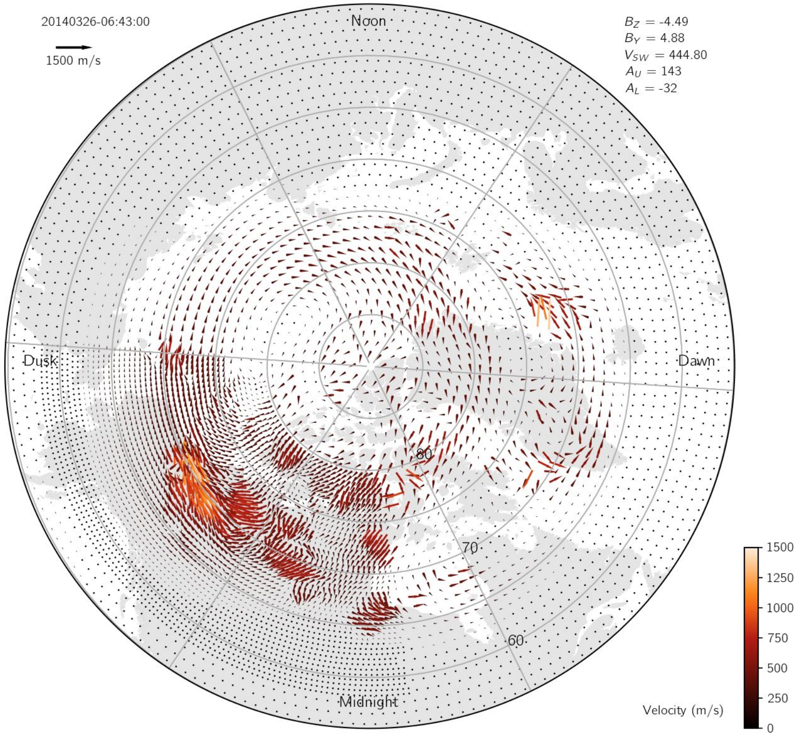
Assimilation run is way more realistic than default run. Lu et al., Space Weather, 2023

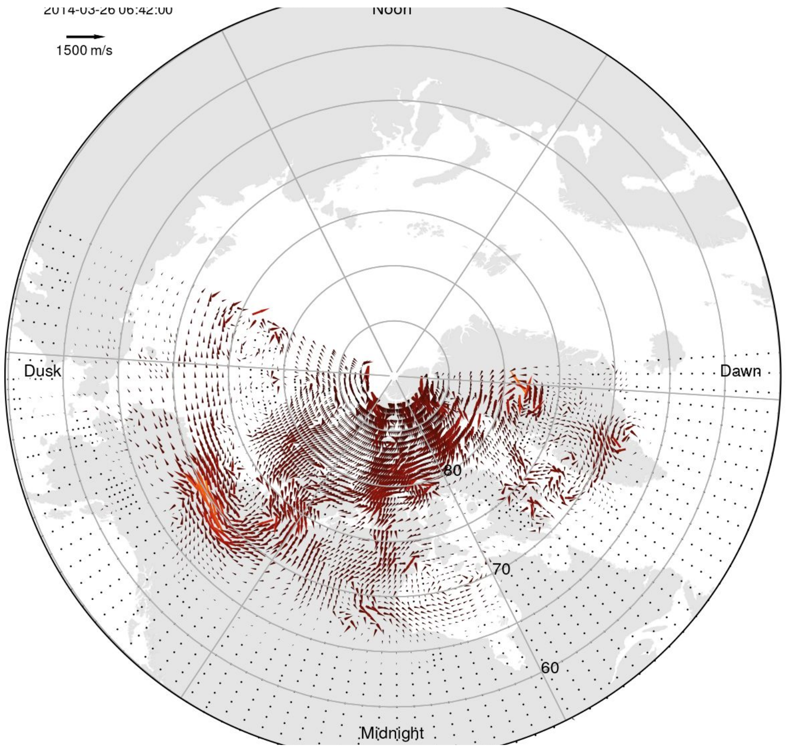


(a) R1 TEC
(b) R2 TEC
Assimilation
Aurora E-Field
R1: No No
R2: Yes No
R3: No Yes
R4: Yes Yes
(c) R3 TEC
(d) R4 TEC
(e) GNSS TEC, 7:5 UT
120°E
60°E
180°
0°
120°W
60°W
50°N
60°N
70°N
80°N
0
5
10
15
20
25
30

Data Infrastructure

Bill Bristow, SuperDARN data availability





In regions where there are large numbers of observations, the plots are similar. The G-LDFF solution is somewhat smoother than the SEC solution. The difference is not due to the climatology. It'smost likely related to differences in the regularization used in the two implementations

SuperDARN Data Policy

Data Acknowledgment

For all usage of SuperDARN data, users are asked to include the following standard acknowledgment text:

> *The authors acknowledge the use of SuperDARN data. SuperDARN is a collection of radars funded by the national scientific funding agencies of Australia, Canada, China, France, Italy, Japan, Norway, South Africa, United Kingdom, and the United States of America.*

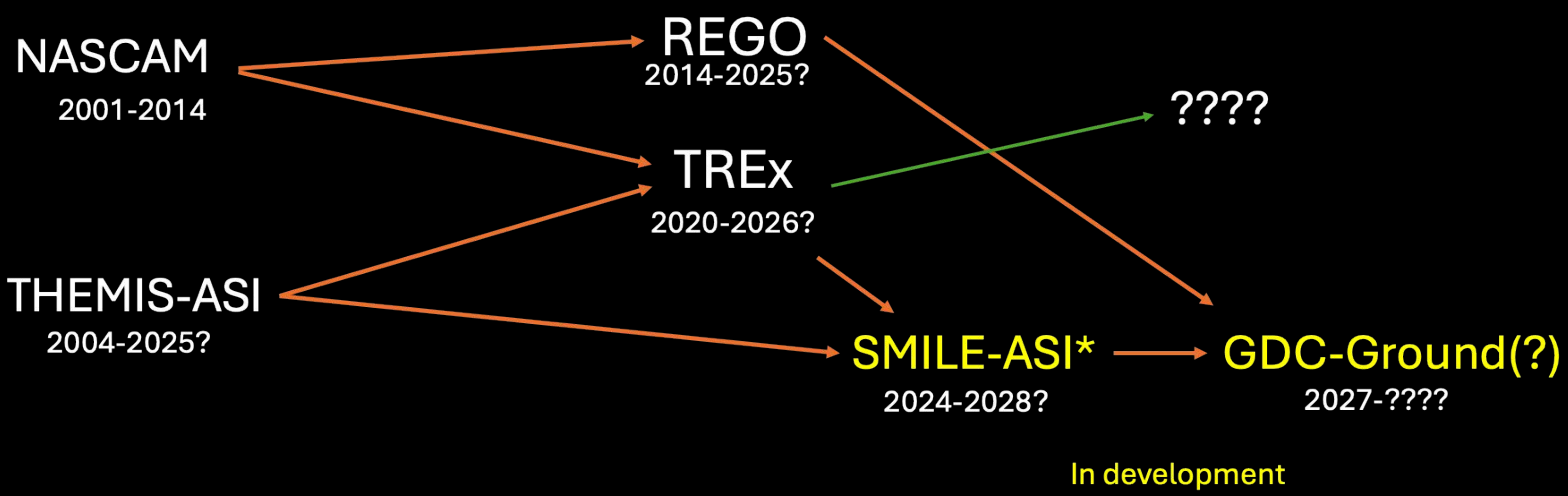
While SuperDARN has an open data use policy, i.e., prior permission to access and analyze the data is not required, the data user is strongly encouraged to establish early contact with any principal investigator whose data are involved in the project to discuss the intended usage and collaboration. The data are not to be used for commercial purposes. SuperDARN and the organizations that contributed data must be acknowledged in all reports and publications that use SuperDARN data.

Informal agreement among PIs:

> In convection maps or large statistical studies where the contribution of individual radars is masked, the general SD acknowledgment is sufficient.
>
> In applications where individual radars contribute in a way that they can be identified, the author should contact the PIs for the identifiable radars.

<u>From Emma Spanswick</u>

Today's data…. a connected set of imagers…



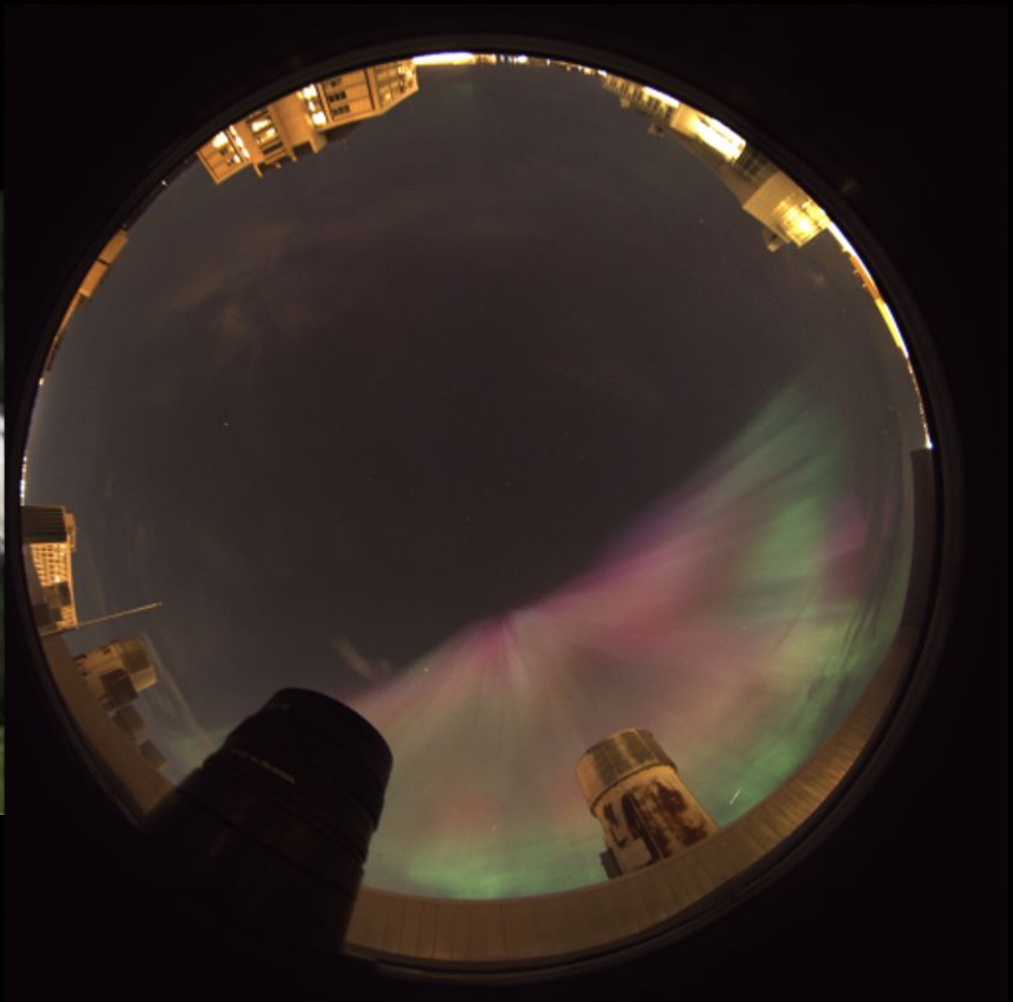
*will also produce THEMIS-equivalent data stream

1. Eureka, NU
2. Resolute Bay, NU
3. Clyde River, NU
4. Iqaluit, NU
5. Kuujjuaq, QC
6. Labrador City, NL
7. Sanikiluaq, NU
8. Kapuskasing, ON
9. Pinawa, MB
10. Gillam, MB
11. Churchill, MB
12. Rankin Inlet, NU
13. Taloyoak, NU
14. Cambridge Bay, NU
15. Contwoyto, NU
16. Rabbit Lake, SK
17. Lucky Lake, SK
18. Athabasca, AB
19. Fort Smith, NWT
20. Prince George, BC
21. Fort Simpson, MWT
22. Normal Wells, NWT
23. Sachs Harbour, NWT
24. Inuvik, YK
25. Whitehorse, NWT
26. Poker Flat, AK
27. Toolik, AK

New Sensor · Existing

	ASI-RGB	ASI-Redline	Riometer	Magnetometer	GNSS	Spectrograph	Fabry-Perot
1	New	New	New	New	New		
2	New	New	New	New	New		
3	New		New	New			
4	New	New	New	New	New		New
5	New		New	New	New		
6	New	New	New	New	New		New
7	New	New	New	New			
8	New	New	New	New	New		
9	New	New	Existing	Existing	New	New	
10	New	New	Existing	Existing	New	New	New
11			Existing	New			
12	New		Existing	Existing			
13	New	New	Existing	Existing	New		New
14	New		New	New			
15			New	New			
16	New	New	Existing	Existing		New	
17	New	New	New	New	New	New	
18	New		Existing	New		New	
19	New	New	Existing	Existing	New	New	
20			Existing	New	New		
21	New		Existing	Existing			New
22			New	New			
23	New	New	New	New	New		New
24	New	New	New	New		New	
25	New	New	Existing	New	New	New	
26	New	New	New	New	New	New	
27	New		New	New		New	

We can't do everything…..but we can do something (and hopefully it can be leveraged into a larger community efforts)



May 11th 2024 – UofC roof – testing of SMILE-ASI

Tai-Yin Huang, NSF perspective

NSF Geospace Data Infrastructure: Vision and Expectations

Tai-Yin Huang
Program Director
Geospace, AGS Division
Geosciences Directorate, NSF

National Science Foundation

June 14, 2024
CEDAR Workshop

Community's Data Infrastructure Needs

- Easy access to data
- User-friendly interface
- Documentation of data for record-keeping
- A formal data policy for data citation and attribution
- File and data standardization.
- Long-term data repositories.
- Data Curations
- Data access/usage reports to assess the data need
- Data compliant with funders' data policy

Data users Data Providers
Federal Funders

Open Data for A Systems Approach

Data sharing enables new science discoveries, a systems approach, and equitable access

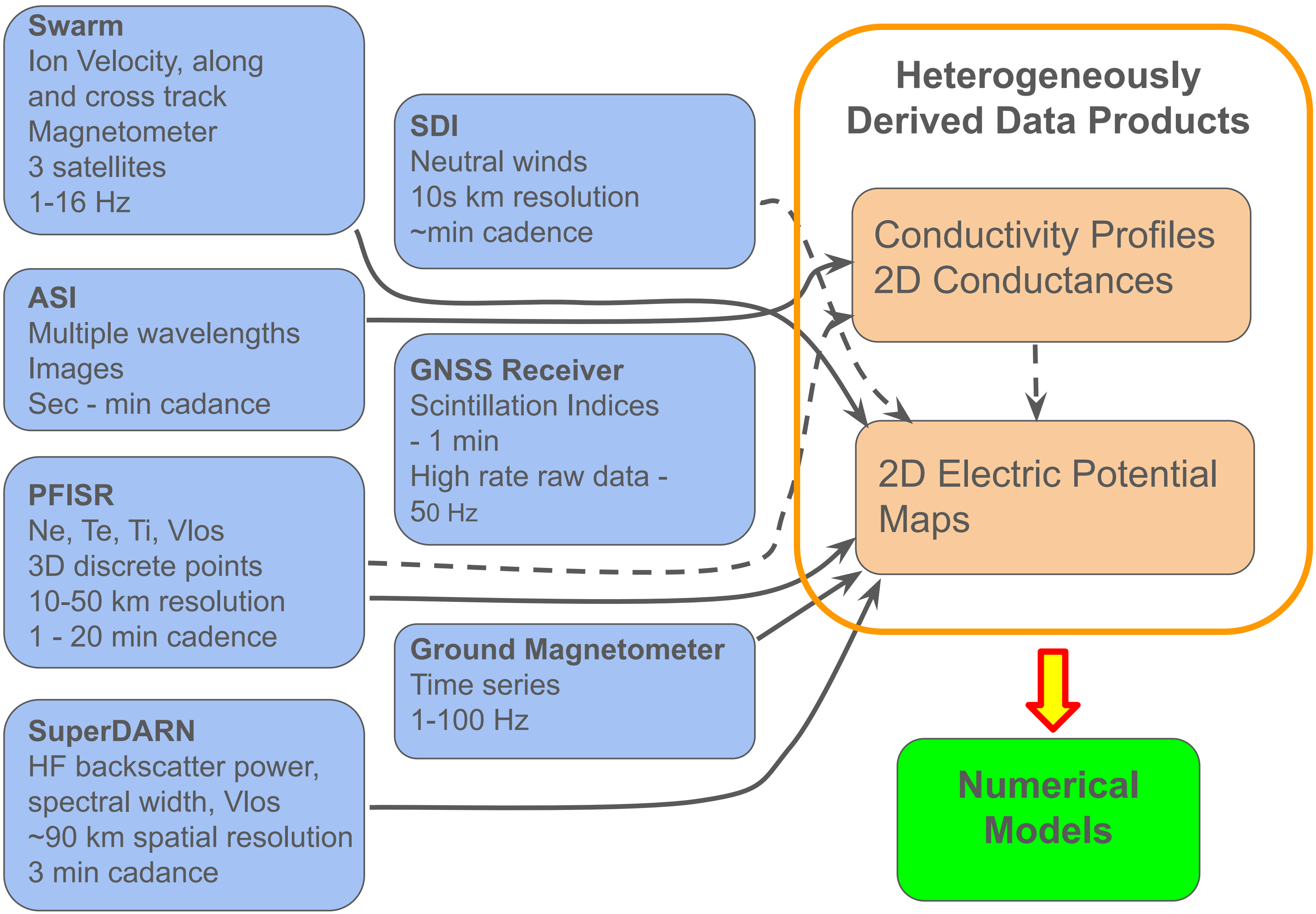
Actionable Deliverables

The community could consider

- developing training courses on how to use data resources to make them more accessible and open access.
- forming working groups to work on specific topics such as:
  - Data standardization
  - Data and documentation formats
  - Data policy for data citation and attribution.
  - Metadata specifications

Swarm-over-Poker 2023 Campaign and Dataset

Leslie Lamarche



Challenges with Sharing Heterogeneous Datasets

- When you create a derived dataset, do you share the derived data product, or the original and the code to create the derived data product?
- Different datasets have vastly different temporal and spatial resolutions, in addition to dimensionality.
  - Challenging to “force” these into a common format
- When you create a derived data product, how do you credit the original data products?
  - Link the original data products to the derived data product in some way?
  - DOIs on datafiles may be useful here
  - Attribution both for the original data and the creator of the derived data product
- Should heterogeneous data products contain copies of the original data?
  - Easiest way to give unambiguous access to the source data
  - For some kinds of data (i.e., imagers), this quickly creates unmanageably large files
  - Potentially creates complications with “redistribution” of data
- Where should heterogeneous data be stored and shared?
  - How do we keep all this organized?

2. Moderated Discussion

Discussion Questions

1. What are the barriers to using heterogeneous data for auroral research?
2. How are heterogeneous data important for system science?
3. What are some of the challenges to using data and models together?
4. Which areas of auroral science require a multifaceted approach to advance?
5. Where are there challenges in the modern CEDAR data infrastructure, both from the data provider and data user standpoints?