On Auroral Boundary Determination and Validation Efforts

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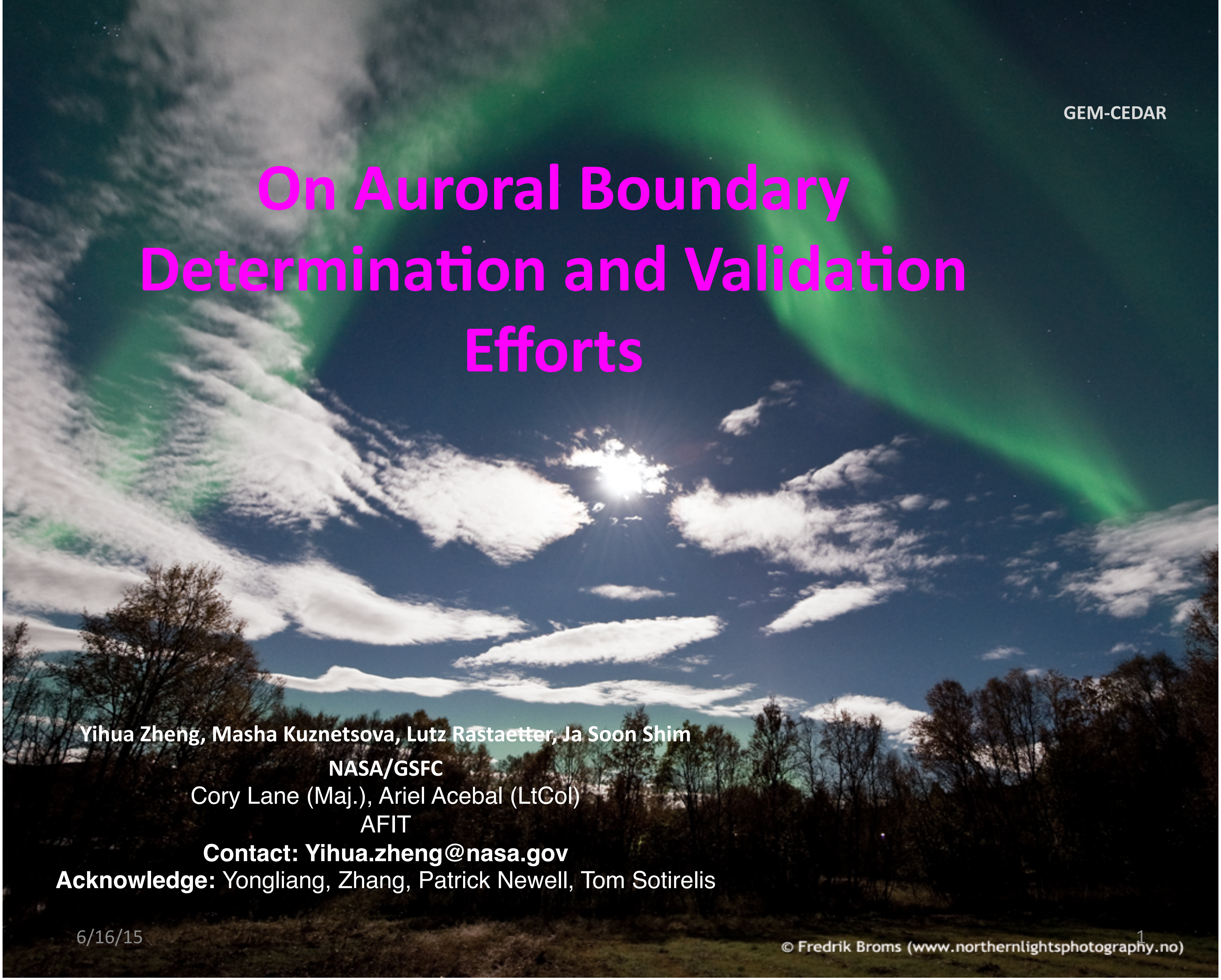
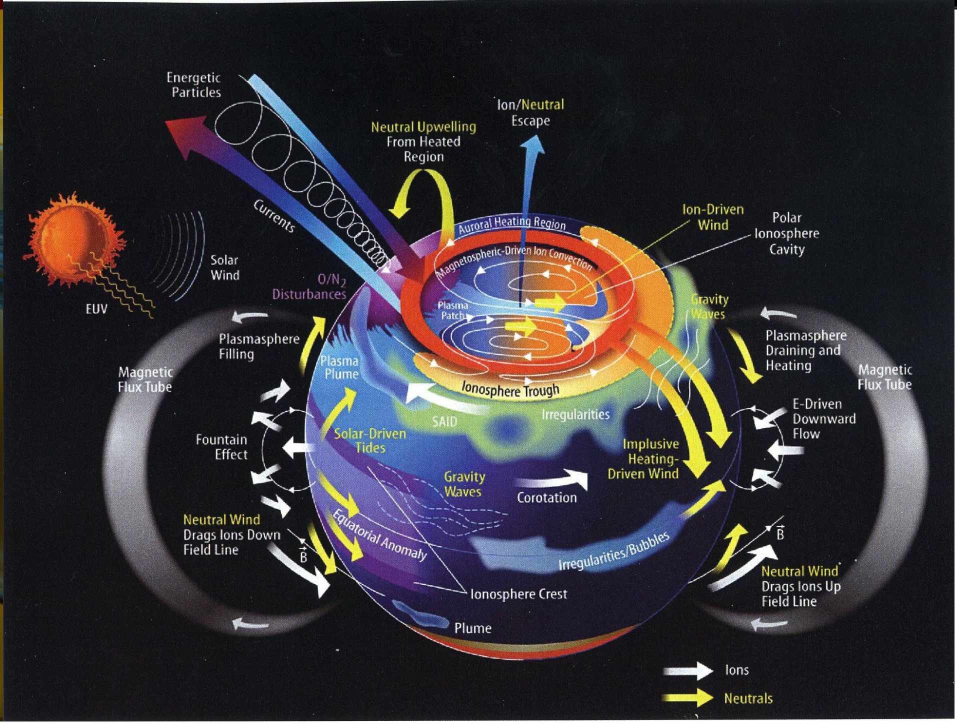


Aurora

- ✓ Surface charging
- ✓ Scintillation – communication/ navg
- ✓ Radar interferences
- ✓ Occasional power grid failure/ outages

- ✓ Manifestation of Solar Wind-Magnetosphere-Ionosphere - Thermosphere Coupling
- ✓ Modulate the global electrodynamic circuit in crucial ways
- ✓ Remote sensing tool for magnetospheric processes



Part I: Auroral Model V& V Results/Efforts (CCMC & AFIT)

Motivation: valuable in space weather applications (particularly for Air Force), space science research, also for aurora tourism

Challenge: choose proper physical quantity (integrated power, equatorward boundary, …)

For the models, choose the proper way of defining the quantity matching better with observed quantity

e.g., Newell et al., 2010 – used nightside precipitation power

Machol et al., 2012 – fixed energy flux

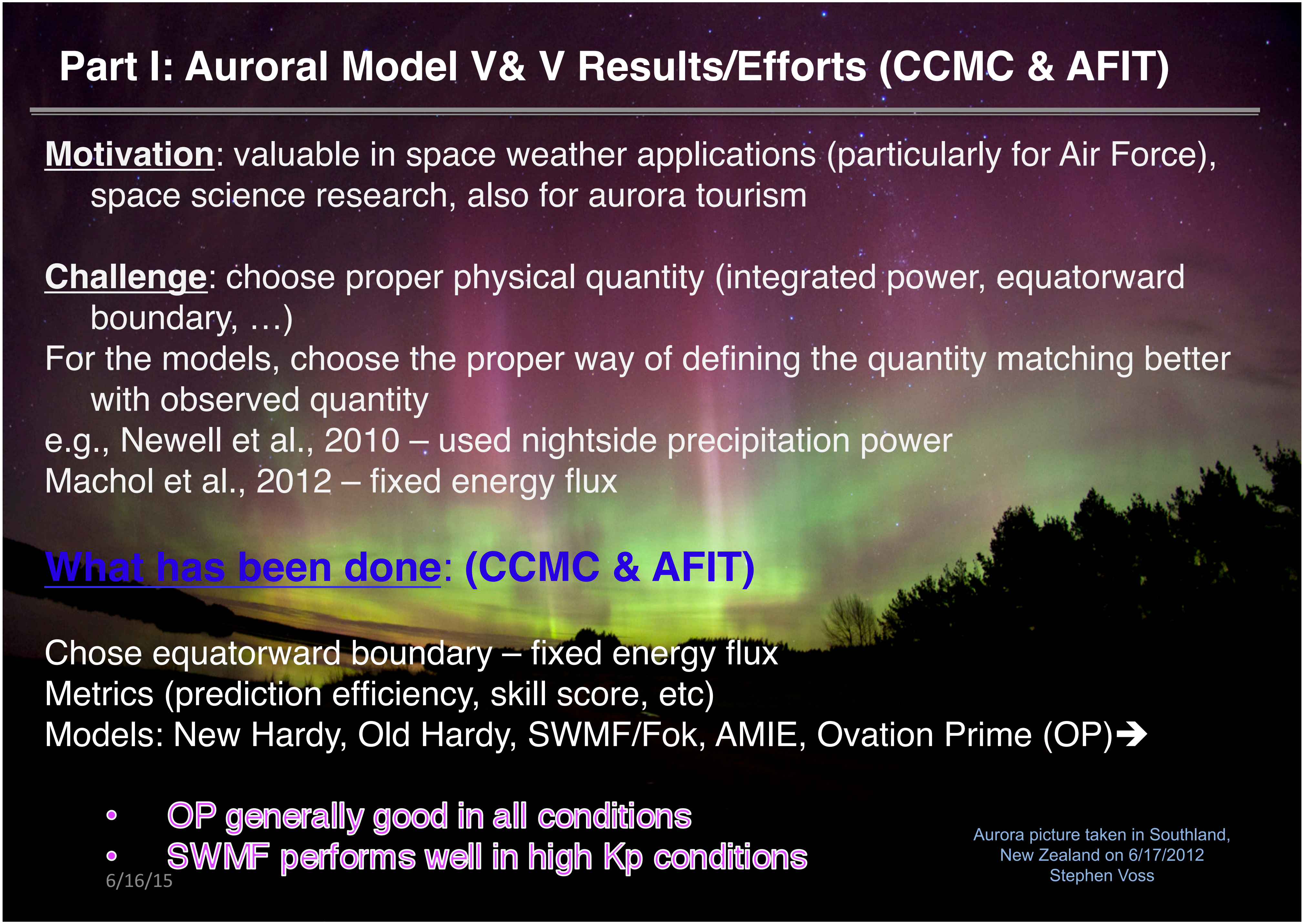
What has been done: (CCMC & AFIT)

Chose equatorward boundary – fixed energy flux

Metrics (prediction efficiency, skill score, etc)

Models: New Hardy, Old Hardy, SWMF/Fok, AMIE, Ovation Prime (OP)➔

- OP generally good in all conditions
- SWMF performs well in high Kp conditions



Aurora picture taken in Southland, New Zealand on 6/17/2012 Stephen Voss

Different Measure of Performance

- Model performance at a fixed local time
  - How well model performs in terms of **temporal revolution**
- Model performance binned by Kp.
- Models' capability in capturing MLT feature/ characteristics at a specific time or during a period
  - Use standard deviation of the offset
  - correlation in all MLT binned by activity level or for a specific time - auroral imaging

Validation already been done (Newell et al.)

Newell, P. T., et al. (2010), Predictive ability of four auroral precipitation models as evaluated using Polar UVI global images, Space Weather, 8, S12004, doi:10.1029/2010SW000604

r: correlation coefficient

Instantaneous

1. Brautigam IMF model (r=0.68)
2. Evans nowcast model (r=0.70)
3. Hardy Kp model (r=0.72)
4. Ovation Prime (r=0.75)

Hourly averages

1. Brautigam IMF model (r=0.69)
2. Hardy Kp model (r=0.74)
3. Ovation Prime (r=0.76)
4. Evans nowcast model (r=0.77)

↓ better

Physical parameter: Nightside **Precipitating power (in GW)**

Observation: global imaging data: Polar/UVI (UltraViolet Imager)

Validation already been done (Machol et al.)

Machol, J. L., et al. (2012), Evaluation of OVATION Prime as a forecast model for visible aurorae, *Space Weather*, 10, S03005, doi:10.1029/2011SW000746.

Physical parameter: **fixed energy flux**
1.0 ergs/cm^2/s for the model
~ 2.0 ergs/cm^2/s for Polar UVI

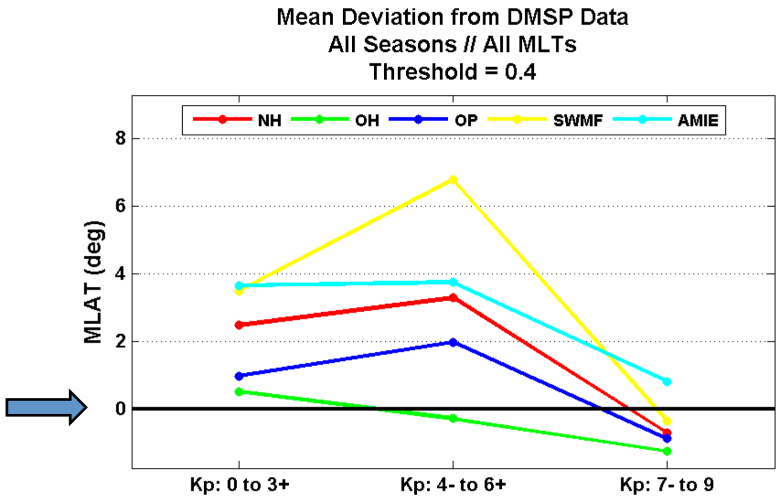
The OVATION Prime model was found to do a good job of predicting the visible aurora. The overall accuracy **is 77%** [(A+D)/(A+B+C+D)].

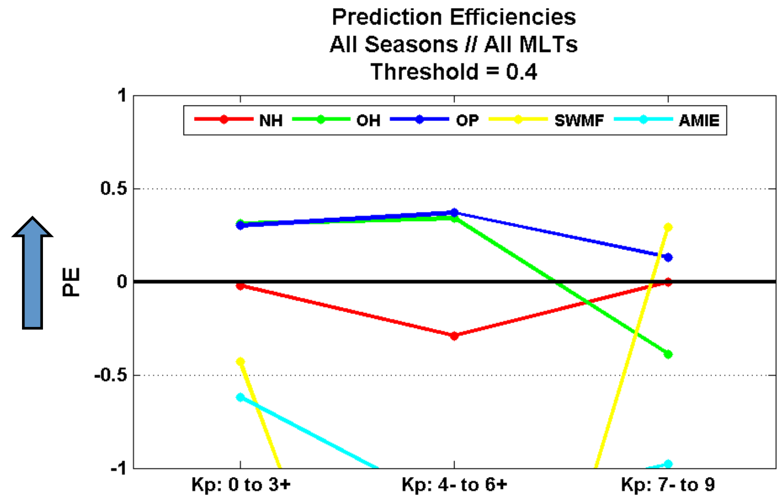
when the aurora is predicted with ~ 1 hour lead time, the forecast accuracy **is 86%** [A/(A+B)].

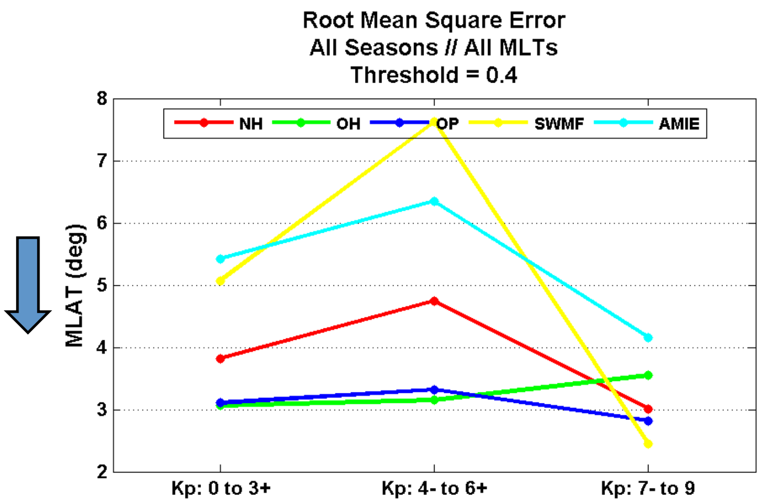
A: True positive
B: False positive
C: False negative
D: True negative

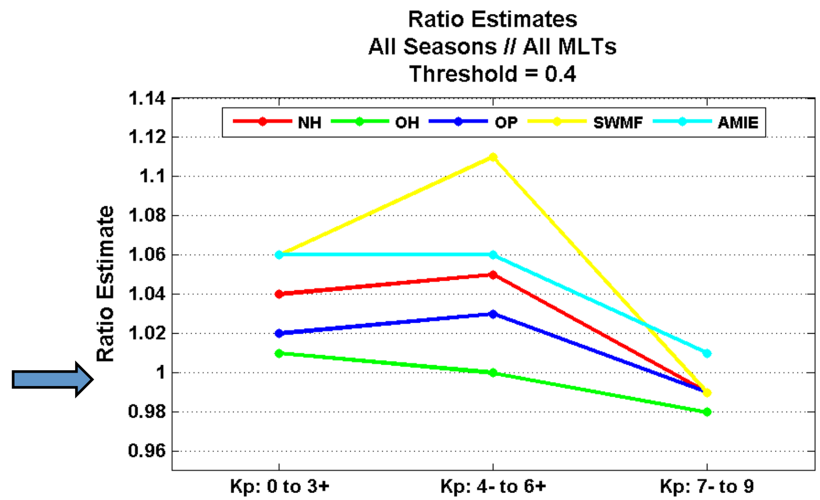
Using Polar/UVI during 1997 -1998

Metrics – All Models









Results Summary

- OP has the best Prediction Efficiency and OH closely follows.
- OH has a regression line that closely approximates 1:1.
- The SkillScore between OH and OP demonstrates no decisive advantage to either model.
- SWMF and AMIE do not perform well (worse than using the mean).
- These conclusions hold true at Low and Mid Kp values.
- At high Kp values, OH and OP suffer.

- SWMF provides the best PE at during High Kp conditions.

Part II: Next Steps

- Not all global models provide direct calculation of auroral precipitation - search for auroral precipitation proxy: global models need to come up a best way in defining tested/validated physical quantities
- More extensive validation using different validation metrics or choosing different physical parameters
- Stimulate model development to include crucial physics

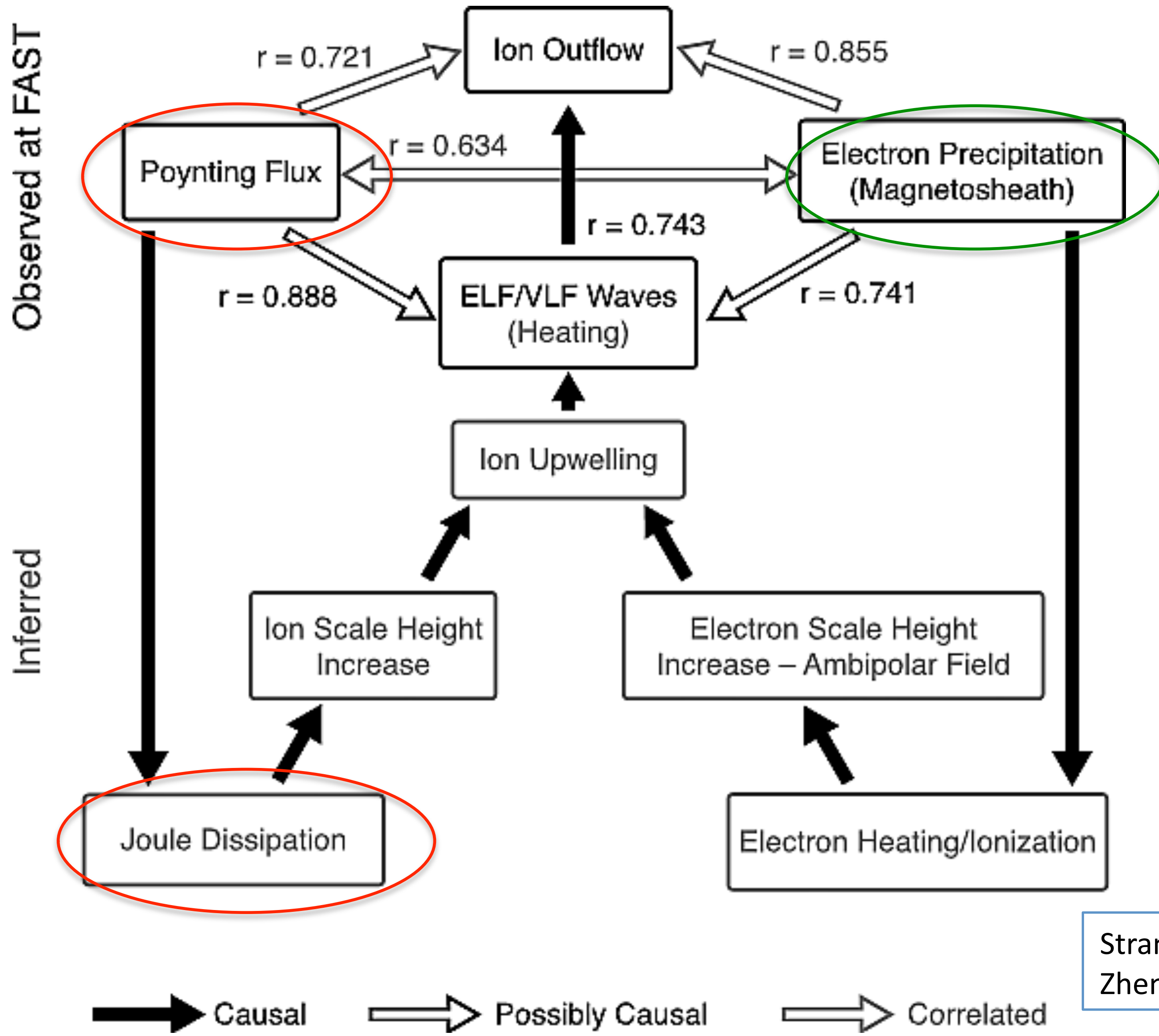
Why Poynting Flux/Joule Heating

- Important physical process/quantity for magnetospheric/ ionospheric dynamics. Poynting flux: not the sole cause for ion outflow, but the necessary first step
- May serve as a proxy for auroral precipitation, especially useful for models that cannot describe precipitation well

Note: Poynting flux v.s. Joule Heating

- ✓ Poynting flux: input of electromagnetic energy into the ionosphere
- ✓ Mainly dissipated as heat (Joule Heating) in the ionosphere

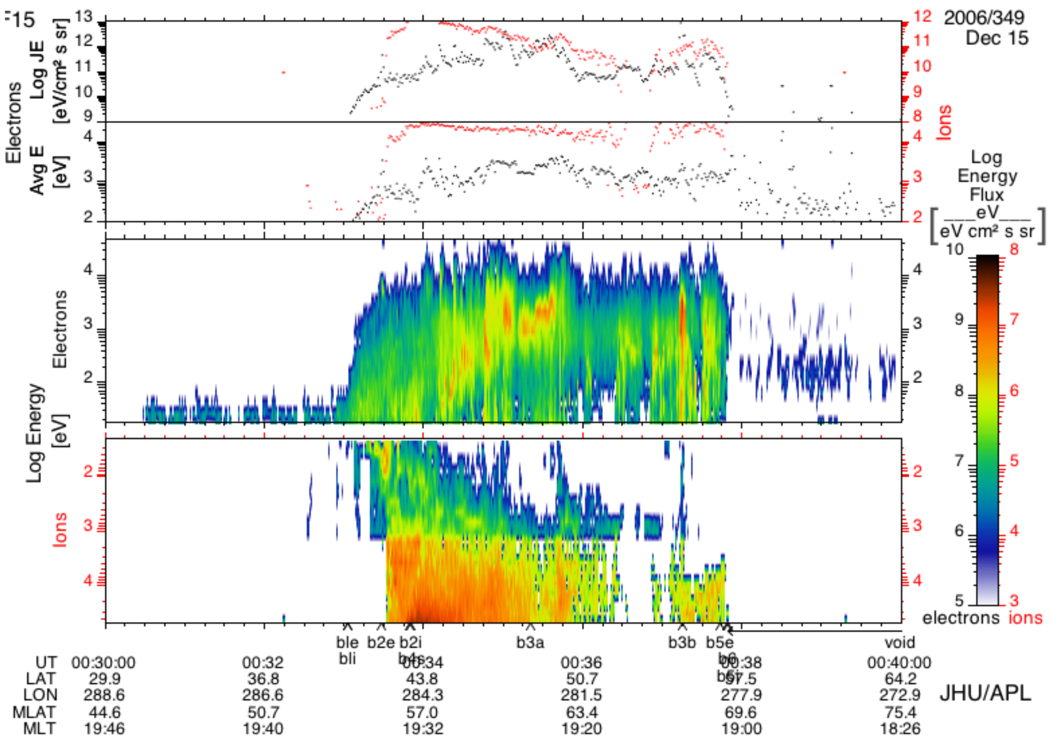
Why Poynting Flux/Joule Heating

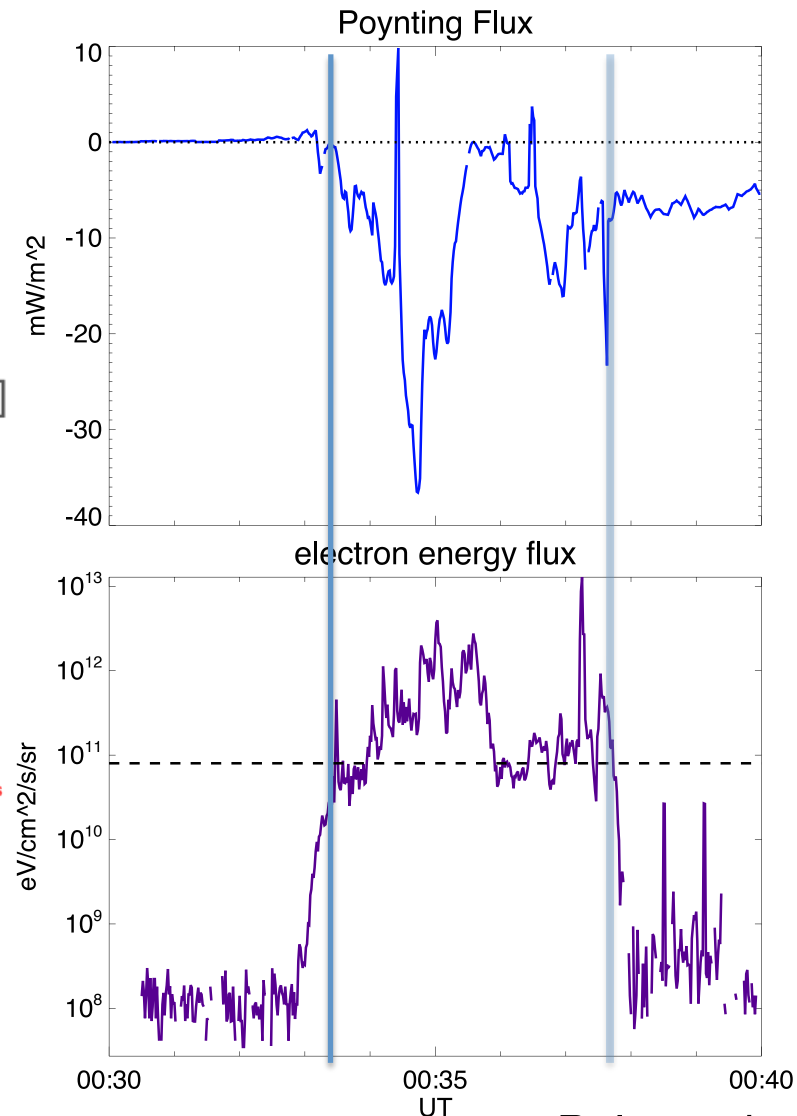


Strangeway et al., 2005
Zheng et al., 2005

Poynting Flux vs Aurora Precipitation

Equatorward Poleward





Poleward

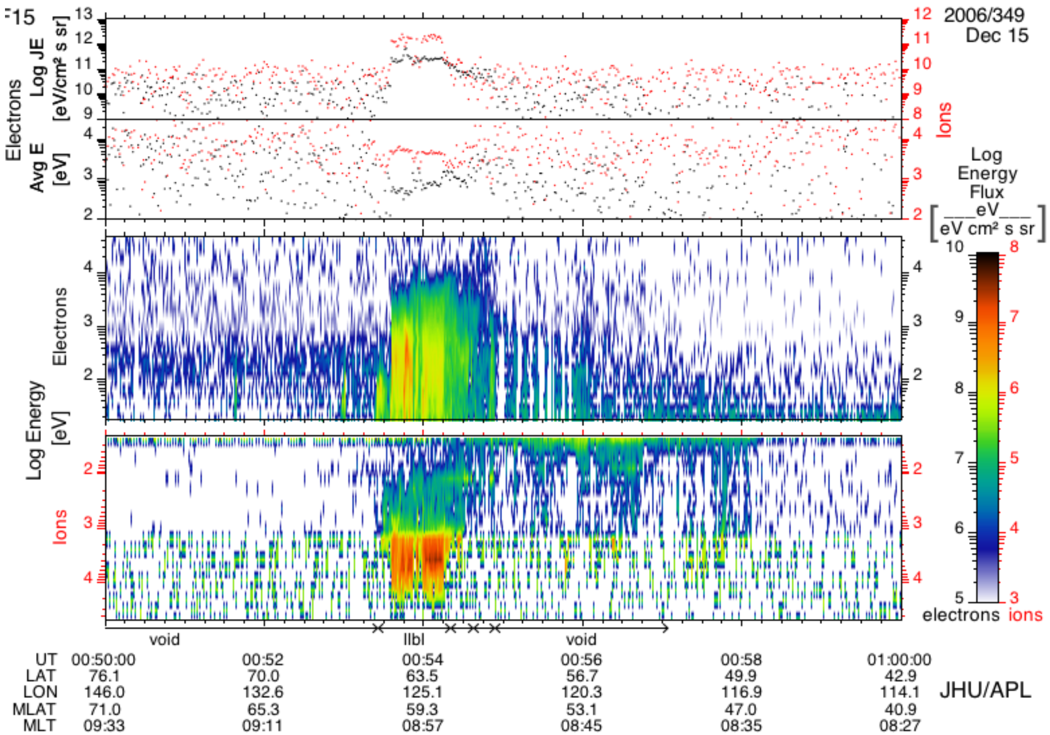
Dusk:

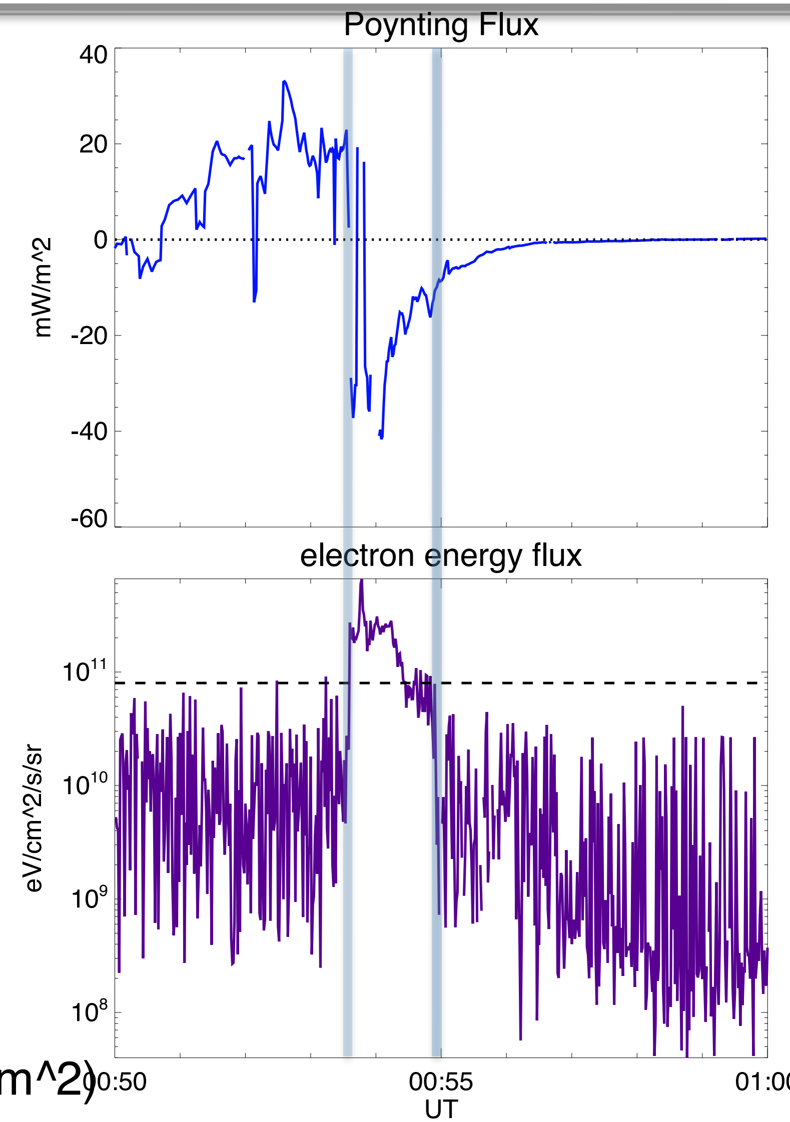
Eqbn: equatorward disturbance of Poynting flux

Pobn: last local maximum on the poleward side

Poynting Flux vs Aurora Precipitation

Poleward Equatorward





Dawn:

Eqbn: Poynting flux exceeds a threshold (3 mW/m^2)

Pobn: last local maximum on the poleward side

Poleward

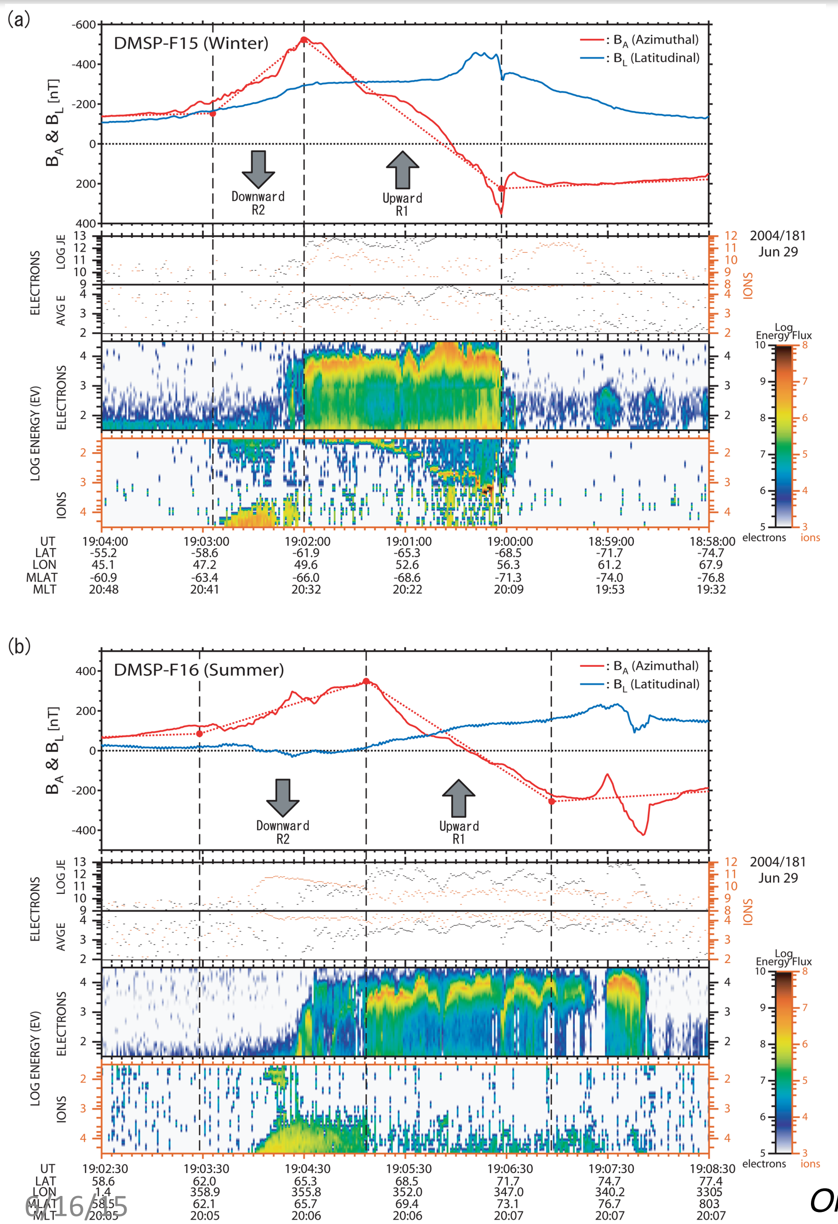
Poynting Flux vs Auroral Precipitation

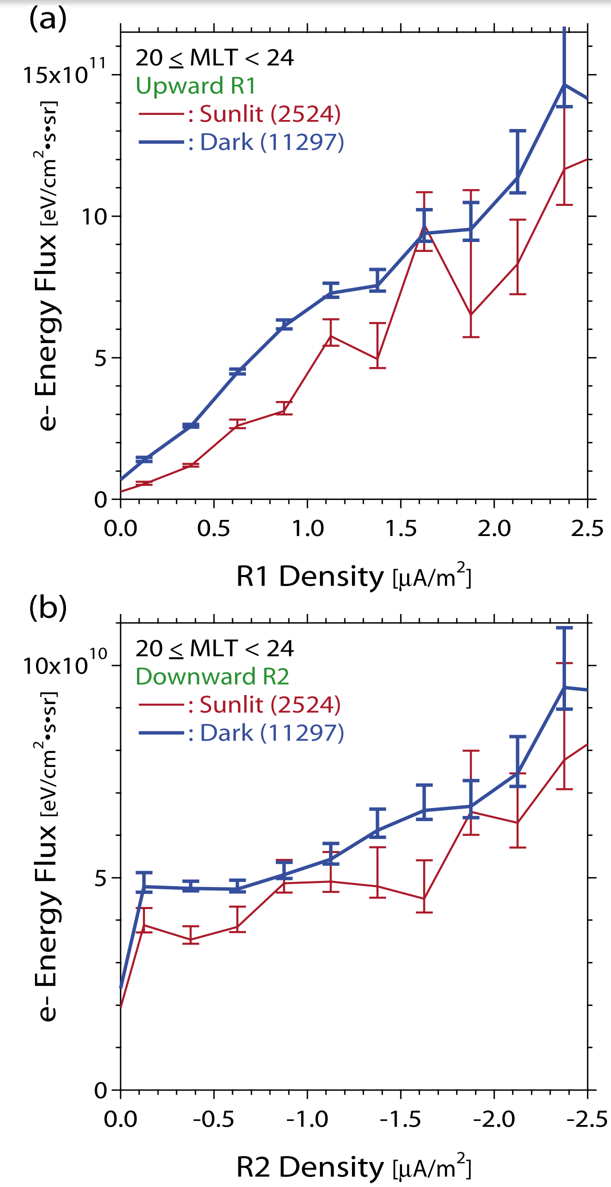
- ✓ Promising correlation. Examining their relationship by looking at more DMSP passes
- ✓ Finding a rule (if solid/concrete) for defining auroral boundaries using Poynting flux behaviors
- ✓ Caveat – e.g., Richmond, 2010

What Is Next: Region 1 FACs

- ✓ Upward region 1 field-aligned currents correlate nicely with precipitating electron energy flux
- ✓ Can be used as a proxy for auroral precipitation
- ✓ Can be a nice physical parameter to validate models with

Nightside: Region 1 FAC vs Aurora Precipitation





Ohtani et al., 2009, JGR

Future Direction

- **More extensive auroral validation using different validation metrics or choosing different physical parameters (including Poynting flux/Joule heating or Region 1 FACs).**
- **Independent model validation in producing Poynting flux/ Joule heating and FACs.**
- **Broader community participation by submitting more model runs**
- **Investigating the interconnection among auroral precipitation, FACs, and Poynting flux/Joule heating**
- **Spur model development/improvement by including complete physics**