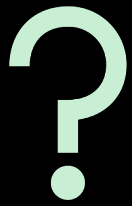
Observationally-driven Ionospheric Conductivity: Where we are, where we need to be, and how to get there

June 22, 2019

Ryan McGranaghan

Atmosphere and Space Technology Research Associates (ASTRA)

Agenda



Why is progress slow?

Why is there hope?

What are the *trends*?

Why is progress slow?

Why is there hope?

What are the *trends*?

Conductivity is…challenging

Need to know:

- **Magnetic field strength**
- **Neutral composition**
- **Temperature**
- **Ion & electron densities**

See Weimer presentation from 'Unsolved Problems of Magnetospheric Physics' Workshop


Why is progress slow?
Why is there hope?
What are the *trends*?

Progress

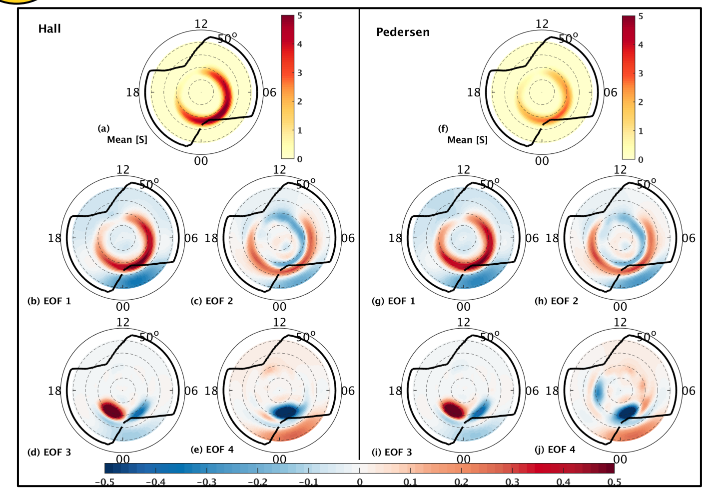
Conductivity assimilation

Progress

Conductivity assimilation

Why? - **Where are we now?** - What's next?

1 Characterize the variability



McGranaghan, R. et al. (2015), Modes of high-latitude conductance variability derived from DMSP energetic electron precipitation observations: Empirical Orthogonal Function (EOF) analysis. J. Geophys. Res. Space Physics, 120, 11,013–11,031, doi:10.1002/2015JA021828.

Progress

Conductivity assimilation

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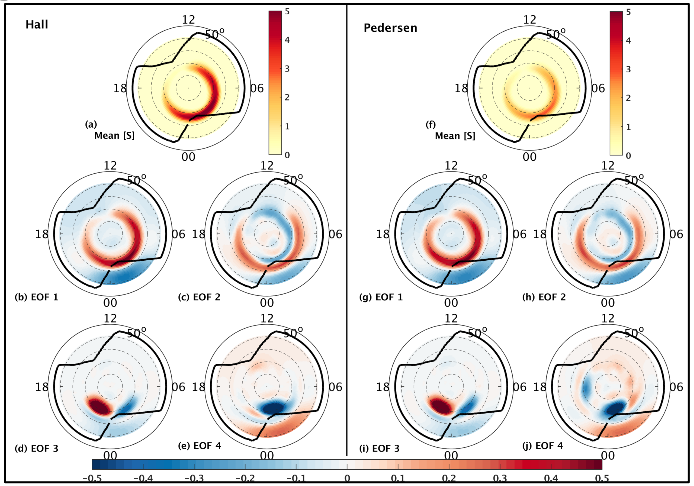
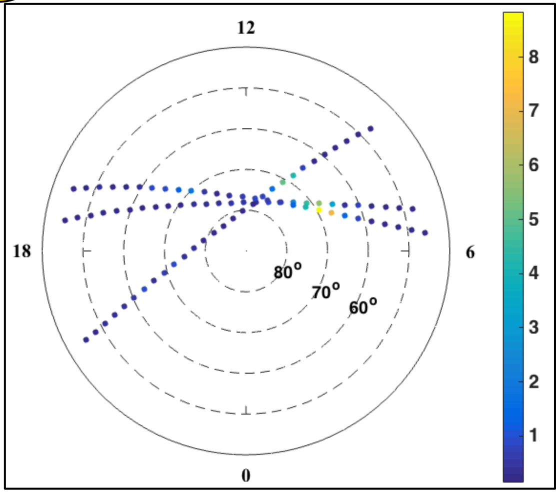


2 Accumulate observations



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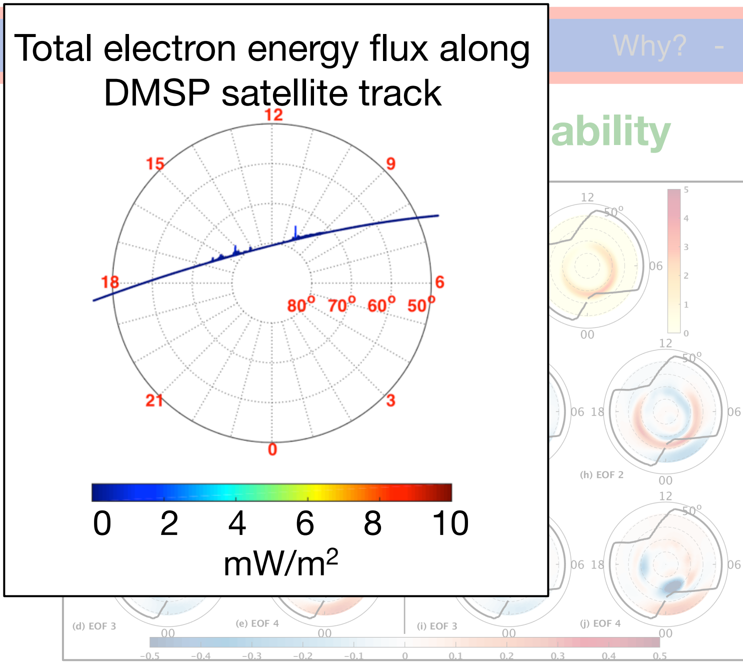
Progress

Conductivity assimilation

ability



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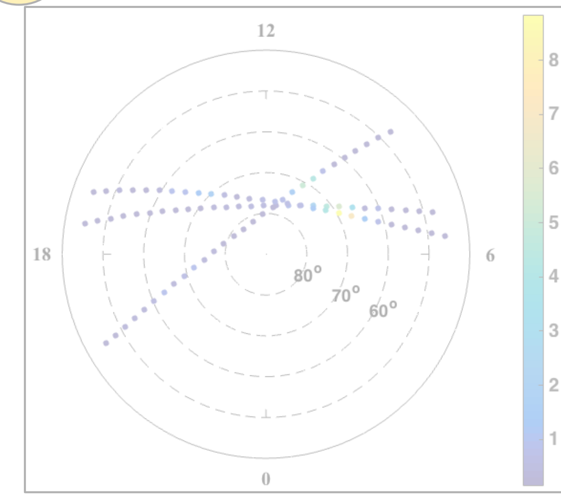

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Conductivity assimilation

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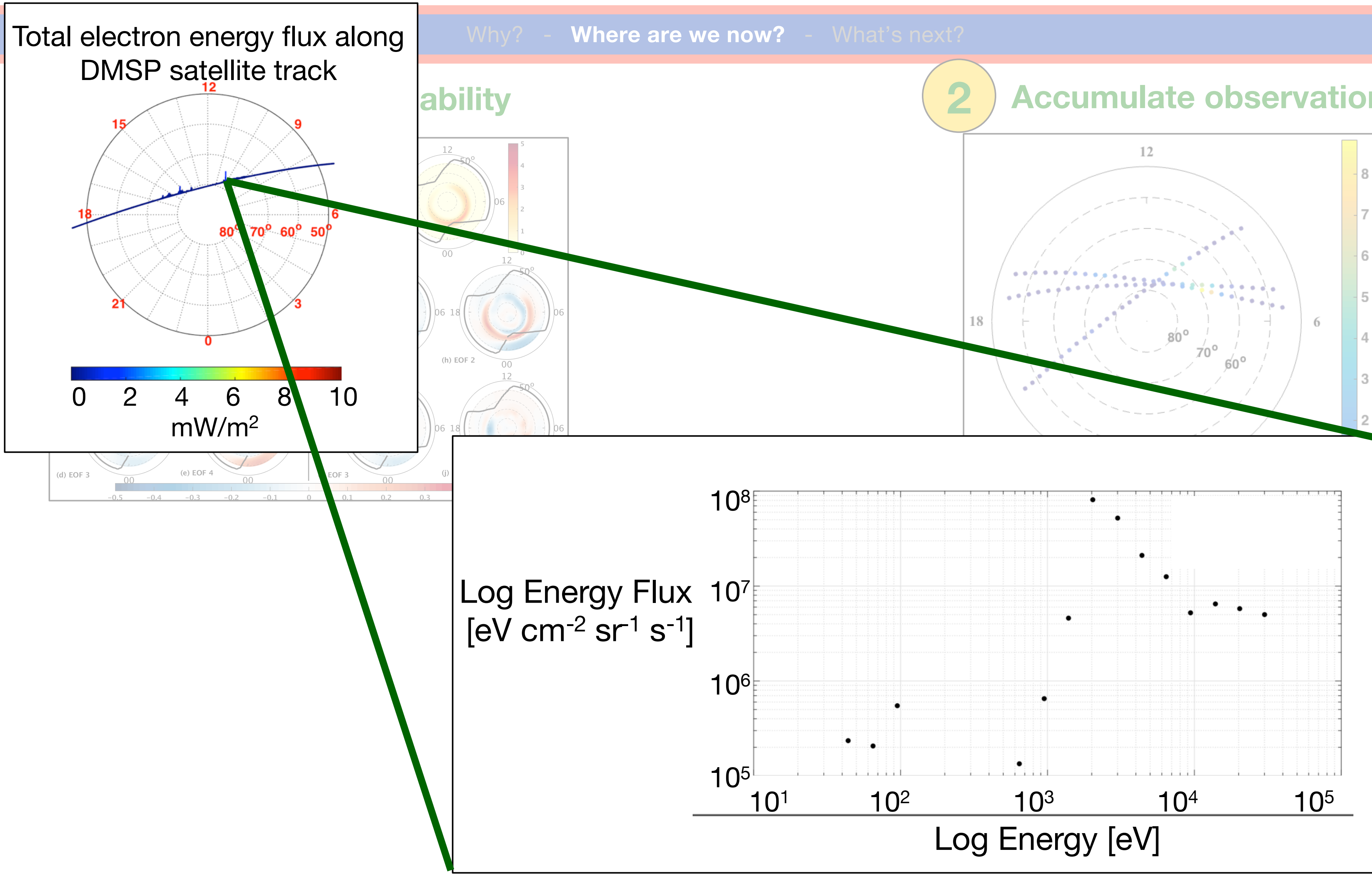
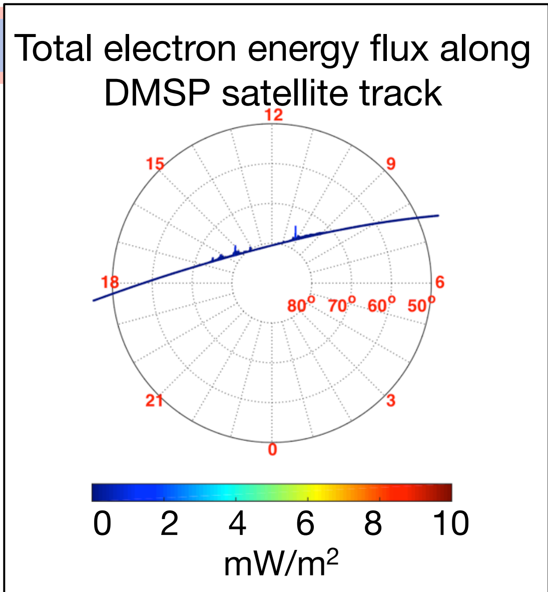


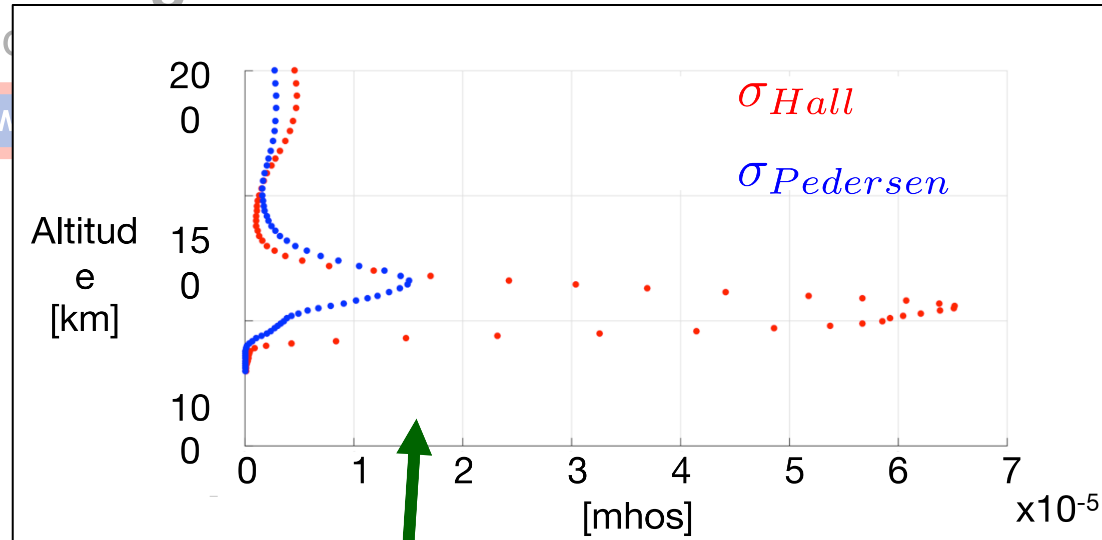
Progress

Conc

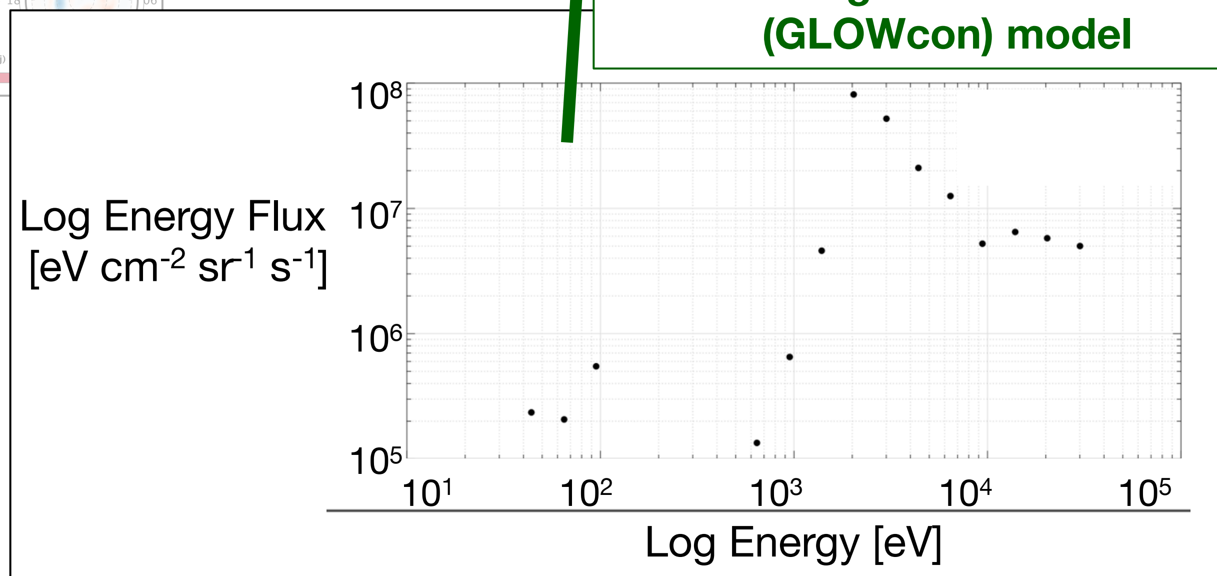
Why? - W

ability





GLobal AirglOW + Conductivity (GLOWcon) model



Progress

Conductivity assimilation

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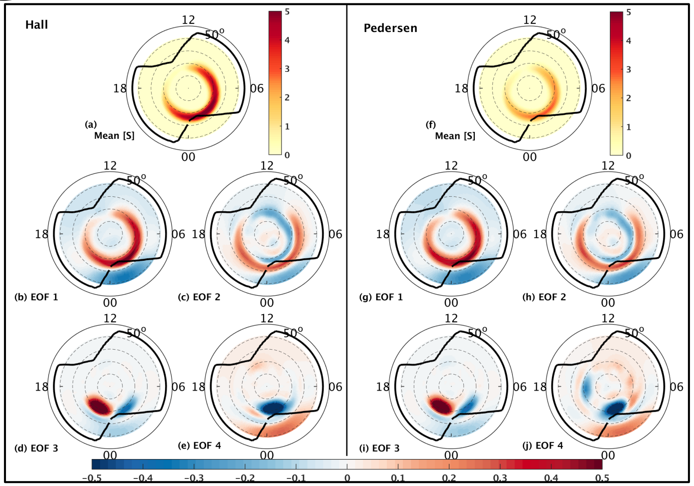

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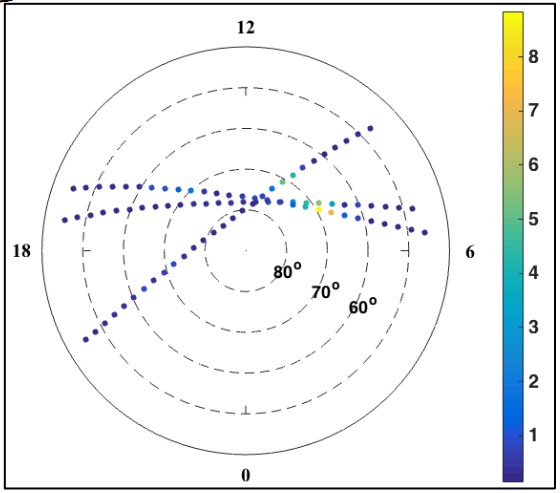

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Progress

Conductivity assimilation

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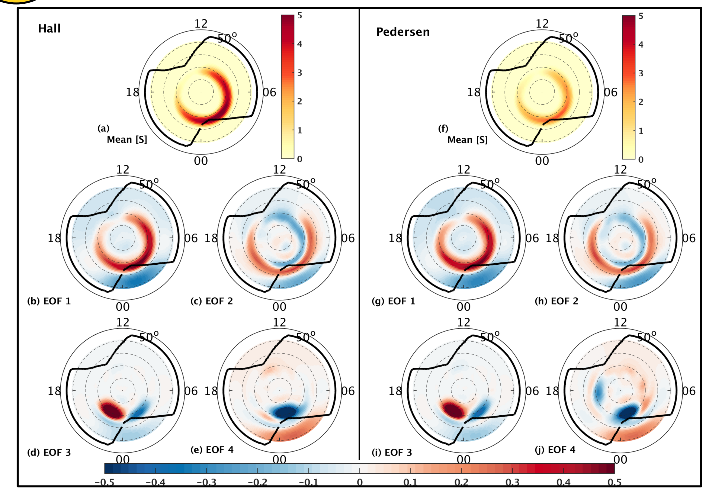

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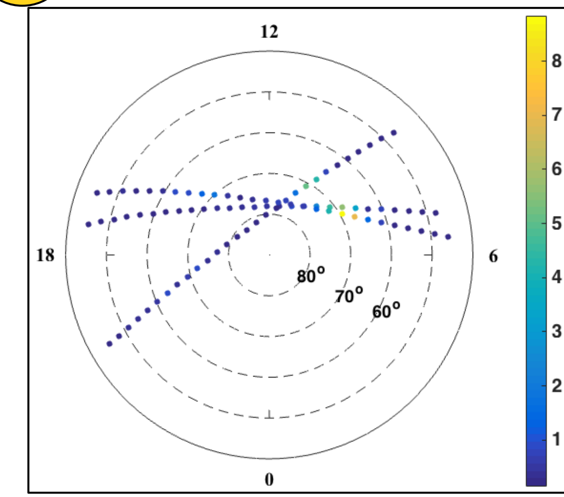
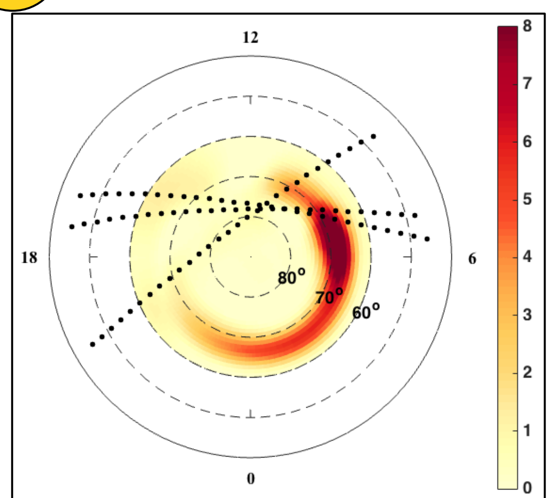


3 Optimal interpolation



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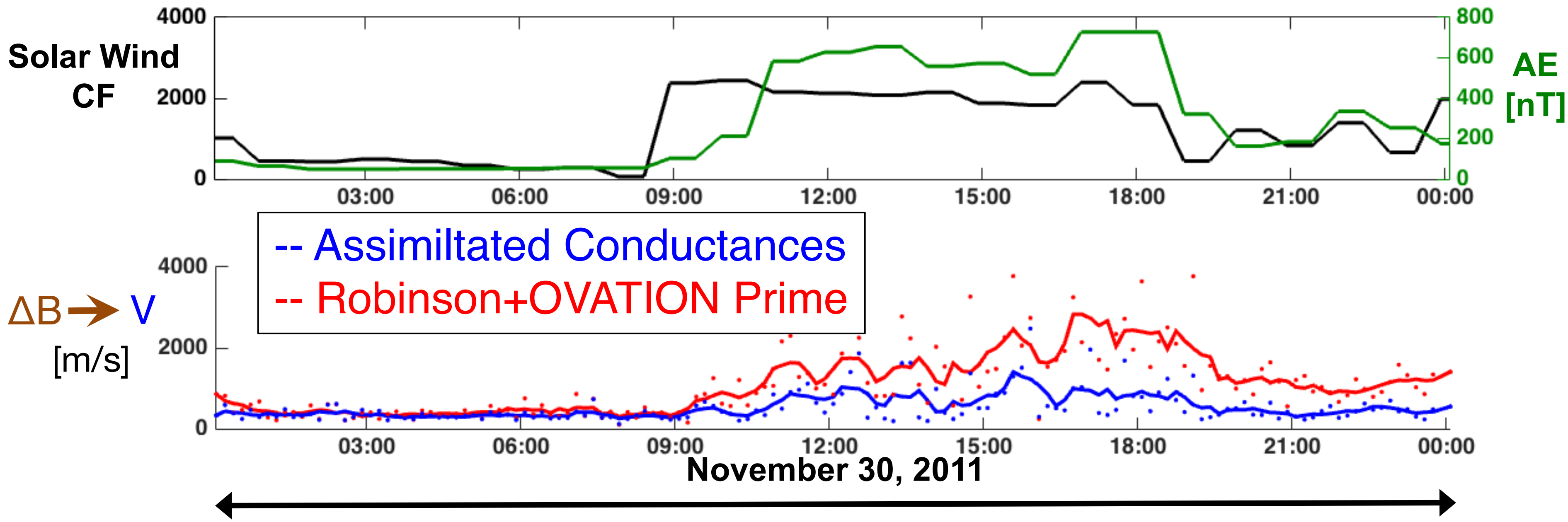
Progress

Conductivity assimilation

$\Delta B \rightarrow V$

Median Absolute Deviations (MADs)



Total $\Delta B \rightarrow V$ MADs [m/s]

Robinson+OVATION Prime:	**684.2**
Assimilated Conductances :	**382.7**

~50% better prediction of SuperDARN observations

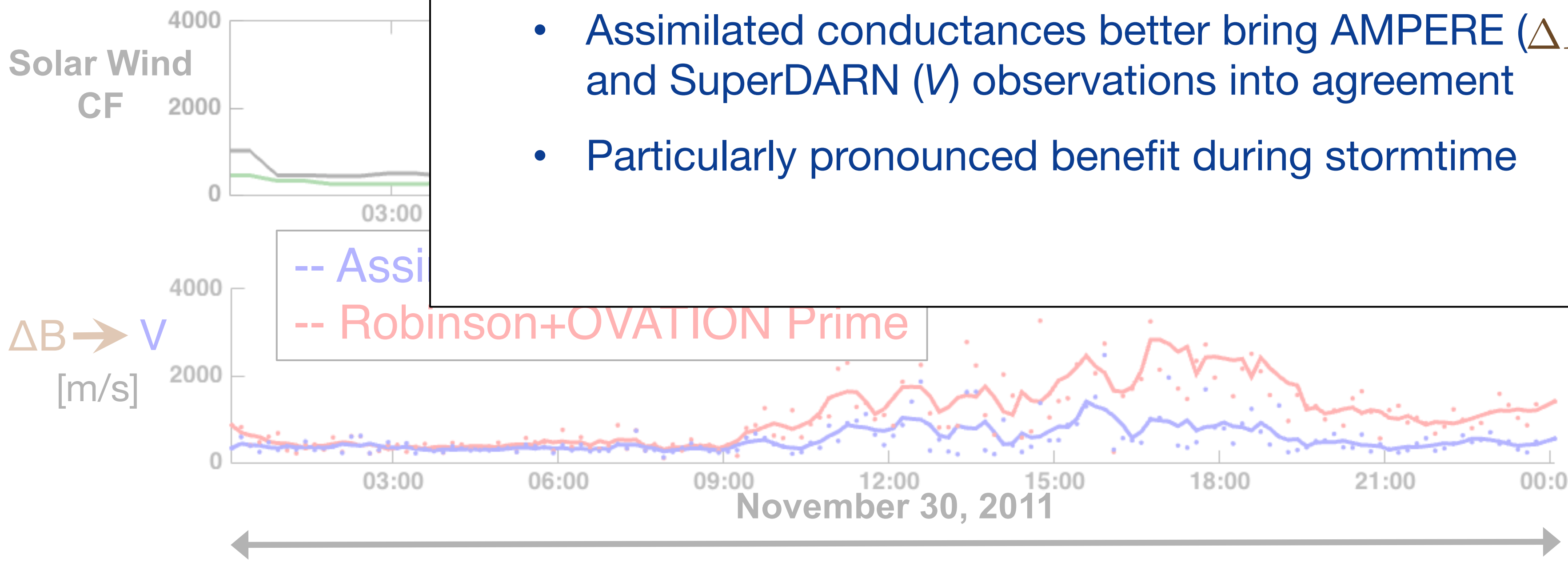
Progress

Conductivity assimilation

ΔB → V

Bottom line:

- Assimilated conductances better bring AMPERE (ΔB) and SuperDARN (V) observations into agreement
- Particularly pronounced benefit during stormtime



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Progress
PFISR – AMPERE

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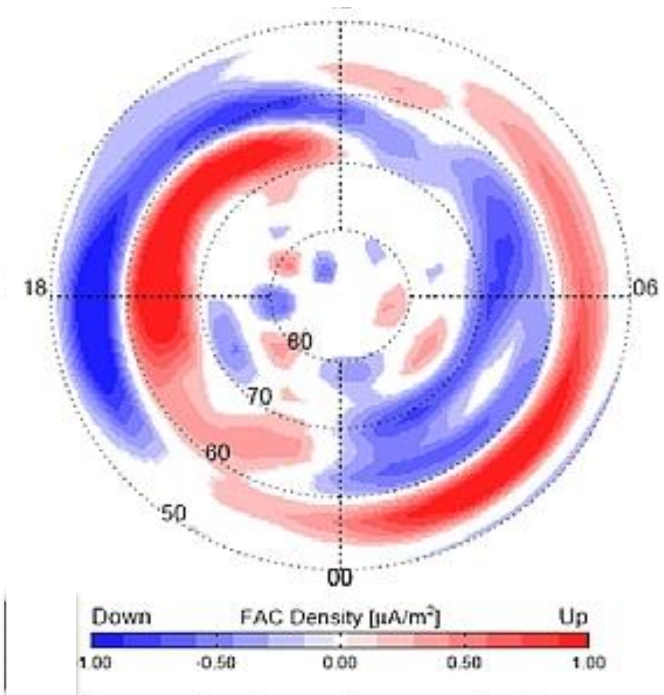
PFISR – AMPERE

Why? - **Where are we now?** - What's next?

Active Magnetosphere and Planetary Electrodynamics Response Experiement (AMPERE)

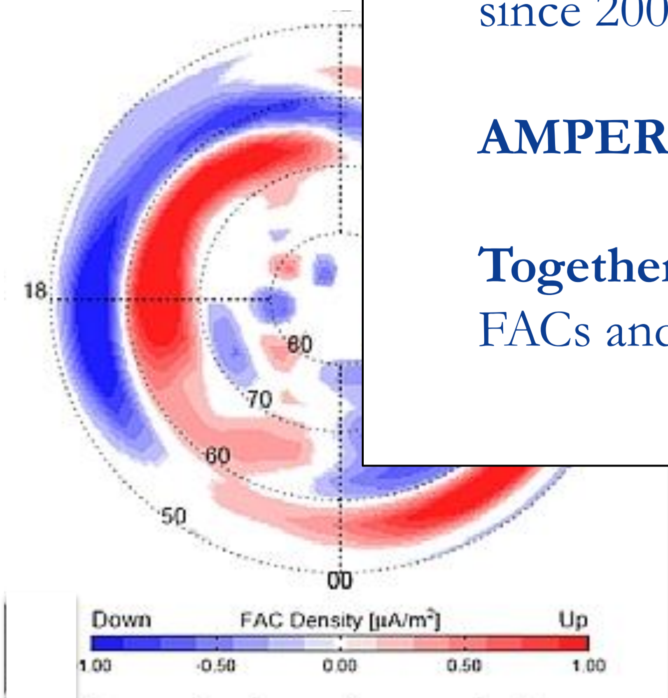


Poker Flat Incoherent Scatter Radar (PFISR)

Courtesy: Bob Robinson & Katie Garcia-Sage

Progress
PFISR – AMPERE

Active Magnet
Planetary Elec
Response Experie

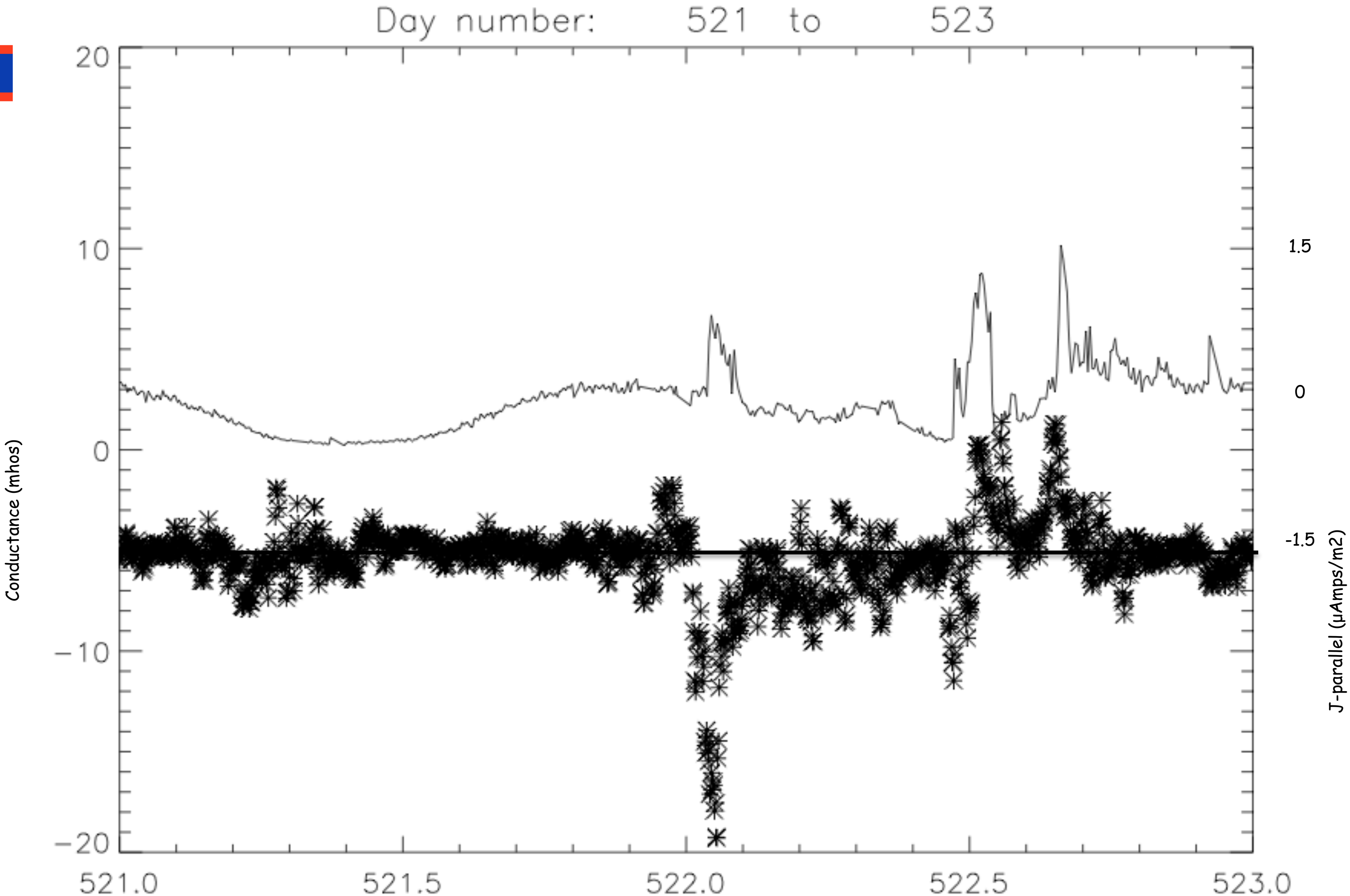


PFISR = ionospheric conductivity data every 10 minutes since 2009

AMPERE = FACs since 2010

Together = ~1.5 million simultaneous measurements of FACs and ionospheric conductivities

Courtesy: Bob Robinson & Katie Garcia-Sage

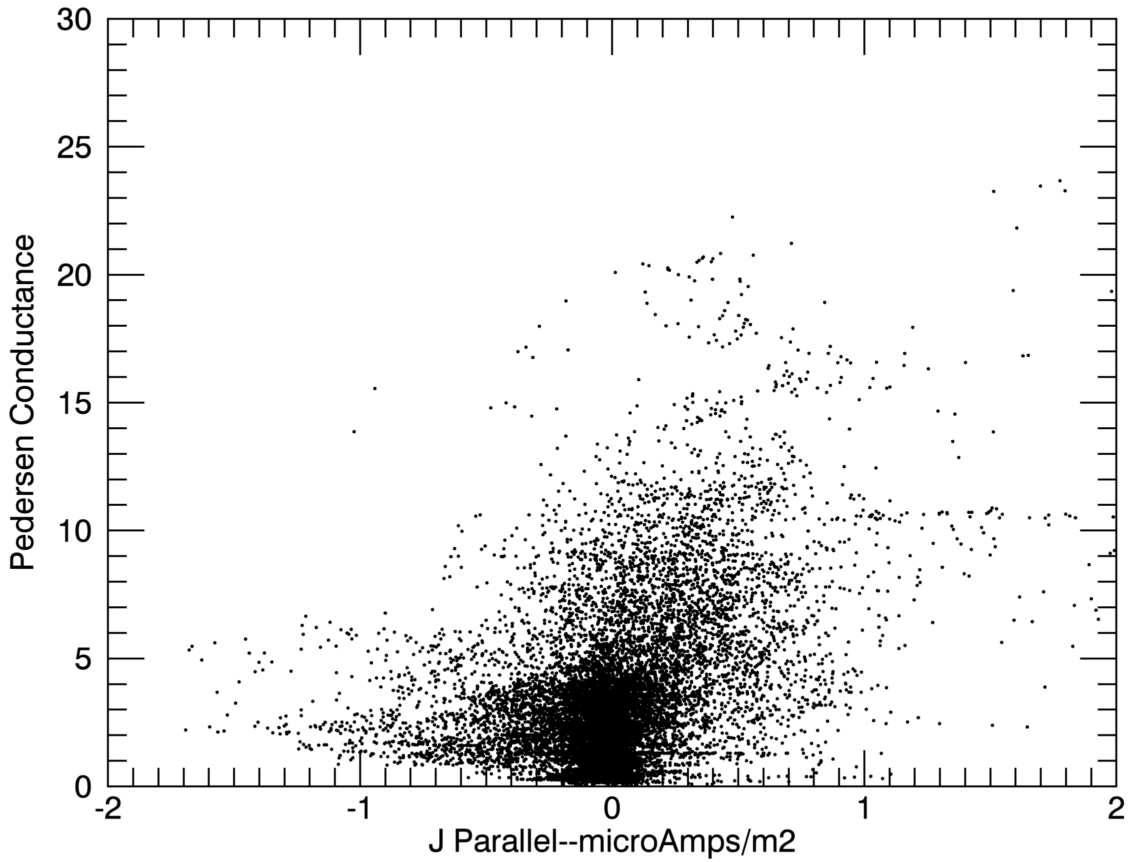


Courtesy: Bob Robinson & Katie Garcia-Sage

Progress

PFISR – AMPERE

Why? - **Where are we now?** - What’s next?



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Progress

PFISR – THEMIS ASI

Progress

PFISR – THEMIS ASI

Why? - **Where are we now?** - What's next?

How Well Can We Estimate Pedersen Conductance From the THEMIS White-Light All-Sky Cameras?

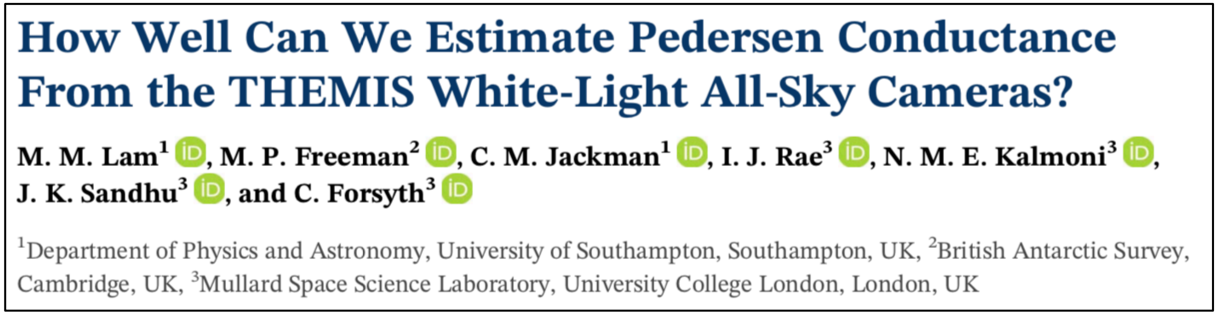
M. M. Lam[1], M. P. Freeman[2], C. M. Jackman[1], I. J. Rae[3], N. M. E. Kalmoni[3], J. K. Sandhu[3], and C. Forsyth[3]

[1]Department of Physics and Astronomy, University of Southampton, Southampton, UK, [2]British Antarctic Survey, Cambridge, UK, [3]Mullard Space Science Laboratory, University College London, London, UK

Progress

PFISR – THEMIS ASI

Why? - **Where are we now?** - What's next?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PFISR = ionospheric conductivity data every 10 minutes since 2009

THEMIS ASI = Wide field-of-view since 2006

Together = Expand conductivity specification over ASI FOV through empirical relationship between PFISR-ASI

Progress

PFISR – THEMIS ASI

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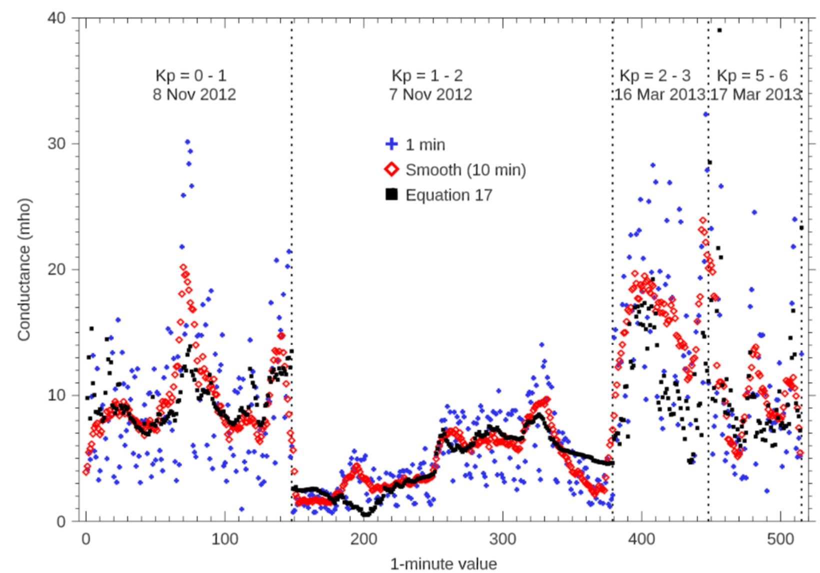

Figure 8. Time-domain comparison of the all-sky imager-derived Pedersen conductance with the PFISR-derived value. For each of the four intervals examined (Table 1), we plot the 1-min PFISR values of Σ_P (blue crosses), the 1-min PFISR values smoothed over 10 min (red diamonds), and the 1-min values of S_P (equation (16)) derived from all-sky imager data (black squares). The conductance is only plotted up to a value of 40 mho for clarity (a single 1-min data point exceeds this at ~64 mho). PFISR = Poker Flat Incoherent Scatter Radar.

Lam et al., [2019]; Kosch et al., [1998] Why is progress slow?

Why is there hope?

What are the *trends*?

Utilizing available observations

What are the *trends*?

Utilizing available observations

ISR capable of tying data together

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ISR capable of tying data together

Data science to culminate efforts

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What are the *trends*?

Analysis Ready Data

Training Data

		features							label
	'time'	'solar wind'				'state of the magnetosphere'			
Sample #1	t1	Bz (t1-x*dt)	Bz (t1-2*dt)	Bz (t1)	...	AL (t1-2*dt)	AL (t1-dt)	AL (t1)	Σ_P (t1+dt)
Sample #2	t2	Bz (t2-x*dt)	Bz (t2-2*dt)	Bz (t1)	...	AL (t2-2*dt)	AL (t2-dt)	AL (t2)	Σ_P (t2+dt)
⋮									
Sample N	tN	Bz (tN-x*dt)	Bz (tN-2*dt)	Bz (tN)	...	AL (tN-2*dt)	AL (tN-dt)	AL (tN)	Σ_P (tN+dt)

Utilizing available observations

ISR capable of tying data together

Data science to culminate efforts

What are the *trends*?

Analysis Ready Data

Robust quantification

			features							label
		'time'	'solar wind'				'state of the magnetosphere'			
Training Data	Sample #1	t1	**Bz (t1-x*dt)**	**Bz (t1-2*dt)**	**Bz (t1)**	**...**	**AL (t1-2*dt)**	**AL (t1-dt)**	**AL (t1)**	**Σ_P (t1+dt)**
	Sample #2	t2	**Bz (t2-x*dt)**	**Bz (t2-2*dt)**	**Bz (t1)**	**...**	**AL (t2-2*dt)**	**AL (t2-dt)**	**AL (t2)**	**Σ_P (t2+dt)**
	⋮									
	Sample N	tN	**Bz (tN-x*dt)**	**Bz (tN-2*dt)**	**Bz (tN)**	**...**	**AL (tN-2*dt)**	**AL (tN-dt)**	**AL (tN)**	**Σ_P (tN+dt)**

Utilizing available observations

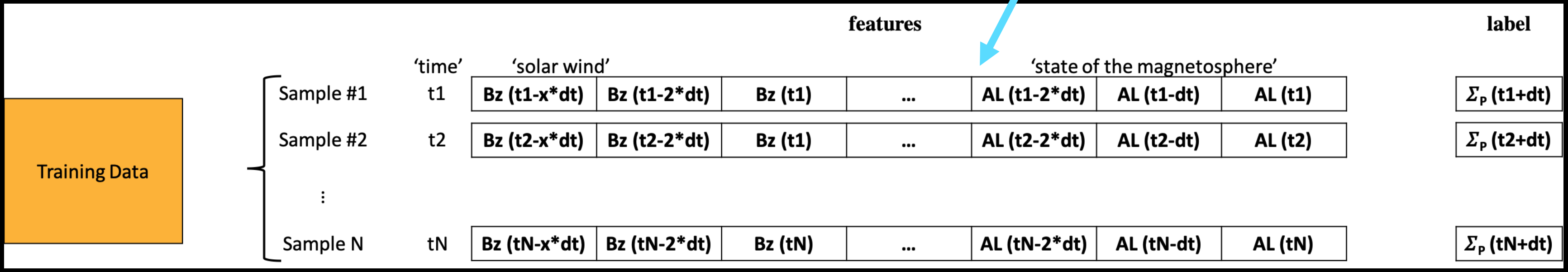
ISR capable of tying data together

Data science to culminate efforts

What are the *trends*?

Analysis Ready Data

Include informative, available data



Utilizing available observations

ISR capable of tyin[g]
together

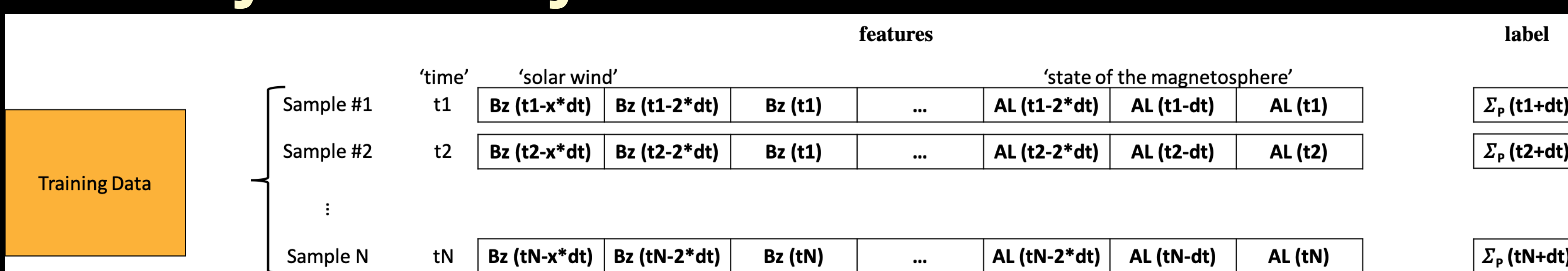
Data science to culminate
efforts

Enables:

- Rapid exploration
- Identification of complex relationships
- Widespread investigation

What are the *trends*?

Analysis Ready Data



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What are the *trends*?

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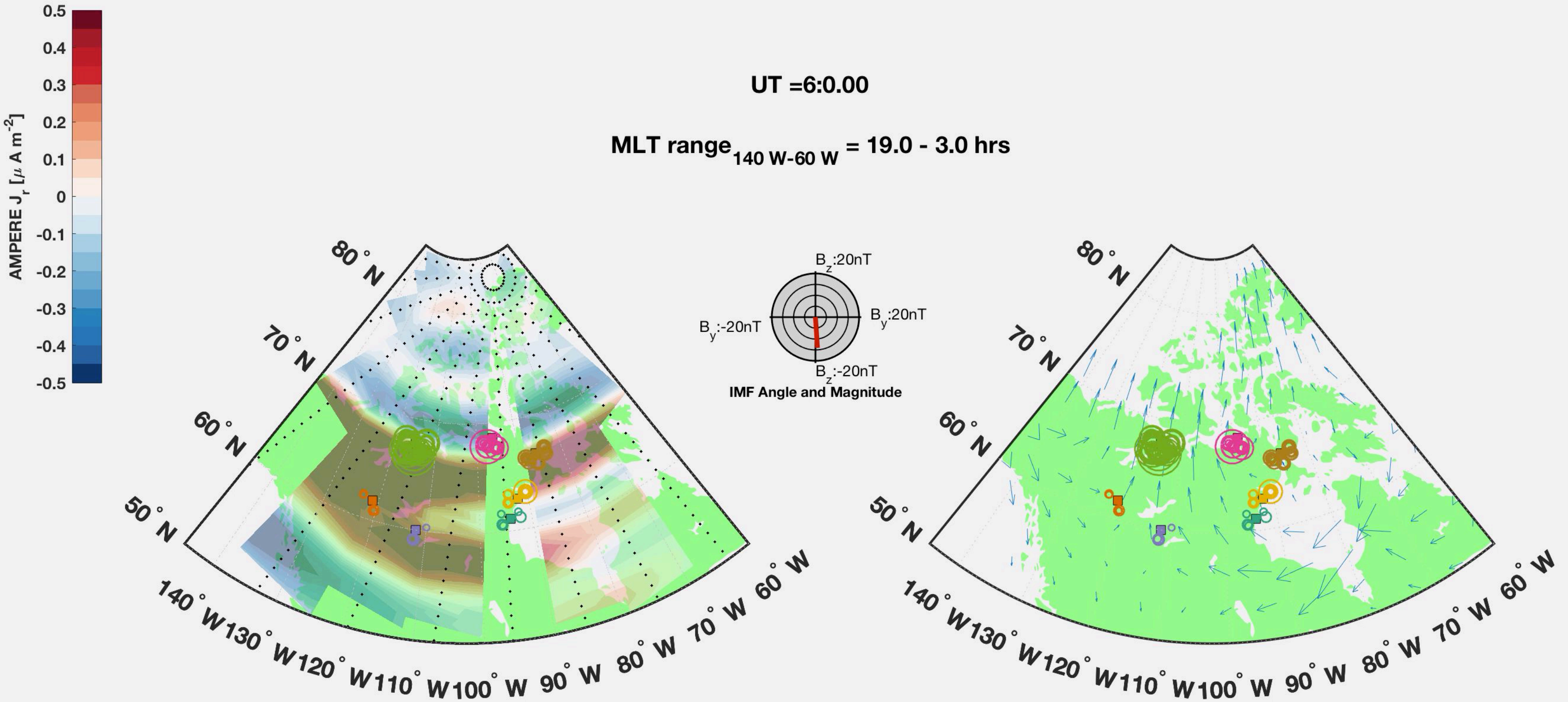
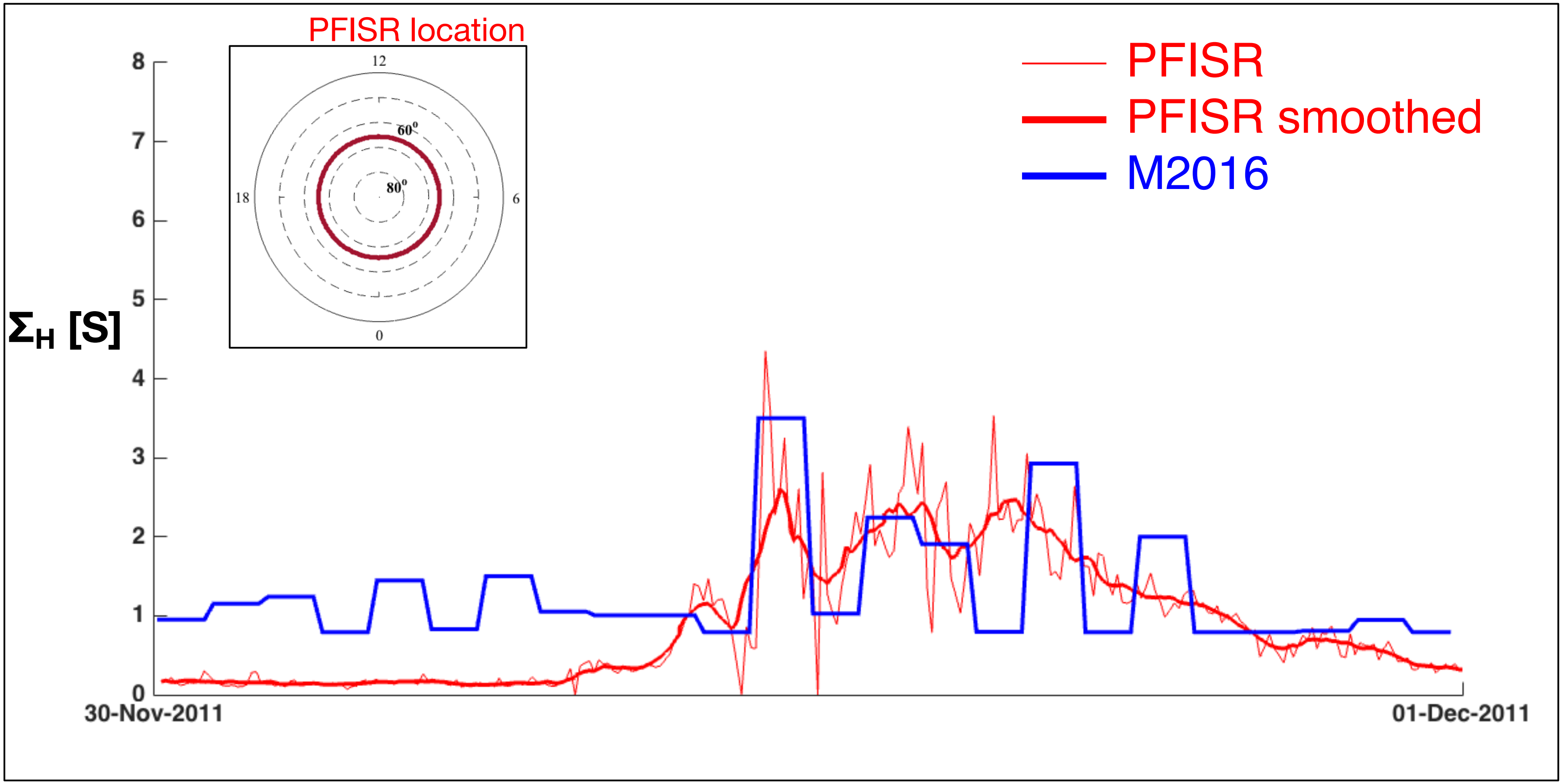
Sample N	tN	Bz (tN-x*dt)	Bz (tN-2*dt)	Bz (tN)	...	AL (tN-2*dt)	AL (tN-dt)	AL (tN)	Σ_P (tN+dt)

Backup slides



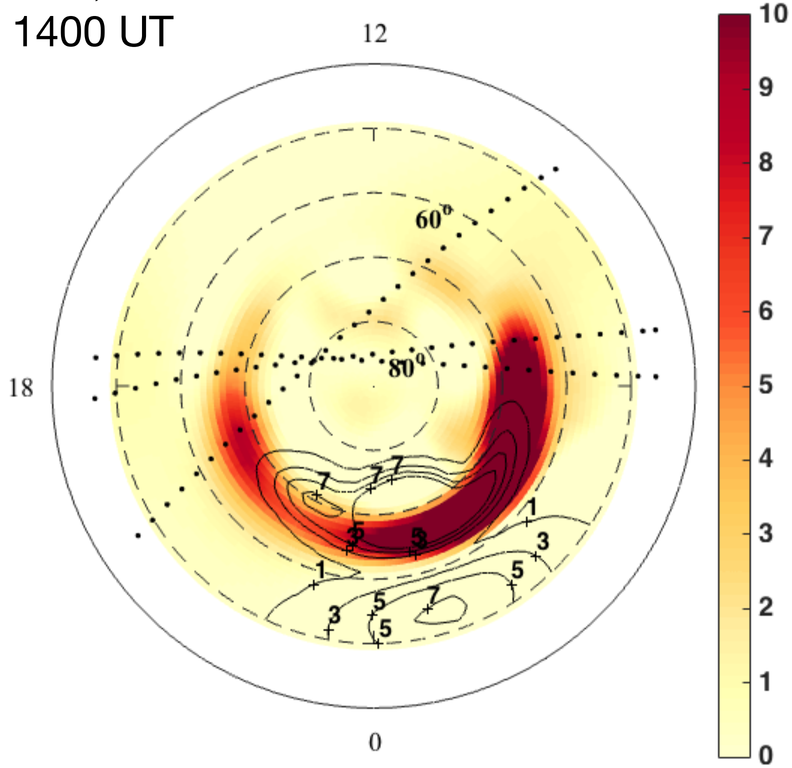
UT =6:0.00
MLT range$_{140\ W-60\ W}$ = 19.0 - 3.0 hrs
AMPERE J_r [μ A m^{-2}]
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
B_z:20nT
B_y:-20nT
B_y:20nT
B_z:-20nT
IMF Angle and Magnitude
80° N
70° N
60° N
50° N
140° W
130° W
120° W
110° W
100° W
90° W
80° W
70° W
60° W

Comparison with PFISR

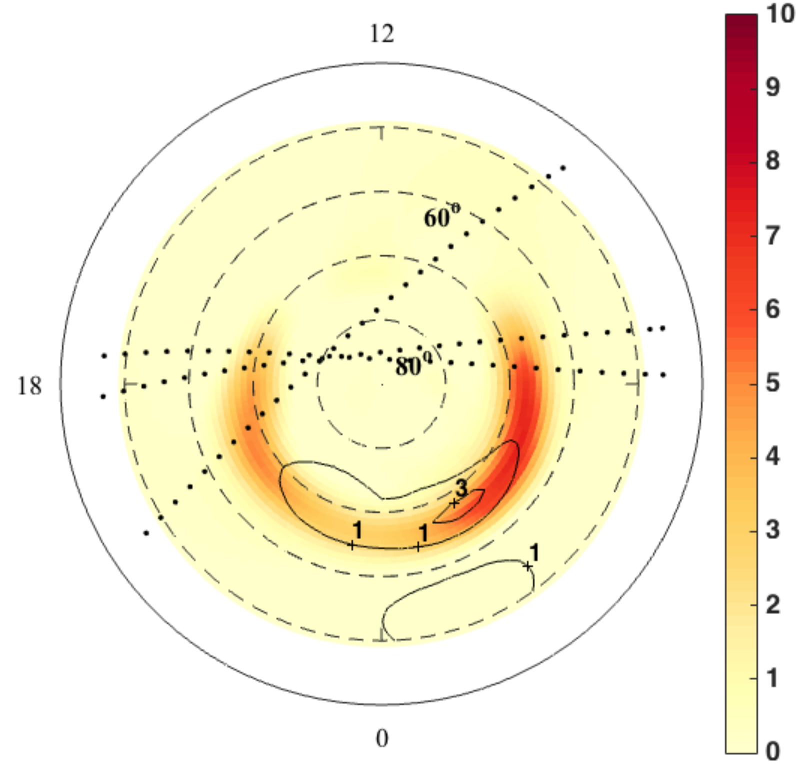


At times, uncertainty on estimates can be large…

November 30, 2011
1300 – 1400 UT



Hall [S]



Pedersen [S]

Contours = uncertainties
Color Map = estimates

At times, uncertainty on estimates can be large…
But ISR data provide opportunity to supplement observations

November 30, 2011
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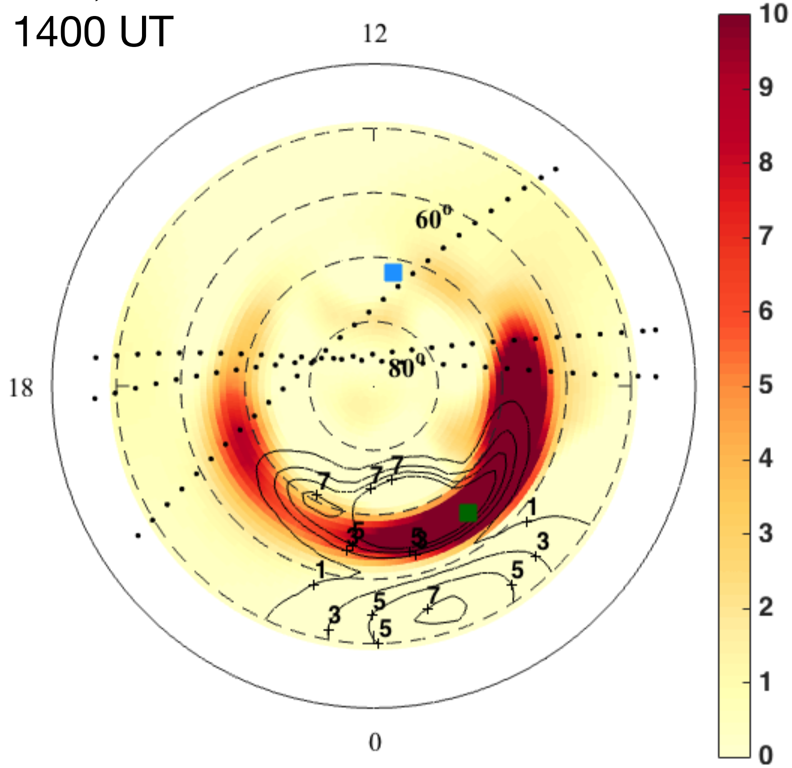

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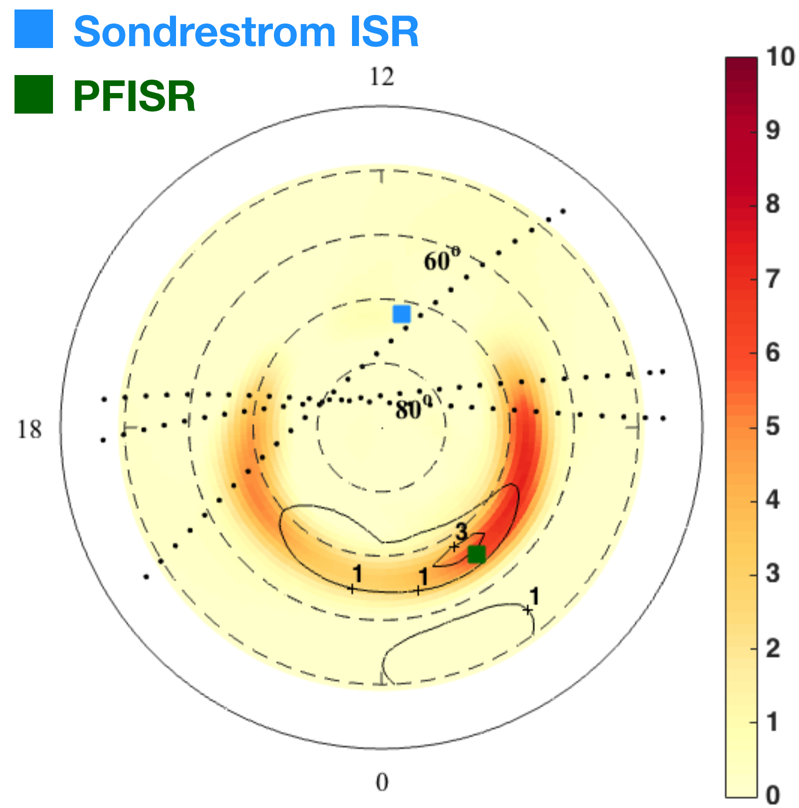

Pedersen [S]

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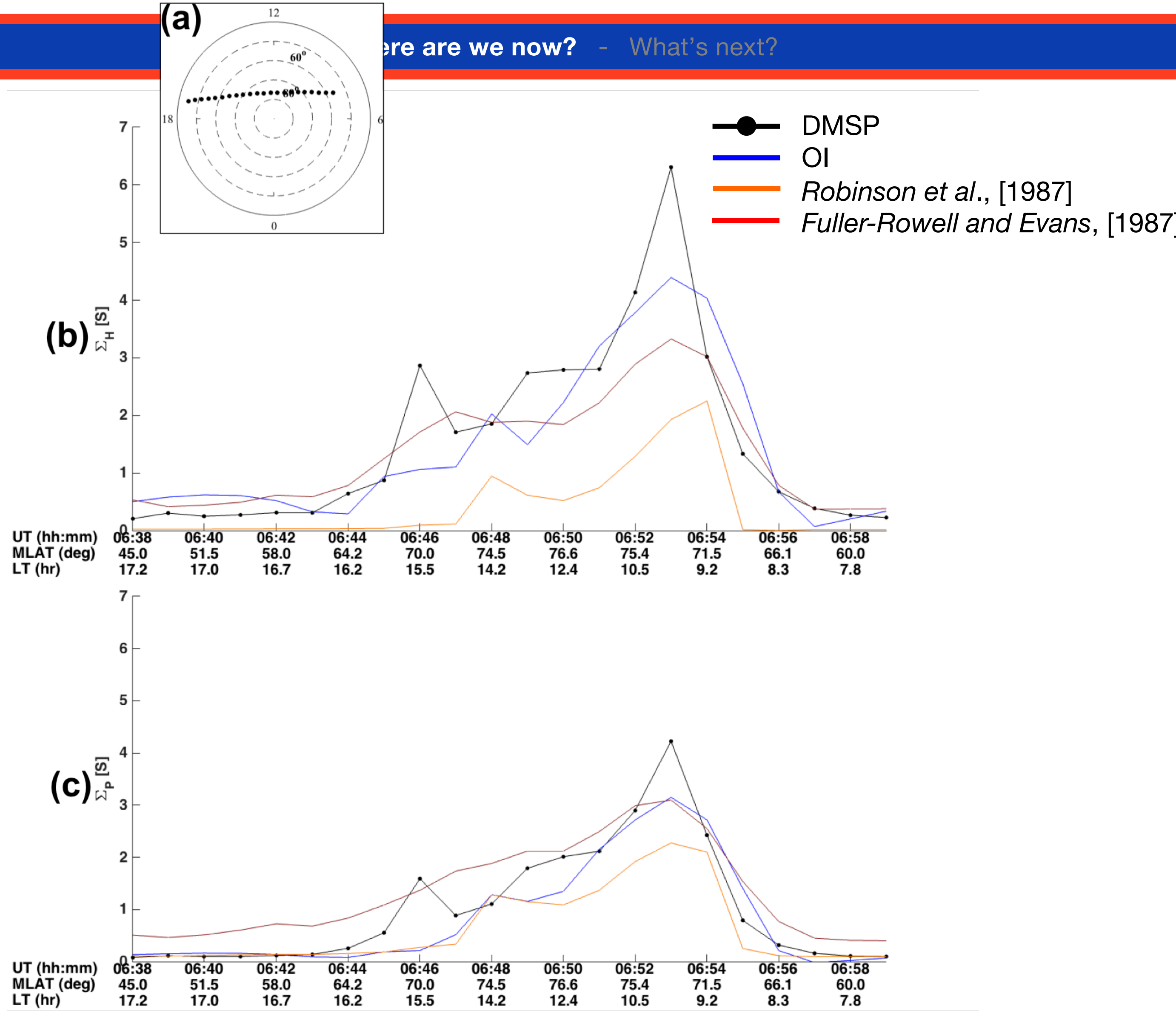
Cross-validation results: M2016 models vs. *Robinson et al.*, [1987] and *Fuller Rowell and Evans*, [1987] models



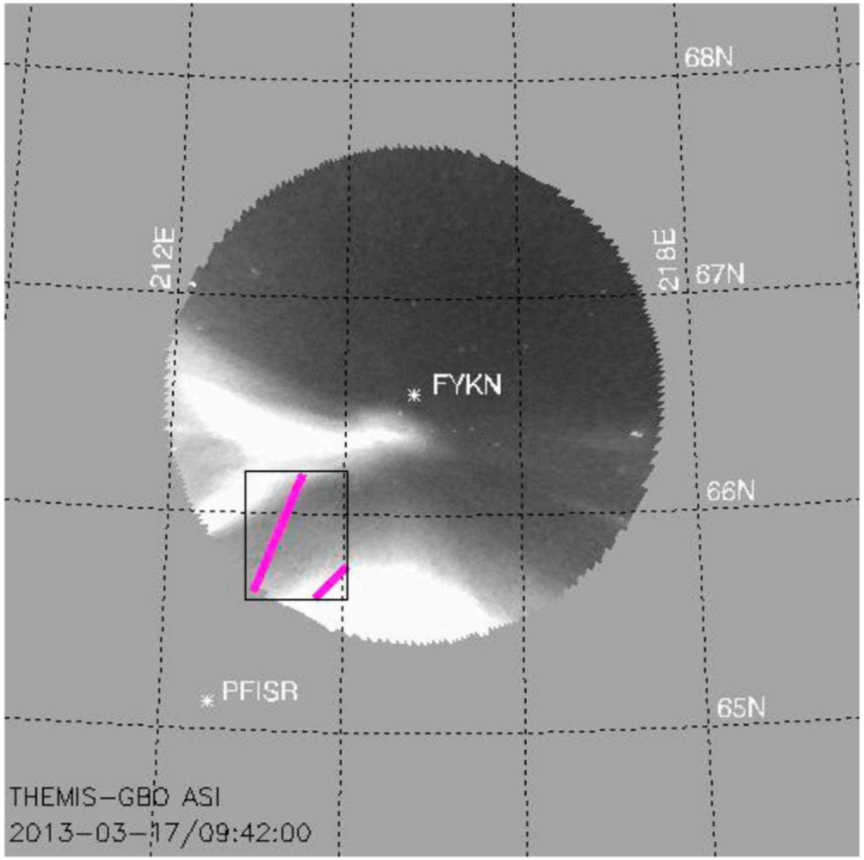


Figure 1. Location of experiment. The location of the PFISR (white asterisk) and of the beams of the 1-min PFISR data used (pink solid lines); the location of the FYKN ASI (white asterisk) and the field of view for elevation angles $\alpha \geq 48°$. The solid black box represents the latitudes and longitudes of the data used. FYKN = Fort Yukon; PFISR = Poker Flat Incoherent Scatter Radar; THEMIS = Time History of Events and Macroscale Interactions during Substorms; GBO = Ground-Based Observatory; ASI = all-sky imager.